NEW SOUTH WALES CURRICULUM

POWERED BY oxforddigital

Science

OXFORD SCIENCE Stage 4

Melinda Mestre
Lily Okati
Timothy Sloane
Mora Soliman
Helen Silvester

NSW Curriculum

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Aboriginal and Torres Strait Islander readers are advised that this book (and the resources that support it) may contain the names, images, stories and voices of deceased persons.

Non-Indigenous readers should be aware that for some Aboriginal and Torres Strait Islander communities, showing the names and photographs of deceased persons may cause sadness or distress and, in some cases, be contrary to cultural protocols.

Contents

Introducing *Oxford Science Stage 4 NSW Curriculum*

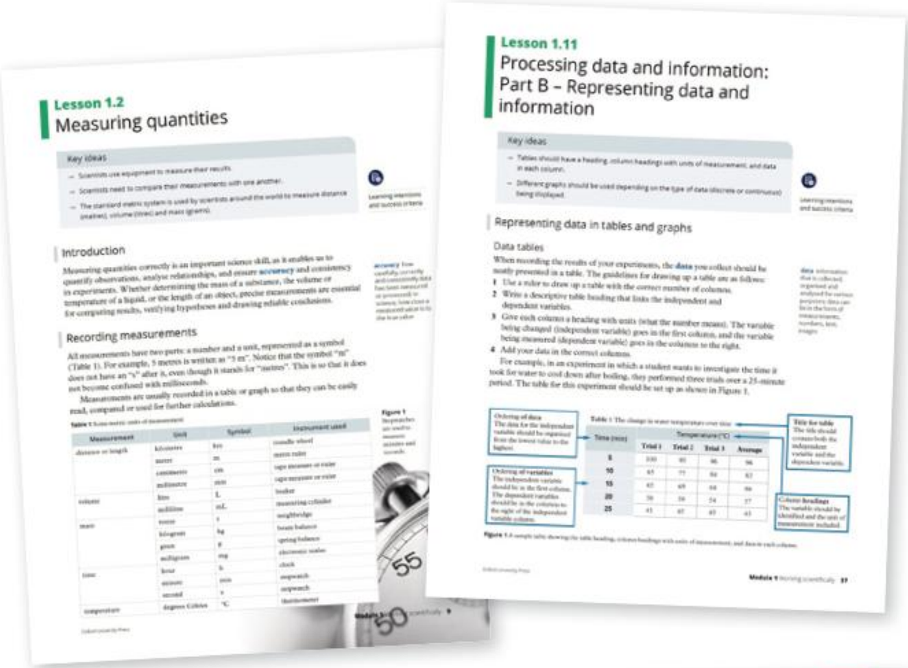
Congratulations on choosing *Oxford Science Stage 4 NSW Curriculum* as part of your studies this year!

Oxford Science Stage 4 NSW Curriculum has been purpose-written to meet the requirements of the Science 7–10 Syllabus (2023). It includes a range of flexible print and digital products to suit your school and incorporates a wide variety of features designed to make learning fun, purposeful and accessible to all students!

Key features of Student Books

The **Working scientifically** is a standalone module that explicitly teaches important Science inquiry skills.

The **Aboriginal and Torres Strait Islander Histories and Cultures** cross-curriculum priority is addressed in both standalone lessons and within other lessons.



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Key ideas

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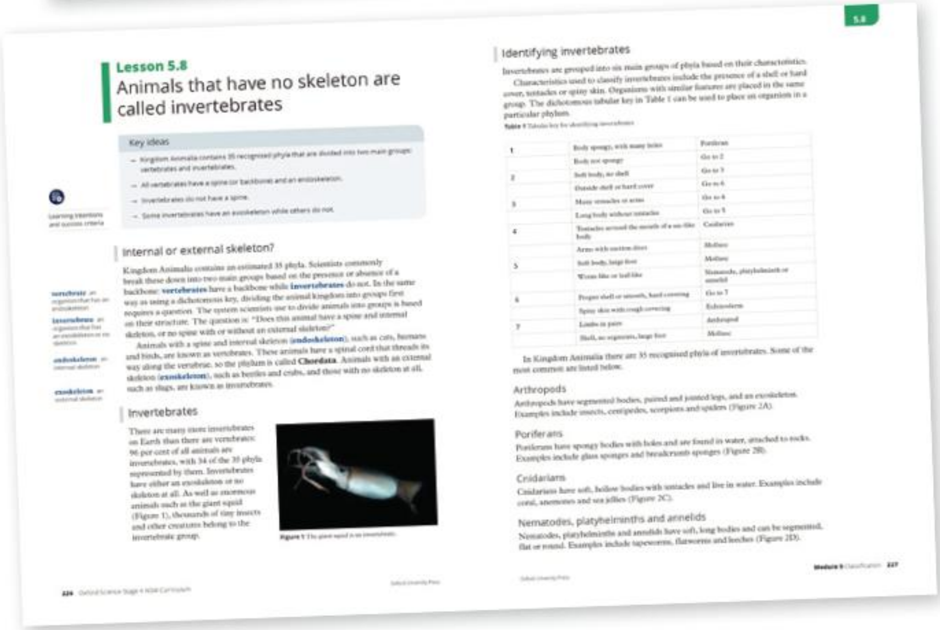
In each core lesson:

- a concept statement summarises the key concept in one sentence
- key ideas are summarised in succinct dot points
- key terms are bolded in blue text, with a glossary definition provided in the margin
- a set of check your learning questions are aligned to the learning intentions for the lesson.



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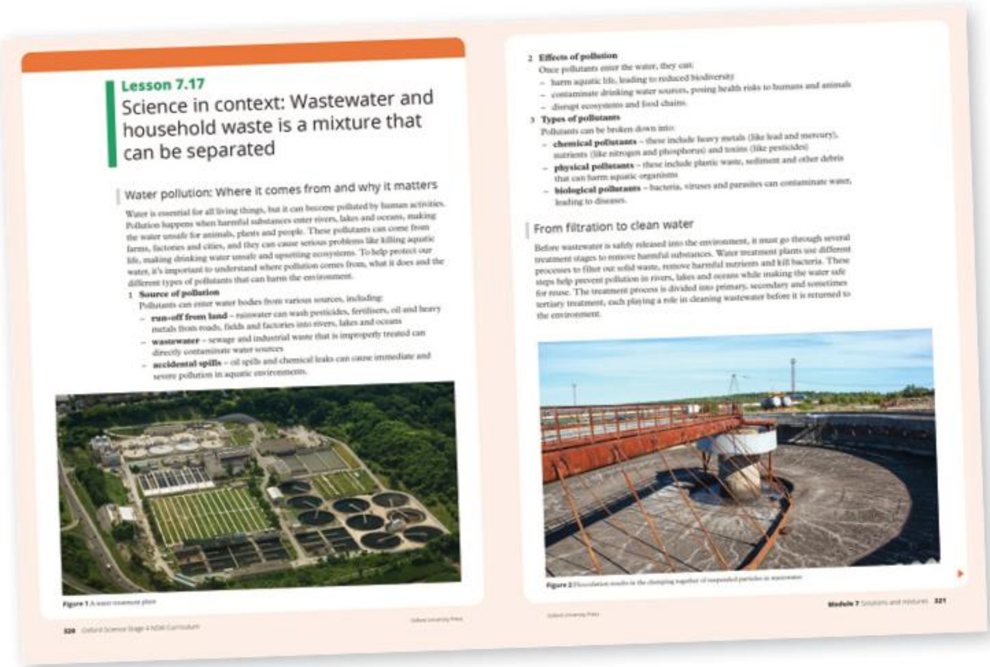

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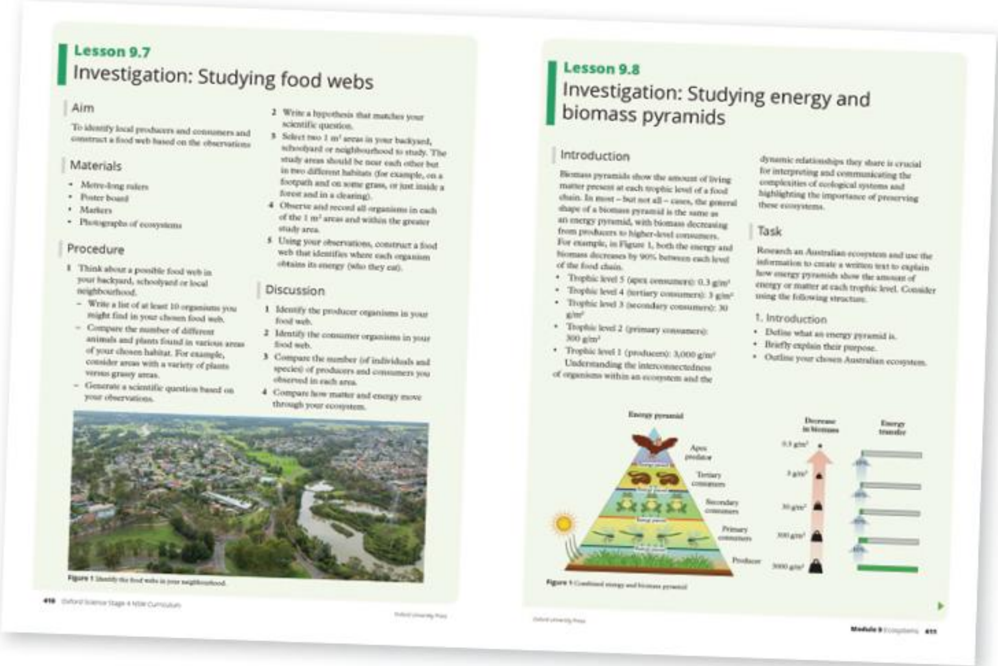
Science in context lessons explore real world examples and case studies, allowing students to apply science understanding.

The **Test your skills and capabilities** section provides scaffolded opportunities for students to apply their science understanding while developing skills and capabilities.



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Introduction

Task

Practical activities appear within each module, directly after the core lesson they relate to. Additional activities are provided through Oxford Digital.

Challenges, Skills labs and **Investigations** provide students with opportunities to use problem-solving and critical thinking, and apply science inquiry skills.

Find out more

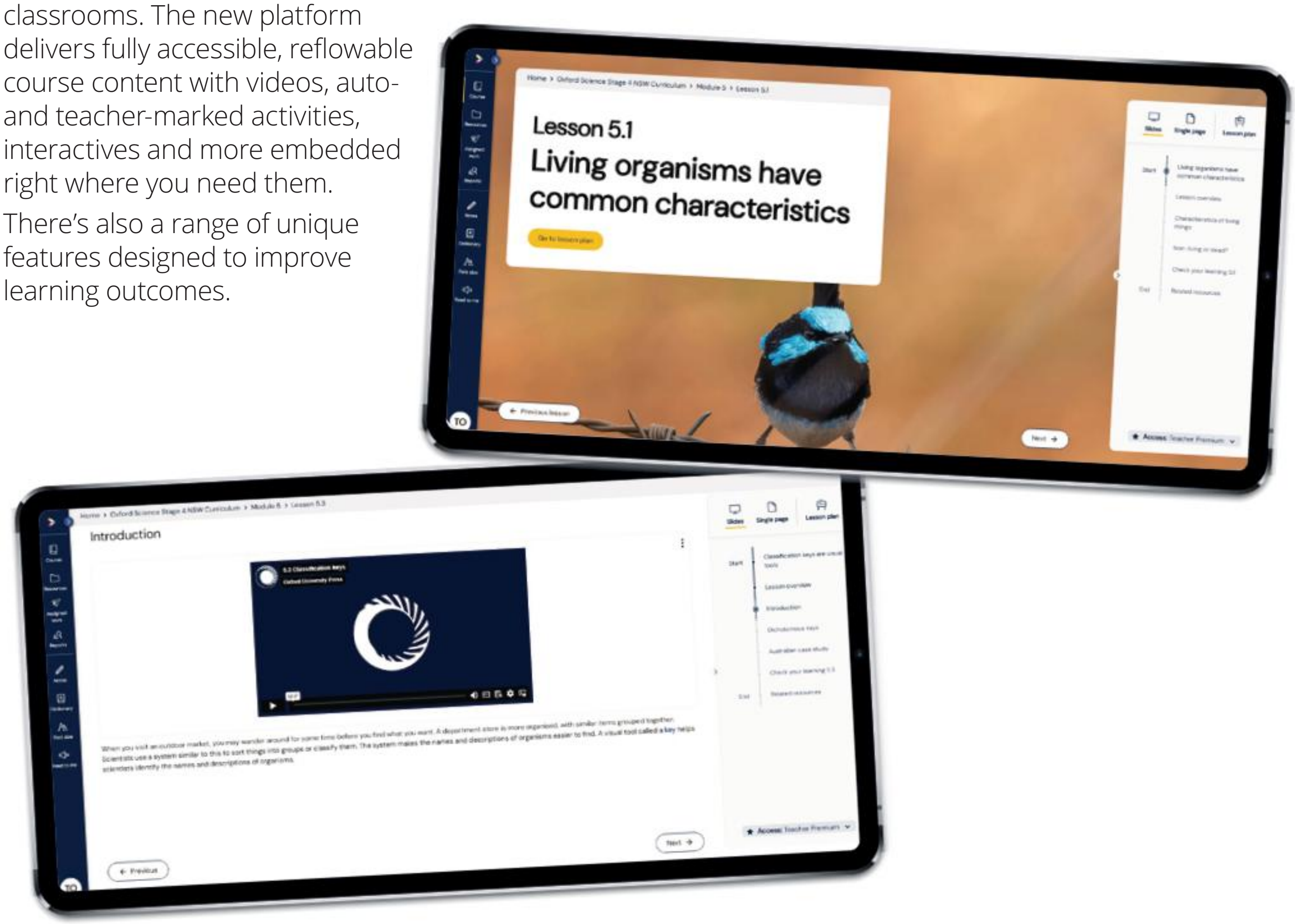
For a complete overview of all the features and benefits of this Student Book:

> activate your digital access (using the instructions on the inside front cover of this book) and click on “Introducing *Oxford Science Stage 4 NSW Curriculum*” in the “About this course” menu.

Key features of oxforddigital

Oxford Digital has been designed in consultation with Australian teachers for Australian classrooms. The new platform delivers fully accessible, reflowable course content with videos, auto- and teacher-marked activities, interactives and more embedded right where you need them.

There's also a range of unique features designed to improve learning outcomes.


Lesson 5.1

Living organisms have common characteristics

As a student, you can:

- **view** all Student Book content in a **fully accessible**, reflowable format that's delivered in bite-sized chunks so you can work at your own pace
- use the "Read to me" button to have any part of the course read aloud to you
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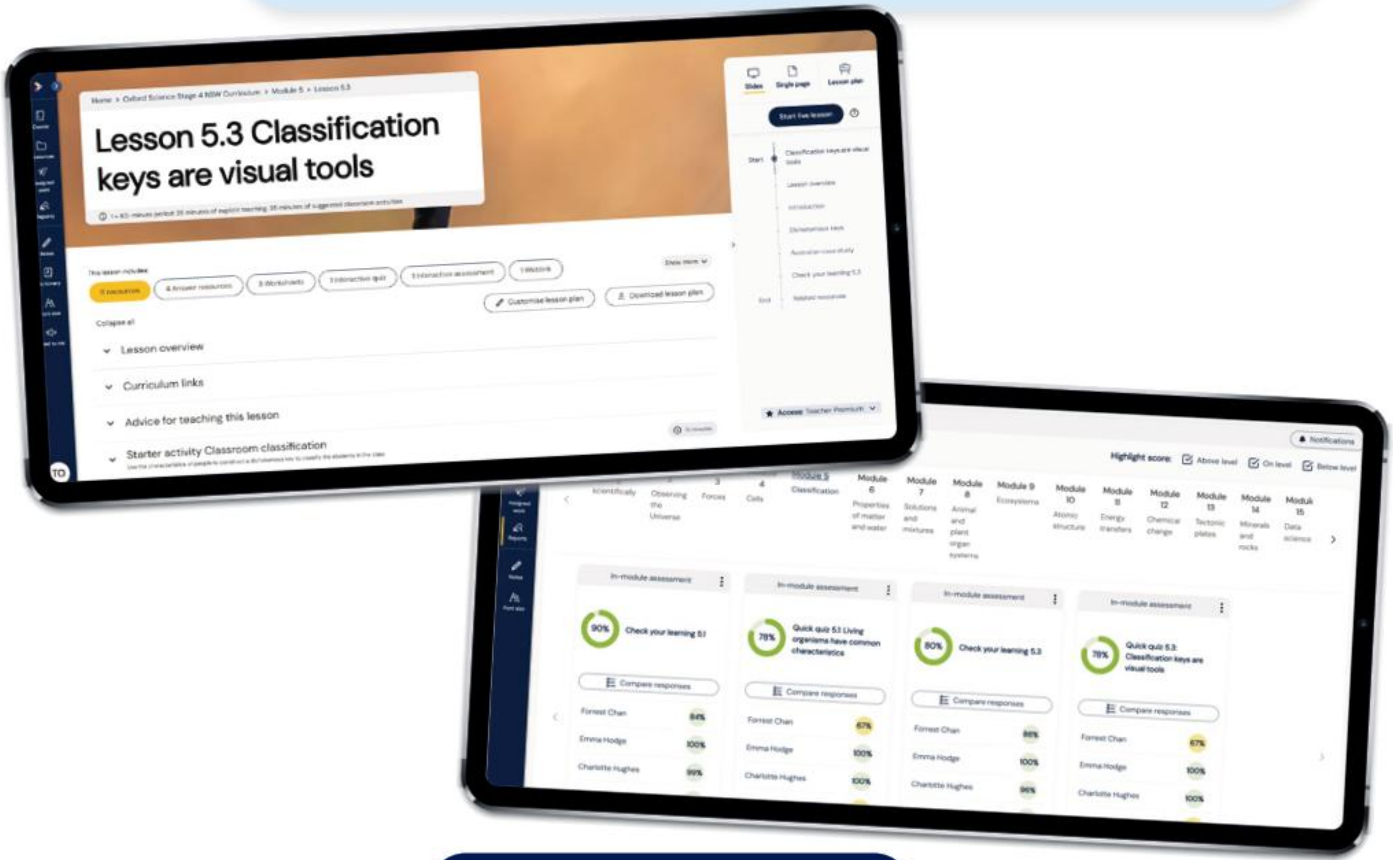

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Meet the authors & reviewers

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Melinda is currently the Head of Science in the independent school's sector. She has a Master of Educational Leadership (with Excellence) and holds degrees in science, chemistry and education. Melinda is also employed by various educational organisations and universities in a variety of roles including a unit convenor and sessional academic, teaching units relating to secondary education and science. Melinda sits on the Science Professional Learning Advisory Committee with the AIS, presenting at various science workshops throughout the last several years. Melinda is a passionate educator who is driven by supporting teachers in their understanding of how to teach science to promote student academic growth.

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Author

Lily Okati has over a decade of experience teaching science, physics, and chemistry across Stages 4–6. She holds a Bachelor of Science, a Master of Physical Chemistry and a Master of Education. In addition to her classroom teaching, she has contributed to the development of physics trial examination papers for the Catholic Secondary Schools Association. Her professional interests lie in curriculum development and fostering deep scientific understanding among secondary students.

Timothy Sloane

Author

Timothy Sloane is the Head Teacher of Science at Concord High School, with over 20 years of experience teaching HSC biology in NSW schools. Before teaching, he was a published research scientist in cardiovascular disease. He holds a Master of Education, focusing on ICT in science education to boost student engagement.

His profile within the science teaching community and expert knowledge of assessment, curriculum content and best practice delivery of that content has led to multiple high-profile leadership and resource development opportunities within the profession. He has presented at numerous conferences and workshops, including HSC Meet the Markers, the BEEST conference and the Centre for Professional Learning, where he has shared his expertise in syllabus programming, and the development of Stage 4 and 5 student research projects, and Stage 6 depth studies and associated marking criteria. Timothy has a keen interest in improving students' scientific literacy, focused on the use of A.L.A.R.M (A Learning and Responding Matrix) to enhance students' writing.

Additionally, he has conducted HSC student study workshops at UNSW, USYD and local community libraries, demonstrating his commitment to enhancing student learning and professional development in education.

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Author

Mora completed a Bachelor of Technology in Biotechnology as her undergraduate degree and was a microbiologist before completing a Graduate Diploma in Education and starting her teaching career in 2003. She completed a Master of Education Leadership in School Education in 2013 and has been working in independent and Catholic schools in NSW over the last 20 years. She is currently Head of Science at St Vincents College in Ashfield and has taught, chemistry, biology and physics for both the old syllabus and current syllabus. She is currently teaching chemistry and Science Extension. She has been a committee member and presenter for Association of Independent Schools and Science Teachers Association NSW. She has also been on exam committees for chemistry and Science Extension and has been a senior HSC marker for both chemistry and Science Extension. She worked with Oxford University Press on the Skills and Activity Book for the previous edition and is an author of the Data Science modules in this new edition.

Helen Silvester

Author

Helen Silvester is a neuroscientist by training and an experienced science educator with a passion for fostering scientific understanding. With over 20 years of experience in education, she has taught science to students ranging in age from 3 to 18 years. Helen is dedicated to science communication in all its forms, including teaching, presenting, curriculum design and textbook writing. She draws on her extensive experience and current research to develop innovative curriculum resources for both students and educators. Helen currently serves as the Learning Area Manager (Science) at the Australian Academy of Science, where she leads the development of the *Primary Connections and Science Connections* resources

Jarrah Cain

First Nations reviewer

Jarrah is a proud Aboriginal woman who descends from the Gomeroi and Darkinyung nations. She is passionate about science and believes that through a culturally inclusive environment, we can learn best practices in environmental sustainability and management. Jarrah is a teacher inspired by her culture and connection to Country. She strongly believes that through sharing, advocating and leading Aboriginal education, we can make a difference and pave a path to a reconciled Australia. Jarrah is the recipient of the Deadly Science STEM Teacher Award for 2024 and is a role model for other Aboriginal women and girls who want to embrace a career in education and science.

Module
1
Working scientifically

Overview

Scientists are curious about the world around them. They investigate how and why things work. To do this, they make observations, ask questions, form hypotheses and conduct investigations to test their ideas. Scientists gather information and organise it into charts or graphs to look for patterns and check for mistakes. They use evidence to support their conclusions and to explain their findings in a way that is easy for others to understand. This process is known as the scientific method.

Lessons in this module

Lesson 1.1

Observing

Learning intentions and success criteria

Key ideas

- → Good scientists need to be observant and notice things around them.
- → Quantitative observations usually contain numbers with units.
- → Qualitative observations contain words and descriptions.
- → Scientists use observations to infer (explain) what is happening.

Making observations

observation the process of using our senses to gather information about the world around us

In science, **observation** is the process of using our senses to gather information about the world around us. The skill of observation usually requires us to notice small differences. Figure 1 shows two scenes. There are 10 differences between the two. Can you find them all?

Quantitative and qualitative observations

quantitative numerical information that can be measured

qualitative descriptive and non-numerical information

Observations are critical in the scientific method as they help formulate hypotheses, develop experiments and draw conclusions. Accurate and detailed observations lead to a better understanding of scientific concepts and phenomena, enabling scientists to build knowledge and make informed decisions based on evidence. Observations can be classified into two main types: **quantitative** and **qualitative**.

Quantitative observations involve numbers, such as measurements, representing data that can be quantified. They are typically written using numbers accompanied by units that describe the size of what is being measured. Examples of quantitative observations include measurements of length (e.g. 10 m), volume (e.g. 10 L), mass (e.g. 100 g), temperature (e.g. 10°C) and time (30 s).

Qualitative observations involve descriptive data that cannot be measured and use words to characterise attributes. They rely on the five main sense organs of the human body: sight, hearing, smell, taste and touch. For example, noting the colour, texture, smell or behaviour of an object or organism qualifies as a qualitative observation. Terms like rough, sour and yellow are qualitative observations. An example would be describing a solution as clear and colourless.

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

Testing your senses

The secret to being observant is to use your senses. The activities in this lesson will make you more aware of your senses. In some activities you will need a blindfold. It is best to use safety glasses that have been painted black or covered with dark paper. You will not use your senses of taste or smell as it is unsafe to eat or inhale substances in a laboratory setting. If smelling is necessary, the special technique of wafting must be used, which involves gently waving your hand to bring the scent towards your nose.

Figure 2 A qualitative observation would be that this substance is dark yellow.

Figure 3 Test your sense of smell. Your teacher will provide you with some test tubes (wrapped in paper) lined up in a test-tube rack. Gently smell each one by wafting the smell towards your nose with your hand. See if you can name the smell.

Figure 4 Test your sense of touch. Wearing your blindfold, feel some common objects. They may be fruit, fabric, sandpaper, plastic or something else. Describe each of them and try to recognise each substance by touch.

Figure 5 Test your sense of hearing. Sit at your desk and put on your blindfold. As your partner taps on the desk or clicks their fingers, point to where you think the noise is coming from. How good are you at finding the direction of a sound?

Based on your responses to Figure 3, Figure 4 and Figure 5, answer the following questions.

- Which is your strongest sense, and which is your weakest?
- Did you discover anything surprising while responding to these figures? If so, what was it?
- What is one thing that you have learnt about your sense of smell, touch, sight and hearing? Write this in your workbook.

Caution

Never smell things in a test tube unless your teacher specifically instructs you that it is safe.

Inferences

inference a likely explanation of an observation

Scientists need to be skilled at **inference** as well as observation. An inference is a likely explanation of an observation. It is how you explain your observation. An inference does not necessarily guarantee that something is true, but it is likely to be true.

Table 1 contains examples of observations, paired with possible inferences.

Table 1 Some sample observations and inferences

Observation	Inference
Your house smells like cooked onions when you get home from school.	You are probably having cooked onions with dinner.
A fabric feels like satin.	The fabric is either satin or something that feels very much like satin.
You see a person running down the street.	The person is either running away from something or running towards something.
You hear a house alarm ringing.	Someone has entered the house.
Lemon juice tastes sour.	Lemons contain an acid.

Using scientific equipment to make quantitative observations

Old ways of measuring

For thousands of years, distances were measured by comparing them to parts of the human body (Table 2). The height of a horse, for instance, is still measured in **hands**.

Using human body parts for basic measurements caused confusion and arguments because everyone's body size is different. There were so many different systems being used to measure things that people were often cheated, such as when buying goods by weight.

Table 2 Measurements used in ancient civilisations

Old unit	Civilisation	Estimated equivalent today (cm)
Royal foot	Ancient Egypt	25.4
Royal cubit	Ancient Egypt	52.4
Finger	Ancient Mesopotamia	1.9
Palm	Ancient Mesopotamia	7.5
Fathom	Ancient Mesopotamia	180.0
Knuckle	Ancient Greece	3.9
Lick	Ancient Greece	15.4

Measurement and units

In 1790, the then king of France, Louis XVI, decided that in his country, at least, a uniform system should be established. This was ultimately called the **metric system**.

The idea of having standard **units** for measurement soon spread, so all types of measurement were included. The metric system is now used by scientists worldwide. A measurement of 2.45 m must be the same in Sydney, Australia, as it is in New York, USA. A temperature of 37°C is just as hot in Kolkata, India, as it is in Penrith, NSW.

Scientists often check each other's work by repeating experiments to see if they get the same results. To do this, they need to use measurements that are consistent with the original experiment. By using a standard system of measurement, scientists everywhere can understand and build on each other's work. Five kinds of measurement are important when you are exploring science: volume, mass, temperature, time and length.

metric system a decimal system of measurement; uses metres, kilograms, litres and so on

units standard measurements

Figure 6 Length Measurements of length can be shown using a unit called metres, with the symbol "m". For long distances, kilometres (km) are used. For short distances, centimetres (cm) or millimetres (mm) can be used. In school science, the devices we use to measure length and distance are the trundle wheel (pictured), metre rule and tape measure.

Figure 7 Mass This measures the amount of matter or substance in an object. Mass is measured in units called grams (g), kilograms (kg) and tonnes (t). Smaller masses are measured in milligrams (mg). Mass-measuring devices are called scales or balances. You will use an electronic balance to measure mass.

Figure 8 Time A watch or clock set to the correct time tells you the time of day. A stopwatch measures how much time has passed. In your experiments, measurements of time will often have the unit called seconds (s).

Figure 9 Temperature This is usually measured using a thermometer. Some thermometers have a digital scale. Measurements of temperature have the unit called degrees Celsius. Its symbol is "°C".

Figure 10 Volume This measures how much space something takes up. Measurements of liquid volumes can be shown with units called litres (L) or millilitres (mL). In science, beakers and measuring cylinders are used to measure the volume of liquids. Some beakers have a measuring scale on them, but measuring cylinders are more accurate than beakers. Scientists usually prefer to use measuring cylinders to measure volume. Liquids cling to the sides of containers, forming a slightly curved surface. This is called a meniscus. The diagram shows how to read a meniscus. Measurements of the volume of solid objects have units such as cubic centimetres (cm^3).

Check your learning 1.1

Check your learning 1.1

Retrieve

1 Distinguish between an observation and an inference. Use an example to support your answer.

2 Contrast quantitative observations and qualitative observations.

3 List some of the things you have measured today. Think carefully – you have probably measured more things than you realise. Try to list at least five things.

4 Identify which tools you would use to measure the following things.

  - **a** Distance around a cricket ground
  - **b** Time it takes a sprinter to run 100 m
  - **c** Mass of a carrot
  - **d** Volume of water in a fish tank
  - **e** Volume of a square block
  - **f** Temperature of a swimming pool
  - **g** Thickness of your favourite book

Comprehend

5 Explain why using body parts as a measuring tool might cause problems for scientists.

6 Examine Figure 11.

  - **a** Draw up a table with two columns: one for "Observation" and the other for "Inference".
  - **b** Write six observations of the crime scene in the "Observation" column.
  - **c** Write down three inferences you can make from your observations in the "Inference" column.
  - **d** Use your inferences to describe what could have happened before you started observing the scene.

Analyse

7 Classify which of the following are observations and which are inferences.

  - **a** You smell a strong odour from a garbage bin.
  - **b** Coffee stays hotter if you add the milk before the hot water.
  - **c** I measured the temperature today at 37°C.
  - **d** It is so hot that the temperature must be 37°C.
  - **e** There is a person in a Santa suit. It must be Christmas.
  - **f** This soup is so hot that it hurts my teeth.

Figure 11 Drawing of a crime scene

Lesson 1.2

Measuring quantities

Key ideas

→ Scientists use equipment to measure their results.

→ Scientists need to compare their measurements with one another.

→ The standard metric system is used by scientists around the world to measure distance (metres), volume (litres) and mass (grams).

Learning intentions and success criteria

Introduction

Measuring quantities correctly is an important science skill, as it enables us to quantify observations, analyse relationships, and ensure **accuracy** and consistency in experiments. Whether determining the mass of a substance, the volume or temperature of a liquid, or the length of an object, precise measurements are essential for comparing results, verifying hypotheses and drawing reliable conclusions.

accuracy how carefully, correctly and consistently data has been measured or processed; in science, how close a measured value is to the true value

Recording measurements

All measurements have two parts: a number and a unit, represented as a symbol (Table 1). For example, 5 metres is written as “5 m”. Notice that the symbol “m” does not have an “s” after it, even though it stands for “metres”. This is so that it does not become confused with milliseconds.

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

Table 1 Some metric units of measurement

Measurement	Unit	Symbol	Instrument used
distance or length	kilometre	km	trundle wheel
	metre	m	metre ruler
	centimetre	cm	tape measure or ruler
	millimetre	mm	tape measure or ruler
volume	litre	L	beaker
	millilitre	mL	measuring cylinder
mass	tonne	t	weighbridge
	kilogram	kg	beam balance
	gram	g	spring balance
	milligram	mg	electronic scales
time	hour	h	clock
	minute	min	stopwatch
	second	s	stopwatch
temperature	degrees Celsius	°C	thermometer

Figure 1 Stopwatches are used to measure minutes and seconds.

Converting units of length

To compare two measurements, their units must be the same. It is difficult to compare 10,000 m with 13 km – which is longer? Comparing 10 km with 13 km is easier. The metric system works in powers of 10, so we can convert using a formula (Table 1). Worked example 1.2A and Worked example 1.2B show how to convert between units.

1 kilometre = 1,000 metres
1 metre = 100 centimetres
1 centimetre = 10 millimetres

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

Table 2 Converting units

Change from	Change to	Conversion
km	m	× 1,000
m	cm	× 100
cm	mm	× 10
m	km	÷ 1,000
cm	m	÷ 100
mm	cm	÷ 10

Worked example 1.2A Comparing measurements that use different units

Two scientists measured the height of two trees. The first tree was 150 m tall, while the second tree was 12,000 cm tall. Identify which tree is the tallest.

Solution

Steps	What to do	Working out
a.	Convert one of the measurements of the trees so they both have the same units.	The first tree is given in metres and will need to be converted into centimetres. 1 m = 100 cm (multiply by 100) 150 m = 150 × 100 = 15,000 cm
b.	Compare the two measurements.	The first tree is 15,000 cm while the second tree is 12,000 cm. 15,000 cm is longer than 12,000 cm.
c.	Answer the question.	Therefore, the 150 m tree is taller than the 12,000 cm tree.

Worked example 1.2B Converting between units

A scientist wanted to send a 295-cm-long metal pipe to a laboratory in England. Should they choose a 2.5 m or a 3.0 m postage cylinder for their pipe?

Solution

Steps	What to do	Working out
a.	Convert the measurement of the metal pipe so it has the same units as the postage cylinders.	100 cm = 1.0 m (divide by 100) 295 cm = 2.95 m
b.	Compare the size of the metal pipe against the postage cylinders.	The pipe is 2.95 m, which is longer than 2.5 m and shorter than 3.0 m.
c.	Answer the question.	Therefore, the 3.0 m postage cylinder should be used as it will fit the pipe; the 2.5 m cylinder is too short.

Measuring accurately

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

You can do several things to improve your accuracy in the science laboratory. Always take your time when measuring and make sure you write down the result straight away. When reading a scale, line up your eye directly in front of the object and the scale. Looking from above or from the side can produce different readings. This is called **parallax error** (Figure 2).

parallax error an error, or inaccurate reading, that occurs as a result of reading a scale from an angle

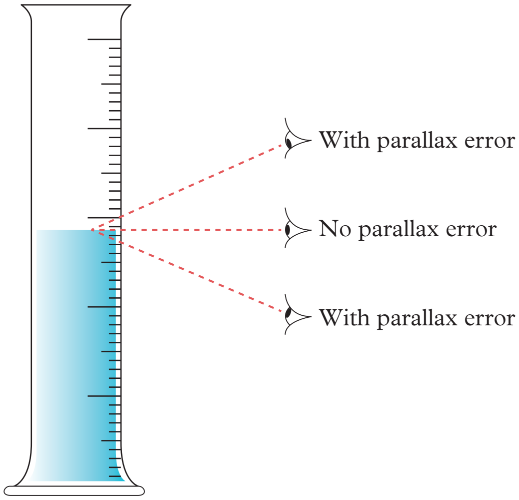


Figure 2 Parallax error occurs when you read a scale from an angle.

Check your learning 1.2

Check your learning 1.2

Retrieve

1 Identify the equipment and standard unit used for measuring each of the following in scientific experiments.

   a Mass
   b Volume
   c Temperature
   d Length

Comprehend

2 Explain why scientists convert measurements into the same units for comparison.

3 Explain the importance of recording both the measurement and the unit during experiments.

4 Provide an example to explain that errors in measurement are sometimes unavoidable.

Analyse

5 Compare the fat content per 100 g for each snack and determine which has the highest fat content per 100 g. Show your calculations. Three snacks, Snack X, Snack Y and Snack Z, have the following nutritional information:

- Snack X: 10 g of fat per 250 g serving
- Snack Y: 8 g of fat per 150 g serving
- Snack Z: 15 g of fat per 300 g serving.

Apply

6 Convert one kilometre into metres, centimetres and millimetres. Show your working.

7 Convert two tonnes into kilograms and grams. Show your working.

8 Explain why you may prefer to walk 14,900 cm instead of 3 km.

Lesson 1.3

Skills lab: Measuring length, mass, temperature and volume

Aim

To make a series of observations and measurements of length, mass, temperature and volume to determine which drinks contain the most sugar

Materials

- A variety of soft drinks
- Flavoured milk
- Fruit juices
- Bottled water
- Sugar
- Scales
- Measuring cylinder
- Beakers
- Thermometer
- Small spoon
- Ruler or tape measure

Method

1 On the side of each drink container, you will find a nutrition panel showing the volume of one standard serve and the amount of sugar in each serve. An example is shown in Figure 1.

Figure 1 A nutrition panel

Measure mass of sugar

2 Place a beaker on the scales and press the "TARE" button that returns the numbers to zero. Add sugar to each beaker until it reaches the mass of sugar in one serve of drink (as shown by the nutrition panel).

Measure volume of liquid

3 Add water to another beaker to carefully measure the volume of a single serve of the drink.

Measure temperature of liquid

4 Use a thermometer to measure the temperature of each drink and record the reading.

Measure dimensions of container

5 Use a ruler or tape measure to measure the dimensions of each drink container. Record the length measurements.

Record data

6 Create a table to record the name of each drink, the sugar content per serve, the volume of each serve, the temperature of each drink, the dimensions of each container and the number of serves of drink that were in each container (Table 1).

Questions

1 Identify the drink that had the most sugar in a single serve.

2 Identify the drink container that had the largest volume.

3 Identify the drink that had the most serves in a single container.

4 Identify the drink that had the most sugar in a whole container.

5 Suggest a situation where knowing the temperature of a liquid would be important.

6 Identify a type of drink that had an unexpected amount of sugar content and explain why you were surprised.

7 Compare the sugar content per 100 mL of each drink. Which drink has a higher sugar concentration? Show your calculations.
Two drinks, Drink A and Drink B, have the following nutritional information:

- Drink A: 10 g of sugar per 250 mL serving
- Drink B: 15 g of sugar per 300 mL serving.

Table 1 Example table

Drink name	Sugar content (g/serve)	Volume (mL/serve)	Temperature (°C)	Dimensions of container $h \times d \times w$ (cm)	Number of serves per container

Lesson 1.4

Questioning and predicting

Learning intentions and success criteria

Key ideas

→ Two things are correlated when they both change in a related way.

→ Correlation of data does not mean one event causes another event.

→ Causation occurs when the independent variable is responsible for the change in the dependent variable.

Scientists ask questions

Many scientific discoveries start with one person who is curious about something. Our world would be a very different place without people wondering, "How does this work?" or "Why is this so?" All scientists share this curiosity about the world they live in. They use all their senses to observe small changes and try to explain why these changes occur by asking what caused them. Scientists develop specific, testable questions that can be investigated through observation or valid scientific **experiments**.

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

A scientific question is considered testable if:

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

Consider the following questions and discuss as a class which, if any, could be considered a testable scientific question.

- What is the meaning of life?
- What is the best brand of toothpaste?
- Do toothpastes with more hydrogen peroxide whiten teeth more than those with less hydrogen peroxide?

Correlation of data

If an experiment is not valid, it may yield misleading results. For example, a scientist might observe that there are a larger number of shark attacks in summer than in winter. They may also notice that the number of ice creams sold by a kiosk on the beach is higher in summer as well. During winter, both shark attacks and ice-cream sales go down. If this is graphed (Figure 1), it could look like the ice-cream sales caused the shark attacks because they both go up at the same time. This is not correct as there is another causative factor: hot weather. In hot weather, more people go swimming, so shark attacks are more likely to occur than when the weather is cold, when few people go into the ocean. People are also more likely to buy ice creams in summer than winter. The hot weather is the cause of the increased shark attacks and ice-cream sales.

A scientist would describe the **relationship** between these variables as a **correlation**, indicating that they are related but not necessarily causal (meaning caused by something). Correlation shows that there is a relationship between the two variables; it does not necessarily mean that one **variable** causes the other to change (that is, **causation**). Can you think of other correlations that are not causative?

relationship the way in which two or more variables interact where changing one variable causes a change in the others

correlation a relationship between two or more things

variable something that can affect the outcome or results of an experiment

causation when the independent variable is responsible for the change in the dependent variable

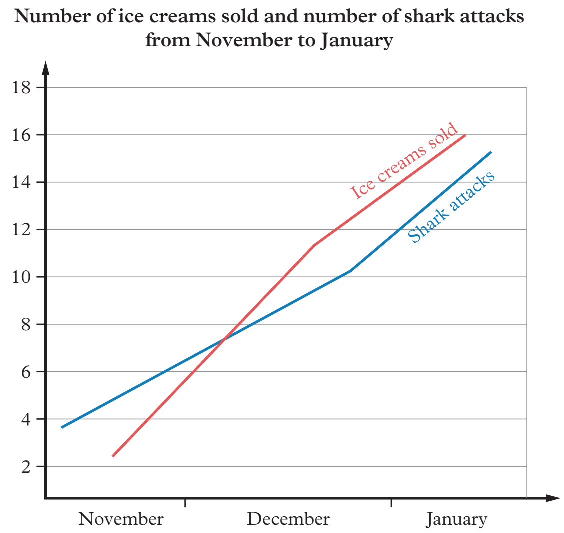


Figure 1 There is a positive correlation between the number of ice creams sold and the number of shark attacks in summer.

When two sets of data are strongly linked (that is, as one changes, the other changes by a similar amount), the data has a strong correlation. A **positive** correlation occurs when both values increase together, while a **negative** correlation occurs when one value increases as the other decreases. This can be shown on a graph (Figure 2).

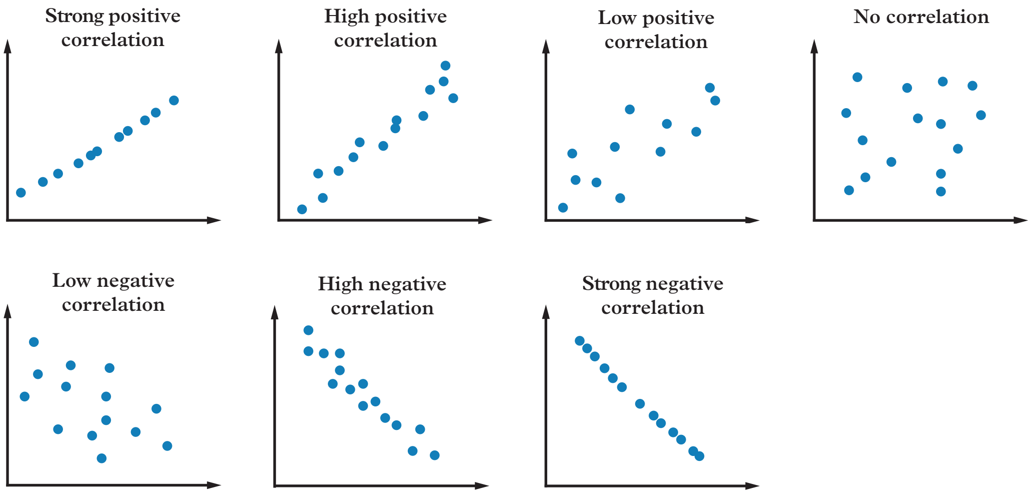


Figure 2 Correlation of data

Reproducible

To identify whether a relationship is causal or a correlation, scientists must design a **reproducible** experiment. This means the experiment can be replicated by other scientists, using the same materials and methods, and produce consistent outcomes.

reproducible an experiment that can be replicated by other scientists, using the same materials and methods, and produce consistent outcomes

Asking "What if?"

A variable is something that can affect the results of an experiment. You can find out how a variable affects the results by asking a "what if" question.

- What if the surface was smoother? Would it affect the speed a ball rolls across it?
- What if the amount of sunlight was increased? Would it affect the growth of a plant?
- What if the animal receives a different diet? Would it increase their response time?
- What if the level of pollution was reduced? Would more fish return to the water?
- What if the structure was taller? Would it be more likely to blow over?

Each of these questions explores the effect of changing an **independent variable**. In a reproducible experiment, only one variable – the independent variable – should be changed at a time to determine its effect on the **dependent variable**, which is the variable being measured.

For example, in an experiment to determine if the temperature of water affects the rate at which sugar dissolves, the temperature of the water would be the independent variable and the time taken for the sugar to dissolve would be the dependent variable. All other variables, such as the amount of sugar, the type of sugar and the volume of water, must be kept constant; these are called **controlled variables**. These controlled variables ensure a **valid experiment** has been conducted, meaning that any observed changes in the dependent variable are due solely to changes in the independent variable.

Each experiment should also be repeated at least three times. Conducting an experiment only once risks random errors affecting the result. Obtaining the same result twice may be a coincidence. If an experiment is repeated three times or more and the same or similar results are obtained, then the results are **reliable**.

independent variable a variable (factor) that is changed in an experiment

dependent variable a variable in an experiment that may change as a result of changes to the independent variable

controlled variable a variable that is kept constant and unchanged throughout an experiment

valid experiment where an experiment investigates what it sets out to investigate

reliable consistency of information across difference sources or measurement

Developing a hypothesis and making predictions

A **hypothesis** and a **prediction** are closely related concepts. The distinction is that the hypothesis provides the expected relationship between the independent variable and the dependent variable and the scientific reasoning behind it, while a prediction gives an expected, specific, testable result.

For example, for the experiment investigating the effect of temperature on the rate of dissolving sugar, the hypothesis could be: "**If** the temperature (independent variable) of the water is increased, **then** the sugar will dissolve more quickly (dependent variable) **because** the water molecules move faster, increasing their interaction with the sugar molecules (scientific reasoning)." The process for converting a "what if" question into a hypothesis is shown in Figure 3.

A related prediction could be, If the temperature is increased to 80°C, then it will take six minutes for two teaspoons of sugar to dissolve in 200 mL of water, compared to 40°C, which would take 12 minutes.

hypothesis a proposed explanation for a prediction that can be tested

prediction the expected result of an experiment

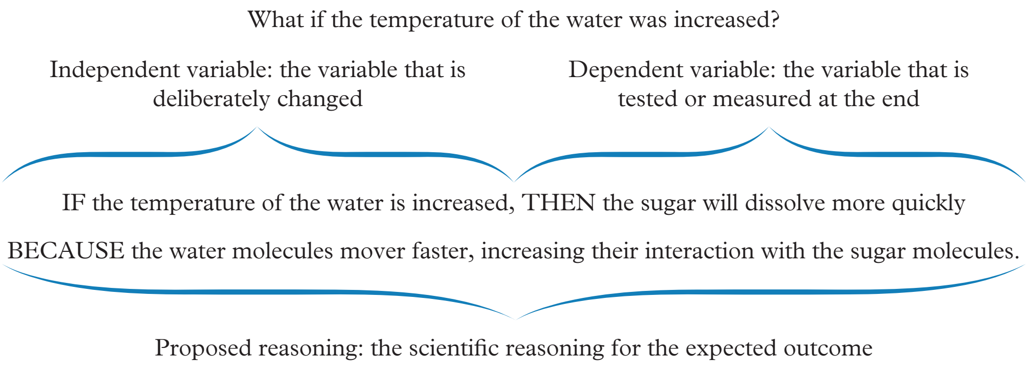


Figure 3 A "what if" question can be changed into a hypothesis by removing the "what" at the start, adding a "then" at the end of the question and a "because" to explain the related science concept.

Check your learning 1.4

Check your learning 1.4

Retrieve

1 Identify the three types of variables in an experiment.

2 Outline what is meant by a valid experiment.

Comprehend

3 Describe the relationship between the sets of data shown in Figure 4.

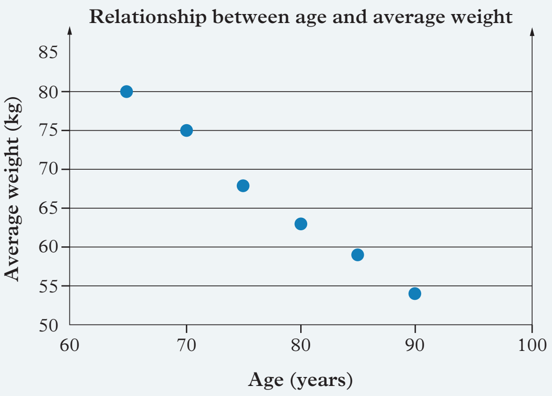


Figure 4 A scatterplot showing the relationship between age and average weight.

4 Explain why it is important for an experiment to be reproducible.

5 Describe how to change a "what if" question into a hypothesis.

Analyse

6 Identify one variable that would be difficult to control in the temperature/sugar experiment example given in this lesson.

Apply

7 Discuss why it is important for experimental methods to be checked by other scientists.

8 Many experimental reports written by scientists are peer-reviewed. Investigate what is meant by "peer reviewed" and write a definition in your own words.

9 A student wanted to convert their science question into a hypothesis (a possible explanation that can be tested in a reproducible test). Complete the following steps to help the student.

Science question: What if a different cleaning agent was used on a stained fabric?

Science prediction: If a more expensive cleaning agent is used on a stained fabric, then …

Science hypothesis: If a more expensive cleaning agent is used on a stained fabric, then … because …

10 Evaluate the following scientific questions. Explain what makes them good or bad.

- **a** Is crunchy peanut butter better than smooth peanut butter?
- **b** Is it colder on Jupiter or Saturn?
- **c** How do plants grow?

11 Propose better scientific questions to replace those in question **10**.

Lesson 1.5

Skills lab: Balloon rocket race

Part A

Aim

To conduct a reproducible experiment using a balloon rocket

Materials

- One balloon
- One long piece of string
- Sticky tape
- One plastic straw
- One tape measure
- Two chairs (or alternative objects to tie off string)

Method

1. Tie one end of the string to a chair.
2. Place the other end of the string through the straw.
3. Tie the loose end of the string to a second support (another chair) so that the string is pulled tight.
4. Blow up the balloon and hold the end closed. While holding the end closed, stick the balloon to the straw with the sticky tape, as shown in Figure 1. (Do not tie the end of the balloon.)
5. Ask a classmate to measure the circumference of the balloon with the measuring tape.
6. Release the end of the balloon so that the straw slides along the string.
7. Measure how far the balloon rocket moves along the string.
8. Repeat this experiment twice more with the same balloon blown up the same amount. You now have a reproducible test for your balloon rocket.

Questions

1. Explain what you did to ensure your experiment was valid.
2. Discuss the reliability of your results.
3. Describe what you could do to further improve the reliability of the results.

Part B

Aim

To design an experiment that increases the distance the balloon rocket travels compared to Part A

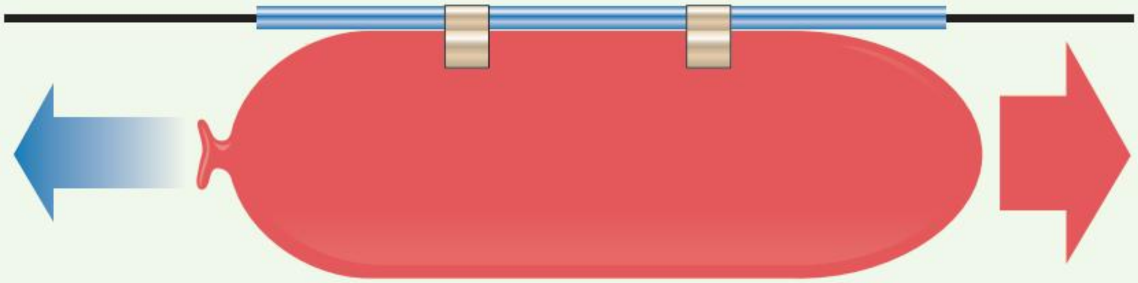


Figure 1 A balloon rocket

Method

1. Using the balloon rocket you made in Part A, choose one of the following questions to investigate.
   - What if the balloon was blown up more?
   - What if the string had less friction?
   - What if the string had more friction?
   - What if the straw was shorter?
2. Write a hypothesis and prediction for your inquiry.
3. Identify the independent variable that you will change from the first method.
4. Identify the dependent variable that you will measure and observe at the end of the experiment.
5. Identify three variables that you will need to control to ensure a valid experiment. Describe how you will control them.
6. Write your method as a step-by-step process.
7. Check your method with your teacher before completing your experiment.
8. Draw a table in which you can record your results.
9. Repeat your test at least three times to make sure your results are reliable.

Results

Record your results in the table. Include the units for all measurements.

Questions

1. Compare (similarities and differences between) the results of the method in Part A with the results of your method.
2. Use evidence from your results to support or refute (disagree with) your prediction by:
   - describing how you changed the independent variable
   - describing how the results (dependent variable) changed
   - describing how the results support or refute your prediction.

Lesson 1.6

A Bunsen burner is an essential piece of laboratory equipment

Key ideas

→ A Bunsen burner is used to heat things in the laboratory.

→ The yellow flame is called the safety flame because it is easier to see.

→ The blue flame produces more heat than the yellow flame (over 1,500°C).

Learning intentions and success criteria

Using a Bunsen burner

A mixture of liquid petroleum gas (LPG) or methane and air is used to produce a good flame for heating. The **Bunsen burner** has a collar that can be turned to open or close the air hole. The position of the collar controls how much air enters the burner and, therefore, how hot the flame is. If the hole is closed, less air can mix with

Bunsen burner a piece of equipment used as a heat source in the laboratory the gas. This results in a yellow safety flame. If the collar hole is open, air mixes with the gas, allowing a hotter blue flame to burn (Figure 2).

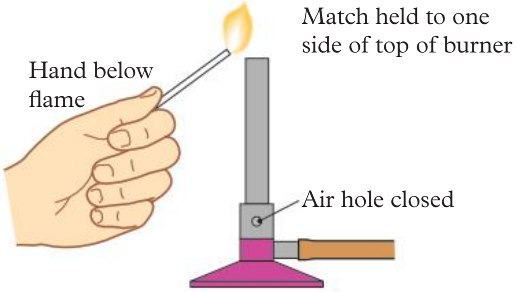


Figure 1 The right way to light a Bunsen burner

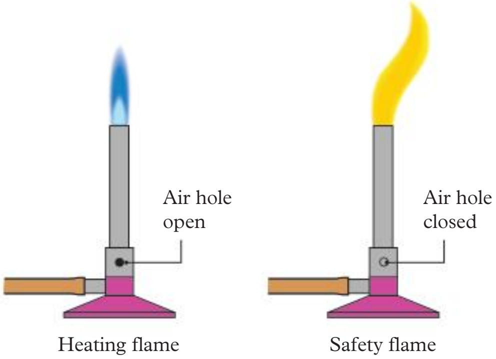


Figure 2 Blue (heating) and yellow (safety) flames on the Bunsen burner

When alight but not being used for heating, the Bunsen burner should be left on the yellow (safety) flame, which is not as hot and is easy to see. The safety flame is always used when lighting the burner.

What to do if there is a fire in the laboratory

1. Let the teacher know immediately (they will turn off the main gas tap if gas is involved).
2. The class fire officer should take a message to the school administration as quickly as possible.
3. If the fire is small, the teacher will use the fire extinguisher.
4. Evacuate the area in an orderly manner.
5. Check that everyone is safe.

Treating scalds and burns

1. Immediately run cold tap water on the scald or burn for at least 15 minutes. Do not use ice or very cold water.
2. Ask another student to tell your teacher about the scald or burn.
3. Remove nearby clothing (unless it is stuck to the burnt area) and jewellery (such as watches, rings and bracelets) because burnt areas can swell quickly.
4. Try not to touch the area if possible. Do not use any creams.
5. Seek medical attention if necessary.

Figure 3 A scalded hand

Figure 4 A burnt hand

Check your learning 1.6

Check your learning 1.6

Comprehend

1 Describe the colour of the Bunsen burner's safety flame.

2 Describe the colour of the Bunsen burner's heating flame.

3 Explain how (what you do) to get a heating flame with your Bunsen burner.

4 Explain how you should treat a scald.

5 If you were heating a substance to check for colour change, describe the flame that you would use to make it easier to observe.

6 Explain why hair should be tied back when using a Bunsen burner.

Apply

7 A student claimed that the top part of the Bunsen burner flame was hotter than the bottom of the flame. Design an experiment that will allow you to test the student's claim.

Lesson 1.7

Skills lab: Lighting and using a Bunsen burner

Caution

- Remember to keep your hand below the flame.
- Keep your notebook and other materials well away from the Bunsen burner.
- Never sit at eye level in front of a Bunsen burner. Stand while you are conducting the experiment.
- The porcelain you heat will remain very hot for a long time. Do not pick it up with your fingers – use tongs. Wear safety goggles and a lab coat.

Aim

To become familiar with using a Bunsen burner

Materials

- Bunsen burner
- Heatproof mat
- Matches
- Notebook
- Coloured pencils
- Grey pencil
- Metal tongs
- Two pieces of white ceramic or porcelain
- Safety goggles
- Lab coat

Method

1 Place the Bunsen burner on a heatproof mat.

Figure 1 A Bunsen burner on a heatproof mat

2 Connect the rubber hosing firmly to the gas tap.

Figure 2 Connecting the rubber hosing to the gas tap

3 Close the air hole by turning the collar.

Figure 3 Closing the Bunsen burner's air hole

4 Light a match and place it above the barrel, with your hand below the flame.

Figure 4 Lighting the Bunsen burner

5 Open the gas tap fully.

Figure 5 Fully opening the gas tap

6 After you have followed these steps, the Bunsen burner will have a yellow (safety) flame.

Figure 6 The yellow (safety) flame of a Bunsen burner

7 Change the flame to blue by opening the air hole on the collar.

8 Write down and draw what happens to the flame when the hole is closed, half open and fully open.

9 Close the collar so that a yellow flame is produced.

10 Using tongs, hold a piece of porcelain in the top of the yellow flame for a minute. Place the hot porcelain on the heatproof mat when you have finished. Describe what happens to the porcelain and draw it.

11 Hold the other piece of porcelain with the tongs. Change the flame to blue and heat the porcelain for one minute by holding it in the top part of the flame. Describe what happens to this piece of porcelain and draw it.

Questions

1 Describe two reasons why the yellow flame is called the safety flame.

2 Identify which flame is noisier: blue or yellow? Explain why this is useful to know.

3 Identify which flame leaves a sooty, black carbon deposit on whatever object it heats.

4 Identify which flame is the "clean" flame for heating.

5 Describe two reasons why you might use a blue flame for heating in an experiment.

Lesson 1.8

Planning investigations

Key ideas

→ Scientists use specialised equipment to conduct experiments in the laboratory and in the field.

→ Scientific experiments must be carefully planned so that they are safe.

Learning intentions and success criteria

Purpose of an investigation

Once you have formulated a scientific question or identified a problem that you wish to investigate, the next step is to plan and design an experiment that will help you determine the answer to your initial inquiry.

Identify the variables

One of the most important stages of planning an investigation is having a clear understanding of the variables and how they apply to your specific experiment. Remember that the independent variable is the one you change in order to determine the effect it has on the dependent variable – the one that you will be measuring. Controlled variables must be kept constant so they do not affect the outcome of the experiment. This ensures that the experiment is valid. Throughout your experiment, you will continually refer back to the relationship between the independent and dependent variables.

Identify the type of data to be collected

Once your variables have been identified, the next step is to determine the type of data that will be collected to measure the effect the independent variable has had on the dependent variable. This will be determined by the aim of the investigation. It is important to plan which data to collect before starting the investigation.

Recall that qualitative data includes descriptive information, such as observations of behaviour. For example, if you are investigating how different amounts of sunlight affect plant growth, you might record qualitative data by noting how the leaves look, their colour and any changes in the plant's overall health.

Quantitative data involves numbers and measurements, such as temperature or mass. For instance, if you are measuring the effect of different fertilisers on plant height, you would collect quantitative data by measuring the height of the plants in centimetres each week.

Identify the equipment needed

Prior to the methods section, a concise list of all the equipment and resources which are needed to perform the investigation should be provided. **Equipment** is the name given to the beakers, Bunsen burners, flasks, stands and other items used by scientists to conduct experiments. Using the correct equipment ensures reliable **results** and the safety of scientists. Commonly used equipment is shown in Figure 1. Some names may sound unfamiliar, but you will soon learn what each piece of equipment is called and how it is used. The equipment in your school **laboratory** may look slightly different because each laboratory has its own types of equipment. Some items of equipment can be used together in an experiment. Equipment placed together for an experiment is called an **apparatus**.

equipment items used in the laboratory to conduct experiments

results the measurements and observations made in an experiment; they are often presented in a table

laboratory a specially designed space for conducting research and experiments

apparatus equipment placed together for an experiment

Figure 1 Types of equipment used in the laboratory

Outline the method

A well-written method should be clear and detailed enough that it can be repeated by another person, yielding consistent results regardless of the time or location. It should include a labelled drawing of any apparatus used and explicit mention of:

- the independent variable and how it will be changed
- the dependent variable and how it will be measured
- the controlled variables and how they will be kept constant
- any steps or processes that are to be repeated.

To draw the apparatus, scientists have a quick and simple way to show scientific equipment. They use drawings called **scientific diagrams** (Figure 2). Using scientific diagrams means you do not have to be an artist to be a good scientist and you have more time to do the experiments.

scientific diagram a clear, labelled, side-view line drawing, usually made using a sharp pencil

The procedure for drawing scientific diagrams is as follows:

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

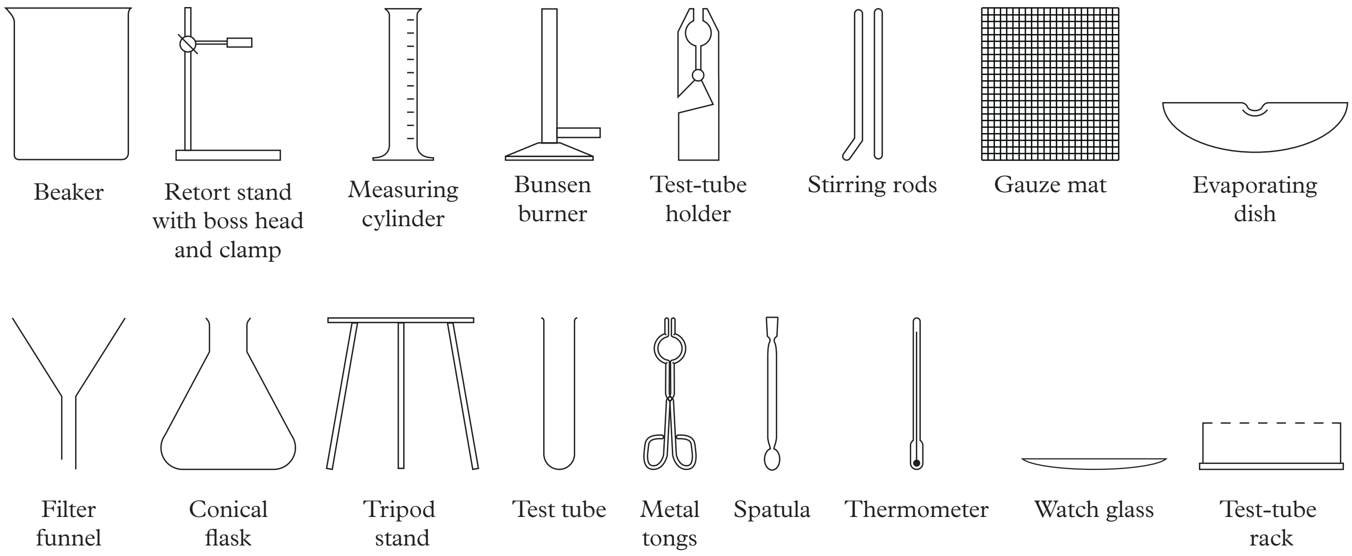


Figure 2 Scientific drawings of laboratory equipment

Identifying and managing risks in the science laboratory

Outline steps to manage safety risks before, during and after an investigation.

Even when following the standard laboratory rules (Lesson 1.7 Skills lab: Lighting and using a Bunsen burner on page 21), every investigation involves some level of risk, making it essential to identify these risks beforehand. A **risk assessment** should be conducted for each experiment, during which **hazards** are identified, the associated **risks** are recorded and **precautions** to mitigate these risks are noted. Risks could include physical hazards, like using sharp tools, or environmental factors, like weather conditions. Once identified, you can develop strategies to manage these risks, such as using safety equipment (Figure 3).

Following safety guidelines is crucial for protecting yourself and others, and regularly reviewing and updating risk assessments helps ensure a safe investigation.

risk assessment a process to identify potential hazards and associated risks in order to take safety precautions

hazard something that can cause harm, like sharp tools or chemicals

risk the chance that a hazard will cause harm

precaution safety measures taken to prevent harm, such as wearing personal protective equipment (PPE)

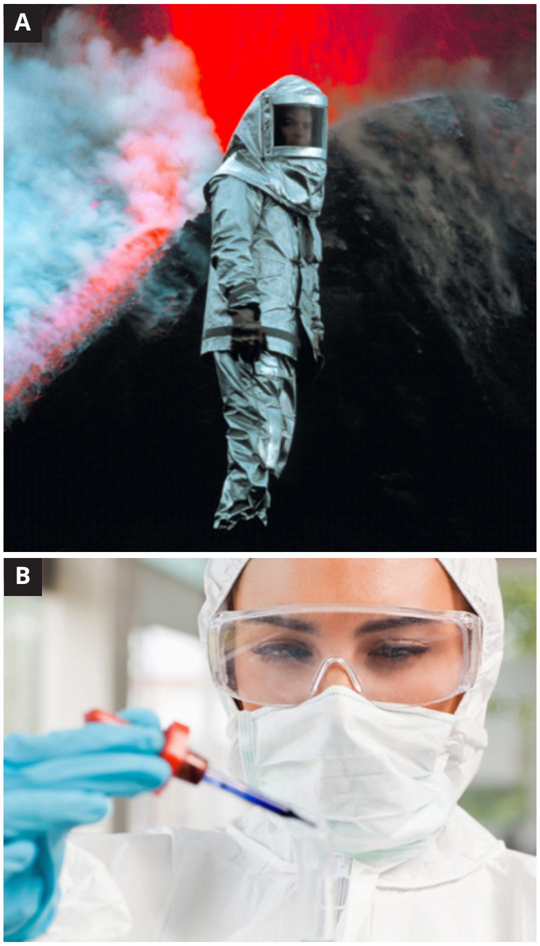


Figure 3 (A) Vulcanologists (scientists who study volcanoes) wear heat-resistant silver suits to protect themselves against heat, ash and molten rock. (B) Microbiologists researching infectious diseases wear protective clothing to ensure they do not get sick.

Check your learning 1.8

Check your learning 1.8

Retrieve

1 Describe the steps involved in creating a scientific diagram.

Comprehend

2 Explain why it is important to identify the purpose of an investigation before starting it.

3 Explain why planning the type of data to collect is necessary before starting an investigation.

4 Explain the importance of providing a clear and detailed method section for an investigation.

5 Explain how identifying risks in an experiment can help prevent accidents.

Apply

6 Identify the independent, dependent and two controlled variables in an experiment, testing the effect of time of day on a student's response time.

7 A student drew an image of their experiment apparatus in their notebook (Figure 4).

- a Identify three incorrect aspects of their scientific diagram.
- b Redraw the image using the correct procedure for drawing scientific diagrams.

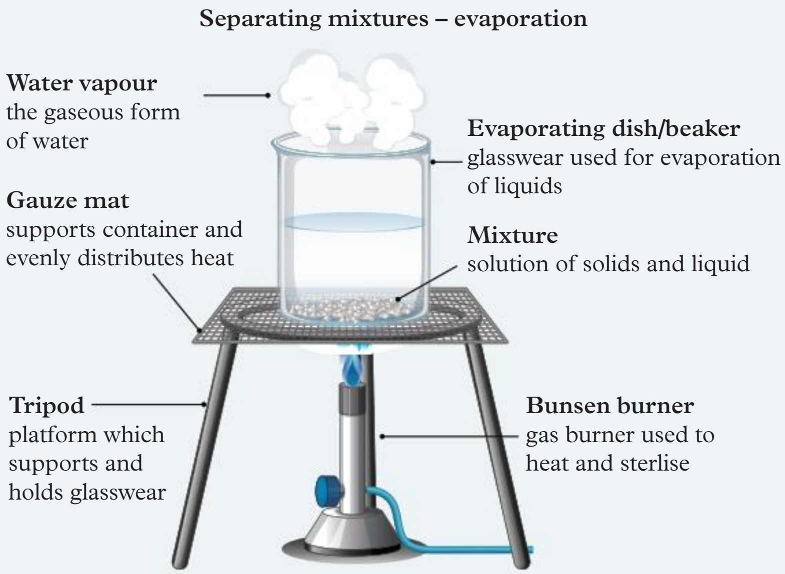


Figure 4 Student drawing of experiment apparatus. Spot the errors.

Figure 5 Associate Professor Elizabeth Tibbetts noticed that the wasps she was studying had individual markings which led her to wonder if the wasps could tell one another apart.

8 A student wanted to determine whether different types of music affected their pet dog's behaviour. Identify whether the data collected in this experiment would be qualitative or quantitative.

9 Plan an experiment that you could perform at home that requires qualitative data to be collected.

  a Outline a method for your experiment.

  b Discuss your method with a classmate and have them critique it based on whether they can identify all variables and whether they can follow the instructions without further assistance.

10 American scientist Associate Professor Elizabeth Tibbets had difficulty putting marks on the wasps she was studying. When looking closely at the wasps, however, she realised that they all had different natural markings to each other (Figure 5). This encouraged her to test if the wasps could tell one another apart.

  a Propose a hypothesis that the Associate Professor could test based on this idea.

  b Design an experiment the Associate Professor could perform to test the hypothesis.

Lesson 1.9

Conducting investigations

Learning intentions and success criteria

Key ideas

- → Following safety practices minimises danger by identifying risks and applying necessary precautions.
- → Using the correct equipment and following a planned procedure improves the reliability of investigations.
- → Recording data accurately improves the quality of scientific work.

Introduction

After posing the initial research question and planning a valid investigation, the next stage in the process is to conduct the experiment. Conducting scientific investigations is a key skill for understanding and exploring the natural world. Successful experiments require careful planning, adherence to safety protocols and the correct use of equipment. Scientists follow strict safety guidelines to minimise risks, assemble appropriate apparatus to ensure reliable results, and record observations and measurements accurately to maintain credibility.

Work health and safety (WHS) practices

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

It is also important to have an understanding of Work Health and Safety (WHS) practices. This includes identifying potential hazards, conducting risk assessments, using appropriate personal protective equipment (PPE), and knowing emergency procedures to ensure a safe laboratory environment for you and your classmates.

Safety symbols

Safety symbols are used in many different settings. You may have seen the symbols in Figure 1 on building sites, at entrances to buildings, at school or on roads.

Figure 1 What does each of these symbols mean?

Your laboratory may already have some of these symbols displayed.

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

Laboratory safety rules

A class laboratory is not like a normal classroom. Along with risk assessments and safety precautions for each experiment, there are additional laboratory rules that must always be followed.

In the laboratory, do:

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

In the laboratory, don't:

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

Assembling and using appropriate equipment

After you have written up your equipment list and method, it is time to perform the experiment. It's best practice to collect all the appropriate equipment and resources and take them to your workbench before commencing the experiment. Assemble the apparatus before starting the experiment.

By having everything organised and within reach, you can minimise unnecessary movement around the classroom which can lead to accidents or disruptions. This will also allow you to focus on the investigation, ensuring that the experiment is conducted effectively and that the results collected are accurate.

Figure 2 Collect all necessary equipment and resources, and set up apparatus before beginning your experiment.

Follow the planned procedure

accurate how close information is to the true value

Following the planned procedure during an experiment is crucial to obtaining reliable and **accurate** results. When you follow the steps exactly as written, it ensures consistency and reduces the chance of mistakes, and helps maintain focus on the relevant variables. By using the correct equipment and ensuring careful measurements, you can observe the effect of the independent variable on the dependent variable while keeping the controlled variables constant.

This approach not only minimises errors but also ensures that other students conducting the same experiment can achieve similar results, making the investigation repeatable and scientifically valid. This will likely produce results that can be confidently analysed to draw meaningful conclusions.

Recording results

Accurate recording of observations and measurements is essential in any experiment, and this is best accomplished using a table that follows certain guidelines (this will be covered in Lesson 1.11 Processing data and information: Part B – Representing data and information (page 37)). Setting up your results table prior to performing the experiment will allow for better organisation of data, streamline the recording process and enhance accuracy in measurements. Using the correct units, like centimetres for length or grams for mass, ensures that your results are easy to understand, and your analysis and can be easily compared between different laboratories.

Using reliable secondary sources

An important skill in conducting an investigation is utilising a wide range of reliable secondary sources to inform the direction of your research and provide context for the results obtained.

Several key features characterise a reliable secondary source.

- The source is authored by an expert in the relevant field.
- The source is current, with up-to-date information that reflects the latest research in the field.
- The source is peer-reviewed and published by a reputable publisher or academic institution.
- The source includes **citations** and **references** to primary sources.
- With online sources, look for websites with domains like .edu (educational institutions), .gov (government), or .org (non-profit organisations), as these are generally more reliable.

citation a brief mention within the text of a document that indicates the source of information, ideas, or quotes

reference a complete entry in a reference list or bibliography that provides full details about a source cited in the text

It is important to acknowledge the secondary sources you use correctly. This provides credit to the authors for their work and enhances the credibility of your work. While there are many different referencing styles, one of the most used in science is the APA (American Psychological Association) style.

Textbook reference format

Author(s). (Year). *Title of the book: Subtitle if applicable* (Edition if applicable). Publisher.

Example

Mestre, M., Okati, L., Sloane, T., & Silvester, H. (2021). *Oxford Insight Science for NSW Stage 4 Student Book* (2nd ed.). Oxford University Press.

Journal article reference format

Author(s). (Year). Title of the article. *Title of the journal, Volume*(Issue), Page range. https://doi.org/xxxx

Example

Geyle, H., Hoskin, C., Bower, D., Catullo, R., Clulow, S., Driessen, M., & Gillespie. (2021). Red hot frogs: Identifying the Australian frogs most at risk of extinction. *Pacific Conservation Biology, 28*(3), 211–223.

Online source reference format

Author(s). (Year, Month Day). *Title of the webpage*. Website name URL

Example

Australian Government. (2024, October 17). Climate Change: Driving climate action, science and innovation so we are ready for the future. https://www.dcceew.gov.au/climate-change

Check your learning 1.9

Check your learning 1.9

Retrieve

1 Identify the three safety symbols shown in Figure 3. Describe the meaning of each symbol.

Figure 3 Three safety symbols

2 Think about what scientists wear in a laboratory.
  - **a** Name three items of protective clothing you might wear in the laboratory.
  - **b** Describe what might happen if you do not wear one of these items of clothing.

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

4 Identify five things you should not do in the laboratory.

Comprehend

5 Explain why it is dangerous to drink from laboratory glassware.

6 Explain why it is important to follow the planned procedure in an experiment.

7 Explain how using the correct equipment contributes to obtaining accurate results.

Apply

8 Evaluate the effectiveness of the protective equipment being worn by the students in Figure 4 (by identifying the ways the students are using the equipment safely and the ways they are being unsafe). Write a list of suggestions you could offer the students to improve their safety.

Figure 4 Protective equipment worn by students

Lesson 1.10

Processing data and information: Part A – Extracting data and information

Learning intentions and success criteria

Key ideas

→ Scientists need to collect data and present it in an organised manner.

→ Information can be extracted from tables, graphs and other representations to identify trends, patterns and relationships that may exist in their results.

Extracting information from different sources

Extracting information from different sources is a crucial skill in scientific research, as it allows researchers to gather data and insights from a wide range of formats.

Texts such as peer-reviewed scientific articles (Figure 1A) and textbooks like this one (Figure 1B) provide detailed written explanations and context that help the reader to understand complex concepts, and the theories and laws that underpin the science.

Figure 1 Scientific texts such as (A) scientific publications and (B) textbooks provide detailed written explanations.

The text will often be accompanied by visual representations such as **diagrams**, **flowcharts**, **graphs** and **tables**, each offering different ways to present and clarify information. These visual tools also assist with the extraction of information, making complex data and concepts more accessible and easier to understand.

Diagrams simplify complex information and support the retention of key concepts. For example, in Module 4 Cells (page 166), you will find diagrams of cells that illustrate the different organelles and their function, helping to clarify how each structure contributes to the overall operation of the cell.

Flowcharts are used to illustrate the sequence of actions or relationships in a particular scientific context. For example, in Module 9 Ecosystems (page 388), flowcharts are used to illustrate how energy is transferred through a food chain, from producers to consumers to decomposers, highlighting the interconnectedness of organisms within the ecosystem.

diagrams visual representations that illustrate concepts, processes or relationships, simplifying complex information for better understanding

flowchart a diagram that uses shapes and arrows to represent the steps in a process or the flow of information

graph a visual representation showing the relationship between variables, using axes to plot data points for easy comparison and analysis of trends and patterns

table organised arrangements of data in rows and columns, facilitating easy access and comparison of specific information

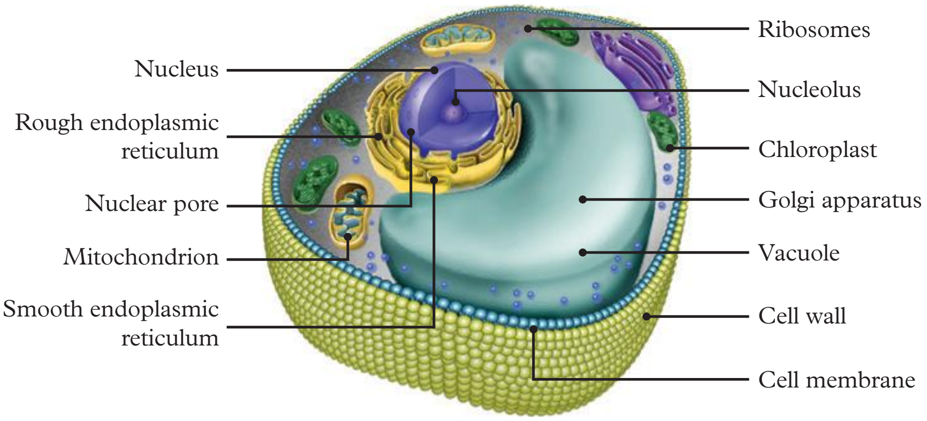


Figure 2 Scientific diagrams provide a visual representation and simplify difficult concepts.

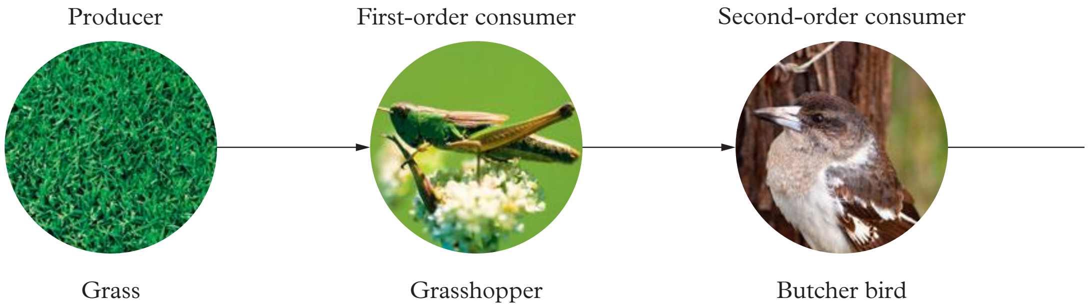


Figure 3 Flowcharts illustrate a sequence of events.

Multimedia resources such as interactive simulations and animations provide engaging ways to illustrate scientific concepts and experiments. For example, an interactive simulation of the water cycle might allow you to manipulate variables such as temperature to see how these changes affect evaporation, condensation and precipitation in real time. **Databases** are important for storing and managing large amounts of data, which can help scientists to find the specific information they need for their studies quickly. For example, researchers studying climate change can use databases that include temperature records, rainfall amounts and carbon dioxide levels, collected over many years. By searching and filtering data, scientists can identify patterns and **trends** that might not be immediately obvious in smaller data sets.

multimedia resource a combination of various media types – such as text, images, audio and video – used to enhance learning and engagement by making complex concepts more accessible

database structured collections of electronically stored data that allow for efficient storage, retrieval and analysis of large amounts of information

Extracting information from tables and graphs

Scientists process data from **first-hand investigations** and **secondary sources** and can present it with tables or graphs. Tables are used to provide easy access to specific data points, while graphs are used to illustrate and identify trends, **patterns** and relationships within the data.

The table in Figure 4A can be used to quickly identify that for Sydney, the average maximum daily temperature in January is 26°C, the average minimum daily temperature in July is 8.1°C and the average total rainfall is 100.9 mm per month or 1,211 mm per year.

The table can also be used to determine the **mean** and **range** of the data set. The mean, or average, is determined by adding up all the numbers in a data set and then dividing the sum by the total number of data points. For example, the average monthly maximum temperature is 261.1 ÷ 12 = 21.8°C. The range is determined by subtracting the lowest from the highest numbers in the data set. The maximum monthly temperature range in Sydney is therefore 26.0 − 16.4 = 9.6°C. Can you work out the mean and range of the monthly rainfall?

From the graph in Figure 4B we can identify a trend showing that monthly temperatures drop between January and July and then increase between July and January. Can you identify any trends with the rainfall data?

Given that the graph shows mean (average) data taken over many years, it reveals a repeating pattern of average monthly rainfall. The volume increases between January and March, then plateaus between March and June. Levels drop between June and September before slowly increasing through to the following January. Can you identify a pattern with the temperature data?

trend the general tendency of a set of data to move in a certain direction

first-hand investigation the direct collection of data through experiments or observations conducted by scientists themselves

secondary source information collected and interpreted by others, such as textbooks, articles and documentaries

pattern when a set of data repeats in a predictable way

mean the average of a set of numbers

range the difference between the highest and lowest numbers in a set

Finally, the graph helps to identify a potential relationship where changes in temperature influence rainfall distribution throughout the year.

A

Sydney long term average temperatures and rainfall.

Month	Mean max (°C)	Mean min (°C)	Mean rainfall (mm)
Jan	26.0	18.8	101.2
Feb	25.8	18.9	119.3
Mar	24.8	17.6	131.6
Apr	22.5	14.8	126.5
May	19.5	11.6	117.4
Jun	17.0	9.3	133.3
Jul	16.4	8.1	96.3
Aug	17.9	9.0	80.2
Sep	20.1	11.2	67.8
Oct	22.2	13.7	76.8
Nov	23.7	15.7	83.7
Dec	25.2	17.6	77.1
Annual	**21.8**	**13.9**	**100.9**

B

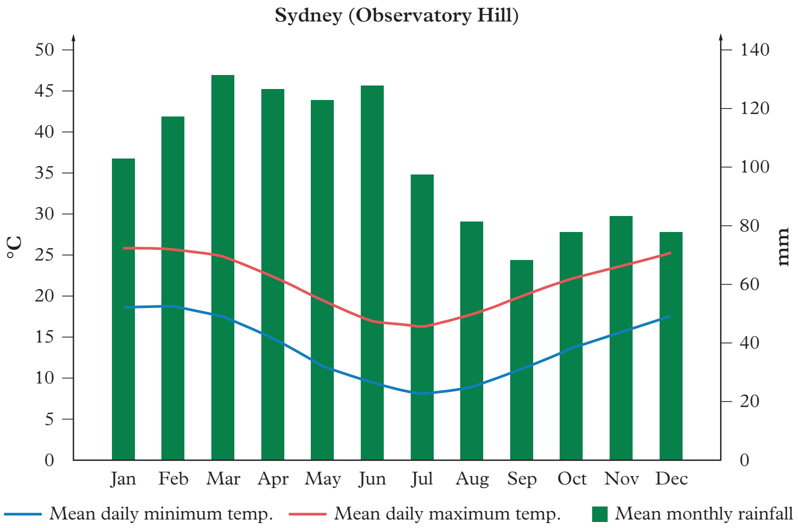


Figure 4 (A) A table and (B) a graph showing the average monthly temperatures and rainfall in Sydney.

Check your learning 1.10

Check your learning 1.10

Retrieve

1 Identify the advantage of using a diagram rather than written text alone.

2 Outline when a flowchart should be used.

Comprehend

3 Describe the steps involved in calculating the mean and range of a data set.

4 Explain the advantage of using databases for managing and retrieving large amounts of data in research.

Apply

5 The data in Table 1 shows the height of 10 students.

a Calculate the mean height.

b Calculate the range of heights.

6 The graph in Figure 5 shows the number of bubbles produced per minute by plant X in various depths of water.

a Identify the number of bubbles that were produced by the plant per minute at a depth of 25 metres.

b Calculate the range of bubbles produced by the plant over the different depths.

Table 1 Heights of 10 students

Student	Height (cm)
1	148
2	155
3	160
4	178
5	158
6	162
7	168
8	170
9	159
10	161

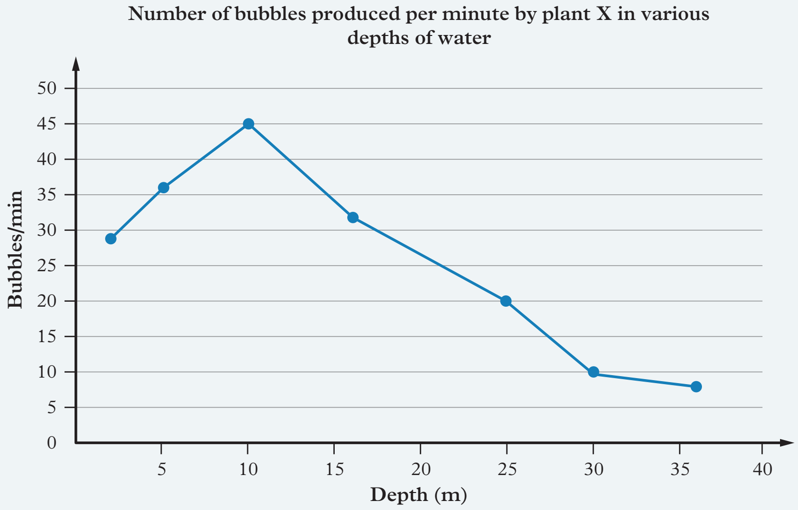


Figure 5 Number of bubbles produced per minute by a plant in various depths of water.

Lesson 1.11

Processing data and information: Part B – Representing data and information

Key ideas

→ Tables should have a heading, column headings with units of measurement, and data in each column.

→ Different graphs should be used depending on the type of data (discrete or continuous) being displayed.

Learning intentions and success criteria

Representing data in tables and graphs

Data tables

When recording the results of your experiments, the **data** you collect should be neatly presented in a table. The guidelines for drawing up a table are as follows:

1 Use a ruler to draw up a table with the correct number of columns.

2 Write a descriptive table heading that links the independent and dependent variables.

3 Give each column a heading with units (what the number means). The variable being changed (independent variable) goes in the first column, and the variable being measured (dependent variable) goes in the columns to the right.

4 Add your data in the correct columns.

For example, in an experiment in which a student wants to investigate the time it took for water to cool down after boiling, they performed three trials over a 25-minute period. The table for this experiment should be set up as shown in Figure 1.

data information that is collected, organised and analysed for various purposes; data can be in the form of measurements, numbers, text, images

Table 1 The change in water temperature over time

Time (min)	Temperature (°C)			
	Trial 1	**Trial 2**	**Trial 3**	**Average**
5	100	95	96	96
10	85	77	84	82
15	65	69	64	66
20	58	59	54	57
25	41	45	43	43

Ordering **of data**
The data for the independent variable should be organised from the lowest value to the highest.

Ordering **of variables**
The independent variable should be in the first column. The dependent variables should be in the columns to the right of the independent variable column.

Title for table
The title should contain both the independent variable and the dependent variable.

Column **headings**
The variable should be identified and the unit of measurement included.

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

Types of data: discrete and continuous data

There are two main types of quantitative data: discrete and continuous. **Discrete data** is counted, not measured, and there are no values between data points, such as the number of people in a class (you can't have half a person). Discrete data is usually represented in a **column graph** or in a **pie chart**, which is used to represent data as proportions or percentages of a whole.

Continuous data can take any value within a range. It is measured rather than counted. For example, the tallest person in the world is 251 centimetres tall; the fastest time in the world for a 100-metre race is 9.58 seconds. Continuous data should always be represented in a **line graph** or **scatter graph**.

discrete data where the numbers can be separated into different groups

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

pie chart a circular graph used to display data as proportional segments of a whole; each segment represents a category, and its size corresponds to the relative frequency or percentage of that category within the total; the entire chart represents 100% of the data

continuous data data that are measured and can be any value

line graph a graph used to display continuous data that are connected by a line; typically used to demonstrate trends in data

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

Figure 2 Sultan Kosen (A) is 251 centimetres tall. Usain Bolt (B) ran 100 metres in 9.58 seconds. Height and time are examples of continuous data.

Common features in graphs

There are several features that nearly all graphs have in common:

- a descriptive title linking the independent and dependent variables
- a grid that is used to plot the points or data
- the independent variable on the horizontal axis
- the dependent variable on the vertical axis
- units included in brackets for both the independent and dependent variables (if appropriate).

If the data in a graph comes from a secondary source, details about the source should be included directly underneath the graph, using an appropriate reference format.

Drawing column graphs

In a column graph, the height of each column shows the numbers that you measured. This type of graph is good for displaying discrete data.

For example, if graphing the number of insects caught at different locations, a scientist changes the location and counts the number of insects at each point. Therefore, location is the independent variable and is found on the horizontal axis. The number of insects is the dependent variable and is found on the vertical axis. The steps for drawing a column graph are listed below.

Step 1: Use a pencil and a ruler to draw a large set of axes (the horizontal and vertical lines of a graph).

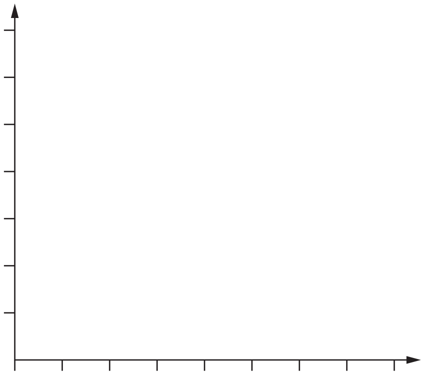


Figure 3 Drawing a set of axes

Step 2: Label each axis. The horizontal (flat) **axis** should show the independent variable, and the vertical (up) axis should show the dependent variable.

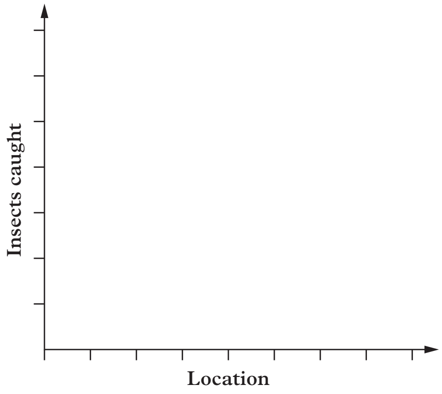


Figure 4 Labelling each axis

Step 3: Add numbers at regular intervals to the lines on the vertical axis, making sure you can fit the largest number. If the numbers are small, spread them out to use the whole graph.

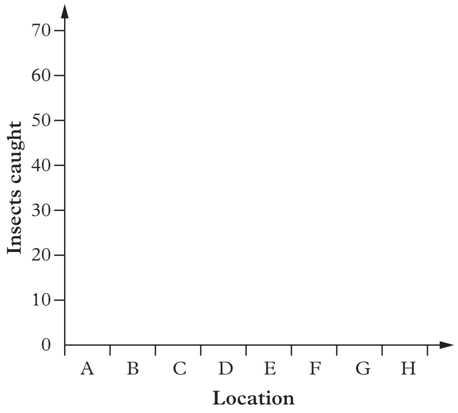


Figure 5 Adding numbers to the axes at regular intervals

Step 4: Add units (what the numbers mean) to the axis. These units are usually metres (m), seconds (s) or minutes (min), but they can also be the number (*n*) of things.

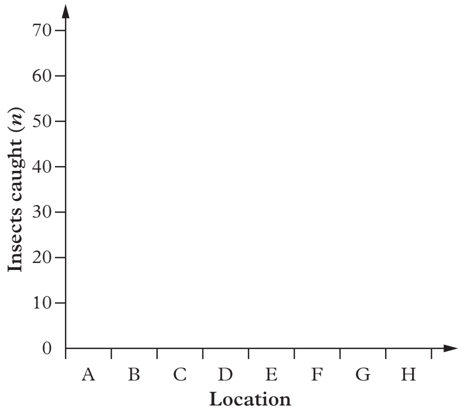


Figure 6 Adding units to the axes

Step 5: Plot your data on the graph. Rule the lines carefully, making sure there is a gap between the columns.

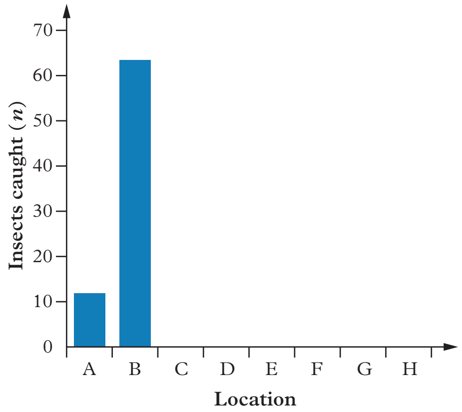


Figure 7 Plotting data on the column graph

Step 6: Complete all columns and add a descriptive title to show the number of insects caught at different locations.

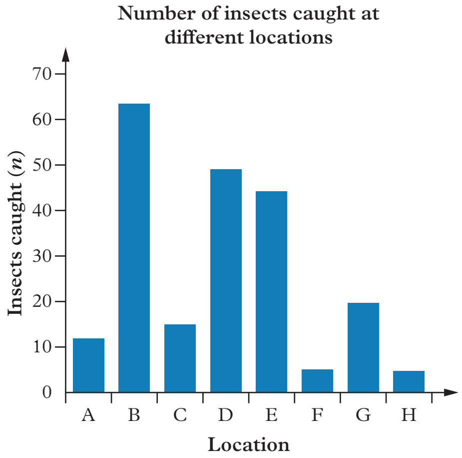


Figure 8 Finishing the column graph

Drawing line graphs

In a line graph, the relationship between two sets of data is compared.

For example, if comparing how long it took for distilled water and honey to increase in temperature when heated, the scientist measures the dependent variable (temperature) at different values of the independent variable (time). Therefore, time is found on the horizontal axis and temperature is found on the vertical axis. The steps for drawing a line graph are listed below.

Step 1: Use a pencil and a ruler to draw a large set of axes (the horizontal and vertical lines of a graph).

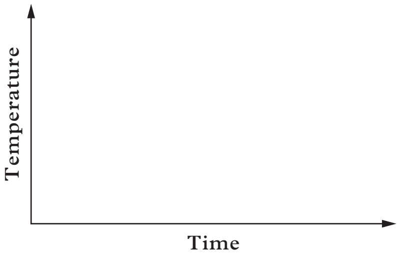


Figure 9 Drawing a set of axes

Step 2: Use an appropriate scale on each axes. Add numbers at regular intervals to the lines on the axes, making sure you can fit the largest number. If the numbers are small, spread them out to use the whole graph. Add units (what the numbers mean) to the axes.

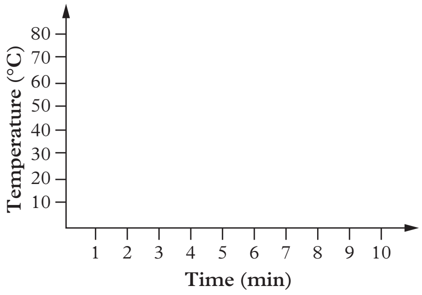


Figure 10 Adding numbers to axes at regular intervals

Step 3: Plot your data on the graph. Use small crosses rather than dots. It is easier to find the centre of a cross than the centre of a dot.

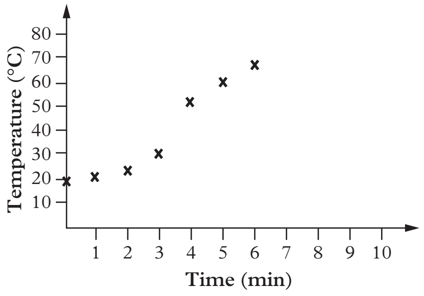


Figure 11 Plotting data on the graph using small crosses

Step 4: Join each data point with a line to complete the line graph.

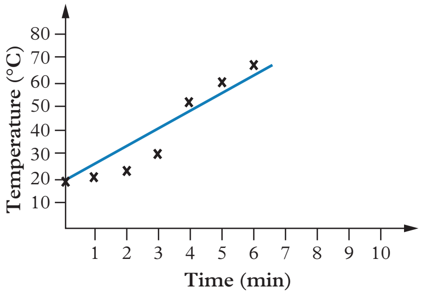


Figure 12 Complete the line graph

Step 5: If you are plotting more than one set of data on the one graph, then use a small circle instead of a cross. Add a legend to help identify which set of data is which.

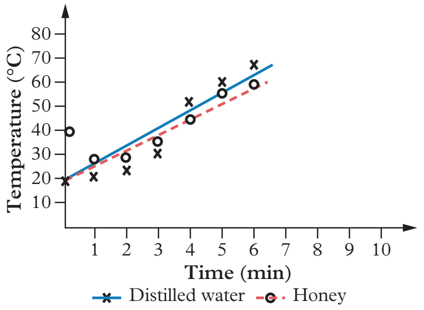


Figure 13 Using small crosses and circles when plotting more than one set of data

Step 6: Write a descriptive title at the top of the graph.

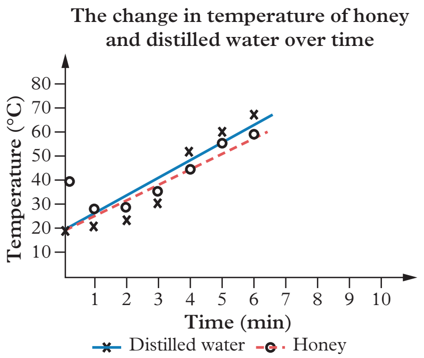
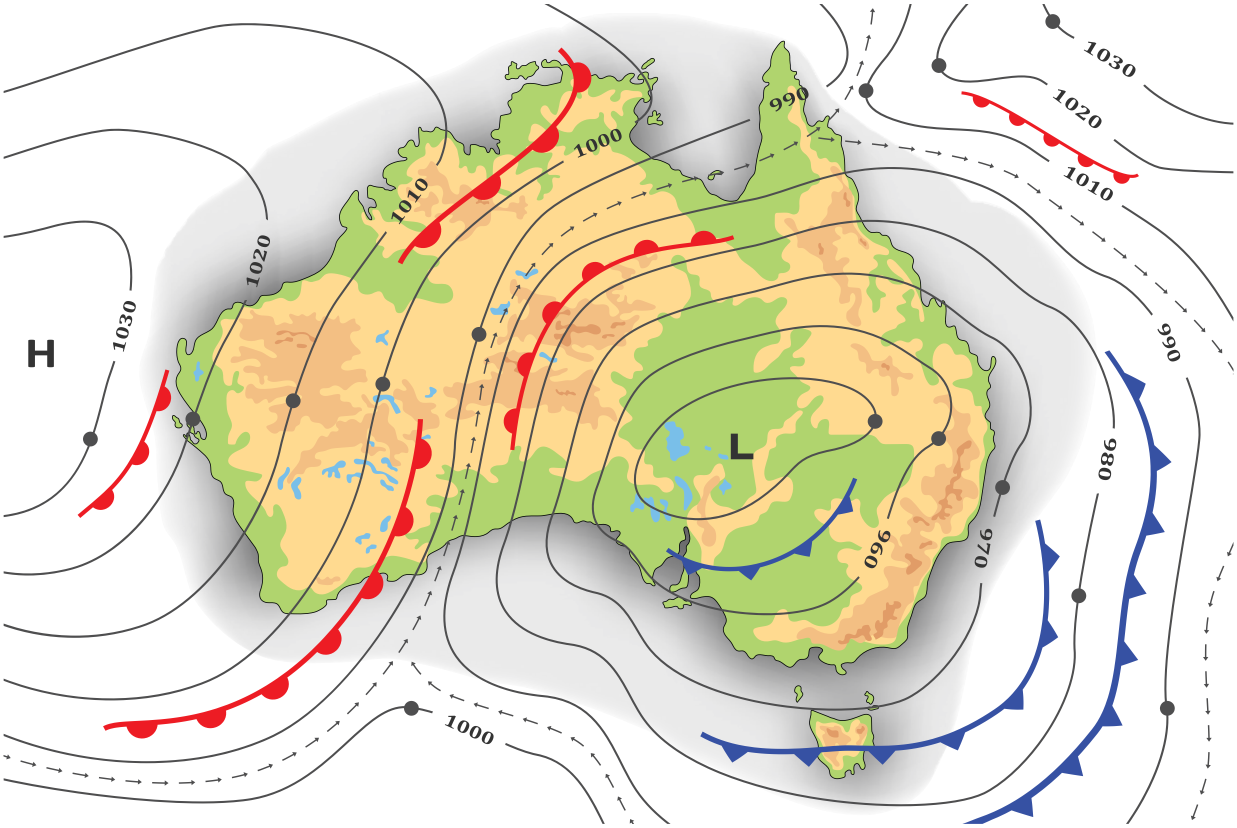


Figure 14 Writing a descriptive title for the line graph

Other ways of representing data

Graphs and tables are not the only ways scientists present their results. Depending on the context, data and information can be communicated via keys, models, diagrams and spreadsheets.

Diagrams and keys that use different colours and symbols can be combined to provide visual representations that assist in interpreting data. For example, the diagram in Figure 15 shows a weather forecast diagram of Australia, including an accompanying key that explains the different colours and symbols used. In this diagram, red lines with semicircles represent warm fronts, while blue lines with triangles indicate cold fronts. Dotted black lines show troughs where high-pressure and low-pressure weather systems meet, often resulting in widespread rainfall. The map itself is also colour-coded with different shades of yellow and green, which represent varying vegetation patterns typically associated with rainfall levels.



Key

H	High-pressure centre
L	Low-pressure centre
—980—	Isobar (air pressure in hPa)
▼▼▼▼▼	Cold front
●●●●●	Warm front
- - - - - - -	Trough

Figure 15 Forecast weather map of Australia with a key that shows what different colours and symbols represent.

model a simplified representation of complex phenomena that are usually too big or too small to be seen by the naked eye

Models are simplified representations of complex scientific phenomena that help in understanding, predicting and communicating how things work. They can take many forms, including drawings, diagrams, 3D models, or computer simulations. For example, models can provide a better understanding of a single cell or the solar system, allowing learners to visualise and grasp intricate concepts more effectively (Figure 16).

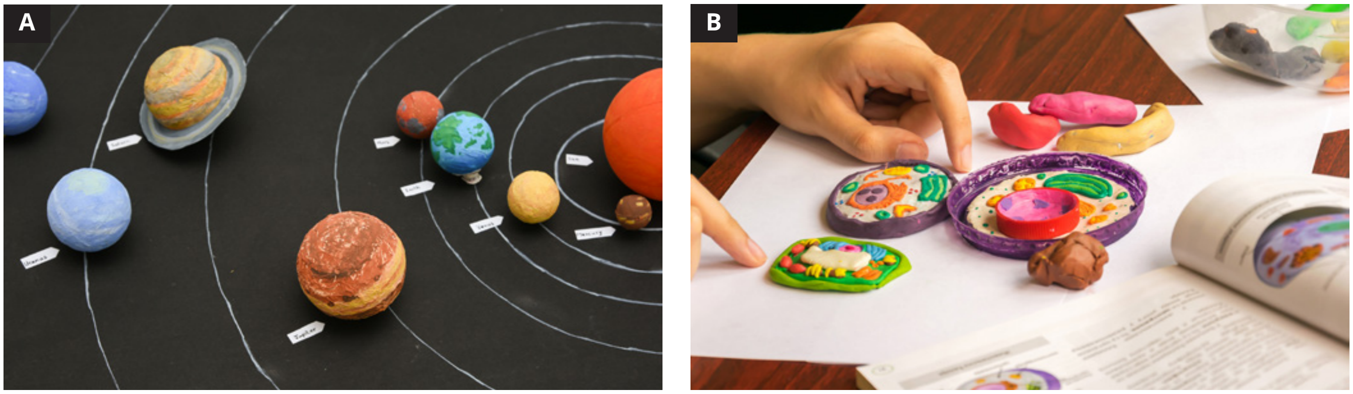
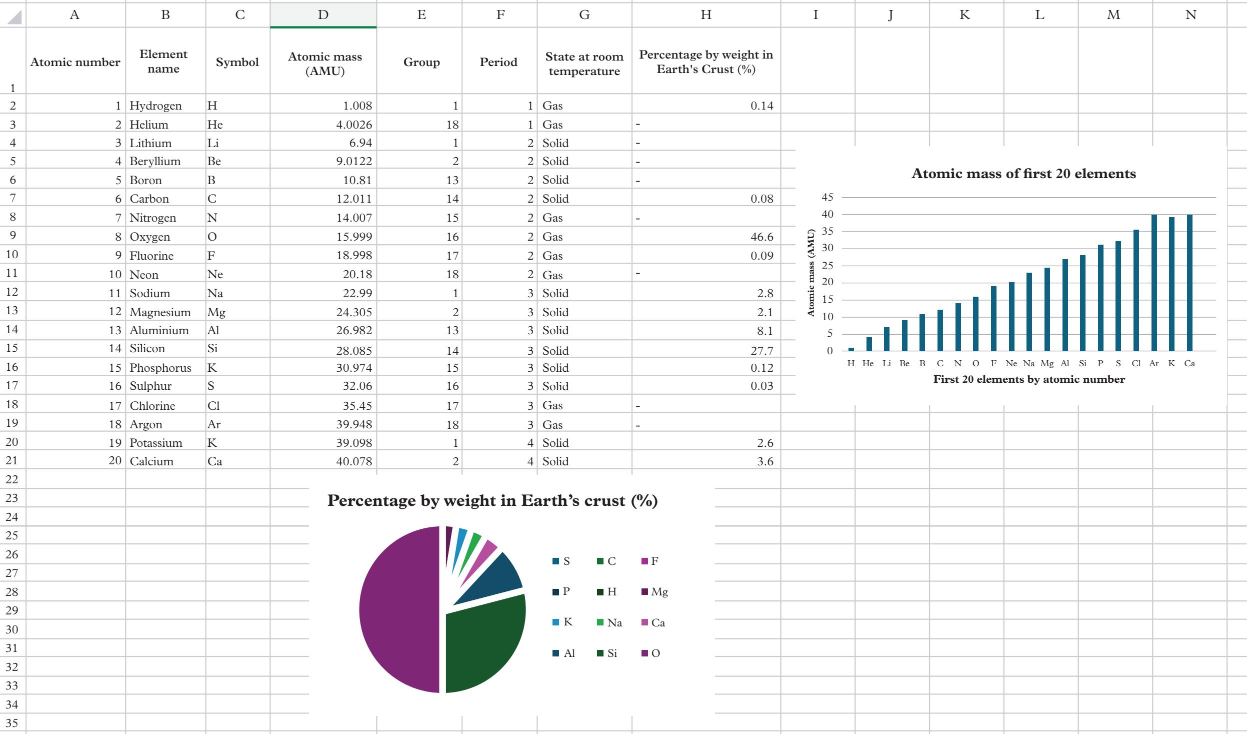


Figure 16 (A) A student model of the solar system showing the relative position of the different planets to the Sun. (B) A student using secondary sources to create models of cells using modelling clay and plastic.

Finally, spreadsheets are digital tools used for organising, calculating and analysing data in table form. They are particularly beneficial in the early stages of processing and analysing information as they allow the user to easily enter, sort, filter and manipulate data to create a wide range of different charts and graphs that can be used to represent results (Figure 17).



	A	B	C	D	E	F	G	H
1	Atomic number	Element name	Symbol	Atomic mass (AMU)	Group	Period	State at room temperature	Percentage by weight in Earth's Crust (%)
2	1	Hydrogen	H	1.008	1	1	Gas	0.14
3	2	Helium	He	4.0026	18	1	Gas	-
4	3	Lithium	Li	6.94	1	2	Solid	-
5	4	Beryllium	Be	9.0122	2	2	Solid	-
6	5	Boron	B	10.81	13	2	Solid	-
7	6	Carbon	C	12.011	14	2	Solid	0.08
8	7	Nitrogen	N	14.007	15	2	Gas	-
9	8	Oxygen	O	15.999	16	2	Gas	46.6
10	9	Fluorine	F	18.998	17	2	Gas	0.09
11	10	Neon	Ne	20.18	18	2	Gas	-
12	11	Sodium	Na	22.99	1	3	Solid	2.8
13	12	Magnesium	Mg	24.305	2	3	Solid	2.1
14	13	Aluminium	Al	26.982	13	3	Solid	8.1
15	14	Silicon	Si	28.085	14	3	Solid	27.7
16	15	Phosphorus	K	30.974	15	3	Solid	0.12
17	16	Sulphur	S	32.06	16	3	Solid	0.03
18	17	Chlorine	Cl	35.45	17	3	Gas	-
19	18	Argon	Ar	39.948	18	3	Gas	-
20	19	Potassium	K	39.098	1	4	Solid	2.6
21	20	Calcium	Ca	40.078	2	4	Solid	3.6

Figure 17 Spreadsheets are useful for organising large amounts of data that can be quickly manipulated to produce different charts and tables to represent results.

Check your learning 1.11

Check your learning 1.11

Retrieve

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

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

3 Identify the type of graph that would be used to show the following data:

- **a** the number of birds found in a particular area each month
- **b** a person's height measured on their birthday every year
- **c** student responses to a survey to determine their favourite subject.

Comprehend

4 Figure 18 shows a graph drawn by a student. Identify all the things that should be corrected on the graph.

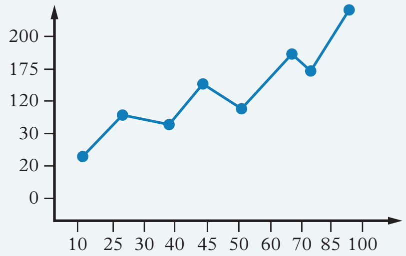


Figure 18 Graph drawn by a student

Apply

5 For each set of data that follows:

- **a** construct the most appropriate graph to show the data
- **b** provide an inference that can be made from the results.

i The number of accidents in the science laboratory during the first six months of the year

Time	Number of accidents
Jan	0
Feb	10
Mar	6
April	3
May	2
June	1

ii The number of cigarettes smoked per day by a pregnant woman affects the birth weight of her baby

Number of cigarettes smoked per day	Birth weight of baby (kg)
0	3.5
10	3.1
20	2.6
30	2.2

iii A survey of 100 students at your school to find out which fruit they preferred

Type of fruit	Preference (number of students)
Apple	20
Banana	30
Kiwi fruit	10
Mango	25
Orange	15

Lesson 1.12

Skills lab: Heating water

Caution

- Always wear safety glasses, a lab coat and closed-toe shoes, and tie long hair back when using a Bunsen burner.
- Allow all hot equipment to cool before handling.

Aim

To identify how adding sugar or salt to water affects its boiling point

Materials

- Beaker (250 mL)
- Water
- Thermometer
- Retort stand
- Boss head
- Clamp
- Tripod
- Gauze mat
- Heatproof mat
- Stopwatch
- Bunsen burner
- Matches
- Glass stirring rod
- Salt (optional)
- Sugar (optional)
- Teaspoon

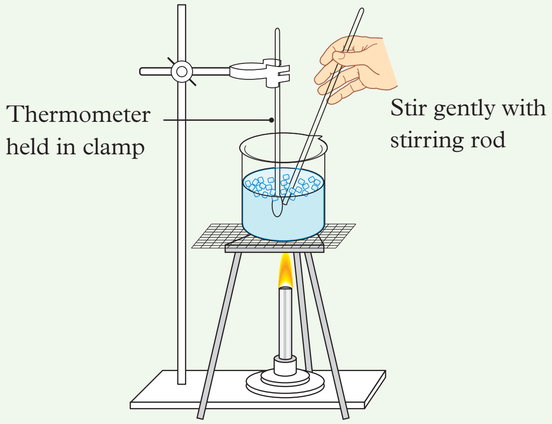


Figure 1 Equipment set-up

Method

1. Set up the equipment as shown in Figure 1. Add 150 mL of water to the 250 mL beaker.
2. Draw a labelled scientific diagram of the equipment in your notebook.
3. Draw a results table with two columns: one for time (in minutes) and the other for temperature (in degrees Celsius) as shown in Table 1.
4. Measure the starting temperature of the water and write it in the table. This is the temperature at 0 minutes.
5. Safely light the Bunsen burner and then open the collar to get a blue flame.
6. Heat the water over the Bunsen burner. Record the temperature of the water every minute for a total of 12 minutes.

Table 1 Results table

Time (min)	Temperature (°C)

Inquiry: What if another substance was added to the water?

Choose one of the inquiry questions.

- What if sugar was added to the water?
- What if salt was added to the water?

Answer the following questions about your inquiry question.

1 Write a hypothesis for your inquiry.
2 Identify the independent variable that you will change from the first method.
3 Identify the dependent variable that you will measure and/or observe.
4 List the variables you will need to control to ensure a reasonable test. Describe how you will control each variable.
5 Test your hypothesis by repeating the method with the independent variable you chose.
6 Collect the data in a results table.
7 Draw an appropriate graph for your data.

Questions

1 Identify the type of data you have collected.
2 Identify the type of graph you have drawn to display this type of data.
3 Explain how your graph supports or does not support your hypothesis.
4 Describe how your experiment was a valid test by providing a definition of a valid test and matching this to your method.

Lesson 1.13

Analysing data and information

Key ideas

→ Science experiments are planned and analysed carefully to minimise errors.

→ Before claiming that a hypothesis is supported or refuted, experimental data must be checked to identify whether it contains any errors or unexpected results.

Learning intentions and success criteria

Interpreting graphs

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

When the line slopes upwards, this means the dependent variable increases as the independent variable increases (Figure 1). This is called a **directly proportional relationship**. For example, if you rode a bike at a constant speed, your distance travelled would increase at a fixed proportion to the time you spent riding.

When the line is horizontal (flat), it means the dependent variable is not affected by the independent variable (Figure 2). For example, most adults – regardless of their age – will sleep the same number of hours each night.

If the line is sloped down, the dependent variable decreases as the independent variable increases (Figure 3). This is called an **inversely proportional relationship**. For example, if you had to travel a fixed distance of 100 km, the time taken to travel this distance would be inversely proportional to the speed at which you travelled.

Occasionally, a graph is curved. These types of graphs should be divided into sections. Section A (between 1 and 4 of Figure 4) shows a directly proportional relationship. Section B (between 4 and 7) shows an inversely proportional relationship. Consider the relationship between the amount of water a plant receives (independent variable) and the plant's growth rate (dependent variable). Initially, as the amount of water increases, the plant's growth rate also increases because the plant benefits from more water. After a certain point, however, too much water can become harmful to the plant, causing its growth rate to decrease.

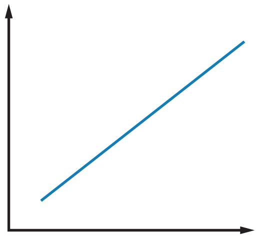


Figure 1 A directly proportional relationship

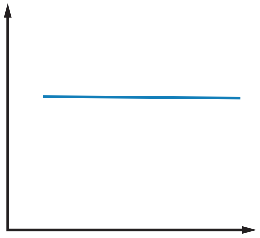


Figure 2 The dependent variable is not affected by the independent variable.

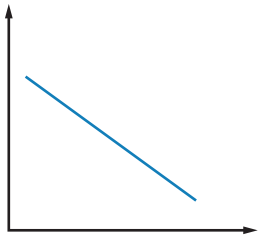


Figure 3 An inversely proportional relationship

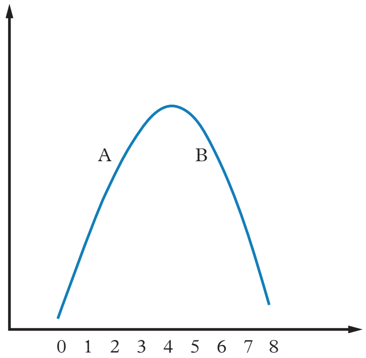


Figure 4 A curved graph is divided into sections to help scientists analyse it.

Evaluating the methods and data of an experiment

An experiment does not finish when the results have been recorded. A scientist should check the data to identify if it contains any anomalies (odd or inconsistent results) or **errors** before they claim that their hypothesis is supported or refuted.

error an inaccuracy or inconsistency in measurement

Sometimes when plotting data on a graph, there may be a single dot or number that is unexpected or that does not fit with the rest of the graph (Figure 5). This is called an **anomaly** or "outlier" in the data. If the anomaly is caused by an identifiable error, removing it will ensure the data is more accurate and reliable. If the anomaly represents natural variation, it should not be removed.

anomaly a result that does not fit in with the pattern of data

If there are significant anomalies or errors discovered within the data that cannot be explained, an important consideration would be to revisit the methods and carefully review them for possible **bias**, inconsistencies in how the experiment was performed, or equipment malfunction. This review should ensure all conditions were controlled correctly and the data collection process occurred as planned. If mistakes were made, the method section should be amended and the experiment repeated if possible before proceeding.

bias leaning towards or against an idea by being prejudiced or unfair

In addition to identifying any anomalies or errors, it is important to compare experimental results with observations and information from other sources, including published scientific writing. This ensures that any conclusions made are not just based on isolated data but are supported by a more comprehensive analysis of the science in the chosen field. By integrating findings from other studies, scientists strengthen the validity of their conclusions and gain greater credibility for their work.

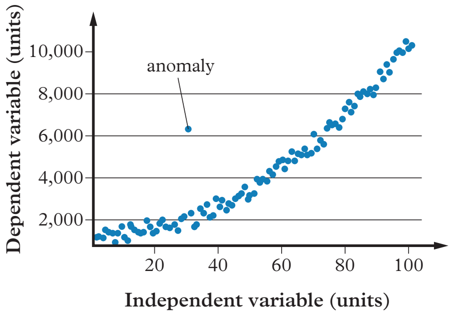


Figure 5 A data anomaly can be identified by a graphed data point that is away from the other data.

Analysing the results

It is important to note that an error is different from a mistake. Errors can occur for various reasons, even if you are very careful. For example, errors can happen if the object you are measuring falls between two markings on a scale, requiring you to estimate the exact measurement. In such cases, it is important to use a more accurate scale or a digital device.

Another type of error can occur if scales are calibrated (set up) incorrectly. This means that no matter what you measure, you will get a slightly inaccurate result (Figure 6). To minimise the effect of this kind of error, it is advisable to always use the same measuring device.

Figure 6 Callipers should always be calibrated to avoid an error.

Analysing the method

If errors in the results are discovered, this should lead to a review of the method to determine if improvements can be made to enhance the quality of the data collected.

Consider the following method that a group of students used to investigate how different types of fertilisers (organic versus synthetic) affect the growth of plants. They were concerned that their results were influenced by factors other than the type of fertiliser.

1 Label 10 pots as "Organic" and 10 pots as "Synthetic".
2 Fill all pots with the same brand of potting soil.
3 Plant one seed in each pot at varying depths (1 cm in some pots, 3 cm in others).
4 Apply the recommended amount of organic fertiliser to the "Organic" pots.
5 Apply the recommended amount of synthetic fertiliser to half the "Synthetic" pots and double the amount to the other pots.
6 Place all pots in the same sunny location.
7 Water half of the pots in both groups with 50 mL of water every day and the other half with 100 mL of water every two days.
8 Repeat the experiment for both groups three times.
9 Estimate the height of each plant in both groups every day for four weeks.
10 Calculate the average height of plants in both groups.

Before proceeding, discuss the following questions in groups or as a class.

1 Explain how the students addressed reliability in the experiment.
2 Identify three controlled variables used in the method.
3 Identify at least three errors in the method that would compromise the validity of the experiment.
4 Discuss any changes you would recommend to improve the validity of the experiment.
5 Discuss the accuracy of the measurements made. How could it be improved?

Using data to support or refute a testable hypothesis

Assuming the appropriate changes were made to the method to ensure the experiment was valid and the results were measured accurately, consider the following data a group of students collected. Their hypothesis stated that "Plants treated with organic fertilisers will grow taller than plants treated with synthetic fertilisers".

They again grew 10 plants in each group under controlled conditions and measured the height of the plants in both groups after four weeks. The average height of the plants is recorded in Table 1.

Table 1 Average height of plants grown with organic or synthetic fertiliser

Type of fertiliser	Average height (cm)
Organic	30
Synthetic	22

Oxford University Press

Based on these results, the average height of plants treated with organic fertiliser (30 cm) is greater than that of those treated with synthetic fertiliser (22 cm). This data supports the testable hypothesis that organic fertilisers promote better plant growth compared to synthetic fertilisers.

It should be noted, however, that if the hypothesis is shown to be wrong, it does not mean the experiment has failed. As stated by famous scientist Isaac Asimov, "The most exciting phrase to hear in science, the one that heralds new discoveries, is not 'Eureka!' but 'That's funny…'"

Making conclusions based on observed results and secondary sources

Recall from Lesson 1.4 Questioning and predicting (page 14) that an inference is an educated guess or conclusion based on observations, but it does not necessarily imply causation. In the fertiliser experiment, a reasonable inference is that organic fertilisers may enhance plant growth more effectively than synthetic fertilisers. This could be due to a higher nutrient content or the presence of beneficial microorganisms in organic fertilisers, which may improve soil health and plant development.

To strengthen these conclusions, it is essential to engage with reliable secondary sources, such as peer-reviewed journals and reputable scientific publications. These sources can provide additional context, support for the findings, and insights from previous research that may help clarify the relationship between fertiliser type and plant growth. Further investigations, including a review of existing literature and **controlled experiments**, are required to determine causation and ensure the validity of the conclusions drawn.

controlled experiment an experiment where all the variables are kept the same except for the independent variable

Figure 7 Testing the effect of different fertilisers on plant growth

Check your learning 1.13

Check your learning 1.13

Retrieve

1 Define the term "anomaly".

2 Identify an assumption that a scientist may make when completing an experiment that tests how fast water boils.

Comprehend

3 Describe how not calibrating scales at the start of an experiment could affect the results of the experiment.

Analyse

4 Contrast the terms "mistake" and "error".

Apply

5 A scientist tested how the amount of light in a glasshouse affected the growth of wheat plants. When they analysed their results, they explained that these results could not be used for all plants growing outside the glasshouse. Discuss why the scientist put a limit on how the results could be used.

6 A student decided to conduct an experiment to find out whether their pet cats preferred full-cream or low-fat milk. They gave one cat a saucer of full-cream milk and the other cat a saucer of low-fat milk and then left them alone. When they returned an hour later, the low-fat milk was gone and there was a small amount of full-cream milk left. The student concluded that both cats preferred low-fat milk.

  a Explain why you agree or disagree with the student's conclusion.

  b Explain whether the student conducted a valid test (by describing if they controlled all other variables, if they would have the same results if they repeated the experiment, and if the test was fair).

  c Identify two variables that need to be controlled. Explain how these variables could have affected the results.

  d Describe two ways you could improve the experiment so that the results were more reliable.

7 A student is testing the effect of light exposure on plant growth. They expose three seedlings of the same species to three different conditions of light: no light, four hours of light exposure per day and seven hours of light exposure per day for the course of two weeks. They control for all other conditions including pot size, soil composition, pH, temperature and watering. The seedling heights in centimetres were recorded on Day 1, Day 7 and Day 14. They hypothesised that the seedling with the highest exposure to light would have the most growth in cm after two weeks. The results of their experiment are given in Table 2.

  a Explain whether the results support the student's hypothesis.

  b Research a reliable secondary source to explain why the student's hypothesis was supported or not.

Table 2 Results of the student's experiment

Seedling number	Light condition	Day 1 seedling height (cm)	Day 7 seedling height (cm)	Day 14 seedling height (cm)
1	Seven hours light exposure each day	0	5.5	9.6
2	Four hours light exposure each day	0	2.6	4.8
3	No exposure to light	0	0.7	2.6

Lesson 1.14

Problem solving

Key ideas

→ Recognising and defining a specific problem is the first step in developing a solution.

→ Group work and creative thinking are often required to solve identified problems.

→ Establishing clear criteria for evaluating potential solutions is necessary to compare and contrast different strategies.

→ Models are used to demonstrate and explain the relationships between causes and their effects in various phenomena.

Learning intentions and success criteria

Identifying problems, devising strategies and suggesting solutions

In scientific research, it is common for problems to arise. This encourages researchers to think critically and creatively to find solutions. Identifying these problems involves discovering the gaps in knowledge or challenges that occur before or during an investigation. Once these issues are recognised, researchers work to create strategies to solve the problem and keep their research on track.

Consider an experiment investigating how different times of the day affect the number of birds observed in your backyard. During your observations, you might notice that on some days the number of birds is unusually low or high regardless of the time of day. This raises a problem: what factors other than time of day might be influencing the number of birds observed?

To address this issue, you would consider other variables such as weather conditions, presence of predators, availability of food, or human activity in the area. You could then design an experiment in which you systematically observe and count the number of birds at different times – morning, afternoon and evening – over a period of two weeks, while also recording additional factors like weather, food availability and disturbances. By analysing the data, you would determine not only the effect of the time of day, but also how these other factors might be influencing bird activity.

An observed problem might also actually inspire an investigation. For example, a group of students observed that a significant amount of food waste and plastic wrapping was being generated from purchases made at the canteen, and this was negatively contributing to landfill. The students proposed the following strategies to solve the problem:

- Conduct a survey to better understand students' food preferences.
- Adjust food portion sizes to minimise food wastage.
- Introduce compostable food wrapping and establish a composting program for organic waste, turning leftovers into nutrient-rich soil for school gardens.

- Conduct an educational campaign to teach students about the environmental impact of food waste and plastic wrapping.

To evaluate the effectiveness of the strategies, the students performed a waste audit for one week prior and one week after implementation of the study.

Use given evaluation criteria to select optimal solutions to problems

Some problems can have multiple solutions, making it essential to use specific criteria to evaluate the different options. The evaluation process helps determine which solutions will be both viable and effective.

Criteria would typically include:

- **effectiveness**: How well does the proposed solution solve the problem?
- **feasibility**: Is the solution practical?
- **time**: Is the timeframe reasonable for the implementation and collection of results?
- **cost**: Are there expenses involved that would prevent implementation?
- **ethics**: Does the solution align with ethical standards and values?

Consider the following problem and the proposed solutions. The urban heat island (UHI) effect refers to the phenomenon of urban areas experiencing higher temperatures than equivalent rural areas. This causes discomfort and leads to increased energy consumption to remedy the heat.

Urban areas typically have more concrete, asphalt and buildings which absorb and retain heat, unlike rural areas that largely consist of vegetation and natural landscapes. Urbanisation often leads to the removal of trees and green spaces, which play a critical role in cooling the environment through shade and evapotranspiration (the process whereby water from the Earth's surface enters the atmosphere through evaporation and transpiration).

The Student Representative Council (SRC) observed that their school was a UHI (Figure 1) and proposed the following solutions that first needed to be evaluated.

Figure 1 Schools are often urban heat islands.

- Plant more trees both in the school grounds and surrounding community. This would provide shade, improve air quality and reduce air temperatures.
- Install green roofs on school buildings. This involves adding vegetation and soil to the roofs of school buildings to improve insulation and reduce heat absorption.
- Promote cool-roof technology. This involves adding reflective materials to rooftops to minimise heat absorption and lower building temperatures.
- Replace traditional asphalt with permeable pavement that absorbs water. This reduces heat build-up and helps manage stormwater runoff.

The evaluation criteria used was based on the criteria listed above: effectiveness, feasibility, time, cost and ethics.

After extensive research and community consultation, they summarised their results as shown in Table 1.

Table 1 Evaluation table

Proposed solution	Effectiveness	Feasibility	Time	Cost	Ethics	Overall decision
Plant more trees	+	+	+	+	+	Proceed
Install green roofs	+	-	+	-	+	Do not proceed
Install cool-roof technology	+	+	+	+	+	Proceed
Install permeable pavements	+	+	+	-	+	Proceed with caution

Key:
+ = Positive evaluation (solution is viable)
- = Negative evaluation (solution may not be viable)

Based on their evaluation criteria, the following decisions were made:

1. The school would proceed with planting more trees on school grounds and in the surrounding area, and they would install cool-roof technology.
2. They would proceed with increasing the use of permeable pavements; however, given cost concerns, they do so with caution.
3. They would not proceed with installing green roofs on school buildings as the costs were prohibitive and the disruption to school made the solution not feasible.

While proceeding with all options would provide a better outcome to the UHI effect observed in the school, this approach is not viable given the evaluation criteria. Therefore, it is more practical to proceed with some options rather than none as this would still provide some benefit.

Modelling cause-and-effect relationships

When performing an experiment or study, models can be an important tool for visualising and understanding complex relationships and processes that are usually too big or too small to be seen by the naked eye. The best choice of model will depend on the topic being covered and the concept being modelled.

For example, a physical model could be used to explain that a plant cell has a rigid structure due to the presence of a cell wall, and the green colour of most plants is due

chlorophyll a green pigment in chloroplasts that absorbs solar energy, which is used by plants in photosynthesis

chloroplast the organelle in plant cells and some algae that perform photosynthesis

to the presence of a green substance called **chlorophyll** inside tiny cellular structures called **chloroplasts**.

A digital simulation of the solar system could be used to illustrate the orbits of planets around the Sun and to explain how gravitational forces maintain the elliptical orbit of the planets and cause tides on Earth.

In chemistry, a three-dimensional molecular model made of ball-and-stick components could be used to demonstrate the arrangement of atoms in a molecule, showing how different elements bond together to form compounds.

As you work your way through different units of work in science, you will be required to study and even develop various models to demonstrate cause-and-effect relationships, each specifically suited to its field, making abstract concepts easier to understand (Figure 2).

Figure 2 Demonstrating cause-and-effect relationships using modelling

Check your learning 1.14

Check your learning 1.14

Apply

1 In small groups, discuss and identify a problem that exists within your school community.

- **a** Propose at least three different solutions to the problem.
- **b** Discuss and decide on at least five criteria that will be used to evaluate the different solutions.
- **c** Research and evaluate each possible solution.
- **d** Present your findings to the class.

  If you're stuck, you could consider topics such as:
  - » litter in the schoolyard
  - » the lack of healthy food offered at the canteen
  - » the lack of shaded areas in the playground
  - » insufficient recycling facilities
  - » limited access to technology
  - » no air conditioners in the classroom.

2 Research one of the following topics: structure of an atom, differences between animal and plant cells, flow of electricity, the solar system or DNA.

- **a** Identify common misconceptions about the topic.
- **b** Design and construct a model that will help clarify the misconceptions.

Lesson 1.15

Science in context: Solving the cane toad problem in Australia

Introduction

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

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

Figure 1 Cane toads are found in much of northern and eastern Australia and are a threat to native Australian animals.

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

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

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

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

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

Figure 2 A cane beetle

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

Test your skills and capabilities

Test your skills and capabilities 1.15

Communicating solutions to problems

Scientists will often provide advice to governments. They do this by asking questions and working with other scientists to find answers, before writing a report with recommendations of how governments could make data-driven policies and laws.

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

2 Many of your questions may be answered using your library or a trustworthy site on the internet, such as universities or zoos. Any website that ends in .edu is an educational institution, while a zoo or wildlife fund will end in .org. If the website address ends in .com, then it is usually owned by a company whose primary focus is to make money. Identify two websites that can be used to answer your questions. Write the answers to your questions. Include the title of the website and the address at the end of your answers.

3 The Kimberley Toad Busters want to contribute to your report by completing some fieldwork. Special safety rules need to be developed for fieldwork. Write a list of general safety rules for fieldwork. You may wish to interview or video call a field environmental biologist to ask them about some of these general safety rules for fieldwork.

4 In 2014, researchers tested a variety of cane-toad traps to determine which would be the best for their study of cane toads. They tested traps that had a light turned on inside the trap against a trap that had the light turned off. Their results are shown in Figure 4. Describe what type of trap you would recommend. Use the data from the graph to support your recommendation.

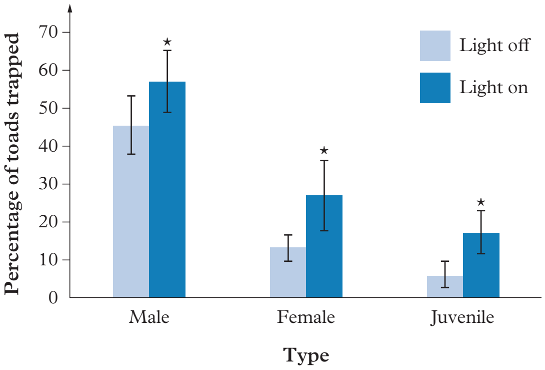


Figure 4 The percentage of male, female and juvenile (young) cane toads trapped with and without lights.

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

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

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

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

Lesson 1.16

Communicating

Learning intentions and success criteria

Key ideas

→ A scientific report is where results and findings are recorded.

→ Scientists use a similar style and language in their reports so that they can be understood by scientists worldwide.

→ Scientists communicate with other scientists so that they can learn from one another and expand on one another's work.

Communicating scientific findings

Effective communication is a vital skill in science. Scientists regularly share their findings, ideas and investigations with others, and how they present this information can greatly impact its understanding and importance.

In science communication, and most subjects for that matter, the **field**, **tenor** and **mode** are essential components that shape how concepts are conveyed to an audience. The field refers to the subject matter being discussed, which includes topics such as ecosystems, forces and energy. The depth required depends on the nature of the task and the audience. The tenor encompasses this relationship between the communicator and the audience. For example, are they classmates, teachers or parents? This is an important consideration as it will influence the formality of the language used.

field the topic or subject being discussed

tenor the people involved in the communication and their relationship

mode the way information is shared; for example, through speaking or writing

Finally, the mode relates to the way the message is delivered, including formats such as scientific reports, oral presentations and research posters. While there are various ways for scientists to communicate their findings, these three main modes follow similar conventions for scientific text structure and typically include sections such as an introduction, materials, methods, results and discussion.

Research posters and oral presentations

Oral presentations involve verbally sharing scientific findings with an audience. This will often be accompanied by visual aids, such as a research poster or slideshow that incorporates diagrams, models and graphical representations to visually support the research findings and enhance audience engagement. These visual elements help to illustrate complex concepts and make the information more accessible.

Both oral presentations and research posters usually follow a consistent format throughout. This includes a clear structure with an introduction, materials required, methodology, results, discussion and conclusion. Care should also be taken to ensure font type, font size and overall theme are consistent throughout. By adhering to a consistent format and effectively using visual aids, you will be able to communicate your scientific findings more effectively and create a lasting impact on your audience.

Figure 1 Modes of communicating scientifically: (A) written science report (B) oral presentation to class (C) research poster

Scientific report

A scientific report should be written in a formal tone and avoid colloquial language. It should also be written in the third person, where you do not refer to yourself or the reader in your writing and avoid the use of personal pronouns (e.g. I, me, our, we, you). For example, "the results of the experiment supported the hypothesis" rather than "my results supported my hypothesis" or "you can see the results supported the hypothesis". If an experiment has been controlled to make it a valid test, then it should not matter whether a professional scientist or your five-year-old sibling conducted the experiment – the results will speak for themselves. When you use personal pronouns, it is tempting to put in a lot of information that is not relevant.

A scientific report usually has the following eight sections:

1. **Title, date and partners** (if you are working in a group) – do not forget to write your own name
2. **Aim** or question – this is what you were trying to find out or why you were doing the experiment
3. **Hypothesis** – this is your initial prediction about the outcome of the experiment and a possible explanation based on your research that will be supported or refuted (not supported) by the experiment
4. **Equipment or materials** – this is a detailed list of the equipment used
5. **Method** – this is the steps or procedure that you use to carry out the experiment, including diagrams of the equipment. There are two reasons to write a method. The first is to plan what you are going to do. This method should be in the present tense. The second type of method is for a formal report. Past tense should be used for this method.
6. **Results** – these are measurements and observations taken in an experiment, usually presented in a table, graph and/or diagram. A few sentences can be used to provide a description of the data in the tables or graphs.
7. **Discussion** – this is your opportunity to discuss the patterns you see in the findings and any anomalies identified. You should describe any assumptions or errors and any suggestions for improvement or further investigation.
8. **Conclusion** – this is the answer to the aim or question. It should be clear and reasoned and should relate very closely to the starting aim or question.

Present findings and ideas in a range of communication forms, including using relevant scientific terms, diagrams and graphical representations that are appropriate to the audience and purpose.

aim the purpose of an experiment

method a series of steps explaining how to do an experiment

discussion a summary of findings, and an analysis of the design of an experiment, including problems encountered and suggestions for improvement

conclusion a statement that "answers" the aim of an experiment

Check your learning 1.16

Check your learning 1.16

Retrieve

1 Define the term “hypothesis”.

2 List the eight steps used when writing a scientific report.

Comprehend

3 Explain why a conclusion is written at the end of an experiment.

4 Explain why personal pronouns are not used in scientific reports.

5 Explain why it is important that scientists complete scientific reports.

6 Explain why using a common format for all scientific reports might make it easier for scientists to communicate with one another.

Lesson 1.17

Skills lab: Writing a scientific report

Introduction

Now it is your turn to do an experiment and produce your first scientific report. Read through the following instructions before you begin. You will be working in pairs.

- Create an outline of the scientific report, including a table for your results, before you begin.
- Conduct the experiment and fill in the table of results.
- Answer the discussion questions, practising using the third person, for example, “the results of the experiment supported the hypothesis” rather than “my results supported my hypothesis”.
- Check back to the aim to remind you of what your conclusion is answering.
- Write a conclusion by following the instructions in the example titled The number of rubber bands required for a bungy-jumping egg.
- Evaluate the design of this experiment.

Experiment: The number of rubber bands required for a bungy-jumping egg

[The title heading sets out what you are trying to discover. It is the “question” you are asking and will be different for each experiment.]

Aim

To drop an egg close to the ground safely

Materials

[This is a list of what you need.]

- Rubber bands
- Mesh or plastic bag
- Raw egg or small bag of water
- Wire or paper clip
- Retort stand
- Boss head
- Clamp
- Metre ruler

Method

[This gives step-by-step instructions and often a diagram of equipment.]

1. Place the egg in the plastic or mesh bag and seal the bag with the wire or paper clip. Be careful to tie it tightly to prevent the egg from slipping through and spilling on the floor. Make a loop at the top of the wire – this is where the rubber bands will be attached.
2. Connect the rubber band around the wire loop and hook it over the retort stand clamp (as shown in Figure 1). One person will need to hold down the retort stand to ensure that it does not tip.

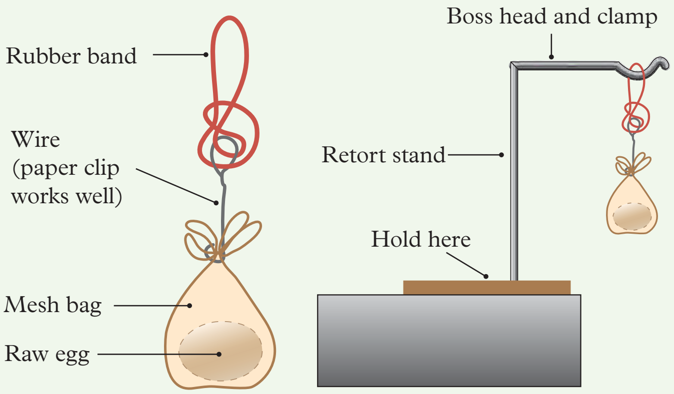


Figure 1 Connecting the rubber band around the wire loop and then hooking it over the retort stand clamp

3. Carefully hold the egg so that it is level with the clamp and let it drop. One member of the group may need to catch the egg on its return up to ensure that it does not hit the clamp.
4. Measure the distance the egg travelled from the clamp. Be careful to avoid parallax error for this measurement.
5. Repeat Steps 2 to 4 using additional rubber bands connected in a chain.

Results

[Possible results: Create a table showing the distance the egg fell for each rubber band added, or draw a graph of the distance the egg fell against the number of rubber bands.]

Questions

[This is where any set questions are answered and where you describe any unusual or interesting results. You can also suggest improvements to an experiment.]

1. Describe the difficulties you had when measuring the distance that the egg fell.
2. Describe how your results would have been affected if the rubber bands were different sizes.
3. Identify one other variable that could have affected the results. Describe how you tried to control this variable.
4. Extend your graph so that it shows how many rubber bands would be needed for a two-metre drop. From this extrapolation/extension, calculate how many rubber bands you would need to safely drop the egg as close to the floor as possible.
5. Explain how your results may have changed if extra weight was added to the egg before dropping it.
6. Explain how your results could help people who want to bungy jump off a bridge.
7. Describe two safety recommendations that should be made to anyone trying this experiment.

Conclusion

[This is the answer to the question you set out to investigate. Look back at the aim and see whether the results support the aim before writing the conclusion. Try to use one to two sentences and to write in the third person.]

Lesson 1.18

Depth studies

Learning intentions and success criteria

Key ideas

→ Identify the five types of depth studies, and describe the key features and purposes of each.

→ Choose a suitable type of depth study for a given scientific topic and explain why it fits the investigation goals.

What is a depth study?

A depth study is a special science project that lets you explore a topic while learning more about science. Different ways of completing a depth study include the creation of a portfolio of work, either independently or in groups, to show what you have learned and how you have used scientific skills like researching, experimenting and analysing data.

You must complete at least one depth study each year in science during Years 7 to 10. You will have around five hours of class time for these projects. During a depth study, you'll use at least two key "working scientifically" skills – for example, asking good questions, making hypotheses and drawing conclusions. You'll also need to do at least one hands-on experiment over the two years to practise real science skills.

Figure 1 When completing a depth study, you must also select the correct equipment to collect data.

Types of depth studies

When conducting a depth study, you have several options to choose from. Each type allows you to explore science in different ways, depending on what you enjoy and what fits your project best.

Practical investigation

A practical investigation involves conducting experiments and recording what happens (Figure 2). For example, you might test how different materials react to heat, measure how fast something dissolves, or investigate how plants grow under different conditions. You'll design an experiment, collect data and analyse your results to see if they match your predictions.

Practical investigations help you practise real scientific skills like making accurate measurements, following safety rules and keeping detailed records.

In Lessons 1.8–1.13 (page 23–50), more information is provided about how to plan, conduct and analyse data for practical investigations. Steps that you should follow are:

Step 1: Identify the research question

- Frame a clear, testable scientific question and write a hypothesis.

Step 2: Complete background research

- Gather sources such as books and websites and summarise the research.

Step 3: Plan the investigation

- Identify the independent, dependent and any controlled variables.
- List the materials and create the procedure.
- Prepare a risk assessment and have it signed off by your teacher.

Step 4: Conduct the investigation

- Follow your procedure and record all quantitative and qualitative data (this also includes taking photographs and recordings).
- Note any changes you make during the investigation.

Figure 2 Conducting an investigation is one way to collect data to test a hypothesis.

Step 5: Analyse the data

- Create any relevant graphs or diagrams to identify trends or patterns in the data.
- Explain what the results mean and if any errors or limitations affected the results.
- Discuss the reliability and accuracy of the results.
- Discuss the validity of the method.
- Suggest improvements for future investigations.

Step 6: Draw conclusions

- Describe the general trend in the results.
- Did the investigation support or refute the hypothesis?

Step 7: Communicate your findings

- Present the findings from your investigation as a report, including any references.

Secondary-source investigation

Sometimes, doing an experiment isn't possible – for example, if you want to study black holes or ancient fossils. In this case, you can do a secondary-source investigation. This means gathering information from books, scientific articles, trusted websites and documentaries. You'll read, watch or listen to what scientists have already discovered and then put that information together into a report.

This type of study builds your research and critical thinking skills, helping you identify what information is reliable and how to explain complex ideas clearly.

These are the steps you can follow when completing a secondary-source investigation.

Step 1: Identify the research question

- Frame a clear and focused research question that can be addressed using secondary sources.
- State the aim.

Step 2: Conduct initial research

- Use credible websites, books, scientific journals such as the CSIRO Publishing website or other media sources to collect background information for your research question, making a list of key terms or concepts you may need and any questions that arise.

Step 3: Evaluate your sources

- Sources you use must be reliable and credible. Refer to Figure 1 in Lesson 15.1 Data science is an interdisciplinary field (page 600) for more information on how to evaluate your sources.

Step 4: Organise your information

- Take detailed notes and highlight information that connects to your research question. This includes any patterns or trends you observe.

Step 5: Analyse the data and information

- Identify any relationships and compare and contrast findings from different sources.
- Determine and discuss the reliability and validity of the data and information.

Step 6: Draw conclusions

- Summarise the information and how it addresses the research question and supports your conclusion.
- Suggest improvements for future investigations or any limitations of the investigation.

Step 7: Communicate your findings

- Present your findings as a report, slideshow or multimedia presentation (as directed by your teacher), including any references.

Research assignment

A research assignment is like writing a detailed report on a science topic that interests you. You might explain how a technology like solar panels works, describe the causes of climate change or explore the science behind new medicines. You'll organise your findings into sections, include diagrams or images and explain key points in your own words.

These are the steps you can follow when completing a research assignment. You'll notice that some are very similar to a secondary-source investigation.

Step 1: Identify the research topic and question

- Frame a clear and focused research question that can be addressed.
- State the aim.

Step 2: Conduct initial research

- Use credible websites, books, scientific journals or other media sources to collect background information for your research question, making a list of key terms, concepts or ideas that you may need.
- Sources you use must be reliable and credible. Refer to Figure 1 in Lesson 15.1 Data science is an interdisciplinary field (page 600) for more information on how to evaluate your sources.

Step 3: Investigate and gather data and information

- Locate and analyse specific evidence such as studies, experiments, graphs, debates and technologies.
- Take detailed notes and record direct quotations, making sure to keep track of all references.

Step 4: Analyse the data and information

- Identify any patterns, trends or connections between sources and evaluate the reliability and validity of the data and information.
- Combine the data and information to present a clear analysis that addresses the research question.

Step 5: Draw conclusions

- Summarise the information and how it addresses the research question and supports your conclusion.
- Suggest improvements for future investigations, any limitations and future directions for investigation.

Step 6: Communicate your findings

- Present your findings as a report, slideshow or multimedia presentation (as directed by your teacher), including any references.

Fieldwork

Fieldwork involves going outside to study the natural world. You might collect soil samples, observe birds, track weather patterns or measure water quality in a nearby stream.

You’ll gather data in the field, take notes and create a report on what you found. Fieldwork helps you understand how science applies to the real world and gives you experience with environmental research.

These are the steps you can follow when completing fieldwork as part of an investigation.

Step 1: Identify the research question

- Frame a clear research question that can be investigated from qualitative and quantitative data collection in the field.
- State the aim and hypothesis.

Step 2: Conduct background research

- Research the topic to understand the scientific concepts and context, including factors you may encounter in the field (e.g. weather and species of plants and animals).
- Record any information you may already have, based on experiences or pre-existing knowledge.

Step 3: Plan your fieldwork investigation

- Identify the independent, dependent and any controlled variables.
- List the materials and create the procedure.
- Prepare a risk assessment and have it signed off by your teacher.
- Check if any protocols must be followed prior to visiting a site (e.g. visiting a cultural site).

Step 4: Conduct the fieldwork

- Follow your procedure to collect and record qualitative and quantitative data.
- Record any changes to the procedure and challenges experienced, and record photographs and sketches made.

Step 5: Analyse the data and information

- Create any relevant tables, graphs or diagrams to identify trends or patterns in the data.
- Did the investigation support or refute the hypothesis?
- Discuss any factors and errors that may have impacted your data.

Step 6: Draw conclusions

- Summarise the key findings and explore how they address the research question and how your research contributes to the understanding of the topic.
- Suggest improvements for future fieldwork and any limitations.

Step 7: Communicate your findings

- Present your findings as a report or presentation (as directed by your teacher), including any references.
- Include diagrams, annotated photographs and maps to support and enhance your investigation.

Figure 3 When conducting fieldwork, you can annotate maps (which means adding notes and details) to communicate your findings.

Presentations

After doing research or an experiment, you'll share your findings through a speech, slideshow or even a video.

You'll need to explain what you learned in a way that's interesting and easy to understand. Presentations help build your communication and confidence skills while letting you show what you've discovered in a creative way.

Make sure to include graphs, charts, table or diagrams to visually enhance your presentation and make it more engaging.

Step 1: Understand your depth study

Research thoroughly

- Gather information from a variety of reliable sources (books, academic journals, credible websites).
- Take notes on important concepts, facts and figures.

Identify key points

- Highlight the main findings or arguments you want to present.
- Create a list of three to five key points that summarise your research.

Contextualise your finding

- Consider the implications of your findings. How do they fit into the larger picture of the subject area?
- Think about how your research can contribute to ongoing discussions or debates in the field.

Step 2: Plan your presentation structure

Create an outline

- Organise your key points into a structured outline with headings for each section (Introduction, Body, Conclusion).
- Determine how much time you will allocate to each section.

Detail each section:

Introduction

- Introduce the topic and provide a brief overview of what you will cover.

Body

- Divide your topic into sections based on themes or key points. Each section should have a clear focus.
- Use subheadings to clarify transitions between points.

Conclusion

- Summarise the key findings succinctly.
- Suggest implications for future research or practical applications.

References

- Use appropriate referencing style. For example, APA (American Psychological Association).

Step 3: Design engaging visuals

Use visual aids

- Create graphs, charts and diagrams to illustrate data or concepts. Ensure they are clear and relevant.
- Use software like PowerPoint, Google Slides, Canva or Prezi to design your visuals.

Keep slides simple

- Limit the amount of text on each slide – aim for no more than six to eight lines of text.
- Use dot points to highlight key information, avoiding long paragraphs.

Consistent design

- Choose a professional colour scheme and font style that is easy to read.
- Ensure that all visuals maintain a consistent style for a cohesive look.

Step 4: Write and edit your script

- Draft your presentation in a script format, including what you will say for each slide or section.
- Use a conversational tone to make your delivery more engaging.
- Review your script for clarity and conciseness. Remove jargon or overly complex language.
- Make sure each point logically leads to the next and transitions are smooth.

Step 5: Practise your presentation and prepare for audience questions

Rehearse

- Practise your presentation several times, focusing on your delivery and timing.
- Record yourself to evaluate your body language and clarity.

Seek feedback

- Use the allocated marking criteria to ensure all content is being covered to the necessary depth.
- Present your presentation to a peer or family member and ask for their feedback on your content and delivery.
- Make adjustments as necessary.

Prepare for questions

- Create a list of potential questions your audience might ask and prepare answers.
- Stay informed about your topic so you can respond confidently.

Figure 5 A presentation can make anyone nervous, but preparation and practice is the key!

Step 6: Deliver your presentation

Engage with your audience

- Minimise your use of palm cards.
- Start with a strong opening statement to capture attention.
- Use eye contact, gestures and movement to connect with your audience.
- Engage with your slides. For example, point to and discuss images and graphs.

Stay calm and confident

- Take deep breaths before starting, to calm your nerves.
- Speak clearly and at a steady pace, and don’t rush through your presentation.

Invite questions

- At the end of your presentation, encourage questions and be open to feedback.
- Listen actively to questions and respond thoughtfully, drawing on your research.

Lesson 1.19

Review: Working scientifically

Summary

Lesson 1.1 Observing

- Good scientists need to be observant and notice things around them.
- Quantitative observations usually contain numbers with units.
- Qualitative observations contain words and descriptions.
- Scientists use observations to infer (explain) what is happening.

Lesson 1.2 Measuring quantities

- Scientists use equipment to measure their results.
- Scientists need to compare their measurements with one another.
- The standard metric system is used by scientists around the world to measure distance (metres), volume (litres) and mass (grams).

Lesson 1.4 Questioning and predicting

- Two things are correlated when they both change in a related way.
- Correlation of data does not mean one event causes another event.
- Causation occurs when the independent variable is responsible for the change in the dependent variable.

Lesson 1.6 A Bunsen burner is an essential piece of laboratory equipment

- A Bunsen burner is used to heat things in the laboratory.
- The yellow flame is called the safety flame because it is easier to see.
- The blue flame produces more heat than the yellow flame (over 1,500°C).

Lesson 1.8 Planning investigations

- Scientists use specialised equipment to conduct experiments in the laboratory and in the field.
- Scientific experiments must be carefully planned so that they are safe.

Lesson 1.9 Conducting investigations

- Following safety practices minimises danger by identifying risks and applying necessary precautions.
- Using the correct equipment and following a planned procedure improves the reliability of investigations.
- Recording data accurately improves the quality of scientific work.

Lesson 1.10 Processing data and information: Part A – Extracting data and information

- Scientists need to collect data and present it in an organised manner.
- Information can be extracted from tables, graphs and other representations to identify trends, patterns and relationships that may exist in their results.

Lesson 1.11 Processing data and information: Part B – Representing data and information

- Tables should have a heading, column headings with units of measurement, and data in each column.
- Different graphs should be used depending on the type of data (discrete or continuous) being displayed.

Lesson 1.13 Analysing data and information

- Science experiments are planned and analysed carefully to minimise errors.
- Before claiming that a hypothesis is supported or refuted, experimental data must be checked to identify whether it contains any errors or unexpected results.

Lesson 1.14 Problem solving

- Recognising and defining a specific problem is the first step in developing a solution.
- Group work and creative thinking are often required to solve identified problems.

- Establishing clear criteria for evaluating potential solutions is necessary to compare and contrast different strategies.
- Models are used to demonstrate and explain the relationships between causes and their effects in various phenomena.

Lesson 1.16 Communicating

- A scientific report is where results and findings are recorded.
- Scientists use a similar style and language in their reports so that they can be understood by scientists worldwide.
- Scientists communicate with other scientists so that they can learn from one another and expand on one another's work.

Lesson 1.18 Depth studies

- Identify the five types of depth studies, and describe the key features and purposes of each.
- Choose a suitable type of depth study for a given scientific topic and explain why it fits the investigation goals.

Review questions 1.19

Review questions Module 1

Retrieve

1 Identify which of the following is most accurate when measuring 10 mL of liquid.
  A Conical flask
  B Beaker
  C Measuring cylinder
  D Test tube

2 Identify which of the following could be used to measure the temperature of the air.
  A Balance
  B Electronic scales
  C Stopwatch
  D Thermometer

3 Identify the step that should be completed first when lighting a Bunsen burner.
  A Open the air hole.
  B Light the match.
  C Turn on the gas.
  D Place the lit match over the Bunsen burner.

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

5 Define the term "mass".

6 Identify the following as either quantitative or qualitative observations.
  a The bus is red.
  b The swimming pool smells of chlorine.
  c I am older than 12 years old.
  d The line to the tuckshop is 4 m long.

7 Name the section of a scientific report that would contain the measurements collected.

Comprehend

8 Illustrate a diagram of a:
  a conical flask
  b tripod stand
  c test tube.

9 Consider the image of the Bunsen burner with a blue flame (Figure 1). Identify whether the air hole on the burner would be open or closed. Explain how the position of the air hole produces a blue flame.

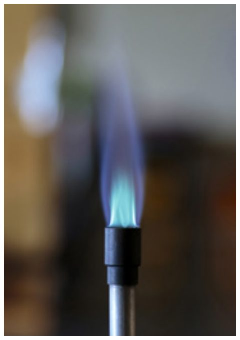


Figure 1 A Bunsen burner with a blue flame

Figure 2 Identifying safety signs

10 Explain what this safety sign means (Figure 2).

11 Describe a valid test.

12 Explain why it is important to control variables in an experiment.

13 Explain why a measurement is not very useful if you do not include the correct units.

14 Answer the following questions about a Bunsen burner.

a Provide an example of when the Bunsen burner safety flame is important.

b Explain what steps you would need to use to achieve a safety flame with your Bunsen burner.

c Describe two reasons why the safety flame is not good for heating.

d Identify which part of the blue flame is best for heating.

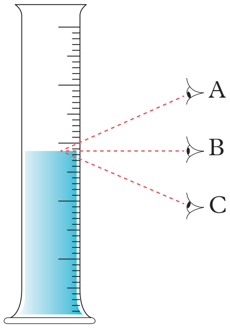


Figure 3 Which angle provides the most accurate reading?

15 A student is conducting an experiment and measuring the amount of water they need to use in a measuring cylinder. They look at their measuring cylinder from three angles: A, B and C (Figure 3).

a Identify which angle would provide them with the most accurate reading.

b Explain your answer to part **a**.

Analyse

16 Write three observations and three inferences about:

a this textbook **b** your own hand.

17 Consider what would happen if the units used by scientists were not the same everywhere in Australia.

18 Identify the correct graph to use to represent the set of data in Table 1 on the number of road deaths each year due to car accidents.

Table 1 Number of road deaths each year due to car accidents

Year	Number of road deaths due to car accidents
2004	1583
2005	1627
2006	1602
2007	1603
2008	1437
2009	1488
2010	1352
2011	1291
2012	1310
2013	1193
2014	1155
2015	1212

19 Measure the length of the palm of your hand. Check the length of your own palm against the suggested value (Table 1 in Lesson 1.1 Observing (page 4)) in centimetres.

a Calculate the length of 50 standard "palms".

b Calculate the length of 50 values of the measurement of your palm.

c Calculate the difference in the two measurements.

Apply

20 There are many unusual measurements. Determine how you might find the answers to these measurement problems.

a What is the temperature inside a furnace?

b What is the thickness of a sheet of paper?

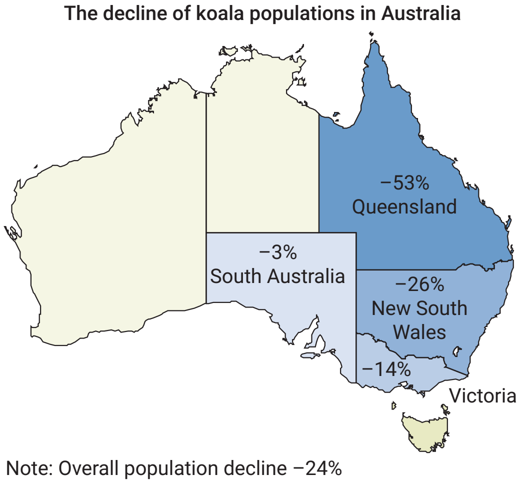
c How fast do your fingernails grow? How could you measure this?

21 The number of koalas has been steadily decreasing across many of the eastern states in Australia since 2012. The size of the decrease in each state is shown in Figure 4.

a Evaluate why a column graph would be the most appropriate graph to use for this data.

b Use the data to draw a column graph.

c Discuss why you could not use this data to determine which state has the largest koala population.



Source: Adams-Hoskin et al. (2016)

Figure 4 The decline of koala populations in Australia (overall population decline – 24%)

Social and ethical thinking

22 Many forms of scientific research are dependent on government funding. Scientists need to apply for the funding, which can result in their projects competing against one another for the limited funds. A selection panel will often need to decide which research project will receive funding and which will not. Read the following Ig Nobel proposals and decide which research proposal should receive funding. Discuss how you made your choice.

- How can we identify a narcissist (self-absorbed) person by the shape of their eyebrows?
- What happens to the shape of an earthworm when it is vibrated?
- What does a crocodile sound like, after it has breathed helium, when they bellow?

Critical and creative thinking

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

- An experiment to test if three types of material are waterproof.
- An experiment to see how high a rubber "bouncy-ball" can bounce on different surfaces.

24 Describe how you would determine if you could trust the information you read on a website. Identify which of the following factors you would consider: who wrote the information, when was the information written, how old is the author of the website and why did the author make the website. Develop one more question that you would ask when you read the website information.

Famous Australian scientists

Scientists become famous when they are experts in their area of research. They may have spent many years working on one particular area or they may have made an important discovery. Some may have even won awards for their work.

- Select one of the scientists from this list: Frank Macfarlane Burnet, Helen Caldicott, Douglas Mawson, Nancy Millis, Gustav Nossal, Suzanne Cory, Mark Oliphant, William McBride and Struan Sutherland.
- Describe the area in which they do research.
- Explain any significant discoveries that they may have made.
- Create a list of questions that you would ask them if you had the chance.

Research

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

Depending on variables

Scientific discoveries rely on carefully controlled experiments. This means that the methods must be repeatable and all the variables must be controlled.

- Explain the difference between controlled variables and the independent variable.
- Describe what would happen if the variables in an experiment were not controlled.
- Describe two experiments: one that is controlled and one that is not controlled.
- Explain how the reputation of a scientist may be affected if they made a claim based on an uncontrolled experiment.

Intellectual property

When you develop a new product or idea, it is said to be your **intellectual property**. This means you have time to use your idea or product to produce something to sell and cover the cost of your research. If you were shown by Aboriginal or Torres Strait Islander Peoples how a native plant could cure an infected finger, would you need to ask their permission before you researched the plant to make a new antibacterial medicine?

- Identify what is meant by the term "biopiracy".
- Describe the things you would need to consider before you started your research.

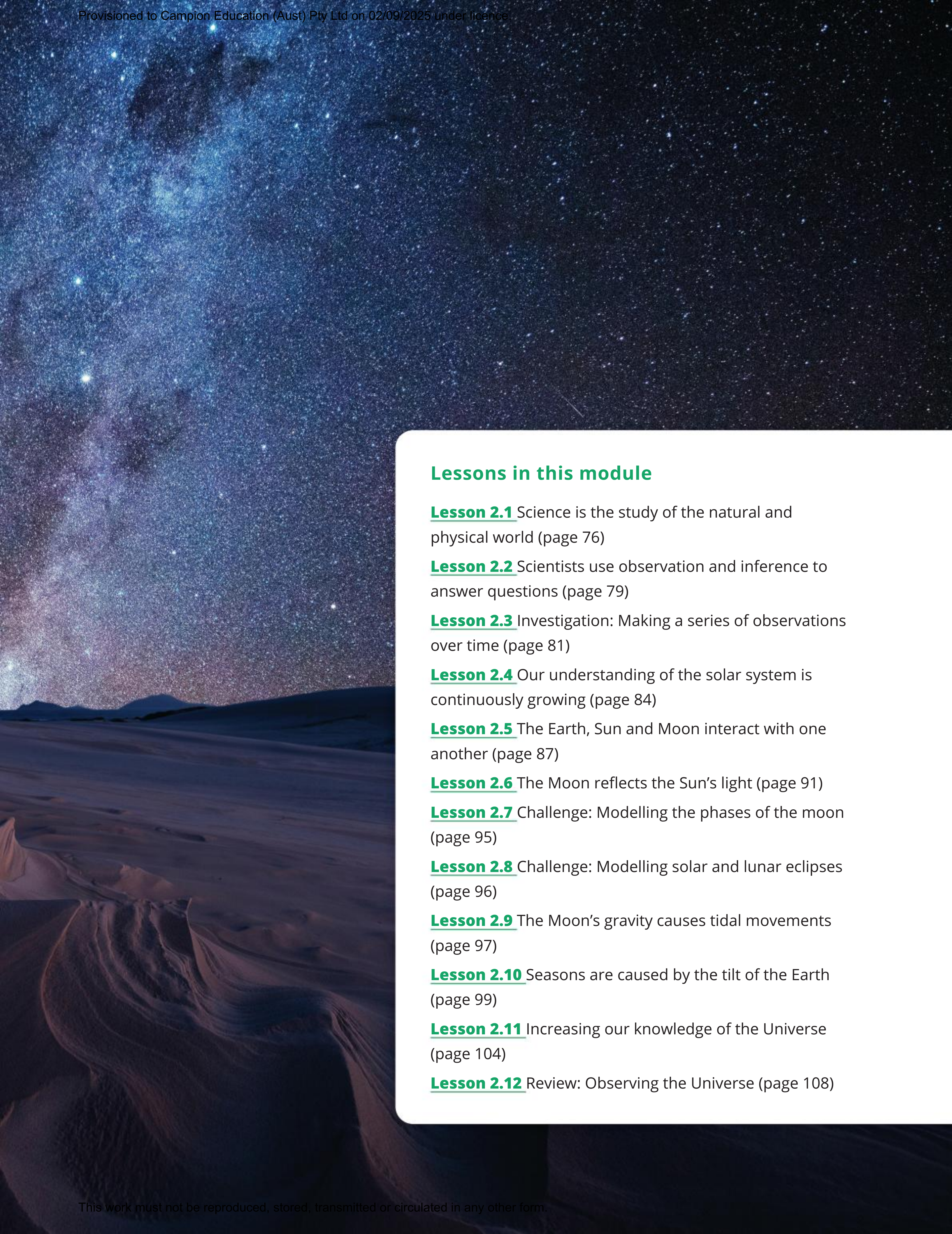
Module

2

Observing the Universe

Overview

From over 65,000 years ago, when Aboriginal and Torres Strait Islander Peoples first observed and interpreted the night skies, to the present day, humankind has always been fascinated by what lies beyond our planet. As scientists work together year after year to increase our understanding of space, our knowledge of the solar system and the Universe expands. With the launch of the James Webb Space Telescope, we can now look further into space than ever before and learn more about the early Universe. Imagine what we might discover and learn over the next 100 years!



Lessons in this module

Lesson 2.1

Science is the study of the natural and physical world

Learning intentions and success criteria

Key ideas

- → Science measures what we observe (see, hear, smell, taste and feel) and organises it into testable explanations.
- → Scientists have jobs that focus on asking questions and finding answers.
- → Some scientists work in a laboratory; all scientists work in teams.
- → Scientists answer questions by observing, recording and interpreting what they find.

Curiosity through history

Scientific discoveries often begin with a single curious individual. The world would be a very different place without people asking questions. These questions lead to research and development as well as inventions to improve our world and our way of life.

Sometimes curiosity comes from necessity. To survive, the first humans had to discover through trial and error which foods were edible and which were poisonous. This was curiosity with life-and-death results! The information was then passed from person to person to benefit many more people.

Curiosity can also come from the desire to know more. In ancient Greece, there was much curiosity about the stars, the Sun, the Moon and our own planet. Early **scientists** were not called scientists at all – they were called “natural philosophers” because of their interest in studying nature (Figure 1). **Philosopher** means “lover of knowledge”. Natural philosophers used their observations to develop calendars, to locate the Earth in the Universe, and to show that the Earth is round and not flat.

Finding answers to problems that affect people and society is another result of curiosity (Figure 2). Many of the great advances in medicine, such as vaccinations and the discovery of penicillin, are the result of years of research. They have changed our lives, mostly for the better.

Figure 1 Early scientists were called natural philosophers.

scientist	a person who studies the natural and physical world
philosopher	a “lover of knowledge”; someone who studies ideas, theories and questions
science	the study of the natural and physical world
theory	an explanation of a small part of the natural world that is supported by a large body of evidence

Curiosity today

Science is in the news every day. Some issues that scientists are curious about right now include alternative and "green" energy sources, clean drinking water and food for a growing world population, and new cures for diseases such as Ebola or COVID-19. Scientists ask questions about the survival of the human race and space travel, and whether the human brain could be replaced by a computer. Science is an ongoing process that is never "finished" – it is always changing.

Scientists in the world

There are four main branches of science: biology, physics, chemistry and geology. Within each of these branches there are many different specific science professions that can overlap with one another. Usually, a scientist has dedicated years of study to specialise in one particular area. Figure 3–8 show six different types of scientists as well as a question they may spend time researching. Science is an ever-expanding search for knowledge, and as you will read, there is still a lot of research to be done.

Science as a collaborative effort

Science is all about discovering how the natural and physical world works. Scientists rarely work alone because solving big problems often requires many different skills and ideas. By working together, scientists can share their findings, learn from each other's mistakes and build on past discoveries. For example, space exploration involves engineers, astronomers and computer scientists all working together as a team. Collaboration helps science progress faster and ensures that experiments are tested by many people to make sure the results are correct.

How scientific theories are formed

Scientific **theories** aren't just random guesses – they are explanations based on years of careful research. When scientists notice patterns in their experiments, they create a theory to explain what's happening.

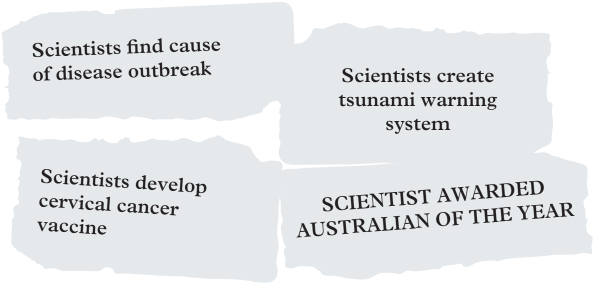


Figure 2 Curiosity leads scientists to new discoveries.

Figure 3 A pharmacologist studies medicines and drugs and their effects on the human body. Is an experimental vaccine for Ebola or COVID-19 safe for human trials?

Figure 4 A palaeontologist studies ancient life, including dinosaur fossils. What can the mass extinction of dinosaurs teach us about modern life on Earth?

Figure 5 An environmental scientist studies the environment. How is climate change affecting the Earth?

Figure 6 A meteorologist studies the atmosphere and weather patterns. How can we accurately predict cyclones?

Figure 7 A marine biologist studies life in the oceans and seas. How will rising sea waters affect the Great Barrier Reef?

Figure 8 A nanotechnologist studies substances at the atomic (very small) scale. Can we design drugs to target individual cells?

Figure 9 Scientists work together to achieve a common outcome.

For example, the theory of gravity explains why objects fall toward the Earth. A theory stays valid as long as experiments keep showing the same results. If new evidence is found that doesn't fit, scientists may adjust the theory or develop a new one. This process makes science reliable and trustworthy.

Scientific laws and predictions

Some scientific ideas become scientific laws, which describe what will happen in specific situations based on repeated experiments and observations. Unlike theories, laws don't explain why something happens – they just describe the pattern. For example, Newton's Laws of Motion explain how objects move when forces are applied. These laws help scientists predict what will happen in new experiments or real-life situations, making science useful for designing technology, building bridges and even predicting weather!

Check your learning 2.1

Check your learning 2.1

Retrieve

1 Identify the name that was given to the early scientists.

2 Identify the four main branches of science described in this section.

Comprehend

3 Describe one reason why being curious and asking questions is important in science.

4 Describe one idea or invention that has changed in your lifetime due to science.

5 The meteorologist in Figure 6 is studying how to predict cyclones. Describe one advantage of this research.

Analyse

6 The environmental scientist in Figure 5 is investigating climate change. Identify two other scientists in this section who may work with an environmental scientist.

Apply

7 It is often said that science is never "finished". Evaluate the truth of this statement (by providing examples of science that is never finished and deciding if this statement is true).

8 Look carefully at Figure 10. Propose a possible question about gorillas that the scientist may be investigating. Describe the risk the close contact may have to:
   - **a** the scientist
   - **b** the gorillas.

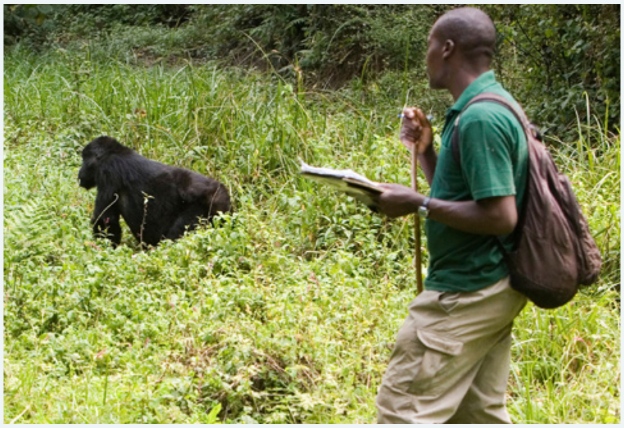


Figure 10 A scientist observes gorillas.

Lesson 2.2

Scientists use observation and inference to answer questions

Key ideas

→ Key concepts in scientific inquiry focus on how data is gathered and interpreted.

→ Observation involves using your senses to collect information.

→ It is important to understand inference and make conclusions or explanations based on observations.

→ Scientists draw conclusions based on observations and inferences.

→ We can understand how data is collected and analysed in experiments.

Learning intentions and success criteria

Introduction

When scientists study the natural world, they often start by observing things around them. As discussed in Module 1 Working scientifically (page 2), observations are what we notice using our senses, like seeing how plants grow toward sunlight or feeling how the temperature drops when the sun sets. These observations can help scientists make inferences, which are educated guesses about why something is happening. For example, if you see birds flying south every winter, you might infer that they do this to find warmer weather. These inferences can lead to testable predictions, like predicting that birds will return north in the spring when it gets warmer.

Testing predictions

To test their predictions, scientists use different methods.

Systematic observations

systematic observations recording observations over time in a structured and consistent way

One common approach is making **systematic observations**. This means carefully watching and recording what happens over time. For example, if you're studying how plants grow, you might measure their height every day and note how much sunlight or water they get. Systematic observations are helpful when it's not possible to control all factors, like when studying animals in the wild.

Controlled experiments

Another approach is conducting controlled experiments. In these experiments, scientists change one thing at a time (the variable) while keeping everything else the same. For example, if you wanted to know if plants grow better with more water, you could set up two groups of plants: one group that gets a lot of water and one that gets only a little. By comparing the results, you can figure out if the amount of water makes a difference. Controlled experiments are great for finding clear cause-and-effect relationships.

More information on making observations can be found in Lesson 1.1 Observing (page 4).

Accuracy and reliability

Scientists aim for their results to be both accurate and reliable. Accuracy is how close a measurement is to its true value (the value of something if it was measured perfectly without any error). The closer a measurement is to its true value the more accurate it is. Some strategies to improve the accuracy of measurements include ensuring that equipment is calibrated and selecting tools that measure to a higher degree of precision. Reliability is extent to which the method of measuring or testing produces consistent results. For example, an experiment that is repeated and produces the same findings each time is more reliable than an experiment that when repeated produces different findings. Reliability can be improved by taking repeated measurements and averaging them as well as using calibrated tools.

analog a tool that changes smoothly and continuously

digital a tool that changes in steps or separate values

Tools of measurement

We use different tools to measure things like length, temperature, time or even the brightness of light. These tools can be **analog**, like rulers, stopwatches or thermometers, or **digital**, like electronic scales, data loggers and infrared thermometers. Each type of tool has its own strengths and weaknesses when it comes to measuring accurately and precisely. For example, a traditional thermometer might give you a general idea of the temperature, but a digital thermometer can often measure more quickly and provide readings with more decimal places, which makes it more sensitive (Figure 1).

Figure 1 An example of an analog scientific thermometer and a digital laboratory thermometer

By comparing different measuring devices, scientists can decide which is best for a specific investigation. Let's say you are measuring the time it takes for a reaction to occur. A stopwatch might be enough for a rough estimate, but if you need very precise timing, a digital timer could be better. The choice also depends on the range of the instrument (how much it can measure) and its accuracy. For instance, a ruler might be fine for measuring the length of a desk, but you'd need a **micrometer** to measure something very small, like the thickness of a sheet of paper. Learning how to choose and use the right tools helps scientists get the most reliable results possible.

micrometer a device that can be used to make precise measurements of very small objects

Check your learning 2.2

Check your learning 2.2

Retrieve

1 Define the term "observation". Use an example to support your definition.

2 Define the term "inference". Use an example to support your definition.

3 Recall why a digital thermometer might be more sensitive than a traditional analog thermometer.

Analyse

4 Give an example of how both systematic observations and controlled experiments could be used together to study a natural phenomenon.

5 Contrast "accuracy" and "reliability".

Apply

6 If you were measuring the thickness of a piece of paper, explain why a micrometer would be more suitable than a ruler.

7 Observation and inference are very important tools for scientists. Propose one reason why you think they are important.

Lesson 2.3

Investigation: Making a series of observations over time

Introduction

Scientists make a series of observations over time because things in the natural world don't always change quickly, and understanding these changes takes careful, repeated measurements. By observing something over a long period, scientists can spot patterns and changes that help them learn more. For example, watching a plant grow or tracking the temperature of something over time allows scientists to gather enough information to understand what's happening. By making observations over time, scientists can see if there are trends or factors that affect their results.

In each of these experiments you will have the opportunity to practise the fundamental skills of a scientist by conducting investigations using various scientific tools and instruments. Through the activities of observing seed germination, tracking rust formation on metal and measuring the cooling rates of liquids, you will make a series of observations over time. These experiments will help you practise gathering and analysing data as a scientist does. You'll tabulate your results, graph them to identify trends and patterns, and use this data to draw conclusions.

Investigation 1: Seed germination rates

Purpose

To investigate how environmental conditions affect seed germination rates over time

Materials

- Seeds (e.g. beans or radishes)
- Paper towel or cotton wool
- Water
- Ruler
- Plastic zip-lock bags or containers
- Permanent marker

Procedure

1 Prepare seeds: Soak seeds in water for a few hours if needed.

2 Set up investigation: Place damp paper towels or cotton wool in plastic bags (or containers). Lay five to ten seeds on the paper towel and cover them lightly with another damp layer.

3 Create conditions: Place the bags in different environments, such as near a sunny window, in a dark cupboard or in a cool place. Label each bag with its condition and the date.

4 Observe and record: Check seeds daily for signs of germination. Measure root and shoot lengths with a ruler and count how many seeds germinate. Record your results.

5 Analyse results: Continue observing for one to two weeks, then compare germination rates and growth across the different conditions. Discuss reasons for the differences.

Investigation 2: Rust formation on metal

Purpose

To investigate how different environmental conditions affect rust formation on metal

Materials

- Metal nails or steel wool (at least four samples)
- Four plastic containers (or jars or beakers)
- Water
- Salt
- Measuring cup or beaker
- Plastic wrap or zip-lock bags
- Permanent marker
- Magnifying glass

Procedure

1 Prepare metal samples: Clean and dry metal nails or steel wool pieces to remove any existing rust.

2 Set up conditions: Place the samples in four containers with different environments:
  - Container A: Water
  - Container B: Saltwater (mix water with salt)
  - Container C: Exposed to air only
  - Container D: Wrapped in plastic (no air exposure).

3 Label and store: Label each container with its condition and place it in a safe, undisturbed location.

4 Observe and record: Check the samples at different intervals (daily, every two to three days or weekly) for rust formation.

Use a magnifying glass if needed and note changes in colour, texture and rust coverage.

Investigation 3: Cooling rates of liquids

Caution

- Both steam and boiling water can scald. Take great care when measuring the higher temperatures. If scalded, place the area of skin under cold running water for at least five minutes and inform your teacher. Do not use ice or very cold water.
- Always use heat-resistant gloves or tongs when handling containers with boiling water.
- Wear safety glasses, closed-toe shoes and a lab coat, and tie long hair back when using a Bunsen burner.

Purpose

To investigate how different types of containers affect the cooling rates of hot water

Materials

- Hot water (boiled)
- Measuring cup or beaker
- Thermometer (digital or alcohol)
- Timer or stopwatch
- Insulated container (e.g. Thermos)
- Metal container (e.g. aluminium can)
- Glass container (e.g. glass jar)
- Plastic container (e.g. plastic cup)
- Permanent marker

Procedure

1 Prepare containers: Label the four containers as “Insulated”, “Metal”, “Glass” and “Plastic”.

2 Add hot water: Pour the same amount of hot water into each container, measuring carefully with the measuring cup or beaker.

3 Measure initial temperature: Use the thermometer to record the initial temperature of the water in each container.

4 Monitor cooling: Start the timer. Measure and record the water temperature every five minutes for 30 minutes. Ensure the thermometer is rinsed and dried between uses.

5 Record and compare results: Create a data table to compare the temperature changes over time. Identify which container cooled the fastest and which retained heat the longest.

Discussion

Answer the following for each of the experiments you completed.

1 Graph your results using an appropriate type of graph (line or column).

2 Discuss the conclusions that can be made from your results.

3 Identify any trends/patterns. Why do you think you observed these?

4 Identify any unusual results or outliers and discuss what might have caused them.

5 Identify the variables that affected the outcome of your experiment the most.

6 Explain your results using scientific concepts. (You may need to research these!)

7 If you were to repeat the experiment(s), discuss what you would change/improve and why.

Lesson 2.4

Our understanding of the solar system is continuously growing

Learning intentions and success criteria

Key ideas

→ Aboriginal and Torres Strait Islander Peoples were the first astronomers.

→ An early understanding of astronomy was that the Earth was the centre of the Universe.

→ Polish astronomer Nicolaus Copernicus realised that the Sun was the centre of the solar system.

Introduction

Imagine standing on the Earth gazing at the sky to learn about the Universe. Scientists have explored the relationship between the Earth, the Sun and the other visible planets in the solar system for hundreds of years using their unaided eyes. Scientists across cultures have developed different ways of understanding what we can observe in the sky. This understanding continues to grow as knowledge is shared and new discoveries are made.

The first astronomers

star a glowing big, hot ball of gases

Aboriginal and Torres Strait Islander Peoples have lived around Australia for over 65,000 years. Their understandings of the Sun, Moon and **stars** make them the world's oldest astronomers who still continue today. Across the hundreds of Aboriginal and Torres Strait Islander communities in Australia, many different languages and cultures exist, along with different ways of observing the skies. This knowledge of the Sun, Moon and stars was integrated into every aspect of Aboriginal and Torres Strait Islander Peoples daily lives, to do things like predict weather, understand seasons and navigate. Constellations in the sky are also given meaning and linked to traditions that are passed on through generations.

For the Wiradjuri people of Central NSW, the Milky Way is the Great Celestial Emu: Gurgumin (Figure 1). The Wiradjuri people can use the position of the emu in the sky to know many things, including when emus are nesting. When the emu is directly overhead after sunset, it is the right time of year to collect emu eggs.

Figure 1 The emu-shaped dark patch in the Milky Way is one of the many constellations which Aboriginal and Torres Strait Islander Peoples use as calendars, to navigate and to tell stories.

The ancient Mayans

The ancient Mayans were one of many ancient cultures who believed the Earth was at the centre of everything. The Mayan people believed that the Sun, Moon, planets and stars were gods, and that by observing their movement, they could understand the will of the gods. For example, the planet Venus was associated with the god of war, so wars and battles were planned around where Venus was positioned in the sky. The Mayan calendar was linked closely to astronomy and is extremely accurate. The length of a solar year was exactly 365 days long, which we know today is about the length of time it takes for the Earth to **orbit** the Sun.

orbit move in a curved path around another object

geocentric model a model of the universe that places Earth at the centre of everything

The geocentric model

The idea that the Earth is at the centre of the Universe and that the planets orbit the Earth was popular for a long period of history. This **geocentric model** also seemed true to people who believed that the Earth was not moving at all – or at least it seemed that way for the people who were living on it (Figure 3).

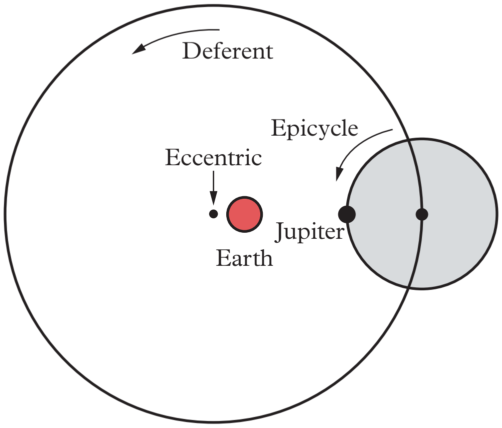


Figure 2 Ptolemy suggested that planets travelled in epicycles around a point close to the Earth called the eccentric, although we know today that this is not accurate.

Ptolemy

Around 150 CE, an astronomer called Ptolemy (*c*. 100–170 CE) described another geocentric model of the Universe. In his model, Ptolemy suggested that the planets orbited around a point slightly away from the Earth called the "eccentric". He also tried to explain why the planets appeared to travel backwards as they orbited the Earth. Ptolemy proposed that the planets travelled in small circles, called epicycles, while they orbited the Earth. He believed these two motions together could explain why planets sometimes appeared closer to the Earth.

Early Islamic astronomy

From the eighth to fifteenth centuries CE, Islamic scholars developed observational techniques and established large-scale observatories that would advance astronomy further. An institute for research and translation was built in Baghdad, called the House of Wisdom, and filled with manuscripts on science and astronomy. During this period, astronomer al-Farghānī (*d*. 865 CE) published the *Compendium of Astronomy*, which updated and combined the work of Ptolemy with the work of other Islamic astronomers. Al-Farghānī incorporated a better method of calculating the circumference of the Earth as well as the movement of the planets. This text became famous in the Islamic world and brought the ideas of Ptolemy to Western astronomers.

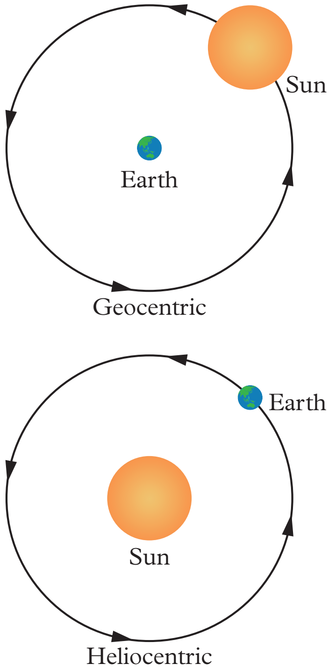


Figure 3 The geocentric model places Earth at the centre of everything. The heliocentric model recognises that the Earth orbits the Sun.

The heliocentric model

Polish astronomer Nicolaus Copernicus (1473–1543) was the first European scientist to argue that Earth was not at the centre of the universe. Based on his observations of the planets' motion and mathematical calculations, Copernicus proposed that:

- the planets orbited the Sun
- the Moon orbited the Earth.

Copernicus's model is called the **heliocentric model** (*helio* referring to the Greek god of the sun and *centric* meaning "at the centre") (Figure 3).

In the seventeenth century, Italian astronomer and physicist Galileo Galilei (1564–1642) made his own **telescope** and looked at the sky (Figure 4). He found evidence in support of heliocentric models.

Later, Issac Newton suggested all matter attracts each other (gravitational force). His law explained how the Earth can rotate around the Sun. New technologies like powerful telescopes (Figure 5) and space missions have helped us learn about the solar system and the universe. We now know our solar system has eight planets and about 293 moons (Figure 6). This shows that scientists always revise and modify scientific knowledge and models based on new observations.

heliocentric model a model of the universe that places the Sun at the centre of everything

telescope an optical instrument that uses lenses and mirrors to make distant objects appear closer and larger

Figure 4 Galileo's telescope

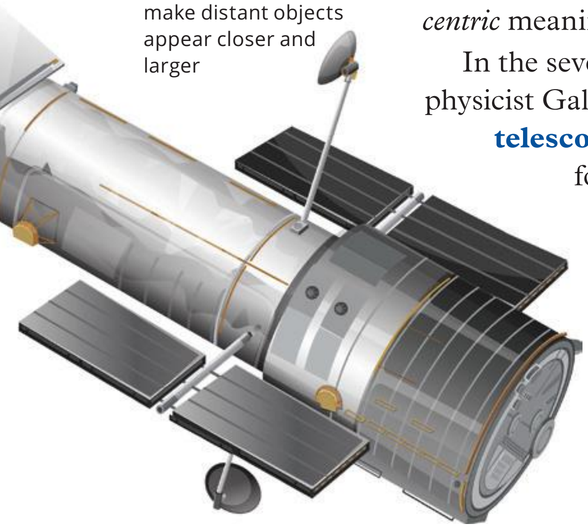


Figure 5 The Hubble Space Telescope is a large and powerful telescope that orbits the Earth. The telescope is named after the famous astronomer Edwin Hubble. It has helped scientists make many important discoveries about the universe.

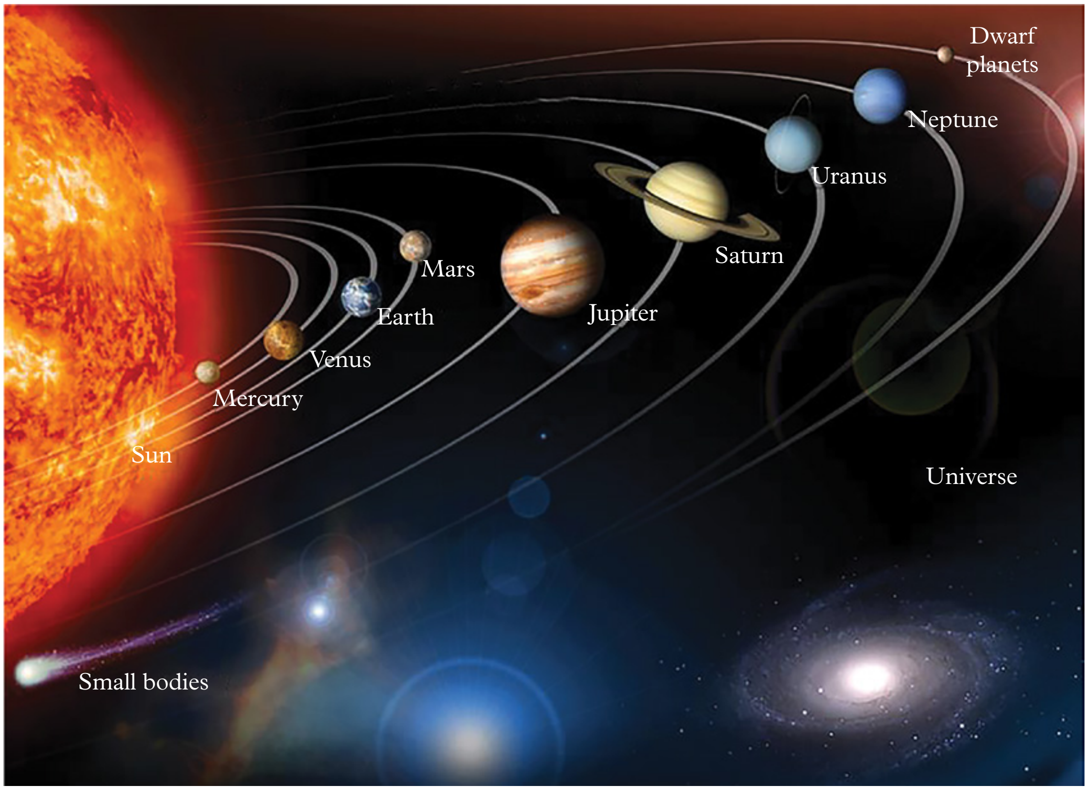


Figure 6 The eight planets of the solar system

Check your learning 2.4

Check your learning 2.4

Retrieve

1 Explain how different cultures have contributed to our understanding of the solar system.

2 Explain the difference between the geocentric and the heliocentric views of the solar system.

3 Identify two key people from different cultures who have contributed to our understanding of the solar system. Describe their contributions.

Analyse

4 Consider why the heliocentric model was controversial at the time it was first proposed by Copernicus and then Galileo.

5 Explain why the geocentric model of the solar system was rejected by the scientific community.

Apply

6 Discuss why people may have believed that the Earth was at the centre of the Universe. What evidence was available (or not available) at the time?

7 Investigate more about the first astronomers – Aboriginal and Torres Strait Islander Peoples. How do the Traditional Owners of the land that you are on understand the stars? Share your findings with your class and explain how this knowledge is used.

Skills builder: Problem solving

8 A student wondered what makes the Sun move across the sky throughout the day. They thought of two possible solutions. Explain which of the student's hypotheses is correct. (THINK: Use your understanding, based on what you have observed during sunrise and sunset combined with your knowledge of the solar system to support your answer.)
   - The Sun is orbiting the Earth.
   - The Earth is orbiting the Sun.

Lesson 2.5

The Earth, Sun and Moon interact with one another

Key ideas

→ The solar system is the collection of planets, their moons and smaller bodies (dwarf planets, asteroids, meteors and comets) that orbit the Sun.

→ The Moon orbits the Earth every 27.3 days.

→ The Earth orbits the Sun every 365.25 days.

Learning intentions and success criteria

Our solar system

Our Sun is a star. It is the closest star to Earth and provides the energy for every living thing. This solar energy is made by atoms colliding with each other in the centre of the Sun. Without the heat and light given off by the Sun, there would be no life on Earth.

Our small planet (it is the fourth smallest in the solar system) is 1,000,000 times smaller than the Sun. The solar system is made up of the Sun at the centre and all the planets, dwarf planets, moons and asteroids that travel around the Sun or each other. The path taken by a planet is called its **orbit** because of its oval or "elliptical" shape.

Figure 1 The Earth is held in orbit by the Sun's gravitational pull.

A year

A year is the time it takes a planet to make one orbit around the Sun. It takes 365.25 days for the Earth to complete one orbit. This means that every four years, our calendar is one full day behind (4 × 0.25 days = 1 day). We account for this by adding an extra day (29 February) every **leap year**.

leap year a year, occurring once every four years, with 366 days

Night and day

spin rotate around an internal axis or centre

axis an imaginary straight line joining the North and South Poles of the Earth

Day and night are caused by the Earth **spinning** on its **axis**, an imaginary straight line joining the North and South Poles. You can model this in your classroom. Stand facing the front of the room and turn around on the spot until you face the front once again. This is one complete rotation. The Earth takes 24 hours to complete one full rotation.

Because of its shape, only half the Earth is exposed to sunlight at any given time. The other half is in shadow (Figure 2). The part facing the Sun is experiencing daytime, whereas the part facing away from the Sun is experiencing night-time. Because the Earth rotates, all parts of the Earth experience day and night, just at different times.

In Figure 2, it is daytime for countries on the right and night-time for those on the left. Can you tell in which countries the Sun would be rising or setting?

Have you ever watched the New Year's Eve celebrations around the world on television? The celebrations in New Zealand are always just before those in Australia. The Earth rotates west to east.

We know this because, as the Earth spins toward the Sun, we see the Sun rise above the horizon in the eastern sky. Sunset occurs when the Earth rotates away from the Sun. New Zealand is east of Australia, so the Sun rises in their sky first.

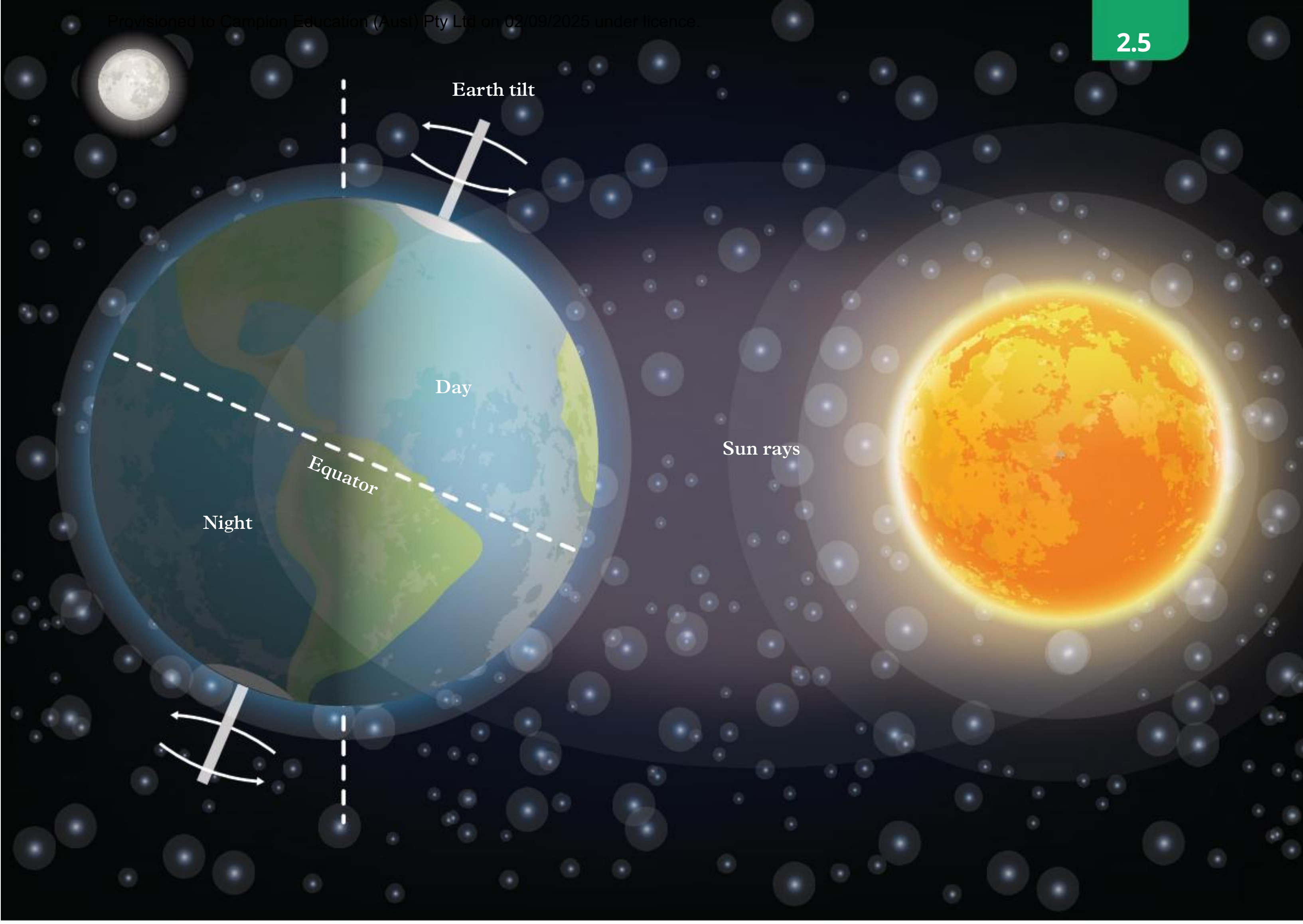


Figure 2 The part of the Earth facing the Sun experiences daytime and the other half experiences night-time.

Solar eclipse

One of the first scientists and mathematicians who investigated the time it took for the Moon to travel around the Earth was al-Battani in the tenth century. Although he was not the first astronomer to build a model of how the Moon travelled around the Earth, his model was one of the most accurate. He was able to correctly calculate the cause of a **solar eclipse**.

A solar eclipse occurs when the Moon passes between the Sun and the Earth once every 27.3 days. Occasionally, the Moon will be in a position where it blocks some of the light from the Sun. This is known as a solar eclipse (Figure 3). During a **total solar eclipse**, the Moon blocks the maximum amount of light from the Sun and the sky goes dark for a short time during the day. The last total eclipse of the Sun, visible from northern Australia, was on 20 April 2023 in Western Australia. The next total solar eclipse visible in Australia is expected to occur on July 28 2028.

solar eclipse when light from the Sun (as seen from Earth) is blocked by the Moon

total solar eclipse when the Moon blocks the maximum amount of light from the Sun, as seen from Earth

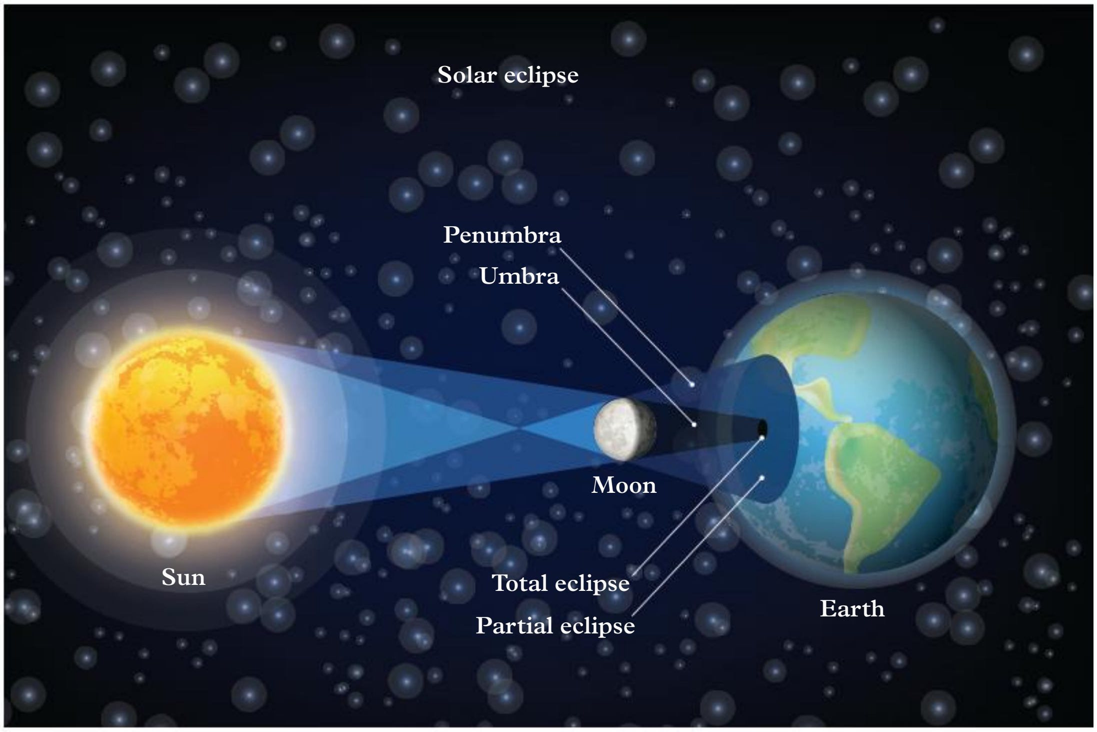


Figure 3 When the Moon is positioned between the Sun and the Earth, it is called a solar eclipse.

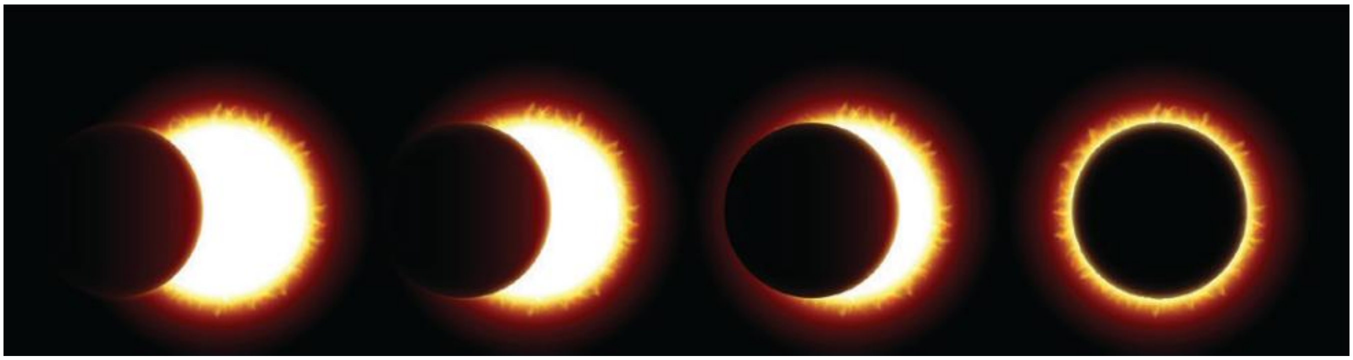


Figure 4 The phases of a total solar eclipse

partial solar eclipse when only some of the Sun's light is blocked by the Moon

When a total solar eclipse is visible in Australia, people somewhere else in the world may only see a **partial solar eclipse**. This occurs when only some of the Sun's light is blocked. Because the Earth and Moon are always moving around their orbits, an eclipse takes a few minutes and then gradually passes as the Earth and Moon continue their motion (Figure 4).

You should never look directly at a solar eclipse because it could damage your eyes.

Check your learning 2.5

Check your learning 2.5

Retrieve

1 Define the terms "spin" and "orbit".

Comprehend

2 Explain why the calendar adds an extra day in February every four years (leap year).

3 Explain the difference between a total solar eclipse and a partial solar eclipse.

4 Explain why a person in NSW and their friend in Darwin do not see exactly the same solar eclipse.

5 Figure 3 shows the shadow caused by the Moon during a solar eclipse. If people living in the region of the darkest shadow experience a total solar eclipse, describe the type of eclipse seen by the people living in the region of the lighter shadow.

Analyse

6 Compare the different time zones around the world. Describe what people in the United States of America, China, Tanzania and France might be doing while you are having lunch in Australia.

7 Identify which of the following terms pair with the explanations from the list below: day, night, year.

   a Experienced by the part of the Earth that is facing away from the Sun

   b The name for the rotation of the Earth over 24 hours

   c The time for the Earth to orbit the Sun once.

Skills builder: Questioning and predicting

8 Explain what is wrong with the following question. (THINK: Is it testable, specific and objective?

> "What would happen to the length of a day if the length of time it took the Earth to orbit the Sun increased?"

Lesson 2.6

The Moon reflects the Sun's light

Key ideas

→ The Moon rotates as it orbits the Earth.

→ The same face of the Moon always faces towards the Earth.

→ The phases of the Moon are caused by the light from the Sun shining on different parts of the Moon.

Learning intentions and success criteria

Introduction

Many scientists believe that a giant collision between two planetary bodies resulted in the formation of the Earth and the Moon.

The first scientific description of the Moon was made in 1609 by Italian astronomer and physicist Galileo Galilei, based on his observations through a telescope. At the time, it was believed that the Moon had a smooth surface, which

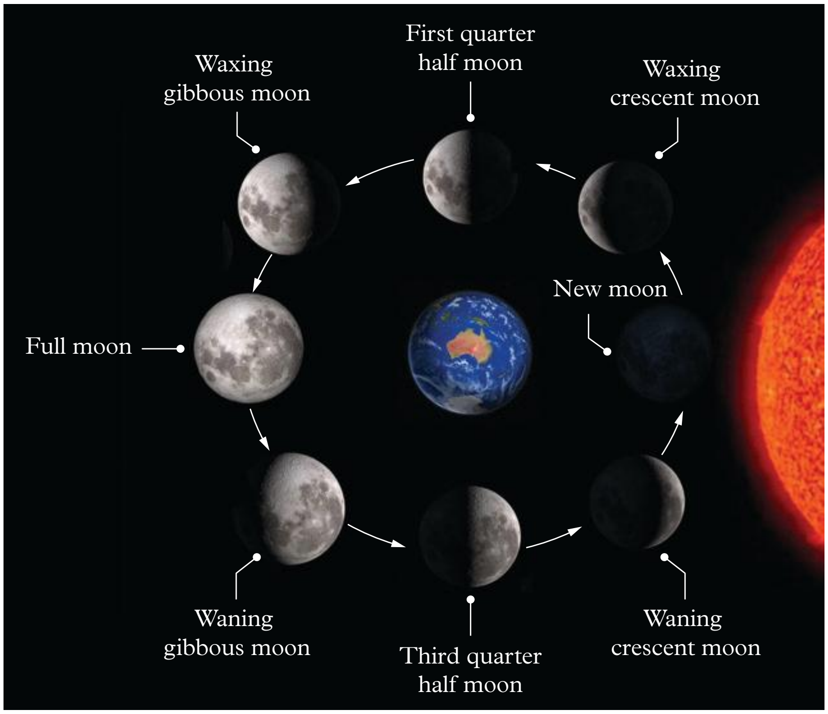


Figure 1 The phases of the Moon as they appear from Australia (the southern hemisphere). The images are not true proportions.

explained its ability to reflect light from the Sun. Galileo knew differently. He saw the rough, mountainous terrain and vast craters that we know cover the surface of the Moon. He even described large flat plains that we call "maria" (pronounced "MAHR-ee-ah"; Latin for "seas") because they look like dark oceans. We now know that these plains are solidified lava.

In 2020, NASA's special SOFIA telescope (the Stratospheric Observatory for Infrared Astronomy), mounted in an aeroplane, identified small molecules of water on the surface of the Moon for the first time. The amount of water found, however, was very small (100 times less than the Sahara Desert).

Moonlight

If you have looked up at the night sky, you might have observed the changing shape of the Moon. Why do you think this happens? The traditional stories of the Nuenonne people of Bruny Island, Tasmania, describe how the source of moonlight is the Sun. They also describe both a waxing and waning moon (Figure 1), which are evidence of their astronomical observations.

Unlike the Sun, the Moon does not create its own light. Instead, it reflects sunlight. Without the Sun, our Moon would be completely dark. The sunlight always comes from one direction (Figure 1). It lights up only the side of the Moon facing it, while the other side of the Moon remains dark. Every night you just see the part of the Moon lit by sunlight. This depends on where the Moon is in its orbit around Earth. When the Moon is closest to the Sun in its orbit, it cannot be seen on Earth. This is because only the side of the Moon that is facing the Sun is illuminated leaving the side facing Earth cast in darkness.

The amount of sunlight reflected varies with the different phases of the Moon, but even the full Moon only provides a faint light that appears bluish to the human eye. We always see the same side of the Moon from Earth because the Moon rotates at the same speed as it orbits the Earth. This is just like walking around a person, making sure you always face toward them. The Moon takes 27.3 days to completely orbit the Earth.

Sometimes, only a part of the Moon is visible. You might see a half-Moon, a crescent-shaped Moon or a fully round Moon. Sometimes the Moon cannot be seen at all, even though it is in the sky. These changes

Figure 2 Neil Armstrong and Edwin "Buzz" Aldrin were the first humans to walk on the Moon.

Figure 3 Buzz Aldrin's footprints on the Moon

in the shape of the Moon are called the **phases of the Moon** (lunar phases, Figure 1). Of course, the Moon does not change shape – it is always round. What changes is the amount of the Moon that is lit by the Sun, which makes it possible for us to see the Moon from Earth. There are eight lunar phases: new, waxing crescent, first quarter, waxing gibbous, full, waning gibbous, last quarter (third quarter) and waning crescent. We are really looking at the "day" and "night" parts of the Moon. The Moon rises and sets, just like the Sun. The Moon rises approximately 50 minutes later from one day to the next. The Moon is always in the sky; however, during the day, the sky is usually so light that the Moon is hard to see.

phases of the Moon (lunar phases) changes in the shape of the Moon as seen from Earth

THEIR DAY ON THE MOON

SOUVENIR ISSUE

EARLY today Neil Armstrong and Edwin Aldrin were dozing in the Eagle after their historic two-hour walk on the moon.

They were due to blast off at 3.55 a.m. to rejoin the Columbia command ship after 21 hours 7 minutes on the Sea of Tranquillity.

The Sun NEWS-PICTORIAL 5c

Figure 4 The first Moon landing was televised around the world and was front-page news on 21 July 1969.

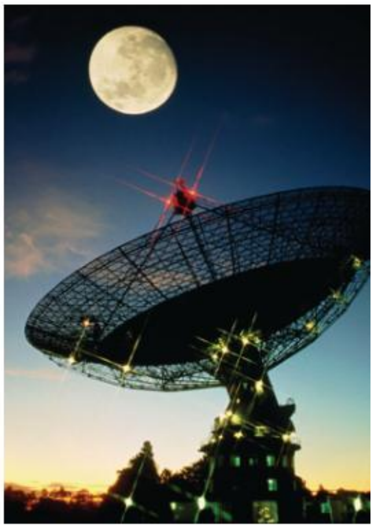


Figure 5 Australian scientists at the Parkes Observatory in NSW played a critical role in the Moon landing.

Exploring the Moon

The Moon is the only body in space on which humans have actually stepped. It has a weak gravitational pull and very little atmosphere; therefore, there is not enough oxygen to breathe. Astronauts must wear space suits fitted with breathing apparatus.

Neil Armstrong and Edwin "Buzz" Aldrin were the first humans to walk on the Moon, in July 1969, as part of the *Apollo 11* space mission (Figure 2 and Figure 3). They found "kangaroo hopping" easier than walking on the Moon. The astronauts could jump higher and further because the pull of gravity on them was only about one-sixth of Earth's gravity.

The surface of the Moon is made of fine grains of dust that stick together like damp sand. The footprints made by the *Apollo 11* astronauts should still be visible in a million years because there is no erosion to destroy them (Figure 3). However, the footprints may be covered with dust from future meteor impacts.

It was possible to beam images of the Moon landing around the world because of the satellite dishes located at Honeysuckle Creek in Canberra and Parkes in NSW (Figure 5).

Lunar eclipse

In eighteenth-century China, a young scientist called Wang Zhenyi developed a way to model a lunar eclipse. This eclipse occurs when the Earth moves between the Moon and the Sun (Figure 6). The Moon

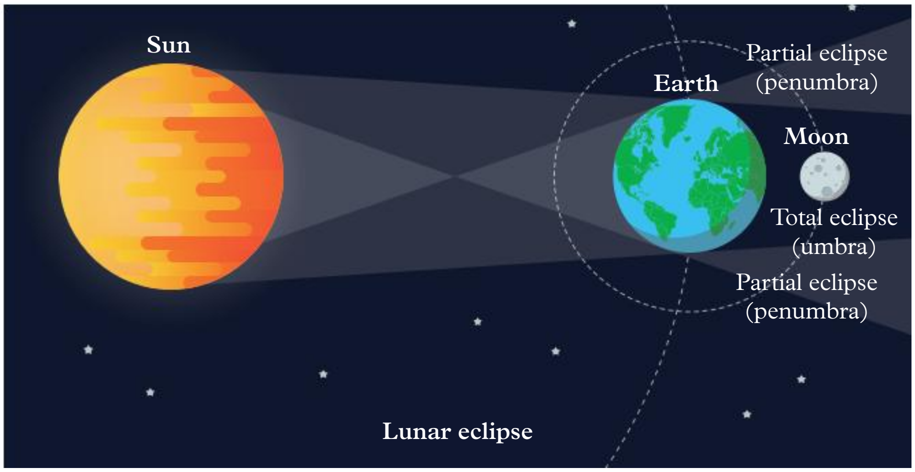


Figure 6 A lunar eclipse occurs when the Earth moves between the Moon and the Sun.

passes into the Earth's shadow and appears dark (Figure 7). Wang modelled this by hanging a lamp from the roof that acted like the Sun above a circular table that acted like the Earth. She then used a circular mirror that acted like the Moon. By moving the Moon mirror under the Earth table, she was able to model the lunar eclipse.

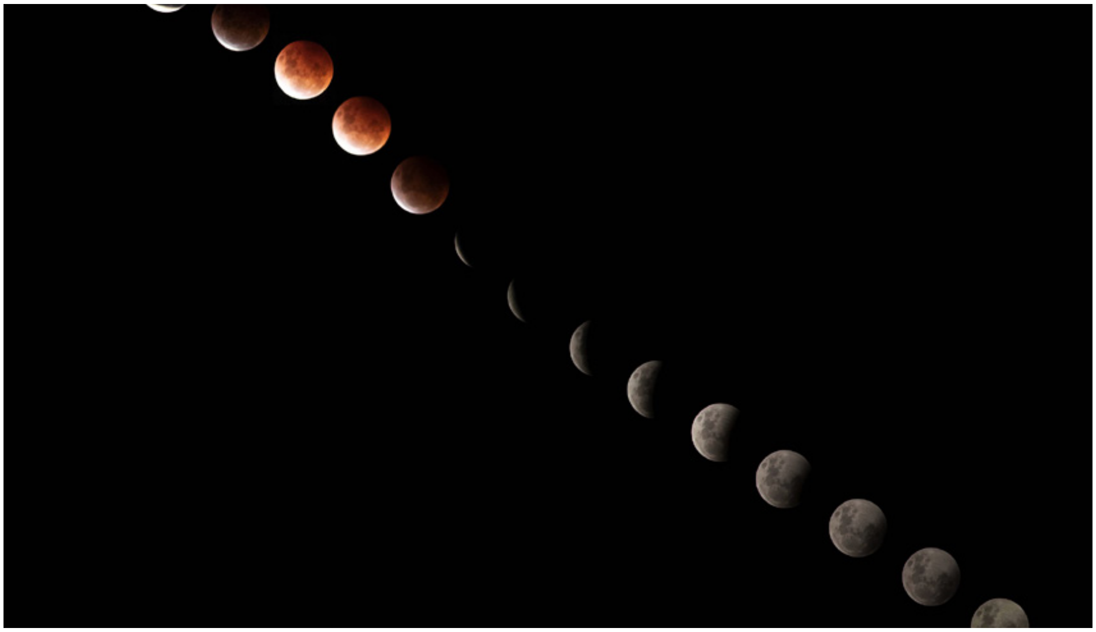


Figure 7 A time-lapse photograph of a lunar eclipse

Check your learning 2.6

Check your learning 2.6

Retrieve

1 Identify if these statements are true or false.
  - **a** The Moon creates light.
  - **b** The Moon does not supply light to the Earth.
  - **c** The Moon changes shape during different phases.
  - **d** The Moon is the closest body in space to the Earth.
  - **e** Craters are large indentations on the Moon's surface.
  - **f** Astronomers are pseudoscientists.
  - **g** We can see both sides of the Moon from the Earth.

2 Recall why astronauts can jump higher on the Moon than on Earth.

Comprehend

3 Use Figure 1 to describe the waxing and waning of the Moon.

Analyse

4 Greek philosopher and scientist Aristotle noticed that, during lunar eclipses, the Earth's shadow was always round. Consider how this led him to suggest the Earth was spherical in shape.

Apply

5 Research an alternative explanation for the phases of the Moon as told by early Aboriginal and Torres Strait Islander Peoples. Explain how they saw the variation in the appearance of the Moon.

Lesson 2.7

Challenge: Modelling the phases of the moon

Aim

To model the different phases of the Moon

What you need:

- Torch or lamp with exposed light bulb
- Globe or basketball
- Tennis ball
- Small foam ball
- Black permanent marker
- Eight Oreo cookies
- A blunt knife
- One piece of A4 paper
- Glue

What to do:

1. In small groups, use a torch or light bulb in a fixed position to represent the Sun. One person should then hold a globe or basketball to represent the Earth, and a second person should hold a tennis ball to represent the Moon.
2. Begin by rotating the Earth as it orbits the Sun. Try to work out how the Moon would orbit the Earth as the Earth orbits the Sun.
3. Use a black permanent marker to colour half of the foam ball. Face the white side of the foam ball towards you. This represents the fully lit face of a full Moon. Slowly rotate the foam ball so that the Moon appears to be getting smaller. (You will gradually see more of the darkened side of the Moon.)
4. Shine the light from a torch onto the white section of the Moon. Pass the tennis ball (now representing the Earth) between the light and the foam-ball Moon.

Questions

1. Explain why people on Earth only see one side of the Moon.
2. Describe and identify the phenomenon that you modelled in Step 4.
3. Explain why the statement “the dark side of the Moon” does not refer to the side of the Moon away from Earth.
4. Draw each phase of the Moon as you saw it on the foam ball in Step 3, or create a model of the lunar phases using Oreo cookies by following the steps below.
   - Separate each cookie carefully so the white cream remains on one side.
   - Use the knife and trim the cream on the cookies to match the eight phases of the moon.
   - Glue your cookie-moon phases onto A4 paper in a similar arrangement to that shown in Figure 1.
   - Label your cookie-moon-phase poster with the name of each phase.

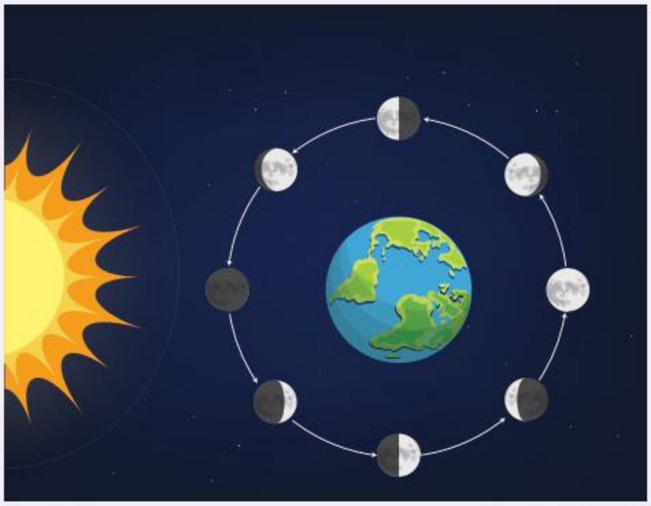


Figure 1 Lunar phases

Lesson 2.8

Challenge: Modelling solar and lunar eclipses

Aim

To model solar and lunar eclipses

What you need:

- One large Styrofoam ball (for the Earth)
- One small Styrofoam ball (for the Moon)
- Blue marker
- Aluminium foil
- 50 cm sturdy, bendable wire
- Torch or lamp with exposed light bulb

What to do:

1. Colour the large Styrofoam ball blue to represent the Earth.
2. Cover the small Styrofoam ball with aluminium foil, ensuring the shiny side is facing out, to represent the Moon.
3. Use the wire to attach the larger ball (Earth) to the smaller ball (Moon) as shown in Figure 1. Make sure the Moon's Equator and the Earth's Equator are at the same height.
4. Position a torch or light bulb in a fixed location to represent the Sun. Adjust the light so it shines directly on the equator of the Earth.
5. Swing the wire to arrange the Earth, Moon and Sun in a straight line.
6. Swing the wire until the Moon is positioned between the torch (Sun) and the Earth.
7. Record your observations and determine whether this arrangement represents a solar eclipse or a lunar eclipse.
8. Swing the wire to position the Earth between the Moon and the Sun.
9. Record your observations and identify if this is a solar eclipse or a lunar eclipse.

Questions

1. Draw labelled diagrams of solar and lunar eclipses.
2. Explain why solar and lunar eclipses can only be observed from certain parts of the world.

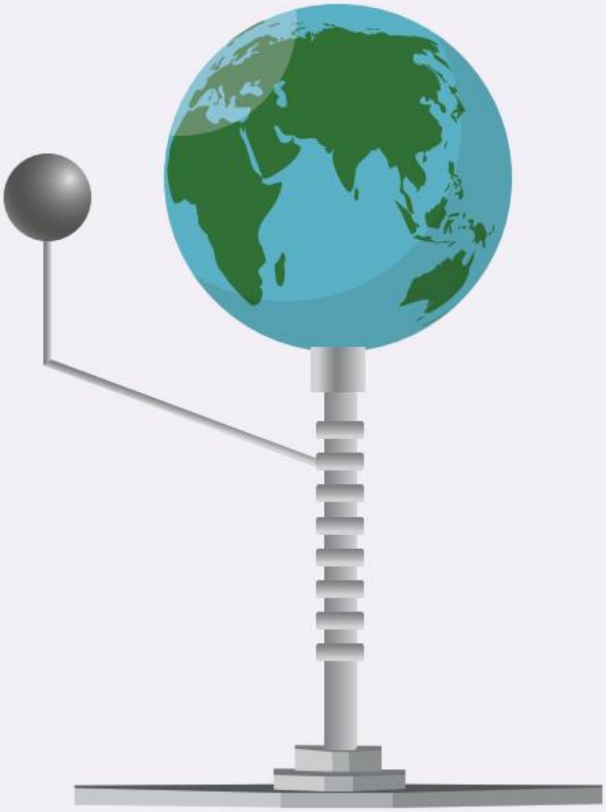


Figure 1 Make a model showing what causes a solar eclipse and a lunar eclipse.

Lesson 2.9

The Moon's gravity causes tidal movements

Key ideas

- → The Earth's pull force holds the Moon in orbit.
- → The relationship between the Moon and the tides was recognised by the earliest Aboriginal and Torres Strait Islander Peoples.
- → The pull force of gravity causes high and low tides.

Learning intentions and success criteria

Introduction

The relationship between the Moon and the tides was recognised by the earliest Aboriginal and Torres Strait Islander Peoples in Australia. The traditional stories of the Yolngu people of Arnhem Land describe water filling the Moon-man (Ngalindi) as he rises. When the Moon is full in the sky, the tidal waters are full. As the tide falls, the Moon is left empty for three days before filling again.

The Yolngu people recognised the connection of the Moon to the Earth and used this knowledge to explain the time of high tides and low tides. The Meriam people from the Eastern Torres Strait used their observations from the phases of the Moon to explain that the best time for fishing is during a quarter moon (when there are neap tides, which is when the difference between high and low tide is at its minimum). The Bardi people of the Western Australian Kimberley region used their knowledge to predict the best time for fishing and collecting the special trochus shells.

Figure 1 The Moon

What causes tidal movements?

The Earth and the Moon pull toward each other. The Earth's pull keeps the Moon in orbit. The Moon also pulls on the Earth. Since the Moon is about one-eightieth the mass of the Earth, its pull on the Earth has much less effect.

Despite the Moon having a lower mass than the Earth, the Moon's pull force still affects the Earth. The pull of the Moon causes the Earth's oceans to bulge toward the Moon. This causes the oceans to cover slightly more land, which we see on the Earth as a **high tide**. The Earth is also being pulled toward the Moon (and away from the water on the opposite side), so another high tide occurs on the opposite side of the Earth. As the Moon travels around the Earth and as both bodies travel around the Sun, the combined pull force from gravity causes the world's oceans to rise to high tides and fall to **low tides**. Because the Earth is rotating while this is happening, two high tides occur each day, approximately 11 hours apart.

high tide when the ocean covers slightly more land; the highest level that the tide reaches on the shore

low tide when the ocean covers slightly less land; the lowest level on the shore that the tide recedes to

High tides happen when the land is rotated toward the water being pulled in by the Moon or Sun. Low tides happen when the land rotates away from the water bulge.

When the Sun, Moon and Earth are aligned, the combined pull of the Moon and the Sun causes very high tides in some parts of the Earth. These are known as **spring tides**. Smaller **neap tides** occur during the Moon's quarter phases. At these times, the Sun and Moon are at right angles to the Earth, causing the sea tides to be pulled in both directions at once. Spring and neap tides are shown in Figure 2.

Worked example 2.9A shows how to calculate the difference in height between low and high tide.

spring tide when there is maximum difference between high and low tides; caused by the combined pull of the Moon and the Sun

neap tide when the difference between high and low tides is smallest; occurs during the Moon's quarter phase, when the Sun and the Moon pull in different directions

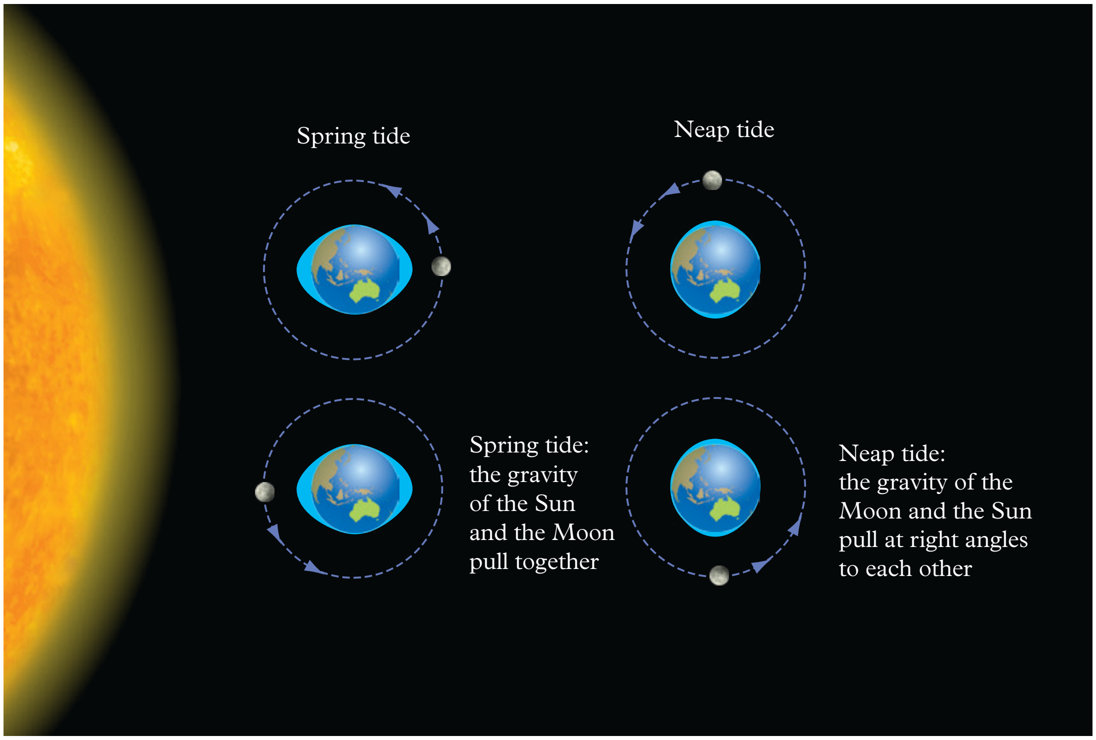


Figure 2 The Sun and the Moon's pull on the oceans create spring and neap tides. (The bulges shown here have been exaggerated so that they are easier to see.)

Worked example 2.9A Calculating tides

Table 1 shows the times of high and low tides at Surfers Paradise in the Gold Coast, Queensland, over three days in June 2022.

Calculate the difference in height between the two high tides on the Friday.

Table 1 High and low tides at Surfers Paradise, Gold Coast, in June 2022

Thursday 2 June 2022		Friday 3 June 2022		Saturday 4 June 2022	
Time	Height (m)	Time	Height (m)	Time	Height (m)
4:01 am	0.35	4:42 am	0.38	5:26 am	0.42
9:36 am	1.05	10:17 am	1.01	11:02 am	0.98
3:12 pm	0.33	3:49 pm	0.38	4:31 pm	0.44
9:58 pm	1.64	10:38 pm	1.59	11:21 pm	1.53

Solution

Table 2 Working out steps

Steps	What to do	Working out
a.	Collect the data needed from Table 1.	One high tide is 1.01 m at 10:17 am and the other high tide is 1.59 m at 10:38 pm.
b.	Subtract the smaller tide from the larger tide.	1.59 – 1.01 = 0.58 m
c.	Answer the question.	The difference between high tide and low tide on Friday is 0.58 m.

Check your learning 2.9

Check your learning 2.9

Comprehend

1 Explain why the Moon has a greater effect on the tide levels than the Sun.

Analyse

2 Referring to Table 1, identify the difference between:

- **a** the last high tide on Friday and the first one on Saturday
- **b** the first high tide and the following low tide on Saturday.

Apply

3 Use the data in Table 1 to predict the times and heights of the tides for Sunday.

4 For one week, graph the high and low tide levels of a beach in your state. Compare (the similarities and differences between) this and the times of the Moon rise and set. Discuss the relationship between the Moon's position and tide levels.

Lesson 2.10

Seasons are caused by the tilt of the Earth

Key ideas

→ The Sun travels different paths across the sky at different times of the year.

→ During summer, the days are longer and the Sun warms the ground and air.

→ During winter, the days are shorter and the ground and air are cooler.

→ The Equinox occurs when the length of day is equal to the length of night.

→ Aboriginal and Torres Strait Islander Peoples use seasonal calendars that describe the weather, plants and animals that are common in the area at that time of the year.

Learning intentions and success criteria

Introduction

solstice either of the times when the Sun is furthest from the Equator

The Wathaurong people marked the movement of the Sun with waist-high stones. The Wurdi Youang egg-shaped arrangement of 100 large boulders at Little River, Victoria, shown in Figure 1, is thought to have been set out by the Wathaurong people, the Traditional Owners of the area which is between Melbourne and Geelong. European settlers saw Wurdi Youang for the first time nearly 200 years ago. It is only recently that archaeologists have discovered that the 1 m high rocks, at the two ends of the egg shape, mark the points where the Sun sets during the middle of winter (the winter **solstice**) and the middle of summer (the summer solstice).

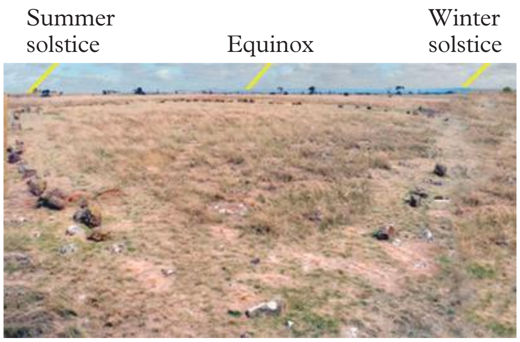


Figure 1 The Wathaurong people, who lived between Melbourne and Geelong, marked the movement of the Sun with waist-high stones.

Figure 2 Deciduous plants change with the seasons.

Summer

The Earth rotates as it orbits around the Sun. It spins around an imaginary line (the axis) going through its centre. The spin of the Earth makes days and nights. The axis of the spin, however, is tilted at an angle of 23.5 degrees. This means that, for part of the year, the southern hemisphere (including Australia) is tilted towards the Sun (Figure 3). The days are longer and the nights are shorter. The Sun is higher in the sky. This allows more time for the Sun's rays to hit the ground and therefore warm up the air. We experience summer. The Wathaurong people in Victoria knew this, and placed stones that marked where the Sun set during the longest day (21 December). This is called the summer solstice.

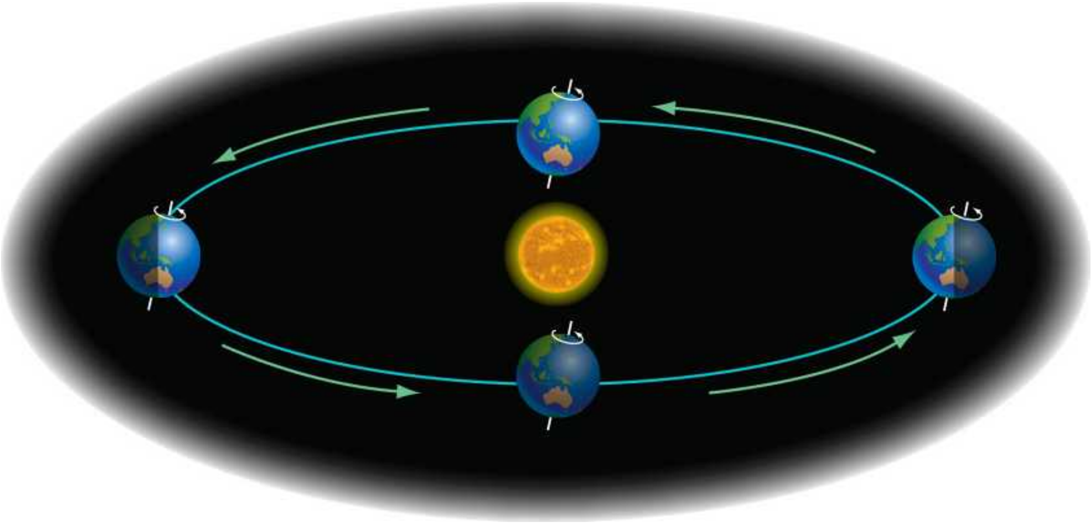


Figure 3 The Earth's rotation and orbit cause day and night, as well as the seasons. This image is not to scale.

Equinox

As the Earth continues its orbit of the Sun, after 21 December, the southern hemisphere starts slowly angling away from the Sun. Twice a year (in autumn around the 20 March and in spring around the 23 September), the position of the Earth allows an equal length of day and night. This is called the **Equinox**. The Wathaurong people marked the sunset of these events with the Equinox stone.

Equinox a day when day and night are the same length; occurs twice each year

Winter

In winter, the southern hemisphere is angled away from the Sun. The days are shorter and the nights are longer. This means the Sun shines lower in our skies. As a result, there is less time for the Sun to warm up the ground and therefore the air is cooler. We experience winter. The shortest day (21 June), the winter solstice, was also marked by the Wathaurong people.

The Wathaurong people found a way to mark the movement of the Sun, and hence the seasons, without using telescopes or undertaking long sailing trips around the world.

The northern hemisphere's seasons are the opposite of ours in Australia, so during a northern summer there is a southern winter.

The tilt of the Earth is more noticeable in the Antarctic. In the summer, the tilt of the Earth causes the Sun to remain in the sky for five months. The Sun does not set; instead, it sits just above the horizon for the whole time.

The reverse is true for winter in the Antarctic. The angle of the southern hemisphere away from Sun means the Sun sets in May and does not rise again until July.

Seasons for Aboriginal and Torres Strait Islander Peoples

Aboriginal and Torres Strait Islander Peoples have lived across the Australian landscape for more than 60,000 years. There are over 250 language groups of Aboriginal and Torres Strait Islander Peoples and most recognise the different seasons that are unique to their area. The Gulumoerrgin (Larrakia) peoples in and around the Darwin area have seven main seasons in their calendar year. These seasons are divided according to the weather and the plants and animals that are common at that time of the year. The rainy season (Balnba) from November to December is when the first rains occur. Gulppula (green tree frog) is said to bring the rain. It is also the time to collect shellfish and the black plum. The monsoon season (Dalay) from January to March is when the saltwater crocodiles are laying their eggs and the barramundi are breeding.

Dalay is the monsoon season (January to March) and it replenishes the dry land. The water gushes from creeks and rivers, covering the floodplains and moving the seeds for new plants to sprout. Mayilema season (March to April) overlaps the monsoon season and is when the speargrass flowers appear and the magpie goose eggs can be collected. Damibila season (April to June) is the time to fish barramundi and collect bush fruit, while the skies are clearing and the clouds are high. Dinidjanggama season (June to August) is when heavy dews are on the ground, and it is the coldest time of the year. During Gurrulwa season (July to September) there are often big winds that appear to come from all directions at once, while Dalirrgang season (September to October) is very hot and humid as the weather slowly builds up to the next rainy season, the Balnba season (November to December). This season brings the germination and fruiting of many plants.

Figure 4, Figure 5 and Figure 6 show the seasonal calendars unique to Larrakia Country in the Northern Territory, Yirrganydji Country in Far North Queensland and Gariwerd Country in Victoria.

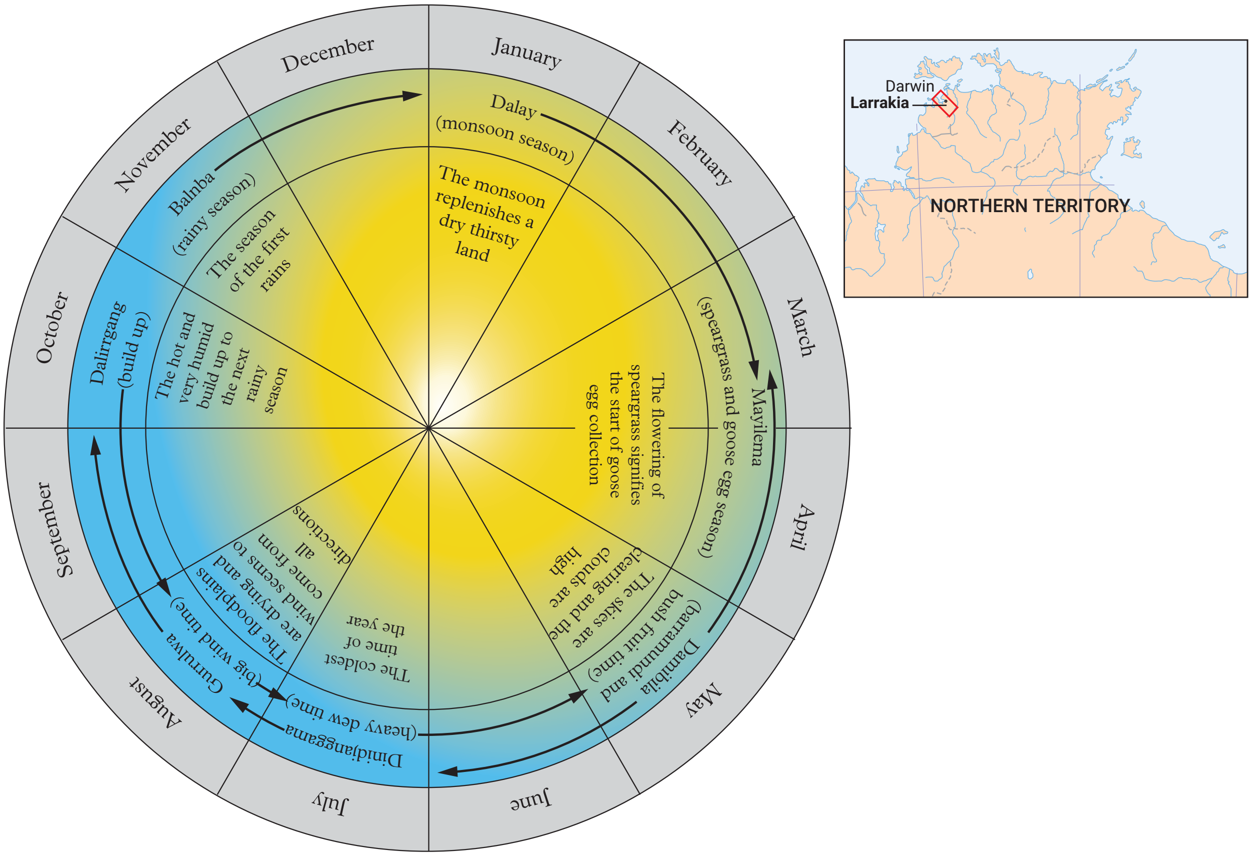


Figure 4 The calendar used by the Gulumoerrgin (Larrakia) people in Darwin.

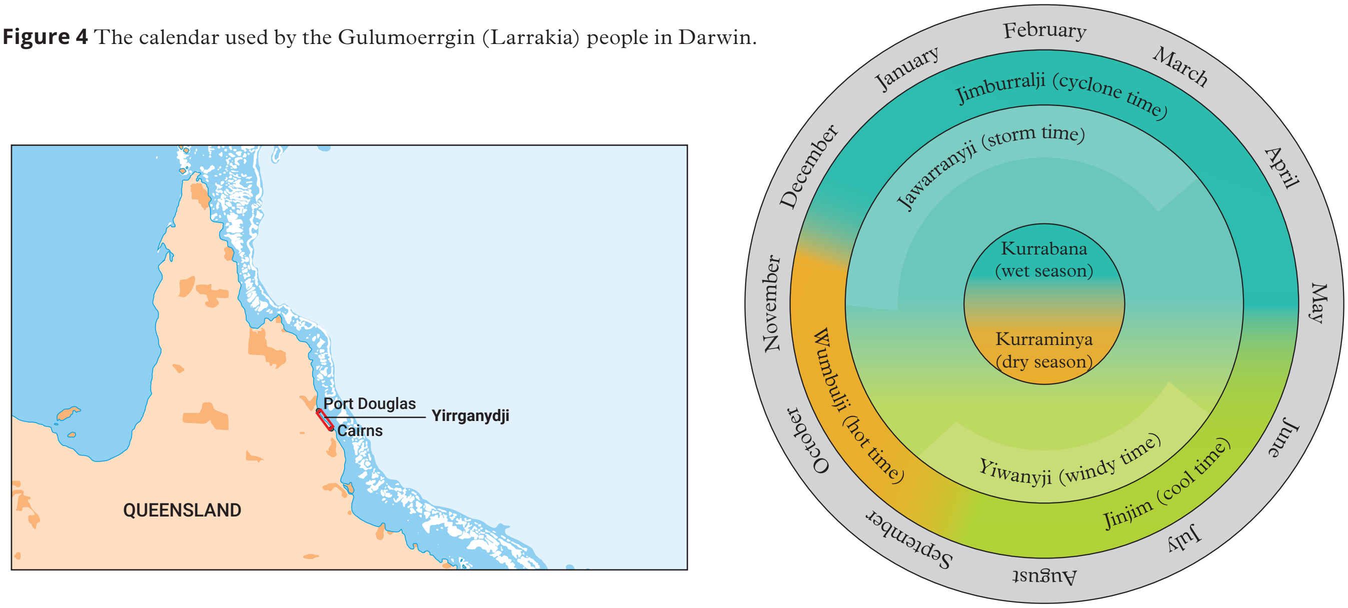


Figure 5 The calendar used by the Yirrganydji people along the coast of Far North Queensland.

The traditional lands and waters of the Yirrganydji people covers the Queensland coast from Cairns to Port Douglas. Their seasonal calendar shows two major seasons: Kurrabana (wet season) and Kurraminya (dry season). The Kurrabana wet season is divided into a time of storms (Jawarranyji) and a time of cyclones (Jimburralji). The dry season is divided into the cool time (Jinjim), the windy time (Yiwanyji) and the hot time (Wumbulji).

Each of the Aboriginal and Torres Strait Islander communities used observations of the local environment to create a unique calendar. This differs from the European approach that recognises the same four seasons in all parts of the world, from the Antarctic to the tropics, despite the very different climate and conditions.

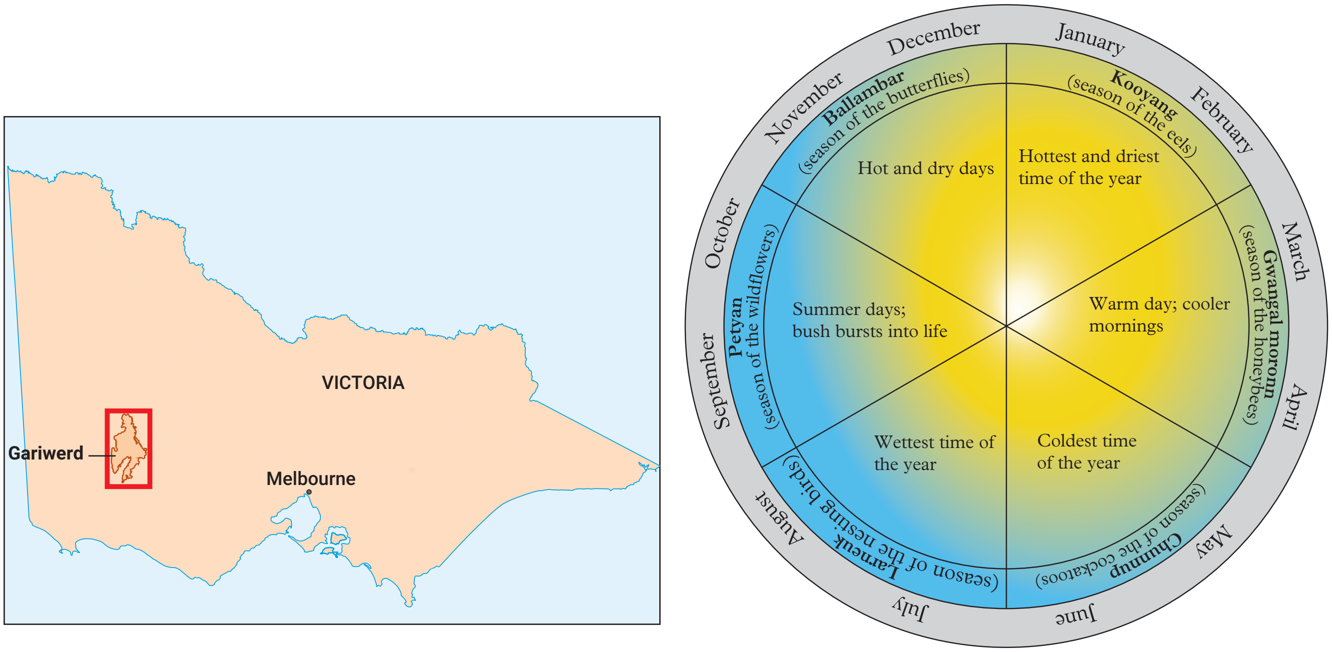


Figure 6 The calendar used by the Gariwerd people in the Grampians region in Victoria.

Check your learning 2.10

Check your learning 2.10

Retrieve

1 Identify the four seasons experienced in Australia, marked with the letters a, b, c and d on Figure 7.

2 Recall the angle of the Earth's rotational tilt away from the Sun.

Comprehend

3 Categorise the seasons in a table. Draw a table with three columns. In the first column, write the months of the year. In the second column, write the names of the four European seasons next to the appropriate months. In the third column, write the names of the seven Gulumoerrgin (Larrakia) seasons.

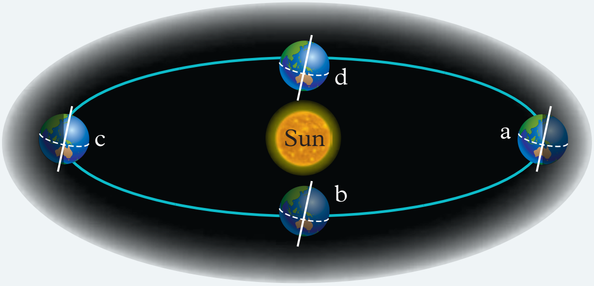


Figure 7 The four seasons in Australia.

Analyse

4 Compare (the similarities and differences between) the winter solstice and the summer solstice.

5 Use the motion of the Earth around the Sun to analyse why January is hotter than July in Australia.

6 Compare (the similarities and differences between) the Gulumoerrgin (Larrakia), Yirrganydji and Gariwerd calendars.

Apply

7 Create a paragraph for Year Five students that discusses how the Wathaurong people gathered and recorded data over many years before placing stones to represent the solstice and Equinox.

Skills builder: Processing and analysing information

8 A student has been asked to find some reliable information online that describes what causes the seasons on Earth to change.

  a Conduct your own research online to identify one website that you would recommend to the student. (THINK: What kind of website would help them?)

  b Explain why you think this site is a reliable source of information. (THINK: Who wrote the information? When did they write it? Why did they write it?)

Lesson 2.11

Increasing our knowledge of the Universe

Learning intentions and success criteria

Key ideas

→ Analysing the light coming from distant objects, like stars, helps us to increase our knowledge about them.

→ Optical telescopes collect light from distant objects and then focus this light using lenses or mirrors.

Introduction

It can take many years of travel for a rocket to land on another planet. Scientists therefore need to rely on other methods to learn about space.

Astronomy

Astronomy is one of the oldest sciences, and astronomy and astrology used to be intertwined. Ancient astronomers believed that stars were permanently fixed to a heavenly sphere and never changed. They tracked the movement of the planets against these heavenly lights, which they grouped into constellations, and used these observations to calculate time and develop calendars. From this, they determined the seasons and calculated the best times to plant their crops. They observed solar and lunar eclipses, and used the positions of the stars and planets to navigate the oceans.

It is impossible to send a space probe to galaxies, stars or even gas clouds that are millions of **light years** from Earth, and yet we know so much about these bodies. To view stars and galaxies, we use instruments such as telescopes and **spectroscopes**.

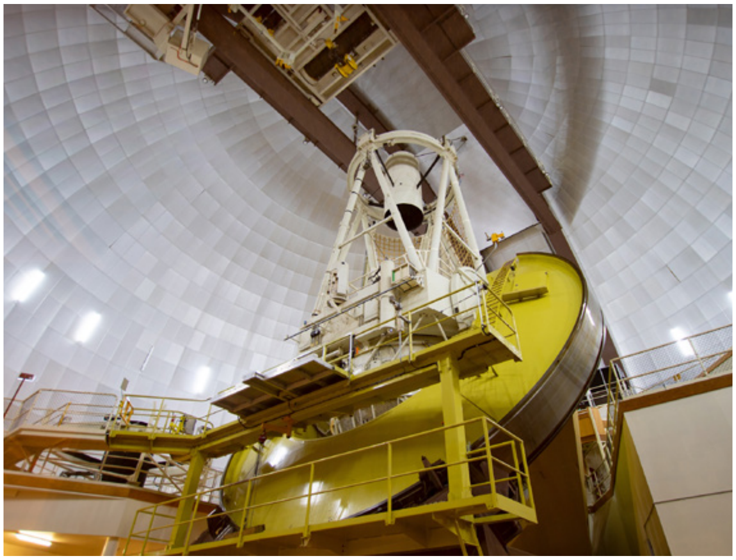


Figure 1 The Anglo-Australian Telescope (AAT) is one of the world's leading optical telescopes.

Telescopes

A lot of information can be gathered about our Sun and distant stars by analysing the light coming from them. Analysing this light reveals information about distant galaxies and stars that would otherwise be impossible to get. Telescopes have been used since the seventeenth century to view distant objects. The most common type of telescope used in astronomy is the optical telescope. This works by collecting more light than the human eye can collect and then focusing this light using lenses or mirrors. A distant object viewed through an optical telescope becomes brighter and magnified. The Anglo-Australian Telescope (AAT) at Siding Spring Observatory, Coonabarabran, NSW, is one of world's leading optical telescopes (Figure 1). It plays an important role in the study of the Universe and the search for planets around stars.

light year the distance light travels in one year. It is 9.46 trillion kilometres per year

spectroscope an instrument that separates light into its different colours

atmosphere the envelope of gases surrounding the Earth or another planet

The Hubble Space Telescope

Our **atmosphere** distorts and blocks the light coming from planets and stars. In 1990, NASA launched the Hubble Space Telescope, which orbits the Earth at 569 kilometres above our atmosphere. This has given scientists a view of our Universe far beyond that of any ground-based telescope because different forms of electromagnetic radiation, such as gamma rays, X-rays and ultraviolet radiation, are available for observation.

From the images beamed back to Earth from the Hubble Space Telescope, astronomers have been able to make an enormous number of new observations.

The Hubble Space Telescope is available for observations by people throughout the international astronomical community, and information and observations are available worldwide. Astronomers have been able to see galaxies developing and have estimated the age of the Universe more accurately at around 13 to 14 billion years.

Figure 2 Image of a galaxy by the Hubble Space Telescope

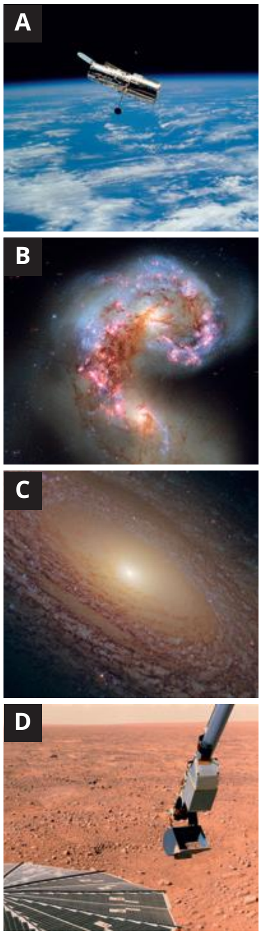


Figure 3 (A) The Hubble Space Telescope is in orbit around the Earth. (B) The Antennae Galaxies are about 45 million light years away from the Milky Way. (C) Dark matter cannot be photographed, but it is represented in blue in this Hubble Space Telescope image of a galaxy cluster. This can be used to help understand the nature of dark energy. (D) The *Phoenix* Mars Lander delivers a soil sample to a microscope.

James Webb Space Telescope

NASA launched the James Webb Space Telescope (JWST) on 25 December 2021 (Figure 4). Unlike the Hubble Space Telescope, which orbits the Earth, the JWST orbits the Sun at a distance of 1.5 million kilometres from Earth. This telescope is the result of an international collaboration between NASA, the European Space Agency (ESA) and the Canadian Space Agency (CSA).

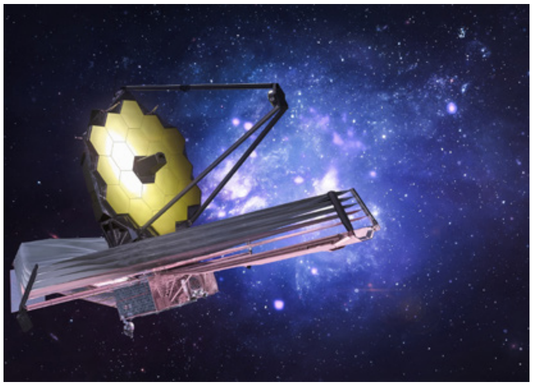


Figure 4 The James Webb Space Telescope is in orbit around the Sun.

The JWST is similar to other telescopes, but it has some special features. It is very large and can see infrared light, helping scientists study the formation of stars and planets and see galaxies that formed at the beginning of the Universe (Figure 5). Scientists hope to make exciting discoveries with the JWST, such as finding new exoplanets (which are planets that orbit a star outside our solar system) or learning more about the early Universe.

Mars mission

Mars is a potential candidate for past life in our solar system. NASA's Mars Exploration Program (MEP) employs robots to study and understand the "Red Planet". NASA is already planning a crewed mission to Mars. But could humans live on Mars? The Mars exploration rovers, *Spirit* and *Opportunity*, were launched in 2003 and landed on Mars in 2004 to find out more about the planet. In 2008, the *Phoenix* Mars Lander touched down on an ice sheet on the Martian surface. Operated from the Earth, its instruments took photographs of ice that was melting away. The lander's robotic arm, shown in Figure 3D, scooped up soil samples. Analysis by the lander's instruments revealed traces of magnesium, sodium, potassium and, importantly, water. NASA scientists consider this discovery a huge step forward.

Figure 5 Image of an exploded star from NASA's James Webb Space Telescope

Currently, there are two operational rovers on Mars: *Curiosity,* launched in 2011, and *Perseverance,* launched in 2021. These rovers are helping scientists learn more about Mars and its potential to support life.

Space probes

Humans are also able to gather new information about space by using space probes. Typically, space probes are

Figure 6 An artist's impression of the *New Horizons* space probe during its Pluto flyby.

remotely controlled and can be launched into space to measure properties of the Earth, the solar system or the Universe around us. The space probe *New Horizons* was launched by NASA in 2006. After a gravity boost from Jupiter in 2007, its six-month flyby of Pluto in 2015 produced an enormous amount of data on Pluto's surface properties, geology and atmosphere that was still being analysed one year later.

Check your learning 2.11

Check your learning 2.11

Comprehend

1 Explain how a telescope helps us view distant objects.

2 Describe the type of information we are looking for when we launch probes into space.

3 Describe one discovery about our solar system that was due to advances in technology.

4 Summarise how our exploration of Mars has been helped by advances in technology.

Apply

5 Imagine that you are an astronomer with NASA. Justify the importance of maintaining the Hubble Space Telescope instead of relying on traditional telescopes on the Earth's surface.

Skills builder: Communication

6 Imagine that you have been asked to explain one of the technologies in this Lesson to a class of eight-year-olds. Write a one-minute speech that you would give to them. (THINK: Who is your audience? What kind of language should you use to address your audience? What kind of science understanding would they have?)

Lesson 2.12

Review: Observing the Universe

Summary

Lesson 2.1 Science is the study of the natural and physical world

- Science measures what we observe (see, hear, smell, taste and feel) and organises it into testable explanations.
- Scientists have jobs that focus on asking questions and finding answers.
- Some scientists work in a laboratory; all scientists work in teams.
- Scientists answer questions by observing, recording and interpreting what they find.

Lesson 2.2 Scientists use observation and inference to answer questions

- Key concepts in scientific inquiry focus on how data is gathered and interpreted.
- Observation involves using your senses to collect information.
- It is important to understand inference and make conclusions or explanations based on observations.
- Scientists draw conclusions based on observations and inferences.
- We can understand how data is collected and analysed in experiments.

Lesson 2.4 Our understanding of the solar system is continuously growing

- Aboriginal and Torres Strait Islander Peoples were the first astronomers.
- An early understanding of astronomy was that the Earth was the centre of the Universe.
- Polish astronomer Nicolaus Copernicus realised that the Sun was the centre of the solar system.

Lesson 2.5 The Earth, Sun and Moon interact with one another

- The solar system is the collection of planets, their moons and smaller bodies (dwarf planets, asteroids, meteors and comets) that orbit the Sun.
- The Moon orbits the Earth every 27.3 days.
- The Earth orbits the Sun every 365.25 days.

Lesson 2.6 The Moon reflects the Sun's light

- The Moon rotates as it orbits the Earth.
- The same face of the Moon always faces towards the Earth.
- The phases of the Moon are caused by the light from the Sun shining on different parts of the Moon.

Lesson 2.9 The Moon's gravity causes tidal movements

- The Earth's pull force holds the Moon in orbit.
- The relationship between the Moon and the tides was recognised by the earliest Aboriginal and Torres Strait Islander Peoples.
- The pull force of gravity causes high and low tides.

Lesson 2.10 Seasons are caused by the tilt of the Earth

- The Sun travels different paths across the sky at different times of the year.
- During summer, the days are longer and the Sun warms the ground and air.
- During winter, the days are shorter and the ground and air are cooler.
- The Equinox occurs when the length of day is equal to the length of night.
- Aboriginal and Torres Strait Islander Peoples use seasonal calendars that describe the weather, plants and animals that are common in the area at that time of the year.

Lesson 2.11 Increasing our knowledge of the Universe

- Analysing the light coming from distant objects, like stars, helps us to increase our knowledge about them.
- Optical telescopes collect light from distant objects and then focus this light using lenses or mirrors.

Review questions 2.12

Review questions Module 2

Retrieve

1 Identify which of the following best describes the Equinox.
  - **A** The longest day of the year
  - **B** A day and night of equal length
  - **C** A lunar eclipse that occurs every year
  - **D** The shortest day of the year

2 Recall that a total solar eclipse occurs when:
  - **A** the Moon blocks out the maximum amount of light from the Sun.
  - **B** the Earth blocks out the light on the Moon from the Sun.
  - **C** the Sun blocks out the view of the Earth from the Moon.
  - **D** a comet blocks out light from the Sun.

3 Identify which of the following statements is true.
  - **A** The Earth orbits the Sun.
  - **B** The planets orbit the Moon.
  - **C** The Sun orbits the planets.
  - **D** The Earth orbits the Moon.

4 State the name for one revolution of the Earth around the Sun.

5 Identify the season in Norway when it is summer in Australia.

6 Recall the name of the event that occurs when the Moon totally blocks the light from the Sun.

Comprehend

7 Explain what causes day and night.

8 Describe how the Sun affects day and night and seasons at the Antarctic.

9 Describe the seven seasons identified by the Gulumoerrgin (Larrakia) people.

10 Describe the phases of the Moon.

11 Explain why 29 February only occurs every four years.

12 A student claims that the Moon is a miniature Sun that shines at night. Explain why they are incorrect.

13 Explain the purpose of the Hubble and James Webb Space Telescopes.

Analyse

14 Compare a solar eclipse and a lunar eclipse.

15 Compare astronomy and astrology.

16 Figure 1 shows how the seasons occur. Answer "A" or "B" to each question.
  - **a** Identify the drawing that represents summer.
  - **b** If the piece of card was the Earth, identify which drawing would represent winter.
  - **c** If the piece of card was the Earth, identify which drawing would represent the warmest day.

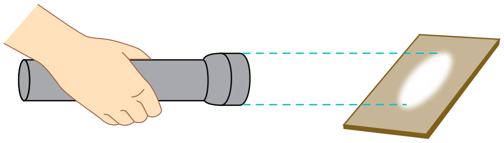


Figure 1 How the seasons occur

17 Figure 2 shows the average number of sunlight hours across Australia in January and June. Evaluate the two maps and use the data to explain why Australian summers have higher temperatures than Australian winters.

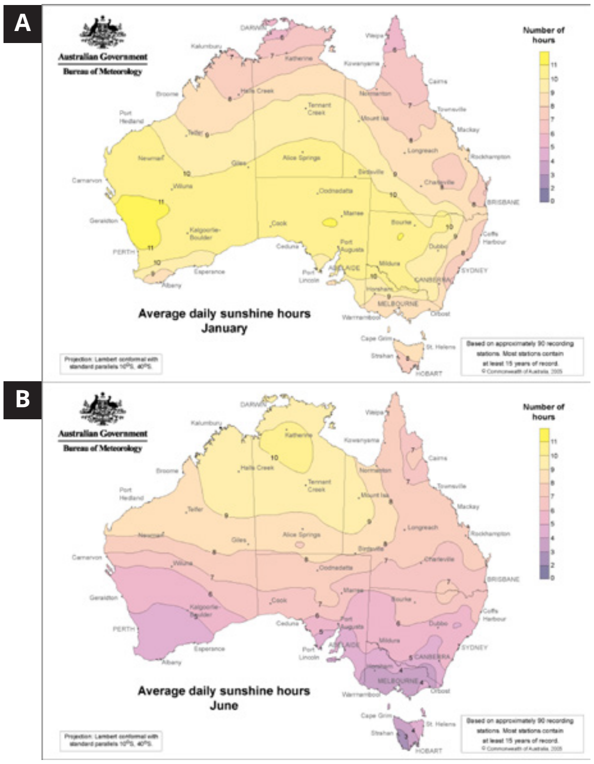
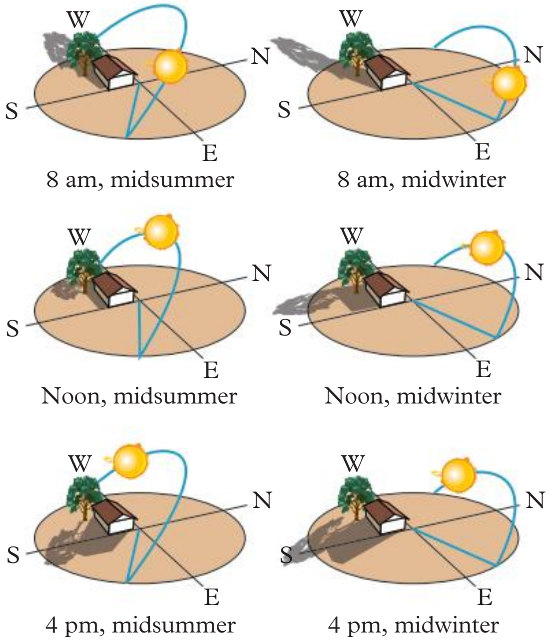


Figure 2 The average amount of sunlight in January (A) and June (B)

18 Study Figure 3 and answer the following questions.

- **a** Identify the season that has the longest shadows.
- **b** Identify the season that gives the least opportunity for solar heating.
- **c** Identify the season where the Sun travels furthest across the sky.
- **d** Identify which side of the house is best to grow plants that like sunlight.
- **e** If a plant is growing on the eastern side of a house, describe the amount of sunlight it receives in the morning.



8 am, midsummer

8 am, midwinter

Noon, midsummer

Noon, midwinter

4 pm, midsummer

4 pm, midwinter

Figure 3 The path of the Sun across the sky in winter and summer

Apply

19 Look at Figure 4, which shows a total eclipse of the Sun as it would be seen in the middle of the day from Earth. Draw and label a diagram to illustrate a:

- **a** solar eclipse
- **b** lunar eclipse.

Figure 4 Total eclipse of the Sun

20 The Persian calendar celebrates the New Year at the moment the Sun crosses the celestial Equator on approximately 21 March each year. In 2014, it was celebrated at 4 am on the east coast of Australia. In 2015, it was celebrated at 10 am. Discuss why the exact time of the New Year changes from one year to the next.

21 Visit NASA's website for the 2020 *Perseverance* rover mission. Navigate to the gallery of "Raw images" showing recent pictures taken by the rover. Select one image and make five scientific observations about what you can see in the image. Discuss what you know about Mars from looking at this image.

Weblink: NASA, Mars 2020: Perseverance Rover

Social and ethical thinking

22 Some nations are planning to develop human settlements on the Moon. Discuss an argument for and against this decision. Decide if you do or do not support this plan. Justify your decision (by comparing the arguments for and against this decision and describing why one argument is more important).

23 Many early European settlers claimed that Aboriginal and Torres Strait Islander Peoples did not use any of the sciences. Describe evidence that refutes this claim.

24 Scientists are continuously exploring space, including Mars. Discuss the ethical implications of finding life on one of these planets.

Critical and creative thinking

25 Find data for the sunrise and sunset times over seven days in summer and winter. From this information, calculate the length of the day and the length of the night. Present your findings in a table. Discuss what you notice about the lengths of the days and nights for each season. Explain why this difference occurs.

26 In May 2021, there was a lunar eclipse visible in Australia. The Moon was referred to as a "supermoon". Investigate what the criteria for a supermoon are and explain why a lunar eclipse may be a supermoon.

Research

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

Search for extraterrestrial intelligence

Astronomers are involved in a Search for Extraterrestrial Intelligence (SETI).

- Find out what instruments the astronomers are using in this search.
- Describe how these instruments will help them to find extraterrestrial intelligence.
- Describe what they may expect to find.

You, too, can use your computer to become a part of this search.

Figure 5 The Search for Extraterrestrial Intelligence (SETI) Institute is America's only organisation entirely dedicated to searching for life in the universe.

Science communication

Investigate what it means to be a science communicator.

- Research the work of Wiradjuri astrophysicist and science communicator Dr Kirsten Banks.
- Describe how Dr Banks combines Aboriginal and Torres Strait Islander astronomy knowledge with her current work.

Figure 6 Dr Kirsten Banks is a Wiradjuri astrophysicist.

Mission to the Moon

The huge *Saturn* rocket that took *Apollo 11* to the Moon was an extremely powerful system in its day. The rocket had three "stages"; each carried its own fuel and dropped off as the rocket went higher into the sky. The rocket carried the "lunar lander", which was itself a very complicated piece of technology.

Build a model of the *Saturn* rocket and explain the role of each stage and how it performed.

Figure 7 The launch of the *Saturn* rocket

The far side of the Moon

The Moon rotates at the same rate as the Earth, so we never see the far side of the Moon from Earth. So what is it like? Is it the same as the near side of the Moon? Some astronauts have flown over the surface of the far side, but only one has landed a ship.

- Identify how many people have seen the far side of the Moon.
- Identify which country landed a probe on the far side of the Moon and brought back material from the Moon's surface.
- Compare the far side of the Moon to the side that faces Earth.
- Describe the complexities of living on the surface of the Moon.

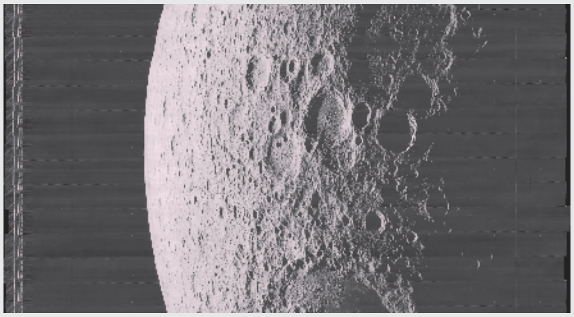


Figure 8 A section of the far side of the Moon

Module
3
Forces

Overview

To understand how objects start moving, stop or change direction, we need to look at the forces pushing and pulling on them. There are many different forces acting on an object. Sometimes these forces are pushing or pulling in the same direction; other times they are pushing or pulling in different directions. Large objects like the Sun or the Earth have a strong gravitational pull. This can affect things on the Earth or in space. Diagrams can help show the direction and size of a force. Understanding forces enables us to use simple machines to make tasks easier.

Lessons in this module

Lesson 3.1

A force is a push, a pull or a twist

Learning intentions and success criteria

Key ideas

→ A force is a push or pull that happens when two objects interact.

→ The effect of a force can be measured, and it can be represented in a force diagram.

→ The force of gravity affects the movement of objects on Earth.

Forces in action

force of gravity the force that pulls everything with a mass towards the centre of Earth

Forces act on everything around us all the time. Usually, more than one force is acting on an object at one time, but often we do not notice them. You have many forces acting on you at the moment! The **force of gravity** is pulling you towards the centre of Earth. The chair you are sitting on is pushing back against you, changing the shape of your leg muscles. Because the forces acting on you are in balance (the same strength and opposite directions), you do not move. You sit still on the chair.

When you kick or throw a ball, you use energy to generate a "push force". This force causes the ball to move (Figure 1). When you catch a ball, you still give it a push. This time, the push force causes the ball to stop moving.

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

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

Examples of these forces are shown in Figure 2–8.

Figure 1 The force of Ronaldo kicking the ball is easy to identify and describe, but what is pulling him towards the centre of Earth?

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

Figure 3 When skateboarders want to **move faster**, they use their feet to exert a force on the ground.

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

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

Force and energy

Energy is the ability to do work or cause change. There are different forms of energy. For example, **kinetic energy** is the energy of motion, and **potential energy** is stored energy. The unit used to measure energy is called the **joule (J)**, named after English physicist James Prescott Joule (1818–1889). Work is done when a force acts on an object and causes it to move in the direction of force. The energy is transferred to the object. For example, when you push a box and the box moves in the direction of your force, you do work, and your energy is transferred to the box (Figure 9). The work done is equal to the amount of energy transferred. If you exerted more force, you would do more work.

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

Figure 7 The hand **turns** the door knob to open the door.

Figure 8 The force of gravity pulling down on the pot plant and the weight of air above it are **in balance** with the force of the ground pushing up on the pot.

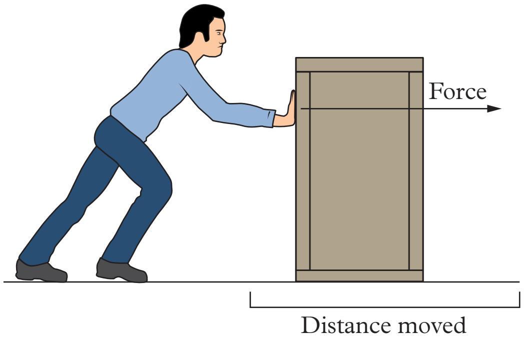


Figure 9 Work is done on the box by the person as the box moves in the direction of the force applied.

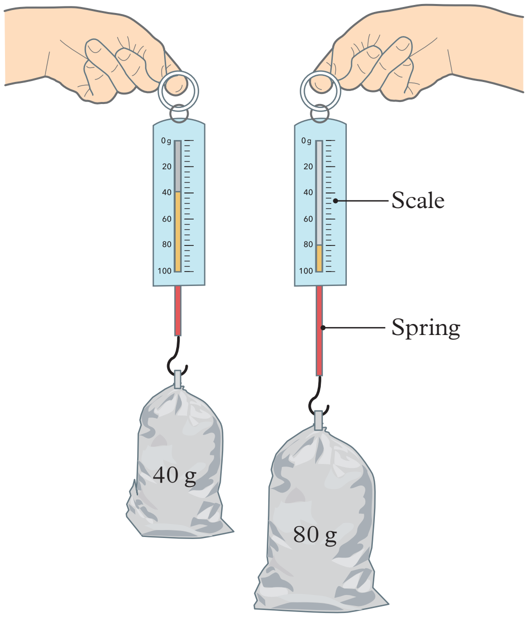


Figure 10 Spring balances are used to measure force.

Measuring forces

One way to "see" a force at work is to measure it. In the kitchen, cooks use scales to measure how much Earth's gravity pulls on the ingredients. 20 grams of flour is pulled to the centre of Earth, causing the flour to push down on the scales. In the laboratory, force is measured using a **spring balance** (Figure 10). A stiff spring in the balance stretches when an object pulls on it. This moves the marker so that the amount of force can be measured. A rubber band can measure the size of forces in a similar way to a spring balance.

Before we can use a rubber band to measure a force, it must be **calibrated**. This means matching the stretch of the rubber band to the force pulling on it. We will explore this more in Lesson 3.2 Investigation: Measuring forces (page 117). The unit used to measure forces is called the **newton** after English physicist Sir Isaac Newton (1642–1727), who first described the force used to pull an apple from a tree. Spring balances measure force in newtons. Scientists around the world have agreed to this standard measurement so that they can communicate with one another. In every country, the force of 100 g being pulled to the centre of Earth is about 1 newton (N). This is roughly the same as one large chocolate bar sitting on your hand.

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

calibrate check the accuracy of a metre or measuring device against known measurements

newton the unit used to measure force; symbol N

Drawing force diagrams

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

- The length of the arrow shows the size of the force – a short arrow represents a weak force and a long arrow represents a strong force.
- The direction of the arrow shows the direction of the force.

When drawing a scientific diagram showing the forces acting on a book on a table, there are several steps to follow (Figure 11).

1. Represent the object with a small box.
2. Draw a dot in the centre of the box.
3. Use a pencil and ruler to draw the force arrows.
4. Draw the arrows coming from the dot.
5. Label each of the arrows with the name and size of the force (measured in newtons – N).

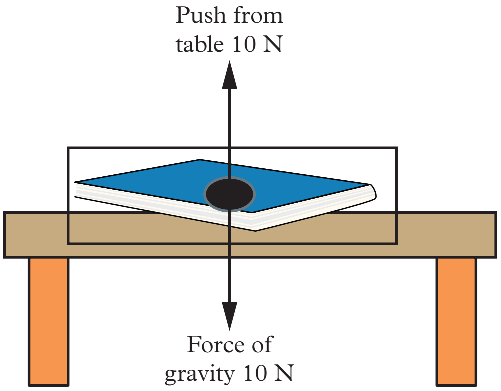


Figure 11 The forces acting on a book on a table can be shown using two arrows. One arrow shows the force of gravity pulling the book towards the table, while the other shows the table pushing up on the book.

Check your learning 3.1

Check your learning 3.1

Retrieve

1 Define the term "force".
2 Recall seven things that forces can do.
3 Name the unit used when measuring a force.
4 Name the person whom the unit of force is named after.

Comprehend

5 Create a force diagram of a bike weighing 500 N resting on the ground. Include the ground pushing up on the bike.
6 Use an example to describe how you can see the effects of a force but not see the force.
7 Many measuring instruments must be calibrated. Use an example to explain why calibration of equipment is important. (HINT: Describe the consequences of not calibrating the equipment and how this would affect the results of an experiment.)

Analyse

8 Classify these forces from biggest to smallest.
  a A truck hitting a pole
  b A rocket being launched
  c Typing one letter on a computer keyboard
  d Kicking a soccer ball
  e Pushing a car along the street

Lesson 3.2

Investigation: Measuring forces

Purpose

To measure a variety of forces in common situations

Part A: Measuring contact forces

Materials

- Rubber band
- Thin strip of timber (or a ruler)
- Mass carrier and masses
- Pen

Procedure

A rubber band can measure the size of forces in a similar way to a spring balance, but it must be calibrated. This means matching the stretch of the rubber band to the number of newtons pulling on it.

1 Calibrate the rubber band on the strip of timber, as shown in Figure 1.

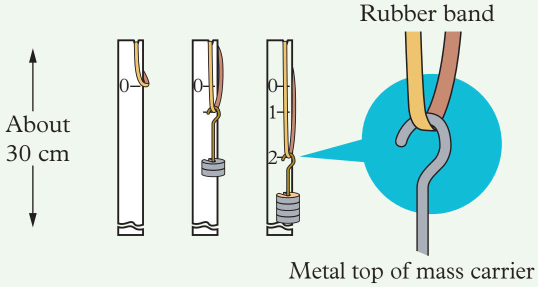


Figure 1 Calibrating the force measurer

2 Mark the distance that the rubber band is stretched on the timber when the mass carrier holds a 100 g mass. Remember: The

weight force of 100 g equals 1 N of force.

3 Repeat for masses of 200 g, 300 g, 400 g and so on, marking the timber each time.

4 Use your measuring device to measure the force needed to:

  - **a** open the door to the room (Figure 2)
  - **b** drag a chair across the floor
  - **c** close a drawer in the laboratory (Figure 3)
  - **d** move your pencil case
  - **e** pull up your sock
  - **f** do three other movements of your choice.

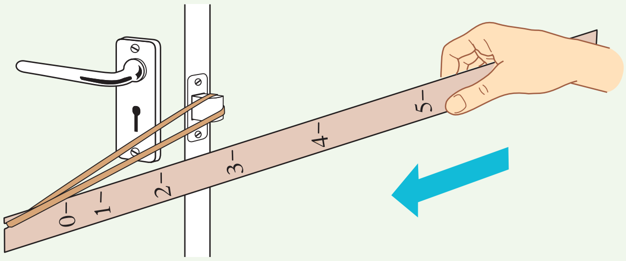


Figure 2 Measuring the force needed to open a door

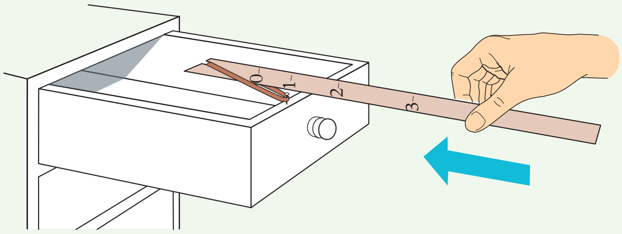


Figure 3 Measuring the force needed to close a drawer

Results

Draw a column graph showing the amount of force needed to move each object.

Discussion

1 Describe the relationship between grams and newtons.

2 Identify if the force metre you constructed measures a pull or push force.

3 Describe how you could increase the amount of force needed to shift your pencil case.

Part B: Measuring electrostatic forces

Materials

- Perspex rod
- Silk fabric
- Paper
- Ruler

Procedure

1 Tear a piece of paper into small pieces.

2 Spread the pieces of paper out on the bench.

3 Rub a Perspex rod 30 times on the silk fabric.

4 Hold the Perspex rod approximately 5 cm away from the pieces of paper.

5 Count the number of paper pieces attracted to the rod.

6 Record your results in a table.

7 Repeat Steps 4 to 6 after rubbing the Perspex rod 60 times and then 90 times on the silk fabric.

Results

Copy and complete Table 1.

Table 1 Effect of number of rubs on paper attraction

Number of rubs with Perspex rod on silk fabric	Number of paper pieces attracted
30	
60	
90	

Discussion

Describe the relationship between the amount of charge on the rod and the force of attraction between the rod and the papers.

Lesson 3.3

An unbalanced force causes change

Key ideas

→ Forces on an object are balanced when they are pushing or pulling equally in opposite directions.

→ If the forces on an object are unbalanced, then the object will change its speed, direction or shape.

Learning intentions and success criteria

Balanced forces

Understanding how forces work together is important to understanding how and why things move. **Balanced forces** are a way of describing the forces acting on an object, even when there is no change in movement or shape. Pushing on a brick wall does not usually cause the brick wall to move. This does not mean your push force did not exist. Your push force was balanced by the wall pushing against your hands. Forces are balanced when both forces are equal in size and acting in opposite directions. Another example of this is the push force of the weightlifter in Figure 1, balancing with the pull force of gravity of the barbell. If these forces are equal and in opposite directions, there will be no movement.

balanced forces two forces equal in size and opposite in direction

net force the vector sum of all the forces acting on an object; also known as resultant force

Forces can be added together

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

In Figure 1 the direction of a force arrow shows the direction of the force. The weight of the barbell is 1,000 N. Each of the weightlifter's hands is pushing up with a force of 500 N. These two push forces can be added together (500 N + 500 N = 1,000 N). This means the net force acting on the barbell is zero. The forces are balanced and the barbell does not move.

If an object is stationary (not moving) or moving at a constant speed in the same direction, then the net force acting on that object is zero. All the forces

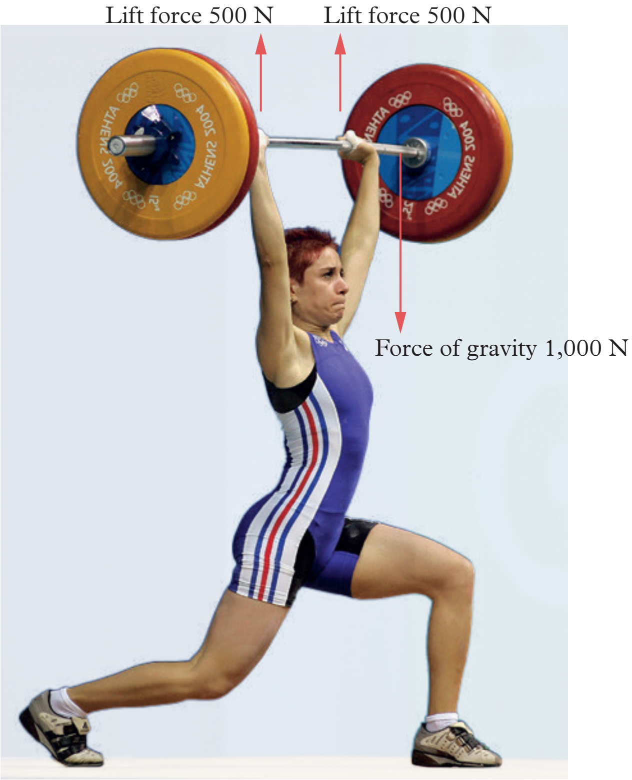


Figure 1 A weightlifter applies a push force (500 N + 500 N) to lift the barbell (1,000 N).

are balanced. If an object changes its speed (by speeding up or slowing down), shape or direction, then a net unbalanced force must be acting on it.

Figure 2 A soccer ball will change direction when kicked due to the unbalanced force.

Unbalanced forces

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

Unbalanced forces are also very important. The barbell in Figure 1 stays up in the air at a particular height because the forces acting on it are in balance. The weightlifter is pushing the barbell up with exactly the same amount of force as Earth is pulling down due to the force of gravity. To move the barbell up, the weightlifter must use a force stronger than Earth's pull. This will make the forces on the barbell unbalanced.

Evidence of an unbalanced force

There are three ways you can tell if a force is unbalanced. Forces are unbalanced if there is a change in the speed, direction or shape of an object. If a ball is resting on the ground, then all the forces acting on it are balanced. If two people are pushing equally in opposite directions on a stationary object, then the forces are balanced and the object does not move. If one person starts pushing harder, then the object will start to move. There is a change in motion because the forces are unbalanced.

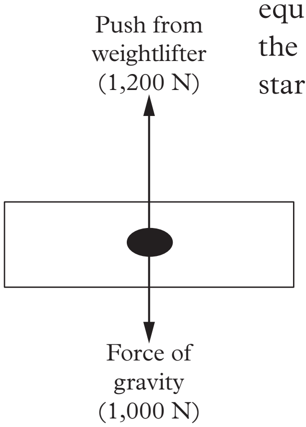


Figure 3 The forces acting on a barbell are combined to show that it is being lifted by a weightlifter.

Representing unbalanced forces

A force diagram can also be used to represent unbalanced forces. A short arrow is used to show a weak force and a long arrow can show a strong force.

Figure 3 uses a force diagram to show the unbalanced forces of a weightlifter pushing a barbell upwards. The push force the weightlifter is using is 1,200 N, and the pull force of gravity is 1,000 N. This means the overall net force is 200 N upwards. The barbell will move upwards.

Worked example 3.3A shows an example of how to calculate net force.

Worked example 3.3A Calculating the net force

Khan and Kim were moving a table tennis table for their parents. Khan pushed the table with a force of 200 N, while Kim pushed with a force of 150 N.

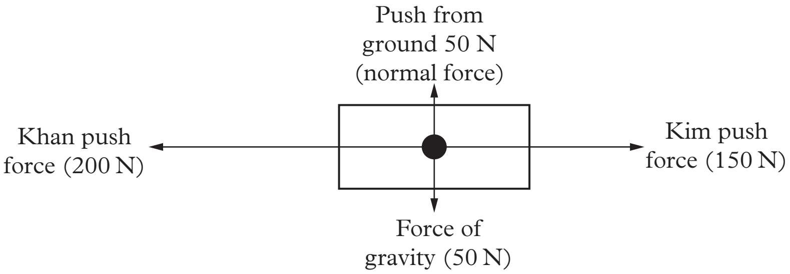
Calculate the net force if both Khan and Kim pushed in the same direction (left).

a Draw a force diagram to represent the forces exerted on the table if Khan and Kim were pushing in opposite directions.

b Calculate the net force if Khan and Kim pushed in opposite directions, where Khan pushed to the left and Kim pushed to the right.

c Describe the direction that the table would move if Khan pushed to the left and Kim pushed to the right.

Solution

Steps	What to do	Working out
a.	Consider the direction of the forces. If both forces are in the same direction (left), they will add together. Note: Always mention the direction of the net force.	Net force = 200 N + 150 N = 350 N The net force is 350 N to the left.
b.	Draw the force diagram, remember that short arrows are used for weaker forces and longer arrows are used for stronger forces.	
c.	Consider the direction of the forces. If both forces are in opposite directions, then they will be subtracted from one another.	Net force = 200 N (left) – 150 N (right) = 50 N (left) The net force is 50 N to the left.
d.	Consider the strength of the forces, the person pushing with the greater force will determine the direction the table moves.	The table will move in the direction of Khan (left) as she is pushing with a larger force (the forces are unbalanced).

Check your learning 3.3

Check your learning 3.3

Comprehend

1 Describe the evidence that shows the forces acting on the objects are unbalanced in the following situations.
   - **a** Pushing down the lever on a toaster
   - **b** Jumping on a trampoline
   - **c** A car starts moving

2 Explain why a brick wall does not fall over when you push against it. Explain why a bulldozer could push the wall over.

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

4 Draw two people having a tug-of-war. Give them names and create a force diagram to show the different forces they are exerting on the rope. Explain who will win and why.

Analyse

5 Use a force diagram to identify one example for each of the following.
   - **a** Forces that are balanced (net force = 0)
   - **b** Forces that add together to make an object fall

6 Salo pushes with a force of 150 N and Marilla pushes with a force of 200 N.
   - **a** Create a force diagram to calculate the net force if both forces are in the same direction.
   - **b** Create a force diagram to calculate the net force if they push in opposite directions. Identify who will win.

Skills builder: Questioning and predicting, communicating

7 Sam wants to investigate if having more people on one side of a tug-of-war will affect the result of the game. He has created this scientific question for his investigation: "Is it good to have lots of people for tug-of-war?"

  a Identify what is wrong with Sam's question. (THINK: Is this question specific enough and easy to test?)

  b Create your own scientific question for Sam's investigation. (THINK: How does your question improve on Sam's question?)

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

  a Create a force diagram to demonstrate the forces in the tug-of-war. (THINK: What kind of representation is normally used to demonstrate forces?)

  b Label your force diagram. (THINK: What does your classmate need to know about heat?)

Lesson 3.4

Electrostatic forces are indirect forces

Learning intentions and success criteria

Key ideas

- → Direct (contact) forces involve two objects touching each other.
- → Indirect (non-contact) forces occur when one object can push or pull another object without touching it.
- → Rubbing two objects together can cause an electrostatic force.
- → Like (two positive or two negative) charges repel.
- → Unlike charges attract.
- → Charged objects attract uncharged objects.

Direct and indirect forces

Some forces make objects move because of a direct push or pull. It is much easier to move a pencil if you push it with your finger. Your finger must touch the pencil or be in contact before the pencil will move. This is called a **direct (contact) force**. Friction is also an example of a direct force.

If an object can push or pull another object without touching, this is called an **indirect (non-contact) force**. Magnetism, gravity and electrostatic forces are examples of indirect forces. These forces work by creating a field around the object.

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

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

A magnet creates a magnetic field around it and can attract or repel another magnet within its magnetic field.

What causes electrostatic force?

Have you ever rubbed a balloon on your hair and seen the hair cling to the balloon? This is a result of a force called an **electrostatic force**. When two objects rub against each other, a small electrical charge builds up. One object becomes positively (+) charged and the other becomes negatively (–) charged. The positively charged objects are pulled, or attracted, to the negatively charged objects. This is called an **attraction force**. The unlike charges attract each other. Because the objects do not need to touch each other to attract, electrostatic forces are indirect forces. Rubbing a balloon on hair causes the hair to become positively charged and the balloon to become negatively charged. When the (negatively charged) balloon moves away, the (positively charged) hair is still attracted to it. The hair lifts up and tries to cling to the balloon (Figure 1).

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

attraction force the force that attracts one object to another

Van de Graaff generators

A Van de Graaff generator works in the same way as rubbing a balloon on hair. In the long shaft of the machine, two long belts rub against each other, making the rounded dome of the machine positively charged. Negative charges are attracted to the dome. If anything comes close enough to the dome, the negative charges are attracted and jump through the air. You might see this as a spark (Figure 2).

As well as negatively charged objects, uncharged objects (neither positively nor negatively charged) are also attracted to the positively charged dome. If you stand too close to the Van de Graaff generator, your uncharged hair might be attracted to the dome.

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

Figure 2 Sparks jump across to a Van de Graaff generator when negative charges come close enough to the positively charged dome.

Anything touching the dome also becomes positively charged. The girl in Figure 4 is standing on a rubber mat so that the negative charges cannot move from the ground into the dome. This means that she becomes positively charged like the dome. Every part of her body becomes positively charged, including all her hair. This makes the strands of the girl's hair try to push away from one another.

The rules of electrostatic forces are:

- unlike charges attract
- charged objects attract uncharged objects
- like charges repel; this is called a **repulsion force**.

repulsion force a force that pushes one object away from another

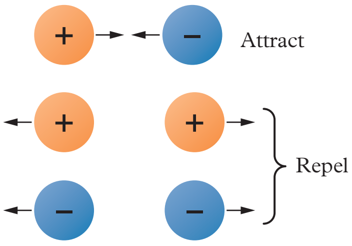


Figure 3 Unlike charges attract and like charges repel.

Figure 4 This student has become positively charged, like the dome of the Van de Graaff generator that she is touching. The strands of her hair are repelling each other.

Electrostatic forces in everyday life

You may have experienced electrostatic forces when you were jumping on a trampoline. Every time you jump, your feet rub against the trampoline mat. This causes a positive charge to build up in your body. Sometimes this causes your hair to stand up because the hair strands are pushing away from each other. When you touch someone else or the framework of the trampoline, you may feel the spark as the negative charges are attracted to you.

Check your learning 3.4

Check your learning 3.4

Retrieve

1 Recall if electrostatic charges are direct or indirect forces.

2 Recall the terms that complete these statements.

  a Unlike charges _______________.

  b _______________ charges repel.

  c Charged objects _______________ uncharged objects.

Comprehend

3 Describe how electrostatic forces can be created.

4 Explain why the hair of a person touching a Van de Graaff generator may stand out out from their head.

Apply

5 A student was leaving the carpeted library to go home. When they touched the door handle, they received an electric shock. Discuss why this happened.

6 When it is about to rain, the water particles in the clouds rub against one another and electrostatic charges form, similar to those seen in a Van der Graaff generator. Explain the similarities between the spark generated by a Van der Graaff generator and lightning.

Lesson 3.5

Gravity is a force existing between objects

Key ideas

→ The Earth's force of gravity can cause an indirect force.

→ Large objects (such as planets, moons and stars) pull objects towards their centre.

Learning intentions and success criteria

Gravity

One day in 1665, a young student named Isaac Newton was sitting under an apple tree when an apple fell to the ground. "Why did it fall?" he wondered. There was nothing he could see that could push it or pull it. He realised that there must be a force that pulled the apple towards the Earth. This is how Newton claimed he first had the idea of gravity.

However, gravity was acting on the apple before it fell; it was balanced by the upward force that the branch of the tree exerted on the apple.

Gravity is an indirect force of attraction between any two objects that are made of matter (small particles called atoms). The force of gravity between two objects is too small to measure unless one of the objects is massive, like a planet.

The Earth is made up of enormous amounts of matter, allowing it to exert a relatively strong indirect force on objects around it. Even you have a weak force of gravity surrounding you. The Earth has much more matter than you do, and therefore its pull force is much stronger than yours (Figure 3). The more matter an object has, the stronger its pull force. Stars like the Sun have much more matter than the Earth. This means that the gravitational pull of the Sun is much stronger.

The Earth attracts all objects made of matter within its gravitational field. This force, called gravity, keeps satellites in orbit around the Earth. Similarly, the Sun's gravity keeps the planets in our solar system in orbit around it. This means it keeps the planets from travelling off into space.

Figure 1 Newton is famous for the story of the apple falling from a tree as he sat in his family orchard. Although the story is fictional, Newton himself is responsible for its creation.

Figure 2 The large mass of the Earth can pull objects to its centre.

The difference between weight and mass

The Moon is made of less matter than the Earth. This means that the Moon's ability to pull objects is much less than the Earth's. An astronaut jumping on the Moon will be able to jump much higher

weight a measure of the gravitational pull on an object and is the same as the force of gravity on Earth

mass the amount of matter in a substance, usually measured in kilograms; the mass of an object never changes, even in space

than on the Earth. This is because the Moon does not have as strong a pull force as the Earth. **Weight** is a measure of the pull force on an object. Your weight on the Moon would be less than that on the Earth. This does not mean you are smaller. It just means the Moon is pulling you down less. Because weight is a measure of the pull force of gravity, it is measured in newtons.

If weight is a measure of the pull force, then how do scientists describe the amount of matter of an object? **Mass** (measured in kilograms) is the term used to describe how many particles or atoms make up an object. The mass of an object does not change, no matter where it is in the Universe. If a brick has a mass of 1 kg on the Earth, it has this mass everywhere. However, the weight of the brick will change. On the Earth, the brick may weigh 9.8 N, but on a large planet such as Jupiter, it would weigh 23.6 N. On the Moon, the brick would weigh approximately 1.6 N because the Moon is small and has less pull force (Figure 4).

Figure 3 The Earth pulls base jumpers towards its centre, 6,371 km below.

The force of gravity changes

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

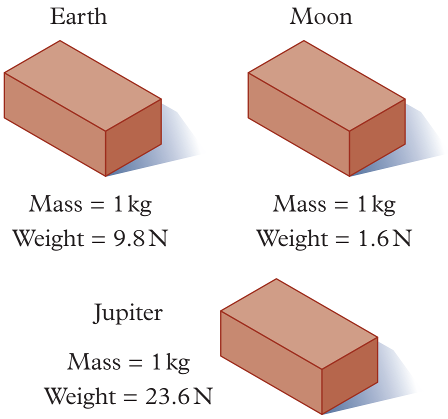


Figure 4 The mass of a brick does not change whether it is on the Moon, on Jupiter or on the Earth, but its weight is affected by gravity.

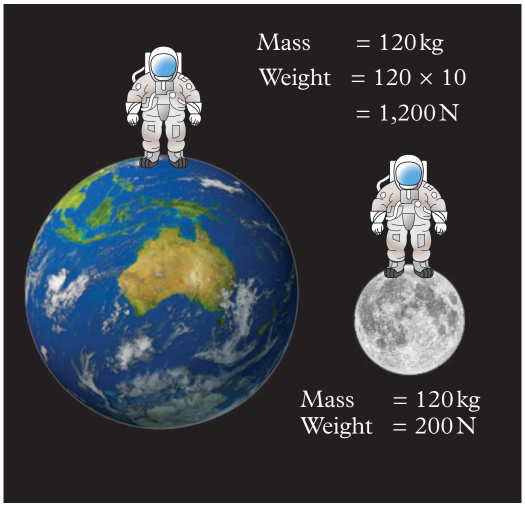


Figure 5 A person who wants to lose weight could go to the Moon. A person who wants to lose mass could take off their shoes.

Gravity is not the same for every object. Objects with a larger mass experience a greater pull than objects with less mass. This means a 3 kg bowling ball feels a stronger pull force than a basketball, which is lighter, does. Does this mean that the bowling ball will fall faster than the basketball?

If you do this experiment, you will find that both balls hit the ground at the same time. This is not what most people expect to happen. Logic might suggest that heavier things hit the ground first. You may need to do the experiment a few times until you believe it. The heavy bowling ball needs more force to start it moving than the basketball does. This offsets the larger pull, so both balls fall at the same rate and hit the ground at the same time (Figure 6). If both balls were dropped from the top of a building, air resistance may slow the basketball a little more than the bowling ball. We do not recommend that you try this for safety reasons.

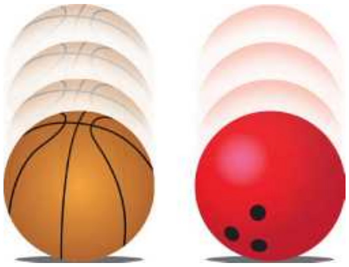


Figure 6 A bowling ball has more mass than a basketball and therefore takes more force to start it moving. The Earth pulls more on the bowling ball, causing both balls to fall at the same rate.

Table 1 Weight force and mass information

Term	Definition	Unit of measurement	Changes/remains constant?
Weight force (*F*)	Force on an object due to gravity	Newton (N)	Differs in different places due to the difference in gravitational pull
Mass (*m*)	Amount of matter in an object	Kilogram (kg)	Remains constant, no matter where you are

Calculation of weight force

The weight of an object depends on two factors:

- the mass of the object
- the location of the object.

The larger the mass of an object, the larger its weight. They are directly proportional, meaning that if you double the mass, the weight will also double. Different locations have different accelerations due to gravity. Gravity (g) is the acceleration experienced by an object with a mass of 1 kg at a given location. Weight and acceleration due to gravity are also directly proportional. We can express this relationship with the following equation:

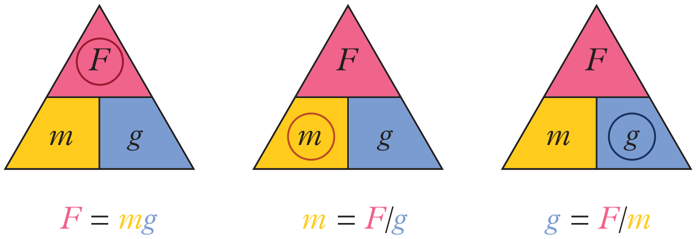


Figure 7 These triangles can be used to remember the relationship between weight, mass and acceleration due to gravity.

Weight force = mass × acceleration due to gravity

$F = mg$

F is the weight force of the object, measured in newtons (N)

m is the mass of the object, measured in kilograms (kg)

g is the acceleration due to gravity, measured in metres per second squared (m/s^2)

Worked example 3.5A Calculating weight on the Earth

Calculate the weight of a student with a mass of 50 kg on the Earth with an acceleration due to gravity of 10 m/s^2.

Solution

Steps	What to do	Working out
a.	Read the question and summarise the information.	m = 50 kg; g = 10 m/s^2; F = ?
b.	Check the units.	m (kg) and g = (m/s^2)
c.	Write the equation to find *F*.	$F = mg$
d.	Substitute with given values.	$F = 50 \times 10$
e.	Calculate *F* and write the unit of force.	$F = 50 \times 10 = 500$ N
f.	Answer the question.	The student with a mass of 50 kg weighs 500 N.

Worked example 3.5B Calculating weight on the Moon

Calculate the weight of the student in Worked example 3.5A if they travel to the Moon with an acceleration due to gravity of 1.6 m/s^2.

Solution

Steps	What to do	Working out
a.	Read the question and summarise the information.	m = 50 kg; g = 1.6 m/s^2; F = ?
b.	Check the units.	m (kg) and g = (m/s^2)
c.	Write the equation to find *F*.	$F = mg$
d.	Substitute with given values.	$F = 50 \times 1.6$
e.	Calculate *F* and write the unit of force.	$F = 50 \times 1.6 = 80$ N
f.	Answer the question.	On the Moon, the student with a mass of 50 kg weighs 80 N

Note: As you can see in this Worked example and in Worked example 3.5A, the mass of the student remains constant at 50 kg, but their weight changes depending on the location due to the difference in the acceleration due to gravity. On the Moon, the student's weight is lower because the gravitational pull is weaker compared to the Earth.

Worked example 3.5C Calculating acceleration

Calculate the acceleration due to gravity on a planet where the weight of the student in Worked example 3.5A is 200 N.

Solution

Steps	What to do	Working out
a.	Read the question and summarise the information.	m = 50 kg; F = 200 N; g = ?
b.	Check the units.	m (kg) and F (N)
c.	Write the equation to find *g*.	$g = \frac{F}{m}$
d.	Substitute with given values.	$g = \frac{200}{50}$
e.	Calculate *g* and write the unit of force.	$g = \frac{200}{50} = 4$ m/s^2
f.	Answer the question.	The acceleration due to gravity on the planet is 4 m/s^2

Check your learning 3.5

Check your learning 3.5

Retrieve

1 Name the person who first described gravity.

Comprehend

2 If a half-full water bottle was dropped from the top of a flight of stairs at the same time as a full water bottle of the same size, explain which bottle would hit the ground first.

Analyse

3 Identify whether the following statement is true or false. "The pull of the Earth is stronger on an elephant than on a feather."

4 Contrast mass and weight.

Apply

5 An astronaut on the Moon dropped a feather and a hammer at the same time. There is very little atmosphere on the Moon to slow down objects. Discuss why the feather and hammer hit the ground at the same time.

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

7 Calculate the mass of a student whose weight force is 550 N on the Earth, where the acceleration due to gravity is 10 m/s^2.

Skills builder: Questioning and predicting

8 Imagine that you are asked to compare how fast a basketball and a bowling ball fall to the ground when they are dropped from different heights (Figure 6).

a Recall the terms to complete the scientific question for this investigation. (THINK: What variables are you measuring?) How does ____________ affect ____________?

b Evaluate your question against the following:

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

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

iii Is the answer to this question based on opinion?

Lesson 3.6

Gravity affects all objects in space

Key ideas

→ Earth's gravity constantly pulls the Moon towards its centre, resulting in its orbit around Earth.

→ A planet's gravity causes moons to orbit it.

→ A star's gravity causes planets to orbit.

→ A black hole's gravity causes galaxies to orbit and prevents light from escaping.

Learning intentions and success criteria

Moons orbit a planet

When you throw an object, it has many forces acting on it. Before it leaves your hand, there is the push force of your hand on the object. Because forces always act in pairs, the object also pushes back on your hand (Figure 1).

Once the ball leaves your hand, there is no more push force. Instead, the main force experienced by the ball is the force of gravity that pulls the object down towards the centre of Earth. This is much stronger than the pull force the small object has on Earth. This causes the ball to move in a curved shape (Figure 2).

This is similar to objects moving around a planet. All of the objects in space are constantly moving. As they move through space, they are always being pulled towards bigger objects. Similar to the motion of a thrown ball, the path they take is curved around the object.

Our Moon orbits Earth because the force of Earth's gravity constantly pulls it down. Because it is moving through space, it travels in the same shaped path as a thrown ball that never quite hits Earth (Figure 3).

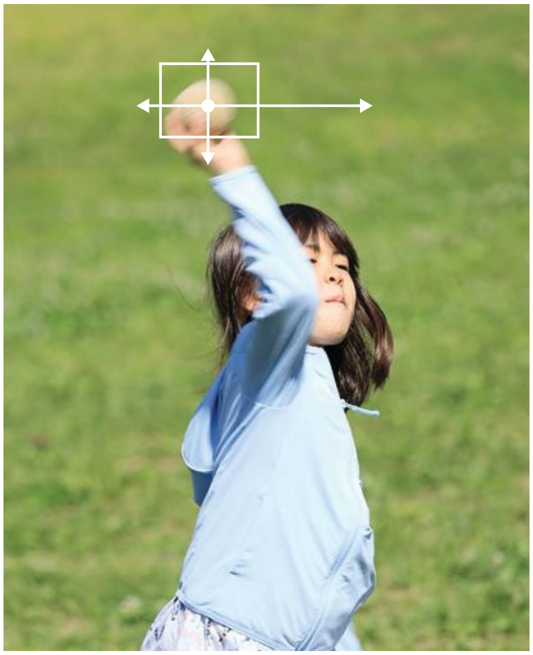


Figure 1 The forces acting on a ball as you throw it

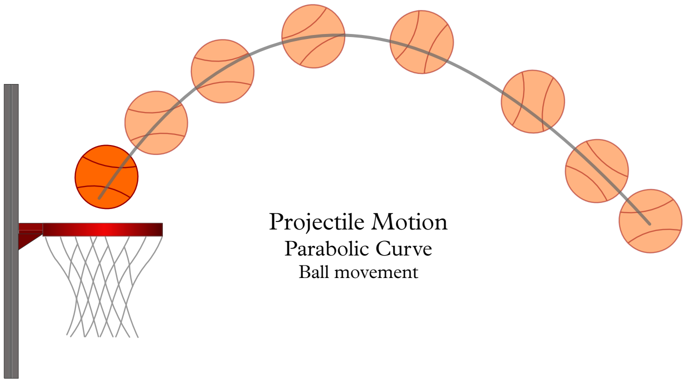


Figure 2 After you throw a ball, the force of gravity is the main force that acts on the moving ball.

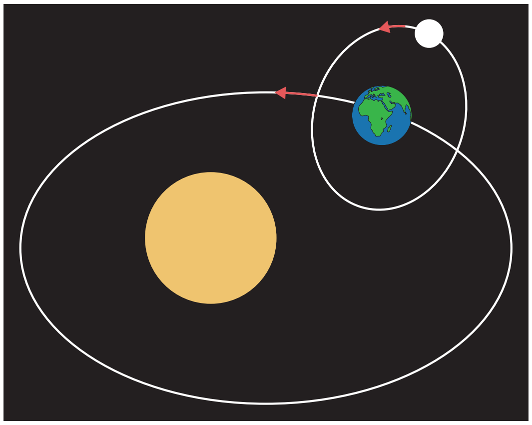


Figure 3 The orbit path of the Moon is affected by the force of Earth's gravity.

Planets and galaxies are affected by gravity

Planets such as Earth are also constantly moving around the Sun. Their orbit around the Sun is similar to the way the Moon orbits Earth. As the Sun (a star) is much larger than Earth, its force of gravity is much stronger. This pulls Earth towards the Sun. Because we are constantly moving forward, we do not fall into the Sun. Instead, we travel in an orbit around the Sun.

All of the planets in our solar system orbit around our Sun. Each planet travels at a different speed. The further away a planet is from the Sun, the slower it travels. For example, Neptune is 30 times further away from the Sun than Earth. It orbits the Sun six times slower (Earth's orbit speed is 29.8 km/s, while Neptune's orbit speed is 5.43 km/s). If Neptune travelled any faster, it would be able to escape the Sun's force of gravity and travel into space.

When stars are similar masses, their force of gravity is also similar. This means two stars can orbit each other. This is called a binary star system.

When a group of stars travel through space together, they can be held together by a combined force of gravity. A group of stars held together by gravity is called a **galaxy**.

galaxy a system of stars and their solar systems, dust and gas held together by gravitational force

black hole a region in space of infinite density where gravity is so strong that nothing, not even light, can escape from it

supernova explosion of a star

singularity a point that has infinite gravity and density; the centre of a black hole

Black holes

A **black hole** is not a hole in space. Instead, it is a part of space that does not have any light. It is the darkest part of space.

A black hole is made when a large star (many times bigger than our Sun) reaches the end of its life. The energy that held the star together disappears, causing the star to collapse in on itself. This causes a massive explosion called a **supernova**. All the matter that is left over from the large star shrinks into the smallest space possible. This point is called a **singularity**.

Because there is so much mass in such a small area, a singularity generates the strongest force of gravity that we know. This gravitational field pulls in everything around, even light. That is why it is called a black hole – no light can escape its gravitational field. The area around a black hole, where light can start to be seen, is called the "event horizon" (Figure 4).

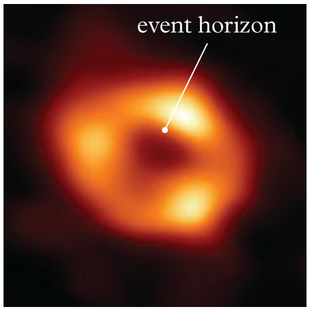


Figure 4 A black hole is the darkest part of space. Sagittarius A is the black hole in the centre of our Milky Way galaxy.

A black hole can have many different types of objects orbiting it (similar to the way planets orbit the Sun, or moons orbit a planet). The closer the objects are to the black hole, the faster they orbit. This means they can stretch out and start to glow (Figure 4).

When an object moves too close to a black hole, it is stretched out like a noodle (Figure 5). It happens because the side of the object closest to the centre of the black hole experiences a greater force of gravity than the other side of the object. This causes stretching that is called "spaghettification". Eventually, the object moves past the event horizon, into the black area of a black hole. This means we can no longer see the object.

The black hole in the centre of our Milky Way galaxy is called Sagittarius A and it is 4 million times the mass of our Sun. Our solar system is too far away from Sagittarius A to ever become spaghettified or move past the event horizon.

Figure 5 Spaghettification is the stretching of an object when it moves too close to a black hole.

Check your learning 3.6

Check your learning 3.6

Retrieve

1 Define the following terms:
   a orbit
   b galaxy
   c spaghettification.
2 Describe a black hole.
3 Identify the black hole found at the centre of our galaxy.

Analyse

4 Explain why the Moon does not “fall” into Earth.
5 Compare a galaxy and a black hole.

Apply

6 Explain why our galaxy (the Milky Way) orbits around Sagittarius A.
7 If Mercury is closer to the Sun than Earth, would you expect it to be travelling faster or slower than Earth? Justify your answer (by describing why planets orbit the Sun rather than falling into it, comparing the speed of travel of Neptune and Earth to their distances from the Sun, and describing the distance between Mercury and the Sun).

Lesson 3.7

Magnets can repel or attract each other

Learning intentions and success criteria

Key ideas

→ Magnetism is an example of an indirect force.

→ Magnets have two magnetic poles: north and south.

→ Like poles repel and unlike poles attract.

Introduction

All forces occur between two or more objects. These objects can be living or non-living.

How magnets push and pull

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

alloy a mixture of two or more metals, or a metal and another element, designed to enhance properties like strength, durability, or resistance to corrosion (e.g., steel is an alloy of iron and carbon)

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

When the north pole of one magnet is placed near the south pole of another magnet, the two magnets are pulled towards each other (Figure 2). The two **unlike poles** (a north and a south) attract each other. Magicians use this attraction force to slide something along a table. You can do this too. Place one magnet on top of a thin table and a second magnet under the table. Can you make the top magnet move? Can you see the pull force? Are the two magnets contacting each other?

When two **like poles** (two north poles or two south poles) are placed close together, they push each other apart (Figure 3). You can use one magnet to push another magnet along a table. The two magnets do not need to touch to be affected by the repulsion force. It is an indirect force.

magnetic poles the north and south ends of a magnet

unlike poles the north and south poles of a magnet

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

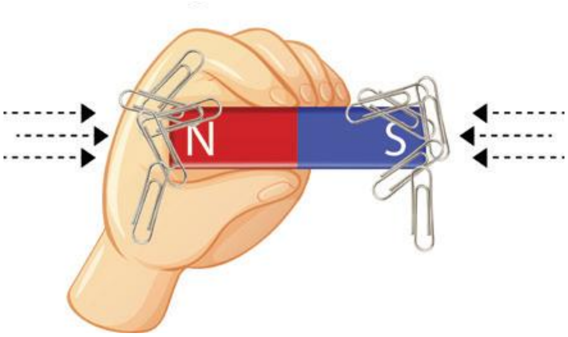


Figure 1 The attraction between the paper clips and the magnet is an indirect force.

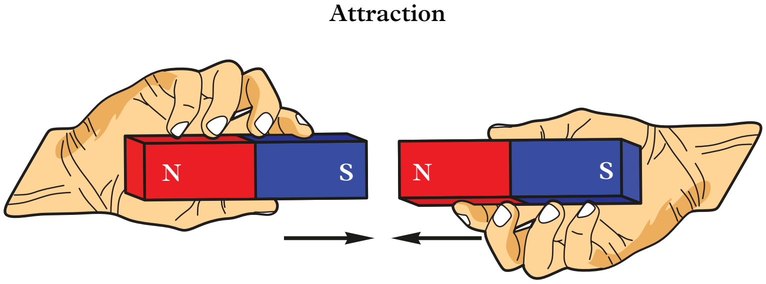


Figure 2 The north pole of one magnet is pulled by the south pole of another magnet.

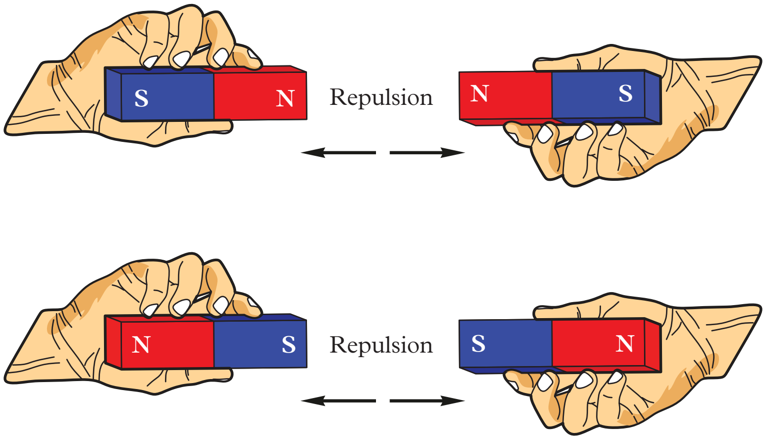


Figure 3 Like poles push away from or repel each other.

What causes a magnetic force?

domain a small section of a magnet where the magnetic field of all the atoms is aligned in the same direction

An iron needle can be made into a magnet by sliding a strong magnet along one side of it (in one direction only). The strong magnet pulls tiny groups of particles so that they all line up in one direction. Each time you stroke the needle, these particles line up. This causes larger sections of the metal, called **domains**, to point in the same direction. When most of the domains are pointing the same way, the needle becomes magnetic. Dropping the needle can cause the domains to become mixed up again.

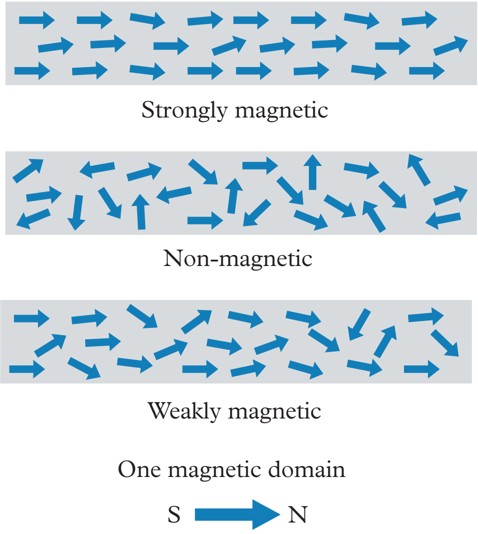


Figure 4 The magnetic domain theory

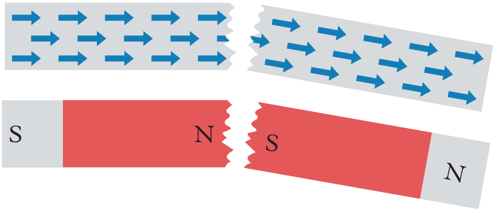


Figure 5 When a permanent magnet is broken, it forms two magnets.

Some magnets never lose their magnetic force. These magnets are called permanent magnets. The domains in these magnets are often arranged while the metal is still buried deep under the ground. Breaking these magnets in half does not change the arrangement of the domains. The two halves become smaller magnets with the same pull or push forces as the larger magnet (Figure 5).

The push forces of magnets are used in the design of Maglev (magnetic levitation) trains (Figure 6). A series of electronic magnets on the train and track suspend the train above the tracks. The magnets on the train and the track have like poles, causing them to push away from each other and for the train to sit above the track. There is no contact between the train and the metal track. To make the train move, the driver changes the pole of the train magnet, and the track magnet pushes the train magnet forward.

Figure 6 The magnetic force of repulsion causes the Maglev train to move.

Check your learning 3.7

Check your learning 3.7

Retrieve

1 Name three places where you might find a magnet.

Comprehend

2 Identify a magnetic force as either a direct or an indirect force. Explain your answer.

3 Explain why one part of a magnet is called the north.

4 Describe what will happen when the following poles of two magnets are pushed close together.

- **a** N and S
- **b** S and S
- **c** N and N
- **d** S and N

Apply

5 Draw how you could arrange multiple bar magnets like the one shown in Figure 7 to create the letters of your name. Label the north and south poles of the magnets.

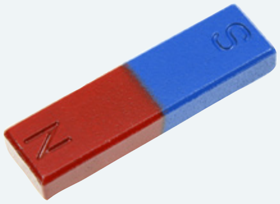


Figure 7 A bar magnet

6 Predict how you might levitate a magnetic skateboard above a large magnet on the ground. Mention the arrangement of the poles of the magnet in your description.

Skills builder: Planning investigations

7 Using what you've learnt in this topic, suggest a method to create your own magnet out of an iron needle.

- **a** Identify a list of materials that you will need. (THINK: Are these materials or equipment easy to access?)
- **b** Describe a step-by-step process to create your magnet. (THINK: Is this method clear for someone else to follow? Number each step in the order it needs to be carried out.)

Lesson 3.8

Investigation: Testing the effect of distance on magnets

Purpose

Design an experiment to determine how far away your magnet needs to be to attract a metal paper clip

Variables

- Identify the independent variable.
- Identify the dependent variable.
- Identify two controlled variables.

Hypothesis

Predict the effect of the distance between the paper clips and the magnet on the force experienced by the paper clips.

Discussion

1. Describe the changes you would make to improve your design.
2. Describe the most successful feature of your design.
3. Describe how you would modify your design if you were doing this experiment again.

Conclusion

Present the various stages of your investigation in a formal experimental report.

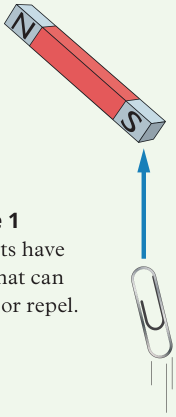


Figure 1 Magnets have poles that can attract or repel.

Lesson 3.9

Magnetic fields can apply a force from a distance

Learning intentions and success criteria

Key ideas

- → A magnetic field is the area around a magnet where a magnetic force is experienced.
- → A magnetic field cannot be seen, but we can see the way it interacts with other objects.
- → The further away an object moves from the magnet, the weaker the magnetic field.

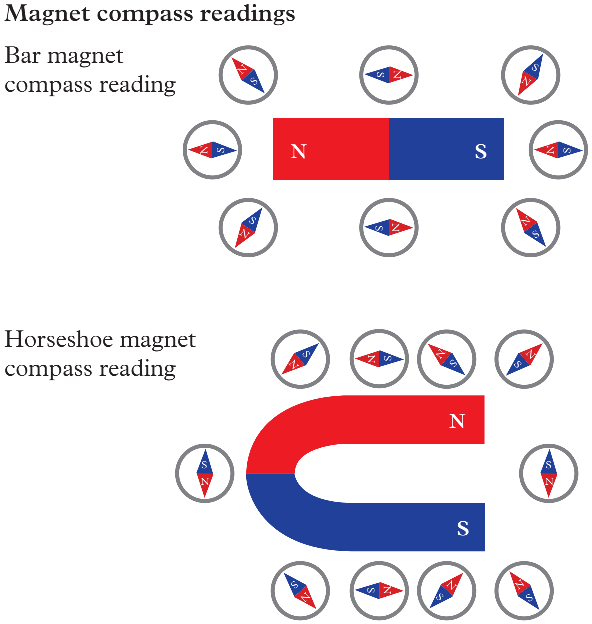


Figure 1 A compass needle points in the direction of the magnetic field (north-south direction).

How compasses work

A compass needle is a weak magnet. When a compass is placed near a strong magnet, the compass needle points in the direction of the magnetic field. You can see this by moving a compass around the sides and ends of a bar magnet. The north pole of a compass always points to the south pole of a magnet (Figure 1).

Iron filings and iron powder are tiny bits of iron. If you put them near a strong magnet, they become temporary magnets. They line up like tiny compass needles around the strong magnet. You can draw this pattern and make a map of the magnetic field. Figure 2 shows the magnetic fields around a single magnet and around two bar magnets.

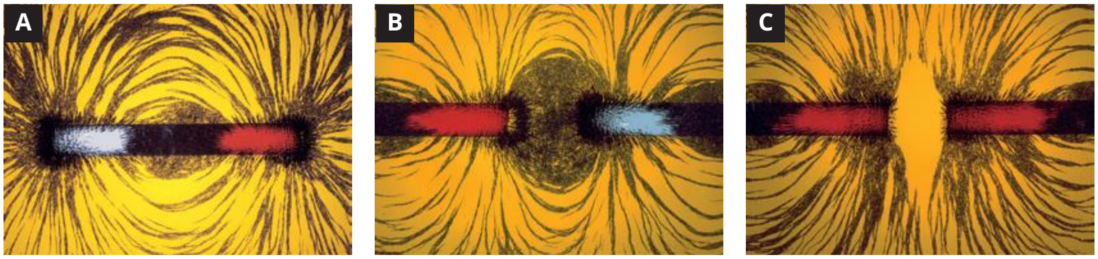


Figure 2 Magnetic fields: (A) around a single bar magnet; (B) between two attracting bar magnets; (C) between two repelling magnets

The stronger a magnet, the closer together are its magnetic field lines. Figure 3 shows a strong magnetic field and a weak magnetic field.

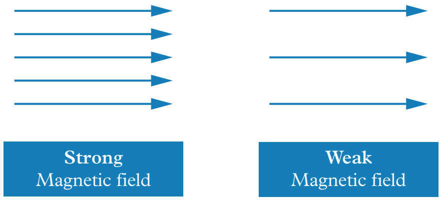


Figure 3 The stronger a magnet, the closer together are its magnetic field lines.

There is a large magnetic field around the Earth. The Earth's magnetic field is generated by molten iron in the outer core of the Earth. To visualise the Earth's magnetic field, imagine a large bar magnet inside the Earth. A compass needle will line up with the Earth's magnetic field. The part of the compass needle with the "N" on it points to the north **magnetic pole** of the Earth. It is important to note that the "geographic" North Pole of the Earth is not the same as the magnetic north pole. They are both in the Arctic Circle, but hundreds of kilometres apart.

magnetic poles the points on Earth where the magnetic field points downwards and a magnetic needle dips vertically

The North Pole, also known as the geographic North Pole or true North Pole, is the northernmost point of the Earth. If you tunnelled through the Earth from the North Pole in a straight line, you would come out the other side at the South Pole. The magnetic north pole is quite different. The magnetic north pole is not a fixed point – it moves about according to the magnetic field of the Earth and has done so for millennia. This movement is caused by the Earth's magnetic field. Figure 4 shows the different locations of the geographic North and South Poles and the magnetic north and south poles.

The Earth's magnetic field shields us from the charged particles emitted from the Sun. Without this magnetic field, life on the Earth would not be possible.

Turtles use the Earth's magnetic field

Turtles use the Earth's magnetic fields for navigation. When a turtle hatches, it crawls across the sand on the beach to the water and swims out to the brightest light on the horizon, which is usually the Moon. For the next 30 years, it will swim in the fast-flowing sea currents around the world. When it is ready to return home to find a mate and reproduce, the turtle detects the magnetic field around the Earth. It can measure the direction of the magnetic field (just like a compass) and how strong it is. All it needs to do is follow the magnetic field back to exactly the same beach where it hatched. Once there, it will mate and lay eggs, beginning the cycle of life once again.

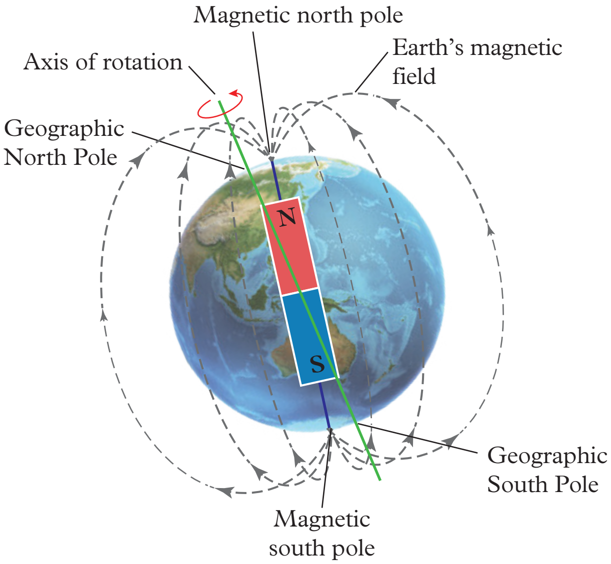


Figure 4 The Earth's geographic poles are not in the same place as its magnetic poles.

Figure 5 What do magnets and turtles have in common? Magnets create a magnetic field, and turtles use the magnetic field to find their way back to the same beach where they hatched.

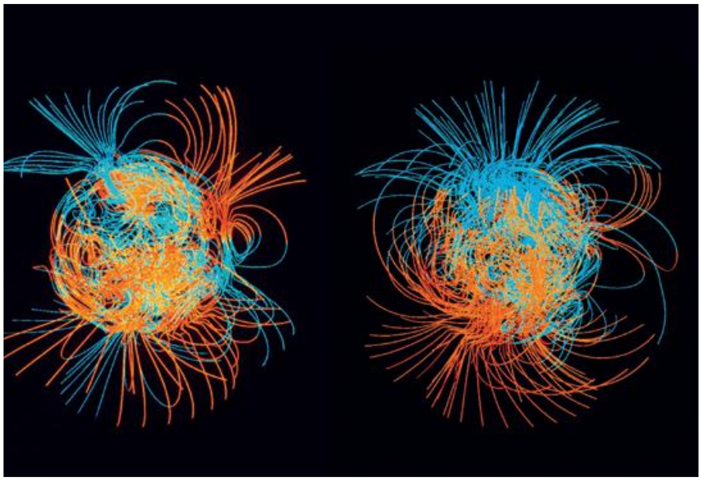


Figure 6 The Earth's magnetic poles between reversals and during a reversal

Flipping the magnetic poles

Throughout history, the magnetic north and south poles have flipped upside down every now and then. The last flip happened about 780,000 years ago. The flip can take a few thousand years to complete. While this happens, the poles become very disordered and a magnetic north or south pole can appear anywhere (Figure 6). How will this affect turtles being able to find their beach?

Bankcards and magnets

Figure 7 The magnetic strip on a bankcard contains zones of magnetised and demagnetised areas.

We use magnetic fields in our own life. The black strip on the back of a bankcard has a series of small, magnetised zones, separated by demagnetised zones (Figure 7). You can see these zones if you sprinkle fine iron filings on them. The iron filings arrange themselves according to the magnetic field surrounding the magnetic zones, which looks a bit like a barcode. When the card is swiped through a card reader, the magnetic barcode is read, and the person's name, bank and account number are decoded.

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

Check your learning 3.9

Check your learning 3.9

Comprehend

1 Describe a magnetic field.

2 Explain how you could map the magnetic field around a magnetic nail.

3 Describe in words the shape of the magnetic field when two magnets are:
  a attracting
  b repelling.

4 Describe how you could decide which magnet was stronger by looking at the magnetic fields made by different magnets.

5 Explain how a compass works.

6 Explain why you should never leave a library card on the demagnetising panel of a shop.

Apply

7 Create a drawing of the magnetic field around a broken magnet:
  a that has been re-joined
  b with the two pieces 10 cm apart
  c with the two pieces 1 cm apart.

Skills builder: Conducting investigations

8 Imagine that you have been asked to conduct an investigation to test the strength of an electromagnet that is made from a nail, a copper wire and a battery.
  a Research the properties of these items and evaluate the risks that you might encounter handling these three items. (THINK: Do they conduct electricity? Are they safe to use around water or to touch with bare skin? What could go wrong?)
  b Identify ways to reduce each of the risks you have identified. (THINK: What can you do to make sure you are safe when you are using this equipment?)

Lesson 3.10

Investigation: Constructing and comparing electromagnets

Introduction

Electromagnets

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

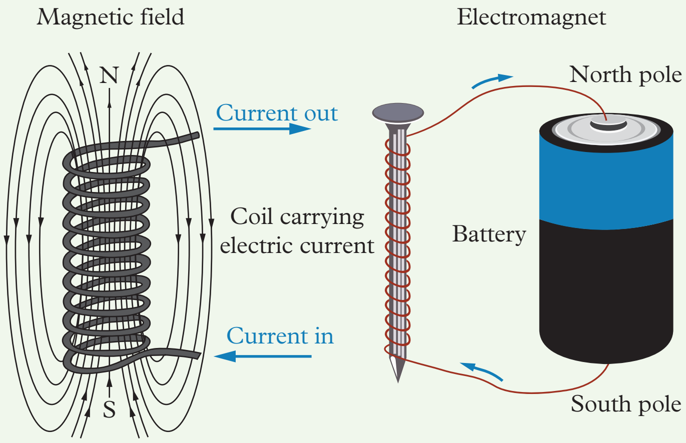


Figure 1 An electromagnet has a north and south pole, but it is created by electricity.

a constant source of electricity. Many everyday technologies use electromagnets. You'll find electromagnets in speakers, microphones, doorbells and the electric locks on a car door.

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

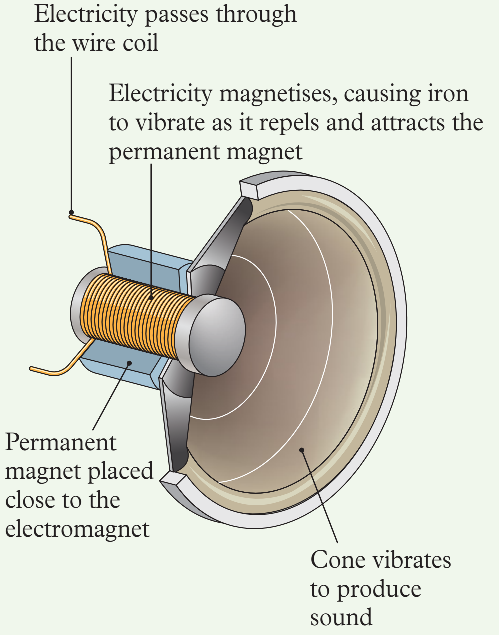


Figure 2 A loudspeaker uses the changing field of an electromagnet to create sound vibrations.

Purpose

To investigate how the strength of an electromagnet can be changed

Materials

- 1 m length of insulated wire (diameter of 0.5 mm)
- One large iron nail or large bolt
- One variable low-voltage DC power pack
- Two connecting wires
- Four crocodile clips
- Paper clips
- Fine-grained sandpaper

Variables

Fill in the blanks:

Independent variable: ___________________

Dependent variable: ___________________

Controlled variables: ___________________

and ___________________

Hypothesis

Write a hypothesis for the investigation.

Procedure

1. Wrap the insulated wire tightly around the nail (bolt) about 50 times, leaving a tail of wire around 5 to 7 cm on each side to create your electromagnet.
2. Strip the insulation from both ends of the wire (about 2 cm) using the sandpaper.
3. Connect one end of the wire to your electromagnet using the crocodile clips.
4. Attach the other end of the wire to the DC power pack.
5. Set the power pack to 0 V.
6. Switch on the power pack.

7 Attach as many paper clips to the electromagnet as it can hold. Count how many paper clips it picks up and record this in a table.
8 Switch off the power pack.
9 Record your observations.
10 Repeat Steps 5 to 9 with the power pack set to 2 V, 4 V, 6 V and 8 V.

Results

1 Record your results in a table like Table 1.

Table 1 Experiment results

Voltage of the power pack (V)	Number of paper clips attracted to the electromagnet	Observations
0		
2		
4		
6		
8		

2 Draw a graph showing the effect of increasing voltage on the number of paper clips attracted to the electromagnet. This will demonstrate the strength of your electromagnet.

Discussion

1 What was the relationship between the voltage and the number of paper clips attracted?
2 Why is it necessary to strip insulation from both ends of the wire?
3 Can you suggest another method to increase the strength of the electromagnet?

Conclusion

Fill in the blanks:

As can be seen in the results, by increasing the applied voltage, the number of paper clips attracted was ____________________, meaning the electromagnet became ____________________. The results ____________________ my hypothesis.

Lesson 3.11

Simple machines decrease the amount of effort needed to do work

Key ideas

- → A lever is a solid rod with a turning point.
- → Levers provide a mechanical advantage of force or distance.
- → All levers need an effort (force used), a fulcrum (turning point) and a load (the section being moved).
- → Levers can be divided into first-class, second-class or third-class levers.

Learning intentions and success criteria

Figure 1 Ancient Egyptians used round logs and ropes to haul large blocks of stone when they built the pyramids.

Introduction

The ancient Egyptians, Romans and Greeks understood forces very well. They made simple machines that helped them to build the pyramids, fight wars and build cities (Figure 1). The simplest machine they used was a lever. A lever can be used to decrease the amount of effort needed to do work. You use levers every day. Scissors, pliers, brooms, shovels, wheelbarrows and can openers are all levers.

Levers

A **lever** is a solid rod or bar that is supported at a turning point called a **fulcrum**. Figure 2 shows the main features of a simple lever – a seesaw. The force used to operate a lever is called the **effort**, and the resisting force it overcomes is called the **load**.

When one person on a seesaw is pulled down by the Earth, the other person is pushed up. The weight of the two people does not need to be equal for this seesaw lever to work. One person can lift a heavier weight by moving further away from the fulcrum in the middle. In fact, a single person two metres away from the fulcrum can lift two people who are one metre away on the other side of the fulcrum.

lever	a simple machine that reduces the effort needed to do work
fulcrum	the turning point of a lever
effort	the force used to operate a lever
load	(in physics) resisting force

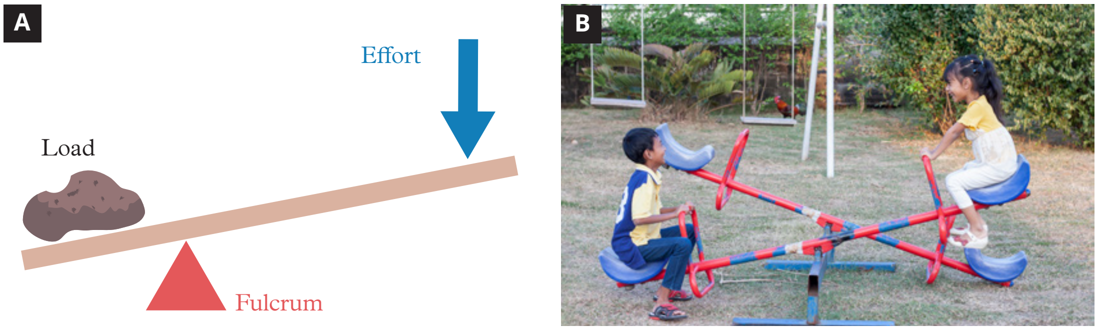


Figure 2 (A) A lever has three features: the fulcrum, effort and load. (B) A seesaw is an example of a lever.

Mechanical advantage

The lever gives you a mechanical advantage. The size of the advantage can be calculated by dividing the size of the load by the size of the effort:

$$\text{Mechanical advantage} = \frac{\text{size of the load}}{\text{size of the effort}}$$

This formula can also be written as:

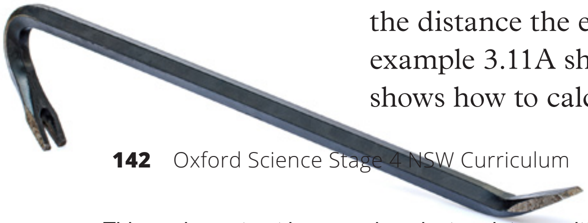
Size of the load = (mechanical advantage) × (size of the effort)

or

$$\text{Size of the effort} = \frac{\text{size of the load}}{\text{mechanical advantage}}$$

The magnification of the force comes with a disadvantage. For this type of lever, the distance the effort must move is greater than that moved by the load. Worked example 3.11A shows how to calculate mechanical advantage. Worked example 3.11B shows how to calculate effort.

Figure 3 A crowbar is a force magnifier.



Some levers are **force magnifiers**. They can change a weak force into a stronger force. An example of this is a crowbar, which can be used to lift a heavy rock, even though the rock is heavier than the effort used. There is a disadvantage to force magnifiers. The effort section of the lever must move a greater distance to move the rock a short distance.

Other levers are **distance magnifiers**. They magnify the distance the effort moves. This means that when the effort moves a short distance, the load will move a long distance. The disadvantage is that the effort force required will need to be larger than the load. An example of this is a tennis racquet. The end of the tennis racquet moves a greater distance (and faster) than the hand holding the racquet.

force magnifier a device that can increase the amount of force available (for example, to shift something); an example is a lever

distance magnifier a lever that changes a strong force that acts over a short distance into a weak force that acts over a longer distance

Worked example 3.11A Calculating mechanical advantage

Calculate the mechanical advantage of a lever that allows an effort of 4 N to lift a load of 12 N.

Solution

Steps	What to do	Working out
a.	Read the question and summarise the information.	Effort = 4 N, load = 12 N
b.	Write the equation to find mechanical advantage.	$\text{Mechanical advantage} = \frac{\text{size of the load}}{\text{size of the effort}}$
c.	Substitute with given values to calculate mechanical advantage.	$\text{Mechanical advantage} = \frac{\text{size of the load}}{\text{size of the effort}}$ $= \frac{12}{4}$ $= 3$
d.	Answer the question.	The mechanical advantage is 3.

Worked example 3.11B Calculating effort

Calculate the effort required to lift a box of books with a load of 6 N using a lever that has a mechanical advantage of 2.

Solution

Steps	What to do	Working out
a.	Read the question and summarise the information.	Load = box of books = 6 N, mechanical advantage = 2
b.	Write the equation to find effort.	$\text{Size of effort} = \frac{\text{size of the load}}{\text{mechanical advantage}}$
c.	Substitute with given values to calculate effort.	$\text{Size of the effort} = \frac{\text{size of the load}}{\text{mechanical advantage}}$ $= \frac{6}{2}$ $= 3$
d.	Answer the question and include the correct unit for effort.	The size of the effort needed is 3 N.

Figure 4 The trebuchet was a powerful machine that used a lever to fling objects such as rocks against enemy defences.

Types of levers

There are three types of levers and they are classified according to the position of the fulcrum (turning point):

- **First-class lever**: the fulcrum is between the effort and the load (EFL) (Figure 5).
- **Second-class lever**: the load is between the effort and the fulcrum (ELF) (Figure 6).
- **Third-class lever**: the effort is between the load and the fulcrum (LEF) (Figure 7).

Use FLEE to remember the middle position for each type of lever.

- **F** (Fulcrum) – first-class lever
- **L** (Load) – second-class lever
- **E** (Effort) – third-class lever
- **E** (Easy to remember!)

first-class lever a lever that has its fulcrum between the point of effort and the load

second-class lever a lever that has its load between the point of effort and the fulcrum

third-class lever a lever that has its point of effort between the fulcrum and the load

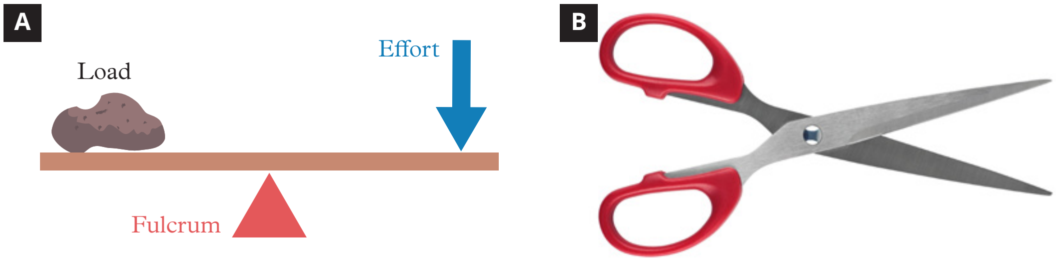


Figure 5 (A) In a first-class lever, the fulcrum is between the effort and the load. (B) Scissors are an example of a first-class lever.

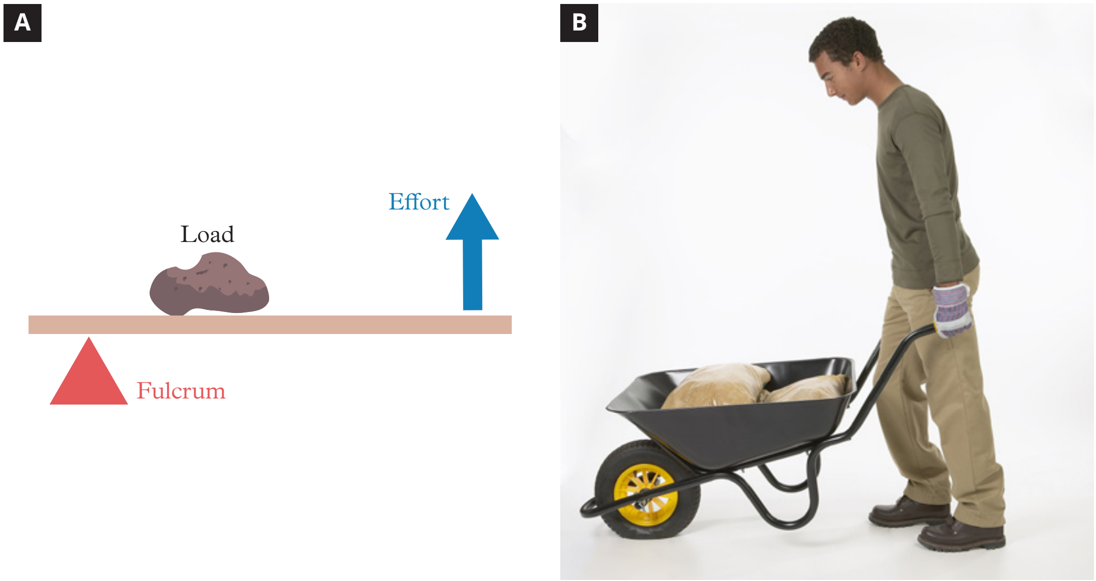


Figure 6 (A) In a second-class lever, the load is between the effort and the fulcrum. (B) A wheelbarrow is an example of a second-class lever.

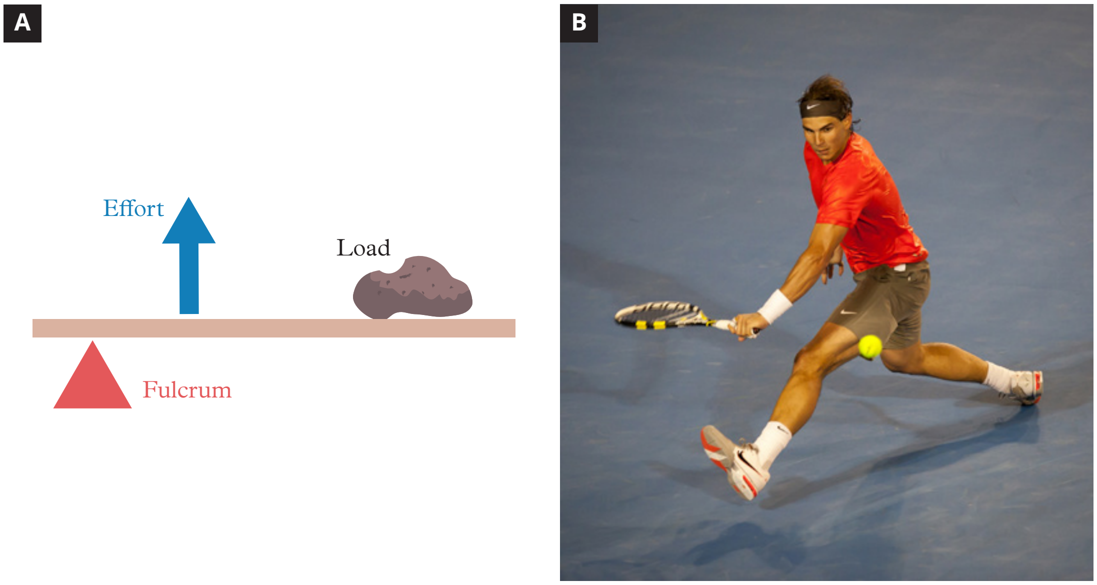


Figure 7 (A) In a third-class lever, the effort is between the load and the fulcrum. (B) A tennis racquet is an example of a third-class lever. When a person uses a tennis racquet to hit a ball, the muscles exerting the effort are between the shoulder fulcrum and the ball load.

Aboriginal and Torres Strait Islander Peoples’ levers

Aboriginal and Torres Strait Islander Peoples have an understanding of the advantage of levels. In hunting, the Dharag people (who occupied areas of NSW) used a woomera, a tool used to launch a spear further and with more force, accuracy and acceleration. The word “woomera” comes from the Dharag language and refers to a spear thrower. A spear is fitted into the 50 to 100 cm long lever and held in place with a short peg that connects to the end. The person throwing the spear could then hold the woomera and launch it over their head, similar to a catapult action. This makes the lever arm longer and moves the spear faster, increasing the speed that the spear left the thrower and making the spear more accurate.

Figure 8 In the Dharag language, the word "woomera" is used for a spear thrower, which is an example of a lever.

The type of lever depends on the position of the fulcrum. If the wrist is used to flick the spear, then this becomes the fulcrum. If the arm and wrist remain straight and the motion is like a bowler's (in cricket), the fulcrum is located between the thrower's shoulder blades.

Once the spear has left the spear thrower, the unbalanced forces of air resistance cause the spear to slow down, and the force from the Earth's gravity causes the spear to eventually fall.

Different Aboriginal and Torres Strait Islander Peoples developed different styles and shapes of spear throwers. Longer spear throwers can increase the speed more than shorter spear throwers. This increase in speed means that the spears used need to be lighter.

Check your learning 3.11

Check your learning 3.11

Retrieve

1 Define the term "lever".

Comprehend

2 Describe how you would identify a first-class lever.

Analyse

3 Compare (the similarities and differences between) a second-class lever and a third-class lever.

4 Examine Figure 9.
  - **a** Identify the type of lever that is shown.
  - **b** Calculate whether a mass with a weight of less than 20 N would lift the load.
  - **c** Describe how you would reposition the fulcrum so that a mass with a weight much less than 20 N could lift the load.

Figure 9 A lever

Apply

5 A crowbar can be used to move a load (Figure 10).
  - **a** Identify the class of lever used.
  - **b** Identify whether this class of lever is a force magnifier or a distance magnifier. Justify your answer.

Figure 10 A crowbar moving a load

6 Modern cranes use leverage to lift heavy objects (Figure 11).
  a Identify where the load for this lever is located.
  b Identify where the effort is located.
  c Identify where the fulcrum is located.
  d Identify the class of lever being used.
  e Identify whether this class of lever is a force magnifier or a distance magnifier. Justify your answer.

Figure 11 A modern crane

Lesson 3.12

A pulley changes the size or direction of a force

Key ideas

- → A pulley is a simple machine that makes it easier to lift an object.
- → Pulleys are wheels with a groove along their edge.
- → The wheel is used to change the size or direction of the force used.

Learning intentions and success criteria

History of the pulley

Between the fifteenth and seventeenth centuries, a period known as the Age of Discovery, the people of Europe were desperate for spices, gold and silver. Sailors navigated the seas looking for these treasures. They returned with large amounts of bounty that included food, weapons and slaves. All this cargo needed to be loaded on and off the ships as quickly as possible. To help the sailors do this work, they used a simple machine invented by Archimedes many centuries before.

Figure 1 Sailing ships have pulley systems for lifting heavy sails and cargo.

Types of pulley systems

The simplest pulley system is made of one pulley. This system only changes the direction of the applied force, not the size of the force. As a person pulls **down** on the rope, the weight on the other end moves **up** (Figure 2). This does not change the amount of effort needed, but it makes lifting easier. This is because the person can use their weight to help in the lifting. You have probably used this type of pulley when you pull the cord to open a window blind at home (Figure 3). The mechanical advantage of a pulley is how much the applied effort is magnified to lift the load. It is calculated by the number of ropes between the upper and lower pulleys; in the roller blind system, it is one.

The more pulleys that are used, the easier it is to lift a load because its mechanical advantage is increased. For example, if two pulleys are used, the system can lift twice the load of a single-pulley system. The mechanical advantage of this system is two (Figure 4).

A four-pulley system can magnify the effect of the effort four times. For example, a 25 N effort can lift a 100 N load in a frictionless pulley system. The simple system shown in Figure 5 not only changes the direction of the applied force, but it also multiplies it by four. This system has a mechanical advantage of four. Worked example 3.12A shows how to calculate effort in a pulley system.

Groups of pulleys are often mounted together in a frame or “block”. This device is called a **block and tackle**. A small effort pulling through a long distance lifts a large load through a much smaller distance.

block and tackle a group of pulleys mounted together in a frame or block, which provides significant mechanical advantage

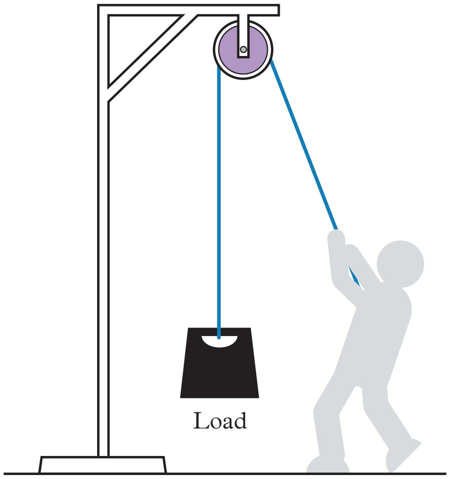


Figure 2 A single-pulley system – the rope is guided through the groove of a rotating wheel.

Figure 3 The simplest pulley system is made of one pulley.

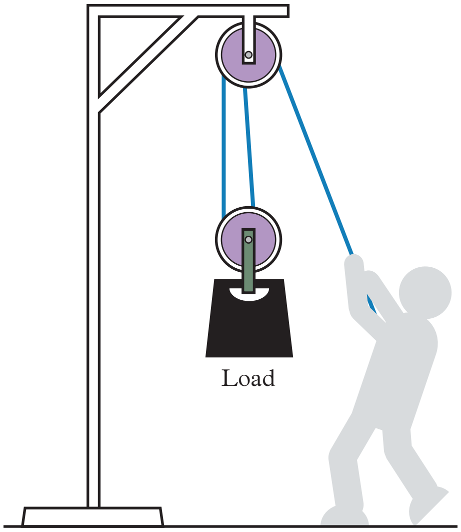


Figure 4 A two-pulley system doubles the mechanical advantage.

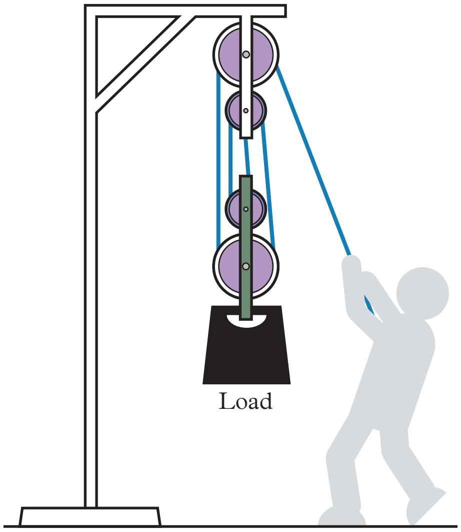


Figure 5 A four-pulley system increases the mechanical advantage by a factor of four.

Figure 6 A block and tackle

Worked example 3.12A Calculating effort

Use the formula below to calculate the effort needed to lift a load of 150 N with a frictionless block and tackle with five pulleys.

$$\text{Effort} = \frac{\text{size of the load}}{\text{mechanical advantage}}$$

Solution

Steps	What to do	Working out
a.	Read the question and summarise the information.	Mechanical advantage = 5 (5 pulleys) Load = 150 N
b.	Write the equation to find effort.	$\text{Effort} = \frac{\text{size of the load}}{\text{mechanical advantage}}$
c.	Substitute with given values to calculate effort.	$\text{Effort} = \frac{\text{size of the load}}{\text{mechanical advantage}}$ $= \frac{150\text{ N}}{5}$ $= 30\text{ N}$
d.	Answer the question and include the correct units.	The effort needed is 30 N.

Check your learning 3.12

Check your learning 3.12

Comprehend

1 Explain why two pulleys are better than one.

2 Describe three examples where single pulleys or pulley systems are used.

3 Describe how pulleys have made loading and unloading huge cargo vessels possible.

Analyse

4 A block and tackle provides a mechanical advantage because it can lift heavy loads. Evaluate the disadvantages of this system.

5 Identify the correct option. A pulley system can:
  - **a** increase force and distance at the same time.
  - **b** decrease distance while increasing force.
  - **c** decrease force and distance at the same time.
  - **d** increase speed and force at the same time.

6 A 100 N mass is used to lift an 800 N mass.
  - **a** Calculate how many pulleys are needed to make this possible.
  - **b** Calculate the mechanical advantage of this machine.

Lesson 3.13

Investigation: Using a first-class lever to lift weights

Purpose

To determine how a first-class lever balances different weights

Materials

- Wooden or metal ruler
- 50 g masses
- Rounded glue stick
- Blu-Tack®

Procedure

1 Place the glue stick flat on the desk and hold it in place with Blu-Tack.

2 Place the centre of the ruler over the glue stick so that it forms a simple seesaw or balance.

3 Add three 50 g masses 4 cm from the centre of the fulcrum on one side.

4 Add three 50 g masses 4 cm from the centre on the other side so that the seesaw becomes balanced (both masses are equal height from the desk).

Inquiry: What if a different weight was placed in a different location?

Choose one of the inquiry questions.

- What if a greater mass was placed closer to the fulcrum?
- What if a greater mass was placed further away from the fulcrum?
- What if less mass was placed closer to the fulcrum?
- What if less mass was placed further away from the fulcrum?

Answer the following questions about your inquiry question.

1 Write a hypothesis for your inquiry.

2 Identify the **independent** variable that you will change from the first method.

3 Identify the **dependent** variable that you will measure and/or observe.

4 Identify two variables that you will need to control to ensure a reasonable test. Describe how you will control these variables.

5 Write down the method you will use to complete your investigation.

Table 1 Using first-class levers to lift weights

Left-hand side			Right-hand side		
Number of 50 g masses	Position from fulcrum (cm)	Number of masses × distance from fulcrum	Number of 50 g masses	Position from fulcrum (cm)	Number of masses × distance from fulcrum
3	4	12	3		
3			2		
3			1		
1			5		

6 Draw a table to record your results.
7 Show your teacher your planning to obtain approval before starting your experiment.

Results

Record your results by copying and completing Table 1 into your notebook.

Discussion

1 Describe the pattern of masses and position from the fulcrum on both sides of the lever.
2 Define the term "mechanical advantage".
3 Calculate the mechanical advantage of the lever when the single mass on the left-hand side lifts the five masses on the right-hand side.
4 Identify another example of a first-class lever that you have used.

Conclusion

Draw and label a first-class lever and describe how to determine its mechanical advantage.

Lesson 3.14

Investigation: Using a second-class lever to lift masses

Purpose

To investigate how changing the distance of the load from the fulcrum affects the mechanical advantage of a second-class lever

Materials

- Shoebox
- Two spring balances
- Cardboard
- Sticky tape
- Two rulers
- Masses

Procedure

1 Write a hypothesis for your investigation.
2 Identify the independent variable (what you are changing between the two conditions) and the dependent variable (what you will measure and/or observe).
3 Identify two variables that you will need to control to ensure a reasonable test. Describe how you will control these variables.
4 Use sticky tape to stick the rulers together in a "V" shape.
5 Divide the shoebox into two compartments using the cardboard.
6 Attach the box on the top of the rulers so that it looks like a wheelbarrow with front and rear compartments, thereby making a second-class lever. The rulers are the handles of the wheelbarrow.
7 Add the mass to the front of your second-class lever.
8 Hook the spring balances to the wheelbarrow handles at the end.

9 Pull up on the spring balances to lift the load.
10 Record the total effort force required to lift the load. (Note: This is the sum of the readings from the two spring balances.)
11 Repeat this measurement three times.
12 Add the mass to the rear of your second-class level.
13 Repeat steps 8 to 11.

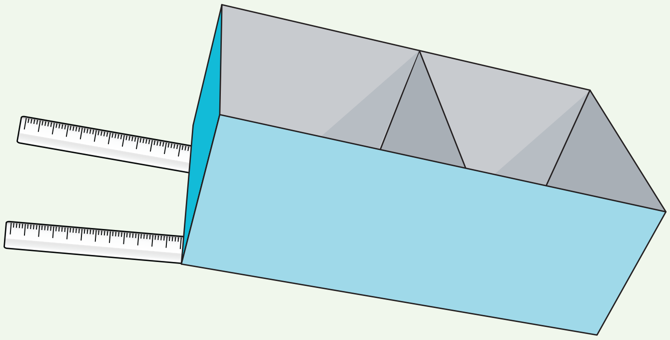


Figure 1 Investigation set-up of a second-class lever

Results

1 Copy and complete Table 1 to show the effort required when the front of the wheelbarrow, closer to the fulcrum, is loaded.

2 Copy and complete Table 2 to show the effort required when the rear of the wheelbarrow is loaded.

3 Use the average total effort to calculate the mechanical advantage for each condition (when loaded in the front and when loaded in the rear).

Discussion

1 Explain why you repeated each measurement three times.

2 Describe the difference in total effort required when the mass was shifted further from the fulcrum on the second-class lever.

3 Use the data from your experiment to explain the most effective way to load a wheelbarrow.

Conclusion

Describe how the distance of the load from fulcrum can affect the mechanical advantage of a second-class lever.

Table 1 The effort required when the front of the wheelbarrow is loaded.

	Spring balance 1 (N)	Spring balance 2 (N)	Total effort (N)
Attempt 1			
Attempt 2			
Attempt 3			
Average			

Table 2 The effort required when the rear of the wheelbarrow is loaded.

	Spring balance 1 (N)	Spring balance 2 (N)	Total effort (N)
Attempt 1			
Attempt 2			
Attempt 3			
Average			

Lesson 3.15

Investigation: Calculating mechanical advantage

Purpose

To see how the number of pulleys affects the size of the effort needed to lift a load and the distance this load travels

Materials

- Retort stand
- 500 g mass
- Spring balance
- Sets of pulley systems (two-, three- and four-pulley systems)
- String

Procedure

1. Use the spring balance to measure the weight of the 500 g mass.
2. Set up a pulley system using one pulley. Attach the spring balance as shown in Figure 1.
3. Pull on the spring balance to raise the load by 10 cm.
4. Record the average reading on the spring balance in newtons.
5. Calculate the mechanical advantage of the pulley arrangement.
6. Repeat Steps 2 to 4 with a two-pulley system.
7. Repeat Steps 2 to 4 with a three-pulley system.
8. Repeat Steps 2 to 4 with a four-pulley system.

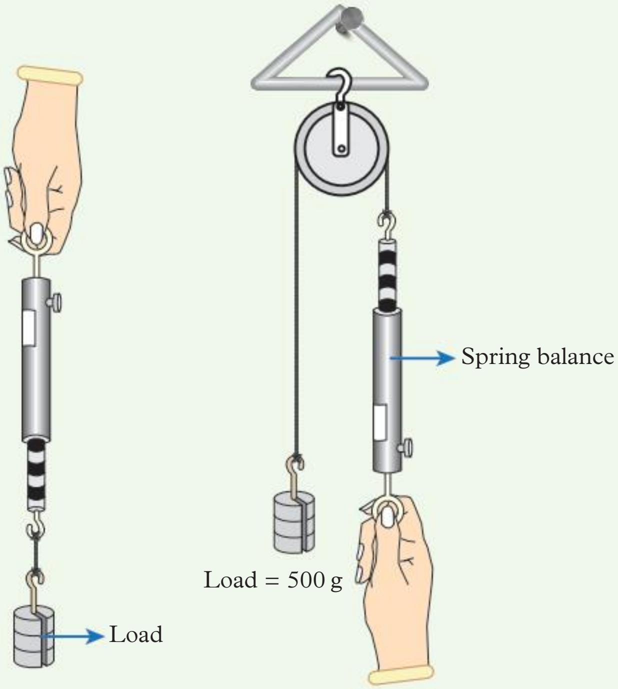


Figure 1 Pulley system set-up

Results

1. Copy and complete Table 1.
2. Draw a column graph showing the

Table 1 The mechanical advantage of pulley systems

Number of pulleys	Effort reading on the spring balance (N)	Weight of the load (N)	Mechanical advantage (load ÷ effort)
1			
2			
3			
4			

relationship between the number of pulleys and the mechanical advantage.

4 Calculate the effort that is needed to lift a load of 500 N through six pulleys.

Discussion

1 Describe how adding more pulleys changed the effort needed to lift the load.

2 Compare the distance the effort moves with the distance the load moves.

3 Calculate the effort that is needed to lift 500 N with five pulleys.

Conclusion

Describe how the number of pulleys affects the size of the effort and the distance moved by the load.

Lesson 3.16

There are different types of machines

Learning intentions and success criteria

Key ideas

- → Inclined planes such as ramps can provide a mechanical advantage.
- → A wedge or screw can reduce the effort needed to split or enter an object.
- → A wheel and axle is a special lever that turns about a fulcrum.

Introduction

Many different machines have been developed through the centuries that make less work for us. Ancient Greek mathematician Archimedes (*c.* 287–212 BCE) developed a screw that carried water to the top of a house. The screw was just a hollow pipe with an inclined plane (a simple machine) wound around the inside (Figure 1).

In addition to pulleys and levers, other simple machines are the wheel and axle, ramps, wedges and screws.

Figure 1 Archimedes' screw

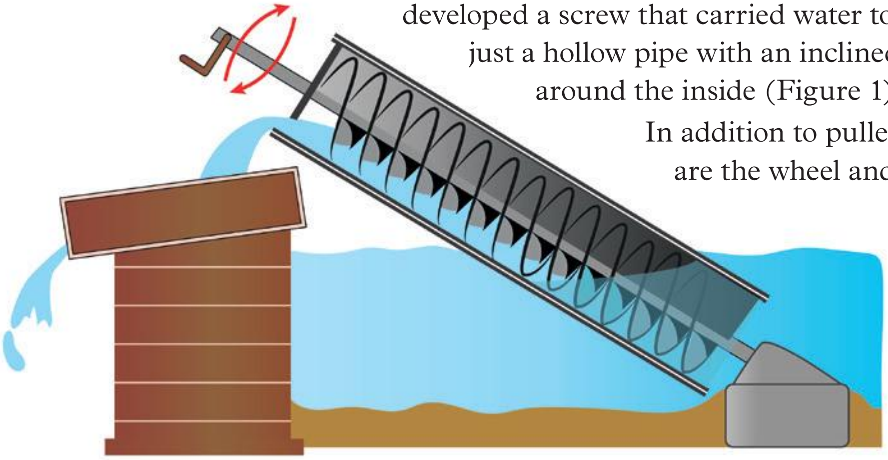


Figure 2 A skateboard ramp is an example of an inclined plane.

Ramps

Ramps are the simplest type of inclined planes. A **ramp** is used to lift heavy objects (the load) up to a higher level. For example, a piano mover might use a ramp to get a piano from the ground onto a truck. Ramps are used to bridge gaps between uneven surfaces. Escalators are moving ramps with steps (Figure 3). A ramp is called a simple machine because it makes moving a load easier. Going up the ramp might take longer than a single step up, but it requires a lot less force from your legs.

ramp a sloping surface joining two different levels

Wedges

A **wedge** is an inclined plane that moves through another object and changes the direction of a downward force to a sideways force. An axe is a wedge. When an axe hits a log, the downward force is changed to a sideways force, which splits the log (Figure 4).

Humans discovered the benefits of wedges when they used the jagged edges of rocks to cut animal flesh and skin. It is more than likely that you have used a wedge today: a knife is a wedge and so are your teeth. Each small tooth in a zip is a tiny wedge that fits tightly with the adjacent teeth.

wedge a piece of wood, metal or other substance that tapers to a thin edge and is driven between two objects or parts of an object to secure or separate them

Figure 3 An escalator is an example of a ramp.

Figure 4 An axe is an example of a wedge.

Screws

screw a sharp-pointed metal object with a spiral thread running along its length and a slotted head

thread the spiral ridge of a screw

You might be surprised to know that a **screw**, like the wedge and the ramp, is also an inclined plane (Figure 5). The indent that spirals around a screw, called the **thread**, looks almost like a road (a ramp) spiralling up the side of a mountain. Screws penetrate materials such as wood or cork by using the turning effect of a force. The effort needed to turn a screw into an object is much less than that required to hammer the screw into the same object.

Figure 5 Corkscrews are used to pull the cork out of a bottle and are an example, surprisingly, of an inclined plane.

Wheel and axle

If you have used a circular door handle or travelled in a car, bus or train today, you have used a wheel-and-axle simple machine. A wheel is a type of lever that turns in circles about its centre – the centre is the fulcrum or pivot point. An axle usually links the lever and the wheel. For example, when you turn a doorknob, you apply an effort force to the door handle and the axle exerts a force on the load (the latch), which opens the door.

wheel and axle a type of lever that can rotate about its centre, magnifying force or distance

A **wheel and axle** is sometimes a force magnifier. For example, you apply a small effort to a doorknob to move a larger load, the latch. This is because the outside edge of the wheel or doorknob moves a larger distance than the axle- or latch. A Ferris wheel is an example of a wheel and axle (Figure 6).

Wheel-and-axle machines can also act as distance magnifiers. When you pedal a bike, you apply a force to the pedals (Figure 7). This force causes the larger wheels to turn. The distance the wheel travels is much further than the distance the pedal travels. The distance has been magnified.

Figure 6 A Ferris wheel is an example of a wheel and axle.

Figure 7 A bike wheel is an example of a distance magnifier.

Check your learning 3.16

Check your learning 3.16

Retrieve

1 Name the six types of simple machines.

2 Identify a circular doorknob as either a force magnifier or a distance magnifier.

Analyse

3 Identify which of the following is not an inclined plane.

  a Knife used to cut bread
  b Screwdriver used to turn a screw
  c Nail driven into a piece of wood
  d Spear thrust into a tree

4 Identify the part of a circular doorknob that is a wheel and the part that is an axle. Draw a labelled diagram to support your answer.

5 Compare (the similarities and differences between) a wedge and a ramp.

Figure 8 A can opener is an example of a wheel and axle and is also a type of lever.

Apply

6 Discuss how the can opener shown in Figure 8 is acting as a wheel and axle by identifying the effort, load, fulcrum, wheel and axle.

Lesson 3.17

Investigation: Comparing different machines

Purpose

To determine the force magnification of different machines

Part A: Ramps

Materials

- 50 g mass (with a hook to attach to the spring balance)
- Ramp (30 cm ruler or a wider or longer piece of thin wood or plastic)
- Box (or pile of books or plastic tub upside down)
- Spring balance
- Metre ruler

Procedure

1 Measure and record the height of the box (or pile of books or plastic tub).

2. Using the spring balance, measure and record the force required to carefully lift the 50 g mass vertically at a constant speed on to the top of the box.
3. Repeat Step 2 several times and calculate the average force.
4. Position the ramp against the box and measure and record its length.
5. Slowly pull the 50 g mass up the ramp using the spring balance and record the force required.
6. Repeat Step 5 three times and calculate the average force.

Figure 1 A pile of books

Discussion

1. Identify the method – lifting or dragging up the ramp – that provided the greatest mechanical advantage. Justify your answer by using data from your experiment.
2. A student claimed that an inclined plane was not a machine. Use evidence from the experiment to evaluate the truth of this statement.

Part B: Wedges

Materials

- Two blocks of wood
- Two thick, tight rubber bands
- Wedge-shaped piece of wood

Procedure

1. Place the rubber bands over the two pieces of wood to hold them tightly together.
2. Try pulling the blocks apart with your hands.
3. Place the pointed edge of the wedge between the two blocks and push it in.

Discussion

Describe the advantage of using a wedge to separate the two blocks of wood.

Figure 2 A wedge

Part C: Screws

Materials

- G-clamp
- Two matchboxes filled with play dough

Procedure

1. Try crushing the matchboxes using only your fingers. Record your observations.
2. Place the matchboxes between the faces of the G-clamp and tighten it until it crushes them. Record your observations.

Discussion

1. Contrast the effort needed to crush the matchboxes using both methods.
2. Explain how the screw mechanism in the G-clamp provides a mechanical advantage in crushing the matchboxes.

Figure 3 A G-clamp

Part D: Wheels and axles

Materials

- Simple machine kit with a wheel-and-axle model or one made from LEGO® or K'NEX®
- Cotton thread or string
- Two weights

Procedure

1 Design and build your own working model of a simple wheel-and-axle machine.
2 Use cotton thread or string and two weights to demonstrate how your model can work as a force magnifier.
3 Modify your model or build another one to demonstrate how it can work as a distance magnifier.

Discussion

1 Contrast a force magnifier with a distance magnifier.
2 Describe the change you made for the second wheel-and-axle model.
3 Explain how the change affected the effectiveness of the second model compared with the first model.

Figure 4 A wheel and axle

Lesson 3.18

Science in context: The forces in flight

Introduction

Have you even seen or flown in an aeroplane? When you consider that it is a large metal tube weighing several tonnes, moving through the air, you realise that there must be some amazing forces involved. You can apply the forces you have learnt about in this module to understand how the wings of a plane keep the plane and people in the air.

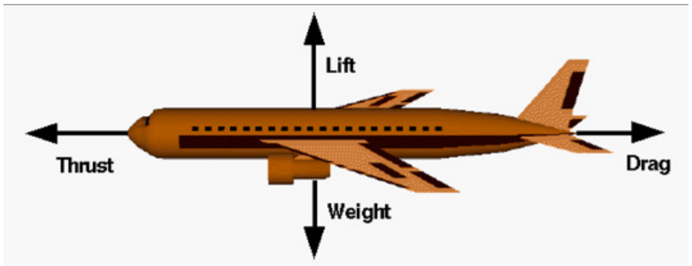


Figure 1 The four forces involved in flying a plane are lift, thrust, drag and weight.

There are four main forces involved in flying: lift, thrust, drag and weight (Figure 1). The thrust is the force produced by the engines of the plane. There may be a propeller, a jet engine or a rocket. All these engines pull in air and push it out the other end. This propels the plane forward.

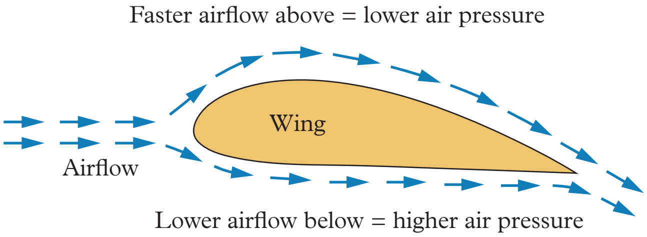


Figure 2 The shape of an aeroplane's wing generates high pressure under the wing and low pressure above the wing, which makes it easier for the wing to move upwards.

The drag is the force caused by the friction of air moving out of the way of the plane. It acts in the opposite direction of the thrust force and tends to slow the plane down.

The weight is the force caused by gravity pulling the plane to the centre of Earth. The greater the mass of the plane, the greater the force caused by gravity.

Lift is the force that holds the wings of the plane in the air. The lift force is generated when the plane moves forward and the air moves over the wings. The shape of the wings encourages the air to move up. This decreases the pressure of the air above the wing and reduces the forces pushing down. This makes it easier for the wing to move upwards. The air under the wing pushes up against the surface of the wing, generating a lift force (Figure 2).

When the lift and weight forces are balanced, the plane can stay in the air. When the forward thrust from the engine decreases, the airflow will slow down and reduce the lift on the wings. The weight of the plane does not change, so there will be unbalanced forces between the larger weight force and the smaller lift force. This means the plane will start moving down towards Earth.

Boomerang flight

One of the unique tools of Aboriginal and Torres Strait Islander Peoples is the boomerang. Its unique way of flying was researched by David Unaipon (1872-1967), a Ngarrindjeri man from the Coorong region in South Australia. You may recognise him from the Australian $50 note. As well as being the inventor of the modern method for shearing sheep, he was the first person to describe the forces involved in
of a boomerang, and in 1914, he developed the idea of a “vertical
g machine” based on his understanding of boomerang flight.

The boomerang's shape is similar to two plane wings joined together at an angle (Figure 3). The top surface of the boomerang generates low pressure, while the bottom surface generates high pressure. These combine to generate lift that keeps the boomerang in the air.

ing boomerang is thrown correctly, it will fly vertically. As it
the wing-shaped boomerang will be moving forward, while the
end will be rotating backwards. This means there are different air pressures generating lift and causing the boomerang to gradually turn and fly back to its original position. The boomerang flies vertically or upright with this balance of changing air pressures.

unique shape similar to the wings of an aeroplane.

Understanding how and why a boomerang flies meant that Aboriginal and Torres Strait Islander Peoples have been able to develop many types of boomerangs that fulfil different functions. Not all boomerangs are designed to return. Some were designed for hunting animals, while others were designed to generate noise to scare birds into flying into the air where they could be caught with a net or spear.

Test your skills and capabilities

Test your skills and capabilities 3.18

Using infographics

Presenting data to an audience can take many forms. An increasingly common way to present important information is an infographic. Infographics are visual ways to present data so that the viewer can easily see the patterns in the data. This can be through the use of graphs, pictures and important figures.

Select two of the sets of data in Figure 5 and Table 1 and develop an infographic that convinces your peers that flying in aeroplanes has become safer in the last 50 years.

1. Identify the key information in the set of data. For example, how many aeroplane crashes were there in 1972? How many crashes were there in 2020? When is the most dangerous part of the flight? Can you explain why?
2. Identify one possible reason why fewer accidents occur now.
3. Draw a picture that represents an aeroplane accident. Draw three different variations of the picture to represent more or fewer accidents.
4. Infographics use short phrases or sentences to pass on the key information. Select the important information that you want people to remember and write it in a short phrase or sentence.

Figure 4 Bicycle safety infographic

*Fatal accidents/incidents involving aircraft certified to carry 14 passengers or more.

Figure 5 Airliner accident fatalities by year from 1972 to 2020

Table 1 Fatal accidents and onboard fatalities by phase of flight (2008 to 2017).

Phase of flight	Fatal accidents	Onboard fatalities
Parked (taxi), load/unload	5	0
Take-off	4	160
Initial climb	4	18
Climb (flaps up)	3	92
Cruise	6	515
Descent	2	74
Initial approach	4	399
Final approach	15	730
Landing	12	273

Lesson 3.19

Review: Forces

Summary

Lesson 3.1 A force is a push, a pull or a twist

- A force is a push or pull that happens when two objects interact.
- The effect of a force can be measured, and it can be represented in a force diagram.
- The force of gravity affects the movement of objects on Earth.

Lesson 3.3 An unbalanced force causes change

- Forces on an object are balanced when they are pushing or pulling equally in opposite directions.
- If the forces on an object are unbalanced, then the object will change its speed, direction or shape.

Lesson 3.4 Electrostatic forces are indirect forces

- Direct (contact) forces involve two objects touching each other.
- Indirect (non-contact) forces occur when one object can push or pull another object without touching it.
- Rubbing two objects together can cause an electrostatic force.
- Like (two positive or two negative) charges repel.
- Unlike charges attract.
- Charged objects attract uncharged objects.

Lesson 3.5 Gravity is a force existing between objects

- The Earth's force of gravity can cause an indirect force.
- Large objects (such as planets, moons and stars) pull objects towards their centre.

Lesson 3.6 Gravity affects all objects in space

- Earth's gravity constantly pulls the Moon towards its centre, resulting in its orbit around Earth.
- A planet's gravity causes moons to orbit it.
- A star's gravity causes planets to orbit.
- A black hole‘s gravity causes galaxies to orbit and prevents light from escaping.

Lesson 3.7 Magnets can repel or attract each other

- Magnetism is an example of an indirect force.
- Magnets have two magnetic poles: north and south.
- Like poles repel and unlike poles attract.

Lesson 3.9 Magnetic fields can apply a force from a distance

- A magnetic field is the area around a magnet where a magnetic force is experienced.
- A magnetic field cannot be seen, but we can see the way it interacts with other objects.
- The further away an object moves from the magnet, the weaker the magnetic field.

Lesson 3.11 Simple machines decrease the amount of effort needed to do work

- A lever is a solid rod with a turning point.
- Levers provide a mechanical advantage of force or distance.
- All levers need an effort (force used), a fulcrum (turning point) and a load (the section being moved).
- Levers can be divided into first-class, second-class or third-class levers.

Lesson 3.12 A pulley changes the size or direction of a force

- A pulley is a simple machine that makes it easier to lift an object.
- Pulleys are wheels with a groove along their edge.
- The wheel is used to change the size or direction of the force used.

Lesson 3.16 There are different types of machines

- Inclined planes such as ramps can provide a mechanical advantage.
- A wedge or screw can reduce the effort needed to split or enter an object.
- A wheel and axle is a special lever that turns about a fulcrum.

Review questions 3.19

Review questions Module 3

Retrieve

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

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

3 Recall what will happen if the north poles of two magnets are pushed together.
  A They will repel.
  B They will attract.
  C They will remain where they are.
  D They will move sideways.

4 Recall why a person jumping on a trampoline may have their hair standing out from their head.

Comprehend

5 Create a force diagram of a bike rider moving forward. Include the following forces on your diagram: pedalling force 400 N, air resistance 50 N, tyre resistance 50 N, weight 750 N.

6 Recall the terms to copy and complete the following sentences.
  a A force is a ________ or a ________ between ________ objects.
  b To measure a force, you can use a ________ ________.
  c The unit used to measure forces is called a ________. Its symbol is ________.
  d When an object is not moving, its forces are said to be ________. Evidence of an unbalanced force is a change in ________, ________ or ________.

7 Identify which of the following examples involves forces. Explain the forces involved.
  a Opening a window
  b Turning a screw with a screwdriver
  c Smelling food cooking
  d Modelling clay
  e Standing on a diving board
  f Watching a candle burn

8 Explain how mechanical advantage is calculated.

9 Your mass at a given time remains the same, regardless of the force of gravity. Your weight, however, changes because of the force of gravity.
  a Explain why the mass of any object is not changed by the force of gravity.
  b Explain why the weight of an object sometimes changes.

10 Describe what happens to the magnetic properties of a magnet when it is broken into two.

11 Explain what a first-class lever is and provide an example of one.

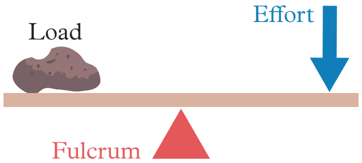


Figure 1 A first-class lever

12 Explain what a second-class lever is and provide an example of one.

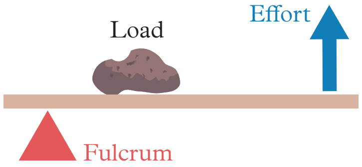


Figure 2 A second-class lever

13 Explain what a third-class lever is and provide an example of one.

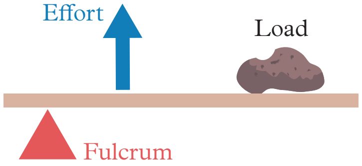


Figure 3 A third-class lever

14 Describe the four main forces involved in flying. Draw a force diagram to represent these forces. Use the size of the arrows to show the plane moving forwards at a constant speed.

15 When skydivers step out of an aeroplane, they begin to fall towards the Earth. Describe the forces acting on the skydivers. Draw a force diagram of these forces. Use the size of the arrows to show that the skydivers are falling.

Analyse

16 Consider the pulley system in Figure 4. Calculate the effort needed to lift the 100 N load.

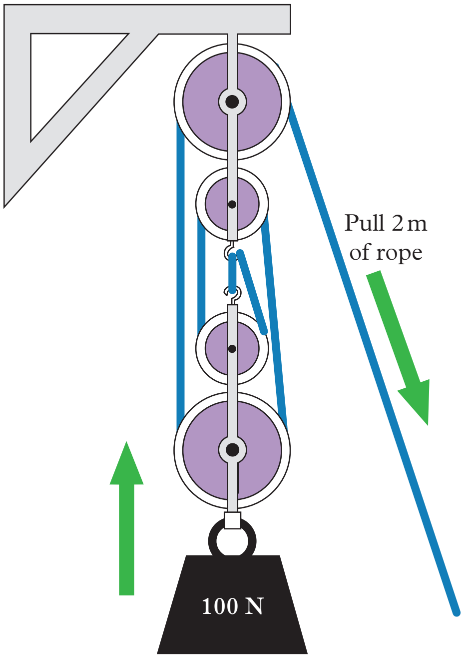


Figure 4 A pulley system

17 Compare a direct force and an indirect force.

18 Compare a lever and a pulley.

Apply

19 Figure 5 shows what happens when you stand on your toes.

- **a** Identify the type of lever that is formed by the foot when you do this.
- **b** Discuss why this lever is a force magnifier.

Figure 5 Standing on your toes

20 Evaluate the kicking action of a soccer player.

- **a** Draw a picture of a leg kicking a ball. On your diagram, identify which of the muscles are involved in moving the foot.
- **b** Identify the class of lever that is formed by the muscle and bone attachments.
- **c** Identify the lever as a force magnifier or a distance magnifier.

21 Evaluate the action of an Olympic shot-putter.

- **a** Explain why the athlete bends backward just before releasing the shot.
- **b** Identify the class of lever that is formed by the upper torso.
- **c** Identify as many levers acting as possible. Label each lever as first, second or third class.

22 Discuss how the motion of an aeroplane will change (rise, fall, slow or accelerate) when:

- **a** lift becomes greater than weight
- **b** drag becomes greater than thrust
- **c** weight becomes greater than lift
- **d** thrust becomes greater than drag.

Social and ethical thinking

23 Understanding the forces involved in a flying aeroplane means that we can modify the design of the aeroplane to make it more efficient.

- **a** Describe how streamlining (Figure 6) will affect the amount of fuel used to generate thrust force.

- **b** Use the information in part **a** to explain how the environment could benefit from understanding the forces involved in flight.
- **c** Describe how using less fuel could affect the cost (the economics) of people flying in an aeroplane.
- **d** Use the information in part **c** to discuss how using less fuel could affect people's ability to maintain contact with their friends and family (social factors).

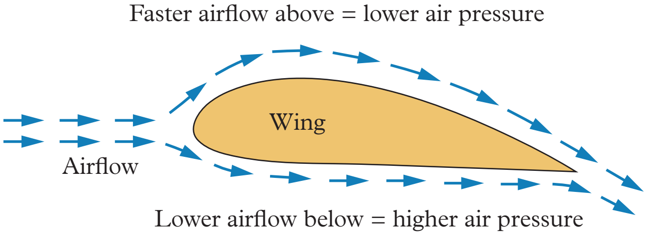


Figure 6 Streamlining makes aeroplanes more efficient.

Critical and creative thinking

24 Create an infographic poster that encourages people to wear their seatbelt when in a car. Use your knowledge of forces to illustrate the dangers of not wearing a seatbelt when in an accident.

Research

25 Select one of the following topics on which to conduct further research. Present your findings in a format that best fits the information you have found and the understandings you have formed.

Musical instruments

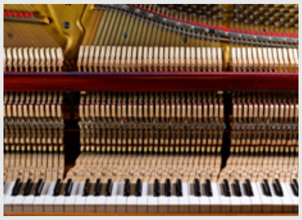


Figure 7 Levers are part of piano keys.

Musical instruments often use simple machines to make it easier for the musician to play. Different types of machines are used in a piano, drum kits, the keys of a string instrument and brass instruments. Select one of these instruments and consider the following questions.

- Describe the machine you have identified.
- Describe how the musician uses the machine.
- Describe how the machine makes it easier for the musician playing the instrument.

Careers in the space industry

Figure 8 Becoming an astronaut is only one career available in the space industry.

Astronauts are people who work outside Earth's atmosphere. Not all astronauts are pilots. Some are flight specialists, flight engineers, botanists, computer specialists or payload specialists.

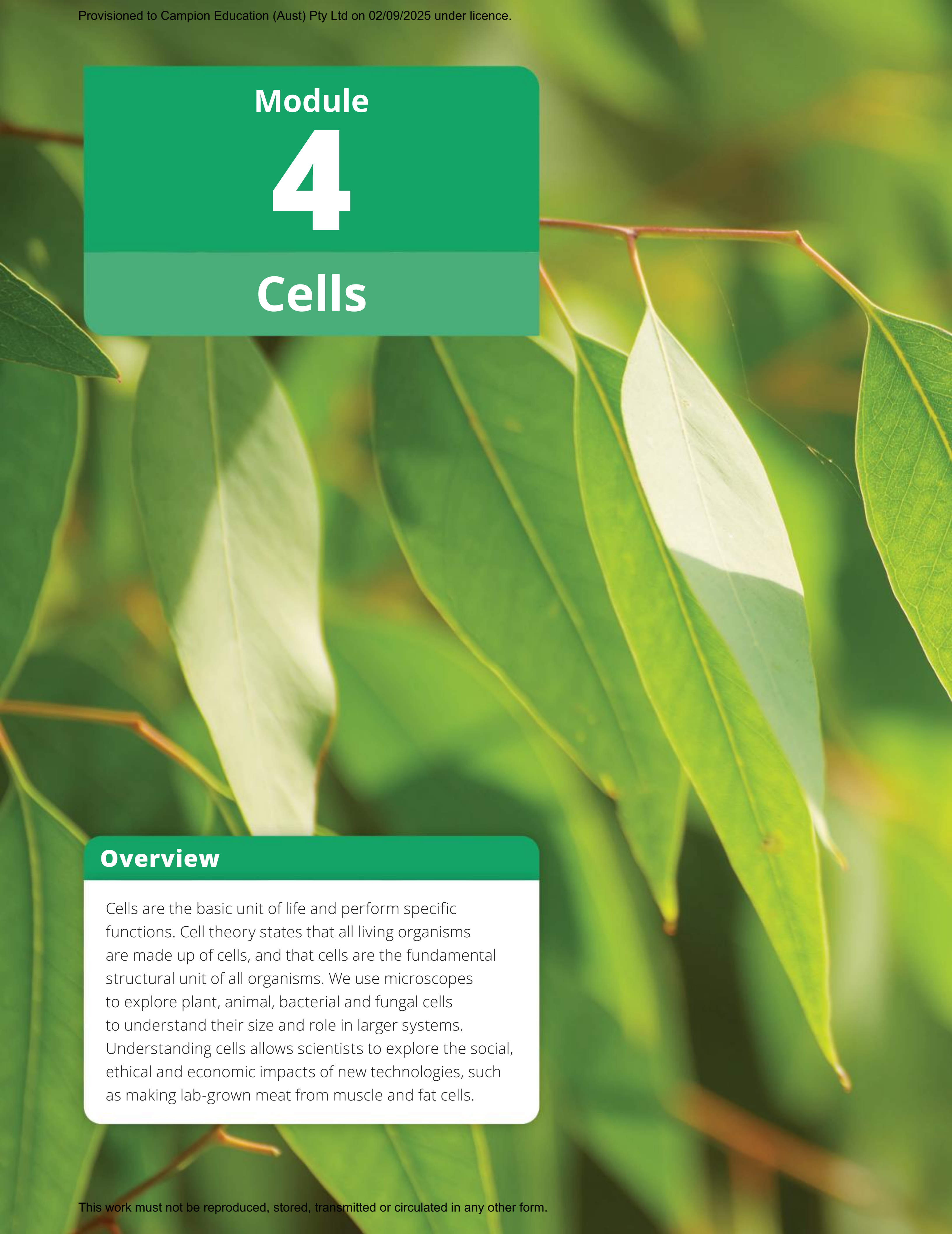
- Research one of the careers involved in space programs around the world.
- Describe the qualifications you need to work in this area.
- Describe the things you would do in an average day.
- Describe the most challenging part of the job.

Spear throwers

Investigate spear throwers that are used in different parts of Australia.

- Identify what the spear throwers are made from.
- Identify the different names of spear throwers and in which parts of Australia they are usually produced.
- Describe the different shapes of each spear thrower.
- Describe how the spear throwers are used.
- Use your understanding of forces and machines to describe how a spear thrower works.

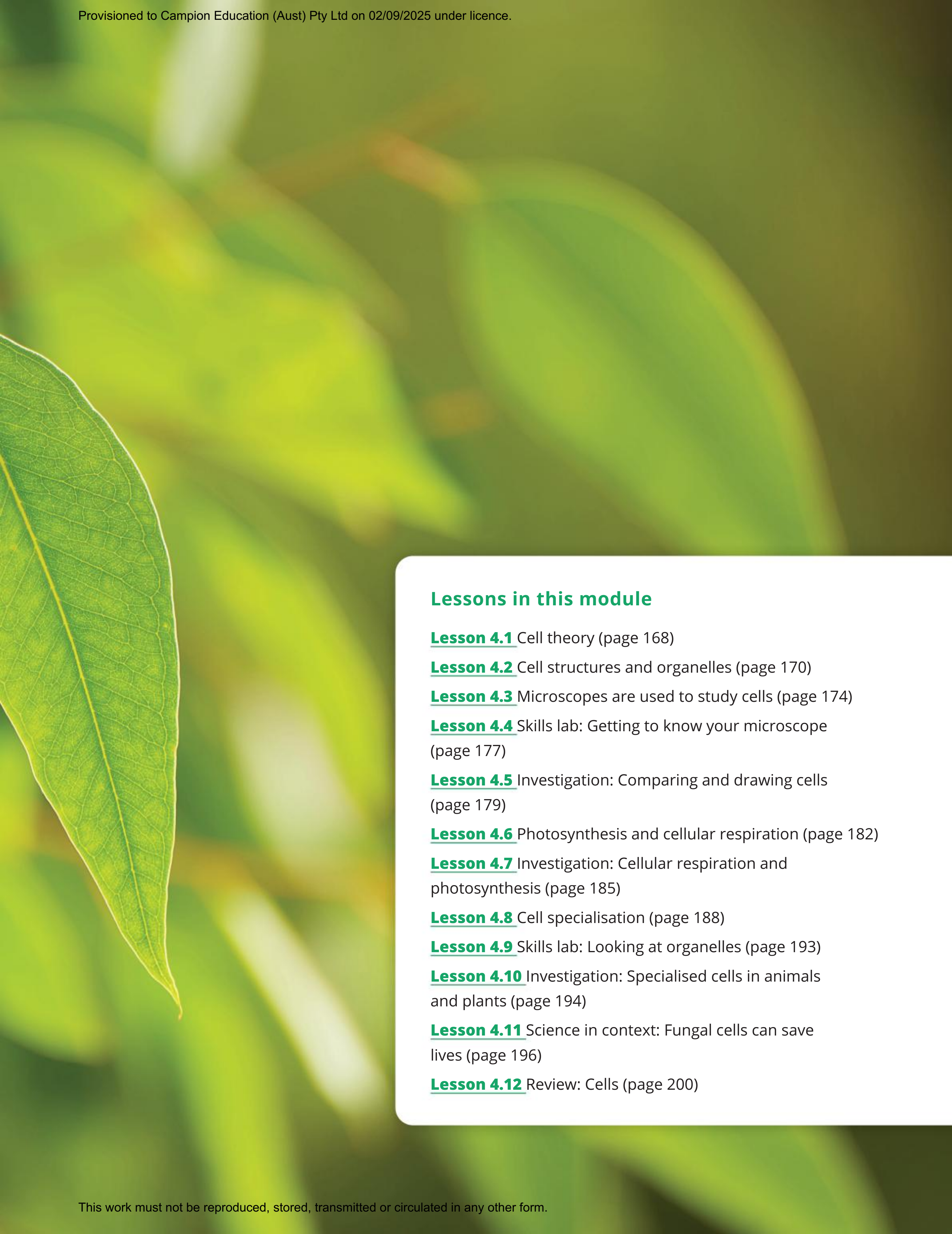
Figure 9 A spear thrower



Module
4
Cells

Overview

Cells are the basic unit of life and perform specific functions. Cell theory states that all living organisms are made up of cells, and that cells are the fundamental structural unit of all organisms. We use microscopes to explore plant, animal, bacterial and fungal cells to understand their size and role in larger systems. Understanding cells allows scientists to explore the social, ethical and economic impacts of new technologies, such as making lab-grown meat from muscle and fat cells.



Lessons in this module

Lesson 4.1

Cell theory

Learning intentions and success criteria

Key ideas

→ All living things are made up of cells.

→ Cells are the basic unit of life and structure.

→ All living cells are created from existing cells.

cell the smallest unit of life

microbiology the science involving the study of microscopic organisms

cell theory theory describing the properties that all cells have in common

Introduction

Scientists have not always known that living things are made up of cells. It was the invention of the microscope in the mid-seventeenth century that allowed us to see the building blocks of life – the tiny units that form every living thing. Microscopes showed that each and every living thing is made up of **cells**.

Discovering cells

When English physicist Robert Hooke (1635–1703) published his book *Micrographia* in 1665, it became a bestseller. Hooke had made one of the first microscopes. With it, he observed many types of living things and made accurate drawings of what he saw.

Hooke's most famous achievement was his diagram of very thin slices of cork (Figure 1). He was surprised to see that, under the microscope, the cork looked like a piece of honeycomb with "holes". He called the small "hole-like" structures "cells" because they reminded him of the small rooms in a monastery which were also called cells. Hooke had discovered the first plant cells.

Although some called *Micrographia* "the most ingenious book ever written", others ridiculed Hooke for spending so much time and money on "trifling pursuits". Thankfully for us and for the whole science of **microbiology**, Hooke ignored the name-calling and kept experimenting with microscopes. It was because of Hooke's contribution to microbiology that other scientists went on to develop a further understanding of cells.

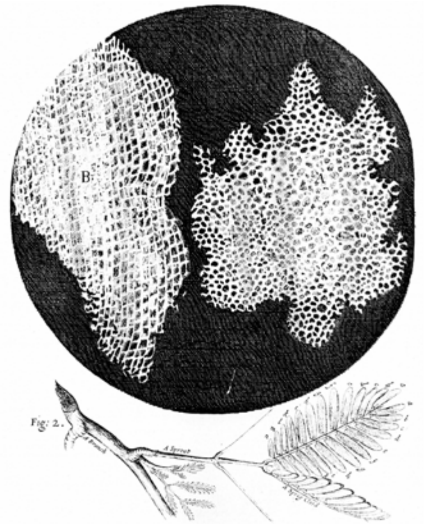


Figure 1 Robert Hooke's drawing of cork

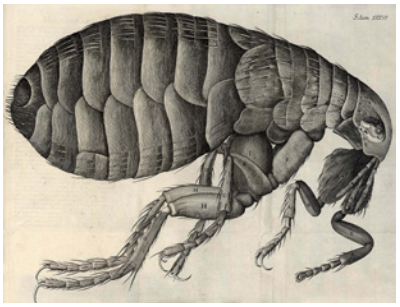


Figure 2 Robert Hooke's detailed drawing of a flea

Cell theory

Cell theory describes the properties of cells and their role in living things. It was first proposed in 1839 by two German biologists, Theodor Schwann (1810–1882) and Matthias Schleiden (1804–1881). In 1858, Rudolf Virchow (1821–1902) concluded the final part of the classic cell theory. The combined cell theory included the following principles:

- All organisms are composed of one or more cells.

- Cells are the basic unit of life.
- New cells are created from existing cells.

Any living thing that has more than one cell is referred to as **multicellular** (Figure 3A). There are many living things, such as bacteria, that consist of only one cell. These are called **single-celled** or unicellular organisms (Figure 3B). **Microorganisms**, which are also often referred to as microbes, are organisms that can only be seen under the microscope – and they can be single-celled or multicellular.

multicellular consisting of two or more cells

single-celled an organism that consists of only one cell; also called a unicellular organism

microorganism a living thing that can only be seen with the use of a microscope

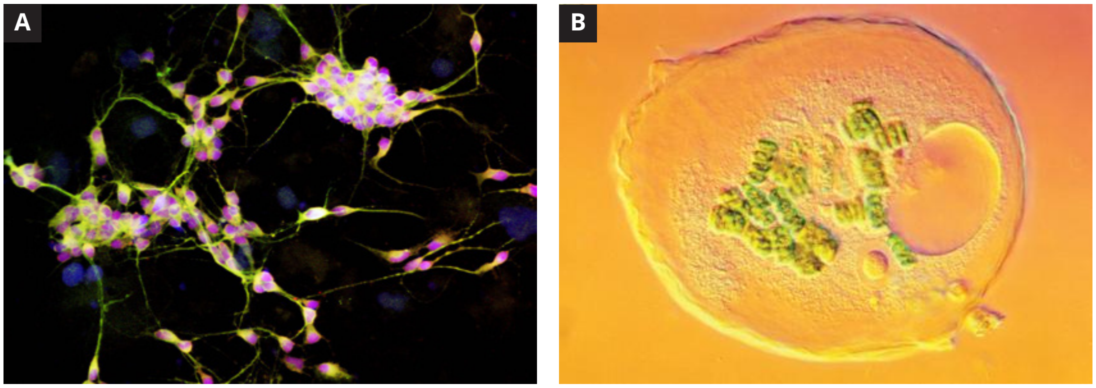


Figure 3 (A) Human nerve cells are one of the many types of cells that are in our multicellular bodies; but (B) the amoeba is a single-celled organism.

Why are cells so small?

The outside surface of a cell is called the **cell membrane**. It controls what can move in (nutrients) or out (waste) of the cell. Large cells have more difficulty staying alive than small cells. Large cells need to move nutrients a long way to reach the centre of the cell and face the same challenge moving waste to the outside. Small cells do not need to make the nutrients or waste travel as far and this makes it easier for all parts of the small cell to stay healthy and alive.

The total space inside the cell is referred to as the cell's volume, while the size of the membrane is called the surface area. As a cell increases in size, both its volume and its surface area increase. The problem is, the volume increases much more than the surface area. Eventually, the volume becomes so big that it is difficult for nutrients to move into the centre of the cell and for wastes to move out. We compare the relationship between the amount of surface area and the volume of a cell through a fraction – the **surface area to volume ratio**. Small cells have a large surface area compared to their volume (a large surface area to volume ratio) and are therefore better able to survive. This explains why single-celled organisms are so small. A single cell must do all the same things that a larger organism does (Figure 4).

cell membrane the barrier around a cell that controls the entry and exit of substances into and out of a cell

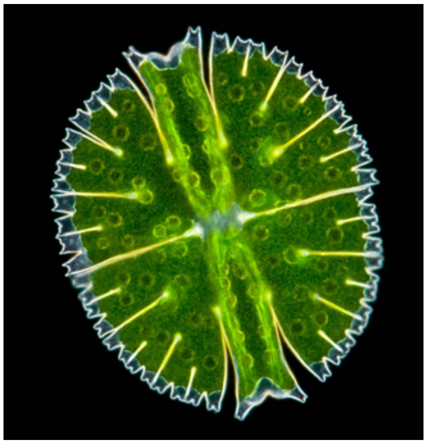


Figure 4 The irregular shape of this single-celled organism (called a desmid) maximises the surface area to volume ratio.

The cell membrane is particularly important because it provides a barrier between the inside of the cell and the external environment. All the nutrients needed to keep the cell alive, and the waste products made by the cell, are transported across the cell membrane. It is essential that the cell membrane provides a large surface area for the transport of so many molecules into and out of the cell.

surface area to volume ratio the relationship between the area around the outside of a cell and its volume, as a fraction

Check your learning 4.1

Check your learning 4.1

Retrieve

1 Name the person who invented the first microscope.

2 Recall why cells are called "cells".

3 Define the terms "unicellular" and "multicellular".

4 Identify two unicellular and two multicellular organisms.

5 Identify two things that all single-celled organisms have in common.

6 State the three principles of cell theory.

Comprehend

7 The common house dust mite is a microorganism. Recall whether you would be able to see this animal without a microscope. Explain your answer (by defining the term "microorganism" and linking the definition to the need for a microscope).

8 Explain whether a cell with a bigger surface area to volume ratio would be able to meet its requirements for nutrients effectively.

9 Explain why single-celled organisms are very small.

Skills builder: Communication

10 Construct a scaled timeline to show the contribution of different scientists to the development of cell theory. (THINK: What information do you need to include to help someone understand the development of cell theory over time?)

Lesson 4.2

Cell structures and organelles

Learning intentions and success criteria

Key ideas

→ All cells have a cell membrane, cytoplasm and genetic material (DNA).

→ All plant and animal cells are made up of smaller parts called organelles (mini organs).

→ Each organelle has a different function.

organelle a specialised sub-unit within a cell that has a specific function

cell membrane the barrier around a cell that controls the entry and exit of substances into and out of a cell

Introduction

A cell is the basic unit of life. It is called this because it is the smallest unit of an organism that is considered living. But, just as the basic unit of length – the metre – can be broken down into smaller parts (such as centimetres and millimetres), the cell is made up of smaller parts too. Cells are made up of **organelles** (mini organs), cytoplasm, DNA, nutrients, wastes and other substances.

Cell structures

All cells, regardless of which type of organism they are found in, share the same basic structure (Figure 1). This basic structure includes three key features:

- **Cell membrane**: This acts like the "skin" of a cell, forming a barrier around the cell. It controls the entry and exit of things into and out of the cell.
- **Cytoplasm**: This is the jelly-like fluid and structures inside the cell membrane. It helps provide structure to the cell and contains many dissolved nutrients and waste products.
- **DNA** (deoxyribonucleic acid): This contains the genetic instructions for the proteins that are produced in important cell structures called **ribosomes** (Figure 2). Proteins are small molecules, each with a different role. Types of proteins include structural proteins (such as hair and nails) and globular proteins (such as haemoglobin, which is found in red blood cells and helps transport oxygen through the bloodstream). Other proteins are involved in chemical reactions and supporting cell structure.

cytoplasm the jelly-like substance inside cells that helps to maintain the structure and facilitate the movement of materials within the cell

DNA (deoxyribonucleic acid) a molecule that contains all the instructions for every job performed by the cell; this information can be passed from one generation to the next

ribosome non-membrane enclosed organelle required for protein synthesis

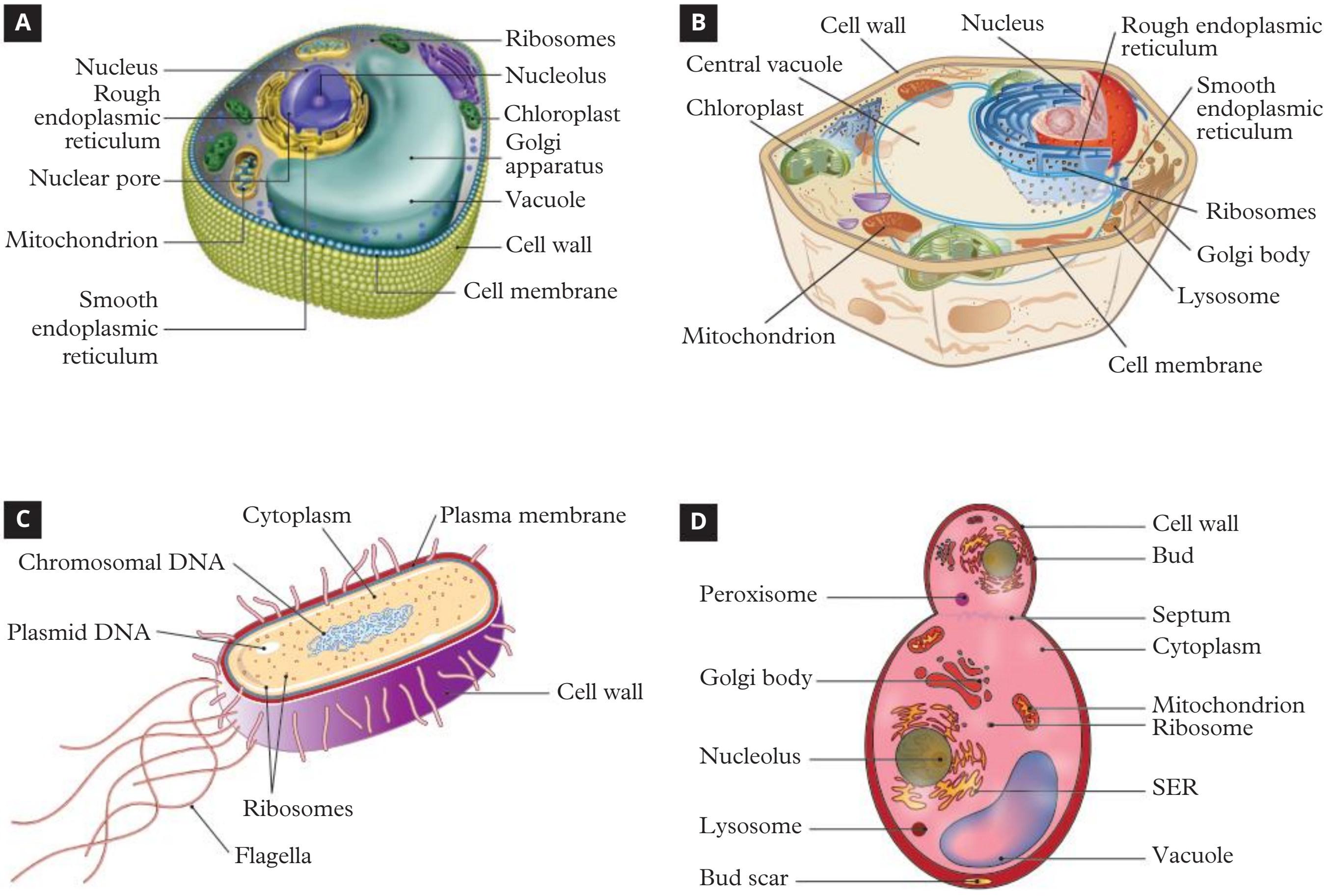


Figure 1 Basic cell structure of (A) an animal cell; (B) a plant cell; (C) a bacterial cell and (D) a fungal cell.

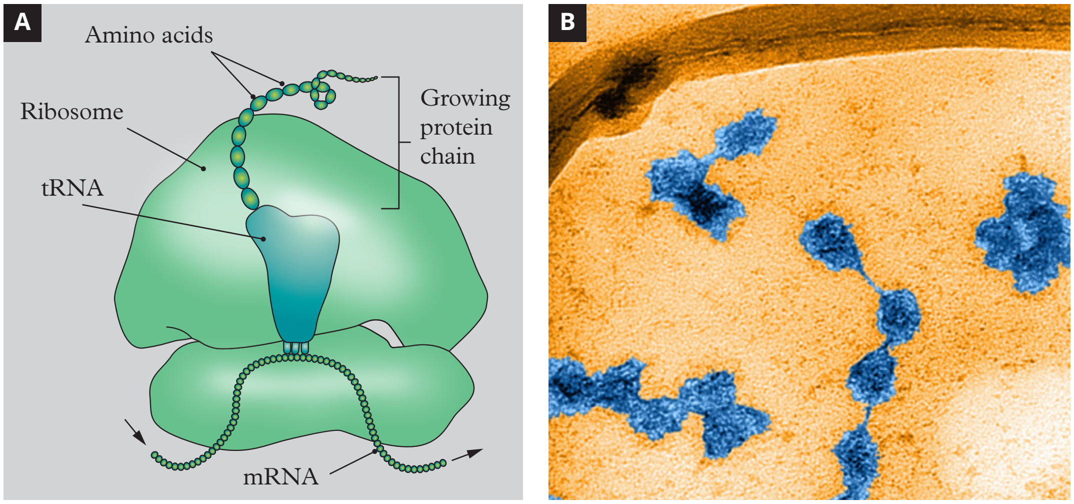


Figure 2 (A) A schematic diagram showing the structure of a ribosome; (B) an electron micrograph of ribosomes

cell wall a structure that provides support around the cell in some organisms, such as plants and fungi

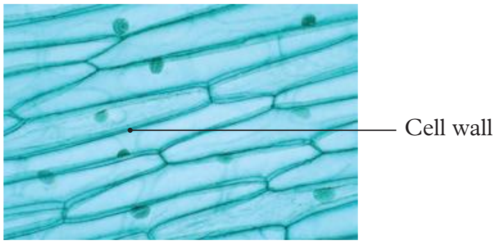


Figure 3 Light micrograph of plant cells showing the cell walls

One cell structure that can be used to distinguish certain cell types is the **cell wall**. Cell walls are found around the outside of plant cells, fungal cells and bacterial cells (Figure 3). They are not found in animal or human cells. The cell wall is important for helping the cell keep its shape, especially in freshwater. Freshwater can easily enter a cell, making the outside membrane swell and possibly burst. If the cell is surrounded by a cell wall, the membrane cannot burst.

A closer look at organelles

The cells of many organisms contain specialised membrane-enclosed structures called organelles (mini organs). Each of these organelles, such as the nucleus, chloroplasts and mitochondria, have a specific function and are essential for the cell's survival (Figure 1A and Figure 1B).

Let's take a closer look at four important organelles – the nucleus, chloroplasts, mitochondria and vesicles – and how they compare between animal and plant cells.

nucleus a membrane-bound structure in cells that contains most of the cell's genetic material

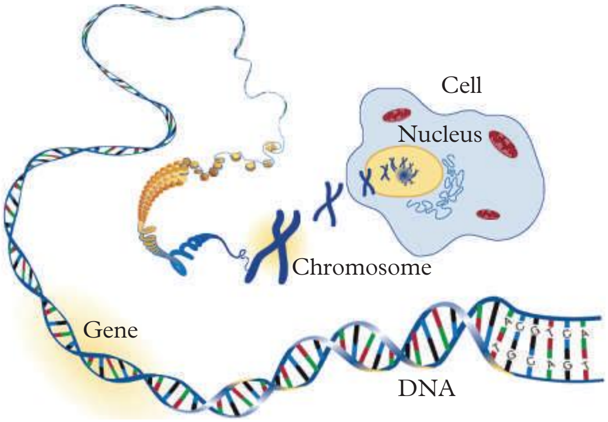


Figure 4 The nucleus contains chromosomes which are made of DNA – the genetic blueprint of life.

Nucleus

Both animal and plant cells have a **nucleus**, often called the control centre of the cell. It contains chromosomes which are made of DNA and it coordinates the cell's activities (Figure 4). The nucleus is surrounded by a nuclear membrane to separate it from the rest of the cell. In humans, the nucleus contains 46 chromosomes. Half of your chromosomes came from your mother, and the other half came from your father. The same complete set of DNA is found in every one of your cells, with a few exceptions: red blood cells and sex cells.

Chloroplasts

Chloroplasts are only found in plant cells and some unicellular organisms (Figure 5). These organelles are like microscopic solar panels that transform solar energy into chemical energy.

Chloroplasts are usually green because of a molecule called chlorophyll. Chlorophyll uses the Sun's light energy to rearrange molecules of carbon dioxide and water into glucose (a sugar) and oxygen. This chemical reaction is called **photosynthesis**. Photosynthesis is explained in more detail in Lesson 4.6 Photosynthesis and cellular respiration (page 182).

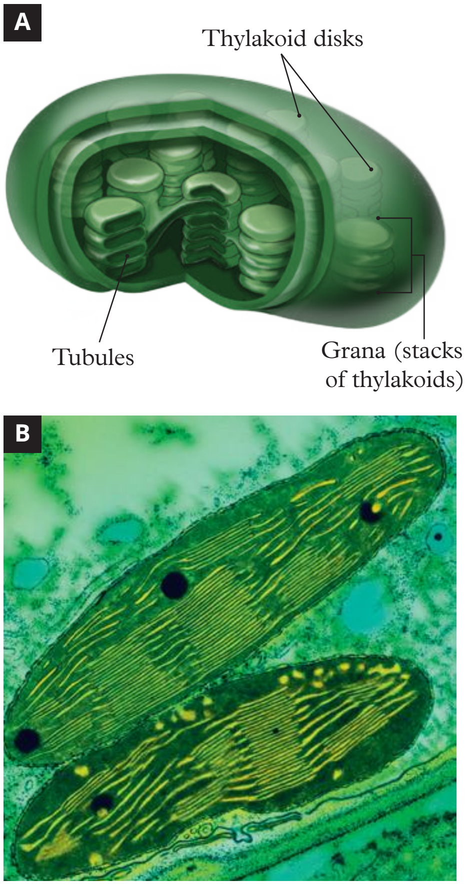


Figure 5 (A) Schematic diagram showing the structure of a chloroplast; (B) an electron micrograph of chloroplasts

photosynthesis the chemical reaction used by plants to convert carbon dioxide and water into glucose

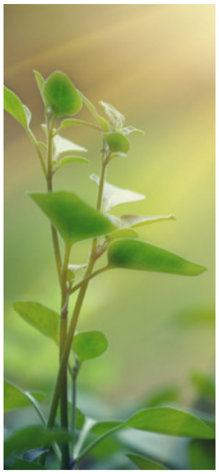


Figure 6 The chlorophyll in plants uses the Sun's light energy to create glucose and oxygen in a chemical reaction called **photosynthesis**.

Mitochondria

Both animal and plant cells also contain **mitochondria** (singular "mitochondrion"). They are the powerhouse of the cell (Figure 7).

Mitochondria are the site of energy production in the cell. There may be several thousand mitochondria in a cell, depending on what the cell does. For example, skeletal muscle cells contain a lot of mitochondria to make sure we have enough energy to run and jump when we need to.

Mitochondria are rod-shaped organelles with an inner and an outer membrane. The inner membrane is folded to increase the surface area of the membrane. An important chemical reaction called **cellular respiration** occurs inside the mitochondria.

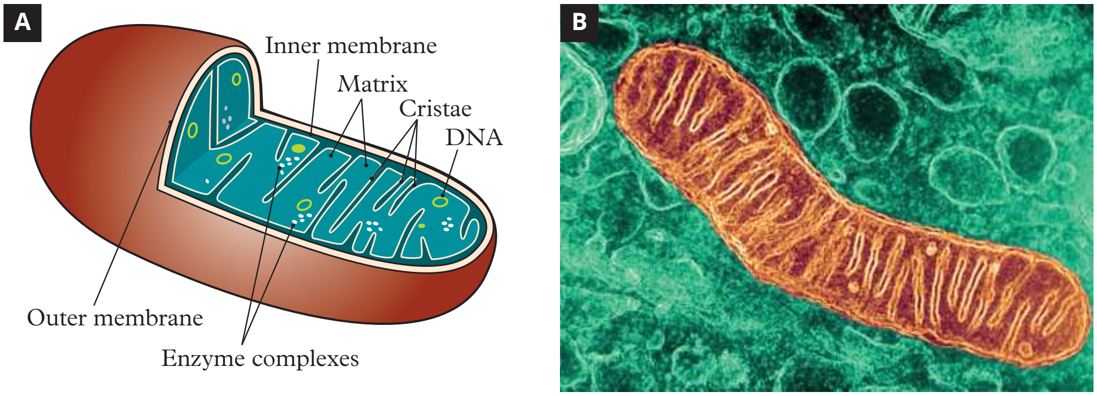


Figure 7 (A) Schematic diagram showing the structure of a mitochondrion; (B) electron micrograph of a mitochondrion

mitochondria the organelle in which cellular respiration occurs

Vesicles

Vesicles are organelles that are used by plant and animal cells to store water, nutrients and waste products. A membrane surrounds the vesicle, separating the substances from the rest of the cell. Plant cells usually have one large vesicle called a **water vacuole**. Animal cells may have many small vesicles.

vesicle an organelle surrounded by a membrane and used by cells to store materials; a vacuole is a type of vesicle found in plant cells

Check your learning 4.2

Check your learning 4.2

Retrieve

1 Recall the function of the cell membrane.
2 Name the organelle where cellular respiration occurs.
3 State three things that are stored in a vacuole.
4 Identify three organelles that are surrounded by a membrane.

Comprehend

5 Describe the features of all living cells. (HINT: Remember MR N GREWW)
6 Describe the role of the cell wall in plants.
7 Explain the function of chlorophyll.

Analyse

8 Identify the reactants (present at the start) and products (present at the end) for the chemical reaction called photosynthesis.
9 Contrast (the differences between) the structure of animal and plant cells.

Skills builder: Questioning and predicting

10 In a multicellular organism, predict which of the following cells would have the most mitochondria: bone cells, muscle cells or hair cells. Justify your reasons. (THINK: What is the function of mitochondria?)

Lesson 4.3

Microscopes are used to study cells

Learning intentions and success criteria

microscope a scientific instrument used to magnify the size of an object

electron microscope a microscope that uses electrons (tiny negatively charged particles) to create images

microscopy the study of living things that can only be seen with the use of a microscope

Key ideas

→ A microscope is an instrument that uses lenses to magnify the size of objects.

→ Microscopes are used to observe and record similarities and differences between different cells.

→ The science of investigating small objects using a microscope is called microscopy.

Types of microscopes

A **microscope** is an instrument that uses lenses to magnify the size of the object placed under it. Over time, the magnifying ability of microscopes has improved and continues to do so. This has made it possible to study cells. As a science student, you will have the opportunity to use a light microscope in your laboratory to observe a range of different cells. You may also see images produced by **electron microscopes**. The study of small objects using a microscope is called **microscopy**.

Light microscopes

There are two common types of light microscope – the **stereomicroscope** and the **compound light microscope**. The stereomicroscope is used for viewing larger objects, such as insects (Figure 1). It can magnify up to 200 times and shows a three-dimensional view.

The compound light microscope is used to observe thin slices of specimens (Figure 2). It can magnify up to 1,500 times. Its view is two-dimensional. The specimen must be thin enough to allow light to pass through it.

The stereomicroscope has two **eyepieces** to look through, whereas the compound light microscope can have one or two eyepieces. The word "monocular" is used to describe a microscope with one eyepiece (mono meaning "one"). Microscopes with two lenses are called binocular (bi meaning "two"). The compound light microscope uses the effect of two lenses (the lens in the eyepiece and the **objective lens** further down the column) (Figure 3). Most cells are clear or transparent, so a **stain**, such as iodine, is used to help make them more visible (Figure 4).

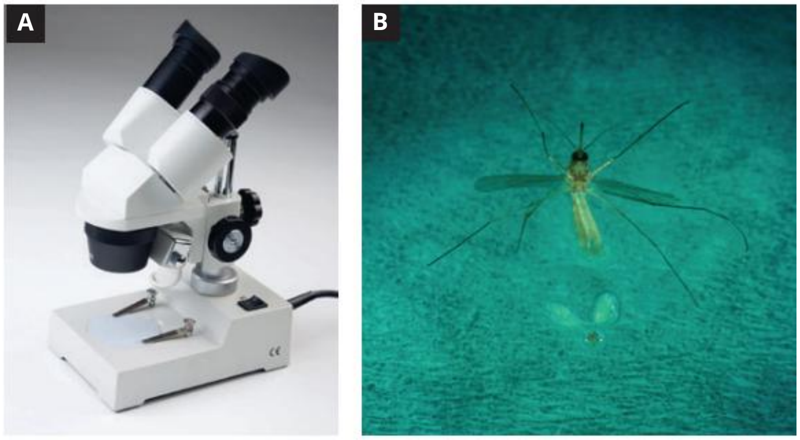


Figure 1 (A) A stereomicroscope; (B) an insect, as seen under a stereomicroscope

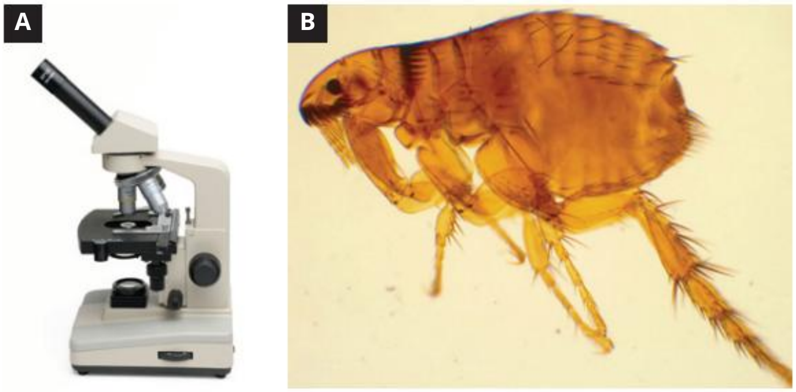


Figure 2 (A) A compound light microscope; (B) a flea, as seen under a compound light microscope

Figure 3 Human hair root that is stained for contrast to make it more visible

stereomicroscope a microscope with two eyepieces that uses low magnification

compound light microscope a microscope with two or more lenses

eyepiece where the eye is placed when using a microscope

objective lens lens in the column of a compound light microscope

stain a substance, such as iodine, used to make cells more visible under a microscope

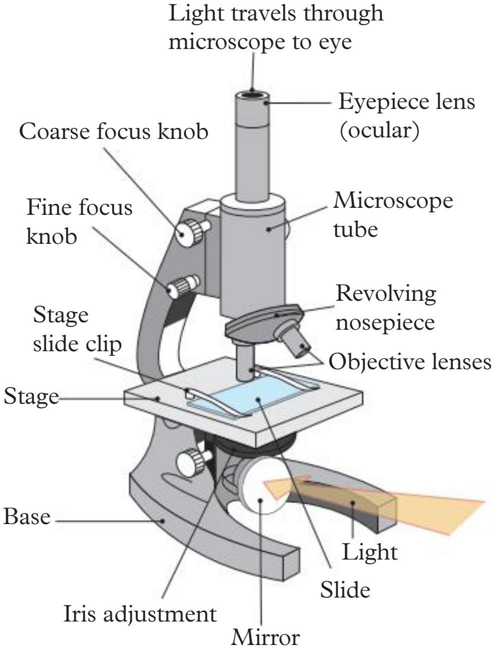


Figure 4 Parts of a compound light microscope

Light microscope magnification calculations

Using different combinations of lenses means you can magnify your object by different amounts. To calculate the total magnification of a compound light microscope, multiply the magnification of the eyepiece lens by the magnification of the objective lens (See Worked example 4.3A and Table 2). These figures are marked on each lens.

Worked example 4.3A Calculating magnification

Calculate the final magnification of a cell that can be seen when using a ×4 objective lens and a ×10 eyepiece lens.

Solution

Table 1 Working out steps

Steps	What to do	Working out
a.	Read the question and summarise the information.	Eyepiece lens magnification = 10 Objective lens magnification = 4
b.	Write the equation to find magnification.	Magnification = eyepiece lens magnification × objective lens magnification
c.	Substitute with given values and calculate magnification.	Magnification = eyepiece lens magnification × objective lens magnification = 10 × 4 = 40
d.	Answer the question.	The cell was magnified 40 times larger than normal.

Table 2 The total magnification of a microscope can be determined by multiplying the magnifications of the eyepiece and the objective lens.

Eyepiece magnification	Objective lens magnification	Total magnification
×5	×10	×50
×10	×20	×200

Electron microscopes

An electron microscope uses electrons (tiny negatively charged particles) to create images. The first electron microscope, called the transmission electron microscope (TEM), was invented in 1933 to help study the structure of metals. The scanning electron microscope (SEM), which was developed later, uses a beam of electrons to scan across the surface of a specimen. A computer is used to create the image, showing details of the specimen's surface (Figure 5).

Electron microscopes can magnify up to a million times. Using this technology, many more details of the cell can be seen and understood.

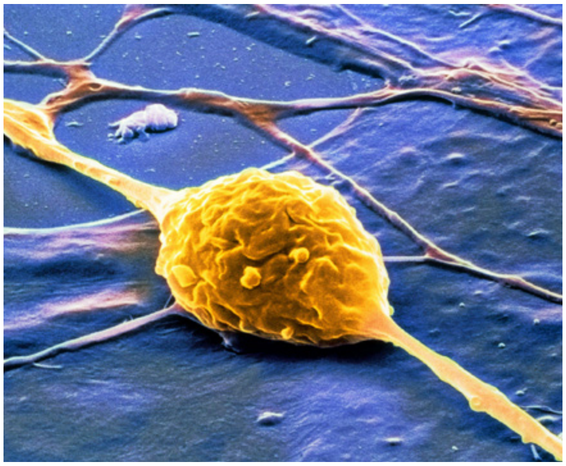


Figure 5 Image of a nerve cell under a scanning electron microscope (SEM).

Check your learning 4.3

Check your learning 4.3

Retrieve

1 Define the term "microscopy".

2 Recall why very thin samples should be used under a light microscope.

Analyse

3 Identify the type (or types) of microscopes in your science laboratory.

4 Infer why you should look from the side when first adjusting the coarse focus knob.

5 Compare (the similarities and differences between) stereomicroscopes and compound light microscopes.

6 Contrast (the differences between) TEM and SEM.

7 Calculate the missing values in Table 3.

Table 3 Magnification table

Eyepiece magnification	Objective lens magnification	Total magnification
×5		×100
	×20	×300
×10	×50	

Lesson 4.4

Skills lab: Getting to know your microscope

Caution

Always use two hands to carry a microscope – one hand should be around the main part of the instrument and the other underneath it.

Aim

To develop the skill of using a microscope

Materials

- Compound light microscope
- Microscope slide
- Glass coverslip
- Small piece of newspaper
- Scissors
- Tweezers
- Eyedropper
- Small beaker of water
- Small piece of tissue paper
- Hair (use your own)
- 1 cm piece of sticky tape (transparent)

Method

1 Some microscopes have a built-in lamp. Others have separate lamps that need to be set up so they shine onto the mirror. Adjust the mirror to project the light through the stage onto the specimen. Do not allow sunlight to shine directly up the column.

2 Place the slide on the stage, then select the objective lens with the lowest magnification first.

3 Cut out two small words from a piece of newspaper (Figure 1).

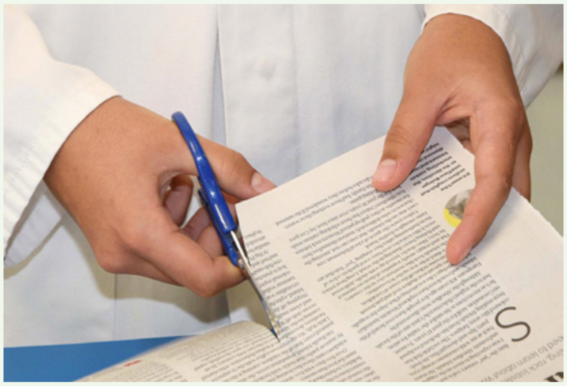


Figure 1 Use scissors to cut out words from the newspaper.

4 Place the cut-out newspaper on the microscope slide and add two drops of water to help it "stick" to the slide. Place a glass coverslip on top (Figure 2). This is called a **wet mount**.

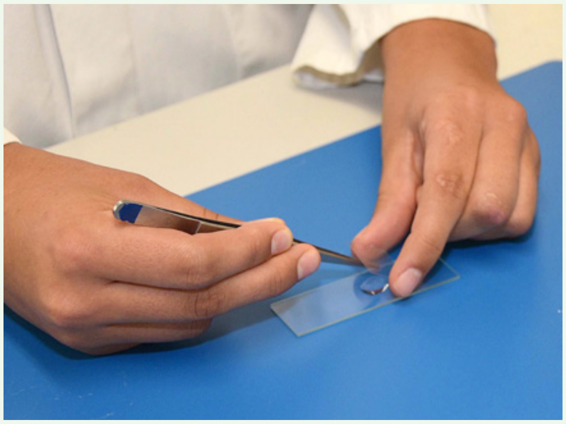


Figure 2 Gently lower the glass coverslip down until it is flat.

5 Look from the side and adjust the coarse focus knob so that the objective lens is just above – and not touching – the slide. Check which way you must turn the knob to move the objective lens away from the slide.

6 Use the coarse focus knob to bring the specimen into view (Figure 3). Find one letter from the newsprint to focus on. Use the fine focus knob to help you see it more clearly.

Figure 3 Carefully adjust the focus of the microscope.

7 Move the slide slightly towards your body and observe what happens.

8 Move the slide slightly to the left and observe what happens.

9 Increase the magnification by rotating the objective lens to a higher magnification.

10 Draw a diagram of the newspaper letter (as a record) using a sharp grey-lead pencil. Never colour or shade areas; if absolutely necessary, use dots or lines instead.

11 Calculate the total magnification.

12 Write the magnification next to your sketch.

13 Label and date the sketch.

14 Remove the newspaper from the microscope stage and prepare another slide using the tissue paper. Make sure a drop of water is added and the coverslip is placed over the top carefully.

15 Sketch what you see.

16 Repeat with a piece of sticky tape and then a hair from your head.

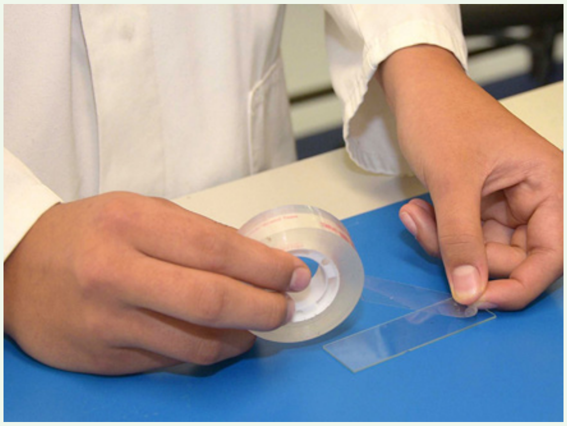


Figure 4 Repeat with a piece of sticky tape.

Questions

1 Describe the direction (right way up or upside down) of the letters on the newspaper with and without the microscope.

2 Describe the features you could see on the tissue paper and sticky tape that you could not see with the naked eye.

3 Use a series of cause-and-effect graphic organisers, similar to that shown in Table 1, to record the results of your experiment when you moved the slide in different ways. For example, the cause link may be "move the slide to the left". Then write what happened in the effect link.

Table 1 Cause-and-effect graphic organiser

Cause	→	Effect
What did you do to cause the change you observed?		What effect did it have?

Lesson 4.5

Investigation: Comparing and drawing cells

Caution

Do not attempt to adjust any of the microscopes. Ask your teacher or laboratory technician to adjust the microscope if you think it has been bumped or has gone out of focus.

Introduction

Single-celled organisms can vary significantly in size. Bacteria, which on average are 0.5 µm in size (which is half a "micrometre", and a micrometre is one thousandth of a millimetre), can be observed with a light microscope, but they are too small for any specific features to be seen. In contrast, an amoeba – a single-celled organism – is around 500 times larger, at 0.25 mm.

When creating a scientific drawing of what you observe under a microscope, there is a set of rules that must be followed:

- The drawing must have a title.
- The total magnification used must be included next to your drawing.
- A sharp grey-lead pencil should be used.
- Lines should be clear single lines without sketching.
- No shading should be used.
- Use a ruler to draw any label lines.
- Make sure label lines don't overlap.

Figure 1 shows a scientific drawing of a photosynthetic unicellular (single-celled) organism, *Phacus pleuronectes*.

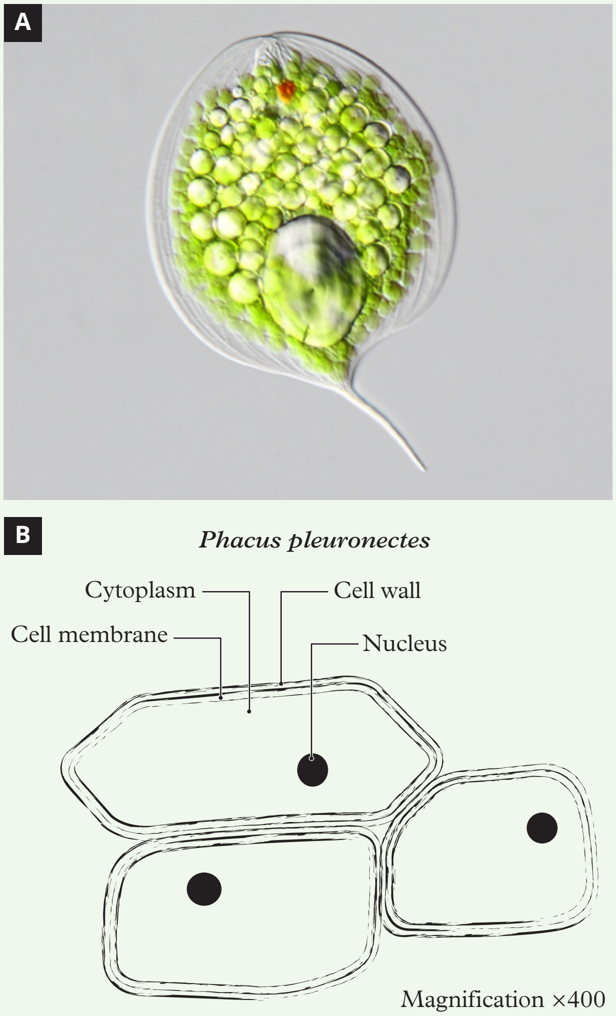


Figure 1 (A) Unicellular (single-celled) organism (*Phacus pleuronectes*) through a microscope; (B) scientific drawing of the cells seen through a microscope

Purpose

To observe and draw a range of single-celled organisms

Materials

- Microscopes
- Prepared slides of single-celled organisms
- Pencil and paper for drawing
- Several stations set up around the laboratory with microscopes adjusted to show different kinds of cells

Your teacher will provide you with a light microscope and prepared slides of a range of single-celled organisms. Use the instructions on how to use a light microscope from the previous section to observe the slides and draw scientific images of each sample.

Part A: Drawing a single-celled organism

1. Look carefully at each specimen. Write down its name and a sentence that describes what you see.
2. Make a scientific drawing of a single cell that you can see. Draw the outside edge of the cell first, including any bumps or unusual shapes you notice.
3. Draw two more cells that are close to your original cell. (Do not attempt to draw every cell that you see.)
4. If you can see anything inside the cells (it may only be a dark dot), mark this on your drawing.
5. Label any parts that you can identify.

Discussion

1. Identify and describe the cell that, in your opinion, was the most unusual.
2. Identify the cells that had walls around them.
3. Identify the cell that was the smallest.
4. Identify the cell that was the largest.
5. Compare the cells you viewed through the microscope with the image of the cell in Figure 1.
6. Describe some of the difficulties of drawing cells seen through a microscope.

Part B: Comparing cell types observed under a transmission electron microscope

The figures show four cell types (animal, plant, fungi and bacteria) observed under a transmission electron microscope (TEM).

1 Draw a scientific diagram of each cell type.

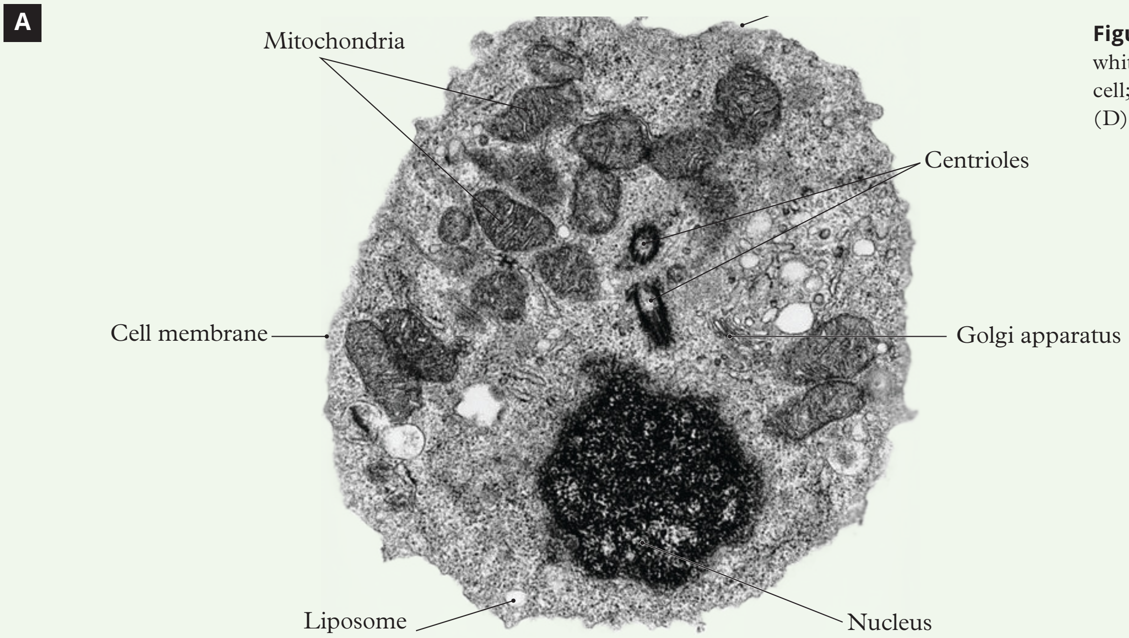
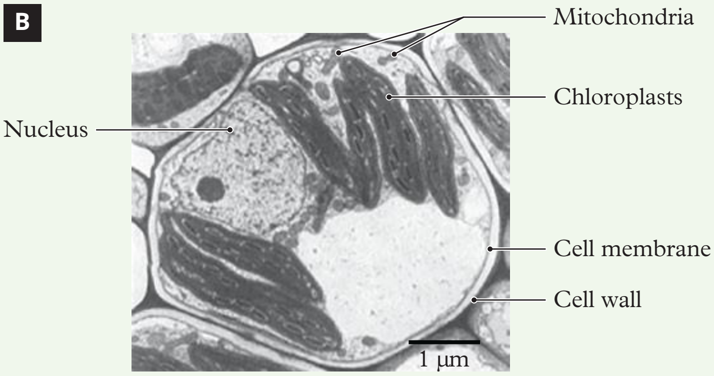
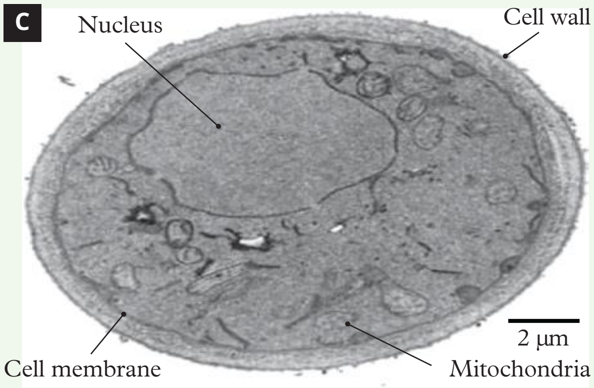
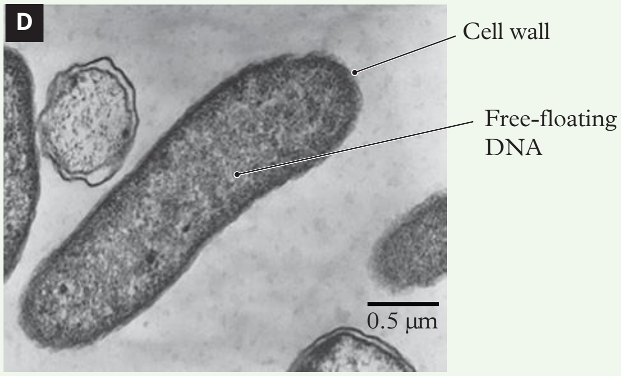


Figure 2 (A) A human white blood cell; (B) a plant cell; (C) a fungal cell; (D) bacteria cells







2 Research the different cell types and copy and complete Table 1 to compare the similarities and differences between the cell types. Note: The role of the nucleus, cell membrane, cell wall, mitochondria, chloroplast and vacuole is explored in Lesson 4.2 Cell structures and organelles (page 170).

Discussion

1 Identify the features that were similar between all cell types observed.

2 Identify the features that could be used to distinguish between an animal, plant and fungi cell.

Table 1 Similarities and differences between cell types

	Animal	Plant	Fungi	Bacteria
Size				
Nucleus				
Cell membrane				
Cell wall				
Mitochondria				
Chloroplast				
Vacuole				

Lesson 4.6

Photosynthesis and cellular respiration

Learning intentions and success criteria

Key ideas

→ Autotrophs make their own glucose (food) through photosynthesis.

→ Photosynthesis is a chemical reaction that requires water and carbon dioxide in the presence of sunlight and chlorophyll to produce glucose (sugar) and oxygen.

→ All organisms convert glucose into useable energy in a process called cellular respiration.

Introduction

Living things need food for energy to survive. Autotrophs are organisms such as plants which make their own food – glucose – using the Sun's light in a process called **photosynthesis**. Heterotrophs, on the other hand, can't make their own glucose, so they get their energy by consuming other organisms in the food chain. All organisms convert glucose into important energy in a process called **cellular respiration**.

cellular respiration the chemical reaction between glucose and oxygen that produces carbon dioxide, water and energy

Photosynthesis and cellular respiration are often considered as a cycle within an ecosystem because the reactants in one are the products of the other (Figure 1).

Photosynthesis

Photosynthesis is used by plants (and some other organisms) to transform light energy into chemical energy. Photosynthesis requires carbon dioxide, light energy and water. The light energy is obtained from the Sun (Figure 2).

Photosynthesis can be summarised by the following equation:

Reactants		Products
carbon dioxide + water	→	glucose + oxygen + water
$6CO_2 + 12H_2O$	→	$C_6H_{12}O_6 + 6O_2 + 6H_2O$

Which is often simplified to:

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

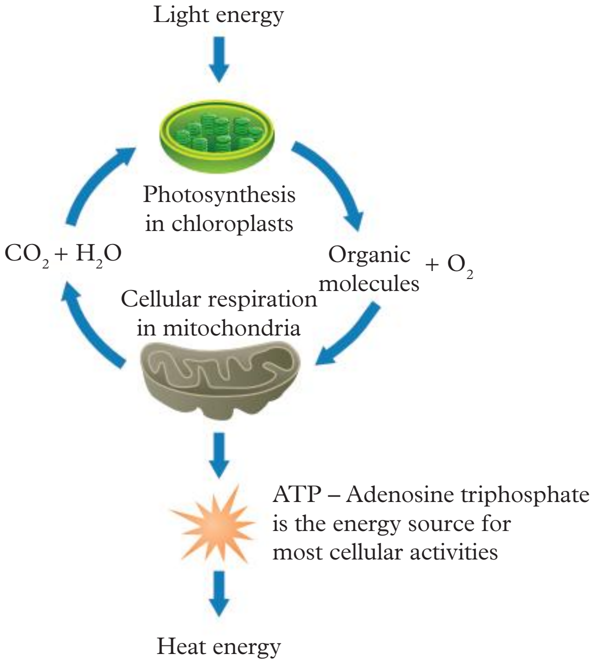


Figure 1 The structure of a photosynthesis–cellular respiration cycle.

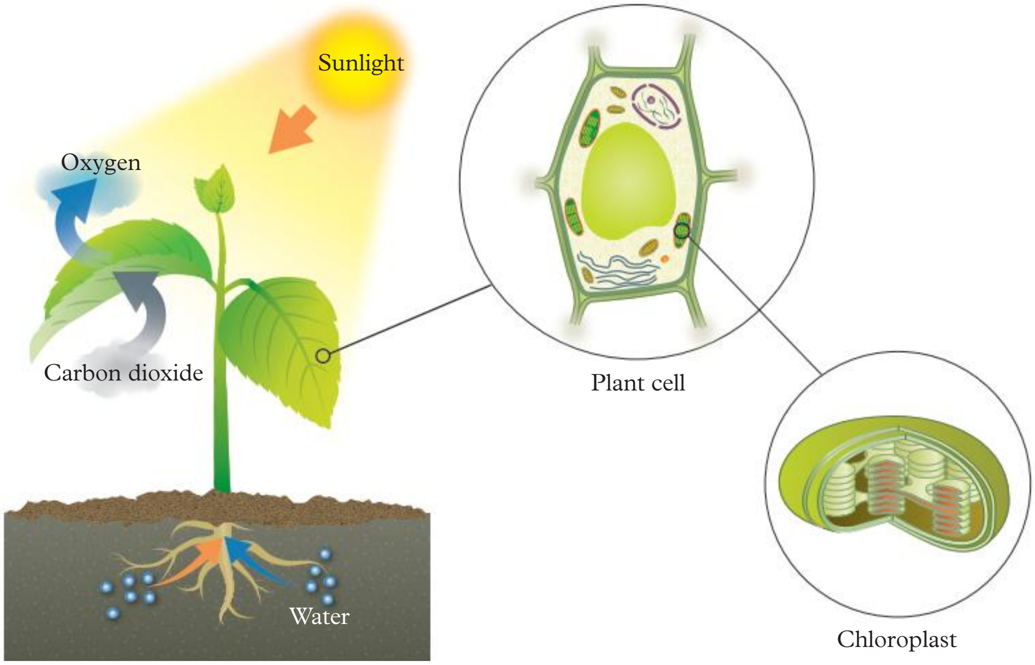


Figure 2 Photosynthesis takes place in the chloroplasts of plant cells to turn carbon dioxide and water into oxygen, glucose and water.

Where does photosynthesis happen?

On average, a plant leaf has tens of thousands of cells, and a single cell contains 40 to 50 chloroplasts. These chloroplasts contain the green pigment called **chlorophyll**. It is this chlorophyll found in the leaf cells of a plant that captures the Sun's light energy and converts it into stored chemical energy in the form of glucose.

The shape and arrangement of the leaves in many plants maximise their ability to absorb sunlight and carry out photosynthesis.

Because plants cannot breathe like we do, the plant must get its carbon dioxide through microscopic pores called **stomata** (singular "stoma") in the leaves (Figure 3). **Guard cells**, which open and close the stomata, also contain chloroplasts. The water needed for photosynthesis enters a plant through the **roots** and travels to the chloroplasts through **xylem vessels**. We will learn more about these structures in Module 8 Animal and plant organ systems (page 332).

stomata pores on leaves and stems for gas exchange, allowing carbon dioxide intake and oxygen release, essential for photosynthesis and transpiration

guard cells specialised plant cells that surround the stomata, regulating their opening and closing to control gas exchange and water loss

root a plant organ involved in absorbing nutrients and water

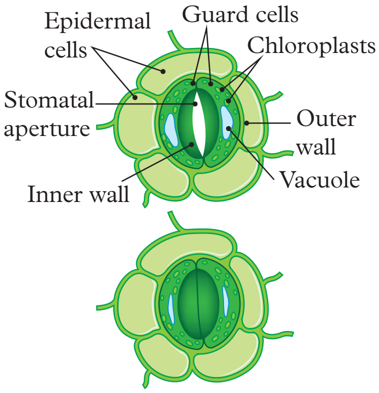


Figure 3 The opening and closing of plant stoma to control gas exchange and water loss.

Factors that affect photosynthesis

Many factors can affect the rate of photosynthesis. Sometimes plants experience conflicting demands, especially in periods of water shortage. The stomata may be forced to close to prevent damage from wilting and dehydration. This will restrict the availability of carbon dioxide, so photosynthesis may be interrupted. In the desert, the lack of rain can restrict the amount of photosynthesis and, therefore, the amount of glucose produced. If there is not enough light, photosynthesis cannot occur. This can be a problem for young plants trying to grow on the floor of a rainforest. The taller plants provide competition for the light.

Cellular respiration

Cellular respiration occurs inside the mitochondria. This reaction involves the rearrangement of the atoms in glucose (obtained from photosynthesis in plants and the food eaten by animals) and oxygen to produce water, carbon dioxide and energy, which is called **adenosine triphosphate** or ATP. This energy is used to perform all life functions. Remember: MR N GREWW (Lesson 5.1 Living organisms have common characteristics, page 206).

adenosine triphosphate a compound that is used as the source of energy for cellular activities

The general equation for cellular respiration is:

Reactants		Products
glucose + oxygen	→	carbon dioxide + water + energy
$C6H_{12}O_6 + 6O_2$	→	$6CO_2 + H_2O + 36ATP$

Cellular respiration is similar to burning wood for fuel. Glucose is the molecule that our body uses for fuel. Each cell uses oxygen to burn glucose and convert the energy into ATP. ATP is much easier for our bodies to use for energy. Fats and proteins can also be converted into ATP in cellular respiration.

Oxygen is used during cellular respiration, and carbon dioxide and water are waste products. Because oxygen is needed for this process, it is often called **aerobic respiration**. Although cellular respiration is summarised as a single equation, it is actually a complex series of reactions. You can learn about this in Stage 6 Biology.

aerobic respiration the process by which cells convert glucose and oxygen into energy, carbon dioxide and water

Check your learning 4.6

Check your learning 4.6

Retrieve

1 Identify the organelles where photosynthesis and cellular respiration occur.

2 Write the equations for photosynthesis and cellular respiration in words (without using chemical symbols).

Comprehend

3 Describe how autotrophs and heterotrophs differ in the way they acquire energy.

4 Describe the role of stomata in regulating gas exchange during photosynthesis.

5 Explain the relationship between photosynthesis and cellular respiration in an ecosystem.

6 Explain factors that can affect the rate of photosynthesis

Skills builder: Communicating

7 Construct a diagram to show the relationship between photosynthesis and cellular respiration. (THINK: What will you include to make sure people understand your diagram?)

Lesson 4.7

Investigation: Cellular respiration and photosynthesis

Part A: Modelling cellular respiration

Yeast are single-celled microorganisms that belong to the fungus kingdom. Yeast uses cellular respiration to create energy. Bakers' yeast is the common name for the strains of yeast used when baking bread and other bakery products.

Materials

- Dry baker's yeast
- Warm water (30–35°C)
- 5% glucose solution
- Two graduated measuring cylinders
- Water bath
- Ice bath
- Thermometer
- Test tube
- Balloon
- 150 mL water
- Universal indicator
- Straw

The following procedure can be used to model cellular respiration in yeast.

Procedure

1 Create a 1:1 suspension of dry baker's yeast and warm water. Stir the mixture gently to activate the yeast and allow it to sit for five minutes. (This is best done by the teacher to create a larger volume that can

be used to distribute 5 mL aliquots to each group.)

2 Measure out 5 mL of the yeast suspension and add to a test tube.
3 Measure out 10 mL of the 5% glucose solution and add this to the 5 mL yeast suspension.
4 Attach a balloon over the mouth of the test tube to capture the carbon dioxide (CO_2) released.
5 Leave the test tube at room temperature (approximately 25°C) for a set period of time.
6 Measure how much the balloon inflates.
7 Repeat Steps 2 to 6 at different temperatures (use a water bath and ice bath, and record the temperature using a thermometer).

Extension

Confirming the gas in the balloon is carbon dioxide:

1 Add 50 mL water to the 150 mL beaker and add enough universal indicator to turn the water green. This indicates that water has a neutral pH.
2 Place one end of a straw in the beaker of water.
3 Place the other end of the straw in the mouth of the room-temperature balloon. Be careful to minimise gas escaping.
4 Slowly release the gas, allowing it to bubble through the water.
5 If the gas is carbon dioxide, the colour will turn from green to yellow as the water reacts with the carbon dioxide to form a weak acid (carbonic acid).

Conclusion

Document your findings in a written report.

Part B:
Modelling photosynthesis

Elodea canadensis is an aquatic plant with leaves that are only two cells thick. The cells contain many chloroplasts. The chloroplasts are the organelles in which photosynthesis occurs. These features make *E. canadensis* very useful in experiments to examine the effect of a specific condition (for example, temperature or light intensity) on photosynthesis.

When plants photosynthesise, they produce oxygen gas. This gas is used to measure the rate of photosynthesis.

Materials

- *Elodea canadensis*
- 1% sodium bicarbonate solution ($NaHCO_3$) – dissolve 1 g of $NaHCO_3$ in 100 mL of water
- Three small funnels
- Three test tubes
- Three 500 mL beakers
- Marker pen
- 30 cm ruler

The following procedure is used to test the effect of light intensity on photosynthesis in *E. canadensis*.

Procedure

1 Place the same amount of *E. canadensis* into three 500 mL beakers.
2 Half-fill each beaker with 1% sodium bicarbonate solution ($NaHCO_3$ – this provides the carbon dioxide needed for photosynthesis).
3 Place a small funnel over the *E. canadensis*, ensuring that the tip of the funnel sits below the solution.
4 Fill 3 test tubes with 1% $NaHCO_3$ and manoeuvre the mouth of each test tube over the tip of each funnel. Be careful to minimise volume loss (Figure 1).
5 Place a mark on each test tube where the liquid and gas bubble meet (= distance 1 or d1).

6 Place one set-up in direct sunlight, leave one in artificial light, and wrap the third in foil or cover to avoid exposure to any light.

7 In the two set-ups that are to be physically observed (sunlight and artificial light), observe for the production of oxygen gas.

8 After a set period of time, place a second mark on each test tube where the liquid and gas bubble now meet (= distance 2 or d2).

9 Determine the volume of oxygen produced by *E. canadensis* in each set-up by comparing d1 and d2.

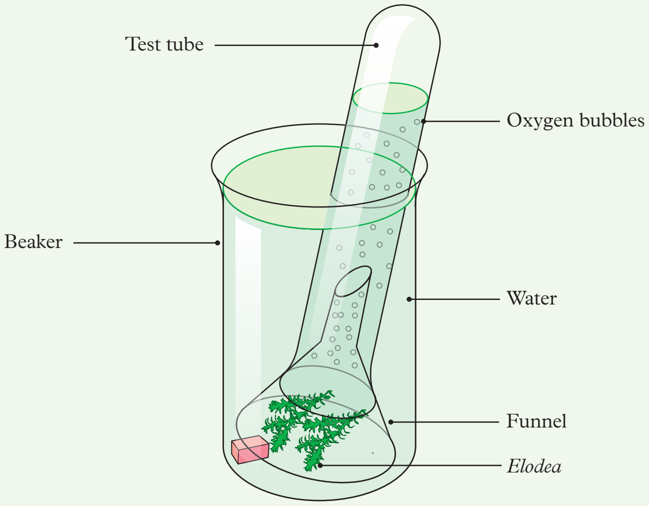


Figure 1 Investigation set-up of *Elodea canadensis* and the effect of light intensity on photosynthesis

Extension

Confirming the gas produced is oxygen (O_2)

1 Gently take the test tube out of the $NaHCO_3$ solution.

2 Keep the test tube bottom pointing to the ceiling. This prevents the oxygen from escaping.

3 Place a lit flint into the mouth of the test tube.

4 Oxygen will cause the flame to burn more intensely.

Alternatives

1 If you have access to a UV lamp, you can change the distance at which the UV lamp sits from the *E. canadensis* (10 cm, 50 cm, 100 cm) and record either the number of bubbles produced per minute for a set period of time or the total volume displaced over a set period of time for each distance.

2 You could determine the effect of temperature on the rate of photosynthesis. Modify the method, using a water bath and ice bath to compare the oxygen produced by *E. canadensis* at 10°C, room temperature and 40°C.

Results

Graph the results to compare the effect of temperature on the amount of carbon dioxide produced by the yeast during cellular respiration.

Graph the results to compare the effect of light on the amount of oxygen produced by *E. canadensis* during photosynthesis.

Discussion

1 Explain why it is important to write a method that includes all steps written concisely and accurately.

2 Explain how you ensured that each experiment was valid.

3 Explain how the results of the experiment could be made more reliable.

Conclusion

Document your findings in a written report.

Lesson 4.8

Cell specialisation

Learning intentions and success criteria

Key ideas

- → As a cell becomes larger, its surface area to volume ratio decreases.
- → Multicellular organisms require specialised cells to perform life's functions.
- → In complex multicellular organisms, there is a hierarchy of organisation which is cells, tissues, organs, organ systems and organism.

The need for cell specialisation

Recall from Lesson 4.1 Cell theory (page 168) that if a cell becomes too large, it becomes difficult for nutrients to move into the centre of the cell and for wastes to move out. Multicellular organisms overcome this problem through **cell specialisation**, where different cell types take on specific roles that are essential for the survival of the organism. This specialisation means that each cell type is dependent upon the others for their survival, while the whole organism is dependent on the correct function and interaction of the different cell types. In contrast, single-celled organisms survive independently from other cells.

Hierarchical structural organisation of multicellular organisms

Multicellular organisms have a hierarchical (ordered) structural organisation. Specialised cells make up tissues, then tissues make up organs, and organs make up organ systems (Figure 1).

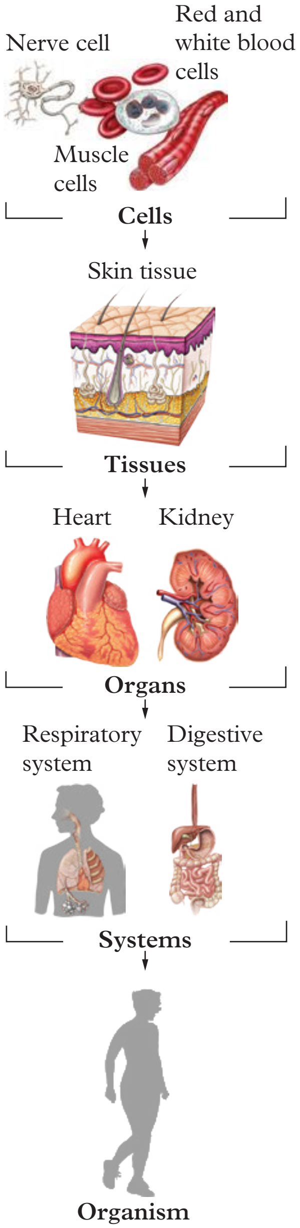


Figure 1 The formation of systems within the human body

Tissues and organs

tissue a group of the same cell type that performs a similar task

organ a group of different tissues that are self-contained and have a specific vital function

Tissues are groups of specialised cells that have a similar structure and perform a similar function. For example, we have skin tissue, muscle tissue, nerve tissue, bone tissue and so on. Groups of different tissues that work together form **organs**. Organs perform tasks that allow multicellular organisms to function. For example, your heart, kidney, brain, skin and intestines are examples of organs.

Organ systems

The human body is made of major systems that perform specialised tasks for survival. These systems consist of the skeletal system, muscular system, digestive system, respiratory system, excretory system, nervous system and circulatory system. These systems will be explored in more detail in Module 8 Animal and plant organ systems (page 332). The function of each of these systems can be seen in Table 1.

Table 1 Human body systems and their functions

System	Organs and parts involved	What the system does
Circulatory	Heart, veins, arteries	Carries oxygen and nutrients to cells and waste materials away from cells via blood
Digestive	Mouth, stomach, small intestine, large intestine, rectum, anus	Breaks down food into substances small enough to be absorbed into the bloodstream; separates some waste
Excretory	Kidneys, bladder, urethra, skin, lungs	Kidneys filter out wastes and control the amount and content of body fluids; we sweat salts through our skin and exhale carbon dioxide from our lungs
Muscular	Muscles, ligaments, tendons	Allows the body to move; muscles are attached to the skeleton
Nervous	Nerves, spinal cord, brain	Central nervous system (CNS) uses brain and spinal cord; electrical messages are sent to and from all parts of the body by the nerves
Respiratory	Lungs, windpipe, diaphragm	Takes in oxygen and transfers it to the blood so that it is taken to all other parts of the body; removes carbon dioxide from cells via blood
Skeletal	All bones, including spine, skull, pelvis, ribs	Gives body shape, holds it upright, supports and protects other organs; attached to muscles for movement

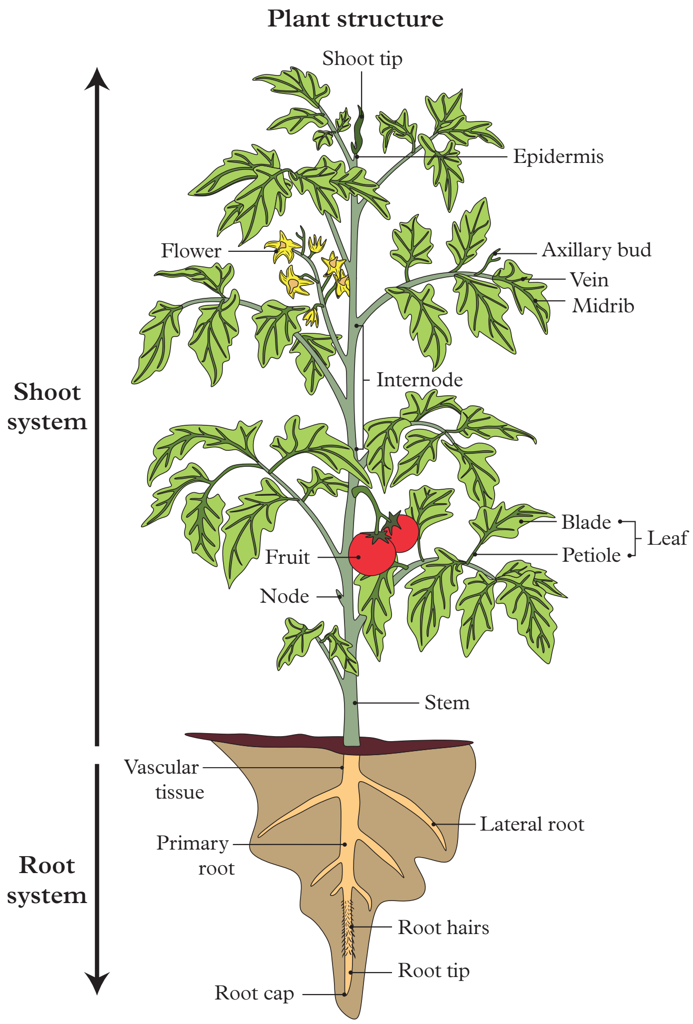


Figure 2 Plants have two distinct organ systems: the root system and the shoot system.

It is important to remember that plants, like animals, are multicellular, and they also have tissues, organs and organ systems. For example, plants typically have two organ systems: the root system and the shoot system. The root system consists of two organs, the roots and root hairs, which in turn comprise tissues such as **dermal** and **vascular** tissue. The shoot system is made up of three organs: the stem, the leaves, and flowers and fruits, each with distinctive tissue vital for the survival of the plant (Figure 2).

dermal outer protective layer of a plant

vascular structures or systems composed of blood vessels or plant vessels

Examples of cell specialisation in animals

Specialised cells usually have a distinct shape and structure that is necessary for their specific function. For example, red blood cells have a **biconcave** shape (which means they are concave on both sides) that increases their surface area. They also lack a nucleus, which allows for more haemoglobin (which is the protein that carries the oxygen required for cellular respiration) to be present in the cell (Figure 3A).

Nerve cells (neurons) detect and send signals around the body. They have a cell body with branched dendrites that catch signals from nearby nerve cells and a long axon that passes the signal on to the next cell. (Figure 3B).

Smooth muscle cells are elongated and contain large numbers of mitochondria for energy production. They also produce specialised proteins that enable the muscle cells to relax and contract, allowing for movement. (Figure 3C).

Sperm cells (Figure 3D) have a long tail (flagellum) that helps them swim toward the egg (ovum) (Figure 3E). They contain half the number of chromosomes of other body cells. When a sperm fertilises an egg, the father's genetic material combines with the mother's genetic material to create the first cell of a new individual.

pathogen a disease-causing agent (e.g. bacteria, viruses, fungi)

cilia small, hair-like structures found on the surface of some cells

Many macrophage (white blood cells) have a round, globular shape that helps them detect and engulf foreign **pathogens** (Figure 3F). These cells are important for the prevention of disease.

Ciliated epithelial cells are important as they prevent pathogens from entering the body (Figure 3G). They have tiny hair-like projections (**cilia**) that move material across the cell surface. For example, in the respiratory tract, they move mucus and trapped particles out of the airway, preventing them from entering the lungs.

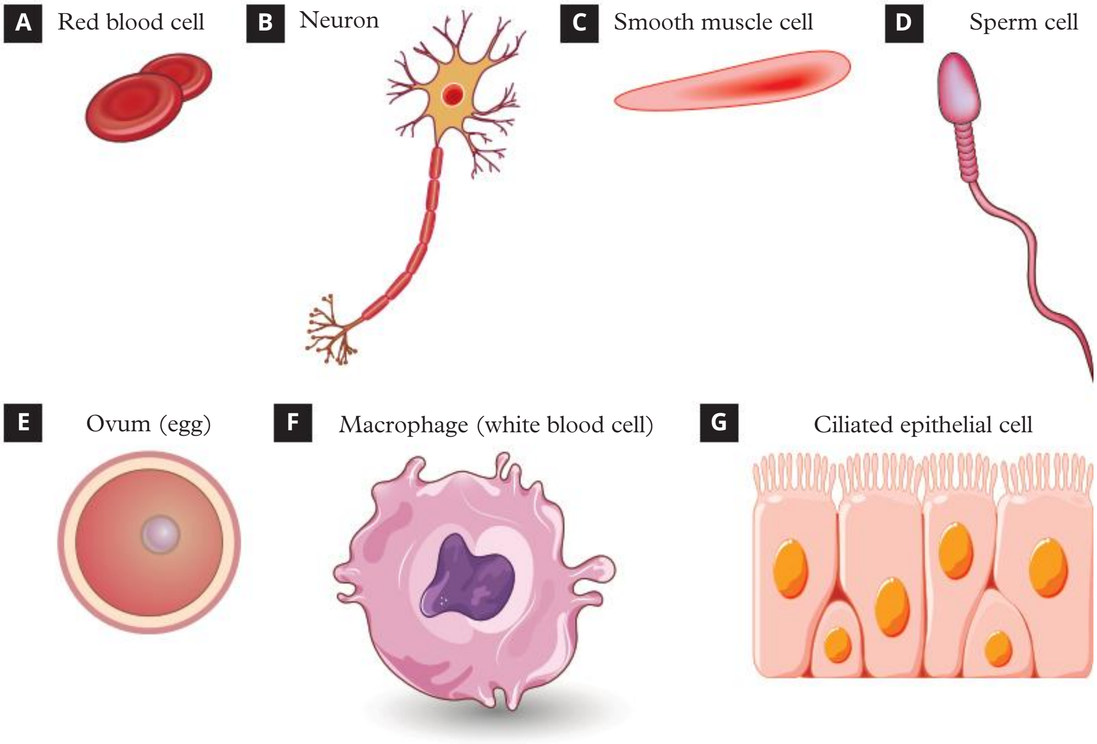


Figure 3 Cells in multicellular organisms are specialised for different functions: (A) red blood cell; (B) neuron; (C) smooth muscle cell; (D) sperm cell; (E) ovum (egg); (F) macrophage (white blood cell); (G) ciliated epithelial cell

Examples of cell specialisation in plants

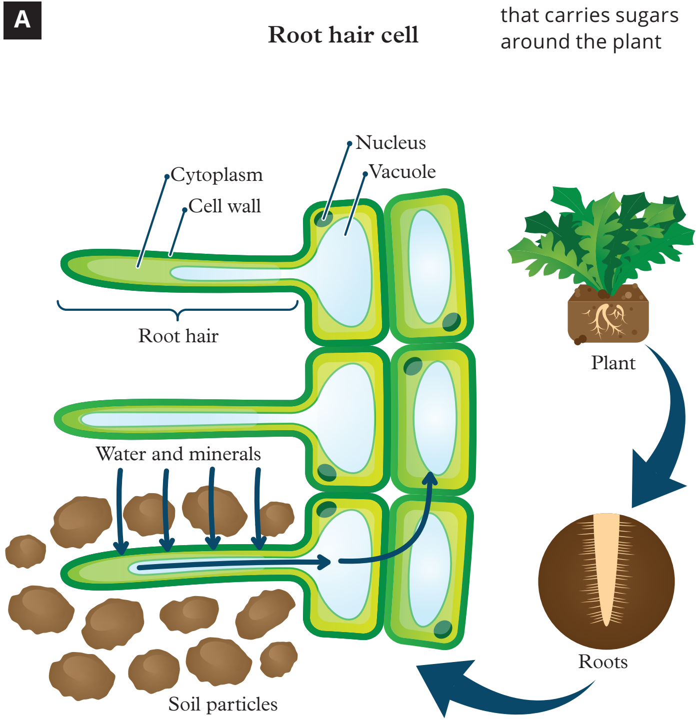
Like animals, plants have a range of specialised cells that are required for survival. Root hairs have thin walls and long hair-like extensions that increase the surface area over which absorption of water and dissolved nutrients can occur (Figure 4A).

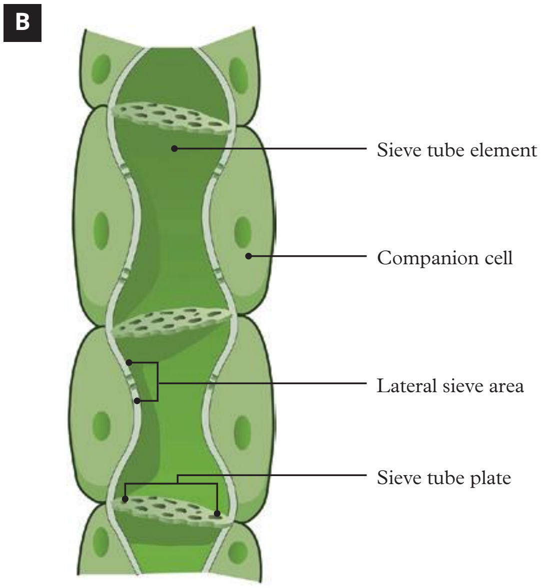
Vascular plants have vessels, called **phloem**, which transport the glucose produced in the leaves during photosynthesis to all other parts of the plant that require the sugar in order to produce energy during cellular respiration. The phloem has structures called **sieve plates**, made from specialised cells called **sieve elements** (Figure 4B). These cells contain no nucleus and very few organelles, which allows for better movement of material along the vessel. In contrast, companion cells next to the phloem have a cytoplasm densely packed with organelles that help move materials in and out of the phloem when needed.

Palisade mesophyll cells in leaves are column-shaped, tightly packed and filled with chloroplasts. They are usually found on the upper-side of the leaf to absorb as much sunlight as possible for photosynthesis. This layer is just below the epidermis, which has pavement cells and guard cells (Figure 4C).

vascular plants plants that have vessels (xylem and phloem) used to transport material around the plant

phloem the vascular tissue in plant stems that carries sugars around the plant





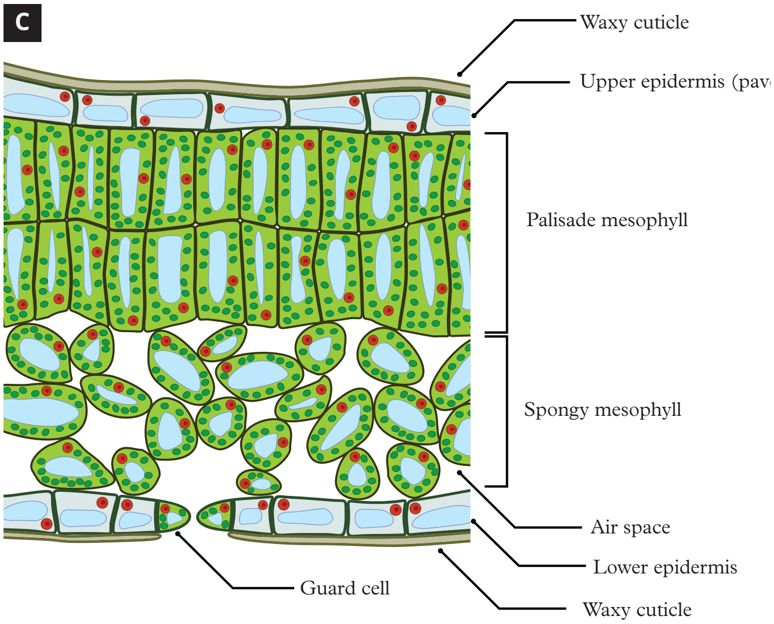


Figure 4 Specialised cells in plants: (A) root hair cells; (B) sieve elements and companion cells; (C) leaf structure showing palisade mesophyll cells, pavement cells and guard cells.

Pavement cells have thick walls and irregular shapes, fitting tightly together to protect against water loss and pathogens.

Guard cells are always found in pairs. These crescent-shaped cells control the opening and closing of stomata by taking in or releasing water, which helps regulate gas exchange and water loss in the plant.

Each specialised plant cell is structured in a way that enhances its ability to perform specific roles, ensuring the plant's overall growth, development and survival.

Check your learning 4.8

Check your learning 4.8

Retrieve

1 Identify two examples of specialised cells in humans and outline their function.

2 Identify two examples of specialised cells in plants and outline their function.

Comprehend

3 Explain the need for a hierarchical structural organisation in multicellular organisms.

4 Explain how the structure of palisade mesophyll cells support photosynthesis.

Analyse

5 Examine the two cubes in Figure 5 and complete Table 2.

6 Based on the information provided and your findings in question **5**, explain which would have more difficulty surviving: a cell with the dimensions of cube A or a cell with the dimensions of cube B.

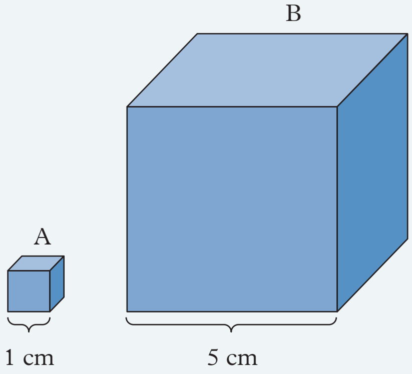


Figure 5 Two different cubes

Skills builder: Questioning and predicting

7 Consider Table 1, which outlines the different functions of the systems in the human body. Choose one of these systems and identify three questions about it that you could investigate using secondary sources. (THINK: What do you already know? What would you like to know more about?)

Table 2 Details of two cubes

	Cube A	Cube B
Total surface area (height × width × number of sides × number of boxes)		
Total volume (height × width × length × number of boxes)		
Ratio of total surface area to total volume		

Lesson 4.9

Skills lab: Looking at organelles

Aim

To prepare slides to view the organelles in the cells of a brown onion and an *Elodea canadensis* plant. You may wish to review Lesson 4.4 Skills lab: Getting to know your microscope (page 177) for slide and microscope use.

Materials

- Onion wedge
- Three glass slides
- Three glass coverslips
- Water
- Light microscope
- Methylene blue stain or iodine
- Leaf from an *Elodea canadensis* plant
- Blotting paper
- Dropper

Method

Onion skin cells – unstained

Light microscopes depend on the light being able to pass through the specimen. When preparing a slide, it is important that the specimen is as thin as possible.

1. Between the fleshy layers of an onion, there are some thin, transparent layers. These layers are one cell thick. Peel off a layer of this skin and put it onto a microscope slide.
2. Add one drop of water and then gently lower the coverslip so that no air bubbles are trapped.
3. Draw and label what you see through the microscope. Try to identify the nucleus, which contains the DNA, and the cell membrane, cell wall and cytoplasm.

Onion skin cells – stained

Stains are often used on specimens because they add contrast to the image. Some highlight a particular feature of the cell.

4. Use another thin layer of onion skin to prepare a second slide as above.
5. Add a drop of methylene blue stain or iodine instead of the water before lowering the coverslip. Lower it carefully so that no air bubbles are trapped. Be careful not to get the stain on your skin or clothes because it is very hard to remove.
6. Draw and label what you see through the microscope.

Elodea canadensis cells

7. Pick a small, green *Elodea canadensis* leaf and put it onto a microscope slide.
8. Add one drop of water and then gently lower the coverslip so that no air bubbles are trapped.
9. Draw and label what you see through the microscope. Try to identify the cell membrane, cell wall and cytoplasm.

Figure 1 Adding a stain to the slide

Results

Include your labelled diagrams in this section.

Questions

1 Describe how the use of a stain changes the image of the onion cells.

2 Both types of cells viewed are from plants. Explain why there are differences between each of the cell types. (HINT: Consider which part of the plant the cells come from.)

3 Explain why it is often difficult to identify the nucleus in the *Elodea canadensis* cells.

4 The *Elodea canadensis* cells contain another structure that is very prominent. Identify and describe the function of this structure.

5 Explain why it is not necessary to stain the *Elodea canadensis* cells.

Conclusion

Explain what you know about the organelles in onion cells and *Elodea canadensis* cells.

Lesson 4.10

Investigation: Specialised cells in animals and plants

Purpose

- To observe and compare specialised plant and animal cells
- To measure the size of various plant and animal cells using a mini-grid

Materials

- Light microscope
- Prepared slides of specialised plant and animal cells
- Mini-grid slide or 1 mm graph paper, photocopied onto a transparency

Part A

Procedure

1 Place your first slide on the microscope stage.

2 Focus the microscope.

3 Draw up to three cells that you observe. Don't forget to label your diagram and write down the total magnification.

4 Repeat for other prepared slides of specialised animal and plant cells.

Results

Draw scientific drawings of the specialised animal and plant cells you observed.

Discussion

1. Compare the sketches you have prepared with the images of plant and animal cells in Figure 2 in Lesson 4.5 Investigation: Comparing and drawing cells (page 179). Identify the similarities and differences between the cells.
2. Use the Venn diagram template in Figure 1 to show how plant and animal cells are similar and how they are different.

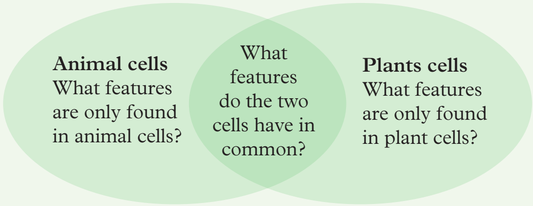


Figure 1 A Venn diagram is used to show the similarities and differences between animal and plant cells.

Conclusion

Describe what you know about plant and animal cells.

Part B

Procedure

1. Focus the cells from a prepared slide under the light microscope.
2. Once in focus, estimate the number of cells that can fit lengthways across the field of view (the circle of light seen down the microscope). Record your estimation.
3. Gently remove the slide and insert the slide containing the mini-grid (Figure 2). Adjust the focus so that the lines are clearly seen.
4. Each box is 1 mm in length. Determine the length of the field of view by counting how many 1 mm boxes fit across the light field.

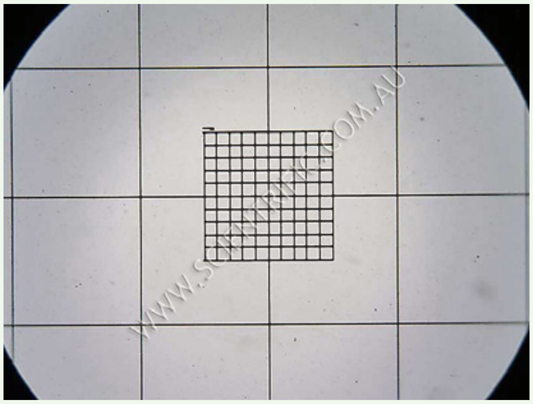


Figure 2 Mini-grid observed under a microscope. The larger squares are 1 mm × 1 mm.

5. Use this measurement to calculate the average length of one onion cell by estimating how many cells fit across the light field.

   $$\text{Length of cell} = \frac{\text{Number of cells that can fit lengthways}}{\text{Field of view length (mm)}}$$

6. Repeat this process for each of the other prepared slides.

Results

Rank the cells viewed in size from smallest to largest.

Discussion

1. Identify the number of micrometres in 1 mm.
2. Compare the ranking of cell size in this investigation to Table 1 from Lesson 4.5 Investigation: Comparing and drawing cells (page 179).

Conclusion

Describe what you know about the relative sizes of plant and animal cells.

Lesson 4.11

Science in context: Fungal cells can save lives

Introduction

Have you ever scratched yourself on a bush or pricked yourself with a needle? Before the discovery of antibiotics, such a simple break in the skin could have been enough to kill you.

The discovery of penicillin

It has been accepted for over 3,000 years that some fungal cells can kill bacteria. Scottish scientist Sir Alexander Fleming (1881–1955) (Figure 1) is credited with discovering the specific chemical responsible for this in 1928.

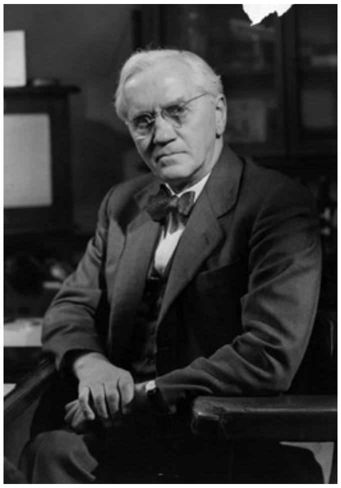


Figure 1 Alexander Fleming

Fleming was trying to grow bacteria on special agar plates as part of his research. Bacteria usually grow very well across the top of agar plates. This day, however, Fleming failed to clean up after his experiment and left an agar plate open on his bench before leaving for a holiday. When he returned from his break, a small spot of mould had started growing in the centre of the plate. All around the mould was a clear circle where the bacteria were unable to grow. Fleming concluded that the mould (*Penicillium*) was producing a molecule that prevented the bacteria from growing (Figure 3). The molecule, which was named penicillin, had the ability to stop bacterial growth by preventing the bacteria repairing or making a new cell wall.

Figure 2 A type of penicillin can grow on orange peels.

Producing penicillin

It took ten more years and the work of Howard Florey (1898–1968) (Figure 4), an Australian scientist, and Ernst Chain (1906–1979) (Figure 5), a German-born British scientist, to develop a way to separate the penicillin and produce it on a large scale. They were part of a team of specialists brought together to grow the mould, extract the penicillin, purify it and trial its treatment on patients.

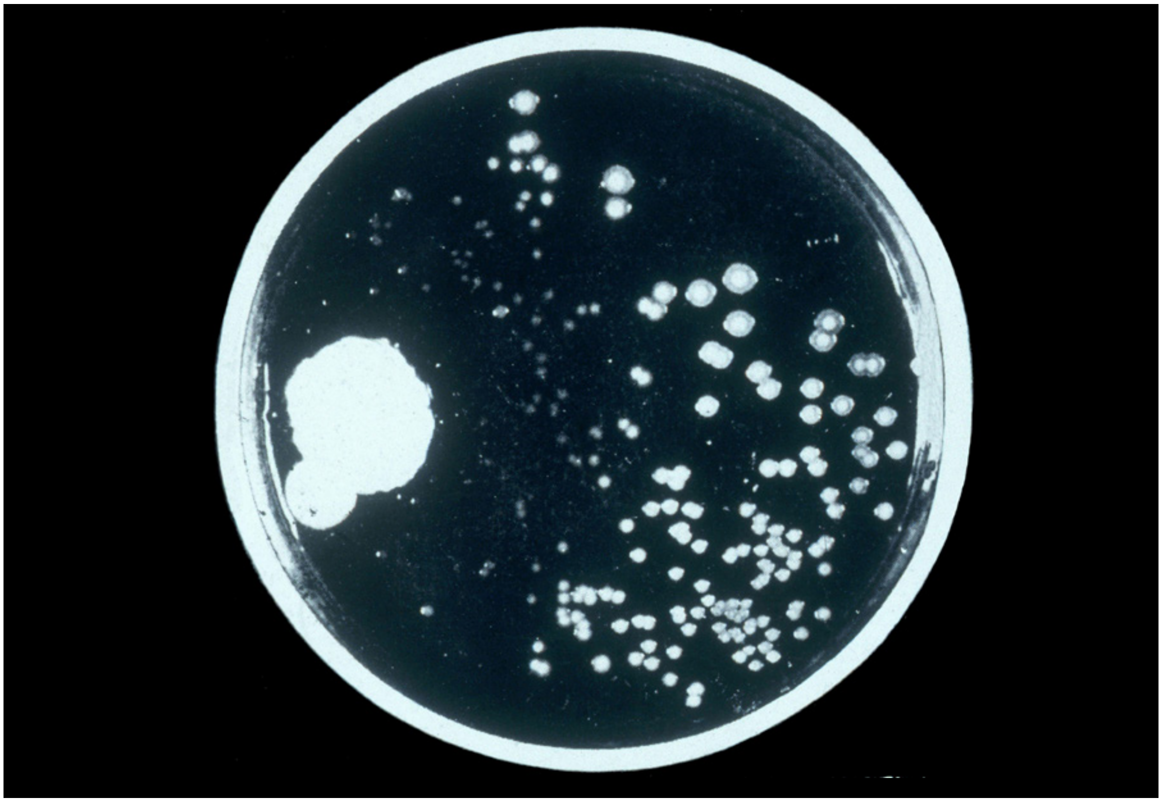


Figure 3 *Penicillium* mould growing on Fleming's agar plate

In May 1940, Fleming's group infected eight mice with streptococcal bacteria. Four of the mice were treated with penicillin. These mice survived, while the mice without the penicillin died.

This led the researchers to trial the penicillin on their first patient. Albert Alexander's whole face was swollen after being scratched by a rose thorn. One eye had been removed and the other lanced to drain the infection. Within one day of being given penicillin, Alexander started to improve. Unfortunately, Fleming's group did not have enough penicillin to finish the treatment, and the patient suffered a relapse and died.

The researchers tried treating children next, as smaller doses could be used and the treatment could last longer. Eventually, their purification methods and resulting treatment were successful (Figure 7). They were awarded a Nobel Prize in 1945 for their work.

Figure 4 Howard Florey

Figure 5 Ernst Chain

The use of penicillin as an antibiotic revolutionised health care and the lives of many people who, without such treatment, would have died from bacterial infections.

The timeline of knowledge development about mould as a treatment for bacterial infection is shown in Figure 6.

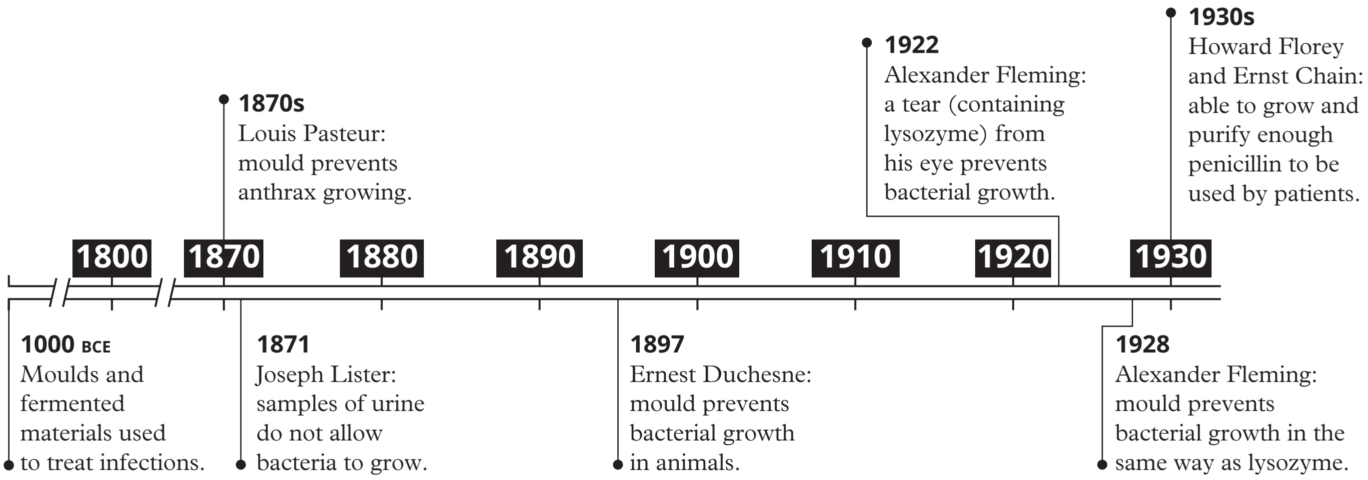


Figure 6 Penicillin timeline

Figure 7 These photos from 1942 show the improvement of a child after penicillin treatment for a bacterial infection: (A) before treatment; (B) four days after treatment; (C) nine days after treatment and (D) fully recovered

Overuse of antibiotics

There are now many antibiotics available, most of which are extracted from fungi. The overuse of antibiotics is a cause for concern. Because bacteria reproduce quickly, some strains of bacteria are becoming resistant to treatment. That is, they are not affected by antibiotics.

Scientists are continually searching for new types of natural and artificial antibiotics to treat these new “superbugs” that are resistant to all known antibiotics.

A dose of antibiotics destroys not only the harmful bacteria but also the good bacteria in your body, so they should only be used to treat bacterial infections when absolutely necessary.

Test your skills and capabilities

Test your skills and capabilities 4.11

Communicating with your audience

When you are sick, you visit the doctor. Doctors have many years of training to ask questions, observe disease symptoms, diagnose disease and decide if medication is needed. Doctors need to communicate their critical thinking to patients that do not have the same training or understanding. Doctors change the words about concepts so that their audience understands them.

Use your knowledge of viruses like influenza and how antibiotics kill bacteria to create a brochure that explains why a patient with influenza cannot be treated with antibiotics. Use the following hints to help you.

Before you begin:

1. Decide the age of the person who will read the brochure.
2. Describe how much they know about cells and viruses.

In your brochure:

3. Describe the symptoms of influenza.
4. Compare (the similarities and differences between) bacteria and viruses.
5. Describe how antibiotics affect bacteria.
6. Describe why antibiotics do not work on viruses.

Lesson 4.12

Review: Cells

Summary

Lesson 4.1 Cell theory

- All living things are made up of cells.
- Cells are the basic unit of life and structure.
- All living cells are created from existing cells.

Lesson 4.2 Cell structures and organelles

- All cells have a cell membrane, cytoplasm and genetic material (DNA).
- All plant and animal cells are made up of smaller parts called organelles (mini organs).
- Each organelle has a different function.

Lesson 4.3 Microscopes are used to study cells

- A microscope is an instrument that uses lenses to magnify the size of objects.
- Microscopes are used to observe and record similarities and differences between different cells.
- The science of investigating small objects using a microscope is called microscopy.

Lesson 4.6 Photosynthesis and cellular respiration

- Autotrophs make their own glucose (food) through photosynthesis.
- Photosynthesis is a chemical reaction that requires water and carbon dioxide in the presence of sunlight and chlorophyll to produce glucose (sugar) and oxygen.
- All organisms convert glucose into useable energy in a process called cellular respiration.

Lesson 4.8 Cell specialisation

- As a cell becomes larger, its surface area to volume ratio decreases.
- Multicellular organisms require specialised cells to perform life's functions.
- In complex multicellular organisms, there is a hierarchy of organisation which is cells, tissues, organs, organ systems and organism.

Review questions 4.12

Review questions Module 4

Retrieve

1 Name the first person to describe a cell.

2 Identify two types of microscopes.

3 Define the following terms.

  a Nucleus

  b Mitochondria

  c Chloroplast

  d Cell wall

4 Identify which of the following is not found in an animal cell.

  A Mitochondria

  B A cell wall

  C Cytosol

  D A nucleus

5 Recall which important process takes place in the mitochondria of a cell.

  A Photosynthesis

  B Excretion

  C Cellular respiration

  D Cell division

6 Identify the cell type involved in fighting disease.

  A Ovum

  B Guard cell

  C Red blood cell

  D White blood cell

Comprehend

7 Explain why multicellular organisms are made up of many cells instead of one large cell.

8 Describe the benefit of using a stain when viewing some specimens using a microscope.

9 Cell walls are found in every plant cell on Earth. Describe the function of the cell wall.

10 Describe how our understanding of how living things function changed with the development of the microscope.

Analyse

11 Calculate the magnification of a cell that is viewed with a "×40" objective lens and a "×10" eye-piece lens.

12 Identify the microscope most likely to have created the images in Figure 1. Justify your decision (by describing the features in the picture that are unique and deciding which microscope would allow these features to be seen).

13 Identify the organelles in Figure 2.

14 Compare a mitochondrion and a chloroplast.

15 Contrast fungal cells and animal cells.

16 A cell membrane is "partially permeable". This means that only certain substances can cross the membrane. Identify some substances that would need to get into the cell and some that would need to get out.

Apply

17 Two students prepare slides from different sections of a spring onion under a light microscope in their school laboratory. Tran views a section of the green leafy part and observes many chloroplasts within each cell, but has difficulty identifying a nucleus in each cell. Emily views a section of the white stem of the plant. She comments that a nucleus is clearly visible in most of the cells, but does not identify any chloroplasts.

- **a** Propose why Tran observed many chloroplasts within each cell when they appeared to be absent from the cells viewed by Emily.
- **b** Emily commented that she could identify a nucleus in most cells. Discuss whether it is possible for a plant cell not to have a nucleus (by describing the function of a nucleus, describing the importance of a nucleus to the cell staying alive and deciding if it is possible for a plant cell to live without a nucleus).

18 Write a very short creative story about a pathogen. Your story needs to be from the point of view of a cell. The first line of your story is: "Once upon a time, a pathogen arrived for an uninvited visit".

Figure 1 An up-close look at tiny details, showing what this microscope can do

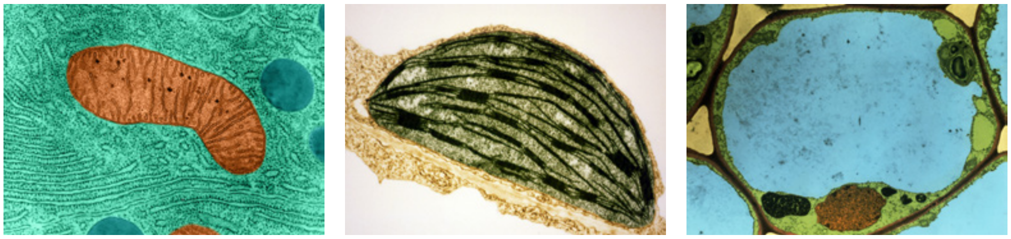


Figure 2 Organelles

19 Use the lenses from an old pair of reading glasses or a magnifying glass to create a model of a microscope. Discuss how your model is similar and different to both Robert Hooke's microscope and modern compound microscopes.

Critical and creative thinking

20 Similes are often used in creative writing to compare two things using the words "like" or "as". Discuss the similarities that allow the following similes to be used.

- **a** Cells are like building blocks.
- **b** The nucleus is like a control centre.
- **c** The mitochondrion is like a power station.

Social and ethical thinking

21 Discuss why a doctor should not prescribe antibiotics for a viral infection by describing:

- **a** the effectiveness of the antibiotics on making the person healthy
- **b** the long-term effects of overprescribing antibiotics on bacterial resistance.

Research

22 Choose one of the following topics for a research project. A few guiding questions have been provided for you, but you should add more questions that you want to investigate. Present your research in a format of your own choosing, giving careful consideration to the information you are presenting.

Linking big concepts

In this module, major concepts about cells were discussed. Consider a creative way to represent these concepts and make links between them, using as many of the keywords in the chapter as you can. You might use a concept map or mind map with each of the questions as major bubbles. You could choose to use diagrams only or draw a picture that shows all the aspects of the particles of life. The method of presentation that you select must enable you to share your ideas with others.

Figure 3 Represent the concepts in this chapter creatively.

Discovery of penicillin

The discovery of penicillin was considered an important factor behind the outcome of the Second World War. Soldiers who were injured on the battlefield could be mended, given a shot of penicillin, and returned to the battlefield again instead of having limbs amputated. Develop and write a newspaper article describing the importance of this major discovery.

Figure 4 The development of penicillin, 1940

Stem cells

Stem cells are cells in multicellular organisms that haven't become specialised yet – they're like blank canvases. Investigate what scientists have learnt about stem cells, where they find them, what they have already achieved with them and what they hope to be able to do with them in the future.

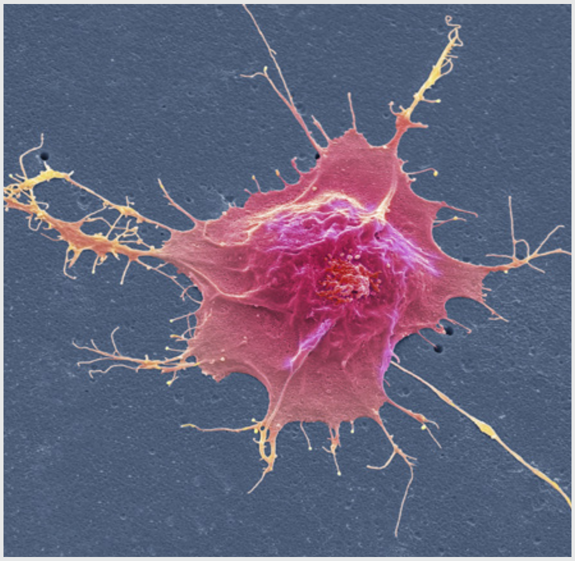


Figure 5 Scanning electron micrograph of a type of stem cell

Specialised plant cells

Plants do not have lungs to breathe. Instead, they have small pores called **stomata** which allow air to pass in and out of the plant. These stomata are made up of two guard cells that can change their shape.

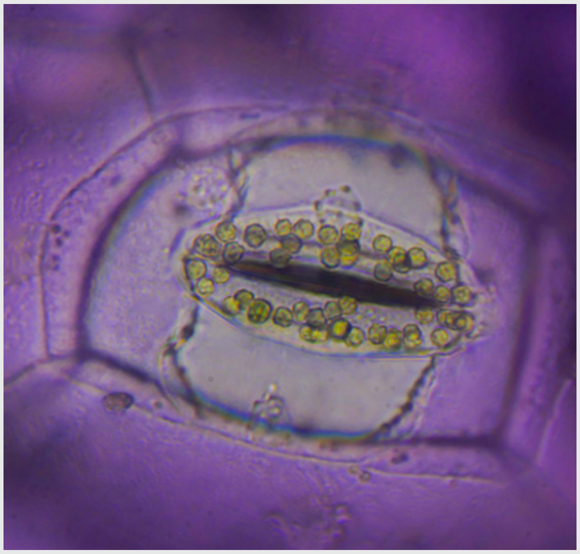
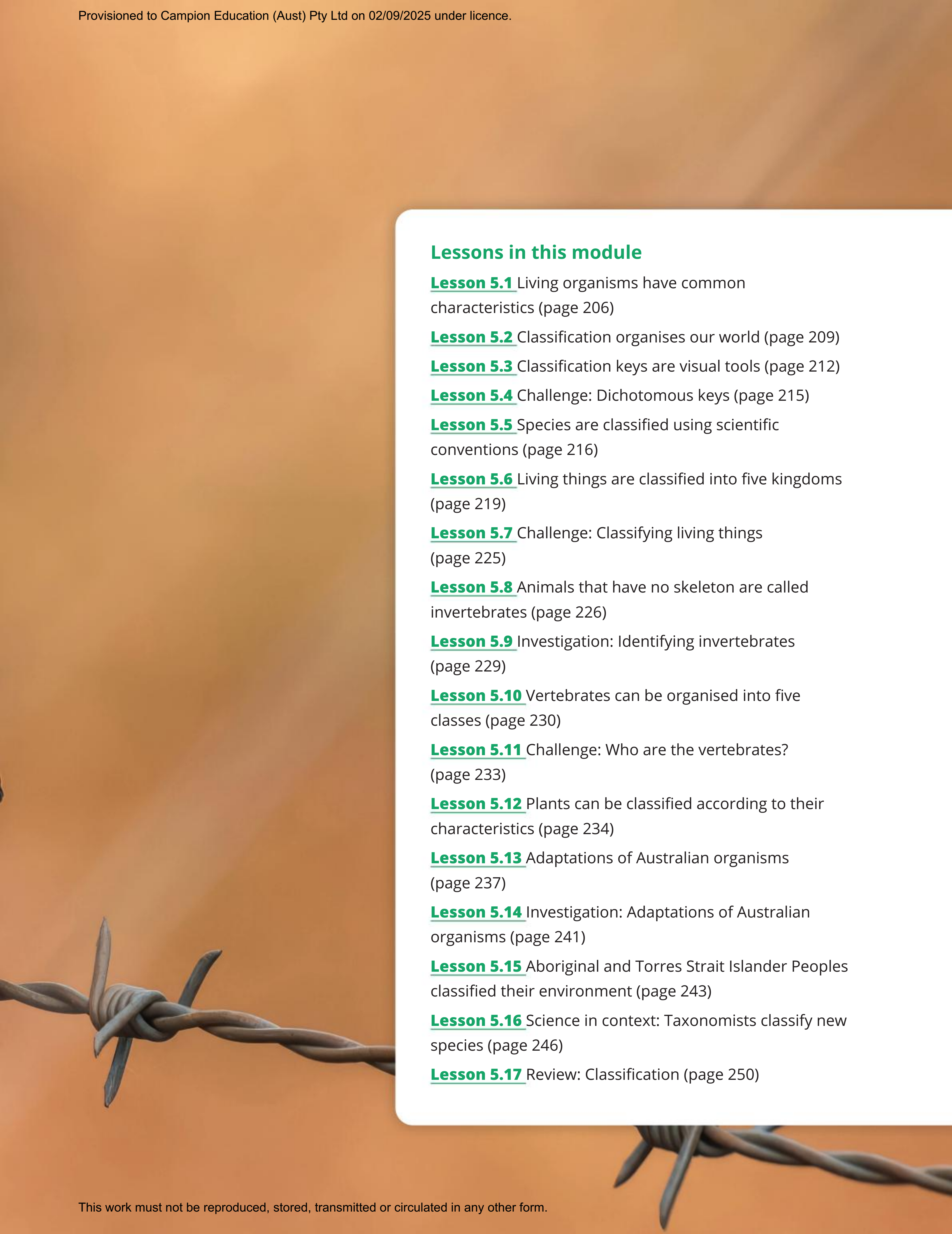


Figure 6 Micrograph of a stomata on a purple and green leaf

Module
5
Classification

Overview

Early scientists worked hard to understand the world around them. One way they did this was by grouping things into categories based on what they had in common or what made them different. Classification helps us organise living things by their shared characteristics. Tools like classification keys help identify all kinds of organisms, from plants and animals to tiny microorganisms. Today, scientists called taxonomists still use these methods to keep discovering and organising new species.



Lessons in this module

Lesson 5.1

Living organisms have common characteristics

Learning intentions and success criteria

Key ideas

→ Living things move, reproduce, grow, respond, exchange gases, produce waste and need nutrition and water.

→ Something that is dead used to have the characteristics of living organisms, whereas something that is non-living never had these characteristics.

Characteristics of living things

Before we can begin to classify living things, also called organisms, we must first understand what it means to be alive. It has taken many years of observation and discussion for scientists to develop eight characteristics that all living things – plants, animals and even **microorganisms** such as bacteria – have in common. To remember all eight characteristics, just recall: MR N GREWW.

microorganism a living thing that can only be seen with the use of a microscope

reproduction the production of offspring by a sexual or asexual process

nutrient a substance that an organism must obtain from its environment for growth and the maintenance of life; examples include carbohydrates, proteins, fats, vitamins, minerals and water

M: Living things can MOVE by themselves

Animal movements are easy to see. Picture a bird flying or a dolphin swimming. But do plants move? Look at the leaves on an indoor plant – they usually face the window (a source of light). Turn the plant around so that the leaves face into a darker part of the room. In a few days, the leaves will be facing the window again. The leaves have moved by themselves. Sunflowers turn their heads to follow the Sun as it moves across the sky each day (Figure 1B).

Figure 1 (A) Major Mitchell's cockatoo in flight; (B) Sunflowers follow the Sun as it moves across the sky.

R: Living things can REPRODUCE

Reproduction is the process by which living things make new life. Animals mate and produce offspring, plants produce seeds that grow into new plants and bacteria divide to produce more bacteria. Without reproduction, living things would become extinct (Figure 2).

Figure 2 Living things reproduce.

N: Living things need NUTRITION

All living things need **nutrients** to survive. Animals obtain most of their nutrients by eating food and drinking. Plants absorb nutrients through their roots, while fungi have structures called **hyphae** that absorb nutrients from decaying organisms. Plants are classified as **autotrophs**, which means they make their own food. Animals and fungi are **heterotrophs**, which means they rely on other organisms for food (Figure 3).

Figure 3 Living things need nutrients to survive.

autotroph an organism that produces its own chemical energy through photosynthesis or chemosynthesis

heterotroph an organism that must consume other organisms in order to obtain its energy requirements

metamorphose to change into a completely different physical form

G: Living things GROW as they get older

All living things grow during their lives. Mushrooms start off as tiny spores. Humans are born as babies, developing into children, teenagers and then adults. Tadpoles will hatch from their eggs and then **metamorphose** into adult frogs (Figure 4). In every case, an organism, when fully grown, resembles its parents.

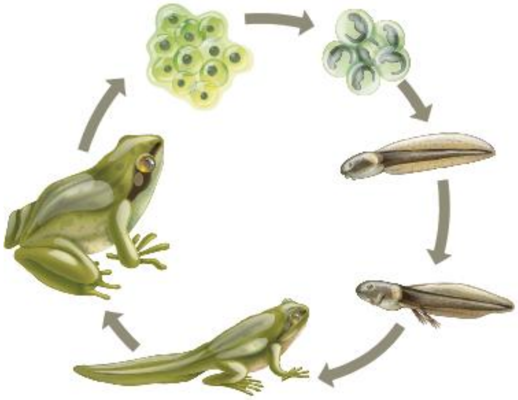


Figure 4 Living things grow during their lives.

stimuli a changes or event in the environment that causes a reaction from an organism

R: Living things RESPOND to change

All living things respond to their environment. For example, a Venus flytrap snaps shut in response to the **stimuli** of an insect landing in its trap (Figure 5). The sunflowers shown in Figure 1B are responding to the changing stimuli of light and warmth. When an animal realises it is being chased, it might run or swim away. It is responding to stimuli (the sight and sound of a charging predator) in its environment.

Figure 5 A Venus flytrap has modified leaves with "teeth" that snap shut when it detects a stimulus on its surface. The prey is unable to escape and will be digested by the plant.

E: Living things EXCHANGE GASES with their environment

Plants and animals have organs and structures that allow them to exchange oxygen and other gases. For example, all mammals use their lungs to inhale oxygen and then exhale carbon dioxide. Fish have gills, while amphibians exchange gases mainly across their skin (Figure 6).

Figure 6 The axolotl has gills to exchange gases with its environment.

W: Living things produce WASTES

We, like other animals, take in food, water and air to fuel our bodies. Chemical reactions occur in our bodies and wastes are produced as a result. We get rid of these wastes by exhaling, sweating, urinating and defecating (emptying our bowels). Plants get rid of their wastes through their leaves (Figure 7).

Figure 7 Sweating is one way humans get rid of waste products from their bodies.

Figure 8 An animal's body uses water for many jobs, including maintaining body temperature.

W: Living things require WATER

All living things need water; it is required for many jobs. For example, water transports substances in our bodies to where they are needed, and it is involved in many essential chemical reactions. In animals, water helps maintain body temperature (Figure 8).

Non-living or dead?

Something classified as living needs nutrition and water, and is able to move by itself, reproduce, exchange gases, grow, respond to stimuli and produce wastes. If something doesn't have these characteristics, it would seem logical to assume that the thing is non-living. But what about something that is dead? Something dead, such as a dried flower or an Egyptian mummy, was once living. When it was alive, it *did* have the characteristics of a living thing. Something that is non-living, such as a computer or your watch, never had these characteristics.

Check your learning 5.1

Check your learning 5.1

Retrieve

1 Identify what the letters of MR N GREWW represent when discussing the characteristics of living things.

Analyse

2 Consider the following things:
eucalyptus tree, water, paper, robot, dinosaur fossil, wombat, roast chicken, plastic chair.
With a partner or by yourself, classify each thing as living, non-living or dead.

3 Contrast non-living and dead things.

Apply

4 Identify the items listed in question 2 that are dead. Justify your answer (by defining the term "dead" and comparing the definition to the item).

5 Identify a bushfire as either living, non-living or dead. Justify your answer (by describing the characteristics of a living thing and comparing it with the properties of a fire).

Skills builder: Questioning and predicting

6 Analyse the image of the Venus flytrap in Figure 5.
   - **a** What physical structures can you observe that would help the plant to live?
   - **b** Write a scientific question about one of your observations. (THINK: What would you like to know more about? Your question should be specific and easily tested.)

Lesson 5.2

Classification organises our world

Key ideas

→ Classification is the process of grouping or organising things.

→ Scientists identify all living things through scientific names.

→ Classification systems help scientists to communicate and understand the relationships between living things based on their similarities or differences.

Learning intentions and success criteria

Why do we classify living things?

Classification involves grouping or organising things based on similarities or differences in their characteristics. For example, in biology some animals can be classified as mammals, birds, reptiles, amphibians or fish, while plants might be grouped as flowering or non-flowering. There are many reasons why classification is important. Classification allows scientists to better understand and communicate the relationships between organisms and determine evolutionary relationships. Classification also allows scientists to make predictions about **species** behaviour and requirements, which is essential for conservation efforts.

classification the systematic process of organising and grouping living organisms or objects based on shared characteristics

species a group of organisms that look similar to one another, and can breed in natural conditions and produce fertile young

Role and importance of classification in ordering and organising life

Classification helps us to organise information

Early humans first classified plants and animals to assist their survival. They had to learn which plants were edible, which could help sick people and which were poisonous. Similarly, some animals could produce food, such as milk and eggs, while other animals might be dangerous. Any new plant or animal that was discovered by humans was – and still is – studied and organised into a group. Each generation of scientists continues to improve how these groups are classified.

Classification helps scientists to communicate

Early scientists did not have modern technologies that would allow them to record and capture images of any curious new plants or animals they discovered. Instead, they relied on hand-drawn pictures and written descriptions. This led to challenges, as many animals share very similar features.

Consider the photographs of the South American greater rhea, the Australian emu and the southern cassowary in Figure 1. All three birds have obvious similarities. The word “emu” is derived from an Arabic word for large birds. Portuguese-speaking South Americans refer to the greater rhea as an emu. Early Portuguese explorers to Australia and Indonesia used the word “emu” to first describe cassowaries.

Figure 1 (A) the greater rhea (*Rhea Americana*); (B) the Australian emu (*Dromaius novaehollandiae*); (C) the southern cassowary (*Casuarius casuarius*)

Then European explorers used the same word to describe the Australian emu. In short, three birds were all given the same name. To overcome this kind of confusion and assist with classification, a system was developed by Swedish scientist Carolus Linnaeus (1707–1778) (Figure 2) in which all organisms were given a unique scientific name. The name *Dromaius novaehollandiae* for the Australian emu means the same to scientists in every country around the world.

Figure 2 Swedish scientist Carolus Linnaeus developed a classification system which gave unique names to all organisms.

Discovery and recognition of new species

There are many living things that are yet to be discovered or named. In 2020, seven new species of peacock spiders were identified in Australia (Figure 3). These spiders are the same size as a grain of rice. During the courtship dance, the male spider

Figure 3 Peacock spiders are unique to Australia, and new species of peacock spiders have been discovered recently.

waves his brightly coloured abdomen to attract prospective mates. To be formally recognised as a new species, a description and scientific name must be published in accordance with the International Code of Zoological Nomenclature.

Small groups of scientists are trying to find undiscovered plants in Brazilian rainforests before they are destroyed by logging and farming (Figure 4). Often the scientists are supported by large pharmaceutical companies from other countries in the hope that it may lead to the discovery of new medications. Many of the medications we currently use come from organisms. The antibiotic penicillin was discovered from a type of mould, and aspirin comes from a substance in the bark of willow trees. The next painkiller could come from a small fungus in the rainforest or an insect that relies on the fungus for food. Without classification and a scientific name, these new discoveries could easily be lost and forgotten.

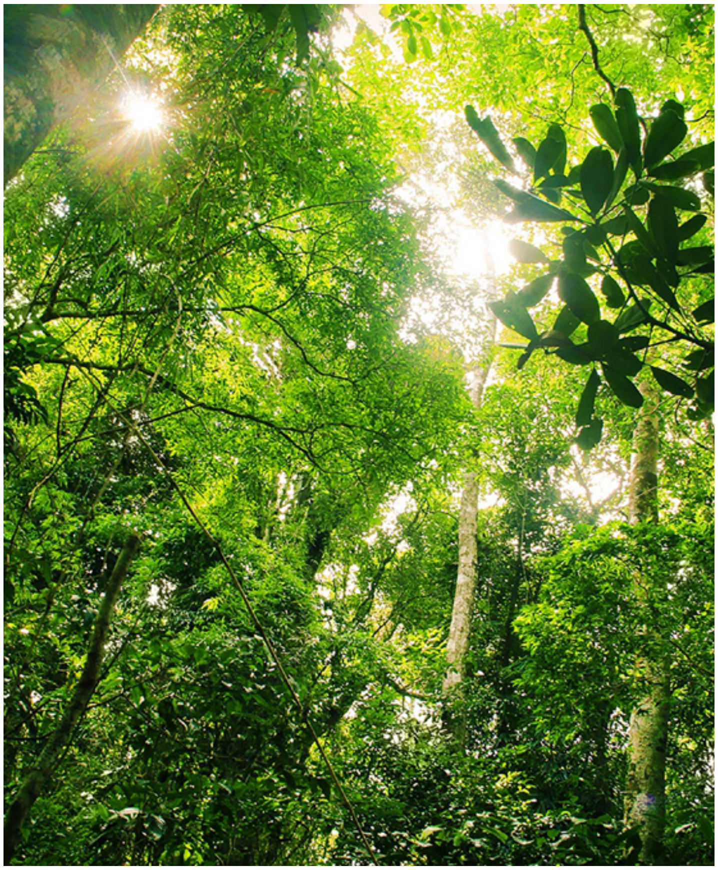


Figure 4 The rainforests of Brazil contain many undiscovered plant species.

Check your learning 5.2

Check your learning 5.2d

Retrieve

1 Define the term "classification".

Comprehend

2 Explain the advantages of the simplified Linnaeus classification system over previous attempts to classify living things.

3 Explain why it would be difficult to classify frogs and tadpoles before the Linnaeus classification system.

Apply

4 Propose two reasons why scientists still classify organisms today.

5 The earliest scientists did not have pens or paper. Describe how they would have passed on the information they discovered. Discuss the accuracy of this approach (by describing the advantages and disadvantages of using this method).

Skills builder: Planning investigations

6 A student found a strange species of insect in their backyard, but they could not identify what it was. Suggest what equipment they could use to record their observation so that they could ask an expert later. (THINK: What information would they need to record so that an expert could help them? What is the best way to capture this information?)

Lesson 5.3

Classification keys are visual tools

Learning intentions and success criteria

Key ideas

- → A key is a visual tool used in the classification of ideas.
- → Scientists use dichotomous keys to identify the scientific name of an organism.
- → A branched dichotomous key can show the relationship between different organisms.

Introduction

When you visit an outdoor market, you may wander around for some time before you find what you want. A department store is more organised, with similar items grouped together. Scientists use a system similar to this to sort things into groups or classify them. The system makes the names and descriptions of organisms easier to find. A visual tool called a **key** helps scientists identify the names and descriptions of organisms.

key a visual tool used in the classification of organisms

Dichotomous keys

A **dichotomous key** (pronounced "dye-COT-o-muss") is used to identify and classify organisms or objects based on their characteristics. It is called "dichotomous" because, at each step of the key, there are always two options to choose from (*di* means "two"). In biological classification and identification, two common types of dichotomous keys are used: branched keys and tabular keys.

dichotomous key a diagram used in classification; each 'arm' of the key contains two choices

Branched dichotomous key

A branched dichotomous key provides a series of paired statements or questions that guide the user through a step-by-step process to identify an organism based on its characteristics. At each step, there are always two contrasting options to choose from, allowing scientists to make simple "yes" or "no" decisions. For example, a user might be asked whether the animal has a pouch (yes/no) or whether it has scales (yes/no). Each answer leads to another branch and another question, directing the user closer to the correct identification of the organism (Figure 1).

Tabular dichotomous key

If a scientist is going out into the bush to study plants and animals, a large drawing like the branched key in Figure 1 may not be ideal. Instead, a tabular dichotomous key, such as that shown in Table 1, is often more appropriate because it is compact and allows the user to compare multiple traits across different organisms simultaneously. This approach provides a more visual and comparative analysis, making it easier to identify specific characteristics quickly. They are used in the same way as the branched key version. Two choices are offered at each stage. When a decision is made, the scientist is led to the next characteristic to consider.

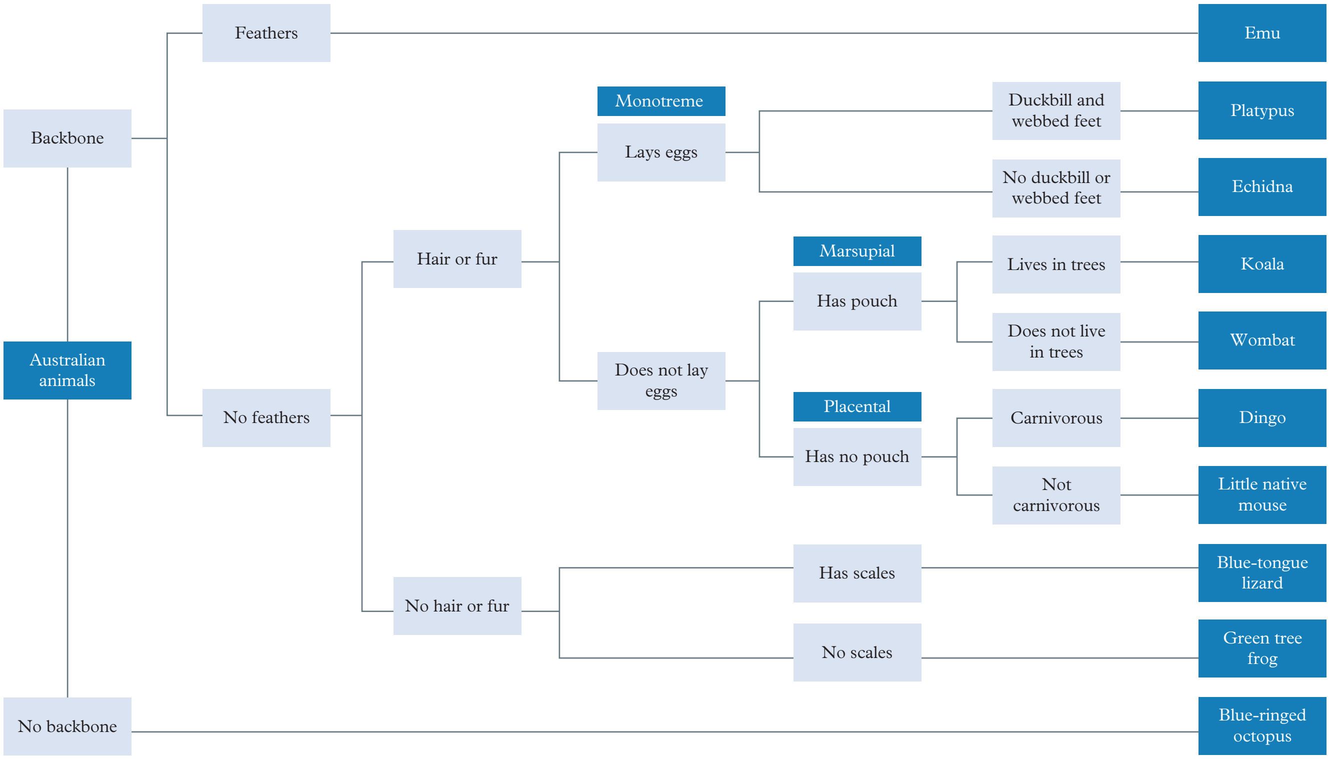


Figure 1 A dichotomous key to identify some Australian animals

Table 1 A tabular key to identify some Australian animals

1	Has a backbone (vertebrate)	Go to 2
	Does not have a backbone (invertebrate)	Blue-ringed octopus
2	Has feathers	Emu
	Does not have feathers	Go to 3
3	Has fur or hair	Go to 4
	Does not have fur or hair	Go to 9
4	Lays eggs	Go to 5
	Does not lay eggs	Go to 6
5	Has a duck-like bill and webbed feet	Platypus
	Does not have a duck-like bill and webbed feet	Echidna
6	Has a pouch	Go to 7
	Does not have a pouch	Go to 8
7	Lives in trees	Koala
	Does not live in trees	Wombat
8	Carnivorous	Dingo
	Not carnivorous	Little native mouse
9	Has scales	Blue-tongue lizard
	Does not have scales	Green tree frog

These dichotomous keys only work if the organism has already been identified by someone else. A newly discovered organism would need to be studied first and then new branches added to an existing key.

Classifying Australian mammals

Australia has one of the most diverse ranges of animals on the planet. We are one of only two places in the world (the other is our close neighbour New Guinea) that has all three groups of mammals – **placental mammals**, **marsupials** and **monotremes**. Many of these animals are **endemic** (found only in Australia).

A student wanted to send postcards (Figure 2 and Figure 3) to friends from overseas who they met while studying on exchange. The friends had never encountered any Australian animals. Just for fun, the student included two dichotomous keys to help the friends identify the different Australian animals.

Use the dichotomous keys provided Figure 1 and Table 1 to identify the Australian animals in Postcard A and Postcard B. Create another key you could attach to the postcard that could be used to help someone identify whether a mammal is a placental mammal, marsupial or monotreme.

placental mammal a type of mammal whose young develop inside the mother's uterus, and are joined to the uterus via the placenta

marsupial a type of mammal that gives birth to young that continue to develop in their mother's pouch

monotremes a type of mammal that lays eggs

endemic found only in a specific country or region

Figure 2 Postcard A

Figure 3 Postcard B

Check your learning 5.3

Check your learning 5.3

Retrieve

1 Define the term "dichotomous key".

2 Distinguish between a branched and tabular dichotomous key.

Apply

3 A scientist needs to carefully select the characteristics that are used to classify organisms in a dichotomous key. For each of the characteristics listed below, consider if it is appropriate for use in a dichotomous key of birds. Justify your answer (by explaining how it can or cannot be used to identify a bird).

- **a** Eating bird seed
- **b** A blue stripe above the eye
- **c** A broken leg
- **d** Sitting on the ground

4 Use the tabular key (Table 2) to answer the following questions.

Figure 4 Some of Australia's rare amphibians and reptiles

- **a** Identify the six rare Australian animals shown in Figure 4.
- **b** Redo the tabular key in Table 2 using different criteria to identify each organism in Figure 4.

Table 2 Tabular key of some Australian amphibians and reptiles

1	Has legs	Go to 2
	No legs	Go to 8
2	Has tail	Go to 3
	No tail	Go to 4
3	Clubbed (round tail)	Knob-tailed gecko
	Tail not clubbed (elongated)	Arnhem phasmid gecko
4	Solid green colour	Green tree frog
	Not solid green in colour	Go to 5
5	Yellow and black stripes	Southern corroboree frog
	No yellow and black stripes	Go to 6
6	Mottled orange and brown skin	Beautiful nursery frog
	No mottled orange and brown skin	Go to 7
7	Green, yellow and brown stripes	Green and golden bell frog
	No green, yellow and brown stripes	Turtle frog
8	Brown and yellow stripes	Go to 9
	No brown and yellow stripes	Go to 10
9	Stripes run from head to tail	Striped legless lizard
	Stripes do not run from head to tail	Tiger snake
10	Red colour on abdomen only	Red-bellied black snake
	Red colour not on abdomen only	Collett’s snake

5 Create a dichotomous key that could be used to identify a cassowary, wedge-tailed eagle, flying fox (bat), sugar glider, Tasmanian devil and saltwater crocodile.

Lesson 5.4

Challenge: Dichotomous keys

Aim

To design a dichotomous key

Questioning and predicting

Many groups of organisms have really obvious differences that make it easy to create a dichotomous key to identify each of them. Sometimes, however, it can be a little more challenging. The following 10 animals are all Australian marsupials.

- Red kangaroo
- Grey kangaroo
- Yellow-footed rock wallaby
- Quokka
- Bilby
- Spotted quoll
- Ring-tailed possum
- Brush-tailed possum
- Numbat
- Wombat

Research and gather images of the different animals and create a key that could be used to identify each of them.

Keep a copy of your images in a file that you will later give to your classmates, who will put your key to the test.

Planning and conducting

- Compare the similarities and differences of each animal.
- Describe the similarities that will allow the animals to be divided into two groups.
- Select one of the groups and compare the similarities and differences of features in that group.
- Describe the similarities that will allow these animals to be divided into two further groups.
- Repeat this procedure until all animals are in a group of one.

Processing and analysing

1. Draw a dichotomous key to show how you grouped the animals.
2. Describe the difficulties of classifying the animals into groups.
3. Describe how you would improve your grouping if you repeated the challenge.

Communicating

Swap your dichotomous key with another group. Ask them to evaluate your key by comparing how easy it was to identify the key feature of each animal that allowed it to be classified.

Lesson 5.5

Species are classified using scientific conventions

Learning intentions and success criteria

Key ideas

→ Carolus Linnaeus was the first scientist to use a dichotomous key to classify living things.

→ Scientific names are binomial (two names): the genus name and the species name.

→ The Linnaean taxonomy system is still used today.

The Linnaean taxonomy

A species is like the specific address of an organism in the vast "Google Earth" of life. Just as you narrow down from the Earth to a country, state, town, suburb, and street to find a particular house, biologists classify organisms from broader groups down to the species level. A species is the most precise classification, identifying organisms that share common characteristics and can interbreed to produce fertile offspring. The broader categories, like genus or family, help in understanding relationships, but are not as specific as the species.

In a similar way, Carolus Linnaeus developed a classification system, known as **Linnaean taxonomy**, which is still in use today. Before Linnaeus introduced his systematic approach, there was no universally accepted or standardised number of classification groups; the classification of organisms was arbitrary and varied significantly among scholars. Different naturalists and scientists employed various criteria and methods, leading to inconsistent and often overlapping categories. Linnaeus examined earlier classification systems but found them to be too lengthy and complicated. He determined that a simpler system was needed, simplifying descriptions to single words and reducing the number of classification groups to seven (Figure 1).

CAROLI LINNÆI REGNUM ANIMALE

ADRUPEDIA | II AVES | III AMPHIBIA | IV PISCES | V INSECTA | VI VERME

PARADOXA

Figure 1 Part of Linnaeus's classification system

Linnaean taxonomy a hierarchical system of classification developed by Linnaeus in which all organisms are grouped into kingdom, phylum, class, order, genus and species, with each individual organism known by its genus and species names

The Linnaean system starts with large groups called **kingdoms** and then divides into smaller, more specific groups called **phyla** (singular "phylum"). Each phylum has several classes. The classes have orders and so on. There are seven hierarchical levels – kingdom, phylum, class, order, family, genus and species, with each level having fewer types of organisms that belong in them. (Tip: To remember the order, use the following mnemonic or come up with your own: "**K**ing **P**hillip **C**rawled **O**ver **F**our **G**ooey **S**nails".)

kingdom the highest category in taxonomic classification

species a group of organisms that look similar to one another, and can breed in natural conditions and produce fertile young

Giving organisms a precise name

A **species** is a group of organisms that can reproduce with one another in nature and produce fertile offspring – in other words, the offspring can also breed and have babies. For instance, all red kangaroos belong to the one species because they can breed together and have joeys.

Every recognised species is given a unique scientific name that is determined by the last two levels of the Linnaean classification system: the genus and the species.

This system, called the **binomial system**, uses two names. The **genus** name always begins with a capital letter, while the species name does not, and both are written in italics. For example, the scientific name for a red kangaroo is *Macropus rufus*. Also, have you eaten a *Musa sapientum* (Figure 3) lately or have they been too expensive to buy? And did you pat your *Felis catus* this morning (Figure 4)?

binomial system a double-name system created by Linnaeus to name organisms; the first name is the genus and the second name is the species

genus a group of closely related species

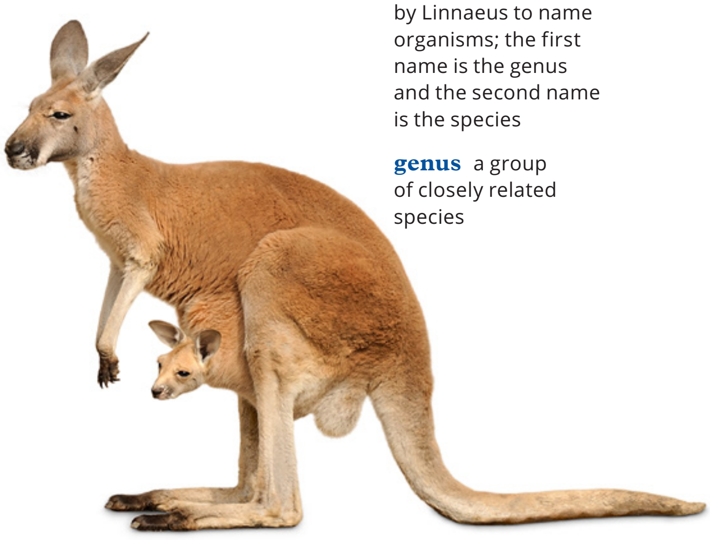


Figure 2 All red kangaroos belong to the same species: *Macropus rufus*.

Figure 3 *Musa sapientum* is the Linnaean name for a banana.

Figure 4 *Felis catus* is the Linnaean name for a domestic cat.

The Linnaean classification system can also be used to determine evolutionary relationships. For example, while the physical and behavioural similarities of humans and chimpanzees is obvious, examining Figure 5 shows that we share classification up to the family level: Hominidae. This indicates that we share a relatively recent common ancestor and that chimpanzees are one of our closest living relatives.

Increasing relatedness

Common name	Human	Chimpanzee	Bottlenose dolphin	Great white shark
Kingdom	Animalia	Animalia	Animalia	Animalia
Phylum	Chordata	Chordata	Chordata	Chordata
Class	Mammalia	Mammalia	Mammalia	Chondrichthyes
Order	Primate	Primate	Artiodactyla	Lamniformes
Family	Hominidae	Hominidae	Delphinidae	Lamnidae
Genus	Homo	Pan	Tursiops	Carcharodon
Species	*sapiens*	*troglodytes*	*truncatus*	*carcharias*

Increasing group size

Figure 5 Classification of humans, chimpanzees, bottlenose dolphins and great white sharks

In contrast, although the bottlenose dolphin and great white shark may share obvious physical similarities, they are only distantly related. The dolphin, in fact, belongs to the same class as humans and chimpanzees: Mammalia. The shared characteristics of dolphins and sharks are due to the similar environment in which they live, rather than close evolutionary ties.

Check your learning 5.5

Check your learning 5.5

Retrieve

1 Identify the person responsible for the naming system that is still used today to name living things.

2 Recall the seven levels or groups that are used to divide all living things. Write them in order from the largest group or level to the smallest level of organisation.

Comprehend

3 Explain how you would know whether two organisms are the same species.

4 Select three species of animal. For each animal:

  a describe its appearance

  b identify its common and scientific names.

Analyse

5 Identify which two organisms would be most alike: *Felis catus*, *Canis familiaris* and *Felis bieti*. Justify your response.

Apply

6 Compare the scientific names of two different species within the same genus and explain what this indicates about their evolutionary relationship. For example, how are *Macropus rufus* (red kangaroo) and *Macropus giganteus* (eastern grey kangaroo) related?

7 Based on the Linnaean classification system, explain how the shared family classification of *Hominidae* for humans and chimpanzees supports the idea of a common ancestor. What implications does this have for understanding human evolution?

Skills builder: Planning investigations

8 A student is asked to classify a species of butterfly. Suggest how they might find the information they need to discover its binomial name. (THINK: Does this require first-hand and secondary sources?)

Lesson 5.6

Living things are classified into five kingdoms

Key ideas

→ All cells can be split into two groups – prokaryotes and eukaryotes.

→ Organisms can be classified into five kingdoms – Animalia, Plantae, Fungi, Monera and Protista – based on key structural cell features.Microorganisms can only be seen under a microscope and include bacteria and most protists.

→ New information that compares genetic material may change the five-kingdom system.

Learning intentions and success criteria

Building blocks of life

All organisms are made up of cells. Cells are often called the building blocks of life. Think of the way bricks are used to build a house. Cells build living things in a similar way. There are, however, usually many more cells in living things than bricks in a house. Any living thing with more than one cell is **multicellular** (Figure 1A and Figure 1B). Many living things such as bacteria, however, consist of only one cell. These are single-celled or **unicellular** organisms (Figure 1C).

multicellular consisting of two or more cells

unicellular consisting of only one cell; an example is a bacterium

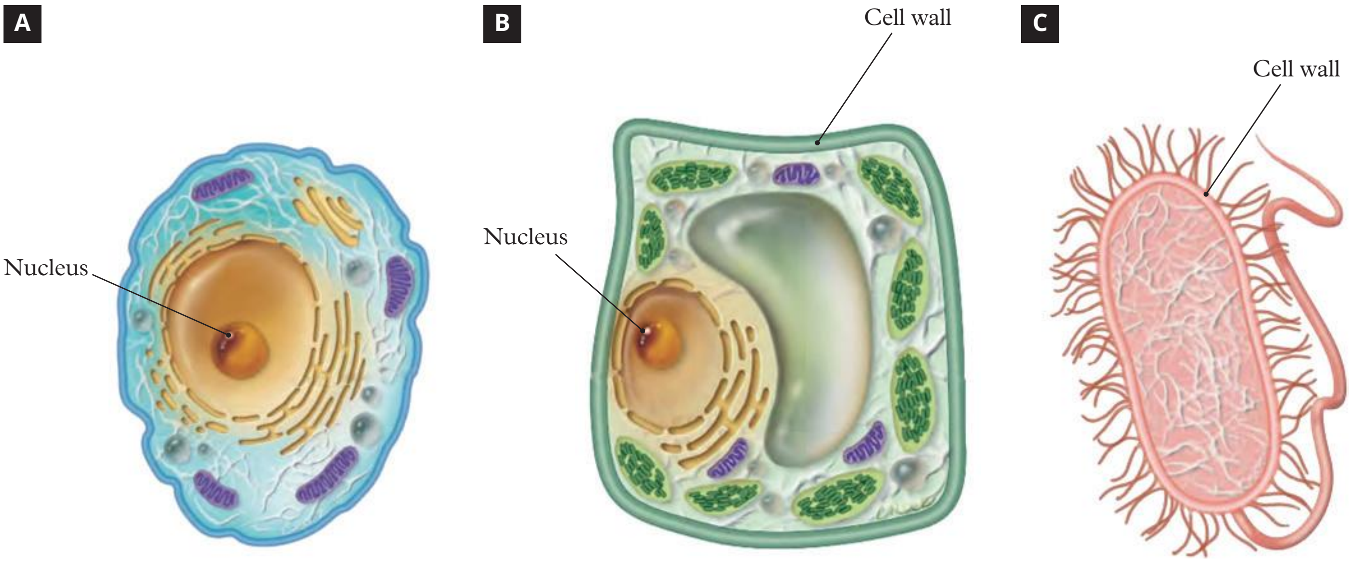


Figure 1 (A) Simple animal cell; (B) plant cell; (C) bacterial cell

Parts of a cell used for classification

nucleus a membrane-bound structure in cells that contains most of the cell's genetic material

cell wall a structure that provides support around the cell in some organisms, such as plants and fungi

Taxonomists are scientists who research the classification of new species. They ask three questions when they are trying to classify the cells of an organism:

1 Does the cell keep its genetic material (called DNA) inside a **nucleus**? The nucleus protects the DNA that carries all the instructions for staying alive.
2 Does the cell have a **cell wall** around it for extra support?
3 Does the cell use sunlight to make its own nutrients (autotroph)? Plant cells can do this, but fungi (like mushrooms) need to absorb their nutrients from other living things (heterotroph).

These three features are used to divide all living things into big groups called **kingdoms** (Table 1).

Table 1 Characteristics of eukaryotic and prokaryotic cells

Characteristic	Kingdom				
	Eukaryotes				Prokaryotes
	Animalia	Plantae	Fungi	Protista	Monera
Number of cells	Multicellular	Multicellular	Multicellular, some unicellular (e.g. yeasts)	Multicellular or unicellular	Unicellular
Cell wall	Absent	Present	Present	Present in some	Present
Genetic material	Present	Present	Present	Present	Present
Nucleus	Present	Present	Present	Present	Absent
Mitochondria	Present	Present	Present	Present	Absent
Chloroplasts	Absent	Present	Absent	Present in some	Absent
Large vacuoles	Absent	Present	Absent	Present in some	Absent
Ribosomes	Present	Present	Present	Present	Present

Prokaryotes and eukaryotes

Cells are classified into two main groups – prokaryotic cells and eukaryotic cells.

Prokaryotic cells belong to Kingdom Monera. They are the most primitive cellular forms on Earth and are unicellular (single cells). They are much simpler than eukaryotic cells and do not have many of the organelles that eukaryotic cells possess. For example, they have no nucleus, and their genetic material (DNA) is found free in the **cytoplasm**. While both prokaryotic and eukaryotic cells have **ribosomes** for protein synthesis, prokaryotic ribosomes are smaller and differ in structure. Prokaryotes include all the bacteria found on Earth.

Eukaryotic cells are more complex and are found in organisms from each of the other four kingdoms – Animalia, Plantae, Fungi, and Protista. These cells contain their genetic material within a nucleus and have membrane-bound organelles, which perform specific functions to support cellular processes. Most eukaryotes are multicellular.

prokaryotic cell a primitive single-celled organism that has no nucleus

cytoplasm the jelly-like substance inside cells that helps to maintain the structure and facilitate the movement of materials within the cell

ribosome non-membrane enclosed organelle required for protein synthesis

eukaryotic cell a complex cell that contains a nucleus and membrane-bound organelles

zoologist a scientist who studies animals

Kingdom Animalia

All organisms in Kingdom Animalia are multicellular (Figure 2). Each cell stores its genetic material (DNA) in a nucleus. Animal cells do not have a cell wall. Animals gain energy from consuming other living things. We belong in this kingdom. Scientists who study animals are called **zoologists**.

Figure 2 Kingdom Animalia: (A) Proboscis monkey (*Nasalis larvatus*) with the world's largest nose; (B) Port Jackson shark; (C) damselfly

Kingdom Plantae

Kingdom Plantae includes trees, vines, bushes, ferns, mosses, weeds and grasses (Figure 3). They are distinguished by the presence of chloroplasts that are used to carry out **photosynthesis**, using sunlight to gain energy and make their own food (autotrophs). They are multicellular and their cells have a cell wall around the outside of the cell, as well as a nucleus inside the cell containing DNA. Most plant cells also have a large **water vacuole** that stores water and nutrients and provides structural support. Scientists who study this kingdom are called **botanists**.

photosynthesis the chemical reaction used by plants to convert carbon dioxide and water into glucose

water vacuole a membrane-bound organelle found in plant cells that primarily stores water and nutrients and provides structural support

botanist a scientist who studies plants

Figure 3 Kingdom Plantae: (A) Rafflesia, the world's smelliest plant, is found in South-East Asia. Its flower can measure up to 90 centimetres across and weigh about 11 kilograms. It gives off a rotten-meat odour when it blossoms to attract insects; (B) flowering gum; (C) moss

Kingdom Fungi

Kingdom Fungi includes mushrooms, toadstools, yeasts, puffballs, moulds and truffles (Figure 4). Some fungi grow in wood and soil, and develop from tiny spores. Fungi also store their genetic material in a nucleus. Like animals, fungi are heterotrophic: they do not make their own food. Instead, they feed on the remains of dead animals and plants. What distinguishes fungi from animals is that fungal cells possess a cell wall. Some fungi can cause diseases, such as tinea (athlete's foot). **Mycologists** study fungi.

mycologist a scientist who studies fungi

Figure 4 Kingdom Fungi: (A) The hair-like filaments of the yeast *Candida albicans* as seen under a microscope; (B) mould; (C) mushrooms

Monera and Protista: Microscopic organisms

When the microscope was invented, scientists began to understand and document the differences between organisms at a cellular level. It also helped them to realise the existence of organisms that we could not see without a microscope.

Microorganisms or microbes are organisms that are so small that they can only be identified with a microscope. They include all bacteria from Kingdom Monera and most species from Kingdom Protista. **Microbiologists** are the scientists who study microorganisms in the Kingdoms Monera and Protista.

microbiologist a scientist who studies microorganisms

Kingdom Monera

The development of microscopes led to the discovery of Kingdom Monera. This kingdom is made up of the simplest and smallest living things. There are an estimated 10,000 different species in Kingdom Monera, and they are all unicellular and have a cell wall but no nucleus.

Bacteria are the most common organism in Kingdom Monera. Many people think of bacteria as harmful to humans, but this is not always true. For example, good bacteria in our intestines help us to digest the food we eat. Bacteria in the soil break down rubbish and wastes produced by animals (especially humans). Without bacteria, we would be surrounded by mountains of smelly rubbish. Bacteria such as *Lactobacillus casei* have also been used by humans to make food such as cheese and yoghurt (Figure 5B).

bacteria unicellular organisms with a cell wall but no nucleus

Figure 5 Kingdom Monera as seen under a microscope: (A) *Spirillum volutans*; (B) *Lactobacillus casei*; (C) *Streptococcus pyogenes*

There are many different types of bacteria that come in all different shapes. As you can see in Figure 5, bacteria can look:

- spherical (cocci)
- rod-shaped (bacilli)
- curved or spiral-shaped (spirillum).

Bacteria can also be classified based on the way they are grouped:

- individually
- in pairs (diplo)
- in chains (strepto)
- in clusters (staphylo).

What do you predict the species from the genus *Streptobacillus* would look like when grouped?

Kingdom Protista

In Kingdom Protista, approximately 100,000 species are currently identified. The cell structure of these protists is more complex than that of the Monera, with all having DNA contained within a nucleus. Most, but not all, organisms in Kingdom Protista are unicellular and microscopic organisms. Often, organisms that don't fit into any other kingdom are grouped in Protista. Many taxonomists believe the kingdom should be classified further, based on the significant diversity that exists at both the cellular and whole-organism levels. For example, protists can range in size from unicellular to much larger multicellular organisms. The microscopic **amoeba**, an organism that changes its shape to trap its food (heterotrophic), and the large giant kelp (seaweed), which is autotrophic, belong to this kingdom. **Plankton**, the tiny sea creatures eaten in their millions by whales, are also part of this group (Figure 6).

amoeba a type of single-celled organism belonging to the Protista kingdom

plankton microscopic organisms that float in fresh or salt water

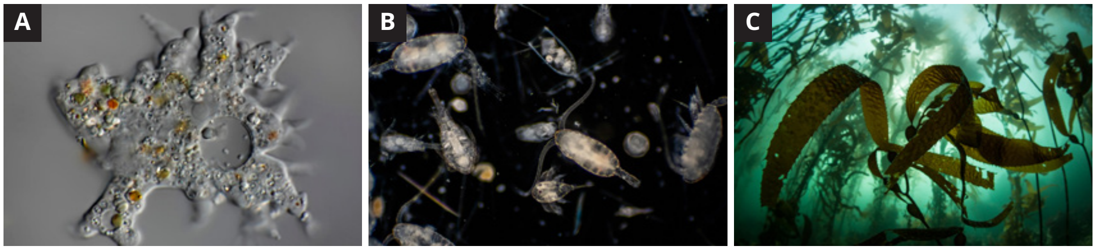


Figure 6 Kingdom Protista: (A) amoeba; (B) plankton; (C) the large giant kelp

The future of classification

After 250 years, scientists are still testing and modifying the Linnaean classification system. The development of microscopes led to the discovery of single-celled organisms (protists and bacteria). This resulted in the number of kingdoms increasing from three – plants, animals and fungi – to the current five – Plantae, Animalia, Fungi, Monera and Protista.

In the 1970s, a discovery was made of a group of single-celled organisms previously thought to be bacteria that could live in extreme environments, such as very salty or hot waters. The cell structure and genetic material (DNA) of these organisms was different from that of other bacteria. This led to the suggestion that a sixth kingdom, Archaea, was needed.

Scientists have been discussing this approach of six kingdoms and comparing it with a whole new level that comes before kingdoms. The "three-domain system" was first suggested in 1990. This system suggests one super domain, Eukaryota, for plants, animals, protists and fungi. The single-celled organisms in Kingdom Monera would then be split into two domains, according to their structure and genetic material: Archaea which live in extreme environments and Eubacteria (true bacteria) (Figure 7). Currently, the debate goes on.

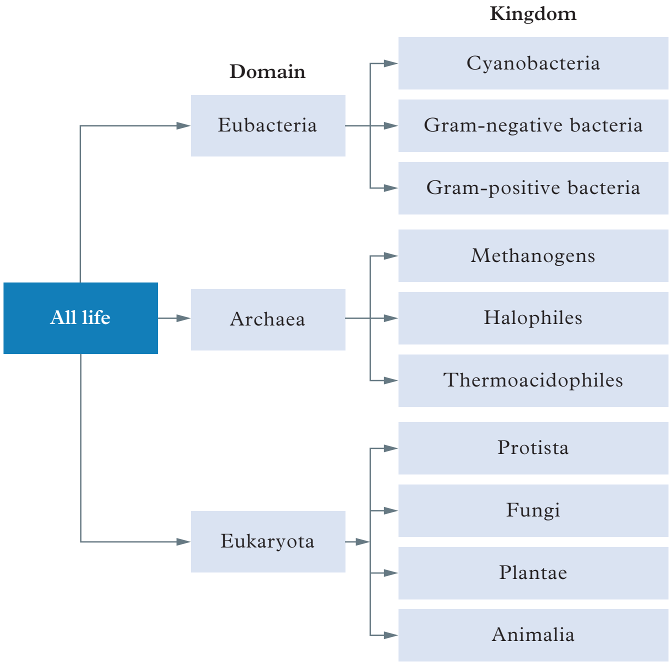


Figure 7 The three-domain system of classification

Check your learning 5.6

Check your learning 5.6

Retrieve

1 Identify where a plant cell stores its genetic material (DNA).

2 Distinguish between prokaryotic and eukaryotic organisms and provide an example of each.

3 Define the terms "unicellular" and "multicellular".

4 Name four features of Kingdom Fungi.

Analyse

5 Contrast (the differences between) a protist and a bacterium.

6 Compare (the similarities and differences between) the cells in Kingdom Plantae and those in Kingdom Fungi.

Apply

7 Discuss why the invention of the microscope was important to our understanding of living things.

Skills builder: Communicating

8 Construct a table that compares and contrasts the structural features of each kingdom. (THINK: How can you group features together?)

Lesson 5.7

Challenge: Classifying living things

Introduction

The scientist whose main role it is to classify living things is known as a taxonomist. In this activity, you become the taxonomist.

Figure 1 A collection of living things

Aim

To use the identifying features of different organisms to classify them into kingdoms

What you need:

- A3 card or paper
- Scissors
- Glue
- Pictures of different living things from Figure 1 (or from the internet or magazines)

What to do:

1 On a sheet of A3 card or paper, mark up a table with four columns.

2 Label the columns “Animalia”, “Plantae”, “Fungi” and “Other (Monera and Protista)”. (Do not try to distinguish between Monera and Protista.)

3 Print Figure 1. Cut and paste each of the pictures in Figure 1 into the correct column of your table.

Questions

1 Describe the identifying features for each kingdom.

2 Name one organism that was difficult to identify. Describe why it was difficult to identify the key feature that allowed it to be classified.

Lesson 5.8

Animals that have no skeleton are called invertebrates

Learning intentions and success criteria

Key ideas

→ Kingdom Animalia contains 35 recognised phyla that are divided into two main groups: vertebrates and invertebrates.

→ All vertebrates have a spine (or backbone) and an endoskeleton.

→ Invertebrates do not have a spine.

→ Some invertebrates have an exoskeleton while others do not.

Internal or external skeleton?

vertebrate an organism that has an endoskeleton

invertebrate an organism that has an exoskeleton or no skeleton

endoskeleton an internal skeleton

exoskeleton an external skeleton

Kingdom Animalia contains an estimated 35 phyla. Scientists commonly break these down into two main groups based on the presence or absence of a backbone: **vertebrates** have a backbone while **invertebrates** do not. In the same way as using a dichotomous key, dividing the animal kingdom into groups first requires a question. The system scientists use to divide animals into groups is based on their structure. The question is: "Does this animal have a spine and internal skeleton, or no spine with or without an external skeleton?"

Animals with a spine and internal skeleton (**endoskeleton**), such as cats, humans and birds, are known as vertebrates. These animals have a spinal cord that threads its way along the vertebrae, so the phylum is called **Chordata**. Animals with an external skeleton (**exoskeleton**), such as beetles and crabs, and those with no skeleton at all, such as slugs, are known as invertebrates.

Invertebrates

There are many more invertebrates on Earth than there are vertebrates: 96 per cent of all animals are invertebrates, with 34 of the 35 phyla represented by them. Invertebrates have either an exoskeleton or no skeleton at all. As well as enormous animals such as the giant squid (Figure 1), thousands of tiny insects and other creatures belong to the invertebrate group.

Figure 1 The giant squid is an invertebrate.

Identifying invertebrates

Invertebrates are grouped into six main groups of phyla based on their characteristics.

Characteristics used to classify invertebrates include the presence of a shell or hard cover, tentacles or spiny skin. Organisms with similar features are placed in the same group. The dichotomous tabular key in Table 1 can be used to place an organism in a particular phylum.

Table 1 Tabular key for identifying invertebrates

1	Body spongy, with many holes	Poriferan
	Body not spongy	Go to 2
2	Soft body, no shell	Go to 3
	Outside shell or hard cover	Go to 6
3	Many tentacles or arms	Go to 4
	Long body without tentacles	Go to 5
4	Tentacles around the mouth of a sac-like body	Cnidarian
	Arms with suction discs	Mollusc
5	Soft body, large foot	Mollusc
	Worm-like or leaf-like	Nematode, platyhelminth or annelid
6	Proper shell or smooth, hard covering	Go to 7
	Spiny skin with rough covering	Echinoderm
7	Limbs in pairs	Arthropod
	Shell, no segments, large foot	Mollusc

In Kingdom Animalia there are 35 recognised phyla of invertebrates. Some of the most common are listed below.

Arthropods

Arthropods have segmented bodies, paired and jointed legs, and an exoskeleton. Examples include insects, centipedes, scorpions and spiders (Figure 2A).

Poriferans

Poriferans have spongy bodies with holes and are found in water, attached to rocks. Examples include glass sponges and breadcrumb sponges (Figure 2B).

Cnidarians

Cnidarians have soft, hollow bodies with tentacles and live in water. Examples include coral, anemones and sea jellies (Figure 2C).

Nematodes, platyhelminths and annelids

Nematodes, platyhelminths and annelids have soft, long bodies and can be segmented, flat or round. Examples include tapeworms, flatworms and leeches (Figure 2D).

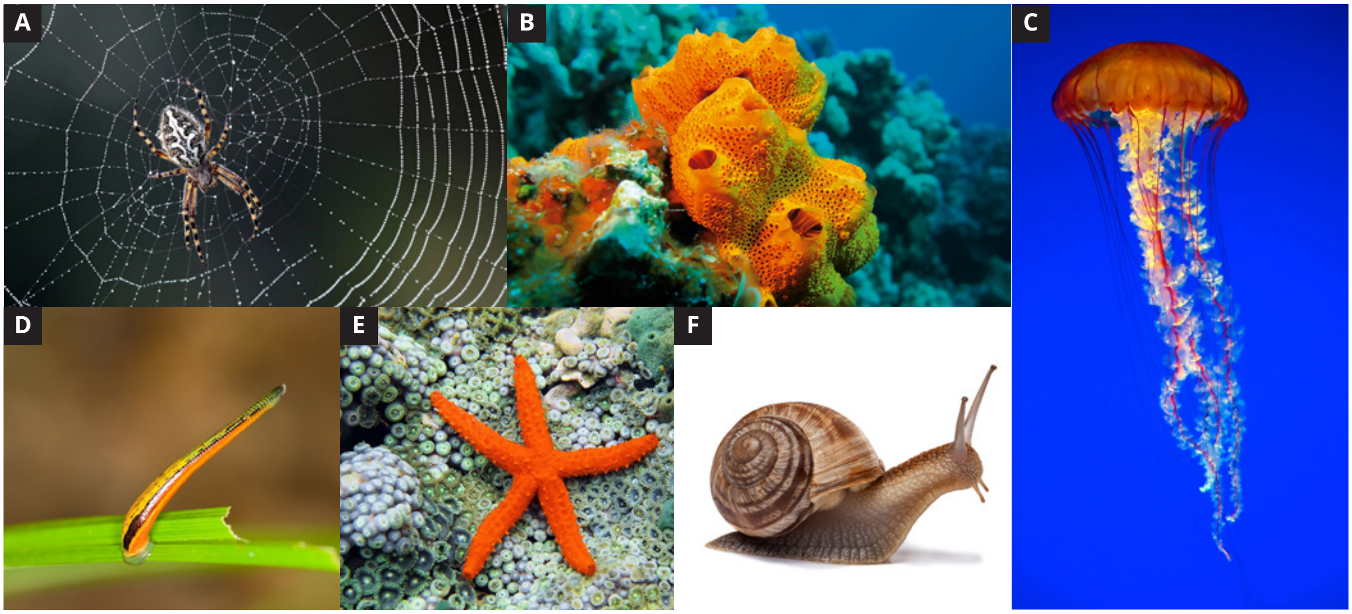


Figure 2 Some commonly found invertebrate phyla: (A) spider; (B) breadcrumb sponge; (C) sea jelly; (D) leech; (E) brittle star; (F) snail

Echinoderms

Echinoderms have rough, spiny skin, their arms radiate from the centre of the body and they are found in the sea. Examples include sea urchins, sea cucumbers and brittle stars (Figure 2E).

Molluscs

Molluscs have soft bodies and usually have a protective shell. Examples include octopuses, oysters and snails (Figure 2F).

Check your learning 5.8

Check your learning 5.8

Retrieve

1 Animals are divided into two main groups.
  - **a** Identify the names of the groups.
  - **b** Name the main characteristic of each group.

2 State the percentage of animals that are invertebrates.

3 Recall two examples of animals with an exoskeleton.

4 Recall two examples of animals with no skeleton at all.

Analyse

5 Beetles have segmented bodies and jointed legs. Identify the phylum that contains beetles.

6 Use Table 1 to identify the group that a scientist would place the following animal into: a non-spongy soft body, with many tentacles around the mouth.

Apply

7 Eighty per cent of animals on Earth are arthropods.
  - **a** Discuss what characteristic the name arthropod suggests. (Hint: Consider arthritis and podiatrist.)

b Draw three different arthropods and label the features that make them part of this phylum.

Skills builder: Processing and analysing information

8 Use the tabular key (Table 1) to classify the organism in Figure 3. (THINK: What features can you observe to answer the questions in the key?)

Figure 3 Ladybugs are also known as coccinellidae.

Lesson 5.9

Investigation: Identifying invertebrates

Purpose

To use the identifying features of invertebrates to classify them using a tabular key

Materials

- Magnifying glass or stereomicroscope
- Petri dishes
- Jars with lids
- Tweezers
- Vinyl or latex glovesAlternatively, your teacher may provide prepared samples for you to look at. Complete the classification exercise for each prepared sample.

Figure 1 Some common invertebrates

Procedure

1 Visit a local natural environment (e.g. a garden, beach, park or pond) and observe invertebrate specimens.

2 Wearing gloves, use tweezers to collect up to 10 invertebrate specimens in separate jars.
   - – Do not touch any animal that might bite or sting. Check with your teacher if you are unsure.
   - – Use tweezers to pick up the animals.
   - – Place any animal immediately in a jar and secure the lid.

3 Use the tabular key in Table 1 in Lesson 5.8 Animals that have no skeleton are called invertebrates (page 226) to classify the invertebrates into their particular phylum.

4 Use a magnifying glass or stereomicroscope to help you sketch each animal. Write the common name for the animal (if you can) and write down its classification group under the drawing.
5 Return the invertebrates to their natural environment after you have finished.

Discussion

1 Identify the common characteristic that all invertebrates displayed.
2 Describe the key characteristics that allowed you to recognise and classify the organisms you collected.

Lesson 5.10

Vertebrates can be organised into five classes

Learning intentions and success criteria

Key ideas

→ Vertebrates are animals with a spine (or backbone).

→ Vertebrates can be broken down into classes based on their body covering, how their young are born and their body temperature.

→ Endotherms have a constant body temperature.

→ Ectotherms have a body temperature that changes with the environment.

Introduction

Vertebrates are animals with a spine (or backbone). Vertebrates as a group are broken down into further subgroups called classes based on:

- their body covering
- how their young are born
- their body temperature.

Vertebrates either have a constant body temperature (**endotherm**) or a body temperature that changes with the environment (**ectotherm**).

endotherm an organism that has a constant body temperature regardless of the temperature of its environment

ectotherm an organism with a body temperature that changes with the environment

Class Mammalia

Mammalia is a class of vertebrates well known to many people. Many of our pets belong to this class: dogs, cats, horses, rabbits, guinea pigs and mice. We belong to this class too. Mammals are animals with hair or fur, and they can keep their body temperature constant (endotherms). This means their body temperature remains the same despite the environment being hot or cold.

Class Mammalia can be further broken down into three subgroups based on the way their young develop (Figure 1).

In placental mammals, the foetus develops inside the mother's uterus, attached via a placenta, and the young are birthed relatively well-developed (such as dingoes). In contrast, marsupial young are born underdeveloped and mature mostly in the pouch (such as kangaroos), while monotremes lay eggs (such as platypuses). No matter the type of mammal, however, they all feed their young milk.

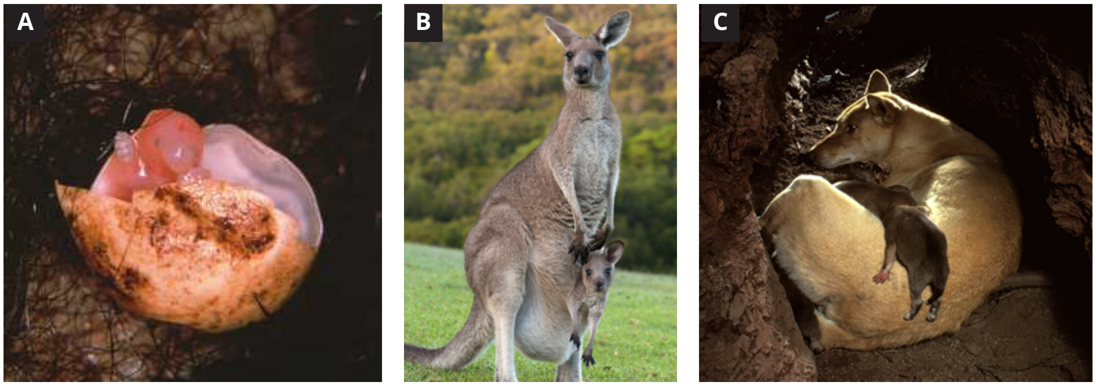


Figure 1 The three subgroups of mammals: (A) monotremes lay soft-shelled eggs; (B) marsupials are born immature and need to spend the first few months in their mother's pouch; (C) placentals are born with the general shape of the adult animal.

Class Aves

All birds in phylum Chordata belong in this class. Like mammals, they are endotherms (having a constant body temperature). Two of their main distinguishing characteristics (the way they differ from the other classes) are their covering of feathers and their scaly legs (Figure 2). All animals in this class lay eggs with a hard shell.

Figure 2 Class Aves contains all birds, including this Gouldian finch.

Class Reptilia

The skin of reptiles, such as snakes and lizards, is usually covered in a layer of fine scales (Figure 3). Reptiles use lungs to breathe, even if they live under water (sea snakes). These animals are ectotherms because their body temperature is always very similar to the environment. We do not use the term "cold-blooded" to describe these animals because a lizard that has been lying in the Sun has very warm blood, even though at night its blood is cool.

Turtles also belong to this class. Many people become confused by the hard outer shell of turtles and tortoises, thinking it is an exoskeleton. Underneath the shell, however, there is a hard backbone with a nerve cord running through it (Figure 4).

Figure 3 Class Reptilia: a king brown snake

Figure 4 Despite having a hard outer shell, turtles and tortoises have a hard backbone with a nerve cord running through it.

Class Amphibia

Like reptiles, amphibians are ectotherms; however, the skin of amphibians is usually soft and slimy to touch. They lay their eggs, without hard shells, in water. For the first part of their life, amphibians have gills and live in the water. As they get older, lungs develop and they become able to live on land. The only remaining group of native amphibians in Australia is frogs (Figure 5). In other parts of the world, caecilians and salamanders may be found.

Figure 5 Class Amphibia: a growling grass frog

Class Pisces

Most fish are ectotherms. They are covered in a layer of scales and most have fins (Figure 6). They spend all their life in water and so need gills to breathe. Fish are further grouped according to their skeleton. Sharks, rays and skates have a skeleton made entirely of cartilage, whereas all other fish have bony skeletons.

Figure 6 Class Pisces: a tuna

Table 1 Tabular key for identifying vertebrates

1	Has a backbone	Go to 2
	Does not have a backbone	Not a vertebrate (key ends)
2	Has fur or hair	Class Mammalia (mammals)
	Does not have fur or hair	Go to 3
3	Has feather	Class Aves (birds)
	No feathers	Go to 4
4	Has scales on legs or whole body	Go to 5
	Does not have any scales	Class Amphibia (amphibians)
5	Breathes through gills	Class Pisces (fish)
	Does not breathe through gills (lungs)	Class Reptilia (reptiles)

Check your learning 5.10

Check your learning 5.10

Retrieve

1 The vertebrates have five classes: Mammalia, Reptilia, Amphibia, Aves and Pisces. Identify the common names for each of these classes.

Comprehend

2 Describe the main characteristics of mammals.

Analyse

3 Contrast the appearance of a placental mammal when it is born with that of monotremes and marsupials.

4 One of the classes of vertebrates is Amphibia. Identify the characteristics of amphibians that would make it difficult for them to live in arid environments like deserts. Identify the other animal classes that would struggle to survive in arid environments.

Apply

5 A dolphin lives in the ocean and has fins. It breathes air, gives birth to live young and feeds them milk. Identify the class that the dolphin belongs in. Justify your answer (by comparing the characteristics of the class with the characteristics of the dolphin).

6 A flying fox can glide through the air like a bird but is covered in fur. Identify the class that the flying fox belongs in. Justify your answer.

7 Seals have fins like fish and live on the land and in the water like amphibians.

a Investigate how a seal's young are born.

b Given that the seal has long whiskers, is endothermic and breathes air, identify the class of vertebrate to which a seal belongs.

Skills builder: Communication

8 Construct a dichotomous key to show the five classes of vertebrates. (THINK: What information needs to be included to explain the different classes to someone who does not know about them?)

Lesson 5.11

Challenge: Who are the vertebrates?

Aim

To identify a variety of different vertebrates

What you need:

- A3 paper
- Pencils

What to do:

Task 1: Vertebrate alphabet graffiti

This task could also be completed as a webpage, with images and links to further information about each animal.

1 Choose one class of vertebrate to study, and form a group with others in the class to study it.

2 Label an A3 sheet of paper with the name of your class of vertebrate.

3 Write the letters of the alphabet down the left-hand side of the page.

4 For each letter, write the name of an animal that fits this category.

5 When finished, you will have the names of up to 26 different vertebrates. Some categories will be harder to fill than others.

6 Put the finished sheets up around the room.

Task 2: Jellyfish organiser for vertebrates

A jellyfish graphic organiser (Figure 1) is a good way to show how subgroups make up a whole. It can also be used to list specific examples at the same time.

1. Individually, go around to each of the five lists of vertebrates from Task 1 and select six animals from each class.
2. On a full page, draw five "jellyfish" connected to the main group (vertebrates), as shown in Figure 1.
3. Label each jellyfish with the class name: birds, mammals, fish, reptiles and amphibians.

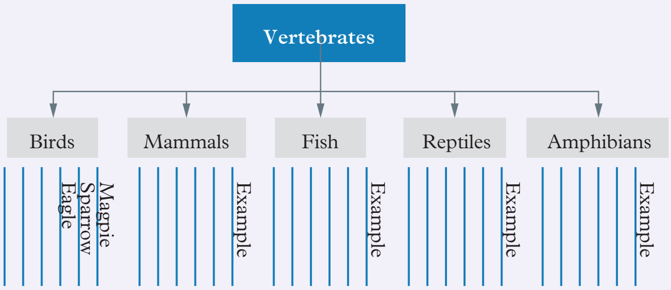


Figure 1 A jellyfish organiser for vertebrates

4. Write a description of the characteristics of each class in the appropriate body of each jellyfish.
5. Place the six animals you selected along the six tentacles of each jellyfish.

Lesson 5.12

Plants can be classified according to their characteristics

Learning intentions and success criteria

Key ideas

→ Plants belong in one of the five kingdoms of living things.

→ All plants are multicellular organisms that use sunlight to produce their own energy.

→ Plants have a variety of different characteristics that allow us to classify them into different phyla.

Introduction

As you saw earlier in this topic, plants belong in one of the five kingdoms of living things. All plants are multicellular organisms that can produce their own energy using sunlight. This does not mean all plants look the same, however. Plants have a variety of different characteristics that allow us to classify them into different phyla (Figure 1).

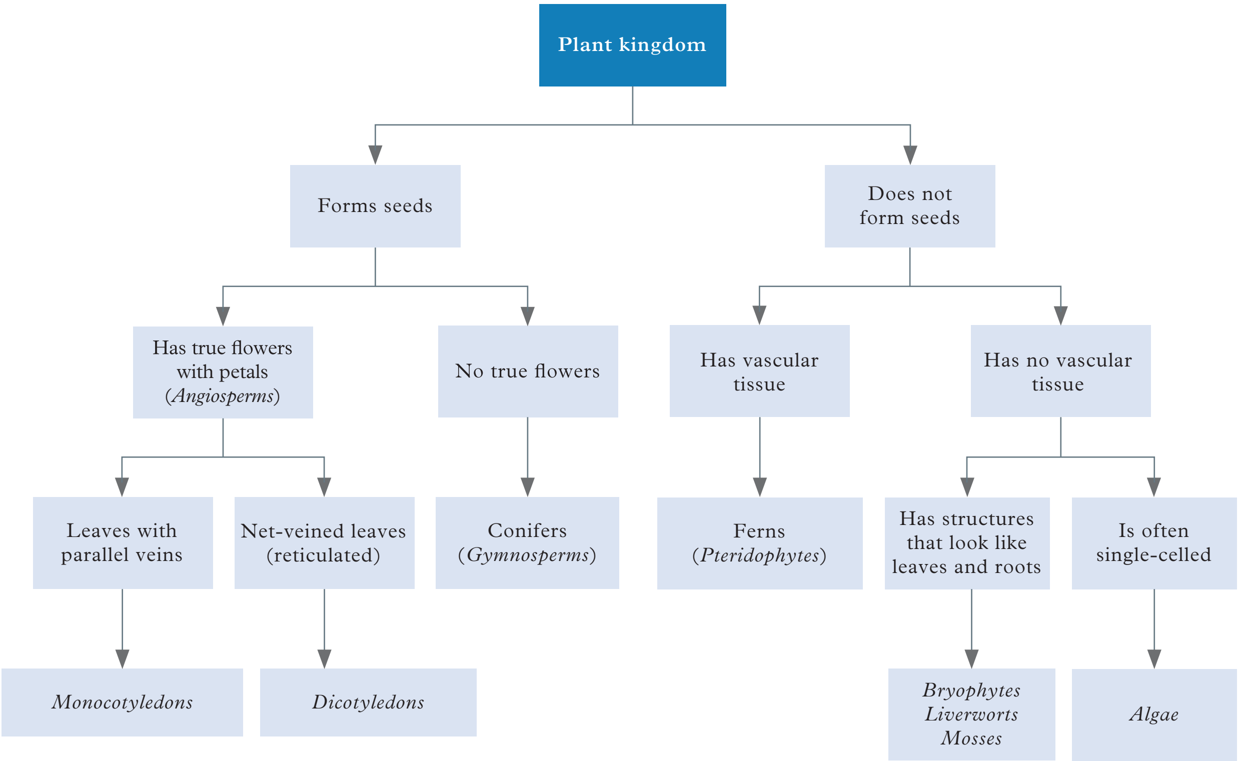


Figure 1 A sample plant key

Seeds or spores?

Planting a seed and watching it grow is something many people do. But not all plants have seeds. Some plants, such as ferns, produce **spores**. Spores are much smaller than seeds and only contain half the genetic material needed to make a fern. They are found clinging to the underside of a fern frond (Figure 2).

Figure 2 Not all plants germinate from seeds. Ferns produce spores instead.

spore a tiny reproductive structure that, unlike a gamete, does not need to fuse with another cell to form a new organism

Vascular tissue

Plants, like all living things, need water to survive. Many plants use their roots to absorb water and transport it through tube-like structures called **xylem** to the leaves. Food (a sugar called glucose) produced in the leaves during photosynthesis is transported around the plant in **phloem**. This system of tubes is called the **vascular tissue** of the plant.

Figure 3 Mosses and liverworts can absorb water through all parts of their structure.

xylem the tissue in plants that carries water from the roots to the rest of the plant

phloem the vascular tissue in plant stems that carries sugars around the plant

vascular tissue vessels that transport material around an organism

non-vascular plants that lack a vascular system (xylem and phloem)

Not all plants are so organised. **Non-vascular** plants, such as mosses and liverworts, need to live in damp places where they can absorb water through all parts of their structure. This is much more difficult and is why non-vascular plants tend to be very small and are restricted to damp environments. (Figure 3).

The importance of flowers

Most plants in your school or home garden produce flowers (angiosperms). Flowers are the way plants attract birds and insects to encourage pollination. These pollinators transfer pollen between plants of the same species, resulting in fertilisation and the production of seeds.

Not all plants have true flowers (gymnosperms). Conifers have needle-like leaves and produce cones instead of flowers (Figure 4). Pollen from one cone is often transferred to another cone (pollination) so that a seed can be produced.

Figure 4 Some plants use flowers or cones to produce seeds.

Monocots and dicots

Flowering plants can be divided into two main groups. Monocotyledons (monocots) have a single leaf that grows from the seed. They can usually be recognised by the parallel veins in the leaves and by counting the number of petals in the flowers. Monocot flowers always have petals that are multiples of three (Figure 5).

Dicotyledons (dicots) grow two leaves from the seed. Their leaves have veins that are reticulated (spread out from a central vein), and they tend to have four or five petals on each flower (Figure 6).

Figure 5 The number of petals on a monocot flower is always a multiple of three.

Figure 6 A dicot flower usually has four or five petals on each flower.

Check your learning 5.12

Check your learning 5.12

Comprehend

1 Describe how mosses, ferns and conifers reproduce.

Analyse

2 Use the key in Figure 1 to identify the features of the following plants.

  - **a** Ferns
  - **b** Mosses

3 Use the key in Figure 1 to identify the following kinds of plants.
  - **a** Fruit tree
  - **b** Palm tree
  - **c** Green weed in a fish tank
  - **d** Maidenhair fern
  - **e** Bird's-nest fern
  - **f** Moss on the path
  - **g** Rose bush
  - **h** Vegetables
  - **i** Pine tree
  - **j** Grass and lawn

4 Contrast (the differences between) vascular and non-vascular plants.

5 Who am I? I am large and green. I use sunlight to make my own food. I smell nice and like to come inside at Christmas. Some people do not like me because my leaves can be prickly and needle-like. I use a cone to help me reproduce. Categorise me into the plant phylum I belong to.

Apply

6 Locate a plant in your garden.
  - **a** Create a labelled diagram of the plant.
  - **b** Identify the features that could be used to categorise your plant.
  - **c** Propose at least one feature that is not currently present that would help you to categorise your plant.

Skills builder: Problem solving

7 Is it better to be a vascular or non-vascular plant in a dry climate? Evaluate the advantages of vascular plants and non-vascular plants for surviving in dry weather. (THINK: What features help each type of plant to survive?)

Lesson 5.13

Adaptations of Australian organisms

Key ideas

→ Adaptations are the physical features or behaviours that help living things to survive and reproduce in their environment.

Learning intentions and success criteria

Introduction

Plants and animals need to be suited to the area where they live if they are to have the best chance of survival. The survival of a species relies not only on the individuals of the population living healthy lives, but also on their ability to produce healthy offspring.

Australia has a wide variety of ecosystems, including deserts, tropical rainforests and open eucalyptus woodlands. In each case, there is a wide range of unique flora (plants) and fauna (animals) that have adaptations that enable them to survive.

What is an adaptation?

adaptation a characteristic or feature of an organism that assists in its survival and reproductive success

An **adaptation** is a specific characteristic of an organism that gives it the best chance of survival in its environment. These characteristics are used to classify and identify the organism. Adaptations can be physical, like the folds of skin between the front and back legs of a sugar glider that allow them to glide long distances between trees (Figure 1), or behavioural, such as a brush tail possum foraging for food at night to avoid predators.

Figure 1 The sugar glider developed folds of skin between its front and back legs as well as a prehensile tail (which means the tail is capable of grasping). These help the glider to steer when gliding from tree to tree.

How do adaptations arise?

Looking around your classroom, you will notice that, even though you're all human and about the same age, you're all slightly different. The same applies to all species. There is variation within a population. If environmental conditions change, individuals with characteristics better suited to the changes will be more likely to survive, reproduce and pass these favourable features on to their offspring. This is referred to as "survival of the fittest". Individuals without the favoured characteristics are less likely to survive and reproduce.

Consider a particular animal species with individuals all of slightly different heights that obtains its food from only one type of tree. In this instance, taller individuals would be favoured if food was running out and there was only the possibility of getting the resource from the top of the trees. Over time, if the food availability stays the same, the population is likely to become taller because only the tall members of the species are able to survive and reproduce (Figure 2).

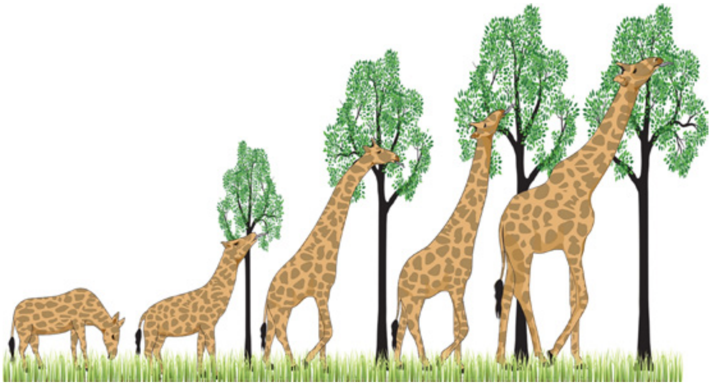


Figure 2 Adaptations occur over generations. Taller giraffes that can reach the food source high up in trees will survive and produce tall offspring. The shortest giraffes that cannot reach the leaves do not survive and therefore do not reproduce.

Australian animal adaptations

Australian fauna is unique to the rest of the world. It is dominated by marsupial mammals, with over 250 species found here. In contrast, other continents are inhabited mainly by placental mammals. Marsupials came to dominate Australia due to our geographical isolation, lack of competition from placental mammals and mainly arid conditions. Marsupials are better adapted to these harsh conditions, with specialised features such as pouches for early-stage development, making reproduction more energy efficient. They also require less water than placental mammals due to their ability to produce concentrated urine, which conserves water. Australia and its close northern neighbour New Guinea are also the only countries where monotremes are still found.

The common wombat

The common wombat (Figure 3) has many adaptations to help it survive in Australia. The backward-facing pouch stops the mother from suffocating her young with soil as she digs her burrows underground. To dig their burrows, wombats are armed with powerful claws and rodent-like front teeth. They have a barrel-shaped body with short legs and a hard rump (lower back), which they can quickly reverse back up their burrow to prevent entry of, and even cause injury to, would-be predators. Wombats are usually nocturnal and produce distinctive cube-like faeces (droppings) that they stack to mark their territory and attract mates.

Figure 3 The common wombat can be found in south-eastern Australia and has many adaptations to help it survive.

The short-beaked echidna

The short-beaked echidna (Figure 4), a monotreme, is found throughout Australia. Echidnas have a long, strong snout that helps them to break logs and termite mounds in search of food. They have long, sticky tongues that are also useful for catching ants. Other physical adaptations include fur-like hair for warmth, spines for protection and sharp claws for digging.

Figure 4 The short-beaked echidna's snout is adapted to eating ants.

The thorny devil

Reptiles are particularly well suited to Australia's dry desert environment. The thorny devil (Figure 5) uses the environment to regulate its temperature. When it wants to become active, it lies in the Sun; however, when it is too hot outside, it hides in a burrow until the heat has passed. One fascinating feature of the thorny devil is that it can drink water with its feet! It places its feet in a puddle and water moves up its body by capillary action along grooves in the skin to the corner of its mouth.

Figure 5 The thorny devil has adapted to live in the Australian desert.

Australian plant adaptations

Plants species have also adapted to better suit their environment. Many Australian plants have adapted to extreme conditions. For example, many plants in rainforest environments have waxy leaves with a "drip tip" on the end that allows water to drain away easily (Figure 6).

Figure 6 Plants in the Daintree Rainforest are adapted to receive lots of rain.

Spinifex grass

Spinifex grass (Figure 7) is one of the most abundant plants in Australia as it is uniquely adapted to the continent's extremely poor soils and great aridity. Initially, the leaves of the plant appear as "typical" grass leaves. When the plant experiences its first dry spell, the leaves roll in on themselves and stay that way for the remainder of the plant's life. This adaptation protects the plant from drought by reducing the leaves' surface area that is exposed to the hot Sun, therefore minimising water loss. The leaves have a silvery upper surface that reflects sunlight and assists in preventing water loss. Spinifex grass also has a very deep root system, up to three metres below the ground, which allows it to go long periods of time without water.

Figure 7 Tufts of spinifex grass growing in the Australian outback

Eucalyptus, *Acacia*, *Banksia* and *Grevillea*

Australia is well known for its dry **sclerophyll** forests. Plants in these forests are typically from one of four genera (singular "genus"): *Eucalyptus*, *Acacia*, *Banksia* and *Grevillea*. These **evergreen** plants are identified by their woody stems, and tough, thick and often spiky leaves. All these features assist the plants in surviving nutrient-poor soils, attacks from predators and unpredictable rainfall. Many of these Australian plants are also adapted to survive through times of bushfire. Not only can some survive through extreme fire heat, but some plants also cannot exist without it. For example, *Banksia* seeds germinate when they are exposed to the extreme heat of a bushfire. *Eucalyptus* trees also sprout after fire (Figure 8).

sclerophyll a type of vegetation characterised by hard, thick and leathery leaves that are adapted to arid conditions and nutrient-poor soils

evergreen a type of plant that does not lose it leaves during autumn

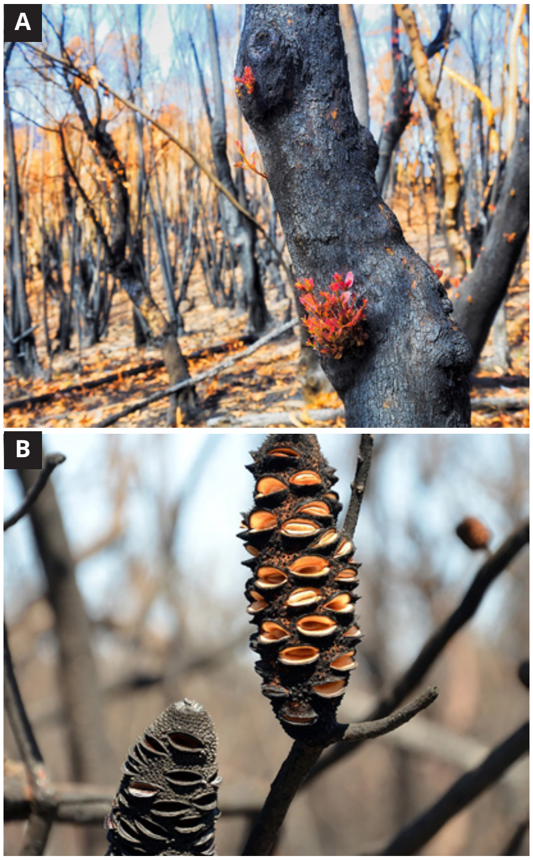


Figure 8 (A) A *Eucalyptus* tree sprouting after fire in the Blue Mountains; (B) a *Banksia tree* releasing seeds after a bushfire in Kamay Botany Bay National Park, NSW

Check your learning 5.13

Check your learning 5.13

Retrieve

1 Define the term "adaptation".

2 Identify the differences between physical and behavioural adaptations. Give an example of each.

Comprehend

3 Explain how adaptations help an organism to survive.

Analyse

4 Propose how the following adaptations of a bilby could be useful.
  a Is nocturnal
  b Lives in a burrow
  c Has large ears

Apply

5 Propose and justify a reason to explain why a species or population with a long life cycle is likely to take much longer to physically adapt to an environmental change than one with a short life cycle.

Skills builder: Questioning and predicting

6 Imagine two birds from the same species. One bird will eat any plant material grown on trees. The other bird will only eat fruit from a tree that depends on good rainfall each year.
  a Predict which bird is most likely to survive. (THINK: Which bird is more likely to get enough food?)
  b Predict what will happen to the species. (THINK: What will future generations eat? What do you know about the way species adapt to survive?)

Lesson 5.14

Investigation: Adaptations of Australian organisms

Introduction

Australia is home to a diverse range of habitats, from arid deserts to rainforests, each supporting unique organisms that have evolved specific adaptations to survive in often harsh and changing environments. Both plants and animals have various structural, behavioural and physiological adaptations that enable them to survive in their respective habitats, despite the often challenging conditions that can include extreme temperatures, drought and nutrient-poor soils.

The aim of this investigation is to research and document the adaptations of two Australian plants and two Australian animals in a specific type of ecosystem (e.g. desert, coastal area, rainforest). You will document your findings in a written scientific report. Include the following sections in your report.

Title

Your title should be clear and concise and reflect the investigation. For example: “Adaptations of organisms in an Australian desert habitat”.

Research question

Write a clear research question. For example: "How do the adaptations of organisms in an Australian desert habitat support their survival?"

Abstract

The abstract is a brief summary (150 to 250 words) of your entire research, including a brief introduction to each species and their habitat with a conclusion.

Figure 1 A koala has a uniquely adapted digestive tract that allows it to live on a diet of eucalyptus leaves.

Introduction

Provide a more extensive description of the ecosystem, each organism and their adaptations that assist in their survival.

Materials and procedure

A brief section in this report. Include details of any resources (e.g. textbooks, scientific articles, websites) that were used.

Results

Summarise your findings in a table that includes the following headings: Organism name, Adaptations, Description of how each adaptation supports survival.

Discussion

- Interpretation of results: Discuss how the findings relate to the title of your research question. How do the observed adaptations help organisms survive in the Australian habitat?
- Adaptations: Explain the types of adaptations observed:
  - Structural adaptations (e.g. thick fur, specialised limbs)
  - Behavioural adaptations (e.g. nocturnal behaviour, burrowing)
  - Physiological adaptations (e.g. water conservation, temperature regulation).
- Comparison with other ecosystems: If relevant, compare the adaptations of organisms in your ecosystem to those found in different environments.
- Limitations: Discuss any limitations of the investigation (e.g. lack of data, time constraints).
- Suggestions for further research.

Conclusion

- Summarise the main findings of your research.
- Restate how each organism's adaptations enable it to survive in their specific Australian habitat.
- Answer the research question based on the findings.

References

- A list of all resources (e.g. scientific articles, books, field guides, websites) used to gather background information or support claims made in the report.
- Use a standardised referencing format (e.g. APA, Harvard).

Lesson 5.15

Aboriginal and Torres Strait Islander Peoples classified their environment

Key ideas

→ Australia is the second driest continent in the world and the driest inhabited continent.

→ Despite the harsh climate, Australia is home to hundreds of different organisms.

→ Aboriginal and Torres Strait Islander Peoples were the first to identify and utilise the organisms that are unique to Australia.

Learning intentions and success criteria

Introduction

Aboriginal and Torres Strait Islander Peoples have a deep understanding of their environment, developed over tens of thousands of years and passed down through oral traditions and practical experience. There are approximately 250 Aboriginal and Torres Strait Islander language groups Australia-wide, which are further divided into clans (family groups). Each of these groups has its own distinctive culture, beliefs and languages.

Early European settlers to Australia often depended on the Aboriginal and Torres Strait Islander Peoples to identify and describe the plants (flora) and animals (fauna) in the unique environment. This can be seen by the names that were used when these animals were "discovered" by European scientists. Many uniquely Australian mammals such as the *wulaba* (wallaby), *buduru* (potoroo), *wularu* (wallaroo), *wumbat* (wombat) and *dingu* (dingo) were all first classified by the Dharawal people of NSW.

Classification of plants

Plants were categorised by Aboriginal and Torres Strait Islander Peoples based on their uses – whether they were edible, medicinal or useful for crafting tools and weapons. The knowledge of which plants were useful, their location within an ecosystem and at what time of year they could be harvested, formed part of a broader ecological understanding and connection to Country.

The Eora people in Sydney and its surrounds used the *murnong* (yam daisy, *Microseris lanceolata*) as a primary food source, digging up the tubers to consume as part of their regular diet.

Figure 1 The edible tubers of the yam daisy (*Microseris lanceolata*)

Figure 2 (A) The kurrajong tree (*Brachychiton populneus*) was used for its seeds; (B) the quandong (*Santalum acuminatum*) was used for its medicinal edible fruit.

Figure 3 The goanna (*Varanus varius*) is a valuable food source for many Aboriginal and Torres Strait Islander Peoples.

Figure 4 The arrival of the magpie geese (*Anseranas semipalmata*) in Northern Australia signals the arrival of the wet season.

The Wiradjuri people of NSW, one of the largest language groups in Central NSW, utilised the *kurrajong* (kurrajong tree, *Brachychiton populneus*) for its strong fibres to make ropes and its seeds which could be ground into an edible paste. They also used the *guwandhang* (quandong, *Santalum acuminatum*) for its edible fruit, but also for its medicinal purposes and for crafting tools and weapons. The bark of the tree was used for treating skin ailments.

The Yolngu people in Arnhem Land used the *gadayka* (cycad palm, *Cycas arenicola*) as a source of starch for food but also to make fishing lines and nets from its fibrous bark.

Classification of animals

Animals were similarly classified based on their behaviour, their role in the ecosystem and their importance to human survival. The Wiradjuri people valued the *gugaa* (goanna, *Varanus varius*) (Figure 3) as a key food source. Their knowledge of the goanna's breeding cycles and seasonal behaviour informed their hunting practices.

The Dharawal people around Sydney knew the patterns of *julara* (mullet fish, *Mugil cephalus*) migration and would use specific fishing techniques to capture them. These fish were a staple, particularly during their seasonal runs along the coastline.

The Kamilaroi people classified the kangaroo and *dhinawan* (emu, *Dromaius novaehollandiae*) as vital animals, not only for food but also for tools made from their bones and skin. They also classified different species of kangaroo, such as the *bawurra* (red kangaroo, *Macropus rufus*) and the *bandaarr* (eastern grey kangaroo, *Macropus giganteus*), based on their behaviour, habitat, size and hunting techniques required.

Seasonal calendars were also used, which were more precise than the European concept of four seasons. The Yolngu people divided the year into six or more seasons, with each season recognised by changes in weather, plant growth and animal behaviour. They knew that the migration of species like the *gurrumattji* (magpie goose, *Anseranas semipalmata*) (Figure 4) signalled the onset of the wet season in the region of North-east Arnhem land.

Classification linked to Country

When Europeans first visited Uluru and Kata Tjuta (The Olgas) in the 1870s, they were confronted with a harsh landscape. Their initial aim was to find a route for the overland telegraph line from Adelaide to Northern Australia and to set up pastures for sheep and cattle grazing. They soon decided that the region was unsuitable and left.

However, the local Aboriginal Traditional Owners of the land, the Anangu people (who occupy the lands surrounding Uluru), had lived on this land for thousands of years and understood it well. They classified their environment to help them navigate and manage Country. They use the following names:

- *Puti*: open woodland; after the rains, this area has an abundance of grass which the kangaroos eat, and honey ants build their nests in this area (Figure 5)
- *Pila*: spinifex plains, low areas between dunes; this is the best place to gather seeds to eat (Figure 6)
- *Puli*: rocky areas, gorges, stony slopes; animals come to this area to find shelter and water (Figure 7 and Figure 8).

The Yanyuwa people in the Northern Territory (who occupy the coastal region of the Gold of Carpentaria) also classified all organisms according to where they were located. Their classification system was first divided into two broad categories: coastal/marine or inland. This was then further divided according to the characteristics of the organism. For example, *walya* can refer to all dugong (*Dugong dugon*) but this is divided into 16 further names according to the dugong's age, size and gender, and even the dugong's status in its herd. This is much more detailed than the descriptions in the Linnaean system.

Figure 5 *Puti* habitat

Figure 6 *Pila* habitat

Figure 7 *Puli* habitat

Figure 8 Another example of *Puli* habitat

Check your learning 5.15

Check your learning 5.15

Retrieve

1 Identify the names given to different environments by the Anangu people and describe the features of each.

2 Describe the traditional classification system used by a specific Aboriginal and Torres Strait Islander language group for local animals.

3 Outline what the Wiradjuri people utilised the kurrajong tree for.

Comprehend

4 Explain how the classification of animals and plants by Aboriginal and Torres Strait Islander Peoples reflects their understanding of the ecosystem.

5 Explain how the classification of animals and plants by Aboriginal and Torres Strait Islander Peoples reflects their deep understanding of the environment developed over thousands of years.

Analyse

6 Explain how the classification systems used by the Yolngu people, including their seasonal calendars, demonstrate an important understanding of ecological changes. What advantages does this provide for food gathering?

Apply

7 Investigate the mammals, reptiles, birds and invertebrates found in the Uluru–Kata Tjuta National Park. Make a list of five for each category. Classify each one into its correct group.

8 Investigate the kind of environment that the Anangu people lived in and the foods they ate. List at least five animals and five plants.

9 Early Europeans left areas of inland Australia because they could not survive. Propose why they struggled to find food and water here.

10 In a group of four, use a large sheet of paper to create two collages about things you would expect to find in Uluru–Kata Tjuta National Park. The first collage should show living things and the second should show non-living things. One pair should create the “living” collage and the other should create the “non-living” collage.

Lesson 5.16

Science in context: Taxonomists classify new species

Introduction

Taxonomists are scientists who research the classification of new species. There are many organisms in Australia that are yet to be identified. This requires the identification and analysis of primary and secondary data to classify and name the new organism.

Unique specimens

When a new organism is discovered, it must first be compared with other known organisms to determine if it is different and unique. This is not as simple as it might first seem. For example, in 2012, a new species of horse fly was identified in Queensland by Australian entomologist Bryan Lessard (Figure 1).

Like many insects, flies have different stages in their life cycle (Figure 2).

When a specimen is collected, it is not always known if it is a fully mature organism. The specimen needs to be compared with other **type specimens**. A type specimen is usually one of the first organisms that were collected from each species. It could be a dried plant, a preserved animal or a fossil. These specimens are usually stored in a museum or herbarium.

In 2018, the Australian National Insect Collection was digitised to preserve their almost 15 million biological specimens (Figure 1 and Figure 3). Each specimen was photographed under a microscope and the details recorded. Citizen scientists (members of the public who collect and record data) then recorded the information from the individual labels, allowing the taxonomists to use this information to create an online key that can be used to identify new specimens.

Naming specimens

There are many rules that must be followed when a new organism is identified. Before it can be named, the organism must be accurately described, drawn and a type specimen preserved. The phylum, class, order and genus must be identified before the species can be named. One of the rules is that the organism cannot be named after the scientist who discovered it. This means that if you did find a new species and went through the taxonomy process, you could not use your own name.

Figure 1 Bryan Lessard (aka Bry the Fly Guy) digitising the type specimen flies

type specimen the specimen used for naming and describing a new species

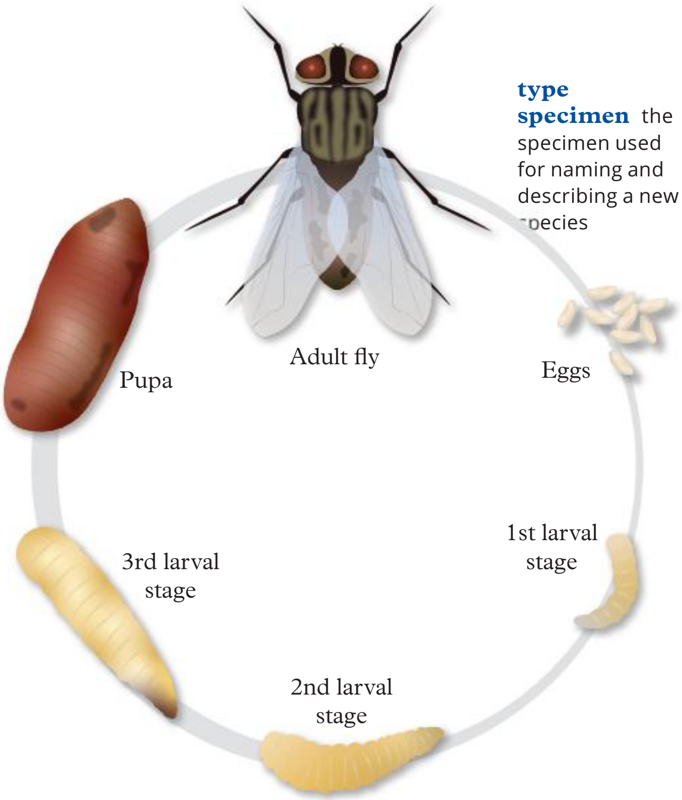


Figure 2 The fly has many different stages in its life cycle.

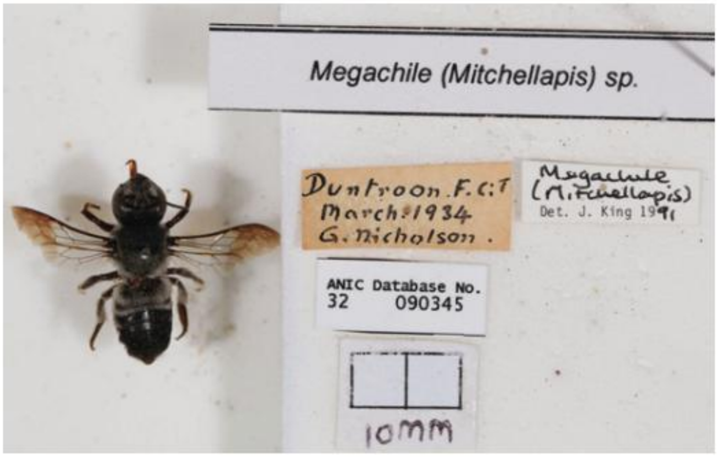


Figure 3 This leafcutter bee was collected in Canberra in 1934 and is stored in the Australian National Insect Collection.

Figure 4 *Scaptia beyonceae* was named after the singer Beyoncé.

This does not mean you cannot name it after someone else. Many famous people have animals named after them. After naming almost 50 different species of flies, Lessard named the horse fly with a golden back *Scaptia beyonceae* after the singer Beyoncé (Figure 4).

Other taxonomists used names to indicate their sense of humour, including beetles named "not another one" (*Cyclocephala nodanotherwon*) and flies named "piece of cake" (*Pieza kake*).

Test your skills and capabilities

Test your skills and capabilities 5.16

Newly discovered species

While estimates can vary significantly, it is widely published that our planet is home to between 7.5 and 9 million different eukaryotic organisms. Of these, only 1.2 million have been formally described and assigned a taxonomical classification. Each year, a further 15,000 to 20,000 new species are discovered and formally identified.

Some notable examples from the last several years include:

- African pygmy squirrel (*Myosciurus pumilio*)
- Alabama undersea forest mussel (*Vadumodiolus teredinicola*)
- Black soul aphelandra (*Aphelandra almanegra*)
- Blob-headed bristlemouth armoured catfish (*Chaetostoma sp.*)
- Dwarf deer (*Pudella carlae*)
- Ghost octopus (*Muusoctopus ghosti*)
- Ghost palm (*Plectocomiopsis hantu*)
- Himalayan snake (*Anguiculus DiCaprio*)
- Khammouane karst dragon (*Laodracon carsticola*)
- Leaf-nosed bat (*Hipposideros kingstonae*)
- Leafless orchid (*Chiloschista quangdangii*)
- Liana plant (*Keita deniseae*)
- Lime-green tree frog (*Zhangixalus melanoleucus*)
- Madagascar orchid (*Solenangis impraedicta*)
- Northern green anaconda (*Eunectes akayima*)
- Pit viper (*Trimeresurus uetzi*)
- Pygmy pipehorse (*Cylix nkosi*)
- Red cross jellyfish (*Santjordia pagesi*)
- Sauron's piranha (*Myloplus sauron*)
- Semi-aquatic mouse (*Daptomys sp.*)
- Skeleton sea squirt (*Aplidium californicum*)
- Small-clawed otter (*Aonyx cinereus*)
- Spiky-nosed spookfish (*Harriotta avia*)
- Tiger cat (*Leopardus pardinoides*)
- Vampire hedgehog (*Hylomys macarong*)

Research one of these newly discovered species and provide the following information:

1. the full taxonomical classification from Kingdom through to species
2. the characteristics of the species that justify its inclusion in each of the identified taxonomic ranks identified above
3. the mechanism by which the organism exhibits each of the characteristics shared by all living things (MR N GREWW).


Source: © JAMSTEC/Dhugal Lindsay

Figure 5 Red cross jellyfish (*Santjordia pagesi*)


Figure 6 Ghost octopus (*Muusoctopus ghosti*)


Figure 7 African pygmy squirrel (*Myosciurus pumilio*)

Lesson 5.17

Review: Classification

Summary

Lesson 5.1 Living organisms have common characteristics

- Living things move, reproduce, grow, respond, exchange gases, produce waste and need nutrition and water.
- Something that is dead used to have the characteristics of living organisms, whereas something that is non-living never had these characteristics.

Lesson 5.2 Classification organises our world

- Classification is the process of grouping or organising things.
- Scientists identify all living things through scientific names.
- Classification systems help scientists to communicate and understand the relationships between living things based on their similarities or differences.

Lesson 5.3 Classification keys are visual tools

- A key is a visual tool used in the classification of ideas.
- Scientists use dichotomous keys to identify the scientific name of an organism.
- A branched dichotomous key can show the relationship between different organisms.

Lesson 5.5 Species are classified using scientific conventions

- Carolus Linnaeus was the first scientist to use a dichotomous key to classify living things.
- Scientific names are binomial (two names): the genus name and the species name.
- The Linnaean taxonomy system is still used today.

Lesson 5.6 Living things are classified into five kingdoms

- All cells can be split into two groups – prokaryotes and eukaryotes.
- Organisms can be classified into five kingdoms – Animalia, Plantae, Fungi, Monera and Protista – based on key structural cell features.
- Microorganisms can only be seen under a microscope and include bacteria and most protists.
- New information that compares genetic material may change the five-kingdom system.

Lesson 5.8 Animals that have no skeleton are called invertebrates

- Kingdom Animalia contains 35 recognised phyla that are divided into two main groups: vertebrates and invertebrates.
- All vertebrates have a spine (or backbone) and an endoskeleton.
- Invertebrates do not have a spine.
- Some invertebrates have an exoskeleton while others do not.

Lesson 5.10 Vertebrates can be organised into five classes

- Vertebrates are animals with a spine (or backbone).
- Vertebrates can be broken down into classes based on their body covering, how their young are born and their body temperature.
- Endotherms have a constant body temperature.
- Ectotherms have a body temperature that changes with the environment.

Lesson 5.12 Plants can be classified according to their characteristics

- Plants belong in one of the five kingdoms of living things.
- All plants are multicellular organisms that use sunlight to produce their own energy.
- Plants have a variety of different characteristics that allow us to classify them into different phyla.

Lesson 5.13 Adaptations of Australian organisms

- Adaptations are the physical features or behaviours that help living things to survive and reproduce in their environment.

Lesson 5.15 Aboriginal and Torres Strait Islander Peoples classified their environment

- Australia is the second driest continent in the world and the driest inhabited continent.
- Despite the harsh climate, Australia is home to hundreds of different organisms.
- Aboriginal and Torres Strait Islander Peoples were the first to identify and utilise the organisms that are unique to Australia.

Review questions 5.17

Review questions Module 5

Retrieve

1 Identify a reason for classifying living things.
  - **A** Classification helps scientists invent more ways of discussing organisms.
  - **B** Classification helps scientists to communicate new discoveries.
  - **C** Classification helps scientists to keep new information to themselves.
  - **D** Classification helps scientists to shelter living things.

2 Identify which of the following is an example of a microorganism.
  - **A** Bacterium
  - **B** Chicken
  - **C** Kelp
  - **D** Sand

3 Identify an example of plants moving by themselves.

4 Name the five main classes of vertebrates and give an example of each.

5 Name two phyla of invertebrates and give an example of each.

Comprehend

6 Identify two Australian plants and animals and explain how specific adaptations assist in their survival.

7 Describe the advantages of using a dichotomous key.

8 Explain why it is important for scientists to use a common system to group all living things on Earth.

9 Describe an example of a plant that has the following characteristics:
  - **a** spores
  - **b** seeds
  - **c** vascular tissue.

10 Identify an example of a plant that does not have flowers with petals. Describe the alternative structure that allows the plant to produce seeds.

11 Biodiversity is the word used by scientists to describe a variety of different organisms in the same region. Explain why it is important to preserve a large biodiversity of plants and animals in the world.

12 Describe the seasonal calendar used by the Yolngu people and how it differs from the European concept of seasons.

13 Imagine that an unknown organism was discovered during a space mission and brought back to Earth. Briefly describe two different methods that scientists could use to decide whether it was living or non-living.

Analyse

14 Contrast a monocotyledon leaf and a dicotyledon leaf.

15 Contrast vertebrates and invertebrates by writing a definition for each.

16 Discuss the impact of European settlers' reliance on Aboriginal and Torres Strait Islander Peoples for knowledge about the Australian environment.

17 Categorise the items from the following list into the correct columns in Table 1: stewed apple, phone, daffodil bulb, headphones, hairs in your brush, your teacher, shark's tooth, germs, soft drink bottle, your pet, silver chain, dinosaur skeleton.

Figure 1 Is this dinosaur skeleton living, non-living or dead?

Table 1 Living or non-living?

Living		Non-living
Currently living	Dead	

18 Use Table 2 to help you identify which phylum the following invertebrates belong to:

a centipede **b** octopus
c coral **d** leech.

Table 2 Tabular key for identifying invertebrates

1	Body spongy, with many holes	Poriferan
	Body not spongy	Go to 2
2	Soft body, no shell	Go to 3
	Outside shell or hard cover	Go to 6
3	Many tentacles or arms	Go to 4
	Long body without tentacles	Go to 5
4	Tentacles around the mouth of a sac-like body	Cnidarian
	Arms with suction discs	Mollusc
5	Soft body, large foot	Mollusc
	Worm-like or leaf-like	Nematode, platyhelminth or annelid
6	Proper shell or smooth, hard covering	Go to 7
	Spiny skin with rough covering	Echinoderm
7	Limbs in pairs	Arthropod
	Shell, no segments, large foot	Mollusc

19 Look at Figure 2 and Figure 3 and identify which class each vertebrate belongs to.

Figure 2 A cockatoo

Figure 3 A frog

Apply

20 Refer to Figure 1 in Lesson 5.3 Classification keys are visual tools (page 212), showing different Australian animals. Propose how the dichotomous keys in Figure 2 and Table 1 in Lesson 5.3 Classification keys are visual tools (page 212) could be modified if the card included a white cockatoo, a sugar glider and two eucalyptus tree species; a red gum and a white gum.

21 One of the main contributors to the *Encyclopedia of Life* is the *Atlas of Living Australia*. Do an internet search for the *Atlas of Living Australia* and click on "Explore". From this page, you can create a species list and map for the area in which you live.

a Identify the most frequently seen animal in your area.

b Identify the most frequently seen plant in your area.

22 Look at Table 3, showing the number of living things on Earth in 2009.

a Determine the number of plant species that were estimated to be on Earth.

b Contrast the number of **known** plant species with the total number of **known** animal species (add animals without a backbone and animals with a backbone together).

Table 3 Types and numbers of living things on Earth in 2009

Group	Number of species described	Number of species estimated to exist	Percentage of total estimated number of living things (%)
Animals with internal backbones (vertebrates)	64,788	80,500	0.7
Animals without a backbone (invertebrates)	1,359,365	6,755,830	61.8
Plants	297,857	390,800	3.6
Fungi	98,998	1,500,000	13.7
Bacteria (Monera)	35,351	>1,200,500	11
Algae and protozoa (Protista)	28,871	>1,000,000	9.2
Total number of species	1,885,230	>10,927,630	100

Source: Chapman, A. D., 2009, *Numbers of Living Species in Australia and the World*, 2nd ed.

Social and ethical thinking

23 There is often conflict between the rights of animals and those of humans. Animal rights' supporters believe it is wrong to use animals in any way. In contrast, animal welfare supporters believe it is acceptable for humans to use animals (such as testing vaccines) as long as the animals do not suffer. Write two reasons that support the views of each group. Discuss the reasons with others in your class.

Critical and creative thinking

24 Download and print a copy of Figure 4.

- **a** Cut out the pictures of the insects.
- **b** On your own, sort the insects into groups based on appearance. Justify your system of classification (by explaining why you made each decision).
- **c** Compare your groupings with those of a partner. Together, identify a third way to classify the insects.
- **d** With your partner, create a dichotomous key.

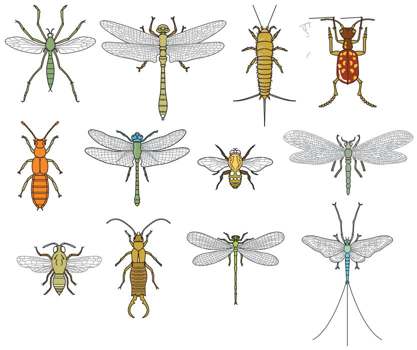


Figure 4 Collection of insects

25 Design an experiment to show that plants are living things that respond to stimuli. Choose one stimulus (such as reaction to light or a lack of water) to investigate. This stimulus is the experimental variable, so you will need to change the variable in some way and control the rest of the variables. Make a list of the equipment you would need.

26 Discuss why the invention of the microscope was important to the development of the classification system.

Research

27 Choose one of the topics to present a report in a format of your choice. Some ideas have been included to get you started. Your report must include a classification key.

A newspaper article

Write a newspaper article about how life on Earth is organised. It needs to be about two pages long (no more than 500 words). You should explain how living things are classified for an audience unfamiliar with science. Make a list of the living things whose images you would like to use to illustrate the article. Try to find their scientific and common names. Your article must contain a key of some description.

A trip to the Kimberley region

You have just returned from a trip to a remote mountain area of the Kimberley in Western Australia. While there, you took your portable microscope and examined water from a previously unknown lake. To your surprise, you found some new creatures in the water that look a bit like bacteria. They are single-celled and are either square or oval; some are hairy (have hairs either on the end of the cell or along the edge of the whole cell).

- Draw six different versions of these organisms.
- Create a dichotomous key for these six new organisms so that you can describe them to other scientists.
- Name each of the groups at the bottom of your key.
- Assuming they are a type of bacterium, identify the kingdom to which they would belong.

Classifying fossils

Living organisms are not the only things that can be classified. The remains or impressions of prehistoric plants or animals that are found in rocks can also be classified according to their unique characteristics.

- Identify a photo of a fossil.
- Describe the characteristics that could be used to classify it.
- Identify the group it could belong to in the Linnaean classification system.
- Justify your decision by comparing it to other organisms in the same group.

Module

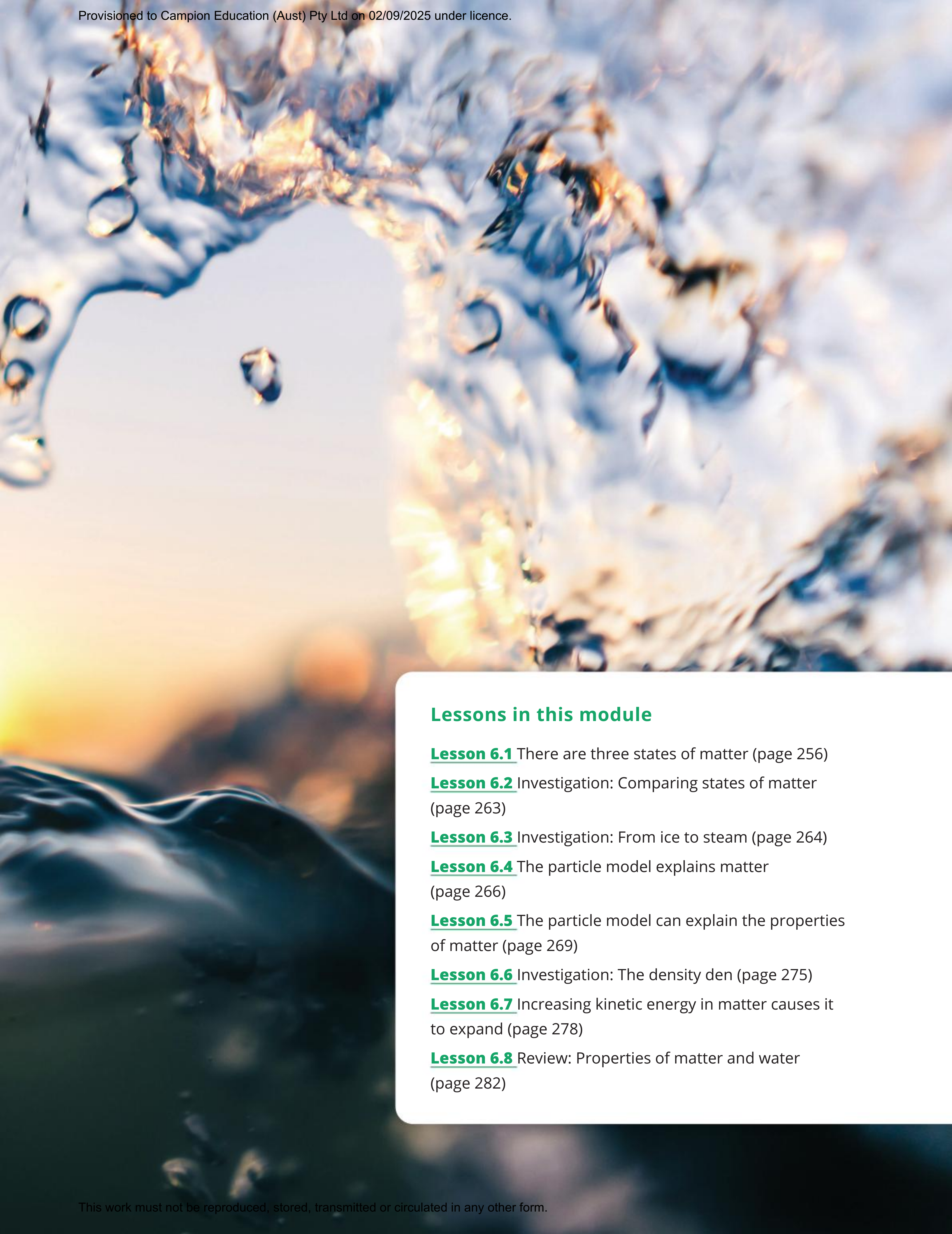
6

Properties of matter and water

Overview

Matter exists in three major states: solid, liquid and gas. Each state has unique properties that we can observe and measure. Solids have a fixed shape and volume, whereas gases fill the entire space available to them.

Water is a liquid with special properties that make it essential for life on the Earth. These include buoyancy, which is a force that helps things float in water, and surface tension, which is like an invisible skin on the top of water.



Lessons in this module

Lesson 6.1

There are three states of matter

Learning intentions and success criteria

Key ideas

- → All things are made of matter.
- → There are three major states of matter – solid, liquid and gas.
- → Many substances can be found in more than one state.

Matter and states – what are they?

Matter is anything that has mass and takes up space. Everything around us is made of matter, from the air we breathe to the chair we sit on and even the food we eat. Matter is made up of tiny particles called atoms and molecules, which are too small to see with just our eyes. These particles are constantly moving, and how they move or how they are arranged determines the state of matter (solid, liquid or gas).

A **state** refers to the condition or form that something takes, based on how its particles are arranged or how they move. Just like the way that we can be in different moods – such as happy, tired or excited – matter can also exist in different states depending on factors such as **temperature** and **pressure** because these affect how particles behave. Matter can change from one state to another, like when water turns into ice or steam, but it is always made of atoms and has mass and volume.

Describing matter

There are three major states of matter – **solid**, **liquid** and **gas**. Solids, liquids and gases are all around us. Steel, concrete, wood and plastic are all examples of solids. Water and cooking oil are examples of liquids. Carbon dioxide is a common gas – you can see it as bubbles in soft drinks. Air is a mixture of gases. The smell of a barbecue is caused by gases that leave the food as it is being cooked.

The properties of a substance can be measured and are always the same for that substance if it is pure. Solids, liquids and gases have unique properties. Solids do not change their shape and cannot be compressed. The forces that pull the particles together are very strong because the particles are tightly packed together.

matter anything that has space and volume; matter is made up of atoms

state condition or form that something takes based on the arrangement of particles and their movement

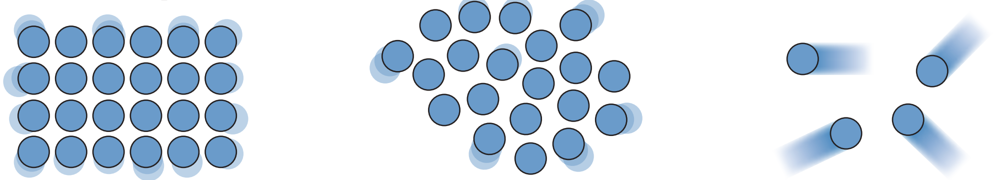
temperature how hot or cold something is. This tells us how much energy the tiny particles in an object are moving. The hotter something is, the faster the particles move. We measure temperature using different scales, like Celsius (°C), or Kelvin (K)

pressure the force something has on a surface; it happens when something pushes on an area; we measure pressure in pascals (Pa)

solid a substance that has a fixed shape and volume

liquid a substance that has a fluid shape with a fixed volume

gas a substance that has no fixed shape or volume, which will freely expand to fill the available space



Solids
The particles are close together. They are held in a regular arrangement and vibrate around a fixed point.

Liquids
The particles are close together, but they can move and slide over one another.

Gases
The particles are far apart and move quickly on their own. They spread out to fill the space available to them.

Figure 1 Illustration of the arrangement of particles in a solid, a liquid and a gas.

Liquids cannot be compressed but they can change their shape. This is because the forces holding them together are weaker than in solids, so the particles can slide past each other. This lets liquids flow and take the shape of the container holding them. Liquids still have a set volume, meaning they don't spread out or shrink easily.

Gases have very weak forces between the particles, so they completely fill the container holding them and can be compressed.

Solids, liquids and gases

Water is a common substance that we experience in different states of matter. Solid water is called ice, we drink and wash with liquid water, and the gas form of water is known as water vapour. Occasionally, we see a fog or mist in the air. This steam-like substance is actually very small droplets of water mixed with the air.

Most glaciers are located in the Arctic and Antarctica. These are vast masses of frozen water in the mountainous and polar regions, created over hundreds of years. Icebergs are smaller pieces of ice that break off glaciers and drift off with the ocean currents. Ice is less dense than liquid water, which is why it floats (Figure 2).

Liquid water flows easily, allowing it to move from one place to another. It plays a vital role in the water cycle, where it **evaporates**, forms clouds and then falls back to Earth as rain or snow. Liquid water supports all life, helping plants grow and providing habitats and hydration for animals.

evaporate to change in state from liquid to gas; also a separation technique used to separate dissolved solids from water

When water heats up, it turns into water vapour, which is its gaseous state. This happens during evaporation, when the Sun heats the water in oceans or lakes. Water vapour rises into the air, where it can cool down and form clouds (Figure 3). Eventually, the clouds release the water back to the ground as precipitation (like rain or snow). This process is a key part of the water cycle, helping to distribute water around the planet.

Figure 2 Solid water (ice) floats on liquid water.

Figure 3 Water condenses in the sky to form clouds.

In summary, pure water will always be the same anywhere on the Earth – or on another planet. Water always has the same properties, no matter where it comes from. So, the movement of water on the Earth can be seen in all three states: as solid ice in glaciers, as liquid water in rivers and lakes, and as gas in the form of water vapour in the atmosphere. Together, these states create a continuous cycle that is essential for life on Earth!

Figure 4 The dew seen on grass in the morning shows how water changes state from a gas to a liquid as the air temperature warms up with the Sun.

Figure 5 Honeycomb is a combination of solid and gas. Or is it?

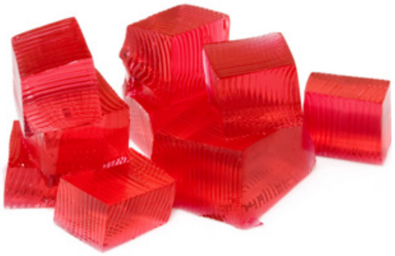


Figure 6 Is jelly a solid, a liquid or a gas?

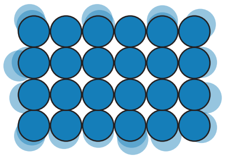
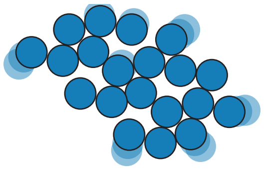
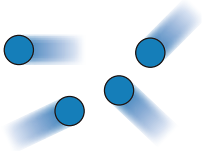
It is usually obvious if a substance is a solid, liquid or gas. Some substances, however, seem to be made of more than one state of matter. Sometimes we can see the states of a mixture, such as in honeycomb confectionery (Figure 5), which is a combination of solid and gas. But other times it is difficult to tell the state of mixtures. How would you classify slime or jelly – solid, liquid or gas? (Figure 6)

Particle arrangement and movement

Particle arrangement and movement refer to how the tiny particles (atoms or molecules) in a substance are arranged and how they move. There are invisible forces that hold particles in a substance together.

Understanding the differences in particle arrangement, movement and attractive forces in the different states of matter can help us understand the properties of matter and how matter can change from one state to another.

Table 1 Particle arrangement, movement and their relative attractive forces for solids, liquids and gases.

State	Particle arrangement	Particle movement	Relative strength of attractive forces	Diagram
Solid	Particles are tightly packed in a fixed structure.	Particles vibrate in place and cannot move freely. They do not take on the shape of their container.	Strongest	
Liquid	Particles are close together but are arranged more randomly. Particles can flow and move past each other.	Particles can move more freely, which allows them to take the shape of their container.	The attractive forces are weaker than in solids	
Gas	Particles are spread far apart.	Particles move quickly in all directions. They will fill the entire space available.	Weakest	

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Change of state

Matter can change state between a solid, liquid and gas. It depends on how much energy it has. Energy changes matter from one state to another when it is added or taken away. If you add heat to matter, you are adding energy to it, making the particles move faster. If you take heat away, you are cooling the substance down, making the particles start to slow down. The energy (heat) is transferred from one object to another. The amount of energy within matter is measured by its temperature. When you boil a kettle (Figure 7), the electricity used adds energy to the water and makes it hotter, so it starts to change state from liquid to gas; this is called **boiling point**.

The minimum temperature required to melt a solid is called its **melting point**. Any substance above its melting point will be a liquid (or a gas), and any substance below its melting point will be a solid.

boiling point the temperature at which a liquid boils and becomes a gas

melting point the temperature at which a solid changes to a liquid

Figure 7 Water boiling in a kettle. When heat is added to water and it reaches 100°C, liquid water changes state to a gas

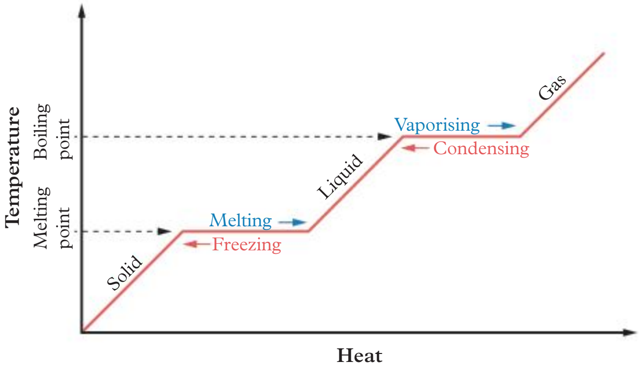


Figure 8 Phase changes of a substance when it is heated

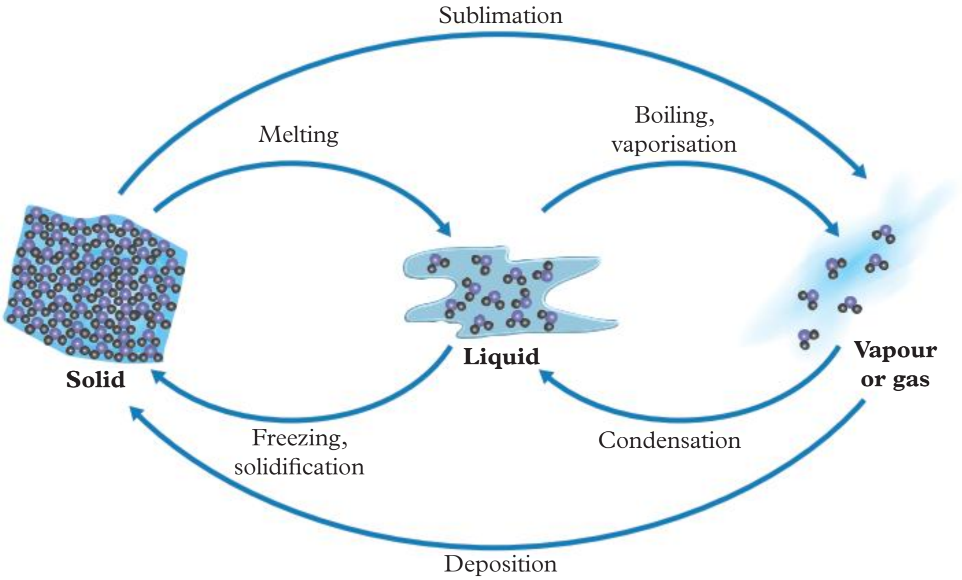
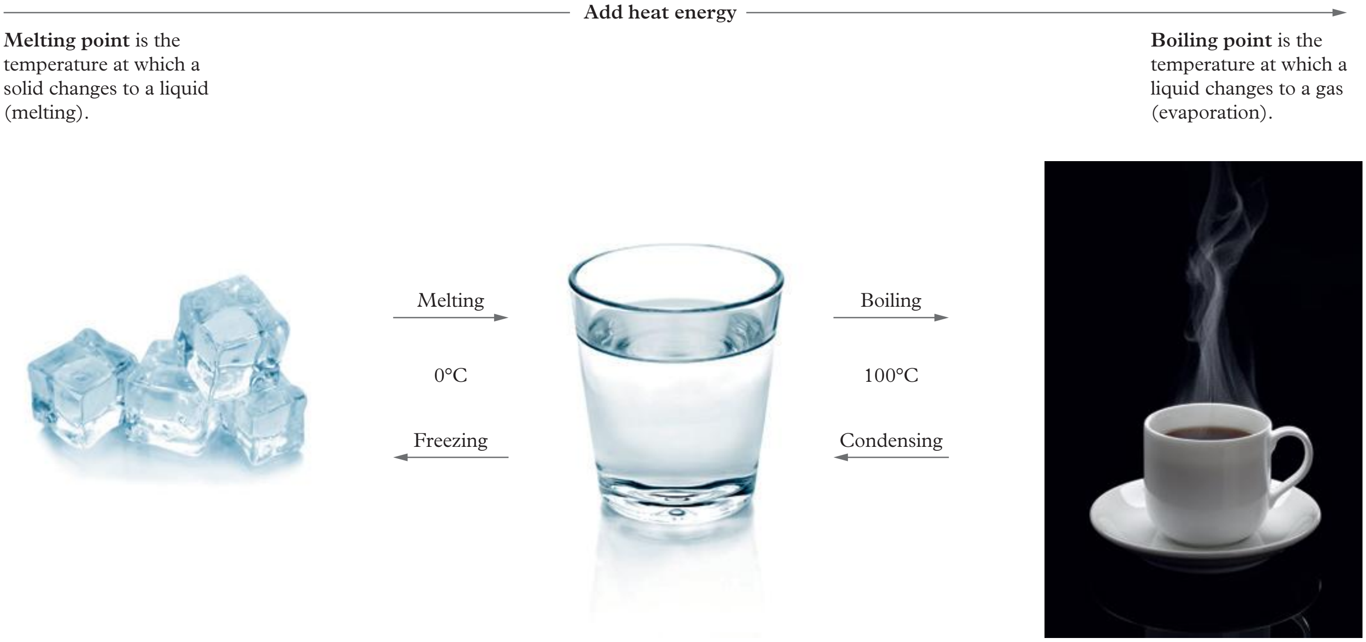


Figure 9 The changing states of water molecules. Solid water (ice) contains lattice water molecules, liquid water contains a loose arrangement of water molecules, and water vapour contains separated water molecules.



Melting point is the temperature at which a solid changes to a liquid (melting).

Boiling point is the temperature at which a liquid changes to a gas (evaporation).

Figure 10 Adding or removing heat energy can change the state of water.

Evaporation and condensation

evaporation a change in state from liquid to gas; also a technique used to separate dissolved solids from water

condensation the change of state from a gas to a liquid; occurs when a gas cools down

Evaporation happens when a liquid turns into a gas. When a liquid is heated, the particles move faster and some of them escape into the air as gas. This is why water can disappear from a puddle or a bowl over time, even when there's no obvious change. Evaporation happens more quickly when the temperature is high, when there's wind or when the air is dry. Evaporation is an important part of the water cycle, as it helps move water from the Earth's surface into the atmosphere.

Condensation is the opposite of evaporation. It happens when a gas cools down and changes back into a liquid. For example, when warm, moist air touches a cold surface, like a glass of ice water, droplets of water form on the outside of the glass. This occurs because the gas cools down, and the particles slow down enough to come together and turn into liquid. Condensation is an important part of the water cycle and helps to form clouds in the sky when water vapour in the air cools and turns into tiny water droplets.

Preventing evaporation

Understanding how water evaporates becomes very important when you live in a hot and dry climate, like some parts of Australia. Bright sunshine, high temperatures and wind will all cause waterholes to quickly dry up. Before Europeans colonised Australia, Aboriginal and Torres Strait Islander Peoples would cover the waterholes with rocks to prevent evaporation.

If water was found in clay, Aboriginal and Torres Strait Islander Peoples would make the hole deeper but not wider so that more water could be stored without increasing the evaporation from the water surface. The Yankuntjatjara people in the Everard Range region of South Australia would also prevent evaporation by adding sand to their local waterholes. The water particles were able to "hide" between the sand grains, preventing evaporation. When it was time to collect the water, a hole was made in the centre of the sand so that the fresh water could drain into a puddle.

Properties of a substance

Some substances are important to us because of particular properties. For example, one property of water is that it can be used to dissolve (mix with) many other substances. This makes water useful for cleaning clothes, cooking and experiments in a chemistry laboratory. The properties of substances can be divided into two groups: physical properties and chemical properties.

- **Physical properties** are what we can observe and measure without changing the substance into something else. Examples of physical properties are colour, texture, boiling point, reversible state changes, density and how much heat it can store (heat capacity). Table 2 lists the physical properties of water.
- **Chemical properties** are what a substance does in a chemical reaction. Examples include bubbling, permanent colour changes and irreversible changes of state.

physical property a property of a substance that can be measured or observed without changing the substance into something else; examples are colour and boiling point

chemical properties how a substance behaves in a chemical reaction, such as how it reacts with an acid

Table 2 Physical properties of water

Physical property	Value
Melting point	0°C
Boiling point	100°C
Colour	Colourless
Density	1.00 g/mL at 25°C

Check your learning 6.1

Check your learning 6.1

Retrieve

1 Identify the properties of:
  - a solids
  - b liquids
  - c gases.

2 Select a common substance, such as cling wrap or vinegar. Name some of the physical properties of this substance.

3 Identify what clouds are made up of.

Comprehend

4 Describe what happens to water when it:
  - a evaporates
  - b condenses
  - c freezes.

5 Describe what is meant by a "property" of a substance.

6 Classify the following objects as solid, liquid and gas.
  - a Bread
  - b Water
  - c Oxygen
  - d Cheese
  - e Oil
  - f Carbon dioxide
  - g Ozone

7 Explain why the properties of matter are so important to us.

8 Describe the difference between an iceberg and a glacier.

Analyse

9 Categorise the following substances as a solid, liquid or gas (or a combination of states):

- **a** ice cream
- **b** chocolate bar
- **c** clouds
- **d** thick smoke
- **e** glass
- **f** honey
- **g** cake or bread
- **h** mashed potato
- **i** paper
- **j** peanut butter (smooth)
- **k** cling wrap
- **l** play dough
- **m** sand
- **n** steam
- **o** slime.

10 Classify each of the following properties as either a physical or a chemical property:

- **a** the ability to be hammered into flat sheets (malleability)
- **b** the ability to explode
- **c** the amount of vapour released at different temperatures.

11 Identify what would happen to liquid water when heat is applied.

12 Justify why water is vital and important for life.

Apply

13 A student claimed a frozen drink bottle was leaking because condensation had formed on the outside of the container. Develop an explanation for the student that describes where the condensed water came from.

Skills builder: Processing and analysing information

14 Interpret Table 3. Which substance has the:

- **a** lowest melting point?
- **b** highest melting point?
- **c** lowest boiling point?
- **d** highest boiling point?

Table 3 Melting and boiling points of different substances

Substance	Melting point (°C)	Boiling point (°C)
Water	0	100
Iron	1,535	2,750
Lead	327	1,750
Mercury	−39	357
Table salt	805	1,413
Oxygen	−219	−183
Nitrogen	−210	−196

Lesson 6.2

Investigation: Comparing states of matter

Introduction

Models in science

In science, a model is a way to represent something that is too small, too large or too complex to study easily. Think of a model as being a simplified version of something real, made to help us understand how it works. For example, when you play with a toy car, you're not using a real car, but the toy car still helps you understand how cars move. Similarly, scientists use models to represent things like atoms, the weather or even how states of matter behave.

Scientists use scientific models to explain and predict how things work. Scientific models are ideas or representations that we can use to explain phenomena that are difficult to observe. For example, the particle model (Lesson 6.4 The particle model explains matter, page 266) helps us to explain matter, which we would not normally be able to see. Other examples of scientific models include models of the solar system or DNA. We cannot view either of these things, but you might have an idea in your head of what they look like.

Creating a model allows you to explore ideas that are difficult to see in real life. You can change your model, make predictions and test it out.

In this investigation, you'll build a model to show the arrangement of atoms in the three different states of matter – solid, liquid and gas. This will help you to understand how atoms are arranged without needing to see every single atom or molecule. Models are powerful tools for learning because they allow you to experiment with ideas and see science in action, even on a small scale!

Models are useful tools in science, but they have some limitations. They are simpler versions of real things, so they leave out some details to make them easier to understand. For example, when we model particles in solids, liquids and gases, we might use simple shapes, like balls, but real particles are more complex. Models may also not always behave exactly like the real thing, and they don't always show how things change over time.

Figure 1 Use your items to model the three states of matter.

Purpose

To model the three states of matter

Materials

- Items such as table tennis balls, coins, lollies, marbles or pieces of modelling clay
- A3 or butchers' paper
- Marker

Procedure

1 Draw on a piece of paper a “vessel” such as a beaker or a measuring cylinder.
2 Use one of the items you have selected to represent the particles of matter. Make models of a solid, a liquid and a gas.
3 Draw a labelled diagram of each model.

Discussion

1 Describe how your modelled particles represent the characteristics of real particles in each of the states.
2 Describe how your model of a solid could be used to explain the process of melting.
3 Create a table with the headings “Strengths” and “Limitations”. Identify the strengths and limitations of your model.

Lesson 6.3

Investigation: From ice to steam

Caution

- Both steam and boiling water can scald. Take great care when measuring the higher temperatures. If scalded, place the area of skin under cold running water for at least 5 minutes and inform your teacher. Do not use ice or very cold water.
- Wear safety glasses, closed-toe shoes and a lab coat, and tie long hair back when using a Bunsen burner.

Purpose

To measure and graph the temperature of water to identify the changes of state (from solid to liquid and from liquid to gas) as it is heated over time

Materials

- 500 mL beaker
- Ice (enough to half-fill the beaker)
- Water
- Hot plate or Bunsen burner with tripod and gauze (heatproof) mat
- Stopwatch
- Stirring rod
- Retort stand, clamp and boss head
- Thermometer (0–110°C) or thermistor probe
- Matches
- Safety equipment (goggles, lab coat)

Risk assessment

Write a risk assessment for this experiment. Use the table headings shown in Table 1.

Table 1 Risk assessment for water heating experiment

Hazard	Precaution	Management

Procedure

1. Set up the beaker on a hot plate (or on a tripod with a gauze mat and Bunsen burner) as per the diagram in Figure 1.
2. Half-fill the beaker with ice and add enough cold water to just cover the ice.
3. Insert the thermometer into the water, making sure it does not touch the sides or bottom of the beaker. Use a retort stand and clamp to help you with this.
4. Turn on the hot plate (or light the Bunsen burner) and begin heating the beaker.
5. Start the stopwatch at the same time as you start heating.
6. Record the temperature of the water every 30 seconds.
7. Once all the ice has melted, continue to heat the water and record the temperature as in Step 6.
8. As the water starts to approach 100°C, monitor when the bubbles start to form.
9. Once you observe a steady boil for a few minutes or when the water level becomes low, stop heating the beaker and end the experiment.
10. Record the final temperature of the water.

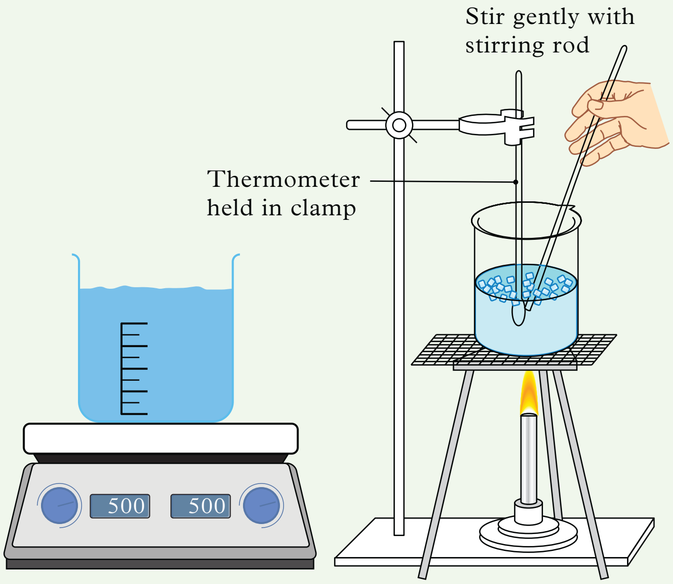


Figure 1 Experimental set-up for measuring the melting point of ice

Results

Using graph paper, plot "Temperature (°C)" on the *y*-axis and "Time (minutes or seconds)" on the *x*-axis. Label key points on the graph, such as when the ice melted and when the water began to boil.

Discussion

1. Identify the sections of the graph where the temperature stays constant. Explain why you think this happened.
2. Explain what is happening as the bubbles are starting to form. Use the data you recorded in your response.
3. Analyse the graph to identify the temperatures at which the water changes state (from solid to liquid and from liquid to gas) and describe the energy transfers at each stage of the process (refer to Lesson 6.1 There are three states of matter (page 256) to assist you here).

Lesson 6.4

The particle model explains matter

Learning intentions and success criteria

Key ideas

- → All particles have kinetic (movement) energy.
- → Adding heat increases the kinetic energy of particles.
- → Removing heat decreases the kinetic energy.
- → The particle model of matter can be used to explain the properties of matter.

The kinetic theory of matter

The particle model of matter is used to describe the properties of all matter.

In the particle model of matter, the particles are always moving. The word "kinetic" refers to the energy of anything that is moving. Therefore, particles always have **kinetic energy**. The faster they move, the more kinetic energy they have. For this reason, the particle model can also be called the **kinetic theory of matter**.

kinetic energy the energy possessed by moving objects

Figure 1 Some of the energy in storms comes from the condensation of water vapour into liquid, which we see as rain.

Particle energy

The movement of people and particles is related to their kinetic (movement) energy.

- When people are sitting quietly, they have little kinetic energy. This is like a solid, where the particles only vibrate, and people only sit quietly and breathe.
- In a crowd, people are standing and moving around and have more kinetic energy. This is like a liquid, where the particles jostle about. Particles in a liquid have more kinetic energy than particles in a solid.
- When people are running, they have much more kinetic energy. This is like a gas, where the particles move fast and on their own. Particles in a gas have the highest amount of kinetic energy.

Using the kinetic theory of matter

The kinetic theory of matter can be used to explain many of the observations and measurements that we make about the substances around us.

Mass is the amount of matter in a substance and is measured in grams (g). Mass depends on the number of particles and the mass of each individual particle.

A particular volume of a solid or liquid has a greater mass than the same volume of gas because it has more particles in it (Figure 2). For example, imagine two containers that are the same size. One container is filled with liquid nitrogen. The other is filled with nitrogen gas. The container with liquid nitrogen is much heavier because the liquid has more particles in it than the fast-moving nitrogen gas particles.

A piece of lead has a much greater mass than the same-sized piece of aluminium. Both are metals that are made of atom particles that are packed closely together. The difference is the mass of each atom. Lead atoms are bigger and have a greater mass than aluminium atoms (Figure 3).

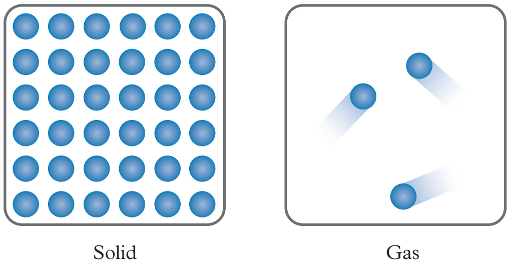


Figure 2 A container of a solid has more particles than the same container of gas.

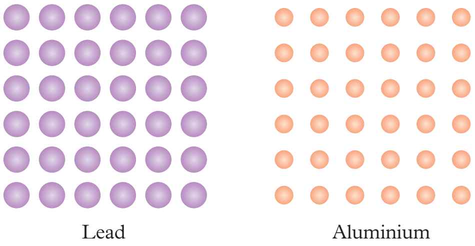


Figure 3 Lead atoms have a greater mass than aluminium atoms.

Check your learning 6.4

Check your learning 6.4

Retrieve

1 List the states of matter – solid, liquid and gas – in order from the highest to the lowest levels of kinetic energy.

2 Define the term "mass".

Comprehend

3 Explain the meaning of "kinetic" in the kinetic theory of matter.

4 Describe how the kinetic theory of matter explains the mass of different substances.

5 Consider the three images shown in Figure 4. Identify whether each image represents a solid, a liquid or a gas. Explain why you think each image represents that state of matter.

6 Explain why a 2 cm^3 block of lead will have a greater mass than a 2 cm^3 block of wood.

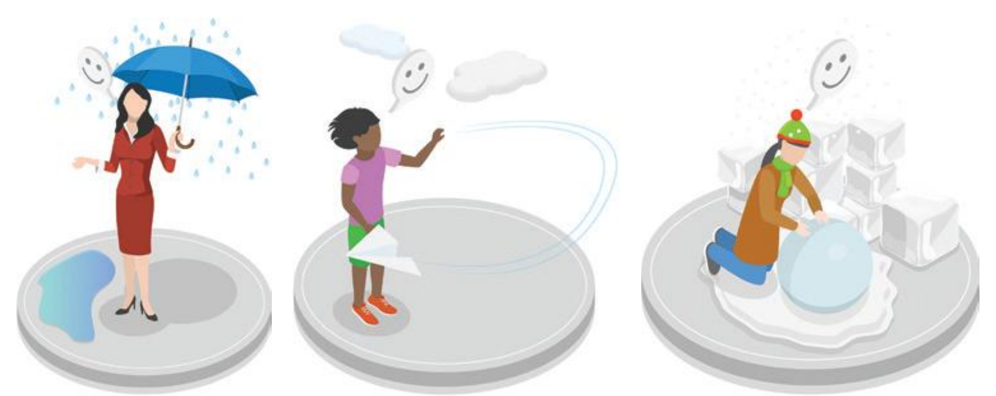


Figure 4 Artistic interpretations of solid, liquid and gas for question 5.

Analyse

7 Consider a school assembly. Everyone is sitting quietly in their seats in rows. When the assembly finishes, there is a crowd at the doors, pushing to go through them to leave. When outside, the students run off in all directions as fast as they can. Explain which parts of this analogy represent a solid, a liquid and a gas.

8 How would you describe the properties of the particles in a chair? Why are they arranged this way, and how do these properties give the chair its strength and shape?

9 If you heat a block of ice (solid water), what happens to the particles as it melts into liquid water? Describe how the particles behave differently in the solid, liquid and gas states. How does this relate to the states of matter of the water?

10 Some people use analogies or models to compare states of matter. Identify which state could be represented by the following situations.

- **a** A swarm of bees crawling over one another
- **b** One thousand tennis balls tidily arranged in a large cardboard box
- **c** Eggs in trays in a large egg container
- **d** A school of fish darting in all directions as they avoid a predator

11 The graph in Figure 5 shows the temperature of water as it is heated over time. Identify the points where the water changes state from solid to liquid and from liquid to gas. What does the graph tell you about the energy needed for each change of state?

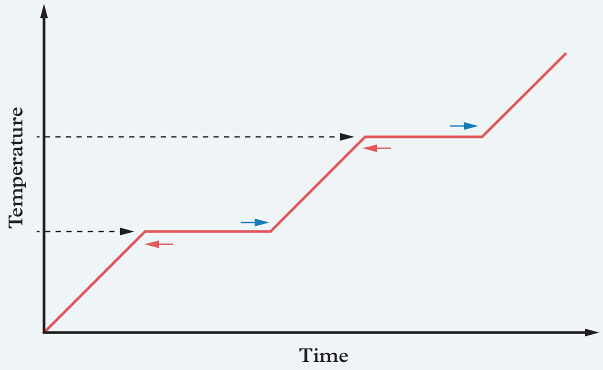


Figure 5 Phase changes of water when it is heated

Skills builder: Conducting investigations

12 A student was asked to investigate how different factors affect the rate of dissolving sugar in liquids. To test this, they placed a spoonful of sugar in one cup of hot water and timed how long it took the sugar to completely dissolve. They recorded the time and repeated the exact method again.

- **a** Will the student's method help them to investigate different factors? Explain your reasoning. (THINK: What are the different factors (independent variables) that the student was testing? Does their method compare factors?)
- **b** Propose how the student could improve their method. (THINK: How can they make this a fair test, including independent, dependent and controlled variables?)

Lesson 6.5

The particle model can explain the properties of matter

Key ideas

→ Strong bonds between particles can make the material stronger (able to withstand force), harder and more viscous.

→ Tightly packed particles make the material dense and less able to be compressed.

Learning intentions and success criteria

Density

One way of comparing the "heaviness" of two substances is to compare their densities. **Density** describes the number of particles there are and how tightly packed they are. The density of a substance will affect its properties, such as its ability to float.

density a measure of mass per unit of volume

Objects with lower density float on liquid if the liquid has a higher density. For example, a piece of cork will float on water. This is because the water has a higher density than the cork. On the other hand, coins will sink to the bottom of the water. This is because the coins have a higher density than the water.

In Figure 1, we see that 1 L of water is heavier than 1 L of air. We say that water has a greater density than air. Sand has a greater density than water or air, but it has a lower density than lead.

The particle model of matter explains density in terms of both the mass and the closeness of the particles. Gases always have low densities because there is a lot of empty space between the particles (Figure 3).

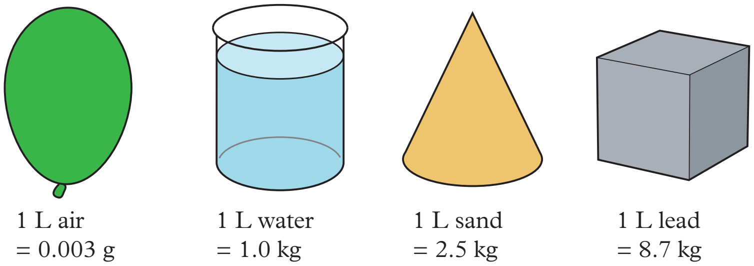


Figure 1 Density compares the mass of objects of the same volume.

Figure 2 The cork, which has a lower density than water, floats, while the coins, which have a higher density than water, sink.

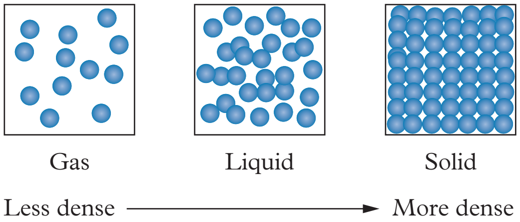


Figure 3 Gases have a low density

Table 1 Densities of some common substances, ordered from lightest to heaviest

Substance	Density (g/cm^3)
Air	0.001
Foam rubber	0.05
Wood	0.3
Oil	0.75
Water	1.0
Glass	2.6
Steel	7.8
Iron	7.8
Copper	8.9
Lead	11.3
Mercury	13.6
Gold	19.3

Solids normally have high densities because there is no space between the particles. The densities of some common substances are given in Table 1.

Buoyancy

Buoyancy is the force that helps things float in water. When you put something in water, like a ball or a boat, the water pushes up against it. If the water pushes up more than the object's weight, it will float. For example, a heavy boat floats because its shape spreads out its weight, allowing the water to push it up.

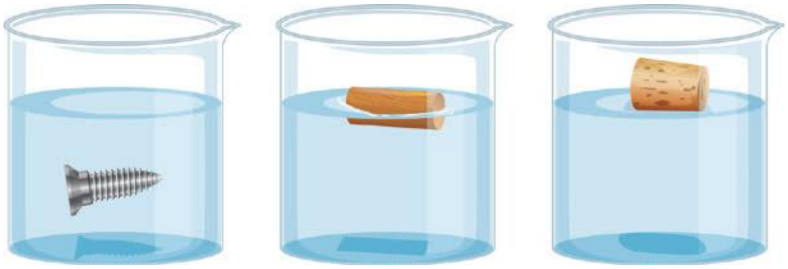


Figure 4 Different materials in water either float or sink, depending on whether the material's downward force is greater or less than the upward force of the water.

Surface tension

surface tension the property of the surface of a liquid that allows it to resist external force, acting as a barrier between the liquid and foreign objects

cohesion the attraction between molecules of the same kind that allows them to stick together

adhesion the attraction between different kinds of molecules that allows them to stick together

Surface tension is like an invisible skin on the top of water. This happens because the water molecules stick together tightly at the surface; there is a force of attraction between them. That's why small, light things like a paper clip or a water bug can float on water without sinking. The molecules are holding each other so tightly that they keep the object from breaking through.

Surface tension can be explained using **cohesion** and **adhesion**. Cohesion is the force that causes water molecules to stick to each other, while adhesion is the force that causes water molecules to stick to other surfaces.

Figure 5 Water bugs – also known as water striders, pond skaters or water skaters – float on water due to a combination of surface tension and water-resistant feet.

In a test tube, water forms a curved surface at the top, called a **meniscus**, because of these forces. The water molecules near the glass are more attracted to the glass (adhesion) than to each other, causing the water to climb slightly up the sides of the test tube. However, the molecules in the centre of the water are held together by cohesion, pulling the surface downward. This combination of forces creates the curved meniscus at the top of the water, with adhesion pulling up at the edges and cohesion pulling the centre down.

meniscus the curved upper surface of a liquid in a tube

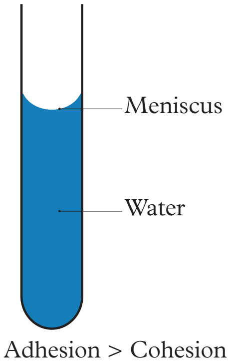


Figure 6 Water molecules near the glass are more attracted to the glass (adhesion) than to each other, but water molecules in the centre are more attracted to each other (cohesion).

Calculating density (ρ)

The density of an object can be calculated by dividing its mass by its volume. Density is shown by the symbol ρ.

$$\rho = \frac{m}{V}$$

where:

ρ = density

m = mass

V = volume

This formula can be rearranged to calculate mass and volume:

$m = \rho \times V$ and $V = \frac{m}{\rho}$

The unit for density is reliant on what units are used for both the mass and the volume.

- If grams (g) are used for mass and millilitres (mL) are used for volume, the unit for density will be g/mL.
- If kilograms (kg) are used for mass and cubic metres (cm^3) are used for volume, the unit for density will be kg/cm^3.
- If kilograms (kg) are used for mass and litres (L) are used for volume, the unit for density will be kg/L.

Note that 1 mL is the same as 1 cm^3. Therefore, grams per millilitre (g/mL) is the same as grams per cubic centimetre (g/cm^3).

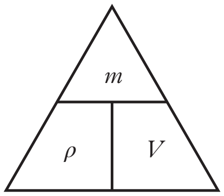


Figure 7 This triangle can be used to remember the relationship between density, mass and volume.

Worked example 6.5A Calculating the density of a glass

Calculate the density of a glass that has a mass of 100 g and volume of 35 cm^3.

Solution

Steps	What to do	Working out
a.	Summarise the information from the question.	m = 100 g V = 35 cm^3 ρ = ?
b.	Write the equation and substitute with the given values to calculate the density.	$\rho = \frac{m}{V}$ $\rho = \frac{100}{35}$ ρ = 2.9 g/cm^3
c.	Answer the question.	The density of the glass is 2.9 g/cm^3

Other properties of matter

hardness how easily a mineral can be scratched; measured on the Mohs hardness scale

viscosity a measure of how slowly a liquid changes its shape; the thickness of a liquid

compressibility the extent to which a substance can be compressed (squashed); gases can be compressed but solids and liquids cannot

tensile strength a measure of the flexibility of the bonds between particles in a substance

compressional strength the ability of a substance to withstand large forces

Physical properties like strength, **hardness**, **viscosity** and **compressibility** describe how materials behave under different conditions. Strength and hardness refer to a material's ability to withstand force or resist scratching; viscosity measures a fluid's thickness or resistance to flow; and compressibility describes how much a material can be squeezed or reduced in volume.

Strength

The idea of strength can be considered in different ways. A rubber band is easily stretched, but what about a piece of wire? Different wires made of different metals will break if stretched. **Tensile strength** is a measure of the flexibility of the links or bonds between the particles. The bonds between the particles in steel are stronger than those between the particles in tin. Another type of strength is **compressional strength**. Substances that can withstand large forces without being crushed have a high compression strength. These substances often have particles that are strongly linked to each other in multiple directions.

Figure 8 Reinforced concrete combines the tensile strength of steel with the compressional strength of concrete.

Hardness

Hardness is the ability of a substance to scratch another substance. An iron nail will scratch a plastic ruler because the iron is harder than the plastic (Figure 9). However, the iron nail will not scratch glass because the iron is softer than glass. For these substances, the order of hardness is glass, then iron and then plastic.

Hardness is not the same as strength. A very hard substance may shatter easily. If this happens, the material is described as "brittle". The particle model of matter explains hardness in terms of the forces that hold the particles together. The particles in hard substances are held together very strongly and it is difficult to separate them. In plastic, the particles are not held together as strongly and can be removed or scraped off. Therefore, plastic is not a hard substance.

There is a connection between hardness and melting. Substances that are hard have strong forces (bonds) between their particles. These strong forces mean that for hard substances to melt, a lot of heat energy is needed. These substances usually have a high melting temperature.

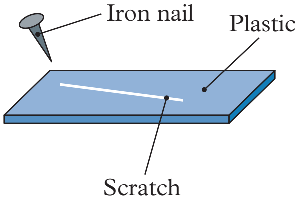


Figure 9 An iron nail will scratch plastic because iron is harder than plastic.

Viscosity

Viscosity refers to the thickness or "gooiness" of a liquid. It describes how easily the particles move around one another. Highly viscous liquids are hard to pour out of a container. Water has a low viscosity, cooking oil is more viscous and honey is very viscous (Figure 10). Engine oils used in engines have different viscosities, affecting how easily the engine parts move at different temperatures.

Figure 10 Honey has a higher viscosity than water, so it cannot be poured as easily as water.

Compressibility

Compressibility refers to the ability of a substance to be squashed or compressed. You can test for compressibility when substances are in a plastic syringe.

If you put your finger over the end of a syringe, you can compress the air inside it. If you replace the air with a liquid such as water, however, you cannot compress the water. Similarly, if you filled the syringe with a solid such as sand, you would not be able to compress it.

In solids and liquids, there are fewer or no empty spaces between the particles compared to a gas, so it is more difficult to compress the particles closer together. Solids and liquids are said to be **incompressible**. Gases, like air, can be compressed. This is because the particles are spread out and there is space between them (Figure 11).

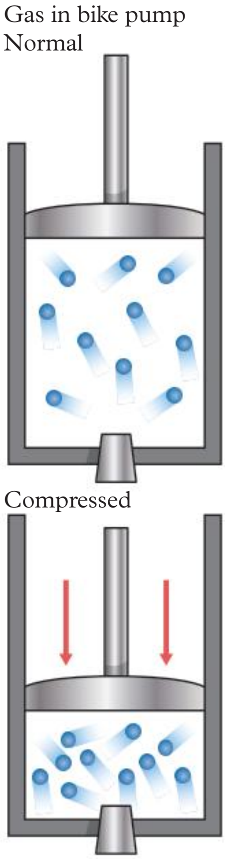


Figure 11 Compression reduces the space between particles.

incompressible unable to be compressed; solids and liquids are incompressible

Calculating the volume of an irregular object by displacement method

If an object has an irregular volume that can't easily be calculated using volume = length × width × depth, a technique called "displacement" can be used. The object is placed in a measuring cylinder of known volume and the change in volume (V) is observed. This change in volume is the volume of the object, and its units are millilitres (mL) (Figure 12).

In Figure 12, the original volume was 25 mL. When the object was added, the final volume was 35 mL. Therefore, the volume the object occupies (the change in volume) is 35 mL – 25 mL = 10 mL.

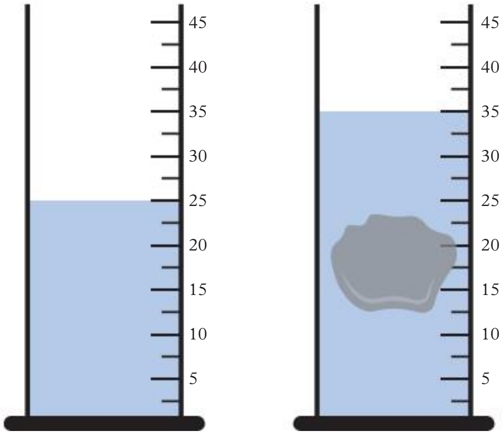


Figure 12 Calculating the volume of an irregular object

Check your learning 6.5

Check your learning 6.5

Retrieve

1 Identify the most and least dense material in Table 1.

2 Name the following in order of compressibility from least to most: solid, liquid, gas.

Comprehend

3 Copy and complete Table 2 by summarising the following physical properties: strength, hardness, viscosity, compressibility, buoyancy, surface tension and density.

Table 2 Physical properties and their meanings

Physical property	Meaning

4 Use the particle model of matter to explain why steel is stronger than tin.

5 Describe what would happen if you placed a highly viscous liquid, such as oil, into a water pistol. Explain your reasoning (by comparing the properties of water and oil and how this will affect how the oil will behave in the water pistol).

Apply

6 Explain why the droplets of water on the leaf shown in Figure 13 look like they do. Use the words "adhesion" and "cohesion" in your answer.

Figure 13 Water droplets on a leaf

7 Use Table 1 to predict which of the following would sink or float in water: oil, an iron nail, a balloon filled with air, a glass marble.

8 Table 3 contains information for six liquids. Use the density formula to calculate and insert the missing information for each liquid.

Skills builder: Problem solving, questioning and predicting

9 Imagine that you are selecting a substance to use to make a protective case for a mobile phone. What physical properties would you consider when choosing your substance? Explain your reasoning.

10 Use Table 1 to predict what will float or sink if the following pairs were in the same container.

- **a** Steel and oil
- **b** Iron and water
- **c** Wood and water
- **d** Foam rubber and oil

Table 3 Mass, volume and density of some liquids

Liquid	Mass (g)	Volume (mL)	Density (g/mL)
Coloured water (green)	3.5	3.5	
Dish soap (purple)		5	1.06
Honey (orange)	4.26		1.42
Milk (white)	4.12		1.03
Rubbing alcohol (blue)	1.58	2	
Vegetable oil (yellow)	2.3	2.5	

Lesson 6.6

Investigation: The density den

Introduction

To calculate the density of a substance, you first need to know its mass and volume. The most appropriate units for the substances you will be working with are grams (g) for mass and millilitres (mL) or cubic centimetres (cm^3) for volume. Millilitres tend to be used for the volume of liquids, whereas cubic centimetres are used for solids.

$$\text{Density} = \frac{\text{mass (g)}}{\text{volume (cm}^3\text{)}}$$

Note that 1 mL is the same as 1 cm^3. Therefore, grams per millilitre (g/mL) is the same as grams per cubic centimetre (g/cm^3).

Station 1

Purpose

To measure the density of liquid substances

Materials

- Graduated cylinder (for measuring volume)
- Electronic balance (for measuring mass)
- Water
- Other liquid substances (e.g. oil, saltwater, alcohol)
- Calculator
- Table for recording data
- SI reference data for densities

Procedure

1 Copy and complete Table 1 and use it to record your measurements.
2 Place the empty graduated cylinder on the electronic balance and record its mass. This will be used to find the mass of the liquid.
3 Carefully pour 50 mL of water into the graduated cylinder. Make sure to read the volume at the bottom of the meniscus for accuracy.
4 Place the graduated cylinder with the liquid on the electronic balance and record the total mass.
5 Subtract the mass of the empty graduated cylinder from the total mass to find the mass of the liquid alone.
6 Repeat Steps 2 to 5 for each of the other substances being tested.

Table 1 Recording the density of substances

Substance name	Mass of the empty graduated cylinder (g)	Measured volume (mL)	Measured mass of the liquid and the graduated cylinder (total mass) (g)	Measured mass of the liquid = total mass – mass of the empty graduated cylinder (g)	Calculated density = mass/volume (g/mL)	SI data
Water						
Oil						
Saltwater						

Discussion

1 Calculate the density of each substance:

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

2 Look up the standard density values (SI data) for each substance and compare them with your measured densities to check for accuracy.

3 Discuss what could have caused your results to differ from the standard value of the density of a substance.

4 Identify whether the amount of water used makes any difference when you calculate the density of water. Explain the reasons for your answer.

5 Exlain why scientists repeat experiments.

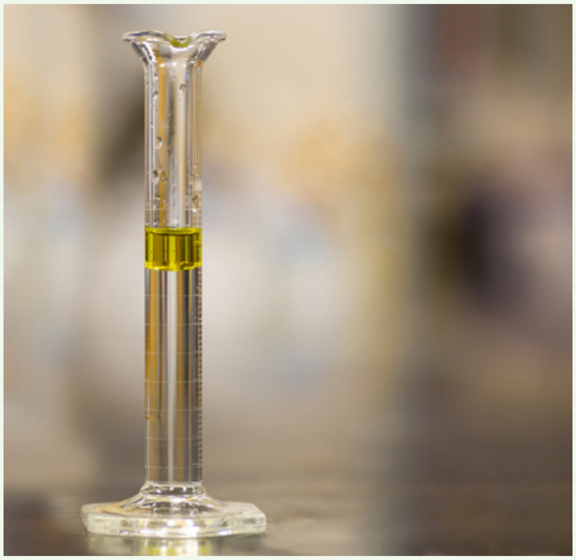


Figure 1 Density of different liquids

Station 2

Purpose

To measure the density of regular-shaped blocks made from different materials

Materials

- Several blocks or cubes made from different substances (e.g. wood, polystyrene, copper, zinc)
- Ruler
- Electronic balance
- Calculator

Procedure

1 Copy and complete Table 2, adding a row for each additional substance.

2 Measure and record the mass of each of the blocks.

3 Use a ruler to measure the length, width and height of each block.

Discussion

1 Calculate the volume of each block (volume = length × width × height). An example has been done for you in the first row of Table 2, using the measurements in Figure 3.

Figure 2 Cubes of different materials

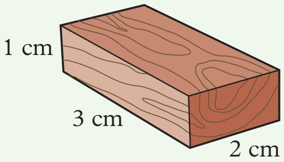


Figure 3 Calculating the volume of a regular-shaped block

2 Calculate the density of each block. Remember to state the unit of density.
3 List the blocks from least dense to most dense.

Table 2 Measuring the density of regular-shaped blocks

Substance	Length (cm)	Width (cm)	Height (cm)	Volume (cm^3)	Mass (g)	Density (g/cm^3)
Wood	3	2	1	3 × 2 × 1 = 6	3	3 ÷ 6 = 0.5

Station 3

Purpose

To measure the density of irregular-shaped objects

Materials

- Four different objects (e.g. spatula, a small rock, a lump of plasticine, an object of your choice) that each fit into the measuring cylinder
- Electronic balance
- 100 mL measuring cylinder

Procedure

Remember how to calculate density using "Calculating the volume of an irregular object by displacement method" from Lesson 6.5 The particle model can explain the properties of matter (page 269).

1 Copy Table 3 with four blank rows.
2 Measure the mass of the first object. Record the mass (in grams) in your table.
3 Use the displacement method to work out the volume of the object.
  - Approximately half-fill the measuring cylinder. Record the volume of water in the cylinder (volume 1).
  - Add the object to the measuring cylinder so that it is fully submerged. Record the volume of water in the cylinder (volume 2).
  - Calculate the volume of the object by subtracting the volume of water in the cylinder before the object was added from the volume after the object was added (volume 2 – volume 1).
4 Repeat the experiment with the remaining objects.

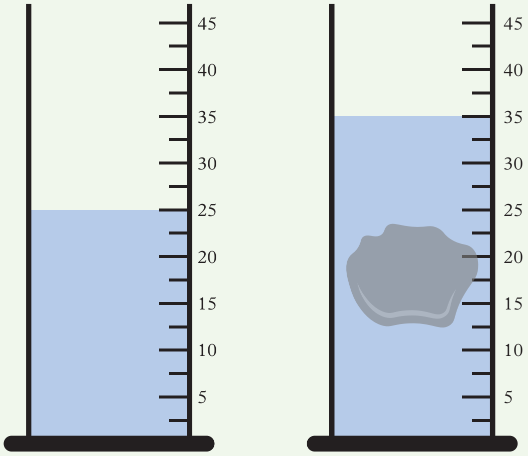


Figure 4 Measuring the density of irregular-shaped objects

Discussion

1 Calculate the density of each object.
2 Describe some of the difficulties that you had using the displacement method for calculating density.
3 Describe some advantages of using the displacement method for measuring volume.

Table 3 Measuring the density of irregular-shaped objects

Object	Mass (g)	Volume before (volume 1, mL)	Volume after (volume 2, mL)	Volume of object (volume 2 – volume 1, in mL)	Density (g/mL)

4 Compare the density of the water with the densities of the other objects you measured. Use the results from all the experiments to list the objects from lowest to highest density.

5 Describe how our world would be different if the density of water was five times as much (that is, 5 g/mL). Explain how this would affect your mass, your life and the world in general.

Lesson 6.7

Increasing kinetic energy in matter causes it to expand

Learning intentions and success criteria

Key ideas

→ Heating matter increases the kinetic energy of the particles.

→ The particles in warm materials move faster than the particles in cool materials.

→ Melting point is the temperature at which the particles in a solid behave like a liquid.

→ Boiling point is the temperature at which the particles in a liquid behave like a gas.

Kinetic energy

Kinetic energy is the energy that particles have because they are always moving. In solids, the particles are packed tightly together. They don't move around like in liquids or gases, but they still have kinetic energy because, even though they stay in one spot, they are constantly vibrating. The faster they vibrate, the more kinetic energy they have.

Temperature is a measurement of this kinetic energy. The higher the kinetic energy, the higher the temperature. As the temperature increases (Figure 1), the vibrations become stronger. The particles in solids are held together tightly by strong forces, however, they can't move freely, and the solid keeps its shape and volume. So in solids, most of the kinetic energy is in the form of vibration, not in movement through space like it is in liquids and gases.

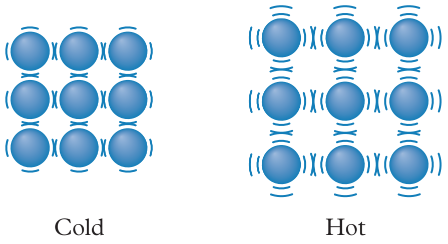


Figure 1 In a hot solid, the particles vibrate harder, faster and wider than in a cold solid.

Diffusion

Diffusion is the process where particles move from an area where there are a lot of particles to an area where there are fewer particles. This happens because the particles are always moving around, spreading out to fill the available space. For example, if you open a perfume bottle, the scent particles spread through the air, and soon you'll be able to smell the perfume even if you're far away from the bottle. Diffusion happens in gases, liquids and even in solids, but it happens faster in liquids and gases because the particles can move more freely.

diffusion the spontaneous spreading out of a substance through a liquid or gas, e.g. the diffusion of perfume in air

Heating particles

Gold is usually a solid at room temperature (20°C). Like all solids, the particles in gold are packed tightly together. When solid gold is given heat energy, the gold particles start vibrating faster and faster. When the gold reaches its melting point (1,064°C), the particles have enough kinetic energy to move around one another, just like the particles in a liquid. The gold has melted.

If you continue heating the gold, the particles continue to gain kinetic energy, move faster and take up more space. Eventually, when the gold reaches its **boiling point** (2,807°C), the gold particles have enough kinetic energy to break free from the other gold particles and move off on their own as a gas.

This process can also happen in reverse. If a gas is cooled down, the particles will move more slowly. The attraction to other particles will now keep the particles close together and the gas will condense into a liquid.

If the particles in a liquid are cooled even further, their movement will slow down even more. Eventually, they are held in place by other particles and do not have enough energy to move on their own – they become particles locked into a solid. The liquid has solidified or frozen.

Remember that the main difference between a hot and a cold substance is the amount of kinetic energy in the particles. The differences in the movement of hot

Figure 2 Melting gold using a furnace requires a temperature of 1,064°C, which is the melting point of gold.

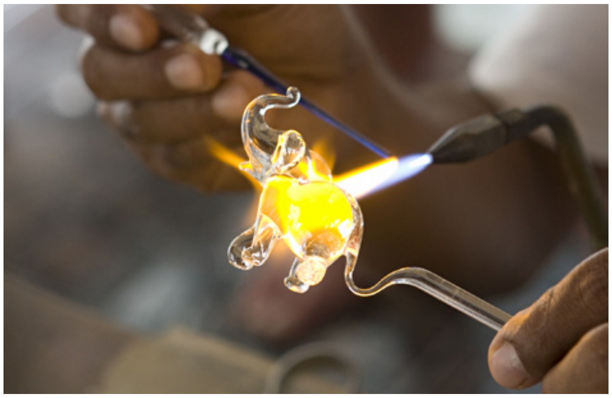


Figure 3 Solidification occurs when a substance cools.

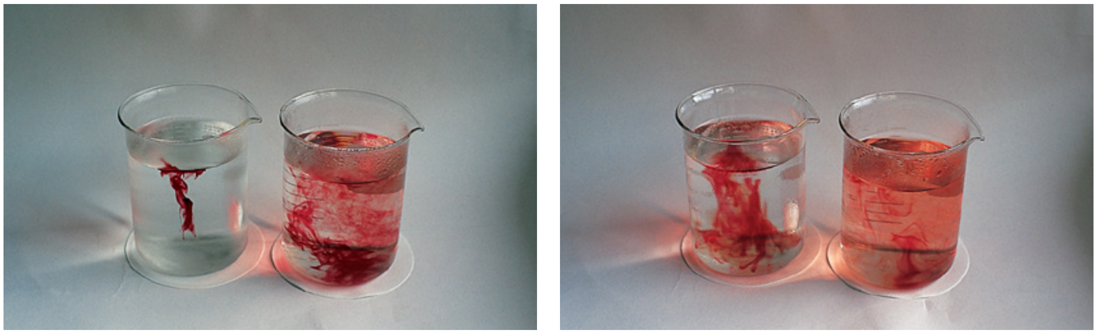


Figure 4 Diffusion occurs faster in hot water (right beaker) than in cold water (left beaker).

and cold particles can be seen in a beaker of water. As the particles move around, they cause diffusion. If the particles move faster, diffusion should occur faster. Diffusion occurs faster in hot water than in cold water (Figure 4).

Heat causes expansion

All objects and substances expand (increase in size or volume) as their temperature increases. These objects contract (shrink) back to their original size when they are cooled back to their original temperature. The expansion is only small, but it is very important for the strength of the object. Expansion effects are seen in large buildings, bridges and railway tracks (Figure 7 and Figure 8). For example, a 30 m bridge only expands roughly 10 mm.

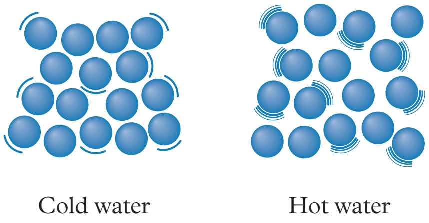


Figure 5 In a hot liquid, the particles jostle around faster and take up more space than in a cold liquid.

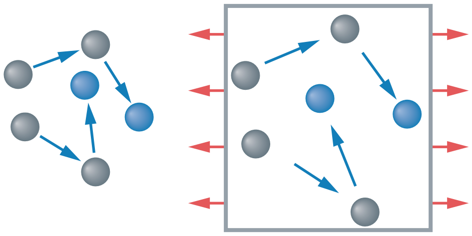


Figure 6 In a hot gas, the particles move faster and collide with one another harder than in a cold gas.

Figure 7 An expansion joint in a suspension bridge

Figure 8 Train tracks would buckle in the heat due to expansion without tiny gaps between them.

Applying heat energy causes the particles in a liquid or gas to gain more energy. The particles jostle more and speed up. As they move around faster, they take up more space and push the other particles further apart.

Expansion and contraction have many important applications, such as liquid-in-glass thermometers. When an alcohol thermometer is placed in your mouth, the heat from your body passes to the liquid inside the thermometer, causing it to expand and move up the tube (Figure 9). Thermometers are filled with red- or green-coloured alcohol, but not the type of alcohol in alcoholic drinks.

Figure 9 The liquid in alcohol thermometers expands when it warms up as we take our temperature.

Check your learning 6.7

Check your learning 6.7

Retrieve

1 Recall what precautions are taken with railway tracks and bridges to make sure that they do not buckle and bend when they expand on a hot day.

2 Define the term "diffusion" and include an example.

Comprehend

3 Explain how the movement of particles changes when a substance gains heat.

4 Explain why objects return to their original size when their temperature returns to normal.

5 When a solid is heated, it expands. Explain why.

Analyse

6 Contrast (the differences between) the terms "expand" and "contract".

7 Draw the diagram shown in Figure 10 in your notebook. Add labels to identify the energy changes between states.

Skills builder: Planning investigations

8 Decide what equipment you would use to measure the temperature of water that is being heated.

- **a** Identify each piece of equipment you would use and how you would use it. (THINK: Imagine the method you would use step by step. What do you need at each step to measure the temperature of water safely?)
- **b** Identify some of the hazards you need to be aware of to conduct the investigation safely. (THINK: What are the dangers of conducting this experiment, and how could you use equipment to prepare for these?)

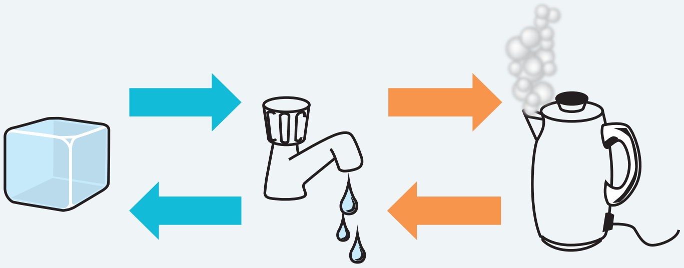


Figure 10 Energy changes between states

Lesson 6.8

Review: Properties of matter and water

Summary

Lesson 6.1 There are three states of matter

- All things are made of matter.
- There are three major states of matter – solid, liquid and gas.
- Many substances can be found in more than one state.

Lesson 6.4 The particle model explains matter

- All particles have kinetic (movement) energy.
- Adding heat increases the kinetic energy of particles.
- Removing heat decreases the kinetic energy.
- The particle model of matter can be used to explain the properties of matter.

Lesson 6.5 The particle model can explain the properties of matter

- Strong bonds between particles can make the material stronger (able to withstand force), harder and more viscous.
- Tightly packed particles make the material dense and less able to be compressed.

Lesson 6.7 Increasing kinetic energy in matter causes it to expand

- Heating matter increases the kinetic energy of the particles.
- The particles in warm materials move faster than the particles in cool materials.
- Melting point is the temperature at which the particles in a solid behave like a liquid.
- Boiling point is the temperature at which the particles in a liquid behave like a gas.

Review questions 6.8

Review questions Module 6

Retrieve

1 Identify what happens to water during condensation.
   A The solid melts into a liquid.
   B The liquid heats to become a gas.
   C The liquid loses heat to become a solid.
   D The gas loses heat to become a liquid.

2 Identify what would happen to the particles in a beaker of water as it is heated.
   A The particles would start moving faster.
   B The particles would start moving slower.
   C The particles would stop moving.
   D The particles would start to disappear.

3 Identify the best description for "density".
   A The ability of a substance to scratch another substance
   B The ability of a substance to be compressed
   C The mass of a certain volume of a substance
   D The thickness of a liquid substance

4 Define the term "volume".

5 Define "kinetic energy" in your own words.

6 Identify the three common states of matter.

7 Recall one word to replace each phrase.
   a The spreading out of a substance such as a dye or smell
   b The ability of one substance to scratch another substance
   c The ratio of the mass divided by the volume

Comprehend

8 Identify which state of matter has particles with the most kinetic energy. Explain your reasoning (by describing the amount of kinetic energy in solids, liquids and gases).

9 Use the particle model to explain the following properties.

- **a** Strength
- **b** Hardness
- **c** Viscosity
- **d** Compressibility
- **e** Density
- **f** Buoyancy
- **g** Surface tension

Figure 1 Glass is a hard but brittle substance.

10 Explain why someone in a room will be able to smell perfume that has been sprayed on the other side of the room.

11 Use the kinetic theory of matter to explain why metal will expand when it is heated.

12 When you are boiling water, the volume of the water is reduced as it evaporates. Use the particle model to explain what has happened.

13 Use the kinetic theory of matter to explain why the pressure inside car tyres will increase on a hot day.

14 Explain how a thermometer determines a difference in temperature.

15 Explain what will happen when the air in a balloon is heated.

16 Explain why train tracks can buckle on very hot days.

Analyse

17 Classify each of the following substances as a solid, liquid or gas.

- **a** Milkshake
- **b** Cheesecake
- **c** Chewing gum
- **d** Sandcastle

18 Contrast physical and chemical properties.

19 Contrast mass and matter.

20 Identify which of the following substances will have particles with the most kinetic energy: ice, milk or the air in a balloon.

21 Identify each of the images in Figure 2 as a solid, liquid or gas.

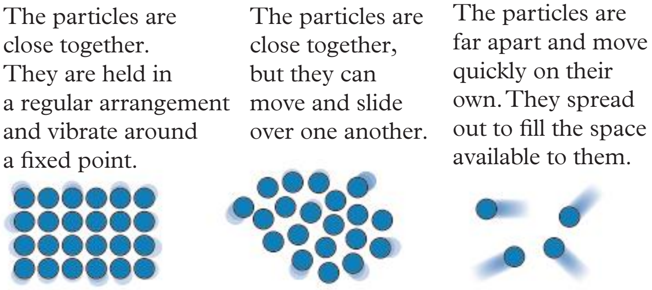


Figure 2 Solid, liquid or gas?

22 Contrast solidification and freezing. Identify an example of each.

23 Compare the processes of melting and boiling. Identify an example of each.

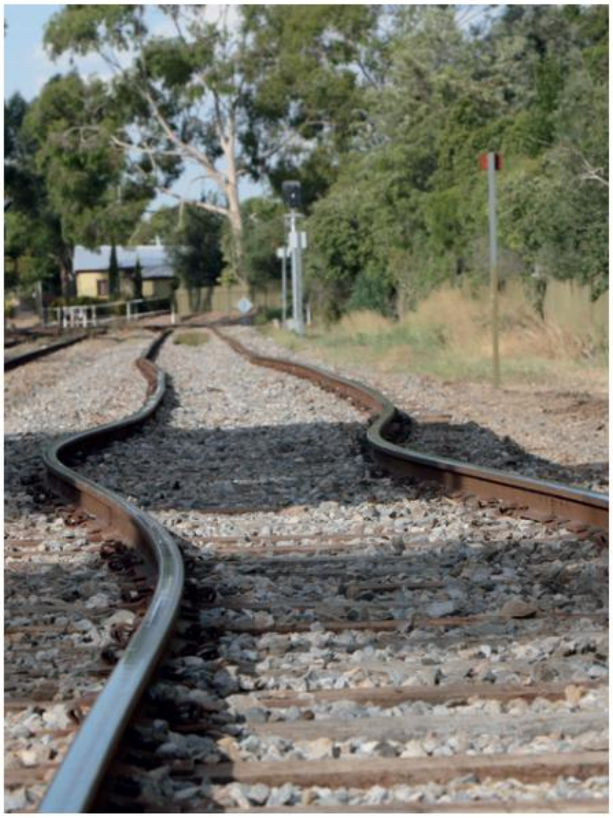


Figure 3 Metal train tracks can buckle on hot days.

Apply

24 Use Table 1 to decide which of the following items would have a greater density.

- **a** 1 L of water or 1 L of oil
- **b** A gold necklace or a glass necklace of the same size
- **c** 10 planks of wood or 10 steel bars (assume they are all equal in size)

Table 1 Density of various substances

Substance	Density (g/cm^3)
Air	0.001
Foam rubber	0.05
Wood	0.3
Oil	0.75
Water	1.0
Glass	2.6
Steel	7.8
Iron	7.8
Copper	8.9
Lead	11.3
Mercury	13.6
Gold	19.3

25 Explain the following observations of solids, liquids and gases by describing the arrangement or the movement of particles within the substance. Create labelled diagrams to help your explanations.

- **a** Water left in an open bottle will gradually evaporate, and if the temperature of the water increases, the water will evaporate more quickly.
- **b** Mercury is a unique substance because it is the only metal that is liquid at room temperature, and it even gives off a vapour (which makes it very dangerous because this vapour can be breathed into our lungs and cause damage).
- **c** Polythene plastic can be produced in two different forms: high-density polythene (HDPE) or low-density polythene (LDPE). If the particles in HDPE and LDPE were the same, suggest how the arrangement of the particles in the two substances would be different.
- **d** When a piece of polythene is heated, it will melt. While it is changing state from a solid to a liquid, it can be formed into a different shape. When it cools, the polythene will stay in this new shape.

26 Create a way to draw or model the following.

- **a** The melting point of a material
- **b** The boiling point of a material
- **c** The density of a material
- **d** The kinetic energy of a particle as it heats up
- **e** Diffusion

Social and ethical thinking

27 Science is communicated in many different ways, including scientific journals and posters, television reports, newspapers and social media, blogs, YouTube and X. Identify which of these forms of communication are most trustworthy. Justify your answer (by describing why the communication you chose is better than the other forms of communication).

Critical and creative thinking

28 The kinetic theory of matter is supported by data from many different experiments, completed by many different scientists across multiple countries. Discuss why a single experiment carried out by a single scientist is not a theory.

Research

29 Choose one of the following topics for a research project. Present your research in a format of your own choosing, giving careful consideration to the information you are presenting.

Hot air balloons

Most of our understanding of how gases move and change is a result of the first hot air balloonists.

- Identify the first person who made a balloon flight not operated by a person or crew.
- Describe how the balloon was made.
- Use your understanding of density to explain why a hot air balloon flies and how the pilots control the descent and landing safely.
- Identify what is meant by the "flight ceiling" and why it is important to stay beneath it when flying.

People matter

The discovery of air pressure is a long and interesting story.

- Research the background of Evangelista Torricelli, Blaise Pascal and Otto von Guericke.
- Describe where they lived, the research that they did, and how they communicated the outcomes of their work.

For example, Otto von Guericke built a large water thermometer in the front of his house and made the Magdeburg Hemispheres (Figure 4). Two opposing teams of eight horses, working like a tug-of-war, could not pull the hemispheres apart.

Figure 4 The Magdeburg Hemispheres are represented by a statue in Magdeburg, Germany.

Gas warfare

Gas was first used in a battle in 1914 by French soldiers, but it was so unsuccessful that it was only noticed in the records after the battle. It wasn't until 31 January 1915 that Germany launched 18,000 gas shells containing xylyl bromide against Russian troops. The cold weather prevented the gas in the shells from diffusing across the battleground. In April the same year, German chemists started testing chlorine gas as a weapon.

- Compare the different gases that were used in warfare and their effects on the soldiers.
- Explain why the use of chemical and biological weapons in war was banned in 1925.
- Compare this ban to the Chemical Weapons Convention signed in 1997 and the Act updated in 2021.

Module

7

Solutions and mixtures

Overview

When we drink pure water, it contains only one type of particle – water. When a substance contains more than one type of particle, it is called a mixture. A mixture may have one substance (the solute) dissolved in another (the solvent), and this is called a solution. When salt is dissolved in water, for example, salt is the solute and water is the solvent.

A variety of different techniques are used to separate mixtures. Filters let through liquids and tiny objects but trap larger particles. Centrifuges separate light and heavy particles by spinning mixtures very quickly. Techniques such as water purification can be life-saving.

Lessons in this module

Lesson 7.1

Mixtures are a combination

Learning intentions and success criteria

Key ideas

→ When different atoms bond chemically, they form compounds with properties distinct from the individual elements, such as water (H_2O).

→ Pure substances consist of identical compounds (e.g. pure water), while mixtures combine different substances without chemical bonds, allowing for easy separation.

→ Mixtures come in various forms – solutions (uniform mixtures), suspensions (cloudy mixtures with settleable particles), colloids (stable dispersions), and emulsions (liquid-in-liquid mixtures often requiring emulsifiers).

Atoms

element a pure substance that only contains one type of atom

substance a solid or liquid that can be mixed

compound a substance made up of two or more types of atoms bonded together (e.g. water)

Atoms are the tiny building blocks that make up everything around us. They are the smallest parts of an **element**, which is a pure **substance**, like oxygen or gold. According to particle theory, an atom has a centre called a nucleus, which contains protons and neutrons, while electrons move around the nucleus (this will be explained further in Lesson 10.1 All matter is made up of atoms, page 434).

Each element has its own type of atom with a specific number of protons. Atoms can exist alone or come together with other atoms to form **compounds**.

Compounds are substances that are formed when two or more different types of atoms bond together in a specific way. According to particle theory, the particles in a compound are different from the individual atoms. For example, water (H_2O) is a compound made of hydrogen (H) and oxygen (O) atoms. When these atoms bond together they create water, which has unique properties like being a liquid at room temperature. Compounds can only be separated into their individual elements through chemical reactions, which means breaking the bonds between the atoms.

Most of the substances we use are compounds. By altering the numbers and types of atoms in a substance, chemists can alter its properties. Many substances that are important to our society are used because of their special properties. These compounds are made in factories or obtained from natural products – for example, pharmaceuticals and fertilisers.

pure substance something that contains only one type of substance (e.g. a single element or a single compound)

Elements and compounds can be **pure substances**. This means all the particles in the substances are identical to each other. Water is an example of this. Pure water contains many molecules of the compound H_2O (water molecules). The flowchart in Figure 1 shows the different types of substances.

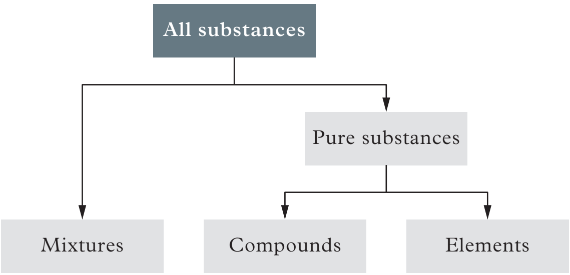


Figure 1 Flowchart showing how pure substances can be further classified into compounds and elements.

Mixtures are made up of two or more substances that are combined but not chemically bonded together. This means that the particles in a mixture still keep their own properties. For example, when sugar ($C_6H_{12}O_6$) is mixed with water (H_2O), there are two different compounds in the mixture. Because the two compounds are not chemically bonded to each other, they can easily be separated. This means mixtures cannot be represented by chemical formulas. Figure 2 shows the difference between compounds and mixtures.

mixture a substance made up of two or more pure substances mixed together

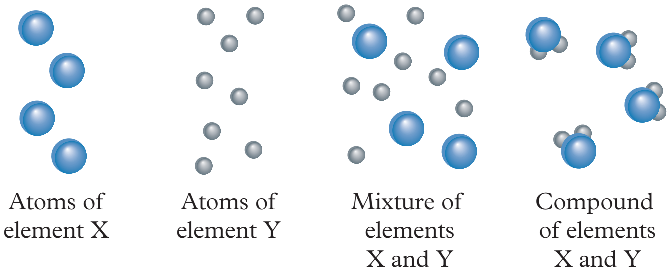


Figure 2 Mixtures are different from compounds

Properties of mixtures

There are many types of mixtures, each with unique characteristics. For this reason, scientists group mixtures according to their properties: what they are made of and how they behave. Knowing the type of mixture and the properties of each particle helps us to work out ways to separate the different particles into pure substances and impure substances (mixtures).

Consider the things around you. Perhaps they are made of wood, glass or plastic. Wood, glass and plastic are all mixtures because they are made up of two or more substances.

Figure 3 Most of the things we use every day are mixtures. What mixtures can you see in this photograph? Can you see any pure substances?

Solutions

When you mix salt into water, it seems to disappear. But we know the salt is still there because we can taste it. The particles of salt become so small that they spread evenly throughout the water. This clear mixture of salt and water will not separate by itself. It is a **solution**. A solution is a mixture of one substance (a solute) dissolved evenly throughout another (a solvent). Solutions are usually transparent (or see-through).

solution a liquid made up of a solvent with a solute dissolved in it

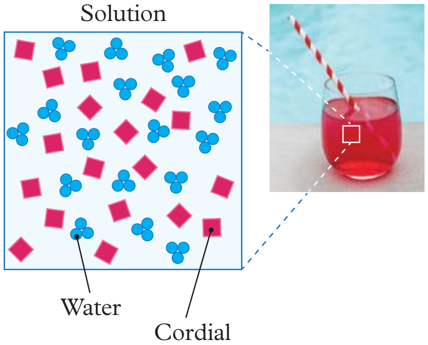


Figure 4 This glass of cordial is an example of a solution. The small cordial particles are dissolved evenly throughout the water. The swimming pool water in the background is also a solution, with chlorine and other chemicals dissolved evenly in the water.

Suspensions

Dirty water is an example of a suspension. A **suspension** is a mixture of two substances in which a solid is dispersed, undissolved, in a liquid. The result is a cloudy liquid. Sand in water is an example of a suspension. If you shake a container of sand and water, the sand will spread through the water, forming a cloudy liquid. The sand will then settle to the bottom of the container as **sediment**. Suspensions will often need to be shaken or stirred before use to spread the solid bits of sediment through the liquid again.

suspension a cloudy liquid that contains insoluble particles

sediment something that settles to the bottom in a mixture

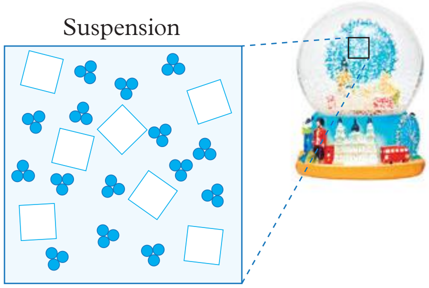


Figure 5 A snow dome can be described as a suspension, with the larger "snow" particles being suspended in the water for a short time before they fall to the bottom of the dome to form a sediment.

Colloids

When two or more substances are mixed, they don't always separate out with time. Suspensions that don't separate easily are referred to as **colloids**. These can be formed by a solid being suspended in a liquid, such as hot chocolate in milk. Occasionally, different particles can get suspended in a gas. Fog is an example of this, where small drops of water are suspended in the air.

The word "colloid" comes from the Greek *kolla*, which means "glue". You can think of a colloid as a substance being "stuck" – suspended in another substance. The benefit of colloids is that there is no need to mix them before using them. Hair gel and hand cream are other examples of colloids.

colloid a type of mixture that always looks cloudy because clumps of insoluble particles remain suspended throughout it – they don't settle as sediment

Figure 6 Milk is a colloid because it contains many substances suspended in what is mainly water.

Emulsions

An **emulsion** is a type of colloid which is formed by two or more liquids. Usually, one liquid is the "base" and the other is broken into tiny droplets and spread throughout the base liquid. Milk is a colloid, which is an example of an emulsion, with tiny droplets of fats and oils spread throughout the base, which is water.

In some cases, when mixtures like this are left to settle, the tiny droplets float above the base liquid. (This differs from what happens in a suspension, where the solid particles tend to fall to the bottom.) A substance called an **emulsifier** can be added to these mixtures to allow the liquids to remain completely mixed.

The most common emulsions we use are mixtures of different types of oils mixed with water and an emulsifier. Examples include food and drinks, and "emulsion" paints for walls and ceilings.

emulsion a colloid made up of two or more liquids

emulsifier a substance that enables two substances that don't normally combine to form an emulsion; for example: oil and water

Check your learning 7.1

Check your learning 7.1

Retrieve

1 Define the terms:
  - **a** pure substance
  - **b** atom
  - **c** element.

Analyse

2 Compare (the similarities and differences between) a pure substance and a mixture.

3 Contrast (the differences between) the types of substances found in seawater and pure water.

4 Classify the following substances as pure substances or a mixture.
  - **a** Cup of tea
  - **b** Soft drink
  - **c** Table salt
  - **d** Soap
  - **e** Olive oil
  - **f** Milkshake

Apply

5 Predict the types of particles you think the mixtures in question **5** might contain.

6 Predict the mixtures in question **5** that would form a sediment.

Skills builder: Processing and analysing information

7 Copy and complete Table 1 to summarise different types of mixtures. (THINK: What information does each column need? Read the headings carefully.

Table 1 Different types of mixtures

Type of mixture	Substances involved	Appearance when light shines through	Separates on standing	Example
Suspension	Solid + liquid	Cloudy	Yes, slowly	Milo® in milk
Emulsion				
Colloid				
Solution				

Lesson 7.2

A solution is a solute dissolved in a solvent

Learning intentions and success criteria

Key ideas

→ A substance is considered soluble if it dissolves completely in a liquid, forming a uniform, clear solution; if not, it is insoluble, leaving visible particles.

→ Water effectively dissolves many substances, playing a crucial role in processes like digestion and supporting aquatic life by transporting dissolved gases.

→ Solutions vary by how much solute is present – ranging from dilute to concentrated – with saturated solutions containing the maximum solute and supersaturated solutions holding extra, unstable amounts.

→ Temperature can enhance solubility, and dissolved substances like metal salts can alter the taste and behaviour of water, demonstrating practical effects of solubility in everyday life.

Solubility and insolubility

In some places in Australia, the water from the local water supply has an unpleasant taste, and washing with soap is difficult because the water forms a scum instead of a foamy lather. In these cases, the water contains metal salts that affect its taste and behaviour. Because they are so small, these metal salts do not fall to the bottom or float on the top of water; instead, they remain evenly spread through the liquid. The resulting mixture (a solution) is clear – light will shine through it. We say that the metal salts have **dissolved** in the water.

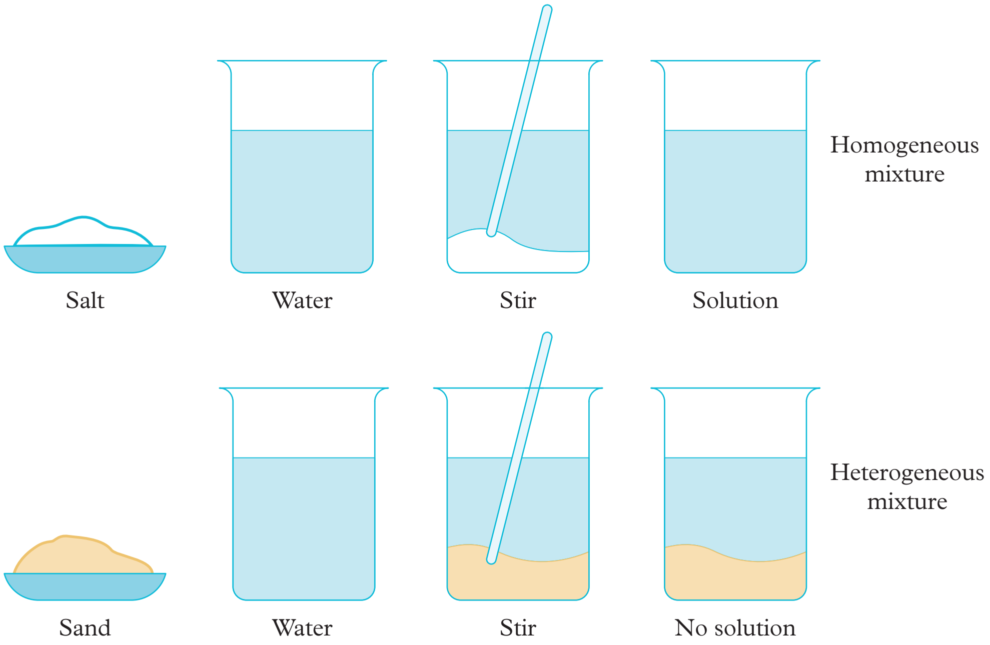


Figure 1 Homogeneous and heterogeneous mixtures

A substance that can dissolve in a liquid is considered to be **soluble**, whereas a solid that cannot dissolve is described as **insoluble**. The substance that is dissolving is called the **solute**, and the liquid into which it dissolves is called the **solvent**. An example of this is salty water. The salt is the solute, and the water is the solvent. Sometimes it is necessary to help a solute such as salt to dissolve. Warming the solvent (water) is the most common way of making a solute dissolve faster.

A **homogeneous** mixture occurs when the solute completely dissolves in the solvent, like salt in water, where the solution looks uniform. A **heterogeneous** mixture occurs when the solute does not dissolve, like sand in water, where you can still see the separate sand particles. The mixture does not look the same throughout (Figure 1).

soluble can be dissolved in a liquid

insoluble cannot be dissolved in a liquid

solute a substance that dissolves in a liquid (solvent)

solvent a liquid in which other substances dissolve

homogeneous refers to when a solute completely dissolves in a solvent

heterogeneous refers to when a solute does not dissolve in a solvent

Water as a solvent

Water is a good solvent. This is one of its most important properties. Our digestive system uses water to dissolve our solid and liquid food, and to break up the food into nutrients that our body needs to build new cells, to grow and to repair.

Our bodies are more than 60 per cent water. Our blood, which is mainly water, transports oxygen to every cell and carries away dissolved carbon dioxide gas (a waste product).

Humans are not the only living things that depend on water as a solvent. Without water's ability to dissolve gases, there would be no underwater life in our oceans and lakes, and no fish in the rivers. These creatures all live by extracting dissolved oxygen gas from the water (Figure 2).

Figure 2 Oxygen dissolved in water is essential for aquatic organisms.

Imagine that you found a colourless and see-through liquid and were really thirsty. Is it water? There are many other colourless and clear liquids, and you do not know what substances might be dissolved in them. Tasting may be dangerous. There are more scientific ways of working out whether a liquid is pure. This is explored further in Lesson 7.6 Investigation: What if the solvent was heated when making a mixture? (page 300).

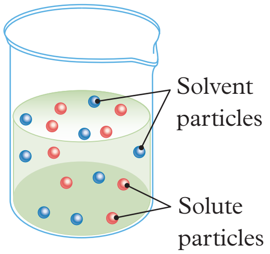


Figure 3 A solute dissolves in a solvent to create a solution.

You have seen that a solution is a solute dissolved in a solvent (Figure 3). Solutions can be compared in terms of their concentration: how much solute is in the solvent. If just a little solute is dissolved, the solution is described as **dilute** (low concentration). If a lot of a solute is dissolved, the solution is described as **concentrated** (high concentration). This is shown in Figure 5. Particle theory can help us visualise the concentration of a solution. As the ratio of solute particles to solvent particles increases, the concentration of the solution also increases.

Figure 4 The concentration of salt in the Dead Sea is so high that, when people try to swim in it, they float instead because their body is less dense than all that salt!

dilute containing a small number of solute particles in the volume of solution

concentrated containing a large number of solute particles in the volume of solution

saturated describes a solution in which the maximum amount of solute is dissolved in a solvent at a certain temperature

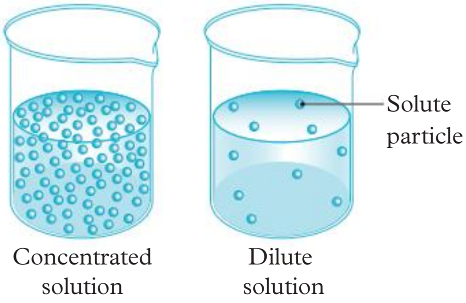


Figure 5 A concentrated solution contains more solute particles in a given volume than a dilute solution.

A **saturated** solution results when no more solute can dissolve in the solvent at a certain temperature. This means it has the maximum amount of solute that the solvent can hold. For example, if you keep adding salt to water and it stops dissolving, the water is now saturated. You will see some salt sitting at the bottom of the container because the water can't take in anymore. If you heat the water, it can dissolve more salt, but when it cools down, some of the salt might come out of the solution.

supersaturated describes a solution that contains more than the maximum amount of solute that can be dissolved in a solvent at a certain temperature

A **supersaturated** solution results when a solution has more dissolved solute than it should normally hold at a certain temperature. This happens when you dissolve a lot of solute in hot water and then let it cool slowly without stirring. Even though it has more solute than usual, it's unstable, meaning it can easily change. If you add a tiny crystal of the solute or disturb the solution, all the extra solutes will quickly come out of the solution and form crystals (Figure 6).

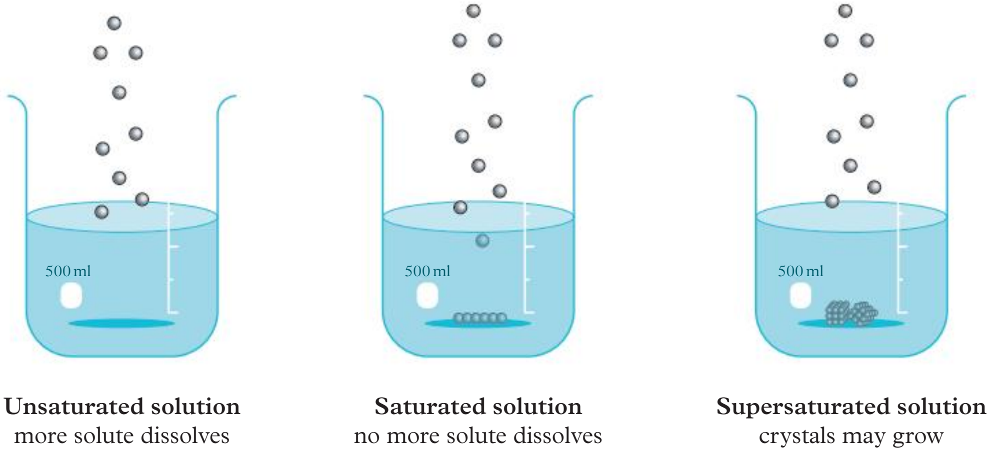


Figure 6 A solute slowly cools in a solution and creates a supersaturated solution.

Check your learning 7.2

Check your learning 7.2

Retrieve

1 Define the following "s" words used in this section: solute, solvent, solution, soluble, saturated and supersaturated.

2 Someone asks for a dilute glass of cordial. Identify if you would add a lot of cordial or only a little.

Comprehend

3 Describe how you could increase the amount of a solute that will dissolve in a solvent.

4 Explain if you can see the particles of a solute in a solution.

5 Explain why water is described as the universal solvent.

6 Explain what happens to sugar particles when they dissolve in water.

Analyse

7 Compare (the similarities and differences between) the solubility of particles in suspensions, colloids, emulsions and solutions.

Skills builder: Questioning and predicting

8 Honey and lemon juice are commonly used in tea and other beverages. When honey is stirred into warm water, it spreads evenly throughout the liquid. Predict what would happen to a teaspoon of honey when the honey particles dissolve in a cup of water. (THINK: What do you know about solutions, solutes and solvents?)

Lesson 7.3

Challenge: Copper sulfate crystals – saturated and supersaturated solutions

Caution

- Copper sulfate is poisonous and stains everything porous.
- Always wear eye protection and gloves.
- Dispose of waste materials appropriately.

What you need:

- Copper sulfate
- 600 mL beaker
- Hot plate
- Stirring rod
- Plastic plate
- Nylon fishing string

What to do:

1 Make a supersaturated solution by heating up some water and adding copper sulfate until no more will dissolve.

2 Let the solution cool, then fill a plastic plate with the solution.

3 Let that solution sit for a day or two to grow **seed crystals** (or you can let it sit for a week or so to grow big, flat crystals).

4 To grow a big rock-like crystal, tie a seed crystal with a nylon fishing string and suspend it in the remaining solution that you have made before.

5 The crystal's growth could take a long time (approximately three days). Make observations each day for five days.

Questions

What did you see? Anything you were not expecting?

Lesson 7.4

Investigation: Comparing different types of mixtures

Caution

Check for egg or dairy allergies (egg and dairy are used in Part B).

Purpose

To observe the characteristics of different mixtures

Part A: Making dirty water

Materials

- Soil
- Water
- Jar with screw-top lid
- Timer

Procedure

1 Put some soil and water in the jar to create a watery mixture.

2 Screw the lid on tightly and then shake the jar. Observe the jar for five minutes.

Discussion

1 Describe the movement of the soil particles using the following prompts:
  - – "When the soil and water was shaken, it …"
  - – "After five minutes …"

2 Identify the types of particles that may float, sink or stay suspended.

3 Use the terms "solution", "suspension" and "sediment" to describe the behaviour of this mixture.

4 Identify the type of mixture that is dirty water.

Part B: Making foam

Materials

- Cream or egg white
- Hand or electric whisk
- Large metal bowl

Procedure

Whip the cream or egg white until it increases significantly in size and holds its shape.

Discussion

Explain why the foam you have created is classified as a colloid by defining what a colloid is and comparing it with the mixture you have produced.

Part C: Mixing olive oil and water

Materials

- Olive oil
- Water
- Jar with screw-top lid
- Detergent

Procedure

1 Fill the jar two-thirds of the way with equal parts of water and oil. Observe what happens and draw a labelled picture to record your observations.

2 Screw the lid on the jar tightly and shake the mixture vigorously. Observe what happens immediately after shaking. Record your observations, e.g. "After mixing the oil and water …"

3 Wait five minutes and record your

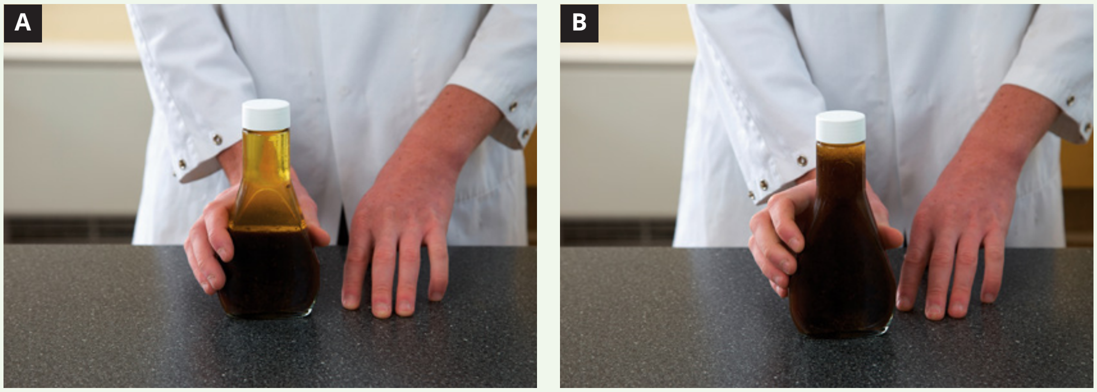


Figure 1 Olive oil and water (A) before and (B) after adding an emulsifier.

observations again, e.g. "After leaving the mixture to sit for five minutes, it …"

4 Add a couple of drops of detergent to the mixture and shake the jar again.
5 Wait five minutes and record your observations again, e.g. "After leaving the mixture to sit for five minutes, it …"

Discussion

1 Describe how the mixture changes when you add the detergent, e.g. "After adding detergent to the oil and water mixture and shaking it, …"
2 Explain what is happening using the terms "colloid", "mixture", "emulsion" and "emulsifier".

Part D: Adding sugar to water

Materials

- Water
- Table sugar
- Teaspoon
- Glass or beaker

Procedure

Add a small amount of sugar to water in a glass and stir.

Discussion

Describe what happens to the sugar, e.g. "When sugar is added to a glass of water, it …"

Figure 2 Do sugar cubes react differently from granulated sugar?

Part E: Making perfume

Materials

- Lavender flowers
- Methylated spirits
- Scissors
- Jar with a lid
- Cotton bud

Procedure

1 Cut the lavender flowers into tiny pieces and place them in the jar.
2 Cover the lavender flowers with methylated spirits.
3 Seal the jar and leave overnight.
4 The following day, dip the cotton bud in the methylated spirits.
5 Allow the methylated spirits to evaporate and then smell the cotton bud.

Figure 3 Lavender is often used in perfume.

Discussion

1 Explain why this mixture is a solution. Identify the solute and the solvent.

2 Predict if this experiment would work if you put the lavender flowers in a jar of water.

3 Explain why it is important that the methylated spirits evaporate easily.

Lesson 7.5

Investigation: Measuring solubility of different solutes in water

Purpose

To measure the solubility of different solutes in water and present the data using tables and graphs

Materials

- Water (at a constant temperature, e.g. room temperature)
- Solutes (e.g. salt, sugar, baking soda, citric acid)
- Four 100 mL beakers (one for each solute)
- Four stirring rods
- Electronic balance
- Thermometer
- 100 mL measuring cylinder
- Filter paper
- Filter funnel
- Conical flask

Figure 1 Dissolving salt in water

Procedure

1 Measure 100 mL of water using a measuring cylinder and pour it into a beaker.

2 Ensure the water temperature remains constant throughout the experiment by monitoring with a thermometer.

3 Weigh a known amount of the first solute (e.g. 5 grams of salt) using the electronic balance.

4 Add the solute to the water and stir until no more of the solute dissolves. This indicates the solution is **saturated**, meaning the maximum amount of solute has dissolved.

5 If the solute does not fully dissolve, add more in small amounts (one to two grams at a time), stirring after each addition, until the solute no longer dissolves.

6 Filter out any undissolved solute using filter paper, if needed, and weigh the remaining solute.

7 Calculate the mass of solute that dissolved by subtracting the mass of the undissolved solute from the total mass initially added.

8 Repeat Steps 1 to 7 for each of the other solutes.

Discussion

1 Identify the independent and dependent variables in this investigation. Present your answer in a table.

2 Identify three variables you will need to control to ensure a reasonable test. Describe how you will control each variable. Present your answer in a table.

3 Read the method and create a table to document your findings for each solute. For each solute, you will need to record the volume of water, mass of solute added, and the mass of solute that dissolved.

4 Plot a graph for each solute, with the *x*-axis representing the solutes and the *y*-axis representing the mass of solute dissolved. You can use a bar graph to compare solubilities, or a line graph if you add data points for increasing amounts of solute tested (to show trends).

5 Identify the solute that dissolved the most in water. Explain why you chose this one.

6 Describe any differences you observed in how quickly the solutes dissolved. Identify some of the factors you think might affect the rate of dissolution.

7 Discuss how the temperature of the water affected the solubility of the solutes. Predict what might happen if you conducted the experiment at a different temperature.

8 Describe any patterns you observed when comparing the solubility of different solutes. Discuss whether you can make any generalisations about solubility based on your results.

Conclusion

Define the terms “solution” and “dissolve” by using examples from your investigation.

Lesson 7.6

Investigation: What if the solvent was heated when making a mixture?

Purpose

To investigate ways to alter the rate (speed) at which a solute dissolves and/or the amount of solute that will dissolve

Materials

- Milo®
- Milk
- Teaspoon
- Small beaker
- 50 mL measuring cylinder
- Thermometer
- Hot plate to heat milk

Procedure

1 Measure out 50 mL of room-temperature milk (use a thermometer to make sure the milk is between 18°C and 22°C) and add it to the small beaker.

2 Carefully measure 1 teaspoon of Milo by smoothing the surface until it is even with the edges of the spoon.

3 Add the spoonful of Milo to the milk and stir until it dissolves.

4 Repeat Steps 2 and 3 until the Milo no longer dissolves.

5 Identify how many spoonfuls of Milo dissolved in the milk.

6 Repeat Steps 1 to 5, however, heat the milk using a hot plate to approximately 70°C to 80°C.

Figure 1 Milo must be used in this experiment because of the way it dissolves. What might happen if you used a different chocolate mix?

Inquiry: What if the milk was heated?

1 Identify the **independent** variable that you will change from the first method.

2 Identify the **dependent** variable that you will measure to determine if it was changed by the independent variable.

3 Identify three variables you will need to control to ensure a reasonable test. Describe how you will control each variable.

4 Predict how many spoonfuls of Milo will dissolve in warm milk.

5 Prepare a table to record your results.

Results

Record your results, e.g. “The number of level teaspoons of Milo dissolved in 50 mL of room temperature milk was …”

Discussion

1. Describe how the amount of Milo that dissolved changed when the milk was heated.
2. Identify a variable that was difficult to control. Describe how you would change your method to make your results more accurate in the future.
3. Describe a situation in everyday life that would benefit from understanding the results of your investigation.
4. Describe how heating a solvent affects the amount of solute that can be dissolved.

Lesson 7.7

Mixtures can be separated according to their properties

Key ideas

→ Mixtures can often be separated by simple physical means, either by manually picking out visible components or by exploiting differences in density.

→ Magnetic separation extracts magnetic materials (e.g. iron-containing items), while decanting, sedimentation and flotation rely on density differences to separate mixtures.

→ The use of flocculants helps clump together suspended particles, making sedimentation more effective in complex mixtures.

→ Aboriginal and Torres Strait Islander Peoples used techniques like winnowing and yandying, which are natural separation methods, and techniques like distillation, which uses boiling-point differences to isolate components such as medicinal oils.

Learning intentions and success criteria

Simple separation

Some mixtures are quite simple to separate. Sometimes we can simply pick out the bits we need to separate. A bag of mixed lollies may contain a few of your favourites. You could easily use your fingers to pick these lollies out so that you could eat them first. This works well if it is a small bag and you can see the individual lollies. But what if the bag contained hundreds of lollies that were too small to see? You may need another way of separating out your favourites.

Figure 1 Different separations need different techniques.

Magnetic separation

Do you separate recyclables from your rubbish? Have you ever wondered how the different recyclable materials are separated once they're out of your house?

magnetic able to be magnetised or attracted by a magnet

Magnetic separation uses magnets to attract and separate particular metals. Some objects are magnetic. Magnetic substances are attracted to a magnet. They are made of iron, or a mixture containing iron.

Because magnetism will only separate substances containing iron, these magnetic materials can be separated from other non-magnetic materials, such as glass, aluminium and paper.

Tin cans are magnetic, whereas aluminium cans are not. Sometimes large magnets are used to separate tin cans in the rubbish from aluminium cans. This means both types of cans can be recycled in different ways.

Figure 2 Magnets are used to separate metals in recycling plants.

Decanting, sedimentation and flotation

decanting a separation technique used to separate a sediment from the liquid it is in by carefully pouring the liquid away

sedimentation a process that uses gravity to remove suspended solids from a solution

Have you ever had a piece of food in the bottom of your drink? Did you use a spoon to remove it? Or maybe you carefully poured your drink into another glass, leaving the food behind? The careful pouring of liquid, or **decanting**, is often done to remove high density sediment from wine.

The objects or liquids that sink are denser than the liquid on the top. The particles in dense objects are packed together more tightly than the particles in less-dense objects. Oil **floats** on top of water because the particles in the oil are packed very loosely. The water particles pack together more tightly, so they sink to the bottom, below the oil.

The particles in a grain of sand are packed together very tightly. Sand is denser than water, therefore, if sand is poured into a glass of water, the sand settles to the bottom. The sand forms a **sediment** in the glass.

Sedimentation and flotation are used in sewage treatment to separate the mixture of substances. Sewage is left in settling ponds to allow the sediment to settle to the bottom (Figure 3). Fats and oils that float to the top of the ponds can be scooped off for digestion by bacteria.

Figure 3 Sewage treatment involves sedimentation and flotation.

Oil floats on the surface of water, and this information can be used to clean up oil spills (Figure 4). Cork and other substances can be sprinkled on top of the oil to soak it up, and these substances are then scooped off and squeezed out.

In certain situations, sedimentation is more difficult. Chemicals called **flocculants** can be added to a mixture to make suspended particles clump together. This makes them heavy enough to settle to the bottom. Flocculation is regularly used to separate substances from water.

Figure 4 When oil spills occur, the oil floats on the surface of the water.

Aboriginal and Torres Strait Islander Peoples used separation techniques

Some mixtures can be separated by their ability to be blown or float away. The Alyawarre people of the Sandover River in the Northern Territory separate mixtures using these properties. In one technique, called **winnowing**, a variety of local seeds are collected before being beaten with sticks to remove the seeds from their pods. Blowing air gently under the mixture blows away the light pods, leaving the heavier seeds to be used for food.

The Yindjibarndi people in Western Australia (who occupy the Pilbara region) separate sand and dirt from seeds in a process called **yandying**. This technique involves placing the mixture in a shallow wooden dish, called a **yandy** or a **coolamon** in other places in Australia, which is gently shaken back and forth. The dense sand sinks to the bottom and the less dense dirt and larger seeds float on the surface, allowing them to be collected for food or growing. This process is very similar to gold panning.

flocculant a chemical added to a mixture to make suspended particles clump together

Distillation

Distillation was a process used by many Aboriginal and Torres Strait Islander Peoples to separate the medicinal oils from eucalyptus plants (Figure 5). When the leaves are placed over a fire, the heat causes the leaves to break apart and the water and eucalyptus oil is released into the air. If someone is sick, they could lean over the steam to breathe in the oil. This could ease their breathing. You will learn more about distillation in Lesson 7.14 Solubility can be used to separate mixtures (page 314).

Figure 5 Eucalyptus oil was distilled from eucalyptus leaves by Aboriginal and Torres Strait Islander Peoples to use as a medicine.

Check your learning 7.7

Check your learning 7.7

Retrieve

1 Define the following terms.
  a Sediment
  b Flocculation
  c Decant
  d Density

Comprehend

2 Describe the property that allows the separation of tin cans from aluminium cans.

3 Explain why flotation allows oil spills to be cleaned up more easily.

4 Use an example to describe what can be done to encourage sedimentation if a suspension does not separate.

5 Use an example to describe a situation where people need to separate a mixture by hand.

Apply

6 Discuss a situation where magnetism cannot be used to separate a mixture. Evaluate how the properties of the materials cause this problem.

Skills builder: Planning investigations

7 You've been asked to separate a mixture of sand, iron filings and chocolate chips. Identify a list of equipment you will need to perform this task. (THINK: What separation processes will you need to perform? What equipment does each of these processes need? What about safety equipment?)

Lesson 7.8

Investigation: What if a flocculant was added to muddy water?

Caution

Handle the aluminium sulfate solution with care, wear eye protection and avoid contact with skin.

Purpose

To investigate the effect of a flocculant (a substance that encourages the clumping of particles together) when separating a mixture

Materials

- Muddy water (3 g dirt in 50 mL water)
- Two jars or beakers
- 0.5 M sodium carbonate solution
- 0.5 M aluminium sulfate solution
- Test tubes
- Marker pen
- Timer

Procedure

1 Half-fill each jar with muddy water and label one jar "A" and the other jar "B".
2 Add half a test tube of aluminium sulfate solution to jar A.
3 Slowly add half a test tube of sodium carbonate solution to jar B.
4 Leave both jars A and B undisturbed for approximately 15 minutes.
5 Record your observations, comparing the water in jar A with that in jar B, e.g.
  - "After 15 minutes, the muddy water and aluminium sulfate in jar A was …"
  - "After 15 minutes, the muddy water and sodium carbonate in jar B was …"

Figure 1 Adding a flocculant to muddy water

Inquiry: How much flocculant is needed to effectively separate a mixture of mud and water?

1 Identify which flocculant you will test.
2 Identify the amounts of the flocculant that you will add to the muddy water mixture.
3 Describe how you will measure if the muddy water is separated enough. (HINT: How much light should shine through the mixture?)
4 Name three variables you will keep the same as those in the first method.
5 Write down the method you will use to complete your investigation. (HINT: Use the method above as a guide.)
6 Prepare a table to record your results.
7 Show your teacher your planning, to obtain approval before starting your experiment.

Results

Complete your investigation, filling in your table of results.

Discussion

1 Describe the effect the aluminium sulfate solution had on the muddy water.
2 Describe the effect the sodium carbonate solution had on the muddy water.
3 Identify which of the two substances – aluminium sulfate or sodium carbonate – acted as a flocculant. Justify your answer by providing data from your results.
4 Explain why it might be important for water treatment plants to minimise the amount of flocculant added to wastewater.

Conclusion

Describe the effect a flocculant has on some mixtures.

Lesson 7.9

Mixtures can be separated according to their size and mass

Learning intentions and success criteria

Key ideas

- → Filtering and sieving use barriers with holes to separate mixtures, based on particle size.
- → Filters allow liquids or fine particles to pass through while retaining larger solids (e.g. colanders, coffee filters), whereas sieves separate solids by size.
- → Separation methods are used in everyday tasks like cooking and recycling, as well as in specialised equipment such as HEPA filters for air quality.
- → Centrifuging separates particles by weight through rapid spinning, effectively isolating heavier components in medical and industrial processes.

Filtering and sieving

Anyone who has cooked pasta will probably have used a colander or sieve to separate the boiling water from the cooked pasta. The holes in the colander or sieve are designed to let the water through, but not the pasta.

A filter has a series of holes in it that let through small things but trap the larger particles. A grate on a storm water drain is an example of a filter. The grate lets the water through while filtering out the leaf matter and rubbish. Fly screens on windows and doors filter insects and some dust from the air, and tea bags filter the tea leaves from the liquid (Figure 1).

Figure 1 Tea bags are a common household filter.

Sieving is a technique that separates substances according to the size of their particles. When you use a sieve, anything that is smaller than the hole can pass through, which can be a solid or liquid; the larger solids are left behind in the sieve.

Sieves can separate solids of different sizes (Figure 2). **Filtering**, on the other hand, separates solids from liquids (or solutions), as the particles of the solution or liquid are smaller than the size of the holes in the filter. The **filtrate** passes through the filter and the **residue** is left behind in the filter.

sieving a separation technique used to separate different-sized particles depending on the size of the holes in the sieve used

filtering a separation technique used to separate solids from liquids or solutions, depending on the size of the holes in the filter used

filtrate the substance that passes through a filter

residue the substance left behind in a sieve or filter

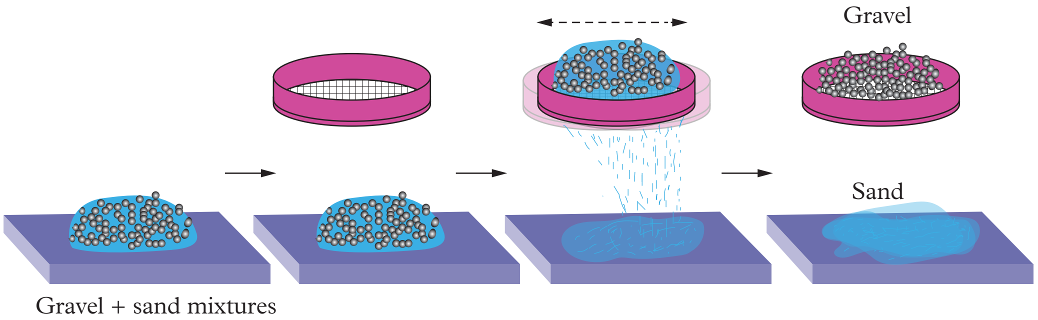


Figure 2 Sieves can be used to separate solids of different sizes, such as gravel and sand.

filter paper a paper sieve with tiny holes that are too small to see; solutions can flow through, but most solid particles cannot

Filter paper is like a paper sieve with holes that are too small to see. Solutions can flow through the filter paper because the particles in the solution are small enough to fit through the holes; however, most solid particles in suspensions are not able to fit through. Different filter papers come with different-sized holes. Coffee filters and the filters found in vacuum cleaner bags are both made of paper filters. HEPA (high-efficiency particulate air) filters are used in vacuum cleaners, air conditioners and face masks to remove even tiny dust particles.

Sometimes filters remove substances using chemicals rather than by physically stopping them. Gas masks often contain a special type of charcoal that attracts and holds onto some poisonous gases (Figure 4).

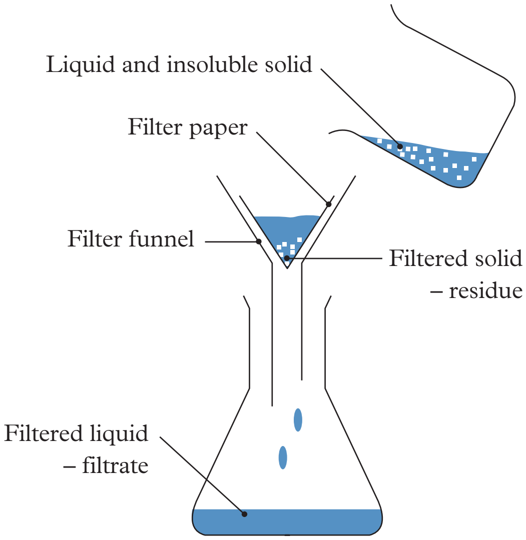


Figure 3 Filters are used in science to separate substances. Particles that pass through the filter are called the filtrate. The filter paper traps the residue.

Figure 4 A gas mask uses activated charcoal to filter poisonous gases.

Centrifuging

Sometimes mixtures do not separate well using sedimentation because the particles are not dense enough. Sometimes things need to be separated using their weight.

Some playgrounds have play equipment that spins around very fast. When you spin on this equipment, you can feel a force pulling you towards the outside of the spin. Heavy objects feel the pull more than light objects.

Centrifuging separates light and heavy particles by spinning a mixture. A centrifuge is a machine that spins very quickly. In a laboratory, small test tubes of mixtures are fixed to the inside of the bowl of the centrifuge. The spinning motion causes the heavier particles to move to the bottom of the test tubes.

centrifuging a separation technique used to separate light particles from heavy particles by rapidly spinning the mixture in a container (called a centrifuge)

Figure 5 A spinning washing machine is a centrifuge, separating water from the clothes.

Centrifuges are used in medical research and at blood banks. When blood is spun in a centrifuge, the red blood cells, which are heavier, sink to the bottom of the test tube, leaving the yellowish liquid part of blood (plasma and platelets) at the top. Medical professionals use different parts of blood, depending on the particular medical need.

Centrifuges are used in dairy processing factories to separate cream from milk. Salad spinners and washing machines also use this principle (Figure 5).

Check your learning 7.9

Check your learning 7.9

Retrieve

1 Recall the missing words and use them to copy and complete the sentences below.
Filtering is like using a ______________.
The ______________ lumps are caught in the sieve, and the ______________ goes through the ______________ paper. The substance caught in the ______________ paper is called the ______________.
The substance that passes through is called the ______________.

2 Name two places where centrifuges are used.

Analyse

3 Identify the filters used around your home and school. Identify the substances that can pass through the filters and the substances they collect.

4 Contrast (the differences between) each of the following pairs.
   - **a** Mixture – pure substance
   - **b** Sedimentation – flotation
   - **c** Residue – filtrate

Apply

5 Discuss why a forensic scientist who is investigating a crime would want to compare a mixture of different types of sand found in a suspect's car with a similar mixture found at the crime scene.

6 In traditional times, the Gunditjmara people of south-west Victoria used honeysuckle cones from banksia trees as filtration straws. The honeysuckle-cone straws allowed them to separate clean water from muddy pools. Justify why this is an example of a filter. (HINT: Compare how a filter works with how the honeysuckle cones work.)

Skills builder: Problem solving

7 A doctor needs to extract plasma and platelets from a patient's blood. She is given two options to perform this task: a centrifuge and a filter.
   - **a** Identify which of these separation techniques the doctor should use. (THINK: What is the best way to separate two liquids that have different densities?)
   - **b** Justify your choice. (THINK: Why did you choose this option? Why not the other?)

Lesson 7.10

Investigation: What if you centrifuge tomato sauce?

Caution

Do not eat or drink in the laboratory.

Purpose

To separate the components of tomato sauce by centrifuging

Materials

- Centrifuge
- Test tubes to fit centrifuge
- Different brands of tomato sauce
- Ruler

Procedure

1. Label your test tube with your name and partially fill it with tomato sauce.
2. Pass your test tube to the teacher and observe how the centrifuge is set up so that each side of the centrifuge is balanced.
3. Examine your test tube when the centrifuge completes the separation.
4. Use a ruler to measure the amount of each separated component of tomato sauce.
5. Draw your test tube after centrifuging. Identify and label the layers of the tomato sauce (i.e. water, tomatoes).

Inquiry: What if different brands of tomato sauce were centrifuged?

1. Identify which tomato sauce you will test.
2. Identify the **independent** variable you will change in this experiment.
3. Identify what effect you expect to see on the **dependent** variable that you will measure and/or observe.
4. Identify two variables that you will need to control to ensure a reasonable test. Describe how you will control them.
5. Write down the method you will use to complete your investigation. (HINT: Use the method above as a guide.)
6. Draw a table to record your results.
7. Show your teacher your planning to obtain approval before starting your experiment.

Results

1. Draw and label the various layers of the tomato sauce you selected.
2. Draw a column graph showing the type of tomato sauce and the amount of each component.

Discussion

1. Describe the differences you noticed between the different brands of tomato sauce after they had been centrifuged.
2. Explain why the different types of tomato sauce might vary in their components.

Conclusion

Describe how centrifuging can be used to separate the components in a mixture.

Lesson 7.11

The boiling points of liquids can be used to separate mixtures

Learning intentions and success criteria

Key ideas

- → Heating a liquid causes it to evaporate into a gas at a specific boiling point, which varies for different substances.
- → Mixtures can be separated by exploiting differences in boiling points, for example, water evaporates before turpentine, leaving the latter behind.
- → When the solvent in a solution evaporates, the solute is left behind and forms crystals, such as salt crystals which are formed after salt water evaporates.
- → Distillation captures evaporated vapours and cools them into liquid form, allowing the collection of substances with lower boiling points. This process is used in refining crude oil.

Evaporation and crystallisation

When water in a saucepan is heated, it will quickly start to boil. This means the water evaporates; it becomes a gas. Every substance evaporates at a different temperature. Table 1 shows the boiling points of some common liquids.

Table 1 Boiling points of common liquids

Liquid	Boiling point (°C)
Water	100
Alcohol	78
Petrol	95
Olive oil	300
Tar	300
Turpentine	160

The different boiling points of liquids are used to separate them in a mixture. A mixture of water and turpentine can be easily separated because the water will **evaporate** first. This means the water will become a gas (steam) and move away from the turpentine. Eventually, only turpentine will be left behind.

evaporate to change in state from liquid to gas; also a separation technique used to separate dissolved solids from water

Figure 1 Water will evaporate when it reaches boiling point.

Evaporation can also be used to separate the parts of a solution. Salt evaporates at 1,414°C. When a mixture of salt and water is heated, the water evaporates first, leaving behind salt crystals (Figure 2). This process of evaporating the solvent (the water) and leaving behind the solute (salt) is called **crystallisation**.

Figure 2 Water will evaporate from a mixture of salt and water, leaving behind salt crystals.

crystallisation a separation technique used in conjunction with evaporation to remove a dissolved solid from a liquid; after the liquid has been evaporated the solid remains, often in the form of small crystals

distillation a separation technique that uses evaporation and condensation to separate a solid contaminant and the solvent in which it has dissolved (e.g. to get pure water from salt water)

condensation the change of state from a gas to a liquid; occurs when a gas cools down

Distillation

What if we want to keep the substance that has the **lowest** boiling point? Collecting drinkable water from seawater is difficult if all the water evaporates into the air. **Distillation** is a way of collecting the gas that evaporates from a mixture and cooling it down so that it becomes a liquid again (Figure 3). This cooling down of a gas into a liquid is called **condensation**.

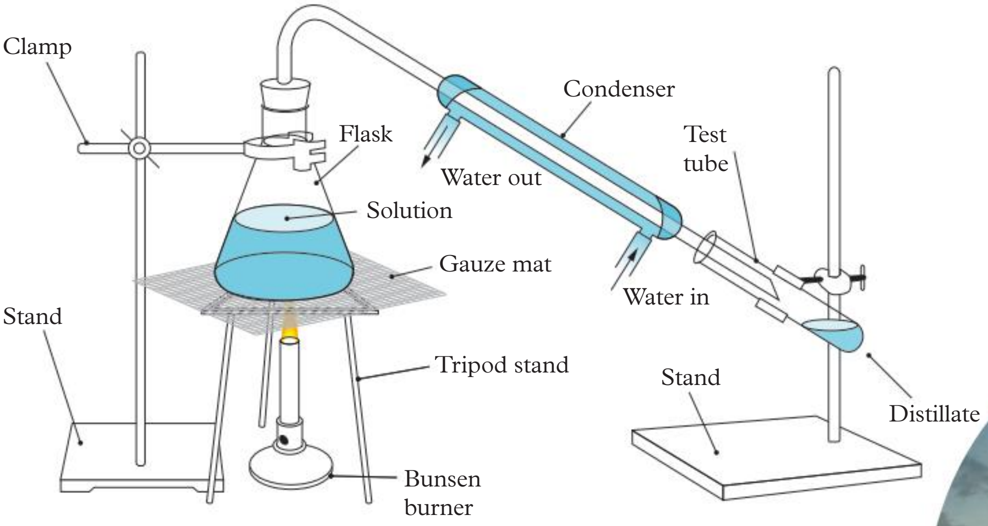


Figure 3 Equipment set-up for distillation

The crude oil that is removed from the earth is a mixture of different liquids that all have different boiling points. When the crude oil is heated, petrol is one of the first liquids to evaporate. The petrol gas rises up the column until it cools and condenses. The liquid petrol is then collected on one of the trays in the column. The oil used in heating has a higher boiling point. It evaporates more slowly and condenses more quickly. It is collected on a tray lower in the column (Figure 4).

Figure 4 Crude oil is separated into different fuels at an oil refinery. This is possible because each fuel boils at a different temperature.

Check your learning 7.11

Check your learning 7.11

Retrieve

1 Recall the difference between evaporation and crystallisation.

Figure 5 Conducting a separation technique

Comprehend

2 Identify an example of a mixture that could be separated by evaporation and crystallisation. Explain why distillation may not be appropriate.

3 Ethanol is an alcohol that boils at 78°C while water boils at 100°C. In a mixture of ethanol and water, explain which liquid would be the first collected through distillation. (HINT: The word “explain” means you need to provide a reason why.)

4 Identify the separation technique that is being conducted in Figure 5.

Apply

5 Create a scientific diagram of the equipment set-up that could be used to produce pure water from seawater by distillation.

6 Propose how you would answer question **5** without using the science equipment found in a laboratory.

Lesson 7.12

Investigation: Crystallisation of salt water

Caution

- Always wear safety glasses, a lab coat and closed-toe shoes, and tie long hair back, when using a Bunsen burner.
- Allow all hot equipment to cool before handling.

Purpose

To separate salt from a solution by evaporation and crystallisation

Materials

- Evaporating dish
- Tripod
- Clay triangle
- Bunsen burner
- Heatproof mat
- Salt solution
- 250 mL beaker
- Magnifying glass
- Matches

Procedure

1 Collect a sample of the salt solution in the beaker.
2 Half-fill an evaporating dish with the salt solution.
3 Place the evaporating dish on the clay triangle over the tripod.
4 Heat the evaporating dish, with the Bunsen burner flame at full strength.
5 When the solution starts boiling, half-close the Bunsen burner collar. (Don't change to a yellow flame – this is not the same.)
6 Add more solution to the dish as the level drops due to evaporation. Be careful as the evaporation nears completion because the hot salt may spit and splatter.
7 Turn off the Bunsen burner when just a little liquid remains with the salt. Leave the dish to cool.
8 Examine the salt crystals with a magnifying glass.

Results

Draw a diagram of the salt crystals in your notebook.

Discussion

After the water has evaporated from the solution, salt remains in the evaporating dish.

1 Explain whether the separation technique used in this investigation would be suitable if the solution contained a mixture of more than one solute.
2 Identify what is wasted in this experiment and whether there is any way this could be avoided.

Conclusion

Explain how evaporation and crystallisation can be used to separate a mixture of salt and water.

Lesson 7.13

Challenge: Design a way to purify water from seawater

Design brief

You are preparing for a natural disaster that will affect the water supply. Using materials available from a supermarket, design equipment that will enable you to provide drinking water for a single person from seawater indefinitely.

Criteria restrictions

- Your materials must be available in a supermarket or your home.
- You must provide the cost of building your equipment.
- Your only available heat source is the Sun.

Planning and conducting

- How will you heat the water so that it evaporates?
- How will you collect the water vapour?
- How will you cool the water vapour so that it condenses?
- Draw a labelled diagram of your design.
- Build a prototype of your design.
- Check the effectiveness of your design with a test and improve it as required.

Processing, analysing and evaluating

1. Describe the changes you made to improve your design.
2. Identify the most successful feature of your design. Identify the least successful feature of your design.
3. Calculate the final cost of your design.
4. Describe a situation where your design could be useful.
5. Describe how you would modify your design to improve its effectiveness.

Communicating

Present the various stages of your investigation in a formal experimental report.

Figure 1 Natural disasters can affect water supply.

Lesson 7.14

Solubility can be used to separate mixtures

Learning intentions and success criteria

Key ideas

→ Solubility defines how easily a substance dissolves in a solvent, enabling separation of mixtures, for example, dye mixtures, based on their different solubilities.

→ In paper chromatography, a solvent moves up absorbent paper, carrying more-soluble dyes further than less-soluble ones.

→ Advanced chromatography techniques allow scientists to separate and detect minute quantities of substances in complex mixtures.

→ Chromatography is employed in diverse fields – from producing historical inks to modern applications like detecting banned substances used by athletes and screening for drugs at airports.

Solubility

Solubility describes how easily a substance dissolves in a solvent. Some dyes have a higher solubility than others. This is used to separate different dyes. Many dyes are small particles that are suspended in a solvent. They are usually made from plants or minerals. Around 2000 BCE, the ancient Egyptians and Chinese both made a dye mixture of soot and vegetable gum that could be used for writing. The ancient Chinese also made red ink from mercury sulfate and black ink from iron sulfur by mixing it with sumac tree sap. Today, many of the inks in textas are made of a mixture of these dyes. We can separate these dye mixtures because the dyes have different solubilities.

solubility how easily a substance dissolves in a solvent

Chromatography

Paper **chromatography** is a common way to separate a mixture. Chromatography works when the end of the absorbent paper is dipped in water, allowing the water to slowly move up the paper. As the water moves past the dye mixture, the most soluble dye dissolves and starts to move with the water. The other dyes in the mixture take longer to dissolve. Eventually, the next dye forms a solution and starts moving towards the top of the paper. Finally, the paper has a series of smudged dyes running up to the top (Figure 1). The coloured dye that is the most soluble is at the top, whereas the dye that is least soluble is at the bottom.

chromatography a separation technique used to separate substances according to differing adsorption to a surface (e.g. coloured dyes that make up pen ink)

More complex and sensitive chromatography instruments are used to separate mixtures such as drinks and polluted air. Science laboratories often contain instruments that are used to detect even one gram of a substance present in thousands of litres of solution. Scientists use chromatography to find out what substances are in a mixture. Different substances will move through the chromatography equipment at

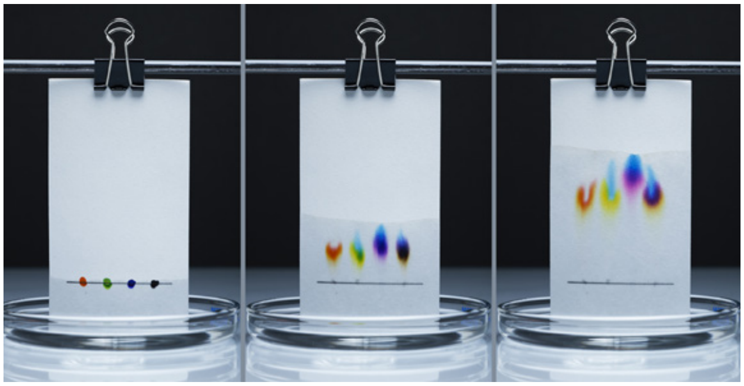


Figure 1 Chromatography is used to separate samples, such as inks and dyes.

Figure 2 Performing gas chromatography

Figure 3 Airport security uses chromatography to test for illegal drugs.

different times and produce a graph (called a chromatogram) like the one shown in Figure 4. The area under each peak tells the scientist how much of a particular substance there is. The higher the area under a peak, the more a substance is present.

One use of chromatography today is to identify athletes who use banned substances when they compete. This is done by testing their urine. A chromatography machine separates all the substances in the urine, including any illegal drugs.

Airport security also tests for illegal drugs using chromatography. A piece of chromatography paper is wiped over a person or their bag and then inserted into a machine (Figure 3). A gas is pushed through the paper. If the drug is soluble in the gas, it will dissolve and be detected by the sensors. An alarm sounds and the security guard will take the person away for questioning.

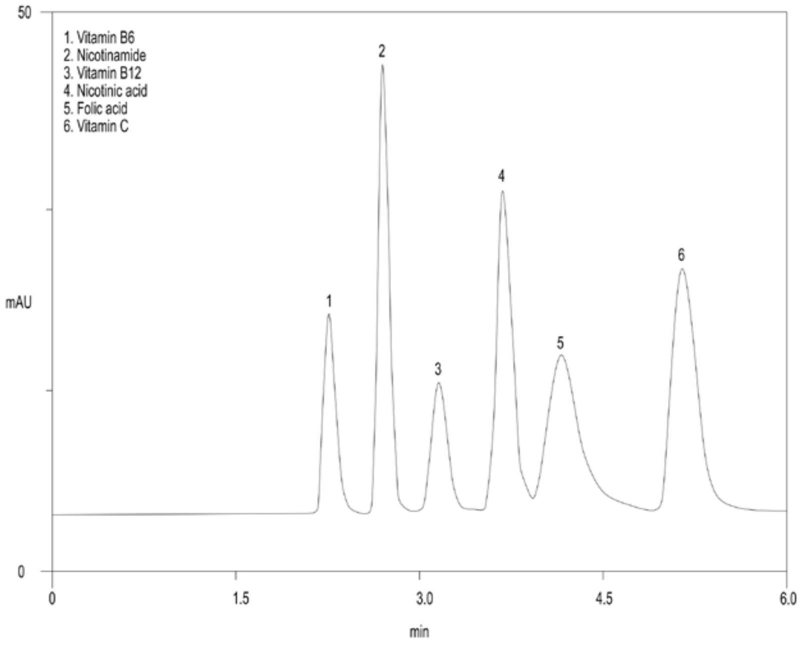


Figure 4 Chromatogram of some common vitamins

Check your learning 7.14

Check your learning 7.14

Retrieve

1. Name the substances that were used to make the first inks.
2. Recall the solvent that is used in the chromatography for drugs at airports.
3. Define the term "solubility".

Comprehend

4. Explain how chromatography can be used to separate inks and dyes.
5. Describe an example of chromatography being used in real life to separate a substance.

Apply

6. Some people think they can disguise drugs at airports by putting them in a strong-smelling substance, such as coffee beans. Discuss why this will not work with airport security that uses chromatography.

Skills builder: Planning investigations

7. Using scientific language, write a logical procedure for separating the ink in Textas (or felt-tip pens) using paper chromatography. (THINK: What order do you need to perform each step? Use the information to recall how chromatography works.) Remember that when you write a method, you should start each step with a verb and avoid using words like "I", "we" and "you".

Lesson 7.15

Investigation: Who wrote the nasty note?

Introduction

Your forensic laboratory is investigating a crime of extortion: one person is forcing or frightening another into handing over money.

The police have identified that the extortion note was written with a black felt-tip pen. They have collected a black felt-tip pen from the three suspects: Suspect A, Suspect B and Suspect C.

Other forensic scientists in your laboratory have already run a chromatography test on the note written by the extortionist. After you have tested the three pens from the suspects, collect the chromatogram for the original note from your teacher for comparison.

Purpose

To separate the inks from three different water-soluble black felt-tip pens

Figure 1 The suspects

Materials

- Three black water-soluble felt-tip pens – they must all be different brands and labelled “A”, “B” and “C” (Note: Permanent markers are not suitable for this experiment because they are not water-soluble.)
- 250 mL beaker
- Glass rod or paddle pop stick
- Salt solution (1%)
- Filter paper or chromatography paper
- Scissors
- Pencil
- Ruler

Procedure

1 Cut the filter or chromatography paper into three strips measuring approximately 2 cm × 10 cm.

2 Draw a faint pencil line across the width of each paper strip, 3 cm from the bottom.

3 Label the first strip “A”, another “B” and the remaining one “C”. Make sure the label is at the very top of the paper strip.

4 Carefully trace over the pencil line at the bottom of strip A with the first felt-tip pen. (Do not make the line too thick.)

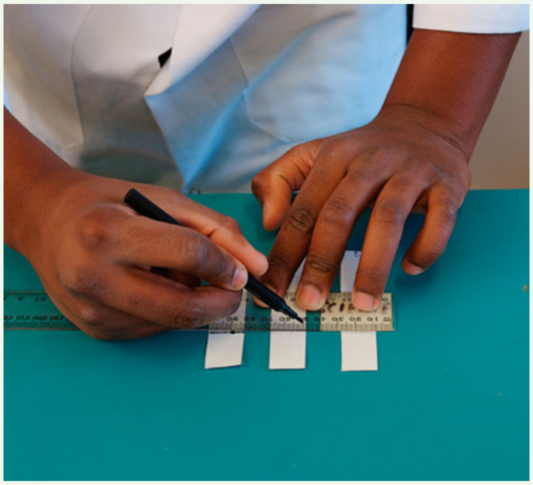


Figure 2 Tracing over the pencil lines at the bottom of the chromatography paper

5 Do the same for the other two pens on their separate strips.

6 Add the salt solution to the bottom of the beaker, no deeper than approximately 2 cm.
7 Hang the paper strips over the glass rod so that they just dip into the salt solution. Make sure the salt solution does not touch the pen lines on the paper.

Figure 3 Hanging the paper strips over a glass rod so that they just dip into the salt solution

8 Leave the papers to soak up the salt solution for approximately 10 to 15 minutes or until the solvent level is up to the top of the paper.
9 In the meantime, draw a diagram of the chromatography equipment in your notebook, labelling all the parts.
10 When the chromatogram is finished, take the papers out of the solution to dry.

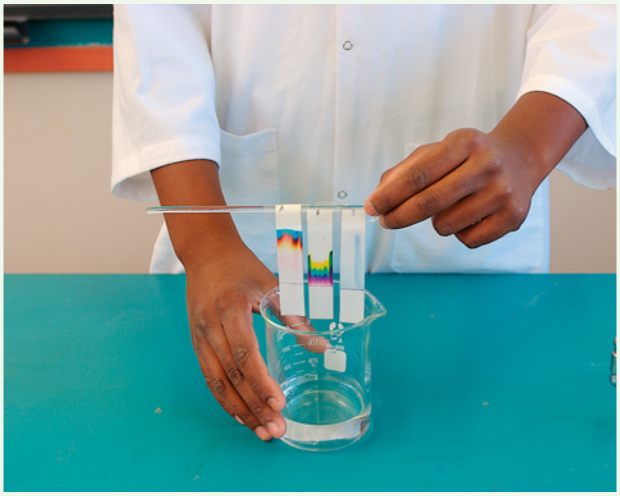


Figure 4 Taking the papers out to dry

Results

Tape the dry chromatograms for suspects A, B and C in your notebook. Collect and copy the chromatogram from the original note. Label this as the extortionist's chromatogram.

Discussion

1 Compare the chromatogram for the extortionist with the chromatograms from the three suspects. Identify if any of the suspects' chromatograms match the one from the original note, and if so, who is most likely to be guilty.
2 Identify which of the felt-tip pens – A, B or C – had the most colours in its black ink.

Conclusion

Describe how the inks from three different black felt-tip pens can be separated.

Lesson 7.16

Challenge: Separation challenge

Design brief

How can you separate the different parts from a mixture of sand, iron filings, sawdust and salt?

Criteria restrictions

You may only use equipment available in the laboratory.

Questioning and predicting

1 Think about the properties of each pure substance that is in the mixture. This may help you to decide on a way to separate the substances. Copy Table 1 and write what you know about the properties of sand, iron filings, sawdust and salt.

2 Discuss with a partner some possible ways to separate the four substances.

Table 1 The properties of sand, iron filings, sawdust and salt

Substance	Soluble in water?	Attracted to a magnet?	Floats/ sinks in water?
Sand			
Iron filings			
Sawdust			
Salt			

Planning and conducting

1 Draw up a flowchart showing the steps you will take to separate the four substances.

2 Devise an aim and a materials list for your experiment.

3 Write a detailed method for separating the substances. Include at least two diagrams.

4 Describe three safety issues that you need to consider when completing this experiment.

5 Have your plan checked by your teacher.

6 Perform your separation experiments and make relevant observations.

Processing, analysing and evaluating

1 Describe the unique properties of each component of the mixture that allowed you to separate them.

2 Describe the different components that you were able to separate from the mixture, including the colour and texture of each final sample.

3 Describe the purity of each sample by describing any contaminants that may have been mixed in the pure samples.

4 Describe one way you would change your method to improve the amount or the purity of your samples.

Communicating

Present your investigation in a formal experimental report.

Lesson 7.17

Science in context: Wastewater and household waste is a mixture that can be separated

Water pollution: Where it comes from and why it matters

Water is essential for all living things, but it can become polluted by human activities. Pollution happens when harmful substances enter rivers, lakes and oceans, making the water unsafe for animals, plants and people. These pollutants can come from farms, factories and cities, and they can cause serious problems like killing aquatic life, making drinking water unsafe and upsetting ecosystems. To help protect our water, it's important to understand where pollution comes from, what it does and the different types of pollutants that can harm the environment.

1 **Source of pollution**

Pollutants can enter water bodies from various sources, including:

- **run-off from land** – rainwater can wash pesticides, fertilisers, oil and heavy metals from roads, fields and factories into rivers, lakes and oceans
- **wastewater** – sewage and industrial waste that is improperly treated can directly contaminate water sources
- **accidental spills** – oil spills and chemical leaks can cause immediate and severe pollution in aquatic environments.

Figure 1 A water treatment plant

2 **Effects of pollution**

Once pollutants enter the water, they can:

- harm aquatic life, leading to reduced biodiversity
- contaminate drinking water sources, posing health risks to humans and animals
- disrupt ecosystems and food chains.

3 **Types of pollutants**

Pollutants can be broken down into:

- **chemical pollutants** – these include heavy metals (like lead and mercury), nutrients (like nitrogen and phosphorus) and toxins (like pesticides)
- **physical pollutants** – these include plastic waste, sediment and other debris that can harm aquatic organisms
- **biological pollutants** – bacteria, viruses and parasites can contaminate water, leading to diseases.

From filtration to clean water

Before wastewater is safely released into the environment, it must go through several treatment stages to remove harmful substances. Water treatment plants use different processes to filter out solid waste, remove harmful nutrients and kill bacteria. These steps help prevent pollution in rivers, lakes and oceans while making the water safe for reuse. The treatment process is divided into primary, secondary and sometimes tertiary treatment, each playing a role in cleaning wastewater before it is returned to the environment.

Figure 2 Flocculation results in the clumping together of suspended particles in wastewater.

Figure 3 An algal bloom in a lake can lead to the death of aquatic life as oxygen and nutrients are used up by the large numbers of algae.

Primary treatment

Initially, the wastewater is filtered to remove any large products. This includes cotton buds, rags and the stickers found on fruit. Aluminium sulfate is added to the wastewater to encourage any remaining suspended particles to coagulate or clump together. This process is called **flocculation** (Figure 2).

The small clumps are then left to sit in sediment ponds. This allows the clumps to form a sediment on the bottom of the pond. This sediment is called **sludge** and is removed and disinfected. Many industries use the sludge as fertiliser or to manufacture biofuels.

Figure 4 Chlorine and wastewater tanks in a tertiary water treatment plant

Secondary treatment

The remaining wastewater often contains levels of nutrients, such as nitrogen and phosphorus, that would be harmful to rivers or oceans. When these nutrients enter waterways in large amounts, algae feed off them and grow into large blooms (Figure 3). The large numbers of algae use all the oxygen and nutrients in the water, leaving other aquatic life to starve. Secondary waste treatment pumps the wastewater through a series of tanks where bacteria remove the excess nutrients from the water.

Tertiary treatment

Sometimes the water is treated at a tertiary treatment plant. Once again, the water is filtered to remove any particles that may be left in the water. Chlorine is added (just like it is to a swimming pool) to kill any bacteria that may still be in the water.

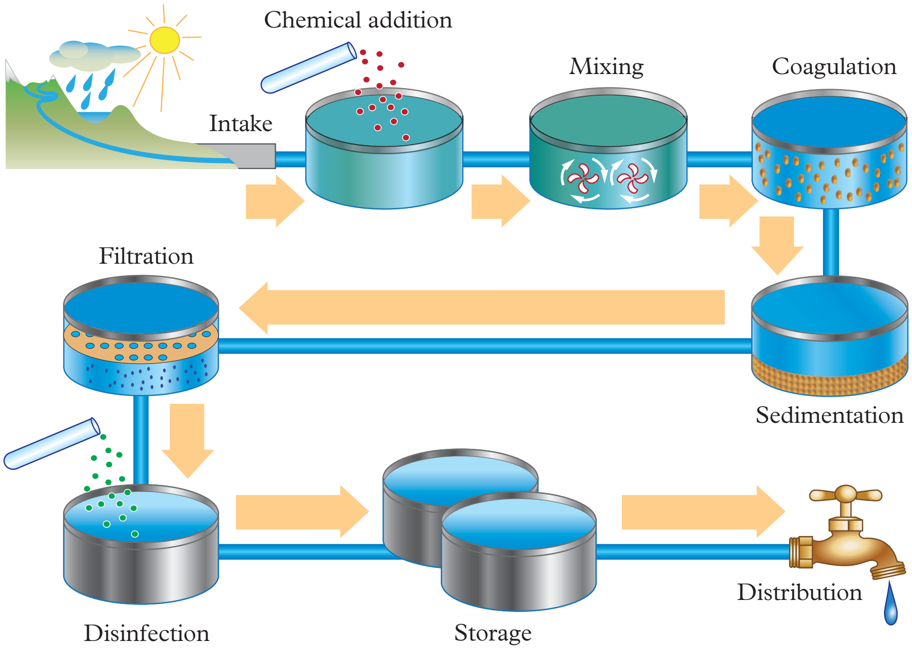


Figure 5 Summary of the water treatment process

Household recyclables

Have you ever wondered what happens to the rubbish in the recycling bins collected by your local council? Most households put their paper, cardboard, glass bottles, cans and recyclable plastics into a separate rubbish bin. These items are collected by different trucks from the general rubbish trucks. Instead of going to landfill, the trucks take the recyclable rubbish to a materials recovery facility. As the name suggests, this facility separates the mixture of rubbish before sending it off to be recycled.

The materials recovery facility

At the materials recovery facility, the truck unloads the recycled rubbish onto a conveyer belt (Figure 6). The conveyer belt carries the rubbish into the facility before allowing the rubbish to drop onto a slight incline belt. Paper, cardboard and other light rubbish stay on the incline belt and are carried up and along to where they are sorted by hand. People separate the paper from the plastic bags, placing each into their special bins for recycling. Heavier

Figure 6 A materials recovery facility

objects, such as larger plastic containers, aluminium and tin cans, fall backwards off the incline conveyer belt onto another moving belt. This conveyer belt uses a large magnet to separate the steel and tin cans into a large bin. Aluminium cans are not attracted to the magnet and remain mixed with the larger glass and plastic containers.

The aluminium cans, glass and plastics are exposed to a special eddy current separator (Figure 7). This separator pushes the aluminium cans away so that the cans fall further than the glass and plastic bottles.

The conveyer belt carries the remaining glass and plastic bottles forwards over a pit. The heavier glass containers fall faster and are collected in a bin. The lighter plastic containers are caught by the last conveyer belt and are separated based on colour. A light scans each plastic container for the type of plastic. Each type of recycled plastic is a different colour. Each colour plastic receives a different blast of air that projects it into the correct bin.

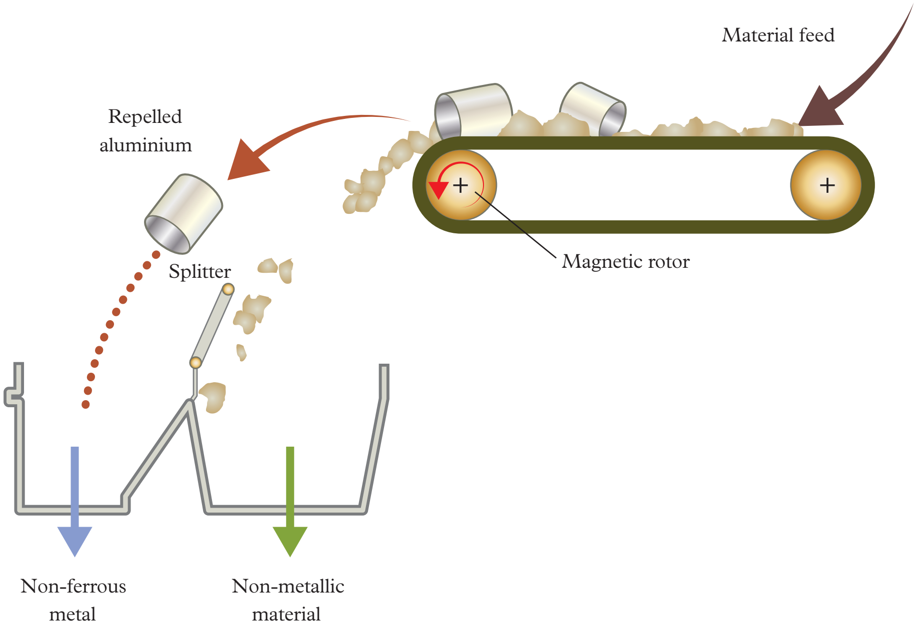


Figure 7 How an eddy current separator works

Test your skills and capabilities

Test your skills and capabilities 7.17

Analysing data in graphs

Scientists often gather data from the water treatment plants to help them understand how water is used and to assess the health of the population. Recording, processing and analysing data are essential skills in science.

1 Water use is often an indication of the amount of wastewater produced per person every year. A graph of the annual water consumption per person in some Australian cities is shown in Figure 8.

   a Identify the city that uses the highest amount of water per person each year.

   b Identify the city that uses the lowest amount of water per person each year.

   c Identify the amount of water that the average person in Canberra uses in a year.

   d Describe one reason why a person living in Brisbane might use more water than a person living in Melbourne.

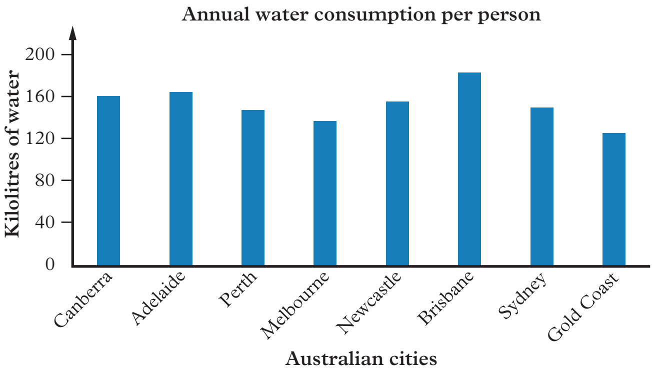


Figure 8 Annual water consumption per person in some Australian cities

2 WaterNSW, the water supply authority for NSW, encourages residents to conserve water, especially during periods of drought and high demand. The Greater Sydney region relies on a network of dams, with Warragamba Dam being the largest source of drinking water. Use Figure 9 to answer the following questions:

   a Identify the month in which Sydney residents used the most water. Suggest a possible reason for this trend.

   b Identify the month in which Sydney residents used the least water.

   c The population of Greater Sydney has continued to grow over the past decade. Based on the data, discuss whether Sydney residents have become more or less efficient in their water usage between 2018 and 2023.

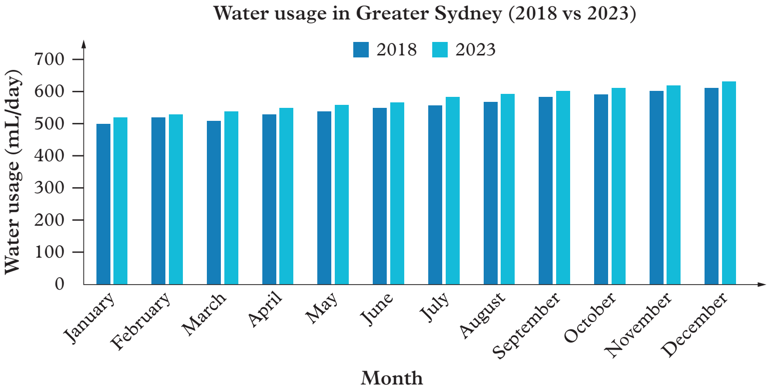


Figure 9 Total water use in NSW for 2018 and 2023

3 The more water that is used by people living in Sydney, the greater the amount of sewage that needs to be treated. Create a poster that encourages the people in your house to use less water in their everyday activities.

Communication, questioning and predicting

4 Consider the information you extracted from the graph in question **1**. Write a paragraph using scientific language that explains how water is used across Australia each year. (THINK: What are the key points to highlight? Write this information objectively – using facts, no opinions, and writing in the third person.)

5 Predict what would happen to an eddy separator (Figure 7) if the magnetic rotator was not working. (What role does the magnet play in the separation process? What would happen to the production line without it?)

Lesson 7.18
Challenge: Removing pollutants

Design brief

Now that you are a scientist who has trained in separating techniques, it is time to separate a mixture that models polluted water. Your polluted water sample contains the following: soil, vegetable oil and gravel.

Criteria restrictions

You may only use equipment available in the laboratory, such as:

- Activated charcoal
- Beakers
- Measuring cylinder
- Filter funnel
- Filter paper
- Sand

Questioning and predicting

1 Think about the properties of each pure substance in the mixture. This may help you decide on a way to separate the substances. Copy and complete Table 1 with what you know about the properties of each of the “pollutants”.

Table 1 Properties of the “pollutants”

Substance	Solubility in water	Size of particle	Floats/ sinks in water?
Soil			
Oil			
Gravel			

2 Discuss with a partner some possible ways to separate the substances.

Planning and conducting

1 Draw up a flowchart showing the steps you will take to separate the substances.
2 Devise an aim and an equipment list for your challenge.
3 Write a detailed method for separating the substances. Include at least two diagrams.
4 What safety issues might there be when doing this challenge?
5 Have your plan checked by your teacher.
6 Perform your separations and make relevant observations.

Processing and analysing

1 Discuss how well your plan worked. Grade the success of the plan on a scale of one to five, where one means the challenge did not work well and five means it was a great success. If you completed this challenge as a group, discuss your grading with others in your team.
2 If your success was lower than five on the scale, describe how you would change “Plan B” to improve the results on another occasion.
3 Identify whether you managed to separate the substances successfully. Write your answer to this question as the conclusion in your laboratory report.

Communicating

Present the challenge in a formal experimental report.

Lesson 7.19

Review: Solutions and mixtures

Summary

Lesson 7.1 Mixtures are a combination

- When different atoms bond chemically, they form compounds with properties distinct from the individual elements, such as water (H_2O).
- Pure substances consist of identical compounds (e.g. pure water), while mixtures combine different substances without chemical bonds, allowing for easy separation.
- Mixtures come in various forms – solutions (uniform mixtures), suspensions (cloudy mixtures with settleable particles), colloids (stable dispersions), and emulsions (liquid-in-liquid mixtures often requiring emulsifiers).

Lesson 7.2 A solution is a solute dissolved in a solvent

- A substance is considered soluble if it dissolves completely in a liquid, forming a uniform, clear solution; if not, it is insoluble, leaving visible particles.
- Water effectively dissolves many substances, playing a crucial role in processes like digestion and supporting aquatic life by transporting dissolved gases.
- Solutions vary by how much solute is present – ranging from dilute to concentrated – with saturated solutions containing the maximum solute and supersaturated solutions holding extra, unstable amounts.
- Temperature can enhance solubility, and dissolved substances like metal salts can alter the taste and behaviour of water, demonstrating practical effects of solubility in everyday life.

Lesson 7.7 Mixtures can be separated according to their properties

- Mixtures can often be separated by simple physical means, either by manually picking out visible components or by exploiting differences in density.
- Magnetic separation extracts magnetic materials (e.g. iron-containing items), while decanting, sedimentation and flotation rely on density differences to separate mixtures.
- The use of flocculants helps clump together suspended particles, making sedimentation more effective in complex mixtures.
- Aboriginal and Torres Strait Islander Peoples used techniques like winnowing and yandying, which are natural separation methods, and techniques like distillation, which uses boiling-point differences to isolate components such as medicinal oils.

Lesson 7.9 Mixtures can be separated according to their size and mass

- Filtering and sieving use barriers with holes to separate mixtures, based on particle size.
- Filters allow liquids or fine particles to pass through while retaining larger solids (e.g. colanders, coffee filters), whereas sieves separate solids by size.
- Separation methods are used in everyday tasks like cooking and recycling, as well as in specialised equipment such as HEPA filters for air quality.
- Centrifuging separates particles by weight through rapid spinning, effectively isolating heavier components in medical and industrial processes.

Lesson 7.11 The boiling points of liquids can be used to separate mixtures

- Heating a liquid causes it to evaporate into a gas at a specific boiling point, which varies for different substances.
- Mixtures can be separated by exploiting differences in boiling points, for example, water evaporates before turpentine, leaving the latter behind.

- When the solvent in a solution evaporates, the solute is left behind and forms crystals, such as salt crystals which are formed after salt water evaporates.
- Distillation captures evaporated vapours and cools them into liquid form, allowing the collection of substances with lower boiling points. This process is used in refining crude oil.

Lesson 7.14 Solubility can be used to separate mixtures

- Solubility defines how easily a substance dissolves in a solvent, enabling separation of mixtures, for example, dye mixtures, based on their different solubilities.
- In paper chromatography, a solvent moves up absorbent paper, carrying more-soluble dyes further than less-soluble ones.
- Advanced chromatography techniques allow scientists to separate and detect minute quantities of substances in complex mixtures.
- Chromatography is employed in diverse fields – from producing historical inks to modern applications like detecting banned substances used by athletes and screening for drugs at airports.

Review questions 7.19

Review questions Module 7

Retrieve

1 A tablet is dissolved in a glass of water. Identify the solvent in the scenario.
  A The tablet
  B The water
  C The glass
  D The tablet and water combined

2 Identify the physical property that allows mixtures to be separated by decanting or sedimentation.
  A Boiling point
  B Magnetism
  C Density
  D Compressibility

3 Identify the separation technique that is used to separate materials with different solubilities.
  A Evaporation
  B Distillation
  C Magnetic separation
  D Chromatography

4 Blood is a mixture that is made up many different substances.
  a Recall the separation technique that is used to separate the parts of blood.
  b Identify the physical property that is being used to separate this mixture.

5 Identify the property used to separate substances through distillation.

6 Define the term “flocculation”.

7 Nail polish remover and paint stripper are both useful solvents for dissolving oil-based substances such as paint.
  a Define the term “solvent”.
  b Identify the solute for nail polish remover and paint stripper.

Comprehend

8 Describe an example of a mixture that could be separated into its parts by filtration.

9 Explain two safety recommendations that you would give to someone using evaporation and crystallisation.

10 Imagine dropping salt in sawdust. Explain how you would separate the parts of this mixture using the particle model.

11 A criminal buries an aluminium drink can containing DNA evidence in the sand. Explain whether the aluminium could be separated from the sand using a magnet.

12 Describe each of the processes involved in the primary, secondary and tertiary treatment of wastewater.

13 A student was measuring the solubility of two chemicals (A and B) in water. They placed a

spatula full of each substance in separate test tubes of water. Figure 1 shows what they saw. Use the terms “dissolve”, “solvent”, “solute” and “suspension” to explain what has happened.

Figure 1 Test tube A (left) and test tube B (right)

14 Imagine that you have just bought a large factory. Due to flood damage, it is filled with tonnes of matchsticks mixed with tonnes of iron scraps.

- **a** Describe how you would separate this mixture.
- **b** List the equipment you would need to make this happen on such a large scale.

15 A particular coloured dye is being created for Fashion Week.

- **a** Look at the chromatogram of the dye mixture in Figure 2. Identify how many pure dyes were mixed to create the colour.
- **b** Identify the colour of the pure dye that is the most soluble.

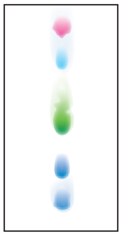


Figure 2 Chromatogram of a dye mixture

16 The Alyawarre, Anmatyerre, Warlpiri and Pitjantjatjara peoples in the desert parts of the Northern Territory use their fingers to separate desert raisins from rotten fruit. Describe a technique used by Aboriginal and Torres Strait Islander Peoples that separates a mixture based on mass or distillation.

Figure 3 Aboriginal and Torres Strait Islander Peoples in the Northern Territory use their fingers to separate desert raisins from rotten fruit

Analyse

17 Examine Figure 4 and identify the suspension, the solution and the colloid.

18 Contrast evaporation and distillation.

19 Compare the use of decanting and filtration to separate mixtures. Identify examples of situations where you would use one over the other.

Figure 4 Identifying mixtures

20 Compare a solution of salt dissolved in water, a suspension of muddy water, and a colloid mixture of milk in water (Figure 5).

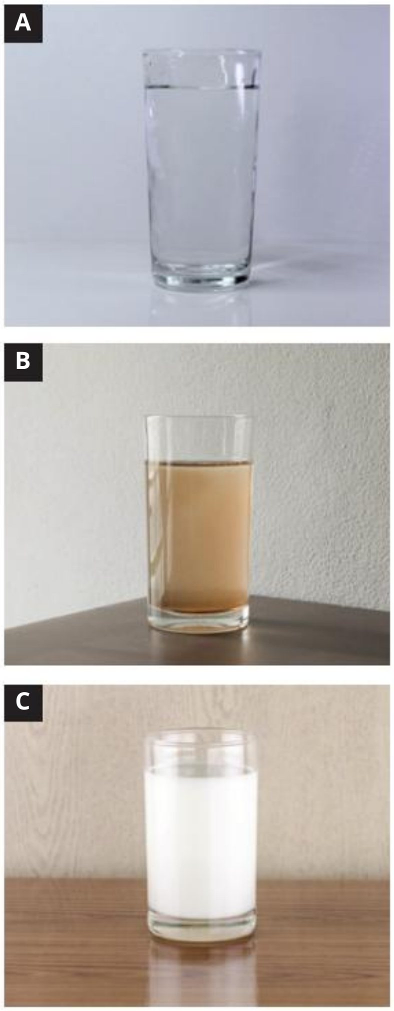


Figure 5 (A) Salty water; (B) muddy water and (C) milk in water

Apply

21 Examine the chromatograms in Figure 6, taken from blue pens belonging to suspects (A to D). Compare these with the one taken from the original forged cheque (X). Decide whether any of the suspects are likely to be the culprit.

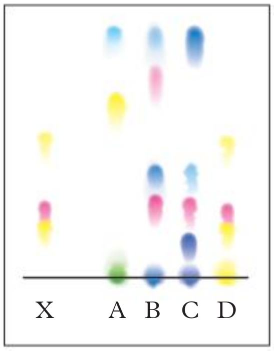


Figure 6 Which suspect is the likely culprit?

Social and ethical thinking

22 Do you think that performance-enhancing drugs are spoiling the image of sports? Pair up with a partner and make a list of all the advantages and disadvantages of athletes using these drugs to compete. Use your list to create and justify an argument for or against the use of drug testing on competing athletes.

Critical and creative thinking

23 List the techniques in the order that you could use them to separate a mixture of iron fillings, sand, marbles and salt. Create a flowchart to present your answer.

24 People sometimes need to enter environments containing poisonous gases. In these situations, they will wear gas masks. Use the internet or other research tools to find out how gas masks interact with poisonous gases and how they change the air before it is inhaled by the person wearing the mask. Create a poster to show how gas masks make the air safe to breathe.

25 Until recently, Australia would ship all their plastic waste to other countries to be processed. This is no longer possible because most countries are refusing to accept the waste. Discuss and suggest reasons why Australia did not previously process their own plastic waste.

Research

26 Choose one of the following topics to research the ways in which we work with mixtures.

How do we work with mixtures?

Research a separation technique that is used in a different industry or in nature.

- Prepare a "SWOT" analysis as part of your report, listing the Strengths, Weaknesses, Opportunities and Threats of the separation technique that you choose to research.
- You could present your report with a series of photographs of the technique.

Filters of the sea

A certain type of whale, known as a **baleen whale**, has a filter in its mouth which is made of a bone-like substance called **baleen**. Humpback whales are a type of baleen whale.

- Identify what these whales eat.
- Describe the baleen filter and how it filters the whale's food.
- Describe the bubble-net feeding behaviour used by humpback whales.
- Investigate how baleen whales are different from other filter-feeders, such as barnacles, sponges and flamingos.

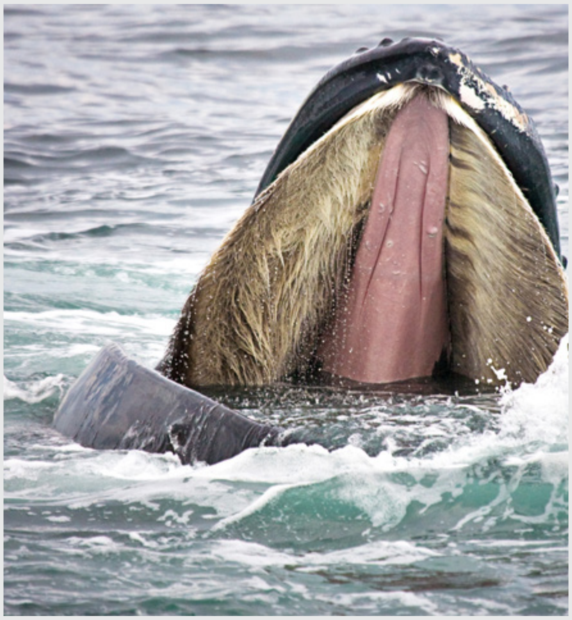


Figure 7 The humpback whale is a type of baleen whale.

Self-cleaning suburbs

As our population grows, new suburbs are being built on the outskirts of cities. In some of these new suburbs, several features have been included to keep the water and air clean.

- Find out about strategies that are used to purify water and air in housing estates.

Distillation for survival

Imagine that you were hiking in central Australia, became separated from your group and then ran out of drinking water.

- Describe the way Aboriginal and Torres Strait Islander Peoples might obtain drinking water in the desert environment.
- Describe how you could turn stagnant or polluted water from a waterhole into drinkable water.
- Describe how you could use your knowledge of separating mixtures to obtain drinkable water if you were isolated near the coast.

Filtration in the human body

The human body needs to control what goes into it and what comes out of it. In particular, the filtering system of the kidneys prevents us from being poisoned by our own wastes, and tiny hairs in our nose filter dust and germs as we breathe.

- Select one of these filtration systems.
- Describe the structure of the system that does the filtering.
- Describe what the system filters.
- Explain why it is important for the body to use the filtering system to remove particles.
- Describe what would happen if these body filtering systems did not work.

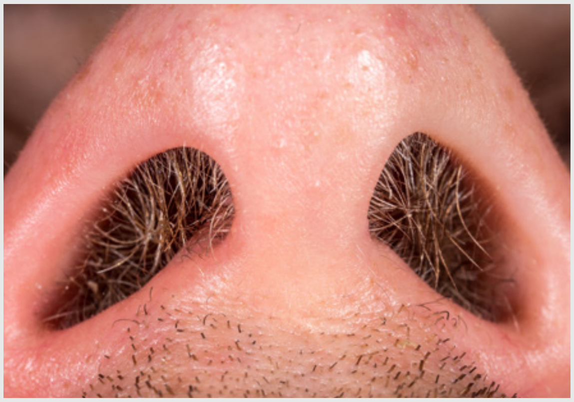
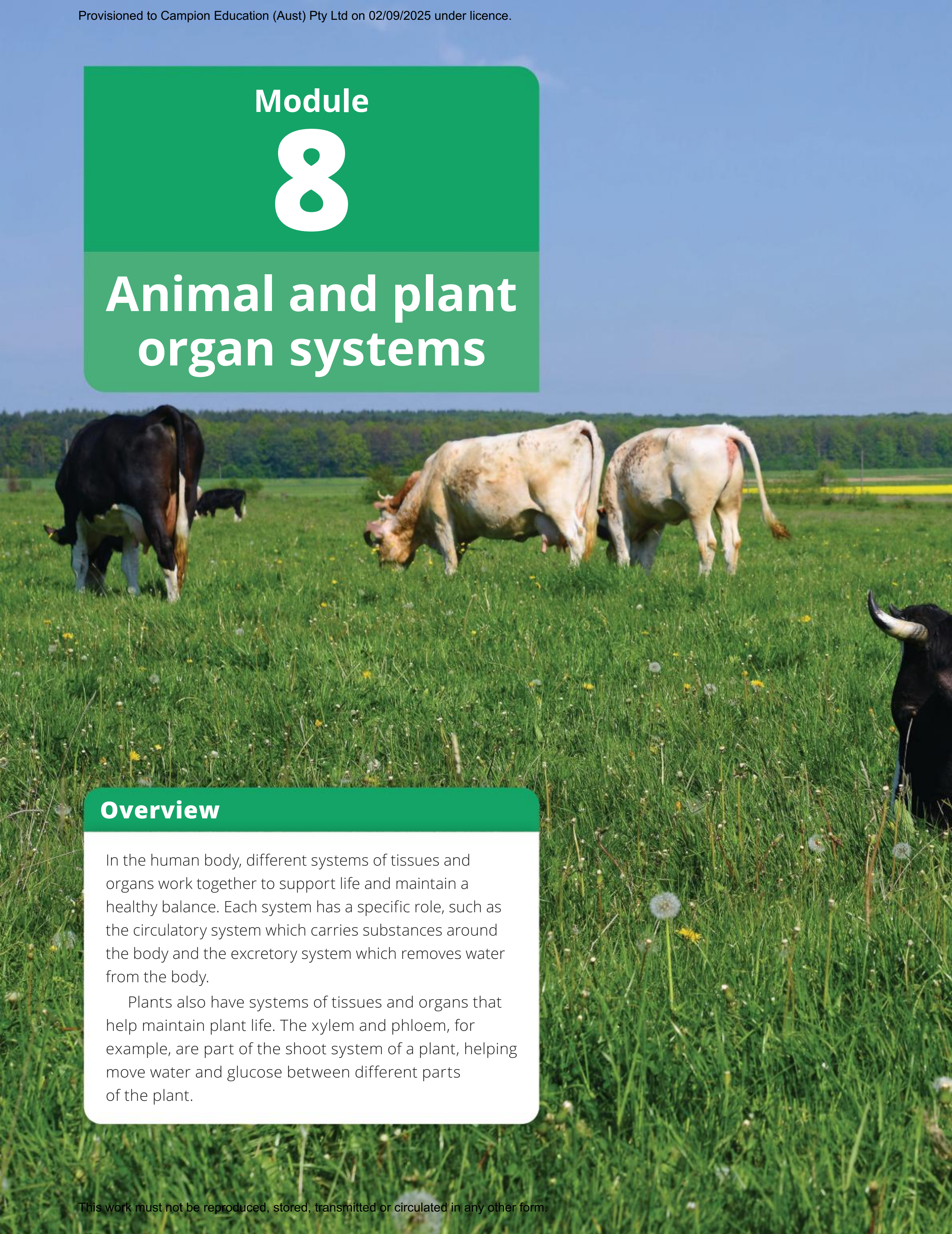


Figure 8 Hairs in our nose filter dust and germs.

Module 8

Animal and plant organ systems



Overview

In the human body, different systems of tissues and organs work together to support life and maintain a healthy balance. Each system has a specific role, such as the circulatory system which carries substances around the body and the excretory system which removes water from the body.

Plants also have systems of tissues and organs that help maintain plant life. The xylem and phloem, for example, are part of the shoot system of a plant, helping move water and glucose between different parts of the plant.

Lessons in this module

Lesson 8.1

Systems are made up of cells, tissues and organs

Learning intentions and success criteria

Key ideas

- → Anatomists study how the body works.
- → Groups of cells that do a similar task are called tissues.
- → Groups of tissues that work together are called organs.
- → When groups of different organs work together, they are called a body system.

The first anatomists

Evidence of the very first anatomists can be found in the X-ray paintings at Burrunggui on the lands of the Gundjeihmi people in Kakadu National Park. These diagrams of internal body parts were painted over 8,000 years ago. They show the different parts of the skeleton and the circulatory system of the painted person (Figure 1).

Figure 1 Internal parts of the body depicted in rock paintings at Burrunggui (Nourlangie), Kakadu, 8,000 years ago.

Other Aboriginal and Torres Strait Islander Peoples' paintings at Injalak Hill show that the Kunwinjku people of West Arnhem Land were able to identify the internal organs and skeletons of birds, fish and mammals. These paintings were made over 6,000 years before the Egyptians removed organs during the mummification process.

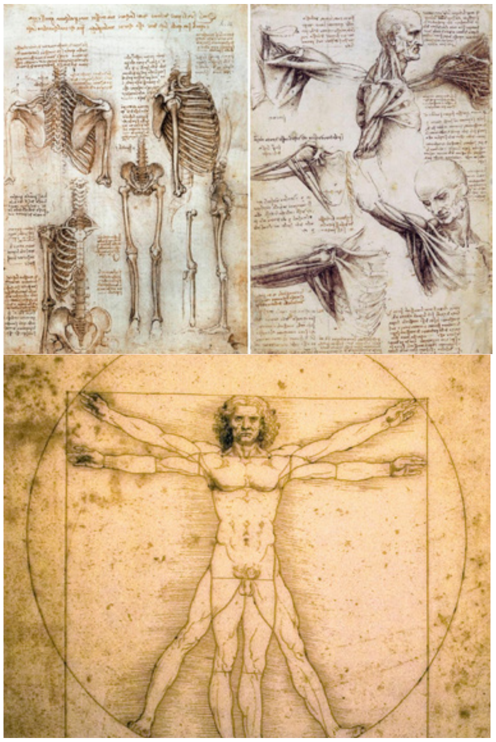


Figure 2 Human anatomy drawings by Leonardo da Vinci

Leonardo da Vinci

Leonardo da Vinci is famous as a painter and architect, but he also studied the human body. Da Vinci began studying the human body over 500 years ago through life drawing (drawing people standing in front of him) and by attending public dissections that were held by medical schools.

He was involved in both human and animal dissections, and from these he created beautiful and highly accurate drawings (Figure 2).

Cells

Recall from Module 4 Cells (page 166) that cells are the smallest unit of life, and their size is limited due to the relationship between surface area to volume ratios; as an object – in this case a cell – becomes larger, the surface area to volume ratio decreases. Cell specialisation has allowed for multicellular organisms to become larger, with different cell types taking on specific roles essential for the survival of the organisms. There is a hierarchical structural organisation: specialised cells make up tissues, tissues make up organs, and organs make up organ systems (Figure 3).

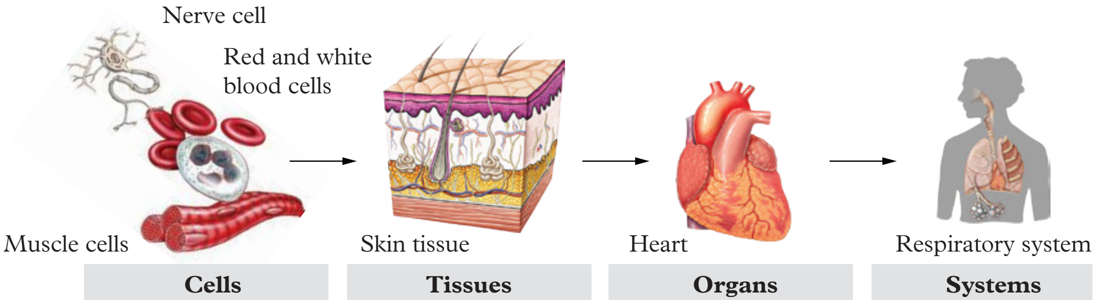


Figure 3 The different levels of organisation in the body

Tissues

connective tissue the group of cells that provide connections to other parts of the body

muscle tissue the group of cells that allow the body to move

The development of the microscope by Robert Hooke in the 1600s led anatomists to examine how cells work together to form the different systems in the body. Over time, they found that similar-looking cells work together to carry out a particular job or function. These groups of cells are called tissues. There are four main categories of tissue, each with a specific function (Figure 4).

Connective tissue includes blood cells, fat cells, bone cells, tendons and ligaments. These cells are all surrounded by a non-living material called a **matrix**. The matrix can be solid or liquid. For example, cells in bone marrow are surrounded by solid bone, and cells in the blood are surrounded by liquid.

The cells in **muscle tissue** are responsible for voluntary and involuntary movement. For example, skeletal muscle cells connected to the skeleton enable us to move when we choose (this is voluntary movement), while cardiac muscle cells in the heart enable

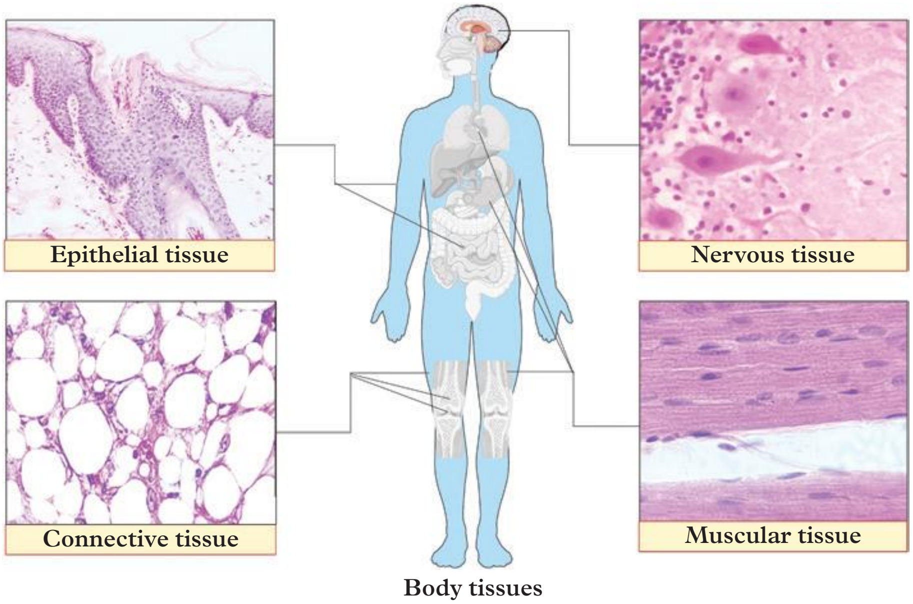


Figure 4 There are four main types of tissue: connective tissue, muscle tissue, nervous tissue and epithelial tissue.

it to beat and pump blood through the body without us needing to think about it (this is involuntary movement).

nervous tissue the group of cells that pass on electrical messages

epithelial tissue the group of cells that cover and protect the body

pathogen a disease-causing agent (e.g. bacteria, viruses, fungi)

Nervous tissue is found in the brain, spinal cord and nerves. Specialised cells called **neurons** receive, process and transmit electrochemical signals throughout the body.

The cells that make up **epithelial tissue** are usually large and flat, allowing them to cover a large surface. Epithelial tissues cover the outside and inside surfaces of the body and help protect the internal parts of the body from damage, water loss and **pathogens** such as bacteria.

Organs

organ a group of different tissues that are self-contained and have a specific vital function

When the four types of tissues work together to perform a particular job, they are called an **organ**. Your heart is an example of an organ. It is lined with epithelial tissue to protect the surface. It contains nervous tissue to help coordinate the muscle tissue that is responsible for the involuntary heartbeat that pumps blood tissue around the body. Other examples of organs include the lungs, stomach, kidneys and liver. Each have different types and combinations of the four tissues necessary to perform the organ's specific role in the body.

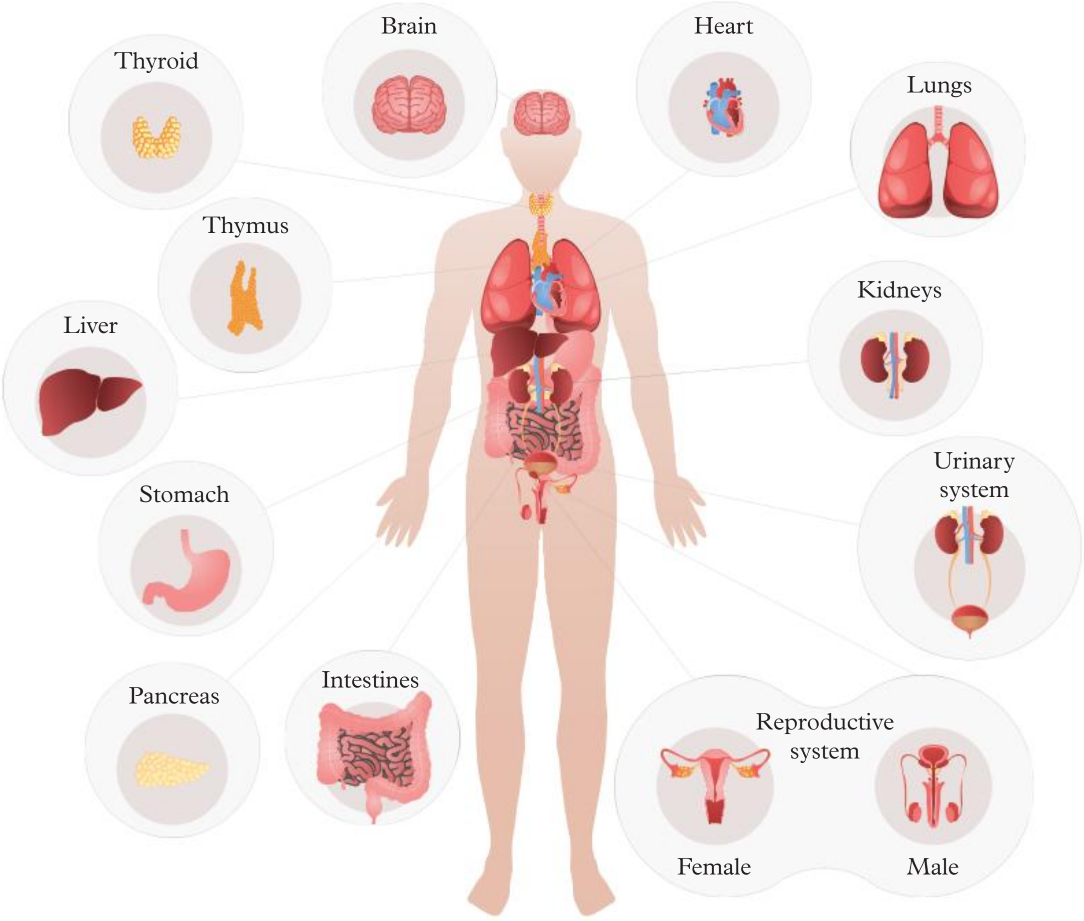


Figure 5 Different organs of the human body

Organ systems

When different organs work together to perform a particular function, they are called an **organ system**. For example, the heart is connected to another organ – blood vessels – which also contain all four types of tissue. Together they make up the circulatory system, delivering oxygen and nutrients carried in the blood to all cells of the body, while also picking up and transporting waste material.

organ system a collection of different organs that work together to perform a particular function

Organ systems do not work in isolation. For example, the oxygen transported by the circulatory system was provided by the respiratory system, while the nutrients were absorbed by the digestive system. The waste products produced by cells are taken to the excretory system for removal from the body. Together, these systems work together to maintain the health of an organism (Figure 6).

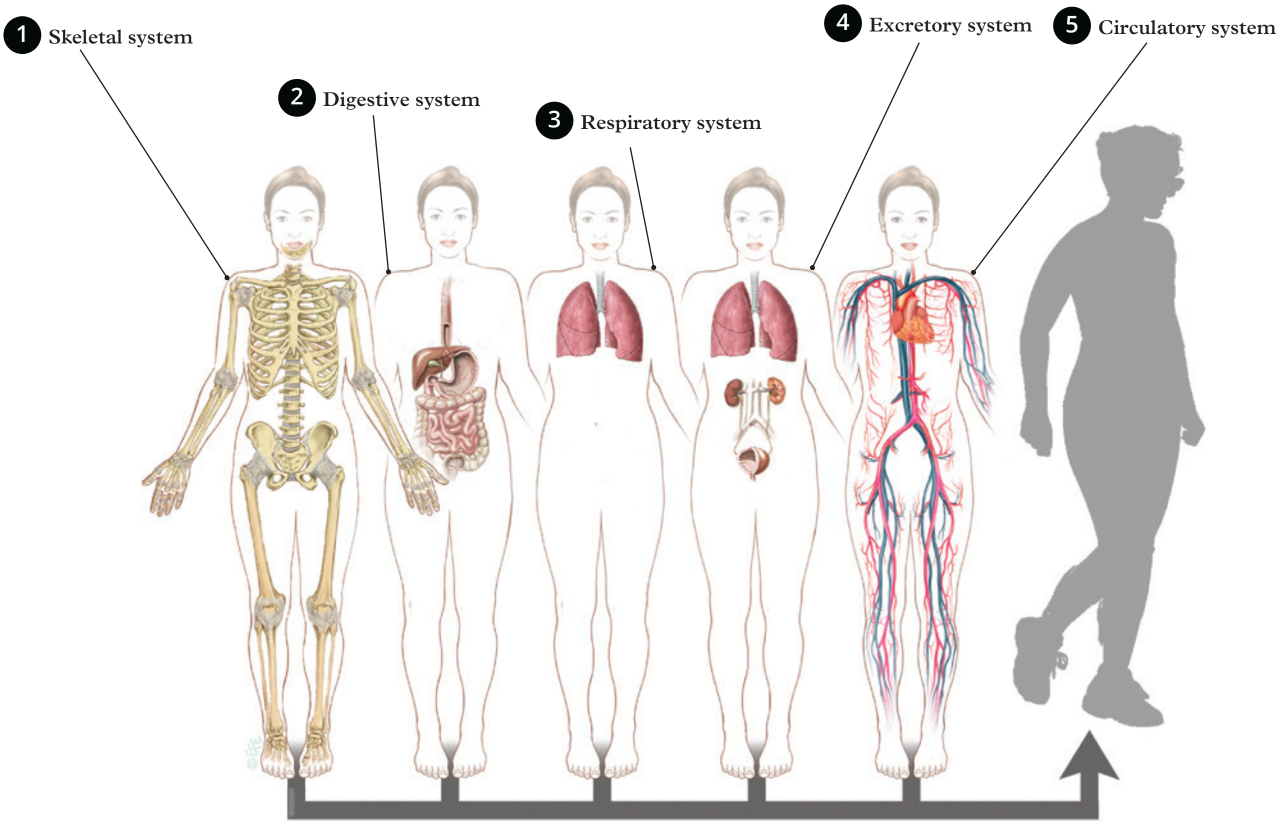


Figure 6 Our body systems work together. The following parts are labelled:

1. Skeletal system: Includes all bones such as the spine, skull, pelvis and ribs. It provides structure and support to the body, protects other organs, and serves as attachment points for muscles.
2. Digestive system: Comprises the mouth, stomach, small intestine, large intestine, rectum and anus. It breaks down food into absorbable substances and separates some waste.
3. Respiratory system: Consists of the lungs, windpipe and diaphragm. It filters oxygen from the air and transfers it to the blood, while removing carbon dioxide from cells, via the blood, back to the lungs.
4. Excretory system: Includes the kidneys, liver, bladder, urethra, skin and lungs. It processes and filters waste from the bloodstream and removes excess water from body fluids.
5. Circulatory system: Comprises the heart, veins, arteries and capillaries. It carries oxygen, nutrients and materials to and from cells via the blood.

Check your learning 8.1

Check your learning 8.1

Retrieve

1 Define the terms "tissue", "organ" and "system".

2 Recall the age of the X-ray paintings at Burrunggui.

Comprehend

3 Explain how cells, tissues, organs and systems are linked.

4 Use Figure 6 to explain how the circulatory system and digestive system work together.

Analyse

5 Infer why surgeons need a thorough understanding of anatomy.

6 Select an organ and examine how the four types of tissue work together so that the organ can function.

Lesson 8.2

The digestive system absorbs nutrients

Learning intentions and success criteria

Key ideas

→ Digestion is the process of breaking down food so that it can be used by the body.

→ Physical digestion occurs when the body manually breaks apart food particles.

→ Chemical digestion occurs when enzyme molecules break the chemical bonds in food.

→ Nutrients are absorbed in the intestines.

The digestive system

Your digestive system is made up of the digestive tract and other organs, including the liver, gall bladder and pancreas. The digestive tract is a long tube that starts at your mouth and ends at your anus. It includes the oesophagus, stomach, small and large intestines, and rectum. The digestive tract and organs work together to break down the food you eat and the liquid you drink so that it can be absorbed across the intestinal wall into your blood for transport to your cells. Food that is not needed by the body (such as fibre) stays in the digestive tract until it reaches the rectum. From there, it is released into the toilet through the anus as faeces (solid waste). This process is called **digestion**. Figure 1 shows the structure of the digestive system and explains the way each part works.

digestion the process of breaking down food into nutrients

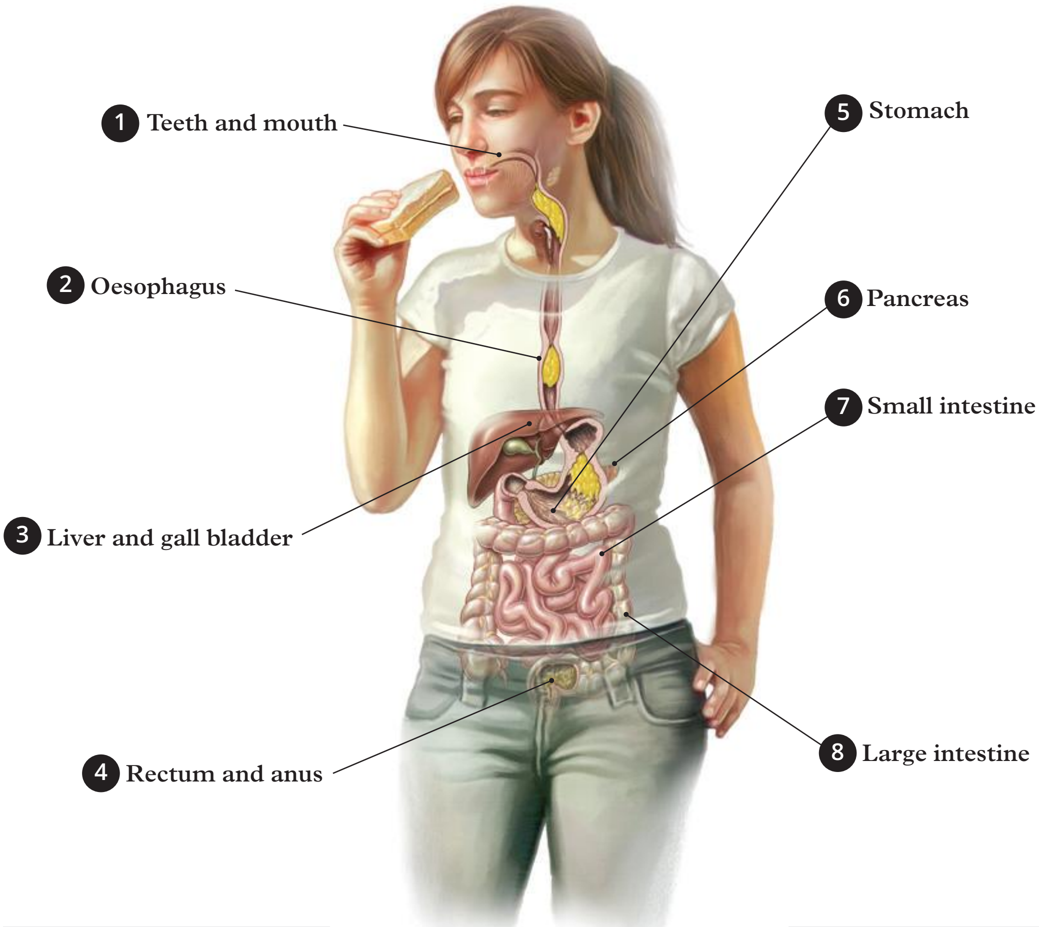


Figure 1 The structure of the digestive system, the following parts are labelled:

① Teeth and mouth: Responsible for the physical breakdown of food. Saliva glands produce saliva, containing enzymes for chemical digestion.

② Oesophagus: A tubular muscle that pushes food from the mouth to the stomach.

③ Liver and gall bladder: The liver produces bile to break down fats. Bile is stored in the gall bladder until needed. The liver also processes nutrients and removes toxins from the blood.

④ Rectum and anus: The rectum stores faeces until they are ready to be expelled through the anus. The anal sphincter controls the release of faeces.

⑤ Stomach: Stores food for about three hours while gastric juices digest the food, turning it into a runny, acidic mixture called chyme.

⑥ Pancreas: The pancreas produces pancreatic juice which contains digestive enzymes. The pancreas also neutralises stomach acid as chyme enters the small intestine.

⑦ Small intestine: About six metres long and is where most digestion occurs. Pancreatic juice and bile break down large molecules, and nutrients are absorbed into the bloodstream.

⑧ Large intestine: Absorbs the remaining water and forms solid waste (faeces), which is stored in the rectum until expelled.

Physical digestion

Physical digestion involves breaking down food into smaller pieces. The process starts in the mouth, with your teeth (Figure 2). There are three main types of teeth. The front ones are called **incisors**, the pointy teeth next to the incisors are called **canines**, and the rest of your teeth, which are flatter, are called **molars**. Each type of tooth has an important function. The front incisors cut your food when you bite down, the canine teeth are for tearing meat, and the molars are good for chewing and grinding food into smaller pieces. Your tongue, a large muscular organ, can push your food upwards, sideways and backwards towards your teeth.

physical digestion the breaking down food into smaller pieces without changing the chemical composition

When you swallow your food, the muscles behind the food squeeze tight, and the muscles in front of the food relax. This forces the food to move in a process called **peristalsis**. This movement also assists with physical digestion.

peristalsis the process of swallowed food being moved along the digestive tract by a wave of contractions

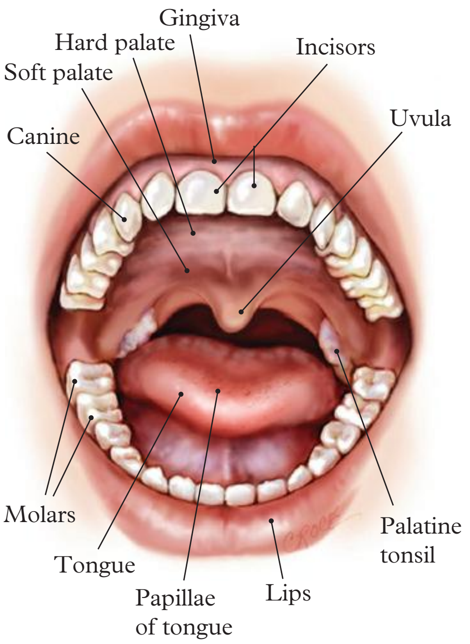


Figure 2 The teeth and mouth physically break down food.

Chemical digestion

Chemical digestion also starts in your mouth. The saliva in your mouth is mostly water, but it also contains different **enzymes**. Enzymes are protein molecules that speed up a chemical reaction. For example, saliva contains an enzyme called **amylase** that breaks up carbohydrates, such as starch found in bread and biscuits (Figure 3). Throughout the digestive system, enzymes assist in breaking up small pieces of food into nutrients that are small enough to be absorbed through the small intestine and into the blood – this is chemical digestion.

chemical digestion the breakdown of food into absorbable molecules through the action of enzymes and chemicals in the digestive system

enzymes a protein that helps speed up chemical reactions in the body

The stomach contains a mixture of gastric juices to help chemically digest the food you have eaten. These juices include acid, which kills any bacteria that may be in the food, and an enzyme called **pepsin**, which digests the protein (found in meat) in your meal. The cells lining the inside of the stomach produce mucus to stop the acid from burning the stomach walls. The resulting mixture of acid, enzymes and partially digested food is called **chyme**.

Figure 3 Biscuits are physically digested by teeth and chemically digested by enzymes in saliva.

chyme a mixture of acid, enzymes and digested food that leaves the stomach

Absorbing nutrients

Most nutrients from food are absorbed in the small intestine. The small intestine is narrow but quite long, at around five metres. The inside of the small intestine is highly folded and full of ridges called **villi** (Figure 4). Villi significantly increase the surface area of the small intestine. At approximately 30 m^2, the surface area of the small intestine has a lot of space over which nutrients can pass, which in turn maximises the opportunity and amount of nutrients that can be absorbed into the circulatory system.

villi small ridges in the small intestine that absorb nutrients from chyme

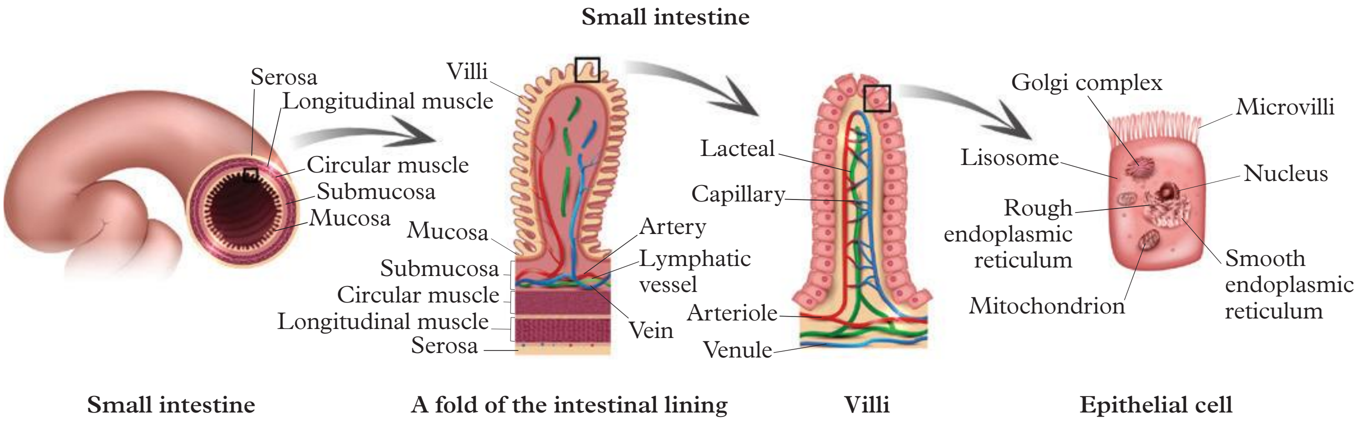


Figure 4 Different magnifications of the small intestine, showing the villi where nutrient absorption occurs

Check your learning 8.2

Check your learning 8.2

Retrieve

1 Recall, in order, the organs of the digestive system that food moves through, from the mouth to the anus.

2 Name the organs that are involved in digestion but do not have food passing through them.

Comprehend

3 Explain the advantage of having different types of teeth in your mouth.

4 Explain how saliva makes it easier to eat dry biscuits.

5 Explain the advantage of the intestine having villi.

Analyse

6 Contrast (the differences between) physical and chemical digestion.

7 Contrast (the differences between) the digestive system and the digestive tract.

Apply

8 Propose some tools that could work the same way as incisors, canines and molars.

Skills builder: Planning investigations

9 Two students were planning an investigation which involved members of their class eating different types of biscuits. Explain why this might be an unsafe activity for some of the students in their class. (THINK: How might food be dangerous?)

Lesson 8.3

Investigation: Digesting protein

Caution

- Some students may have egg allergies.
- Dangerous chemicals are involved. Pour carefully, clean up all spills immediately, and rinse your hands if you come into contact with any chemicals.

Introduction

Safety

Bring the materials to the test tubes, rather than risking the test tubes being dropped when carrying them around the room.

Purpose

To investigate the function of pepsin, an enzyme found in the stomach, and to establish the conditions under which pepsin functions best. Egg white is being used as the source of protein in this experiment

Materials

- Four test tubes and a test-tube rack
- Permanent marker
- Hard-boiled egg white
- 10 mL measuring cylinder
- 1% pepsin solution

- Water
- Dilute hydrochloric acid (1 M HCl)
- Dilute sodium hydroxide solution (0.1 M NaOH)
- 1 mL pipette
- Incubator (37°C)
- Rubber band

Procedure

1 Label the four test tubes A, B, C and D with the permanent marker.
2 Collect some hard-boiled egg white. Cut four cubes of approximately 1 cm^3, ensuring that the cubes are the same size.
3 Put a cube of egg white in each test tube.
4 Using the pipette, add 10 mL of pepsin to tubes A, C and D.
5 Add 10 drops of water to tube B.
6 Add 10 drops of 1 M HCl to tubes A and B.
7 Add 10 drops of 0.1 M NaOH to tube D.
8 Add 10 drops of water to tube C.
9 Bind the four tubes with a rubber band and label the bunch with your initials.
10 Incubate for at least 24 hours at 37°C.

Results

Copy Table 1 and record the ingredients for each test tube with a tick or cross. Provide very brief statements to describe your observations of the results.

Discussion

1 This experiment is a "controlled" experiment. Describe what is meant by the term "controlled".
2 Explain why combining the class's data can improve the accuracy of the results.
3 Construct a sentence to explain how the comparison of test tubes relates to the human stomach for A and B, A and C, and A and D.
4 Identify the test tube(s) that has the protein almost completely digested. Describe the appearance of the digested protein.
5 Define the term "enzyme".
6 Describe the effect HCl alone has on the protein.
7 Copy and complete the following word equations to show what has happened in this experiment.
   a Tube A: protein + __________ + __________ → amino acids
   b Tube B: water + __________ + __________ → __________
   c Tube C: pepsin + __________ + __________ → __________
   d Tube D: pepsin + __________ + __________ → __________
8 Explain why the body digests protein by describing what happens to the protein after it has been digested.
9 Predict what would happen if this experiment was repeated with carbohydrates instead of protein, leaving the rest of the experiment exactly the same.

Conclusion

Explain what you know about the function of pepsin and the conditions under which pepsin functions best.

Table 1 Investigating pepsin

Tube	Egg white	Pepsin solution	HCl	NaOH	Water	Results
A						
B						
C						
D						

Lesson 8.4

The digestive system varies between animals

Key ideas

- → Carnivores are organisms that only eat meat.
- → Herbivores are organisms that only eat plant material.
- → Omnivores, including humans, eat a variety of foods, including both meat and plants.
- → The structure of the digestive system is used to predict the type of food an animal eats.

Learning intentions and success criteria

Teeth tell a story

Each type of tooth has a specific function. Incisors have a sharp, knife-like or wedge structure, and animals such as rats and mice use their incisors to cut their way through food. Canine teeth are pointed and are useful in ripping lumps of meat apart. This is why many carnivores (meat eaters) have large canine teeth. Molars are flatter and are especially good at grinding plant food into small pieces so that it can be digested more effectively by enzymes.

Palaeontologists are scientists who study fossils, including the skulls and teeth of extinct animals. Palaeontologists use the teeth to predict what a fossilised animal ate when it was alive (Figure 1).

Figure 1 This fossil has a lot of molars and a few incisors which suggests that it belonged to a herbivore.

Herbivore digestion

Some plants, such as sugarcane, have a ready supply of the sugar that animals need for energy. Other plants, such as potatoes, contain starch that our enzymes can break up for nutrients. Some parts of plants are very difficult to digest – physically or chemically.

The outside of a plant cell is surrounded by a cell wall made of cellulose. Few animals have the enzyme (cellulase) that can break up this difficult-to-digest molecule. Instead, they rely on good natural flora bacteria to do the job for them. Herbivore digestion is broken into two groups, based on the main location of the gut bacteria: foregut **fermentation** and hindgut fermentation.

fermentation the chemical breakdown of a substance by microorganisms

Herbivore foregut fermenters

Foregut fermenters break down the cellulose early in the digestive process. While slower than hindgut fermentation, it allows for greater nutrient extraction from the food. Foregut fermenters include many of the larger Australian marsupials such as kangaroos and wallabies as well as **ruminants**.

ruminant a hooved animal that has four chambers in their stomachs. Examples include sheep, deer and cows

rumen the first stomach of a cow

reticulum the second stomach of a cow

omasum the third stomach of a cow

abomasum the fourth stomach of a cow

Ruminants are hooved animals that have four chambers in their stomachs. Examples include sheep, deer and cows (Figure 2). When the animal first swallows its food, the grass goes to the first stomach, which is called the **rumen**. This allows the grass to mix with different bacteria that can break up the cellulose in the plant's cell wall. The animal then regurgitates the grass by bringing it back into the mouth to chew it over and over again to help the bacteria break down the nutrients. The second stomach (the **reticulum**) is involved in trapping any unwanted things the animal might have swallowed, such as rocks or wire. The third stomach (the **omasum**) has many leaf-like folds that filter the fine particles and water into the fourth stomach (the **abomasum**). It is this last section that contains acid and enzymes, just like a human stomach.

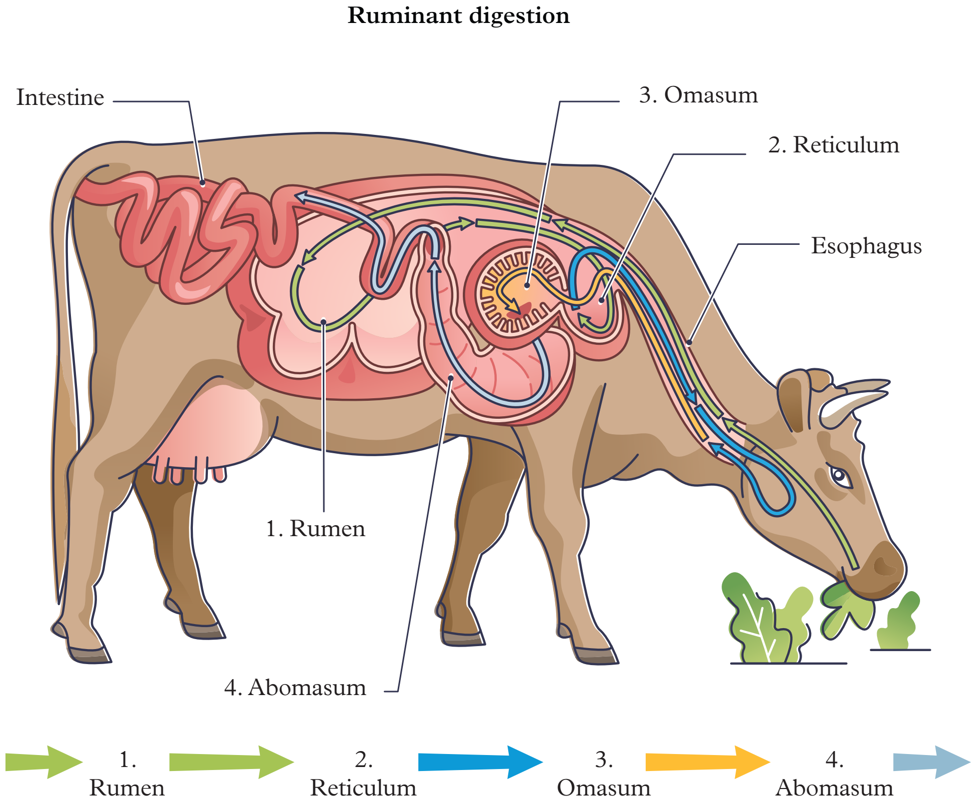


Figure 2 The four stomachs of a cow allow it to digest grass.

Herbivore hindgut fermenters

Hindgut fermenters include horses, rabbits, elephants and koalas. The gut bacteria live in the **caecum**, a dead-end pouch where food is stored until the bacteria can digest it. The caecum is found where the small intestine joins the large intestine (Figure 3). Its location is a problem for the animal, as it means the plant matter is digested after it passes through the small intestine, where most nutrients are absorbed.

caecum a small, dead-end pouch that connects the small and large intestines

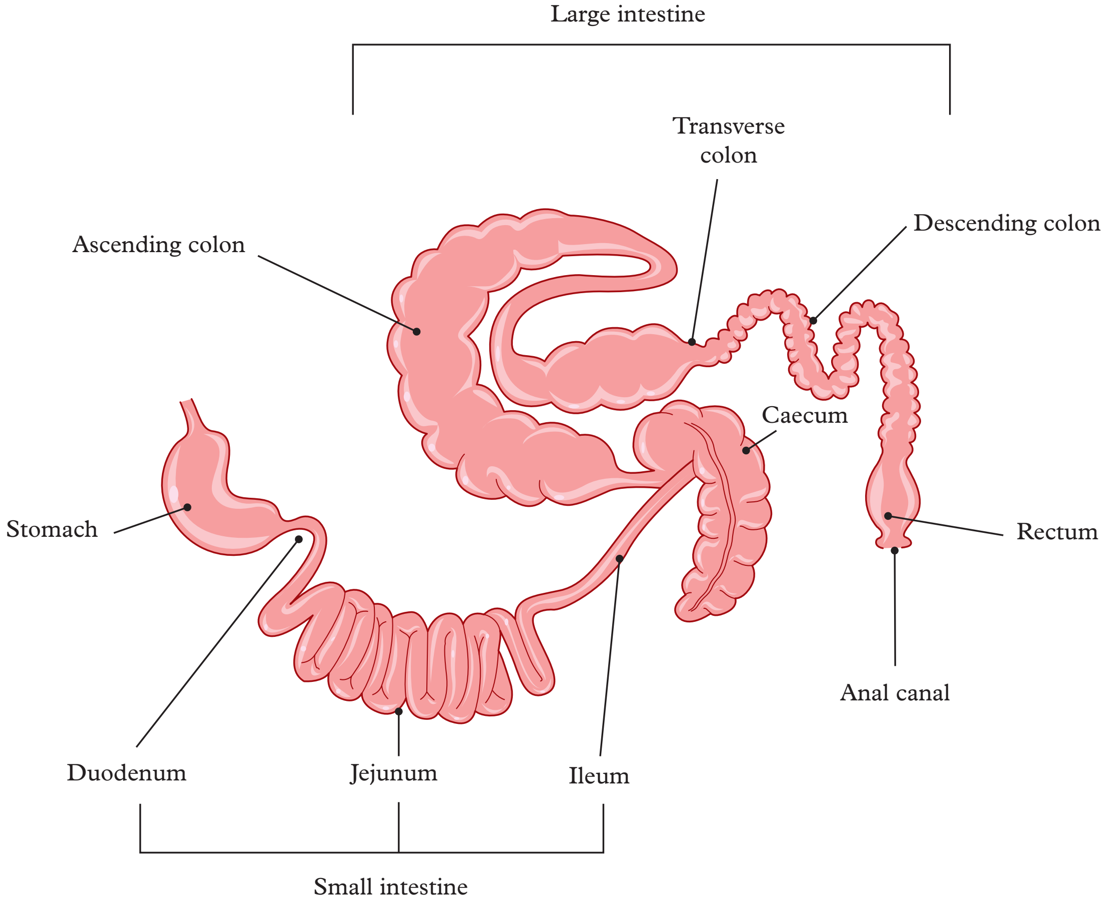


Figure 3 The caecum of a horse is found between the small intestine and the large intestine.

Because the food passes through the digestive tract more rapidly, the extraction of nutrients is less efficient in hindgut fermenters. Many of the good nutrients end up in the faeces. Some animals, such as horses and elephants, obtain the nutrients they need by consuming larger quantities of food; while others, including possums, rabbits and termites, eat their own faeces to get the extra nutrients that may have been missed the first time through.

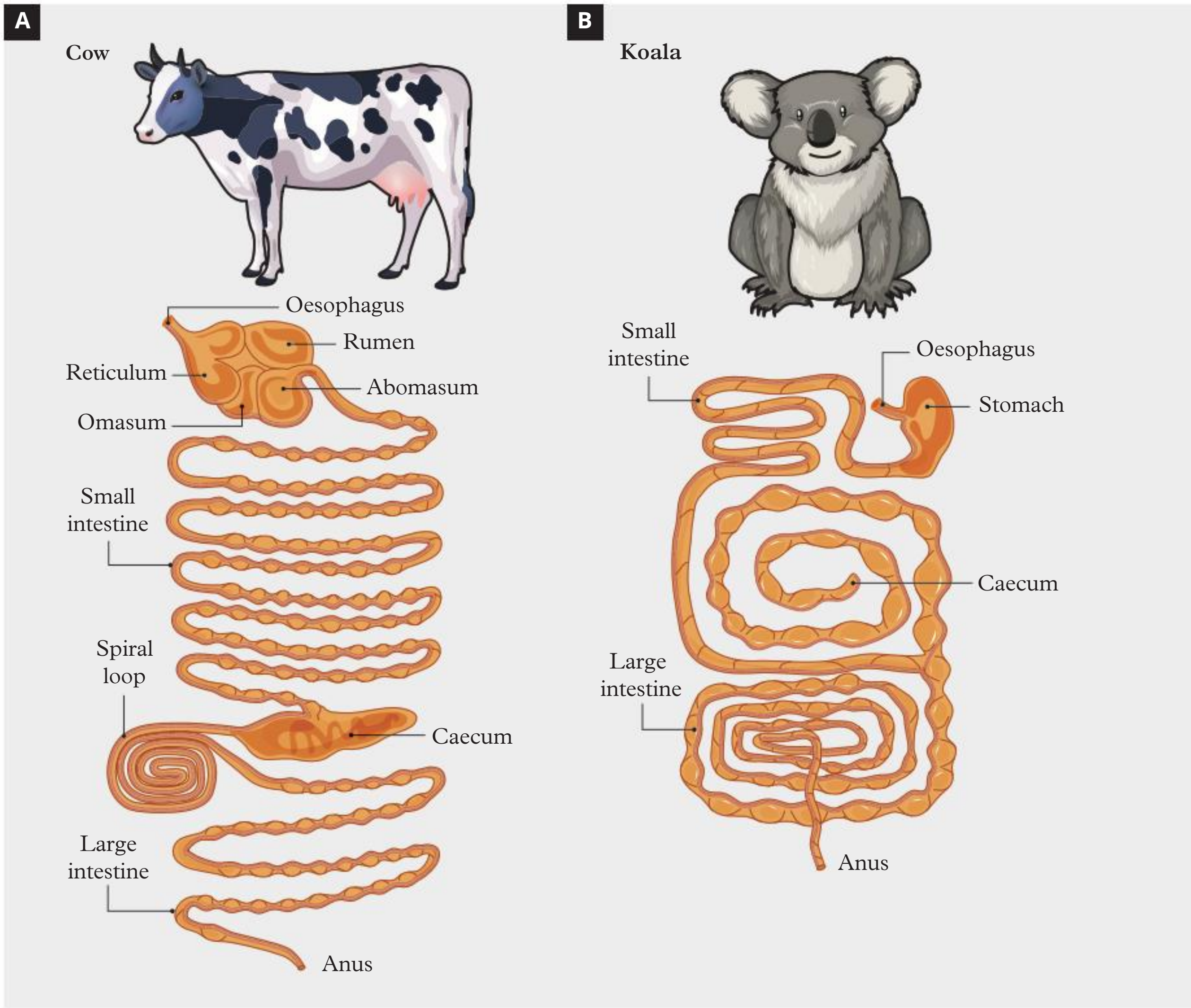


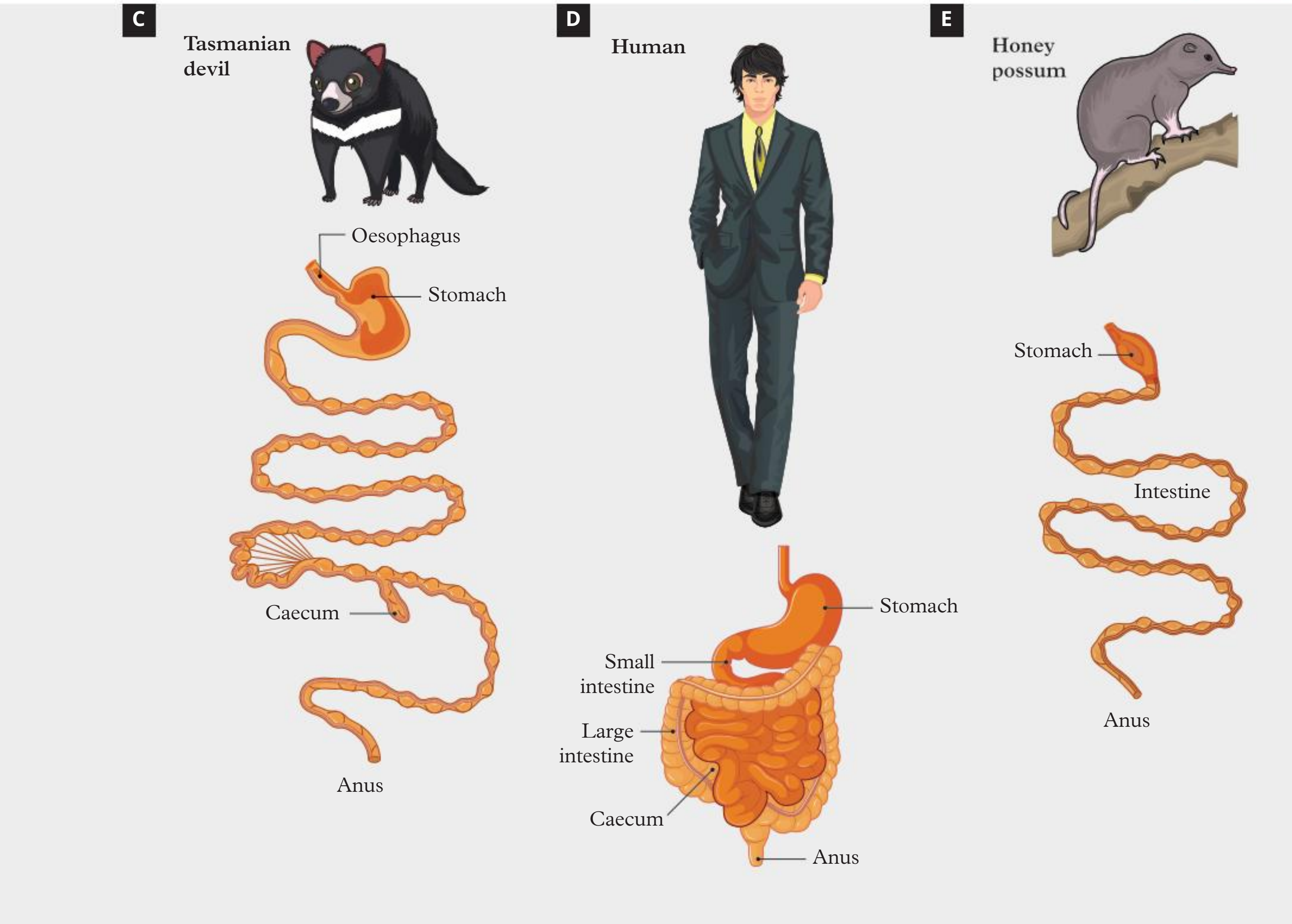
Figure 4 Structural differences in the digestive tract of herbivores, omnivores and carnivores

The koala is another interesting hindgut fermenter (Figure 4B). Their very limited diet of eucalyptus leaves is particularly challenging to break down. Proportionally, at 200 cm long, they have the longest caecum of any animal. Their nutrient-poor diet and the energy required to break down the eucalyptus leaves explain why koalas sleep 20 hours a day!

Carnivore and omnivore digestion

carnivore an animal that eats other animals

The digestive tracts of **carnivores** are simpler than those of herbivores. Because animal cells have no cell wall, meat is easier to digest than a plant-based diet. As a result, carnivores like lions, dingoes and Tasmanian devils have a relatively short digestive tract (Figure 4C). They are more efficient than herbivores at extracting nutrients from their food and therefore spend less time eating through the day. As you might expect, omnivores such as foxes and humans have a digestive tract that sits somewhere between that of herbivores and carnivores (Figure 4D). Because their diet consists of both animals and plants, the overall length of their digestive tract is typically longer than those found in carnivores, and they have a larger caecum to accommodate the bacteria that help them digest the plant-based component of their diet.



Nectar feeders

Although they are feeding off plant-based material, nectar feeders such as the Australian honey possum (Figure 4E) and birds such as spinebills (Figure 5) and wattlebirds have a very short and simple digestive tract with no observable caecum. The sugary nectar they consume from the flowers is extremely easy to digest and is absorbed almost immediately.

Figure 5 The sugary diet of nectar feeders is easy to digest. Examples of nectar feeders include (A) honey possums and (B) spinebills.

Check your learning 8.4

Check your learning 8.4

Retrieve

1 Recall why some animals eat their own faeces.

Comprehend

2 Describe two ways the structure of the digestive system in animals can be different.

3 Explain the function of each of the four stomachs found in a cow.

Analyse

4 Examine the images in Figure 6 of the digestive systems of a carnivore, a herbivore and an omnivore. Correctly label each digestive system according to the animal's diet. Provide evidence from the diagrams to support each of your answers.

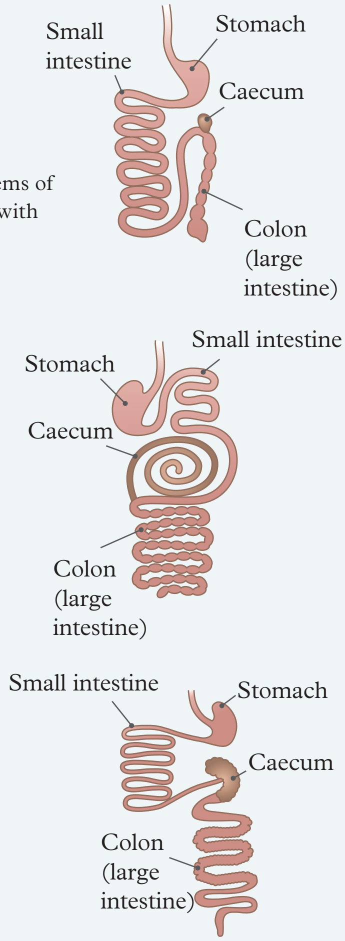


Figure 6 Digestive systems of three animals with different diets

5 Identify the possible diet of the fossils in Figure 7. Provide evidence from the photographs to support each of your answers.

Figure 7 Photographs of fossils

Apply

6 Investigate the digestive system of an animal of your choice. Compare (the similarities and differences between) your selected digestive system and the digestive system of humans. Explain how the structure of your animal's digestive system allows it to digest the food it eats.

Lesson 8.5

Diseases and disorders of the digestive system

Key ideas

- → Peptic ulcer disease is caused by the bacterium *Helicobacter pylori*.
- → Coeliac disease and gluten intolerance are disorders caused by a reaction to gluten.
- → Inflammatory bowel disease (IBD) refers to disorders (Crohn's disease and ulcerative colitis) that cause inflammation and damage to the digestive tract.

Learning intentions and success criteria

Peptic ulcer disease

The terms **disease** and **disorder** are often used interchangeably and often incorrectly. A disease has a known cause and usually quite specific symptoms that cause damage to an organ or organ system. In contrast to a disease, a disorder is associated with an organ system not functioning correctly. An example of a disease is peptic ulcer disease (PUD), which is caused by the bacterium *Helicobacter pylori* and presents with symptoms like frequent burping, bloating and a burning pain in the stomach.

For many years, ulcers (small open sores, Figure 1) in the stomach lining were thought to be caused by too much rich, spicy food and stress. Patients would come to hospital in a lot of pain from the stomach acid burning the other tissue around the ulcer. It was thought that no bacteria could survive in the stomach's acidic environment, so no one considered that bacteria could be the cause of the ulcers.

disease a disorder or condition that interrupts the normal functioning of an organism

disorder a condition that occurs when an organ system does not function correctly; the cause is usually not well understood, and symptoms can vary

Figure 1 A stomach ulcer

Two Australian scientists, Barry Marshall and Robin Warren (Figure 2), noticed that every patient who presented with symptoms of a stomach ulcer also had the bacterium *Helicobacter pylori* present in their stomach. In the early 1980s, they did a series of experiments to show that the spiral-shaped bacteria caused damage to the cells lining the stomach, forming an ulcer. These bacteria can be killed by antibiotics. In 2005, Marshall and Warren were awarded the Nobel Prize in Physiology or Medicine.

Figure 2 Australian scientists Robin Warren (left) and Barry Marshall (right) received a Nobel Prize for their discovery of the cause of stomach ulcers.

Coeliac disease and gluten intolerance

autoimmune disorder a condition in which the immune system mistakenly attacks the body's own healthy cells, treating them as foreign pathogens

A disorder is associated with an organ system not functioning correctly. The specific cause of a disorder is usually not well understood, and symptoms can often be quite different between patients. For example, the poorly named Coeliac disease is in fact an **autoimmune disorder** because it involves a person's own immune system behaving badly when it encounters gluten, a small protein molecule found in many cereals and grains (Figure 3). The body attacks its own small intestine, causing a range of symptoms, including stomach cramps, nausea, vomiting, diarrhoea or constipation. If not controlled, Coeliac disease can cause significant damage to the small intestine and lead to a number of other diseases.

Figure 3 Gluten is found in many types of grains and cereals.

ferments the action of fermentation involving the chemical breakdown of a substance by microflora

Gluten intolerance, also a disorder, presents with similar symptoms to Coeliac disease; however, it occurs because the person does not produce the enzyme required to break down gluten. Instead, the gluten stays in the small intestine and **ferments**, causing symptoms. Once the gluten passes out of the body, the symptoms subside and there are no long-term effects on the body.

Inflammatory bowel disease (IBD)

Inflammatory bowel disease (IBD) is a general term that covers both Crohn's disease and ulcerative colitis, both also considered disorders rather than diseases. A little over 300 in every 100,000 Australians suffers from IBD. Both forms of IBD are characterised by significant inflammation and damage to the digestive tract (Figure 4A). The main differences are that Crohn’s disease can occur anywhere from the mouth to the anus and affects all layers of the digestive tract, while ulcerative colitis only affects the inner lining of the colon (Figure 4B). There is no cure for IBD and if treatments don’t reduce symptoms, surgery is often required to remove the affected part of the digestive tract.

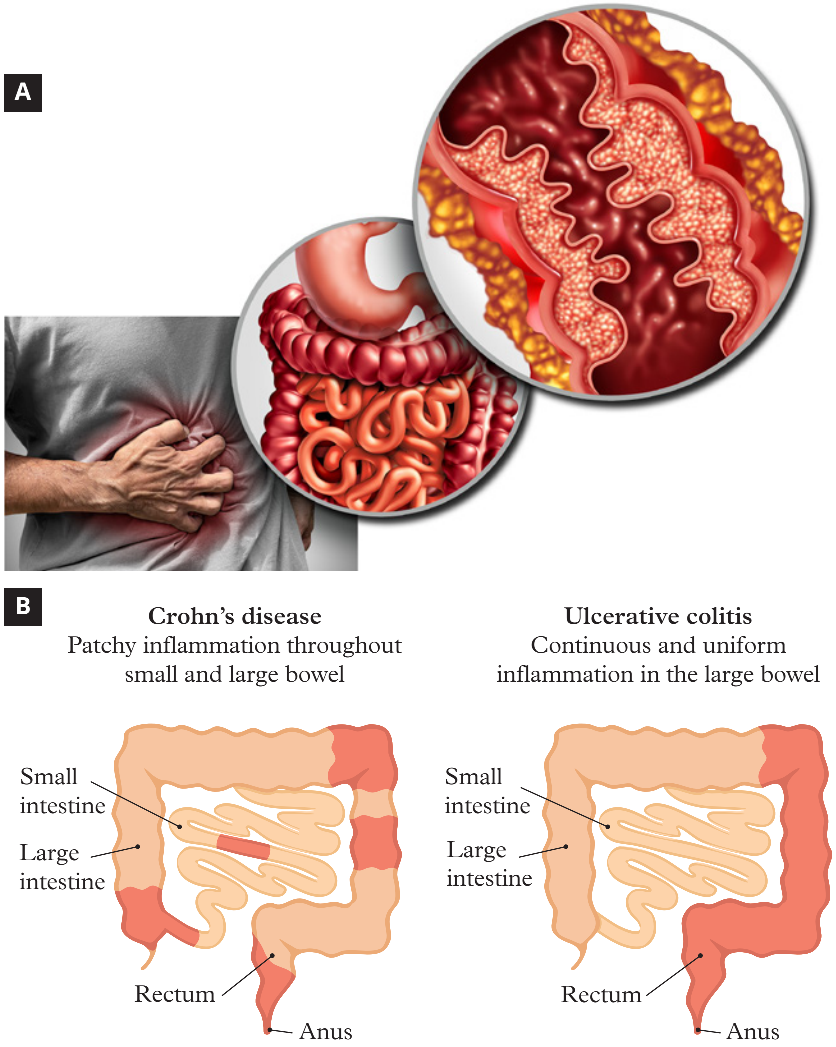


Figure 4 (A) Inflammation of the digestive tract caused by IBD (inflammatory bowel disease); (B) both forms of IBD

Check your learning 8.5

Check your learning 8.5

Retrieve

1 Recall what causes stomach ulcers and how they can be treated.

Comprehend

2 Explain what causes the pain that occurs with a stomach ulcer.

3 Describe a possible solution for Coeliac disease.

Analyse

4 Compare (the similarities and differences between) Coeliac disease and gluten intolerance.

5 Identify one thing that all the diseases and disorders discussed in this topic have in common.

Apply

6 Jarrah often has a sore stomach. Sometimes he needs to leave class in a hurry to go to the toilet. Trung notices that Jarrah often leaves classes that happen after lunch. Propose two possible causes for Jarrah’s pain. Explain why this pain might become worse after eating. Decide which of these two reasons might be the likely cause of the pain and justify your answer.

Lesson 8.6

The circulatory system carries substances around the body

Learning intentions and success criteria

Key ideas

- → The heart pumps the blood around the body.
- → Blood contains red blood cells, white blood cells, platelets, plasma, nutrients and waste.
- → Arteries carry blood away from the heart and veins carry blood back to the heart.
- → Capillaries are thin-walled blood vessels where nutrients and waste move in and out of the blood.

Introduction

The circulatory system is the body's transport system and is responsible for moving **blood** around our body. The heart pumps the blood through the network of **blood vessels**: **arteries**, **veins** and **capillaries** (Figure 1). Different substances including nutrients and wastes are picked up or dropped off at different locations as the blood moves around the body.

blood connective tissue that carries oxygen, nutrients and waste around the body

blood vessel a tube or vessel that carries blood around the body

artery a thick, muscular-walled blood vessel that carries blood away from the heart under pressure

vein a thin-walled blood vessel that carries blood back to the heart

capillaries the smallest blood vessel in the circulatory system; they are thin-walled, allowing for the exchange of oxygen, carbon dioxide, nutrients and waste between blood and surrounding tissues

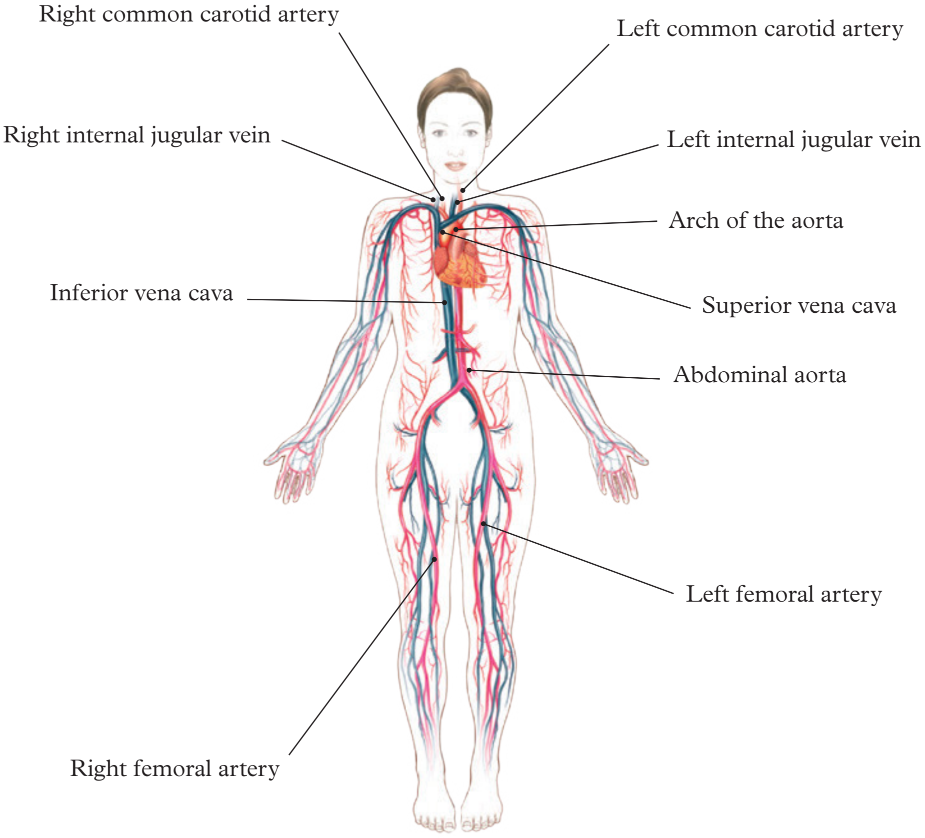


Figure 1 The structure of the circulatory system with key parts labelled

The heart

The heart is a large two-part pump about the size of your fist. It is made of four chambers: two **atria** at the top and two **ventricles** at the bottom. The ventricle on the right of the heart pumps blood to the lungs to “drop off” carbon dioxide and “pick up” oxygen. This oxygenated blood moves back to the left atrium and on to the left ventricle. The left ventricle is more muscular and pumps blood out through the **aorta** at the top of the heart and around the body (Figure 2). Valves are like small gates that prevent the blood from moving backwards.

- Blood is connective tissue containing important cells, liquids and dissolved substances, such as nutrients and waste.
- Oxygen is carried by the **red blood cells** from the lungs to all the cells of the body. Carbon dioxide is dissolved in the **plasma** (the yellowish liquid that is seen at the top of centrifuged blood (Figure 3).
- Nutrients and wastes are also dissolved in the plasma for transport to and from cells.
- **White blood cells** use the blood to travel to places where bacterial cells that cause infection are growing. The white blood cells then kill the bacterial cells.
- **Platelets** are small, cell-like packages that burst when exposed to breaks in the blood vessels. After the platelets burst, they fill the hole and glue the edges together.

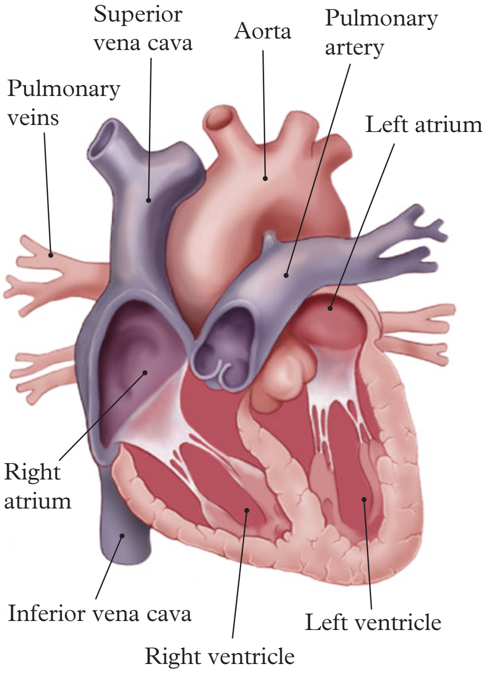


Figure 2 This diagram shows the heart and some of the major blood vessels that travel to and from the heart. The diagram uses a common convention that shows the veins in red and the arteries in blue.

atria the two smaller, upper chambers of the heart

ventricles the two large, lower chambers of the heart

aorta the major artery that carries oxygenated blood from the heart and divides into smaller arteries around the body

red blood cell cell in the blood that carries oxygen around the body

plasma a straw-coloured fluid that forms part of the blood

white blood cell an immune system cell that destroys pathogens

platelets small, disc-like cells in blood that are involved in forming clots

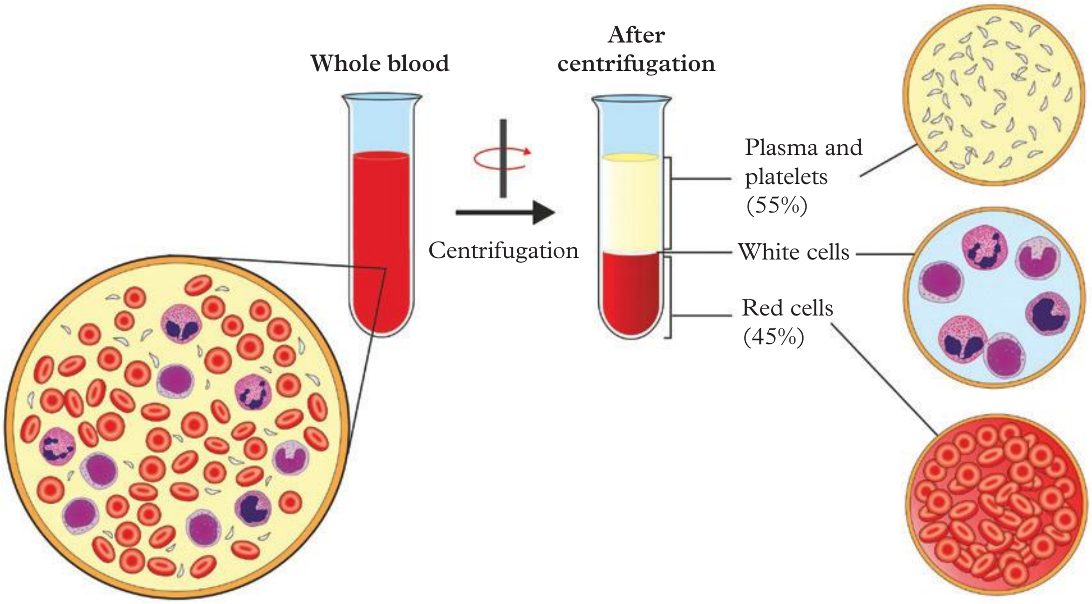


Figure 3 Different components of blood

Blood vessels

Blood travels through tubes called blood vessels (Figure 4). Blood vessels have different sizes and structures depending on the amount of blood they need to carry, as well as the speed of the blood and whether it is picking up or dropping off substances.

Arteries are the largest blood vessels and carry blood away from the heart. They have thick, muscular walls to cope with the higher pressure of the blood that has just been pumped by the heart. As the blood moves further away from the heart, the arteries branch into **arterioles** (smaller arteries).

arteriole smaller artery

Capillaries are possibly the most important of the blood vessels. Their walls are only one cell thick to allow substances to pass easily in and out of the blood. Capillaries connect the arteries and veins. They are sometimes referred to as a capillary bed when they are in large numbers surrounding an organ.

Veins carry blood back to the heart to be pumped elsewhere. These vessels are similar in size to arteries but only have a small amount of muscle in their walls. To avoid any blood going backwards due to a lack of pressure, veins contain one-way valves.

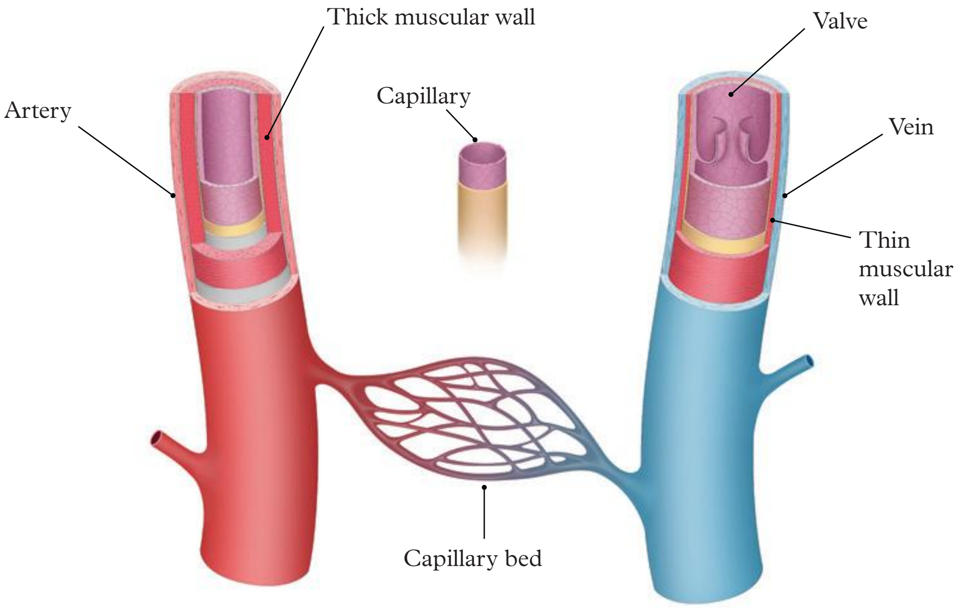


Figure 4 The main types of blood vessels are arteries, veins and capillaries.

Other circulatory systems

Not all organisms have large, organised circulatory systems. Smaller organisms such as hydra (1 to 2 mm long) spend life surrounded by water. They do not have a heart or blood vessels. Instead, gases diffuse in and out of the organism's cells. Other nutrients are partially digested in its small, tube-like stomach, which has one opening, and absorbed directly into the cells.

Insects have open-ended tubes that take in circulation fluid at the back of the organism and small heart-like pumps that push the fluid forward to the brain. The fluid then leaves the tube and moves freely around the open cavity until it enters the open-ended tube once more. Other organisms such as the octopus have three hearts to control the movement of all the substances in their body.

Check your learning 8.6

Check your learning 8.6

Retrieve

1 Recall the function of red blood cells, white blood cells and platelets.

Comprehend

2 Use diagrams to illustrate how the three blood-vessel types differ in their structure and function.

3 Use Figure 2 to describe the path a red blood cell takes as it moves through the body from the heart.

4 Rewrite your answer to question **3**, adding the names of the veins and the arteries involved.

Analyse

5 Identify the body system that supplies the nutrients that the circulatory system moves around the body.

Apply

6 Instead of the blood travelling directly from the lungs to the rest of the body, the blood returns to the heart first. Discuss one advantage of the blood returning to the heart before moving around the body.

Lesson 8.7

Skills lab: Heart dissection

Aim

To explore the structure and function of a heart

Materials

- Sheep, cow, ox or pig heart
- Scalpel
- Dissecting probe and forceps
- Newspaper (for dissecting and disposing of heart)

Method

1 Lay some newspaper out on your bench. Examine the outside of the heart and identify the left and right sides. Your fingers will work better than a probe for that.
2 Use your fingers to feel the right side of the heart. Compare the thickness of the right and left sides. Feel the muscle in the centre of the heart.
3 Using a scalpel, cut open the right atrium and right ventricle. Pull back the wall and look inside to see the atrium and the ventricle. The ventricle is the chamber closest to the pointed end of the heart. The white tendons hold the valves in place.
4 Push a dissecting probe or your finger out through the artery leading from the right ventricle.
5 Cut open the left side of the heart. Locate the atrium, ventricle and tendons holding the valves.
6 Push a dissecting probe or your finger out through the artery leading from the left ventricle.

Figure 1 Identify the right and left sides of the heart.

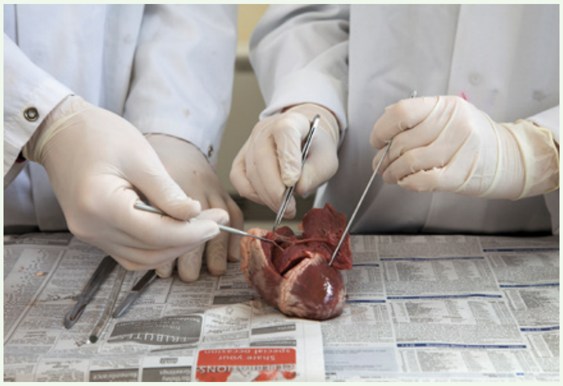


Figure 2 Compare the thicknesses of the right and left ventricles.

Results

Include labelled diagrams and observations here.

Questions

1 Identify the name of the artery from Step 4.
2 Identify the name of the artery from Step 6.
3 Compare the thickness of the artery wall with the thickness of the vein wall.
4 Compare the thickness of ventricle walls with the thickness of arterial walls.
5 Explain the difference between the left and right ventricle walls.

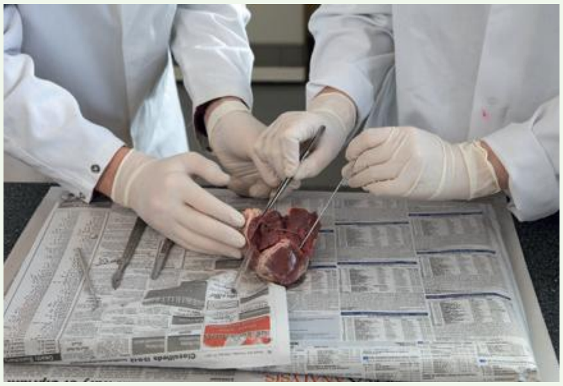


Figure 3 Use the dissecting probe to identify the arteries.

Conclusion

Explain what you know about the structure and function of the heart.

Figure 4 Identify the artery leaving the left ventricle.

Lesson 8.8

Diseases and disorders of the circulatory system

Key ideas

→ Damaged valves can affect the one-way direction of blood flow.

→ Atherosclerosis describes the narrowing of the blood vessels as a result of plaque.

→ Coronary heart disease is caused by blockages in the blood vessels in the heart muscle.

→ Pericarditis occurs when the pericardium sac surrounding the heart becomes infected.

Learning intentions and success criteria

Valve disease

The heart has a series of valves that prevent the blood from flowing backwards (Figure 1). You may have heard a "lub-dub" sound when you listen to your heart. When the atrium contracts, the ventricle fills with blood. The valve between the atrium and ventricle closes (causing the "lub" sound) which prevents the blood from flowing backwards. When the ventricle contracts, the blood is forced to flow out of the heart and into the aorta. The valve between the ventricle and the aorta then closes (the "dub" sound), keeping the blood in the large artery. Now the blood can only enter from the veins again.

Sometimes these valves become damaged. They may become narrowed from scarring (stenosis), leak (regurgitation or insufficiency) or not close properly (prolapse). This prevents the blood from flowing properly around the body. As a result, less oxygen and fewer nutrients get carried to the cells for energy. This makes the person feel very fatigued and tired all the time.

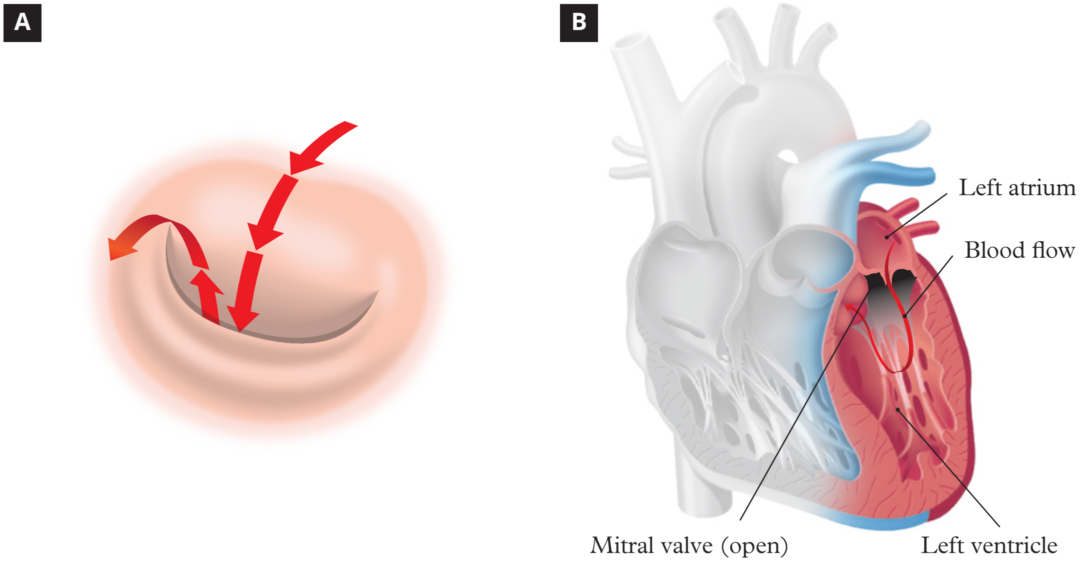


Figure 1 (A) The heart valve opens to allow blood to flow from the atrium to the ventricle. (B) Closing of the valve prevents the backflow of blood so that it can be pumped effectively around the body.

Atherosclerosis

artery a thick, muscular-walled blood vessel that carries blood away from the heart under pressure

Atherosclerosis is a disease that results from the narrowing of the blood vessels. This narrowing is caused by a build-up of plaque on the inside of the **arteries** and veins (Figure 2). Plaque consists of fat, cholesterol and other substances normally found in the blood. Layers of plaque are laid down over time, eventually hardening and restricting the blood flow. The symptoms depend on the part of the body affected by the narrowed blood vessel. If the blood vessel is in the heart, then a heart attack will follow.

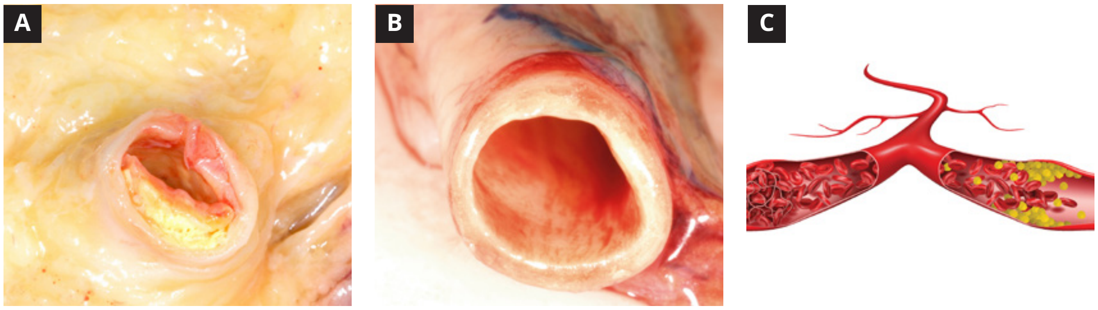


Figure 2 (A) A blocked artery; (B) an unblocked artery; (C) a healthy (left) versus atherosclerotic artery (right)

Coronary heart disease

A heart attack is usually caused by coronary heart disease, which is fatty deposits blocking important blood vessels in the heart. "Coronary" refers to the heart's own blood vessels. The "attack" occurs when the vessels become completely blocked or when a bit of the fatty deposit breaks off and travels into the heart. Heart muscle cells may be killed in the process (Figure 3).

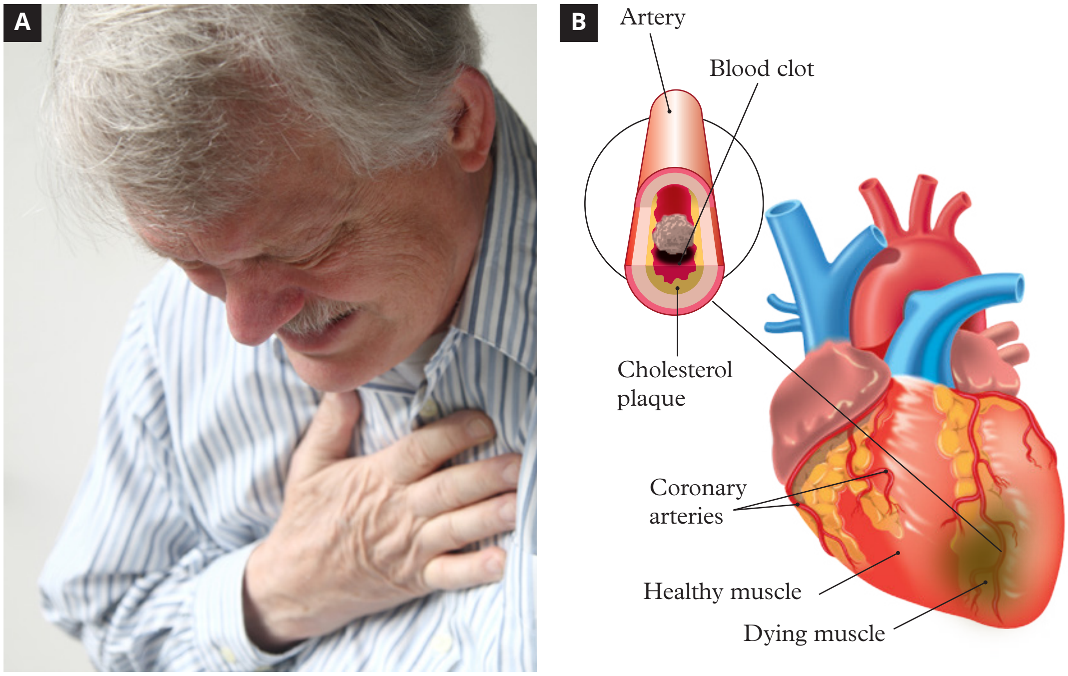


Figure 3 (A) Chest pain is often caused by (B) a blockage in the heart's own blood vessels.

So how can we keep our heart healthy? Eating less processed, fatty food is a really good start, but it's not the only thing we can do.

The heart is a muscle, and like all muscles, it needs exercise to keep it strong. Regular exercise is all it needs (Figure 4). In people who are overweight or who smoke cigarettes, the heart needs to work much harder to do the same job. This is stressful for our heart. Elite athletes work their bodies very hard, so they need to make sure they have their hearts checked regularly by a doctor.

Figure 4 Exercise can help keep the heart healthy and strong.

Pericarditis

The pericardium is the thin sac that surrounds the heart and helps it move easily when it beats (Figure 5). It reduces friction when the heart beats. Sometimes this thin layer of cells can become infected by bacteria, causing the sac to fill with fluid – a condition known as pericarditis. As a result, the heart cannot beat properly. This restricts the heart from properly filling with blood. Antibiotics are needed to help kill the bacteria so that the heart can start functioning again.

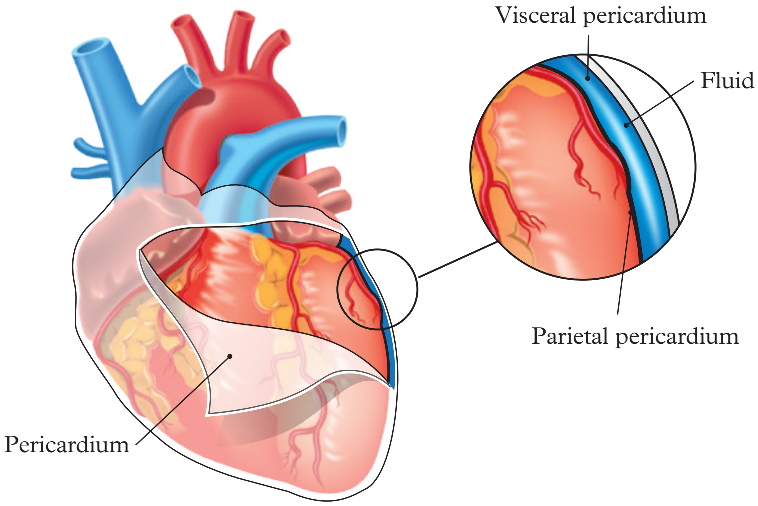


Figure 5 The pericardium reduces friction in a beating heart.

Check your learning 8.8

Check your learning 8.8

Retrieve

1 Identify what causes the "lub-dub" sound you hear when you listen to your heart.

2 Recall the cause of the following valve conditions:
  - **a** stenosis
  - **b** regurgitation or insufficiency
  - **c** prolapse.

3 Recall the function of the pericardium sac that surrounds the heart.

4 Identify two things you could do to ensure your circulatory system stays healthy.

Comprehend

5 Explain the link between atherosclerosis and coronary heart disease.

6 Explain why the heart muscle becomes damaged during a heart attack.

7 Describe how the function of the pericardium is affected when it fills with fluid during an infection.

Lesson 8.9

The respiratory system exchanges gases

Learning intentions and success criteria

Key ideas

→ The respiratory system is the body system responsible for breathing.

→ Air is inhaled down the trachea, the bronchi and the bronchioles into the alveolar sacs and eventually into our blood.

→ Our lungs breathe in oxygen to be used by our cells for energy and they breathe out carbon dioxide as waste.

Why do we need oxygen?

The respiratory system makes sure that every cell in our body gets the oxygen it needs. Why do cells need oxygen? Most of the food we eat is broken down to glucose, a simple sugar. Oxygen is needed to release energy from glucose.

This process is called **cellular respiration**. It is a chemical reaction in which glucose and oxygen are converted to carbon dioxide, water and energy. This energy is then used for all the jobs cells need to perform, from making and breaking down substances to making new cells.

cellular respiration the chemical reaction between glucose and oxygen that produces carbon dioxide, water and energy

You can see why people get confused about the difference between breathing and respiration. "Cellular respiration" is the chemical process that happens in cells, and "breathing" is the inhalation (breathing in) of oxygen and exhalation (breathing out) of carbon dioxide by your lungs and other organs in the respiratory system.

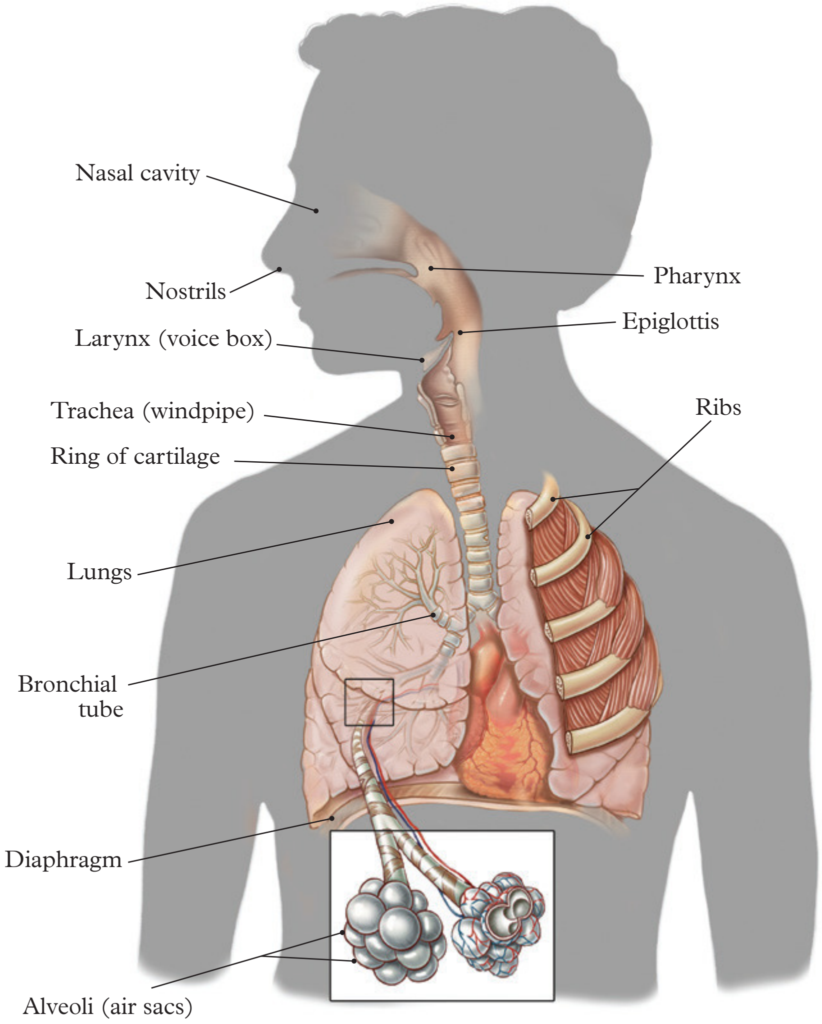


Figure 1 The structure of the respiratory system

Where does the air go?

We breathe air in through our nose and mouth. Any dust and pollens we breathe in are trapped by hairs and wet surfaces as the air travels to our throat or **pharynx**. At the bottom of the pharynx is a trapdoor called the **epiglottis** that controls the passage of food and air. Food goes down the oesophagus to the stomach. Air goes down the **trachea** to the lungs (Figure 1).

epiglottis a flap of skin above the larynx that controls the passage of food and air, preventing food from entering the windpipe

pharynx the throat; connects the mouth to the oesophagus

trachea the large tube that connects the throat to the bronchi; carries air in and out of the body

The lungs

bronchi large tubes branching from the trachea into each lung, helping to carry air, and trapping dust and germs with mucus and cilia

bronchioles small, thin-walled air passages in the lungs that branch off from the bronchi

alveoli tiny sacs in the lungs for gas exchange, allowing oxygen to enter the blood and carbon dioxide to be expelled

gas exchange is the process by which oxygen (O_2) is taken from the environment into the bloodstream, and carbon dioxide (CO_2) is expelled from the bloodstream into the environment

We have two lungs in our chest that expand and fill with air whenever we take a breath. The trachea splits into two **bronchi** which further branch into smaller tubes called **bronchioles**, which connect to tiny air sacs known as **alveoli**. The lungs feel spongy to touch because they are home to millions of these alveoli. If these air sacs were unravelled and flattened, the lungs would have a surface area of approximately half the size of a tennis court. Each tiny alveolus (a single alveoli) is covered by a mesh of capillaries that allows for efficient **gas exchange**, where oxygen moves into the blood, and carbon dioxide (the waste product of cellular respiration) moves out of the blood (Figure 2).

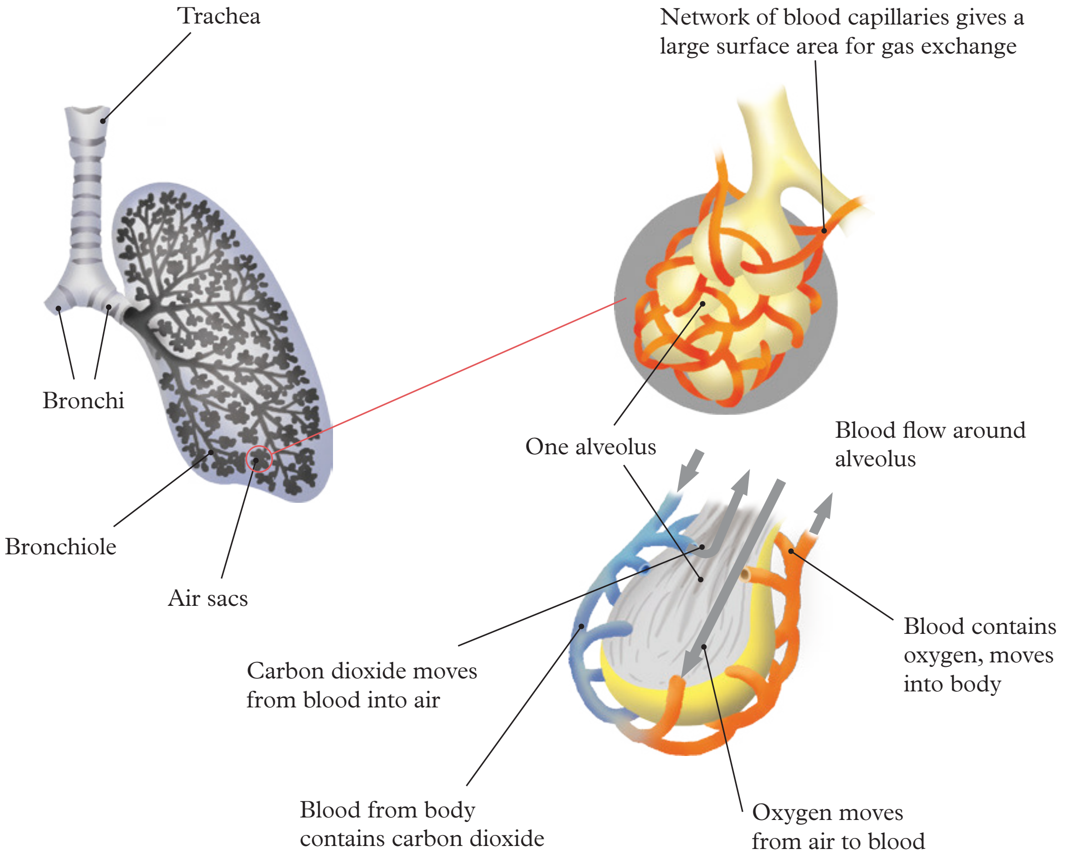


Figure 2 Gas exchange takes place in the alveoli.

The diaphragm

diaphragm a dome-shaped muscle attached to the ribs; moves up and down beneath the lungs

The **diaphragm** is a dome-shaped muscle that is attached to our ribs and moves up and down beneath our lungs. This muscle contracts down and relaxes up. The diaphragm also separates the heart and lungs from the stomach and digestive system. The lungs have no muscle tissue, so they cannot move on their own. Every time we breathe in, the muscles in the diaphragm and between the ribs work together to expand (make our chest larger). As the chest expands, the lungs also expand, pulling air in. When the muscles relax, the chest and lungs become smaller, allowing the air to move out again (Figure 3).

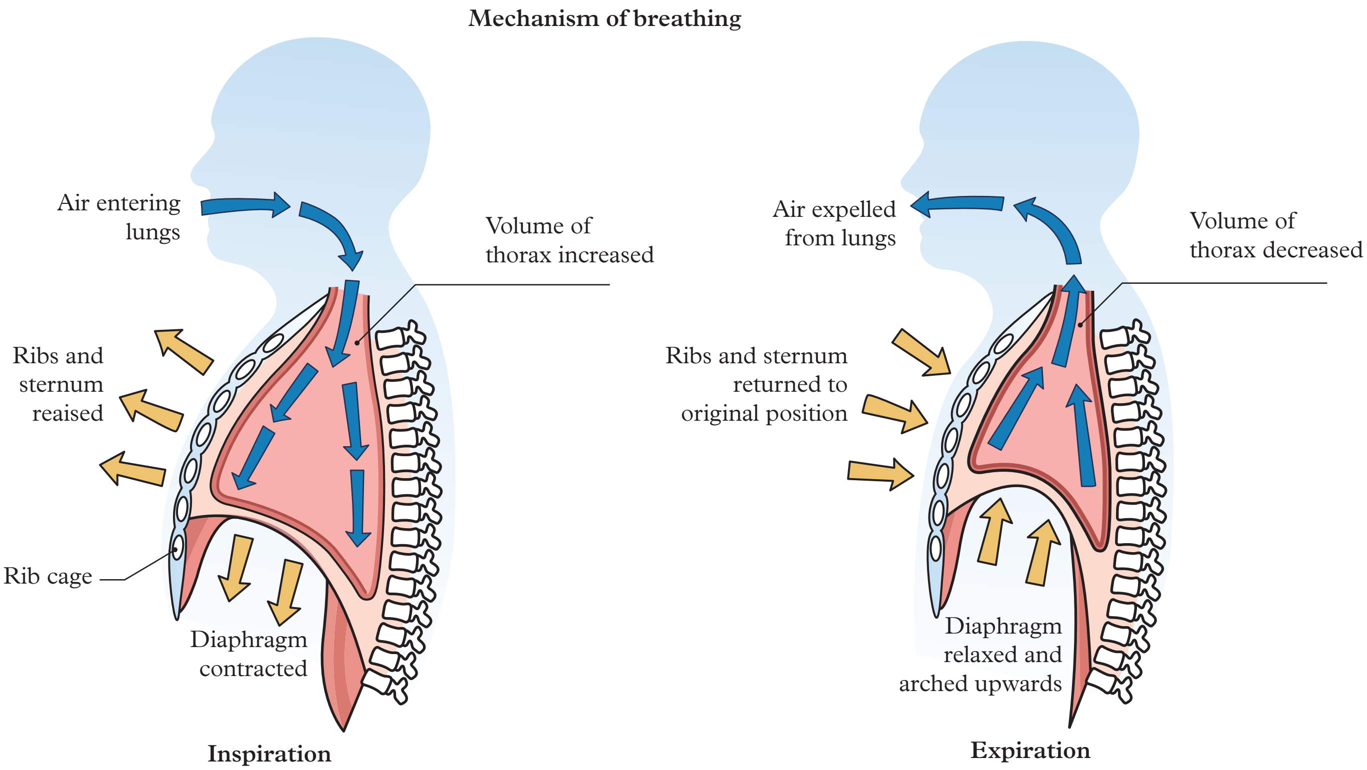


Figure 3 Relaxation and contraction of the diaphragm controls the movement of air in and out of the lungs.

Other respiratory systems

As we learnt in Module 5 Classification (page 204), all living organisms exchange gases. The lungs in many animals, including mammals and birds, provide a large surface for oxygen to move into the blood and for carbon dioxide to move out.

Other organisms have this gas exchange surface on the outside of their body. The gills of fish have water passing over a large surface area, allowing oxygen in the water to be absorbed into the blood of the fish and carbon dioxide to be removed. This water must constantly be replaced so that the fish have a fresh supply of oxygen.

The main gas exchange surface of most amphibians, such as frogs, is their skin. This is why they must always be near water because the skin needs to be kept moist and clean to maximise gas exchange.

Check your learning 8.9

Check your learning 8.9

Retrieve

1 Define the term "gas exchange".

2 Gases constantly move in and out of the blood into the lungs. Identify the gases that move in and out of the respiratory system.

3 Recall the role that the epiglottis plays in the respiratory system.

Comprehend

4 Draw a simple diagram showing how air travels down from the mouth and nose to the alveoli at the end of the branches of the bronchioles.

5 Describe the sequence of steps in breathing in and breathing out.

6 Explain the advantage that the large surface area of the alveoli gives to oxygen needing to pass into the blood.

Apply

7 Discuss why we need to breathe.

Skills builder: Problem solving

8 Copy and complete the cause-and-effect table (Table 1). (THINK: How does the respiratory system function?)

Table 1 Cause-and-effect

Cause	Effect
	A person chokes on food in their trachea.
A person's diaphragm is not working properly.	

Lesson 8.10

Diseases and disorders of the respiratory system

Learning intentions and success criteria

Key ideas

→ Asthma causes the bronchi and bronchioles to become smaller.

→ Emphysema is caused by broken-down alveoli, which prevent oxygen from entering our blood.

→ Pneumonia is an infection that fills our lungs with fluid and blocks the flow of gases.

→ Asbestosis is a chronic lung disease caused by asbestos exposure, while mesothelioma is an aggressive cancer linked to asbestos that affects the lining of the lungs or abdomen.

Asthma

Asthma is quite common in our population, affecting more than one in ten Australians. Asthma usually starts when something in the environment irritates the airways. This causes the bronchi and bronchioles to narrow, making it harder for air to move into the lungs (Figure 1). When this happens, it is hard to breathe. Asthma attacks can be reversed by drugs, such as Ventolin, that relax and open the airways (Figure 2).

asthma a disease caused by narrowing airways

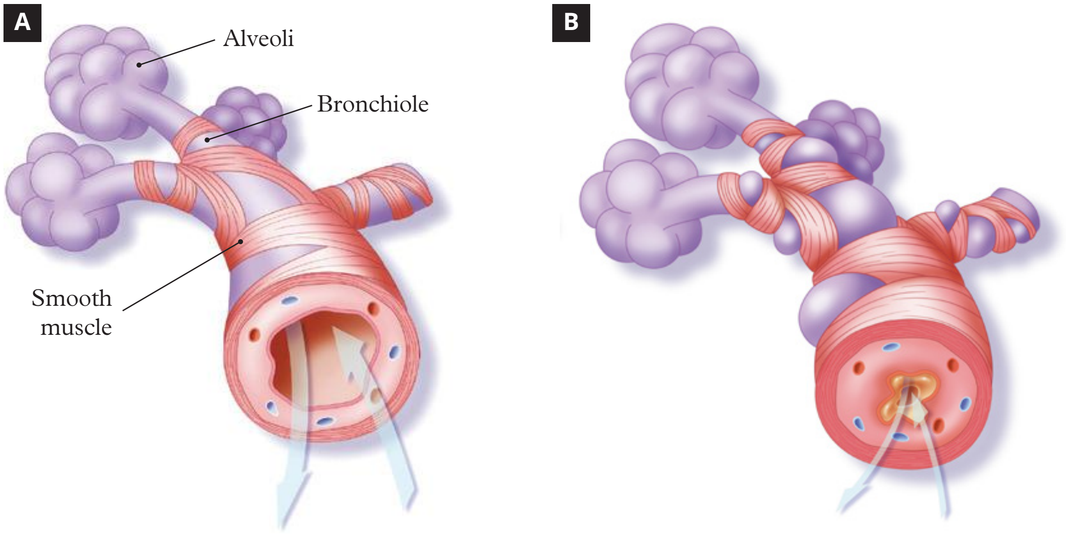


Figure 1 Asthma causes the bronchioles to become narrow: (A) normal airway; (B) asthmatic airway

Figure 2 Ventolin is commonly used to control asthma attacks (blue). It is inhaled through the mouth and nose. Other drugs can also help to prevent asthma (red).

Emphysema

Smoking cigarettes involves breathing toxic chemicals and tar into your lungs (Figure 3B). The tar is thick and sticky like honey, covering the inside of the alveoli and stopping oxygen from moving into the blood. The toxic chemicals kill the cells lining the lungs, destroying the alveolar sacs. They can also travel via the circulatory system and cause harm elsewhere in the body. **Emphysema** is a disease that is caused by the inability of the collapsed alveoli to move air in and out. A person with emphysema struggles to breathe in enough oxygen, making it extremely difficult to perform basic activities like walking even 20 metres. They are also much more prone to chest infections.

emphysema a disease caused by broken-down alveoli in the lungs

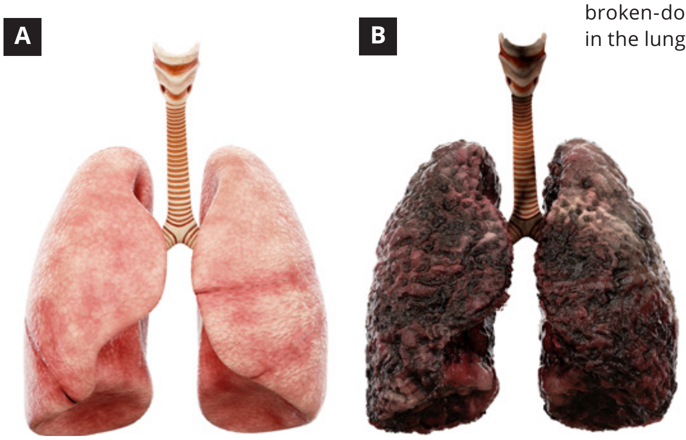


Figure 3 (A) Healthy lungs; (B) a smoker's lungs

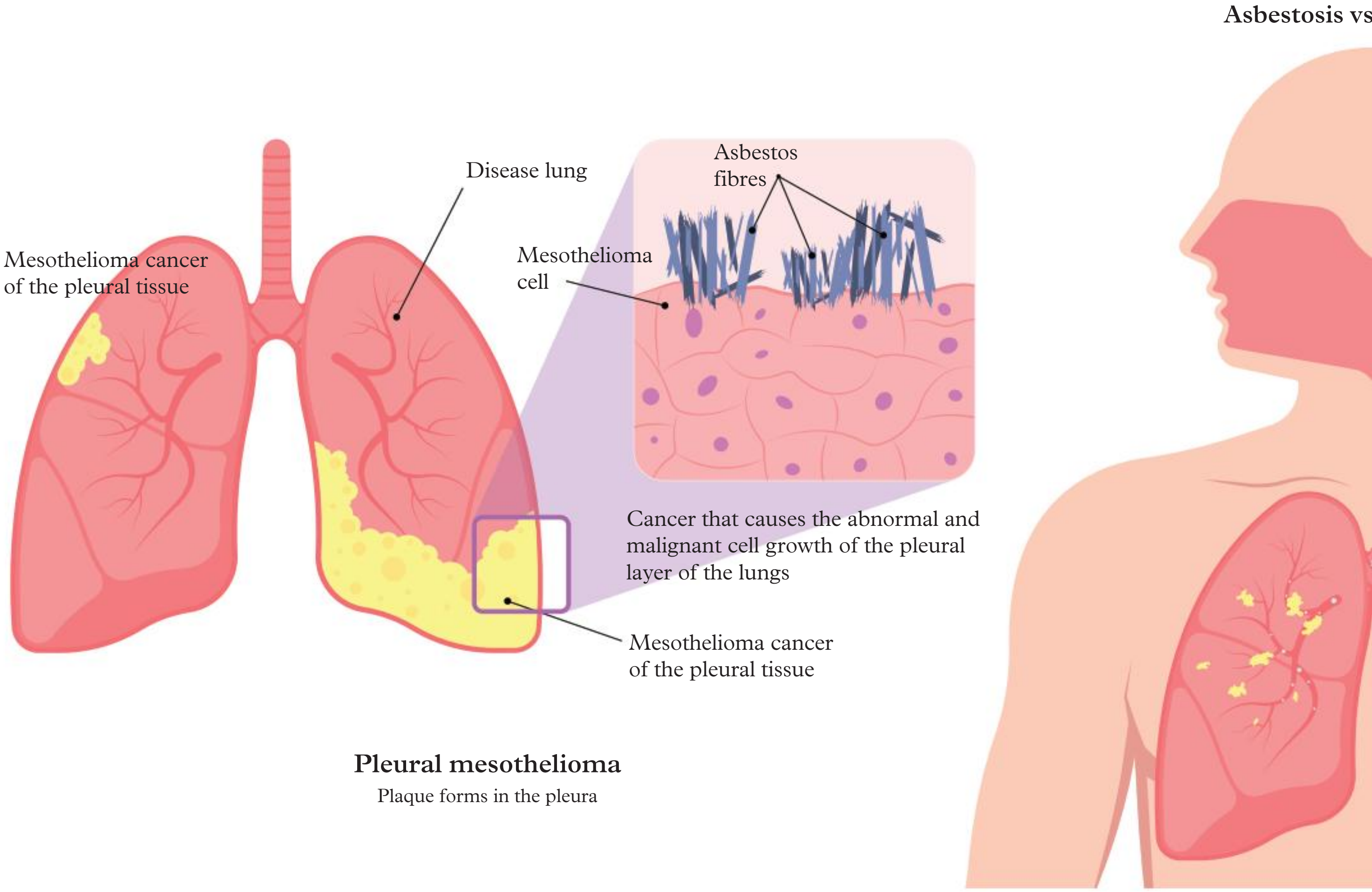


Figure 4 Mesothelioma and asbestosis are life-threatening diseases that affect the lungs.

Pneumonia

pneumonia a disease caused by bacterial or viral growth in the lungs

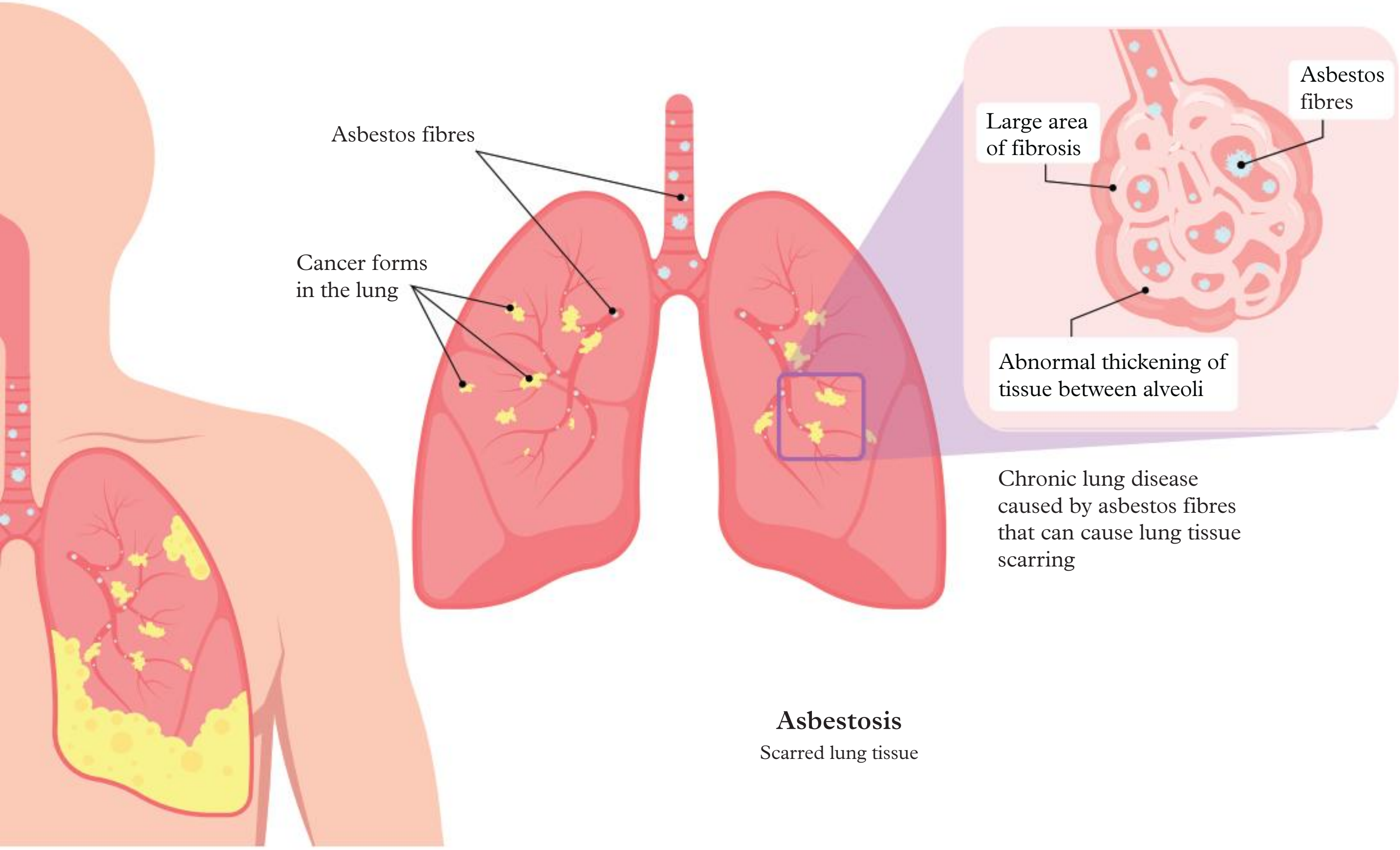
Pneumonia is caused by a bacterial or viral infection in the lungs. The alveoli in the lungs fill up with bacteria, pus and fluid. This prevents air moving into the lungs, which can cause organ failure and even death in some cases if left untreated. Anyone can contract pneumonia, but it tends to be most common in young children and the elderly. A short course of antibiotics (drugs that kill bacteria) can clear the lungs again, allowing the person to breathe.

Asbestosis and mesothelioma

Asbestos is a mineral that was used widely in construction during the 1900s. When asbestos was linked to several life-threatening diseases – including mesothelioma, lung cancer and asbestosis – building materials that contained asbestos were phased out, and a total, Australia-wide ban occurred in 2003. Despite the ban occurring over 20 years ago, an estimated 4,000 Australians still die each year from asbestos-related diseases. This is because it can take up to 50 years after exposure for symptoms to present.

Asbestosis occurs when asbestos fibres lodge in the lungs and cause permanent thickening and scarring of the lung tissue. This destroys the affected alveoli, making breathing difficult.

mesothelioma



Chronic lung disease caused by asbestos fibres that can cause lung tissue scarring

Asbestosis

Scarred lung tissue

Mesothelioma is an aggressive type of cancer that results from asbestos fibres sticking to the protective layer (mesothelium) of the lungs. The asbestos fibres disrupt cell activity of the mesothelium cells and lead to uncontrolled cell division (cancer), which can quickly spread to other organs.

Check your learning 8.10

Check your learning 8.10

Retrieve

1 Identify the primary cause of emphysema.

2 Distinguish between asbestosis and mesothelioma.

Comprehend

3 Describe what happens in the lungs during an asthma attack.

4 Describe one health risk some people take with their lungs and the consequences of this risk.

Analyse

5 Contrast (the differences between) the changes in the lung for emphysema and pneumonia.

6 Infer why people with pneumonia feel tired all the time.

Apply

7 Investigate the purpose of coughing and sneezing as they relate to keeping the lungs healthy.

Lesson 8.11

Skills lab: Measure your lung capacity

Caution

Tubing or bendy straws must be discarded after a single-person use.

Aim

To measure the capacity of a person's lungs

Materials

- Large 5 L drink container with single litres marked
- Access to a large sink or tub
- 1 m of tubing or bendy straws

Method

1. Place 10 cm of water in the bottom of a sink.
2. Fill the large drink container with water.
3. Tip the full container of water upside down into the sink so that the opening is submerged. This will prevent the water from leaving the container.
4. Place one end of the tubing under the opening of the container.
5. Take a deep breath and blow as much as you can into the tubing. As you blow air through the tubing into the upturned container, the water should be pushed out the bottom.
6. Measure how much air you can blow out of your lungs into the container.
7. Repeat the measurement two more times.

Questions

1. Explain why the experiment needs to be repeated three times.
2. Identify two factors that could reduce a person's lung capacity.
3. Compare your results with those of other students in the class. Identify any relationship between the height of the person and their lung capacity.

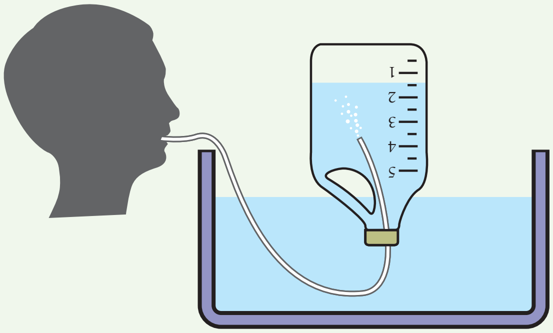


Figure 1 Experimental set-up

Lesson 8.12

Investigation: Fish dissection

Purpose

To identify the respiratory organs in a fish

Materials

- A fish (complete with internal organs) from a fishmonger or market
- Dissection tools
- Dissection board
- Newspaper (for dissecting and disposing of fish)

Part A

Procedure

Lay newspaper out on your board. Use your dissection skills to open the abdomen and head of the fish and record your observations of the internal organs, using labelled diagrams.

Discussion

1 Identify whether the systems are clearly separated or intertwined.

2 Compare the colour (dark red, light red or white) of the different organs.

3 Explain how an organ's blood supply could affect its colour.

4 Explain how the amount of blood supplied is related to an organ's importance.

Part B

Procedure

Identify and remove the gills of the fish. Reflect on the significant features of our lungs that make them such effective gas exchange organs.

Discussion

1 Compare the structure of fish gills to the structure of lungs in a mammal (for example, a human).

2 Compare the function of fish gills and mammalian lungs.

3 Explain how the structure of fish gills allows them to function effectively.

Figure 1 Removing the gills from a fish

Lesson 8.13

The excretory system removes waste

Learning intentions and success criteria

Key ideas

→ The liver helps rid the body of nitrogen.

→ The kidneys filter blood to remove waste, which is excreted as urine.

→ Sweating releases waste products from the body through the skin.

Introduction

Our cells and our bodies create waste products that need to be removed. The process of removing wastes is called **excretion**. The organs of the excretory system are the kidneys, liver, lungs and skin (Figure 1).

The nutrients that our cells require are absorbed by the digestive system and delivered by the circulatory system. Cells use these nutrients in a series of chemical reactions called **metabolism**. Some of the chemical products produced during metabolism are toxic and need to be excreted (removed) from the body. Water is also important for controlling waste because it can dilute harmful substances and their effects.

metabolism all the chemical reactions in the body

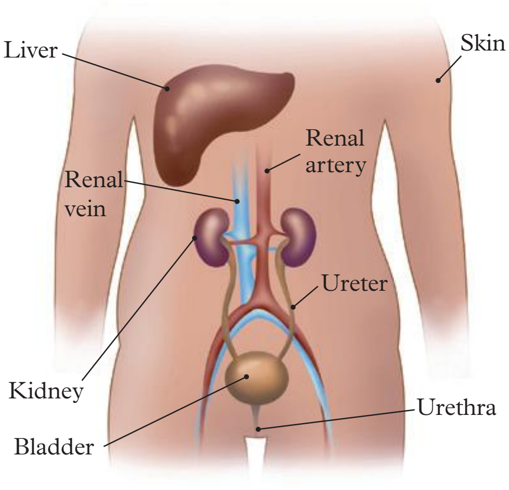


Figure 1 The structure of the excretory system, with key parts labelled

The liver

Molecules containing nitrogen are among the most toxic products in our body. When our body digests nitrogen-containing proteins, it breaks them down into smaller molecules called **amino acids**, which are the building blocks of proteins. The body cannot store the amino acids that it doesn't use immediately. Our liver (Figure 2) breaks down these amino acids (and many other chemicals) into less dangerous substances. When the liver breaks down

amino acids small molecules that are the building blocks of proteins

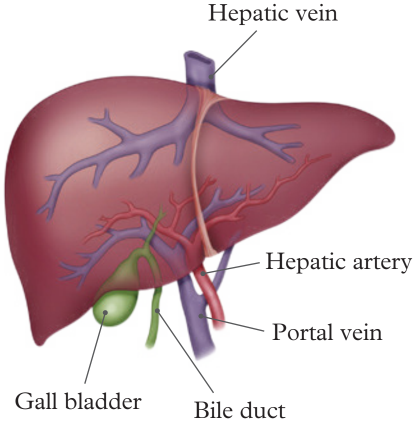


Figure 2 The structure of the liver, with key parts labelled

the nitrogen-containing amino acids, it produces a very toxic substance called **ammonia**. The liver then uses energy to change the ammonia into a safer substance called **urea**, which is filtered by the kidneys for removal in the urine.

The liver is also responsible for the excretion of **bile**, which is then stored in the **gall bladder**. Bile assists in the removal of waste products after they have been metabolised in the liver and in the breakdown of fats in the small intestine during digestion.

ammonia a chemical waste product (NH_3)

urea a chemical waste product produced in the body and removed in urine

nephron a tiny structure in the kidneys that filters the blood

The kidneys

We have two kidneys, one on each side of our lower back (Figure 3). They are approximately 10 cm long. Blood carrying waste products enters our kidneys to be filtered by the million tiny structures in the kidney called **nephrons**. At the end of this filtering process, there are two main outputs: clean blood, which is recirculated around the body, and urine, which is excreted from the body.

The kidneys also regulate the amount of water and salt in our blood. If we don't drink enough water, the kidneys will re-absorb more water back into the blood, which makes the urine appear dark yellow. If we are keeping well hydrated, more water passes in the urine, making it clear in colour.

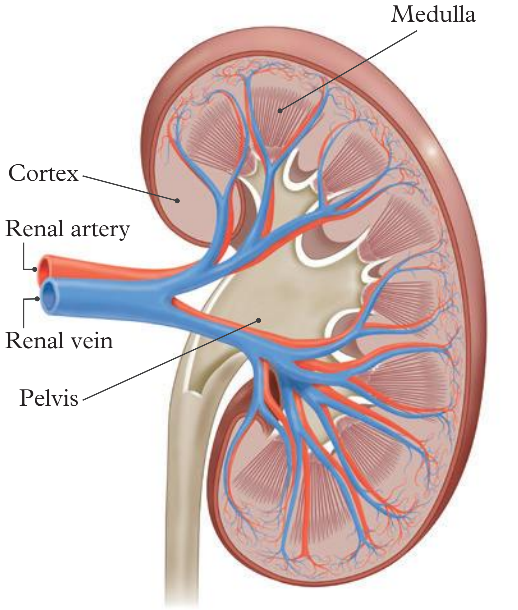


Figure 3 The basic structure of the kidneys, with key parts labelled

The skin

The skin is the largest organ in the excretory system (Figure 4). The skin releases sweat, which contains waste products such as heat, salts and urea. If you lick your upper lip after exercise, you will taste the salt in your sweat. The skin also has many other functions, including providing protection, sensing changes in the environment and regulating body temperature.

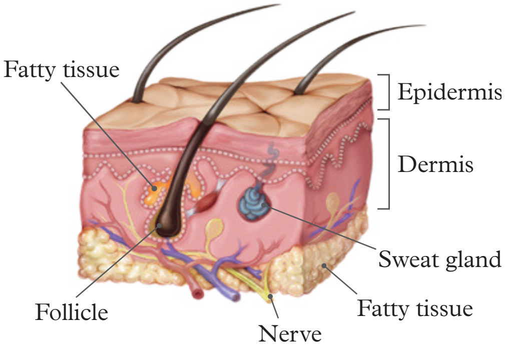


Figure 4 The structure of the skin, with key parts labelled

Other excretory systems

Freshwater fish excrete the highly toxic ammonia directly into the water around them. Because they do not need to conserve water (they live in it), they invest no energy in converting ammonia into the less harmful urea. They have a high urine output to dilute and excrete the ammonia quickly. In contrast, most birds, reptiles and invertebrates, such as insects, excrete nitrogen waste in the form of uric acid paste (the white stuff in bird poo), which is non-toxic. To convert their ammonia to uric acid requires significant energy investment from the animals but benefits them through water conservation.

Check your learning 8.13

Check your learning 8.13

Retrieve

1 Recall how waste products in the body are created.

2 Name the three organs of the excretory system.

Comprehend

3 Explain how the liver and kidneys work together.

Apply

4 Predict the consequences of not drinking enough water. State how you would feel and explain why.

Skills builder: Questioning and predicting

5 A scientist was conducting a study on the impact of exercise on the concentration of urine. He tested a group of marathon runners and a group of people who did not exercise. Predict what effect running a marathon would have on the quantity and concentration of urine. (THINK: What do you know about how the kidney works?)

Lesson 8.14

Diseases and disorders of the excretory system

Learning intentions and success criteria

Key ideas

→ Liver cirrhosis causes irreversible damage to the liver.

→ Kidney stones and chronic kidney disease can impair normal kidney function.

→ Acne and psoriasis are conditions that typically cause localised damage to the skin.

Liver cirrhosis

Cirrhosis is severe scarring of the liver. The most common causes are infection from the hepatitis B and C viruses and alcohol abuse. A continual cycle of inflammation and tissue repair causes permanent and irreversible damage. If not controlled, symptoms progressively worsen and can lead to death due to liver failure (Figure 1).

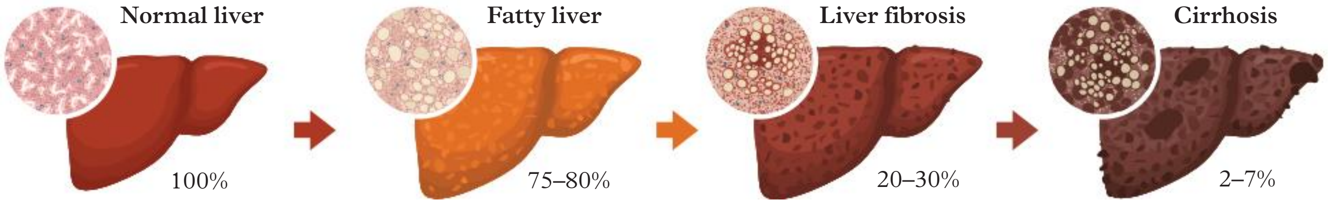


Figure 1 Stages of liver damage

Kidney stones

Kidney stones are hard deposits of minerals and salts that stick together in concentrated urine and lodge in the kidneys (Figure 2). There are a range of causes, including poor diet, excess body weight and some medical conditions. If the stones are dislodged, they can cause intense pain as they pass through the urinary tract. If they are too large to pass, they can cause a blockage that requires surgery to remove.

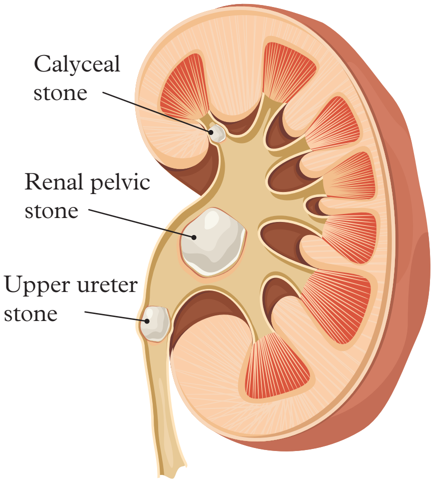


Figure 2 Kidney stones are hard deposits of minerals and salts that become lodged in the kidneys.

Chronic kidney disease (CKD)

Chronic kidney disease (CKD) can have multiple causes. Poorly managed diabetes causes damage to the small blood vessels of the kidneys, as does high blood pressure and smoking. This impairs the kidneys' ability to filter waste products correctly, and if not managed, CKD will lead to organ failure.

Acne

Acne is the most common skin condition in Australia. It is the result of skin follicles becoming blocked with oil and dead skin cells. It is more common in teenagers due to the increase in certain hormones that can cause the oil glands in the skin to become overactive. In severe cases, the skin tissue can be permanently scarred, which impairs normal function in the localised area.

Figure 3 Acne is caused by skin follicles becoming blocked with oil and dead skin cells.

Psoriasis

Psoriasis is a disorder caused by the rapid turnover and accumulation of skin cells, which results in dry, scaly patches of skin. Any part of the body can be affected, and the patches are usually itchy and can be made worse by the localised impact of the skin's sweat glands. The severity of symptoms can vary between sufferers and the specific cause is not known. Current research indicates that the cause is likely to be a combination of an autoimmune response and environmental triggers.

Figure 4 Psoriasis is a disorder caused by the rapid turnover and accumulation of skin cells, which results in dry, scaly patches.

Check your learning 8.14

Check your learning 8.14

Retrieve

1 Identify diseases or disorders that affect the liver, kidneys and skin.

Comprehend

2 Explain how each disease or disorder identified in question **1** affects the organ.

3 Distinguish between kidney stones and chronic kidney disease.

Lesson 8.15

Skills lab: Kidney dissection

Aim

To investigate the structure of a mammalian kidney and explore the various functions of the different parts

Materials

- Sheep's kidney
- Dissecting kit
- Dissecting board
- Newspaper (for dissecting and disposing of kidney)

Method

1. Place the whole kidney on the board and identify as many parts as possible.
2. Draw a labelled diagram.
3. Cut the kidney in half longitudinally (lengthways).
4. Draw a labelled diagram. Identify any key structures that you can see.

Results

Include your labelled diagrams here.

Questions

1. Compare the colour of the kidney on the outside with the colour on the inside.
2. The colour of the kidney gives an indication of the amount of waste products it contains. Use your answer to question **1** to identify whether the outside or inside of the kidney produces the most waste.
3. Explain why you cannot see any nephrons with your naked eye.
4. The medulla, the middle section of the kidney, has a stripy appearance. This is due to the **collecting ducts** heading in the same direction. Research the function of these collecting ducts.

Conclusion

Describe what you know about the form and function of a mammalian kidney.

Figure 1 Sheep kidney cut in half longitudinally

Lesson 8.16

Plants have tissues, organs and organ systems

Key ideas

→ Plants have two organ systems: the root system and the shoot system.

→ Plant organ systems interact to maintain the plant as a functioning organism.

→ Roots use osmosis to absorb water from the soil.

→ Stems transport water and nutrients around the plant.

→ Leaves exchange gases and produce the sugars needed for energy.

→ Flowers are the reproductive organs of many plants.

Learning intentions and success criteria

Introduction

Although plants come in many shapes and sizes, there are two key organ systems common to all plants: the root system and the shoot system (Figure 1). Roots absorb water from the soil. In the shoot system, stems transport water and nutrients around the plant, and leaves exchange gases and produce the glucose needed for energy.

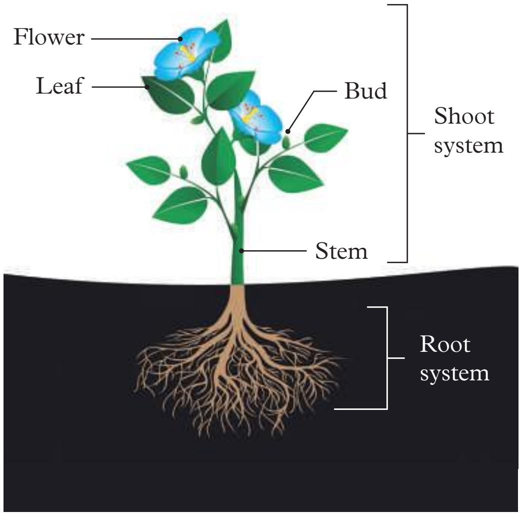


Figure 1 The organ systems and main structures of a flowering plant

Root system

The root system, which is usually underground, is comprised of the roots and root hairs.

Roots

The roots of a plant are the organs that anchor a plant to the soil and help it absorb nutrients and water. First, the roots take mineral salts from the soil and store them in their cells. This makes the inside of the roots saltier than the soil. Water molecules are attracted to the mineral salts in the root cells. As a result, water moves through the root cell membrane and into the plant. This process is called **osmosis**. During osmosis, water molecules move across a **semipermeable** membrane (in this case, the cell membrane of the root) from an area of low salt concentration (outside of the plant) to an area of high salt concentration (inside the plant) (Figure 2).

osmosis the movement of water through a semipermeable membrane from an area of low salt concentration to an area of high salt concentration; occurs in root cells

semipermeable refers to a membrane that allows certain substances to pass through while blocking others, enabling selective movement of molecules across it

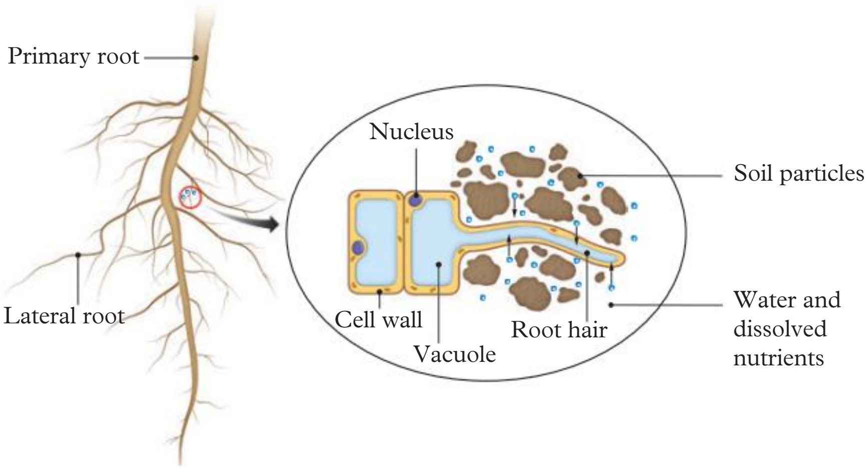


Figure 2 Root hairs increase the surface area over which osmosis can occur.

Root hairs

Most root cells have a series of small hairs to increase the amount of surface area that can take in the water and dissolved nutrients.

Shoot system

The shoot system consists of the following organs: stems, leaves, flowers and fruits.

Stems

stem an organ that transports materials around a plant

vascular bundle a group of tubes in plant stems that carry water and nutrients around the plant

The **stem** of a plant is the organ responsible for transporting water and nutrients between the roots and leaves. There are two main structures in the **vascular bundle** of the stem (Figure 3).

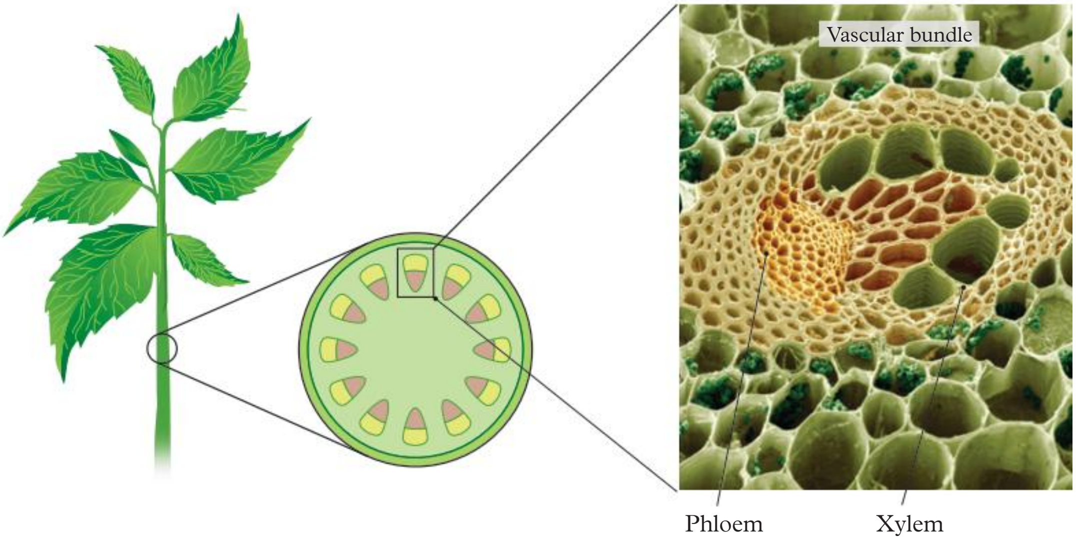


Figure 3 The structure of the stem of a plant

The **xylem** (pronounced zy-lem) is a straw-like structure that moves the water from the roots to the top of the plant. Water molecules like to stick together; we can see this in the way a drop of water forms a spherical shape. When water evaporates from the leaves at the top of a plant (**transpiration**), other water molecules move up to replace it. This process can even pull water molecules from the roots to the top of the world's tallest tree, which stands over 115 metres.

The **phloem** (flo-em) is another network of **vascular tissue** in the plant stem which transports the glucose produced in the leaves during photosynthesis to other parts of the plant. These sugars are needed for all cells in the plant to produce the energy they need to stay alive.

xylem the tissue in plants that carries water from the roots to the rest of the plant

transpiration the process of water evaporating from plant leaves; causes water to move up through the plant from the roots

phloem the vascular tissue in plant stems that carries sugars around the plant

vascular tissue vessels that transport material around an organism

guard cells specialised plant cells that surround the stomata, regulating their opening and closing to control gas exchange and water loss

Leaves

The leaves of a plant are involved in exchanging gases. In sunlight, a plant needs carbon dioxide to produce the sugars it needs for energy. The carbon dioxide moves in and out of cells through small openings called **stomata** (singular "stoma") (Figure 4).

A plant stoma has two specialised **guard cells** controlling the opening and closing of the pore. By taking on more water, the guard cells swell, resulting in an increased opening of the stoma. By releasing water, the guard cells shrink and the stoma closes. This process allows the plant to control both gas exchange and water loss as conditions change.

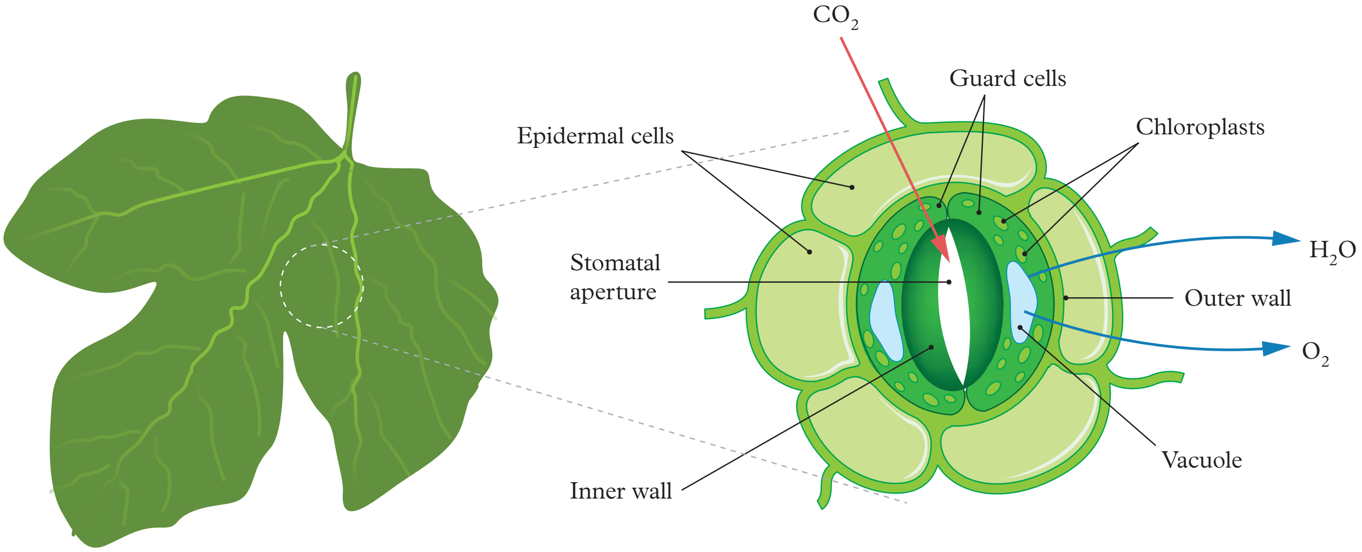


Figure 4 The opening and closing of plant stomata to control gas exchange and water loss

When the Sun is shining, the leaves convert the water from the roots and the carbon dioxide from the stomata into glucose (sugar) and oxygen during photosynthesis. Photosynthesis cannot happen without the help of chlorophyll. The chlorophyll absorbs mainly red and blue light and reflects green light, which is why most leaves appear green. During autumn, some leaves lose their green chlorophyll. This allows the other colours present in the leaves (reds, oranges and yellows) to appear (Figure 5).

Figure 5 Autumn leaves come in a range of colours.

Flowers

Flowers contain the reproductive organs of a plant (Figure 6). The female **gamete**, also called an **ovum**, is located at the base of the **stigma** inside the **ovary**. The stigma and ovary are connected via the **style**. Combined, these female parts are called the **carpel** (Figure 6B). The male reproductive structure is referred to as the **stamen**. The stamen consists of the pollen-containing **anther** situated at the end of a long **filament**. For fertilisation to occur, the male gamete (sperm) contained inside the **pollen** needs to find its way from the anther to the ovum. This requires **pollination** – the process of pollen attaching to the stigma and "burrowing" a pollen tube down to the ovary. Fertilisation only occurs once the male and female gametes unite.

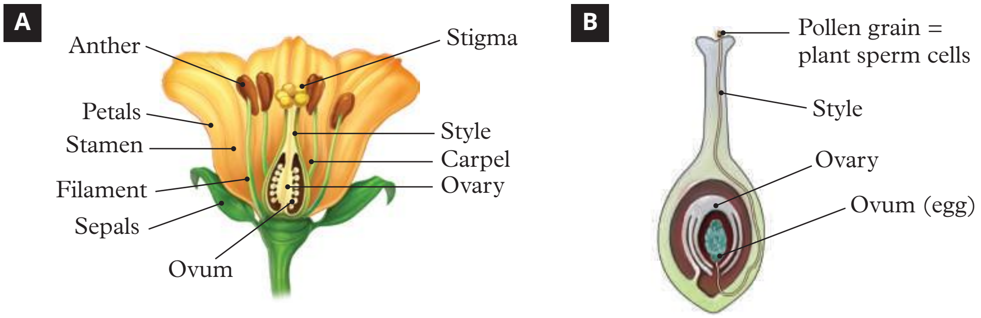


Figure 6 (A) Basic structure of a flower; (B) structure of the carpel, with key structures labelled

Self-pollination involves pollen from a flower landing on its own stigma or that of another flower of the same plant (Figure 7A). **Cross-pollination** occurs when pollen from a flower lands on the stigma of a flower on a different plant, combining two different sets of genetic material (Figure 7B). Just like animals, the pollen from one flower can only fertilise flowers from the same species.

When a male and female gamete combine, it becomes a **zygote**. After fertilisation, the ovary swells to become a **fruit**, which provides nutrition and protection for the zygotes to grow inside the seeds.

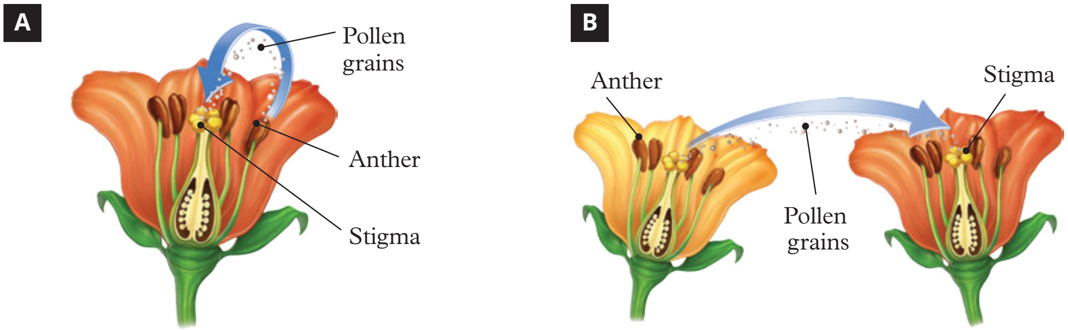


Figure 7 Forms of pollination in flowering plants: (A) self-pollination; (B) cross-pollination

gamete a sex cell; egg in females and sperm in males

ovum the female gamete or egg cell in plants, located within the ovule

stigma the part of the female reproductive structure in flowering plants; the tip of the carpel, where pollen is deposited

ovary the enlarged basal portion of the carpel that contains the ovum

style the slender stalk within the carpel that connects the stigma to the ovary, providing a pathway for pollen tubes to reach the ovules

carpel the female reproductive organ of a flower, consisting of the ovary, style, and stigma

stamen the male reproductive part of a flower, made up of the anther and filament

anther the part of the stamen (male reproductive organ) in flowering plants that produces and releases pollen

filament the stalk that supports the anther in the stamen of a flower

pollen the fine powder produced by the anther of flowers, which contains the male gametes (sperm)

pollination the process by which pollen is transferred from the male part (anther) to the female part (stigma) of a flower

Check your learning 8.16

Check your learning 8.16

Retrieve

1 Define the term “osmosis”.

2 Define the two organ systems found in plants.

Comprehend

3 Name three organs found in most plants and describe their function (what they do).

4 Explain the role of stomata in photosynthesis.

Analyse

5 Contrast (the differences between) xylem and phloem.

6 Identify the system in humans that provides the same function as a plant stem.

Apply

7 Some florists sell blue orchids that are artificially coloured by putting white orchids in blue water (Figure 8). Use your knowledge of plant systems to determine how these orchids may have become blue.

8 A large tree can be killed by cutting a small distance through the bark around the whole tree (known as ring-barking). Using your knowledge of plant vascular tissue, explain how this would kill the tree.

Skills builder: Planning investigations

9 A student was asked to investigate the rate at which tomato plants grow when they receive different amounts of water. They set up three pots and planted a tomato plant in each of them. Each day for a month, they watered pot 1 with 100 mL of water, pot 2 with 200 mL of water and pot 3 with 500 mL of water.

  a Identify the independent and dependent variables in this investigation. (THINK: What factor is being changed, and what is being measured?)

  b Identify an additional two variables that might need to be controlled in this investigation. (THINK: What might influence the results?)

Figure 8 Artificially coloured orchids

self-pollination the transfer of pollen from the anther to the stigma of the same flower or another flower on the same plant, leading to fertilisation without genetic mixing from another plant

cross-pollination the transfer of pollen from the anther of one flower to the stigma of a flower on a different plant of the same species, promoting genetic diversity

zygote the first cell of a new organism created after sexual reproduction

fruit the seed-bearing organ formed from the ovaries of flowering plants

Lesson 8.17

Investigation: Locating the xylem and phloem in a stem

Purpose

To identify parts of the circulatory system of a plant

Materials

- 500 mL beaker
- Water
- Blue or red food colouring
- Fresh stick of celery
- Scalpel
- Cutting board
- Permanent marker
- Glass slide
- Light microscope

Procedure

1. Add 200 mL of water to the beaker.
2. Add 15 drops of food colouring to the water.
3. Cut the bottom 10 cm off the celery.
4. Place the top half of the celery in the beaker of coloured water.
5. Mark the water level with a permanent marker. Leave for 2 to 3 days.
6. Remove the celery from the water and use the scalpel to cut a very thin transverse (horizontal) section of the celery stalk and place it on a glass slide.
7. Observe the transverse section under the light microscope.
8. Draw a labelled scientific drawing of what you observe.

Discussion

1. Describe how the amount of water in the beaker changed after 2 to 3 days.
2. Use the term “transpiration” to explain your answer to question **1**.
3. Identify the name of the pathway that moved the coloured water through the celery.
4. Compare the circulatory system you observed with the circulatory system in humans.

Figure 1 (A) The dye marks the path the water takes from the celery’s roots. (B) As water evaporates from the celery’s leaves, the coloured water replaces it.

Lesson 8.18

Investigation: Modelling root cells

Pupose

To model the function of the root cells of a plant

Materials

- 15 cm dialysis tubing
- Water
- 5 mL of 2% starch solution
- Scales
- 200 mL beaker
- 100 mL measuring cylinder

Procedure

1 Soften the dialysis tubing by running water over the outside of it.
2 Tie a knot in one end of the tubing.
3 Add 5 mL of starch solution to the tubing.
4 Seal the open end by tying a knot.
5 Wash the outside of the tubing with water.
6 Pat dry the outside of the tubing and use scales to determine its weight.
7 Place the tubing in the beaker. Add 100 mL of water.
8 Leave overnight.
9 Remove the dialysis tubing from the water and carefully pat dry.
10 Determine the weight of the dialysis tubing.

Discussion

1 Contrast the weight of the dialysis tube with starch before and after soaking in water.
2 Explain the change in the weight of the tubing.
3 Define the term "osmosis".
4 Use the term "osmosis" to explain how the dialysis tubing is similar to the cells in a plant root.

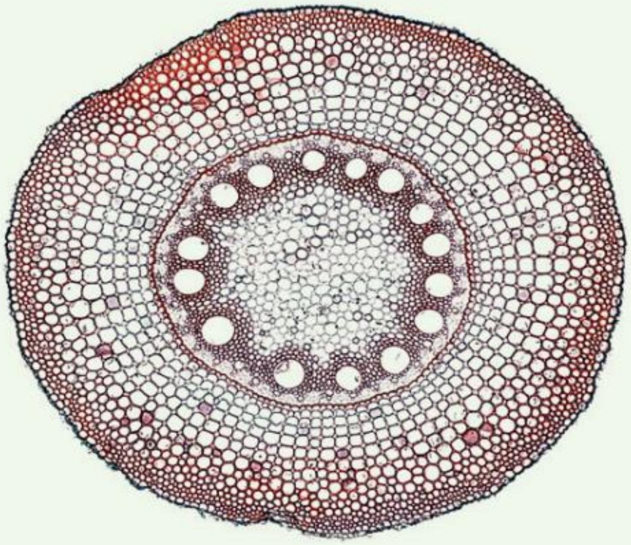


Figure 1 Cross-section of a plant root under the microscope, showing cells in the root

Lesson 8.19

Review: Animal and plant organ systems

Summary

Lesson 8.1 Systems are made up of cells, tissues and organs

- Anatomists study how the body works.
- Groups of cells that do a similar task are called tissues.
- Groups of tissues that work together are called organs.
- When groups of different organs work together, they are called a body system.

Lesson 8.2 The digestive system absorbs nutrients

- Digestion is the process of breaking down food so that it can be used by the body.
- Physical digestion occurs when the body manually breaks apart food particles.
- Chemical digestion occurs when enzyme molecules break the chemical bonds in food.
- Nutrients are absorbed in the intestines.

Lesson 8.4 The digestive system varies between animals

- Carnivores are organisms that only eat meat.
- Herbivores are organisms that only eat plant material.
- Omnivores, including humans, eat a variety of foods, including both meat and plants.
- The structure of the digestive system is used to predict the type of food an animal eats.

Lesson 8.5 Diseases and disorders of the digestive system

- Peptic ulcer disease is caused by the bacterium *Helicobacter pylori*.
- Coeliac disease and gluten intolerance are disorders caused by a reaction to gluten.
- Inflammatory bowel disease (IBD) refers to disorders (Crohn's disease and ulcerative colitis) that cause inflammation and damage to the digestive tract.

Lesson 8.6 The circulatory system carries substances around the body

- The heart pumps the blood around the body.
- Blood contains red blood cells, white blood cells, platelets, plasma, nutrients and waste.
- Arteries carry blood away from the heart and veins carry blood back to the heart.
- Capillaries are thin-walled blood vessels where nutrients and waste move in and out of the blood.

Lesson 8.8 Diseases and disorders of the circulatory system

- Damaged valves can affect the one-way direction of blood flow.
- Atherosclerosis describes the narrowing of the blood vessels as a result of plaque.
- Coronary heart disease is caused by blockages in the blood vessels in the heart muscle.
- Pericarditis occurs when the pericardium sac surrounding the heart becomes infected.

Lesson 8.9 The respiratory system exchanges gases

- The respiratory system is the body system responsible for breathing.
- Air is inhaled down the trachea, the bronchi and the bronchioles into the alveolar sacs and eventually into our blood.
- Our lungs breathe in oxygen to be used by our cells for energy and they breathe out carbon dioxide as waste.

Lesson 8.10 Diseases and disorders of the respiratory system

- Asthma causes the bronchi and bronchioles to become smaller.
- Emphysema is caused by broken-down alveoli, which prevent oxygen from entering our blood.
- Pneumonia is an infection that fills our lungs with fluid and blocks the flow of gases.
- Asbestosis is a chronic lung disease caused by asbestos exposure, while mesothelioma is an aggressive cancer linked to asbestos that affects the lining of the lungs or abdomen.

Lesson 8.13 The excretory system removes waste

- The liver helps rid the body of nitrogen.
- The kidneys filter blood to remove waste, which is excreted as urine.
- Sweating releases waste products from the body through the skin.

Lesson 8.14 Diseases and disorders of the excretory system

- Liver cirrhosis causes irreversible damage to the liver.
- Kidney stones and chronic kidney disease can impair normal kidney function.
- Acne and psoriasis are conditions that typically cause localised damage to the skin.

Lesson 8.16 Plants have tissues, organs and organ systems

- Plants have two organ systems: the root system and the shoot system.
- Plant organ systems interact to maintain the plant as a functioning organism.
- Roots use osmosis to absorb water from the soil.
- Stems transport water and nutrients around the plant.
- Leaves exchange gases and produce the sugars needed for energy.
- Flowers are the reproductive organs of many plants.

Review questions 8.19

Review questions Module 8

Retrieve

1 Recall where chemical digestion occurs in the body.

2 Identify the disease that is caused by a build-up of plaque.
- **A** Pneumonia
- **B** Valve disease
- **C** Atherosclerosis
- **D** Asthma

3 Recall which body system removes wastes.
- **A** Respiratory system
- **B** Circulatory system
- **C** Digestive system
- **D** Excretory system

4 Name the gaseous waste product removed by the lungs.

5 Identify four things that the circulatory system transports around your body.

6 Recall where photosynthesis occurs in a plant.
- **A** Leaf
- **B** Stem
- **C** Root
- **D** Xylem

Comprehend

7 Describe the function of each of the four types of tissue.
- **a** Identify where peristalsis occurs in the body.
- **b** Explain how it causes food to move.

8 Explain how the human digestive system can “feed” all the other systems.

9 Describe how the respiratory system and circulatory system work together.

10 Explain why muscles need more blood during exercise.

11 Some people have had the valves in their hearts replaced with prosthetic valves, either made from synthetic materials or transplanted directly from a pig or cow heart. Explain why it is important that the valves in a heart function properly.

12 Describe a disease that affects the respiratory system and outline how it may impact the sufferer's day-to-day life.

Analyse

13 Contrast organs and systems.

14 Contrast cellular respiration and breathing.

15 Plants do not have a digestive system. Identify which organ helps the plant supply all its energy needs.

16 Infer why you would not expect to find chloroplasts in the roots of a plant.

Apply

17 Propose a possible motivation for the earliest studies of the human body.

Critical and creative thinking

18 Sweating is often considered to be a bad thing. Evaluate this statement (by describing why people sweat, what is in the sweat, what would happen if a person was unable to sweat and deciding if the statement is correct).

19 Mangrove trees get rid of excess waste salt through their leaves. This salt is often seen as white crystals on the underside of the leaves. Determine the human system that this represents in the plant. Identify which organ(s) have the same function in humans.

20 Human dissections have always been used to teach medical students anatomy, but they are less common now than in the past. In many cases, real dissection has been replaced with computer animations and models. Propose why human dissection is important.

21 Imagine it is your job to develop a "user manual" for one of the systems covered in this chapter. Write a list of ten "Frequently Asked Questions" (FAQs) to go at the front of the manual. Write an answer to as many of your questions as you can. If you don't know the answer, write down where you could find the answer or who you could ask.

22 Use your understanding of the different systems of the human body to create a concept map detailing the connections between the systems. An example has been provided in Figure 1 to help you get started.

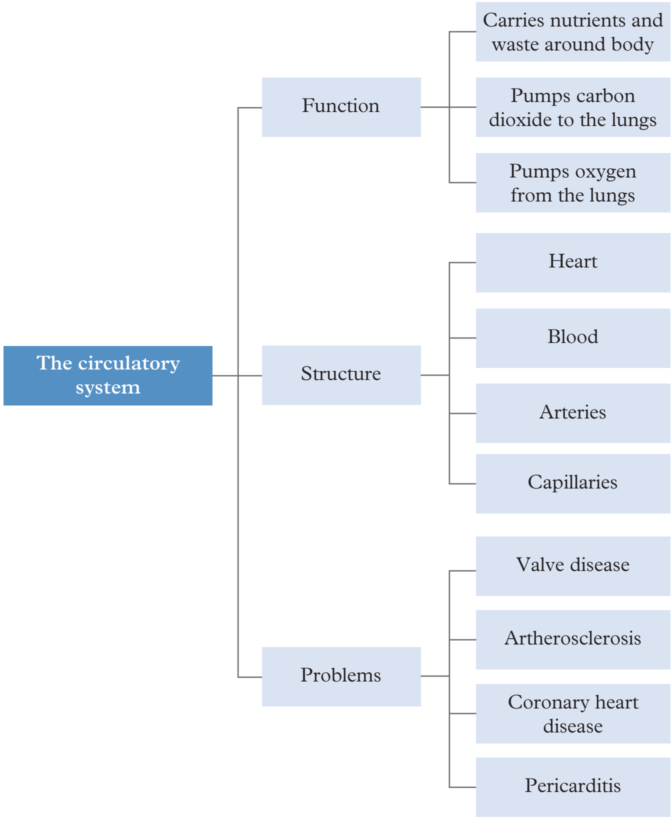


Figure 1 A concept map of the circulatory system

23 Presenting data to an audience can take many forms. An increasingly common way to present important information is in an infographic. Infographics are visual ways to present information so that the viewer can easily see what is important. This can be through the use of graphs, pictures and important figures. Many doctors‘ waiting rooms have infographics to provide patients with information about possible diseases or disorders. An example is given in Figure 2.

Select one of the diseases or disorders of the digestive system and plan an infographic that will provide important information to an audience.

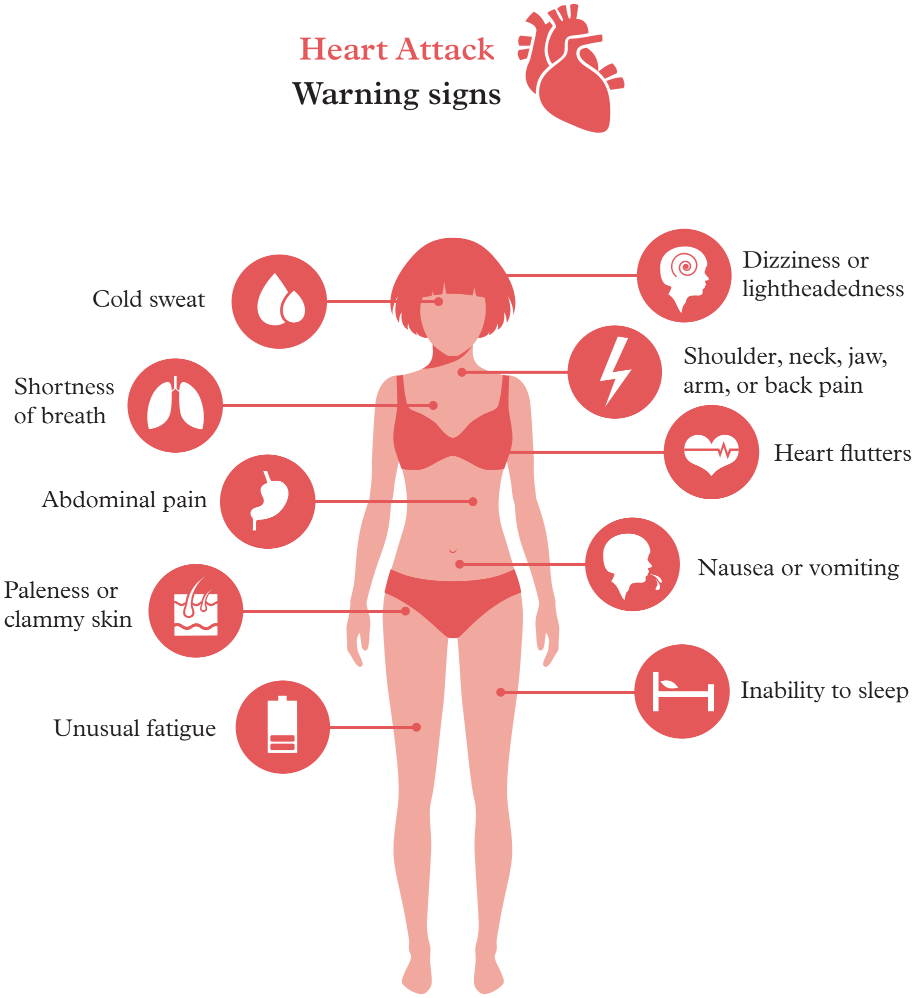


Figure 2 An infographic about heart attack warning signs

- **a** Consider why you are making the infographic. Is it to pass on information or to get people to change their habits?
- **b** Identify the key information about the disease or disorder and how it affects the digestive system. For example, what are the symptoms and how are people affected?
- **c** Propose how the change in the digestive system causes the symptoms.
- **d** For people who have symptoms, identify what they should do. Should they look out for symptoms, change their diet or see a doctor?
- **e** Draw a picture that represents what is happening in the digestive system. Consider how much information needs to be passed on to the person reading the infographic. Try to keep the diagram simple.
- **f** Infographics use short phrases or sentences to pass on key information. Decide the important information that you want people to remember and write it in short phrases or sentences. Carefully consider which words to use so that your audience will know what is important. Have you made the reason for making the infographic clear?

Social and ethical thinking

24 There are many diseases or disorders that affect the different organs in the body. Sometimes, the only treatment available is an organ transplant. Replacement hearts and lungs can only be obtained from critically injured patients who have been certified brain dead. Discuss with a partner the advantages and disadvantages of organ donation. Explain the reason why you would or would not sign up to be an organ donor. Explain why you should let your family know of your decision.

Research

25 Choose one of the following topics for a research project. A few guiding questions have been provided for you, but you should add more questions that you want to investigate. Present your research in a format of your own choosing, giving careful consideration to the information you are presenting.

Artificial organs

When the organs in the body start to fail, their function needs to be replaced. This can be done through organ transplantation from another person or the replacement of the organ with an artificial version.

- Research an artificial heart that is currently being used by surgeons.
- Describe the materials being used to construct the heart.
- Explain how the artificial heart is able to replace the original organ.
- Write a blog outlining why artificial hearts should be used by surgeons more often.

Omega-3 fatty acids

- Describe omega-3 fatty acids.
- Identify the foods that should be eaten to include omega-3 fatty acids in your diet.
- Describe how omega-3 fatty acids help reduce heart disease.
- Describe what other diseases are helped by omega-3 fatty acids.

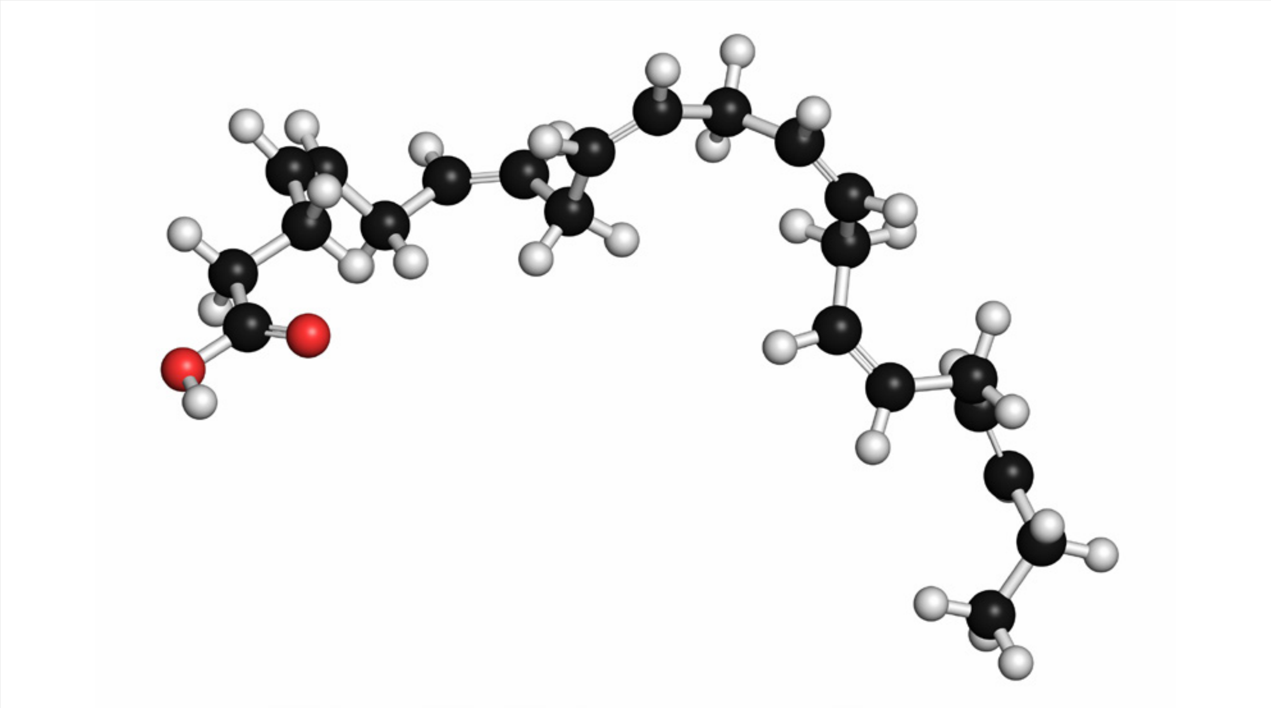


Figure 3 Structure of an omega-3 fatty acid. White represents hydrogen, black represents carbon and red represents oxygen.

Organoids vs. animal testing

Organoids are created when small groups of specialised cells become organised in a flask of nutrients in a lab. These small groups of tissues can be used to mimic almost any organ in the body.

- Describe how the development of organoids could affect the way scientists use animals to test their research.
- Describe reasons for and against the use of organoids.
- Explain how the use of organoids by scientists might change the way people view scientific research.
- Compare the cost of using live animals against the cost of producing and maintaining organoids.
- Prepare an argument that could be presented to a research centre.

Figure 4 An organoid representing the intestines

Smoking bans

Many smoking bans, such as bans in workplaces, are related to the issue of second-hand smoke. This refers to how smoke affects people who are near a person who is smoking.

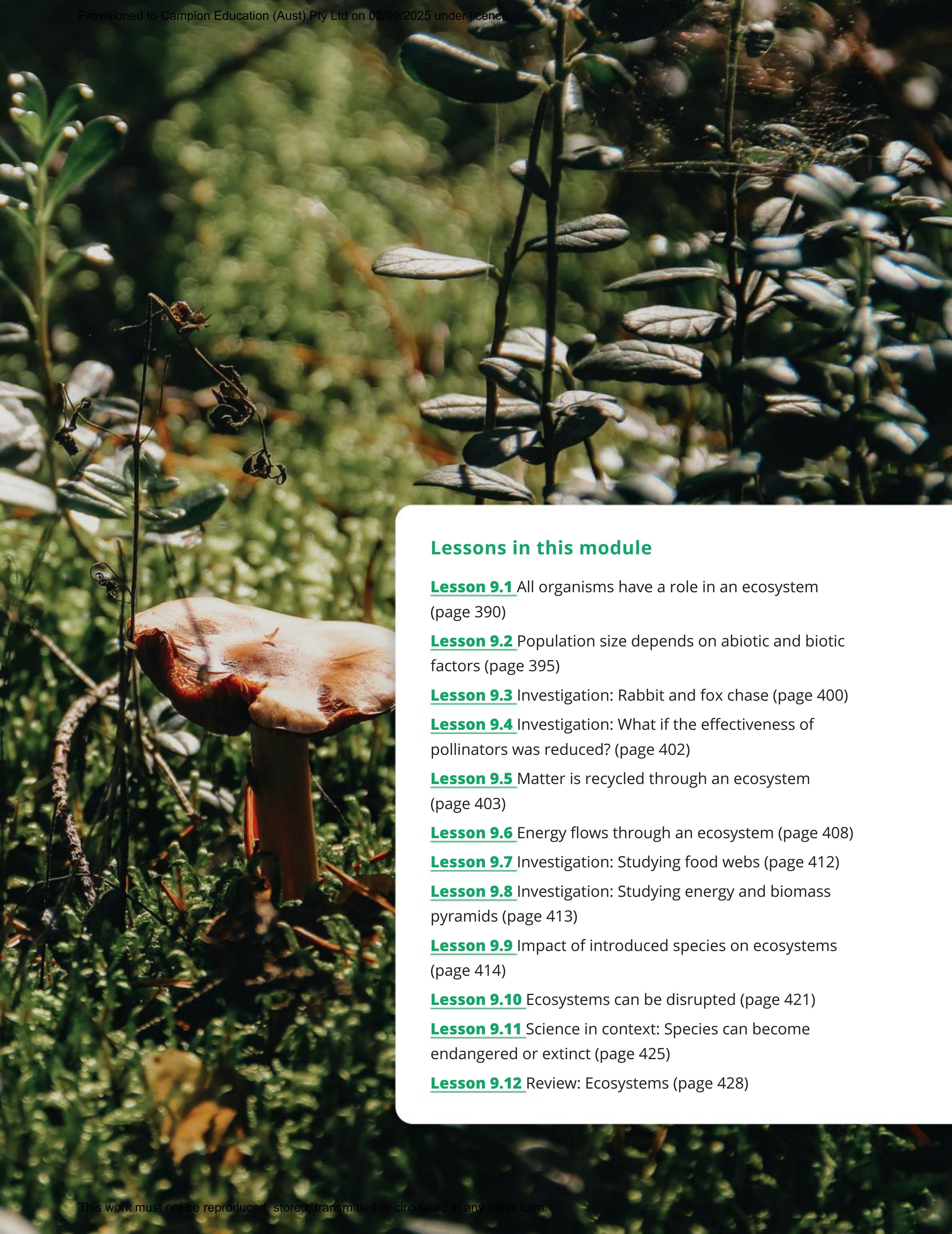
- Find out some facts about the impacts of second-hand smoke.
- Argue your position on whether smoking bans should be extended or removed, or whether you think they are fine as they are now.

Figure 5 Smoking is banned in many public areas.

Module
9
Ecosystems

Overview

Everything in nature is connected, and every living thing is affected by its environment. Understanding these connections helps us see and predict how changes affect the whole system. Food webs show how energy and matter move through an ecosystem. Changes such as losing habitats or losing important animals like pollinators affect the entire ecosystem. Aboriginal and Torres Strait Islander Peoples have used their knowledge of Country for over 65,000 years to work with and protect the environment. This extensive knowledge can help protect ecosystems in the future.



Lessons in this module

Lesson 9.1

All organisms have a role in an ecosystem

Learning intentions and success criteria

Key ideas

- → An ecosystem is a community of living organisms and their surroundings.
- → Predators eat prey.
- → Symbiotic relationships are long-term relationships.

Ecosystems

ecosystem a community of living organisms and their non-living surroundings

biotic all the living organisms in an ecosystem

abiotic all the non-living components of an ecosystem; for example, light, temperature and water

habitat an environment in which an organism lives

An **ecosystem** is any group of **biotic** (living) and **abiotic** (non-living) things which are interacting with each other in a self-sustaining way. Ecosystems can range in size from as small as a puddle to as large as an ocean.

Within ecosystems there are **habitats**. A habitat is a place where a population of organisms lives, and the size of the habitat varies based on the availability of food, water and shelter. For example, in Kakadu National Park (Figure 1A), habitats include billabongs, rivers and floodplains.

Figure 1 Australian ecosystem examples: (A) Kakadu National Park wetlands; (B) Daintree Rainforest; (C) Great Barrier Reef

population a group of individuals of the same species living in the same location at the same time

community different populations living in the same location at the same time

Ecosystems also consist of **populations**. A population is a group of organisms of the same species living in the same place at the same time. When different populations interact, they form a **community**. For instance, a population of humans living in a town along with the plants in their gardens and their pets would be considered a community.

An ecosystem must supply all the needs of the organisms that are part of the ecosystem. These needs include food, water, warm temperatures, oxygen and minerals. These make up the non-living parts of the ecosystem. If these conditions are wrong for a population, then the individuals in that population will move to a better ecosystem or they will die out.

Figure 2 (A) This colony of emperor penguins forms a population. (B) Emperor penguins interact with fur seals as part of a community.

Relationships between different species

Predator–prey

In a predator–prey relationship, one organism (the **predator**) eats another (the **prey**). This relationship only lasts for a short time (until the prey is eaten), and it only happens when a predator is hungry. An example is the relationship between a great white shark and a seal (Figure 3B). The two species only meet when the shark (the predator) is hungry and starts hunting the seal (the prey). When the seal is caught, the relationship ends.

predator an animal that hunts and feeds on another (prey) for food

prey an animal that is hunted and killed by another (predator) for food

Figure 3 Predator–prey relationships: (A) the wedge-tailed eagle (predator) feeds on the kangaroo (prey); (B) the great white shark (predator) hunts the seal (prey)

Predator species and their prey species have a balanced relationship. If all the prey are eaten, then the predators will starve. As the number of predators decreases (shown by the graph in Figure 4 going down), the number of prey will increase again because they are not being hunted as often. This makes the prey numbers in a graph go up. When the number of prey goes up, the predators can hunt more food. This means a predator–prey graph will always show the predator line following the prey line. Figure 4 shows this pattern.

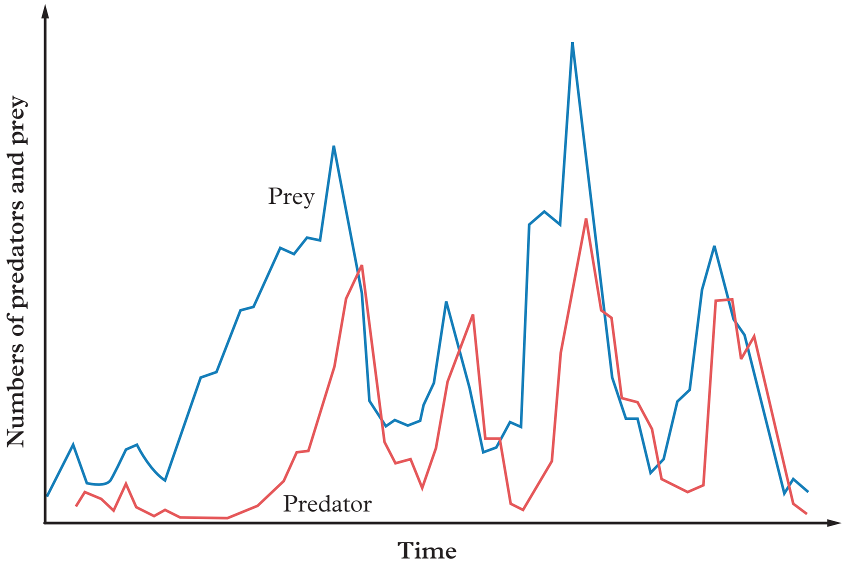


Figure 4 A predator–prey graph; the scales aren't shown, but the prey numbers are mostly greater than those of the predator. Notice that the increase and decrease in prey numbers usually comes before the increase and decrease in predator numbers.

Competition

In a competition relationship, organisms must compete for the same resources (Figure 5). What you may not realise is that most competition comes from members of the same species. This type of competition is called **intraspecific competition**. The reason for this occurring is that members of the same species usually want the same food, water, shelter or mate. In contrast, **interspecific competition** occurs between members of different species. For example, a kangaroo and wombat may compete for the same grasses to eat. Usually, competing species will balance their numbers so that neither one dominates.

intraspecific competition competition between individuals of the same species for the same resources

interspecific competition competition between individuals of different species for the same resources

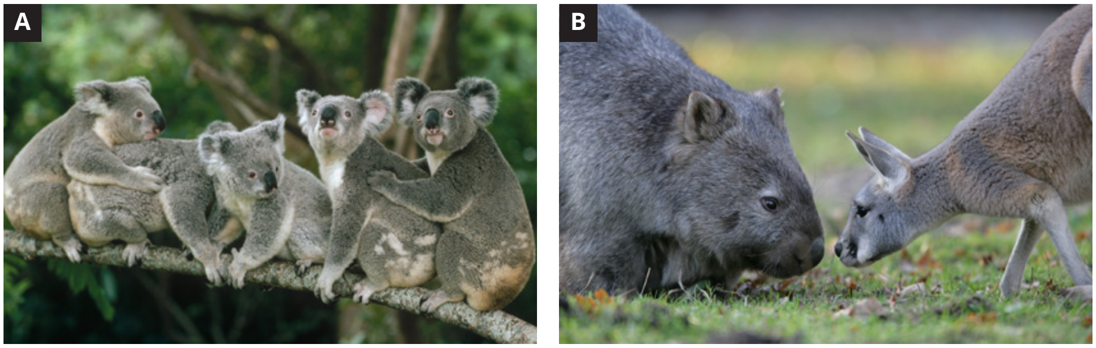


Figure 5 Competition relationships: (A) Intraspecific competition – a group of koalas; (B) interspecific competition – a wombat and an eastern grey kangaroo

Figure 6 The Lantana plant was introduced into Australia and has become a weed. It releases a chemical into the soil that inhibits or blocks the growth of native plant species.

Sometimes, **inhibition competition** occurs when one organism produces a chemical that directly inhibits or blocks the survival or growth of another organism (Figure 6).

Symbiosis

In a symbiotic relationship, organisms from different species develop an ongoing relationship for their survival. When this happens, it is called **symbiosis**. Types of symbiosis include **mutualism**, **commensalism** and **parasitism**.

symbiosis a close, physical relationship between two organisms of different species

mutualism a type of relationship between two organisms of different species in which both organisms benefit

commensalism a type of relationship between two organisms of different species in which one organism benefits and the other is not affected

parasitism a type of relationship in which one organism (parasite) lives in or on the body of another organism (host) and benefits while the host is harmed

Mutualism

Mutualism is a type of relationship between two organisms in which both organisms are able to help each other to survive – they both benefit.

For example, green weaver ants (*Oecophylla smaragdina*) – found in northern Australia – build their nests by weaving together the leaves of a tree (Figure 7). The tree will also provide nourishment in the form of sap to support the ant colony. In return, the ants will aggressively defend the tree from other would-be pests like caterpillars. They do this by biting them and squirting acid into the wound. This relationship benefits both the ants and the tree.

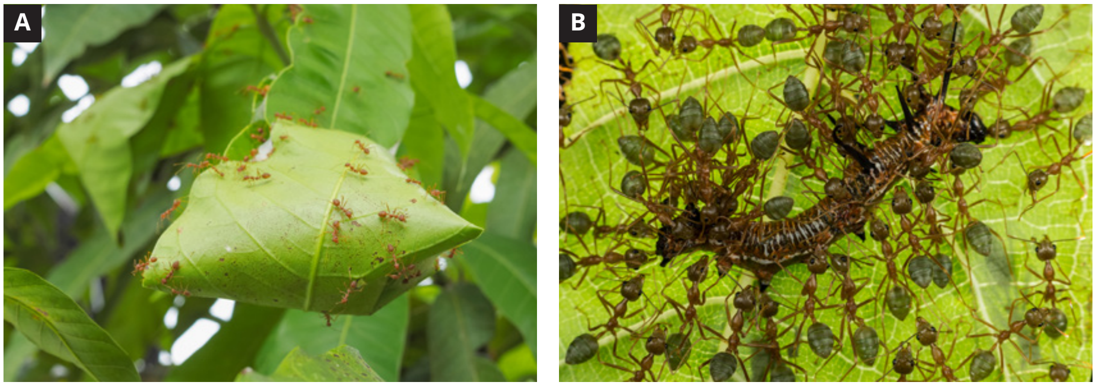


Figure 7 Mutualism is a type of symbiotic relationship. (A) Green weaver worker ants building a nest; (B) protecting the tree from invading caterpillars

Pollination is another example of mutualism. Over 70 per cent of plants are pollinated by animals. Australian honeyeaters (Figure 8), fruit bats and native stingless bees obtain their food (pollen and nectar) from plants such as eucalypts and grevillea. In return, the animals transfer pollen between plants, which helps the plants to pollinate and reproduce.

Figure 8 An example of mutualism is the honeyeater (*Meliphaga gracilis*) feeding on the grevillea and, in doing so, helping the plant to pollinate.

Figure 9 An example of commensalism is the cattle egret (*Bubulcus ibis*) looking for insects on the back of a grazing water buffalo.

Figure 10 An example of parasitism is a large tick feeding on blood above the eye of an eastern grey kangaroo.

Commensalism

Commensalism is a type of symbiotic relationship between organisms in which one organism benefits and the other is unaffected. For example, an egret (bird) is often found sitting on the back of a buffalo. As the buffalo grazes, it stirs up insects which the egret can then find and eat. The buffalo gains no benefit from this relationship and the egret causes no harm (Figure 9).

Parasitism

Parasitism is a type of symbiotic relationship in which one organism (the parasite) benefits, but the other organism (the host) is harmed. For example, ticks are parasites that attach to animals as they move through their habitat (Figure 10). The ticks benefit by taking a blood meal from their hosts. The hosts are harmed due to the loss of blood and the possible spread of disease.

Check your learning 9.1

Check your learning 9.1

Retrieve

1 Define the term “symbiosis”.

Comprehend

2 Describe an example of the following relationships.
  - a Predator–prey
  - b Mutualism
  - c Commensalism
  - d Parasite–host

3 Explain why a large plant that produces a lot of shade prevents smaller plants from growing.

Analyse

4 Contrast (the differences between) a predator–prey relationship and parasitism.

Apply

5 Some eucalypt trees have mistletoe plants living on them. Mistletoe has very similar leaves to eucalypt leaves. Mistletoe can make its own food, but the stems send suckers into the eucalypt to obtain water and minerals. If too much water and minerals are removed, the eucalypt can die. Identify the type of relationship that exists between the eucalypt and the mistletoe. Justify your answer (by defining the relationship and matching it to this example).

6 Epiphytes are plants such as ferns and some orchids that grow high in the branches of other trees, especially rainforest trees. The epiphytes obtain sufficient light to make their own food, collect water from the moist air and obtain minerals from the decaying leaf litter that they catch at their leaf bases. The tree is not affected by these plants. Identify the type of relationship that is described. Justify your answer (by describing how each species benefits from, doesn't notice or is harmed by the relationship).

Skills builder: Communicating

7 Imagine that someone walked up to you and asked the following question: "Why is the environment so important?" Draft a reply, considering the key concepts covered here. (THINK: What are the key points that someone would need to know to be convinced?)

8 Construct a table that summarises the differences between the different symbiotic relationships, including examples of each. (THINK: How can this table help people to understand these relationships?)

Lesson 9.2

Population size depends on abiotic and biotic factors

Key ideas

→ All populations are in a constantly changing equilibrium.

→ Deaths and emigration can decrease a population.

→ Births and immigration can increase a population.

Learning intentions and success criteria

Populations

Like a population of humans in a city, the population of living organisms in an ecosystem is constantly changing. In a drought, there are high temperatures and little rain. This can make it hard for plant and animal populations to survive. The amount of water or temperature are non-living factors, called **abiotic** factors, that can affect the size of a population. Other abiotic factors that can affect the number of organisms in a population include the amount of sunlight, salt in the water, soil quality, available nutrients or places for the organism to hide.

Sometimes it is the number of other organisms competing for food or hunting them that can affect the number of organisms in a population. These "living" factors that affect the survival of organisms are called **biotic** factors (Figure 1).

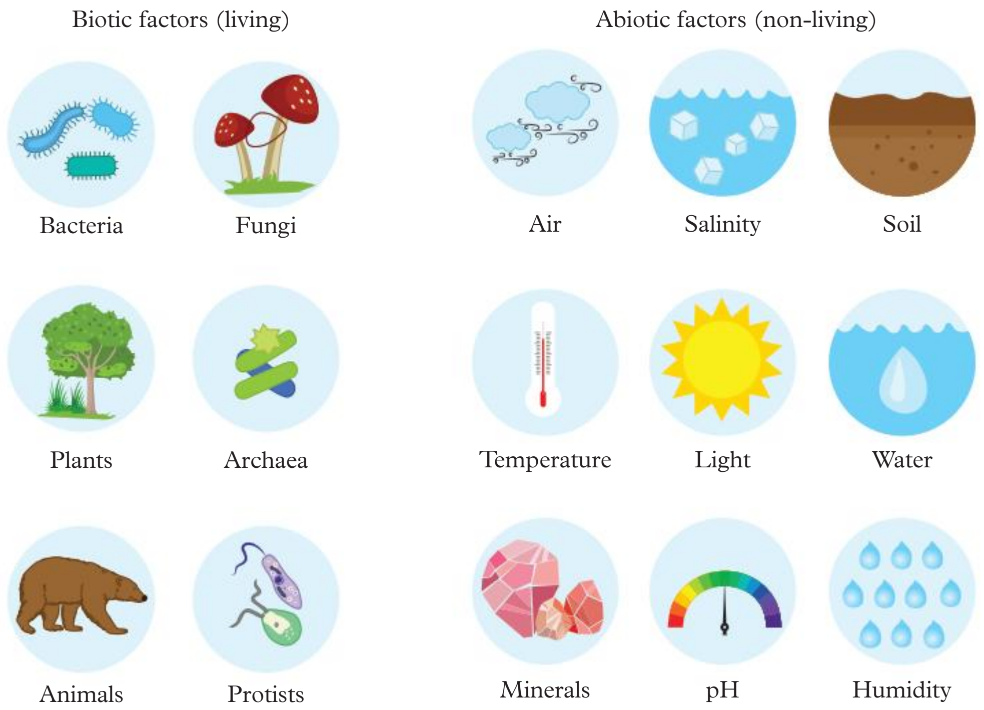


Figure 1 A comparison of biotic and abiotic factors

A dynamic balance

All organisms live in a complex web of interdependent relationships – with each other and with their environment. In an ecosystem, there needs to be a balance so that all species can survive. The more types of organisms in an ecosystem, the healthier the community of organisms in the ecosystem.

Many things can cause a population of organisms to increase in number. A population of birds will increase when new chicks are born or when new birds fly into the ecosystem (**immigrate**). In contrast, the number of birds in the population will decrease if some birds die because of hunger or because they are hunted. Sometimes the birds will leave to fly to another ecosystem (**emigrate**) (Figure 2).

A food web is a complex network of interconnected food chains in an ecosystem, illustrating how different organisms are related through their feeding relationships.

Whenever the size of a population changes, it can affect other organisms in the ecosystem's **food web**. Consider the simple food web for an ecosystem shown in Figure 3. If the number of frogs decreased in this ecosystem, the effects could include:

- an increase in grasshopper numbers, causing the amount of grass to decrease

immigrate refers to when an animal enters a new ecosystem

emigrate refers to when an animal leaves an ecosystem

food web a system of interlocking and interdependent food chains within an ecosystem

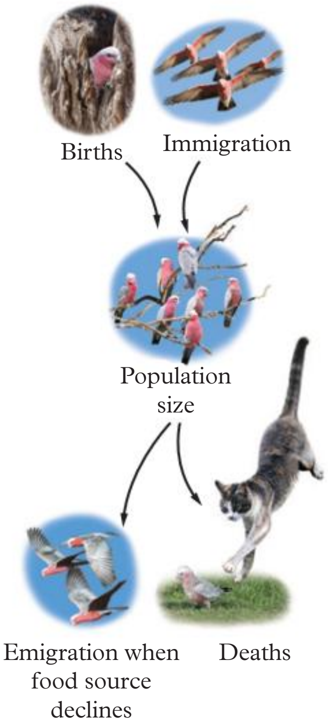


Figure 2 The size of a galah population in a particular area depends on the food available, the number of births and deaths and the number of birds that immigrate and emigrate.

- an initial increase in praying mantis numbers because there are more grasshoppers
- a decrease in lizard numbers
- more birds eat praying mantises rather than frogs and lizards
- a decrease in praying mantis numbers because they are being eaten by birds
- a further increase in grasshopper numbers, who then start eating the grass. If this was severe enough, the ecosystem would be at risk because all food webs depend on a good supply of producers.

The most likely outcome is that the bird population would decrease, so all species would return to balance with smaller population sizes. A positive effect is that decreased bird numbers might enable the frog population to recover.

Ecosystem balance constantly changes before returning to a new, stable balance. This is called a **dynamic equilibrium**. Changes may upset the equilibrium, but another new equilibrium arises. Often, the change is only a small one. Changes in ecosystems occur naturally, but they may be intensified by external abiotic factors such as floods and bushfires. Reproduction, death, migration, natural events (such as seasonal changes), disasters (floods, droughts, earthquakes) and human intervention occur regularly. Biotic factors such as the loss of a species or the introduction of a new species can also change a population.

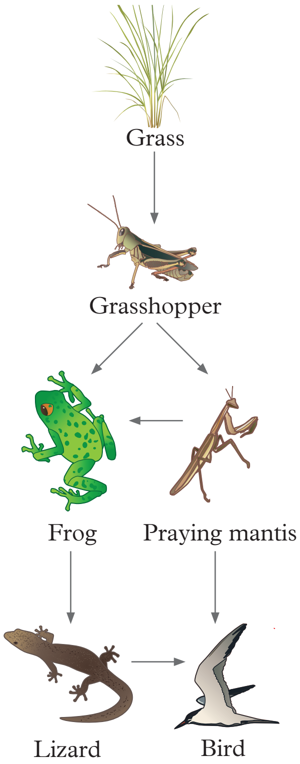


Figure 3 A food web for an ecosystem

Population dynamics

Population dynamics is the study of changes in population numbers within ecosystems. If scientists can measure how many of each species are in a certain location, they can make predictions and try to prevent a species becoming extinct.

Regular sampling provides information about increases and decreases in population numbers, and causes can be identified.

population dynamics the study of changes in species population numbers and the factors that may contribute to these changes

quadrat a randomly selected square plot used to estimate the number of organisms

Counting organisms

There are many ways to measure the size of a population. The simplest way would be to count all the organisms, but in practice this is very difficult. It is easier to estimate the total population by counting a sample from a helicopter or by using quadrats or capture–recapture methods. For human populations, a census is the usual method.

For plants and stationary animals, **quadrats** (randomly selected square plots) are marked in an ecosystem (Figure 4). The organisms in each plot are counted and used to calculate the average number of organisms in each square plot. The total number of organisms in the whole ecosystem can then be calculated by multiplying the average number of organisms by the area of the ecosystem. This method works well if a large number of quadrats are used and the organisms are evenly spread throughout the ecosystem. For animals that are moving, **capture–recapture** is a popular method. Animals are captured in traps and marked with tags, correction fluid or permanent marker on their tails.

Figure 4 Using a quadrat

capture–recapture a method of estimating the number of organisms by capturing, marking and releasing a sample of the organisms

Figure 5 A scientist tagging a bird

The number counted on the first capture are called tagged animals (Figure 5). The animals are then released and it is assumed that they move evenly throughout the population. Another capture (recapture) is made one or two days (or nights) later. Some of these recaptured animals will have tags. An estimate of the population is then obtained using these three numbers:

$$\text{Total number of animals} = \text{number of tagged animals} \times \frac{\text{number of recaptured animals}}{\text{number of tagged animals recaptured}}$$

Capture–recapture is a good way to estimate the population size of small Australian mammals such as the marsupial *Antechinus* (the common bush rat). Most native Australian mammals are nocturnal, so the traps may be set at night and checked the next morning.

Figure 6 Remote sensors are used to record and identify animals without disturbing their normal behaviour.

Modern counting methods

When tags or quadrats are used to count organisms, it can disrupt their environment and affect the way the animals behave. Modern counting methods can avoid this disturbance by using remote sensors that detect movement and turn on remote cameras (Figure 6). These images allow scientists to count the number of animals moving in an area and to study how animals behave when humans are not around. Other ways to identify animals is to record the calls they make to one another. This recording can then be used to identify the species of animal and the number of them making and replying to the calls.

Worked example 9.2A Calculating population size

Scientists wanted to determine the size of a bilby population in a small reserve. They used the capture–recapture method to estimate the size of the population.

They captured and marked 9 bilbies on the first night and 8 bilbies (4 marked) one week later.

Calculate the size of the bilby population.

Solution

Steps	What to do	Working out
a.	Determine the number of marked/tagged bilbies on the first night.	9 captured
b.	Determine the number of marked/tagged bilbies one week later.	8 captured with 4 recaptured bilbies already tagged
c.	Write the equation and substitute in the given values to calculate the population size.	$\text{Estimated number of bilbies} = \text{number of tagged animals} \times \frac{\text{number of recaptured animals}}{\text{number of tagged animals recaptured}}$ $= 9 \times \frac{8}{4}$ $= 18$
d.	Answer the question.	The size of the bilby population is 18.

Check your learning 9.2

Check your learning 9.2

Retrieve

1 Identify two examples of abiotic factors and two examples of biotic factors.

Comprehend

2 Describe two ways a population can:
  a increase
  b decrease.

3 Describe suitable methods for estimating the size of populations of:
  a plants and stationary animals
  b other animals.

4 Explain how predator–prey relationships achieve a state of balance by describing what happens to the number of predators or prey when:
  a prey numbers increase
  b prey numbers decrease
  c predator numbers increase
  d predator numbers decrease.

Analyse

5 Students on a field trip with a national park ranger set traps for a small nocturnal marsupial *Antechinus stuartii* in a heathland ecosystem. They captured eight animals on the first night and marked white dots on their tails. Then they released them. On the second night, they captured 10 animals, of which four were marked.
  a Calculate the estimated population size of *A. stuartii* in this ecosystem.
  b Describe one way the students could check if their estimated population size was correct.

Apply

6 Imagine that you were asked to find out how many different types of animals lived in your backyard or local park. Discuss how you would go about finding this out. (HINT: Would it be possible to individually count them all?)

7 Desalination plants take the salt out from seawater to produce fresh water for us to drink. The remaining seawater with high levels of salt is returned to the ocean through a fast-flow pipe. A study of the desalination plant in Sydney found that the population of mobile sponges decreased near the returning pipe, while populations of barnacles sticking to the rocks increased. Compare (the similarities and differences between) the two populations and propose a hypothesis that might explain the difference between the survival of the two populations.

8 Investigate the rules that regulate the type, number and size of fish that can be caught in your local area. Write a letter to a local paper explaining why these rules are needed.

Skills builder: Conducting investigations

9 When research impacts an ecosystem, the environmental impacts on both animals and plants as well as any cultural impacts on researching that area must be considered.
  a Think about where you live. Identify one animal species that could be investigated via capture–recapture. (THINK: Is this animal native to your area?)
  b Highlight ethical issues of using this method on this animal. (THINK: Does this animal live elsewhere? Will any harm come to the animal? Do you need to think of cultural impacts?)

Lesson 9.3

Investigation: Rabbit and fox chase

Purpose

Modelling the impact of one species (predator) on another (prey)

Materials

- Large packet of popcorn
- Material to represent rabbit tails
- Outdoor space
- Container
- Measuring wheel
- Timer

Part A: Rabbit populations

Procedure

Many scientists use simulations or modelling to determine how the number of organisms of the same species (the population) will be affected by the introduction of a new species.

Figure 1 How does food affect a rabbit population?

1. Measure a 30 m^2 area outside in the schoolyard. Count out 40 pieces of popcorn. Randomly throw handfuls of the counted popcorn through the area.
2. Select five students to represent rabbits. Each "rabbit" should tuck a piece of material into their belt to represent a tail. To survive, each rabbit must collect at least five pieces of popcorn in the 15-second "season". The retrieved popcorn is placed in a container at the end of the time-period and is removed from the available resources.
3. Simulate a second season by adding another 30 pieces of popcorn and having the rabbits collecting popcorn during another 15-second period. After the second season, any rabbit that survives then "reproduces". This involves selecting another student to join the simulation as a rabbit. The simulation is repeated, using popcorn in varying amounts to represent the food production in good and poor years, until "starvation" begins to reduce the population.
4. Copy Table 1 and record your data for six seasons. Highlight the seasons that are droughts (poor food supplies) and those that are bumper years (good food supplies).

Table 1 Population of rabbits over many seasons

Season	1	2	3	4	5	6
Number of rabbits at end of season						

Part B: Introducing foxes

Procedure

1. Repeat the simulation from Part A but this time with additional students modelling foxes. A fox must catch a rabbit to survive. A fox catches a rabbit by removing the cloth tail hanging from their belt (similar to flag football).
2. Copy Table 2 and record your data for six seasons.

Discussion

1. Graph the results of the model as a bar graph showing the number of each animal at the end of a time period.
2. Identify how the following factors were represented in the model:
   - a increased food supplies
   - b decreased food supplies
   - c competition between rabbits or foxes.
3. Use data from the modelling to explain the effect of:
   - a increased food supplies
   - b decreased food supplies
   - c competition on predator populations.
4. Explain the characteristics in a population that will help some animals to survive.

Figure 2 How do predators affect a rabbit population?

Table 2 Populations of rabbits and foxes over many seasons

Season	1	2	3	4	5	6
Number of rabbits at end of season						
Number of foxes at end of season						

Lesson 9.4

Investigation: What if the effectiveness of pollinators was reduced?

Purpose

To examine factors that affect the pollination of fruit

Materials

- 10 chairs
- Two large bags of popcorn
- 10 paper bags
- Timer

Procedure

1. Divide the class into groups, with six students in each group. Each group represents a team of bees.
2. Gather the bees in one corner of the room or on the oval. This is the beehive.
3. Place approximately 10 chairs around the room or oval to represent apple trees. On the seat of each tree, place one handful of popcorn and an empty paper bag.
4. The bees must fly from tree to tree, taking a single piece of popcorn from one tree and putting it in the paper bag of another tree. This represents a bee pollinating the apple trees. Twenty seconds represents one growing season. This can become a competition if the number of pieces of popcorn on each tree is controlled.
5. At the end of 20 seconds, the bees gather back in the hive. A representative counts how many pieces of popcorn are in each paper bag. Each piece of popcorn represents one apple that was able to grow on that tree during the season.
6. Record how many apples are grown in each team's first season. Calculate the average number of apples grown that season for all the teams.
7. Empty the paper bags and reset the popcorn on each chair tree.

Inquiry: What factors can affect the effectiveness of pollinators?

Choose one of the inquiry questions.

- What if the weather becomes colder so that the bees fly (walk) more slowly?
- What if a harsh winter kills half the bees in the hive?
- What if overcrowding in the hive causes half the bees to swarm out of the area?
- What if the apple trees are damaged and lose half their leaves?

Answer the following questions about your inquiry question.

1. Write a hypothesis for your inquiry.

Figure 1 Bees are effective pollinators.

2. Identify how you represent your independent variable in the pollination model.

3. Identify what effect you expect to see on the dependent variable that you will measure and/or observe.
4. What variables will you need to control to ensure a reasonable test? How will you control them?
5. Write down the method you will use to complete your investigation. (HINT: Use the method above as a guide.)
6. Draw a table to record your results.
7. Show your teacher your planning to obtain approval before starting your experiment.

Results

Draw up an appropriate table and graph to show the results of your inquiry.

Discussion

1. Describe the effect that changing bee populations has on the amount of fruit produced.
2. Describe one way your pollination model was not an accurate depiction of real-world pollination.
3. Suggest one way to improve the model you used.
4. Identify one situation where scientists may use computer modelling to carry out research.

Conclusion

Describe why pollinators are important to the supply of fruit.

Lesson 9.5

Matter is recycled through an ecosystem

Key ideas

→ Scientists use food chains and food webs to show the flow of food and energy in an ecosystem.

→ Producers are found at the start of a food chain.

→ Consumers need to gain their energy from eating other organisms.

→ Food webs have many interlinking food chains.

Learning intentions and success criteria

Introduction

Matter is cycled through an ecosystem in a continuous process known as the **nutrient cycle**. Elements and compounds such as carbon, nitrogen, oxygen and water are essential for the survival of all living organisms. If they are not cycled through an ecosystem, the balance and health of the ecosystem can be affected.

For example, carbon, hydrogen and oxygen are essential to produce important biological molecules such as carbohydrates, proteins and fats; while nitrogen and phosphorous are critical for the formation of amino acids, proteins and nucleic acids (DNA and RNA). These elements, like others, move through food chains and food webs as organisms eat each other and are eventually returned to the soil by decomposers (such as bacteria, fungi and worms) and detritivores (organisms that consume dead matter and excrete nutrients).

Food chains

A **food chain** is a model that illustrates the direction in which nutrients and energy flow between organisms. It consists of a sequence of arrows pointing from the food source to the **consumer**. A food chain always begins with a **producer**, followed by a **first-order consumer** (primary consumer), a **second-order consumer** (secondary consumer), and so on (Figure 1).

food chain a diagram that shows who eats whom in an ecosystem, and how nutrients and energy are passed on

consumer an animal that can't convert the Sun's energy into sugars and instead must eat to get the energy it needs to survive

producer a plant or plant-like organism that is at the start of a food chain because it produces its own food, usually using sunlight

first-order consumer an organism that eats only producers such as plants, algae and bacteria; it does not eat other consumers

second-order consumer a carnivore that eats primary consumers

Figure 1 A food chain starts with producers and moves through several orders of consumer.

Producers are usually plants or plant-like organisms. They are always found at the start of food chains because they make their own food using sunlight, air, water and minerals. They convert light energy from the Sun into sugars (chemical energy) which is then stored in the leaves, stems and roots.

Consumers, unlike producers, cannot make their own food and must eat other organisms to obtain their energy. They use this energy for essential functions like pumping blood, moving muscles and operating nerves.

In Figure 2, the grasshopper is a first-order consumer because it eats the grass (producer). The noisy butcher bird eats a first-order consumer, so it is called a second-order consumer. The eagle eats the second-order consumer and becomes a third-order consumer. Most food chains only have four to five organisms in them. Why do you think this is? (This will be explored more in Lesson 9.6 Energy flows through an ecosystem, page 408).

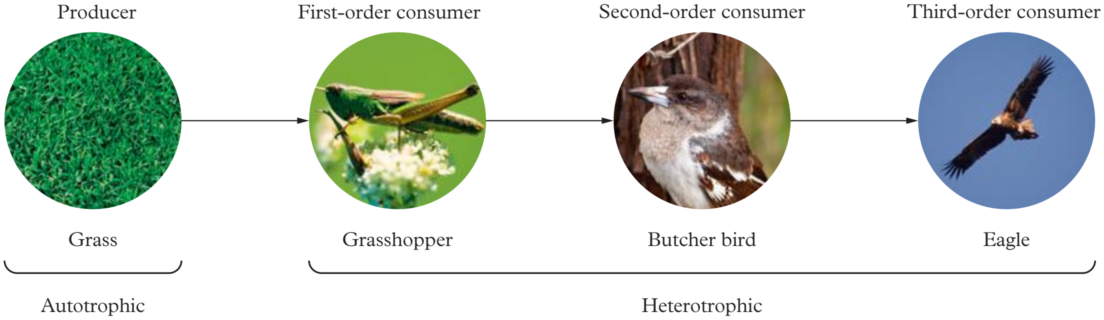


Figure 2 An example of a backyard food chain

Food webs

Most animals, including humans, will eat more than one type of food. This can be represented in a food web which shows several food chains intertwined. Some consumers will have several labels, depending on their eating habits.

Figure 3 shows a food web in which there are four different producers (grass, thistles, wheat seeds and trees). In this example, the sparrow can be considered both a primary and secondary consumer because it eats a producer (wheat seeds) and other primary consumers (snail, caterpillar and beetle). In this food web, the snail is only a primary consumer because it only eats producers (trees).

Food webs show how all organisms within an ecosystem are dependent on one another, even if they do not share a direct feeding relationship. For example, if the spider was removed from the food web in Figure 3, it may impact on the number of beetles and butcher birds. Can you figure out why?

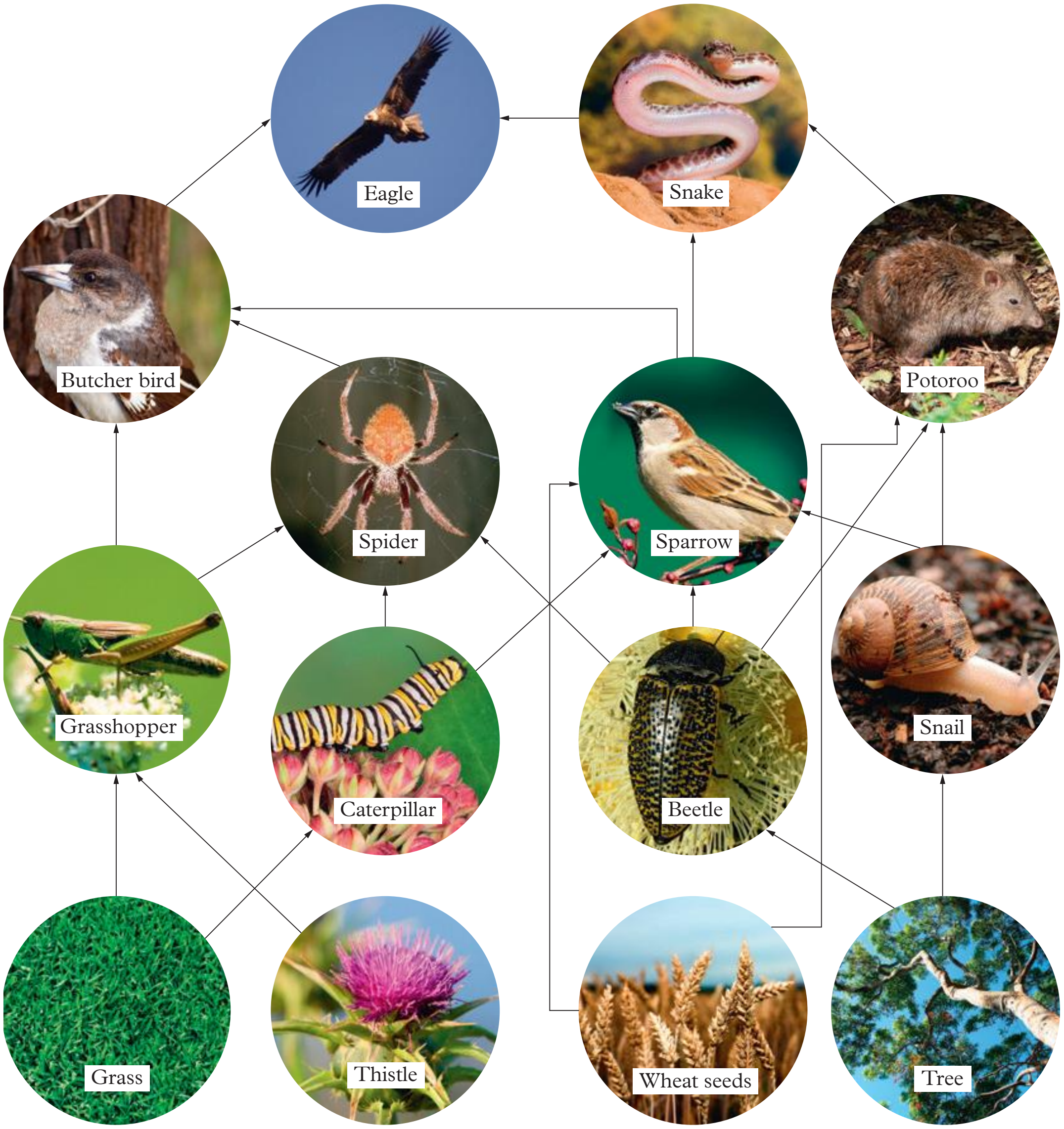


Figure 3 A food web shows the extended relationships between various organisms.

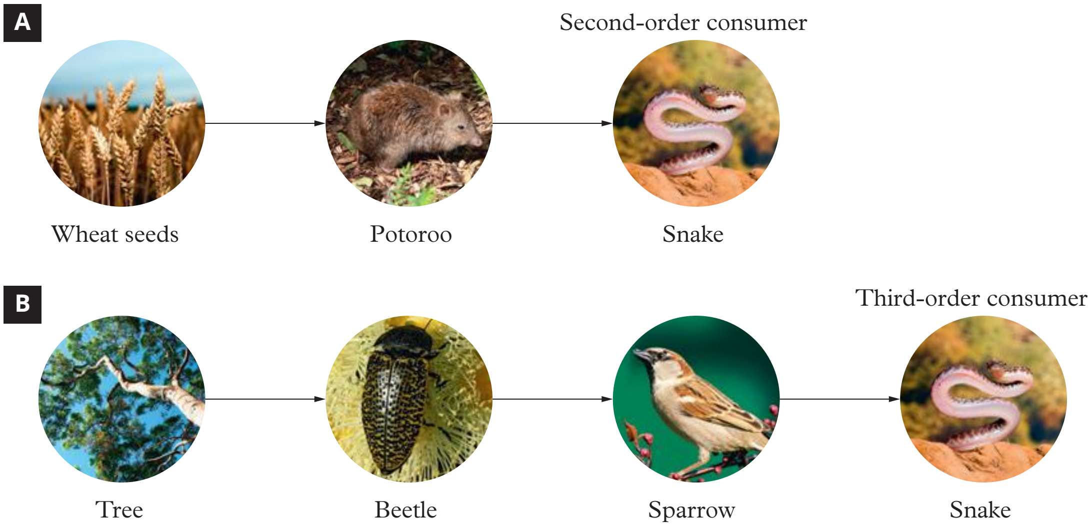


Figure 4 (A) The food chain from the food web in Figure 3, showing the snake as a second-order consumer, and (B) as a third-order consumer.

Decomposers

decomposer an organism, such as bacterium, that obtains nutrients by breaking down dead organisms

detritivore an organism that obtains nutrients by consuming detritus (decomposing plant and animal parts)

Locked inside all organisms is an enormous amount of nutrients. All organisms in a food web eventually end up passing these nutrients on to decomposers when they die. **Decomposers**, such as bacteria, fungi and some invertebrates (for example, slugs and worms) obtain the nutrients they need by feeding on dead organisms. Decomposers such as fungi and bacteria do not eat dead matter – they break it down externally through chemical processes (Figure 5). Other decomposers, known as **detritivores**, consume dead and decaying matter and excrete nutrients. Worms, maggots and termites are classified as detritivores because they feed through oral digestion.

Figure 5 Decomposers recycle important nutrients and energy in an ecosystem.

Decomposers prevent dead organisms from accumulating. Instead, the nutrients stored in the dead organisms are used for energy by the decomposers. When another organism consumes a decomposer, the nutrients (atoms) re-enter the food chain. The nutrients that the decomposers excrete as waste are converted into simpler forms and end up in the soil. Plant roots can then absorb the nutrients and the cycle starts again. Imagine what life would be like without decomposers!

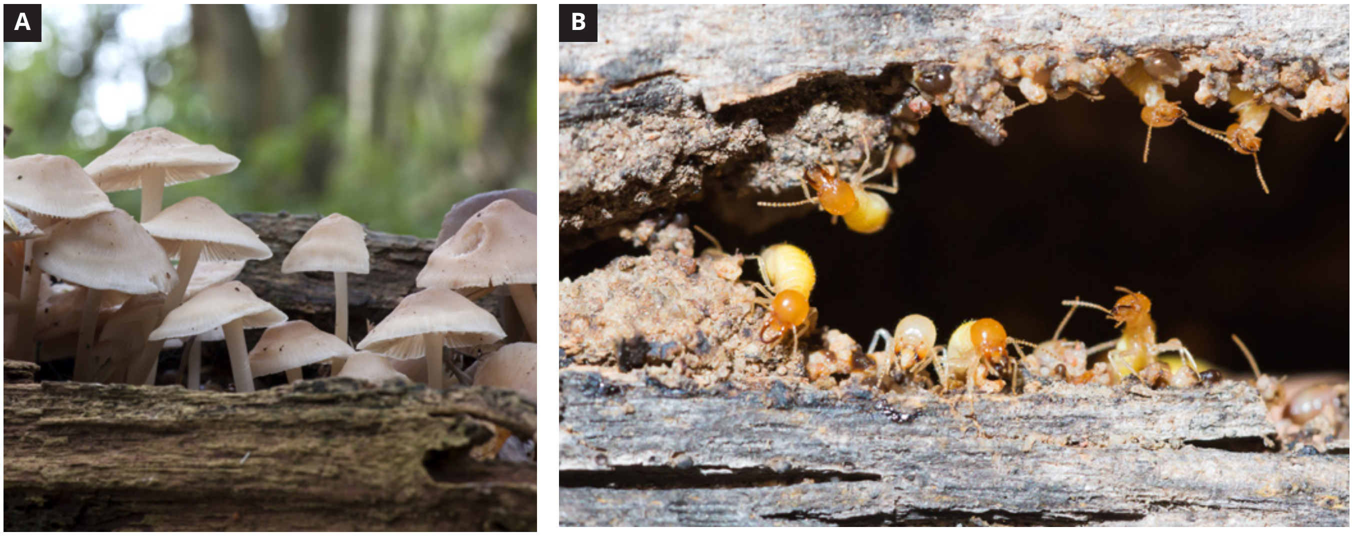


Figure 6 (A) Mushrooms (fungi) are decomposers. (B) Termites are detritivores.

Check your learning 9.5

Check your learning 9.5

Retrieve

1 Identify where producer plants get their energy.

Comprehend

2 Describe how the direction of arrows in a food chain is decided.

3 Describe one consequence that may occur if decomposers did not exist.

Analyse

4 Contrast (the differences between) food chains and food webs.

5 Examine the food web in Figure 3.
  - a Identify an animal that is both a secondary and a tertiary consumer.
  - b Explain two possible consequences to other organisms if the snake was removed from this food web.

Apply

6 Construct your own food web of organisms that you would find in the local park. Correctly identify the producer and all the consumers.

Skills builder: Planning investigations

7 A group of students was asked to go outside of the classroom to observe a food chain in action.
  - a Identify a location they could use to observe a food chain. (THINK: Where would they likely see a food chain in action?)
  - b What equipment should they take with them? (THINK: What will they need to record their observations?)

Lesson 9.6

Energy flows through an ecosystem

Learning intentions and success criteria

Key ideas

→ Energy flows in one direction from the Sun through producers to consumers, with energy loss at each level of the food chain. The hierarchical levels of the food chain are known as a "trophic levels".

→ Energy pyramids show that approximately 10% of energy is passed between each trophic level.

Photosynthesis and aerobic cellular respiration

aerobic cellular respiration the chemical reaction between glucose and oxygen that produces carbon dioxide, water and energy

photosynthesis the chemical reaction used by plants to convert carbon dioxide and water into glucose

The intersection between matter and energy occurs with the all-important biological reactions of photosynthesis and **aerobic cellular respiration**.

Light energy enters a food chain during **photosynthesis** when autotrophs (organisms that can produce their own energy, such as plants) use sunlight to convert water (H_2O) and carbon dioxide (CO_2) into glucose ($C_6H_{12}O_6$). The water is absorbed by the roots of the plant and carbon dioxide is taken in through the leaves. The light energy is required to split water molecules, releasing oxygen (O_2) and hydrogen (H_2). The hydrogen then reacts with carbon dioxide to form glucose ($C_6H_{12}O_6$) which is stored as chemical energy.

At each level of a food chain, the aerobic cellular respiration of autotrophs converts glucose into usable energy in the form of adenosine triphosphate (ATP). Chemical energy is stored in ATP, imagine they are readily available energy packets for the body to use whenever energy is required. The waste products of this reaction are carbon dioxide and water, which themselves re-enter an ecosystem to be used again. This interaction, shown below by the word equations for photosynthesis and aerobic cellular respiration, highlights the continual interplay between matter and energy within ecosystems.

Photosynthesis

Reactants		Products
carbon dioxide + water	→	glucose + oxygen + water
$6CO_2 + 12H_2O$	→	$C_6H_{12}O_6 + 6O_2 + 6H_2O$

Aerobic cellular respiration

Reactants		Products
glucose + oxygen	→	carbon dioxide + water + energy
$C_6H_{12}O_6 + 6O_2$	→	$6CO_2 + H_2O + 36ATP$

Energy transfer

All organisms have one thing in common – the need for energy. But where does this energy come from and how does it move through ecosystems?

Unlike matter, energy only flows in a one-way direction through an ecosystem. The main source of energy on Earth is sunlight, which producers, such as plants, capture and convert into chemical energy through photosynthesis. This process allows plants to obtain all the energy they need, making them **autotrophs** (*auto* meaning "self" and *troph* meaning "nutrition"). The energy is then passed on to first-order consumers (**herbivores**) when they eat the plants.

Figure 1 Plants use energy from the Sun to grow and repair.

Organisms that need to eat other organisms to obtain energy, such as humans, are called **heterotrophs**.

While the original source of energy in most ecosystems is the Sun, there are exceptions. For example, **chemosynthetic** bacteria on the ocean floor and in the craters of volcanoes trap the energy from chemicals and chemical reactions occurring under the Earth's crust.

Knowing who eats whom can be very useful information, particularly when looking at how humans have an impact on the natural environment.

autotroph an organism that produces its own chemical energy through photosynthesis or chemosynthesis

herbivore an animal that eats only plants

heterotroph an organism that must consume other organisms in order to obtain its energy requirements

chemosynthetic a process by which certain organisms, typically bacteria, convert inorganic compounds into organic matter using chemical energy rather than sunlight

trophic level the position an organism holds in a food chain or food web

carnivore an animal that eats other animals

omnivore an animal that eats both plants and animals

Energy pyramids

Energy pyramids are visual models that illustrate the amount of energy transferred between different hierarchical levels in an ecosystem. These are known as **trophic levels**. Each level of the pyramid represents a different group of organisms based on their role in the food chain, starting from producers at the base and moving up through the various levels of consumers.

As we move up the energy pyramid from producers to first-order consumers (herbivores), second-order consumers (**carnivores** or **omnivores** that eat herbivores) and third-order consumers, the amount of energy decreases at each level, with only an estimated 10% of the energy available from one level to the next. By the time the energy that enters a food chain makes its way to the **apex predators** (those at the top of the food chain), as little as 0.01% of the original energy pool remains. This is because organisms at each level use energy to perform all of life's functions (remember MR N GREWW), with a substantial amount of energy also lost to the environment as heat.

Energy pyramids help us understand the efficiency of energy transfer in ecosystems and emphasise the importance of producers. They illustrate how energy availability influences the number of organisms that can be supported at each trophic level. This understanding is essential for studying ecosystems and addressing environmental issues, as it highlights the interconnectedness of all living organisms.

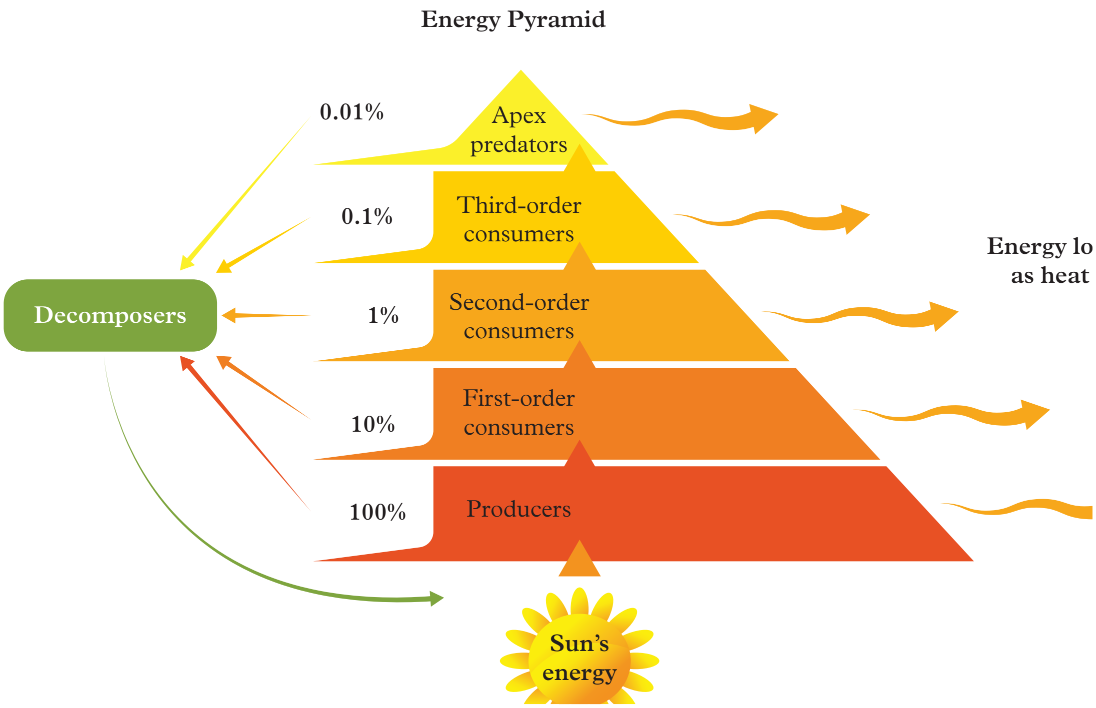


Figure 2 Energy pyramid highlighting the loss of energy as it moves through each trophic level of a food chain

Case study Dorrigo National Park

Dorrigo National Park is located in north-eastern NSW and is filled with different forest environments. Energy flows through the national park from producers to consumers as part of an ecosystem.

Dorrigo National Park has many species of eucalypt trees, such as the Dorrigo white gum. Coachwood trees also grow well there, producing white flowers and red fruits in spring and summer that king parrots can feed on. Brush turkeys living in the park feed on fallen fruit and on insects and seeds they find in the leaf litter.

Figure 3 Dorrigo National Park is home to many plant and animal species that interact.

Common ringtail possums live in the national park and are mainly active at night. The possums use their powerful claws to search trees, foraging for gum leaves, flowers and fruits.

Spotted-tail quolls are also found in the national park. They hunt mostly at night and are known to eat small mammals such as possums and even some small reptiles and birds. The quolls are threatened by foxes. Foxes can hunt spotted-tail quolls for food, but they also hunt for smaller animals like possums, reptiles and birds.

Figure 4 (A) The spotted-tail quoll; (B) a common ringtail possum

Check your learning 9.6

Check your learning 9.6

Retrieve

1 Identify the term used to describe animals that eat both meat and plants.

2 Identify the following as either an input or an output of photosynthesis.
  - **a** Carbon dioxide
  - **b** Glucose
  - **c** Water

Comprehend

3 Explain why most food chains are limited to a maximum of four or five organisms.

Analyse

4 Compare (the similarities and differences between) the following terms: producer, first-order consumer, second-order consumer, herbivore, carnivore, photosynthesising organism.

Apply

5 Humans get the energy we need by eating other living organisms. Determine the source of energy for the following organisms.
  - **a** Plants
  - **b** Herbivores
  - **c** Decomposers

6 "Photosynthesis is the most important metabolic process on Earth."

Evaluate the above statement by:
  - **a** describing why photosynthesis is important in an ecosystem
  - **b** describing what would happen if photosynthesis was not able to occur
  - **c** deciding whether the statement is correct.

Skills builder: Problem solving

7 Assess the following statement: "Photosynthesis and cellular respiration are the opposite of one another, which means they are reversible."
  - **a** Identify two things that support this statement. (THINK: Does this source suggest that they are the opposite of each other? Does it state that they are reversible?)
  - **b** Identify two things that do not support this statement. (THINK: Does this source state that they are not the same?)
  - **c** Determine a conclusion about this statement. (THINK: Have I considered the pros and cons of each argument?)

Lesson 9.7

Investigation: Studying food webs

Purpose

To identify local producers and consumers and construct a food web based on the observations

Materials

- Metre-long rulers
- Poster board
- Markers
- Photographs of ecosystems

Procedure

1 Think about a possible food web in your backyard, schoolyard or local neighbourhood.
  - Write a list of at least 10 organisms you might find in your chosen food web.
  - Compare the number of different animals and plants found in various areas of your chosen habitat. For example, consider areas with a variety of plants versus grassy areas.
  - Generate a scientific question based on your observations.

2 Write a hypothesis that matches your scientific question.

3 Select two 1 m^2 areas in your backyard, schoolyard or neighbourhood to study. The study areas should be near each other but in two different habitats (for example, on a footpath and on some grass, or just inside a forest and in a clearing).

4 Observe and record all organisms in each of the 1 m^2 areas and within the greater study area.

5 Using your observations, construct a food web that identifies where each organism obtains its energy (who they eat).

Discussion

1 Identify the producer organisms in your food web.

2 Identify the consumer organisms in your food web.

3 Compare the number (of individuals and species) of producers and consumers you observed in each area.

4 Compare how matter and energy move through your ecosystem.

Figure 1 Identify the food webs in your neighbourhood.

Lesson 9.8

Investigation: Studying energy and biomass pyramids

Introduction

Biomass pyramids show the amount of living matter present at each trophic level of a food chain. In most – but not all – cases, the general shape of a biomass pyramid is the same as an energy pyramid, with biomass decreasing from producers to higher-level consumers. For example, in Figure 1, both the energy and biomass decreases by 90% between each level of the food chain.

- Trophic level 5 (apex consumers): 0.3 g/m²
- Trophic level 4 (tertiary consumers): 3 g/m²
- Trophic level 3 (secondary consumers): 30 g/m²
- Trophic level 2 (primary consumers): 300 g/m²
- Trophic level 1 (producers): 3,000 g/m²

Understanding the interconnectedness of organisms within an ecosystem and the dynamic relationships they share is crucial for interpreting and communicating the complexities of ecological systems and highlighting the importance of preserving these ecosystems.

Task

Research an Australian ecosystem and use the information to create a written text to explain how energy pyramids show the amount of energy or matter at each trophic level. Consider using the following structure.

1. Introduction

- Define what an energy pyramid is.
- Briefly explain their purpose.
- Outline your chosen Australian ecosystem.

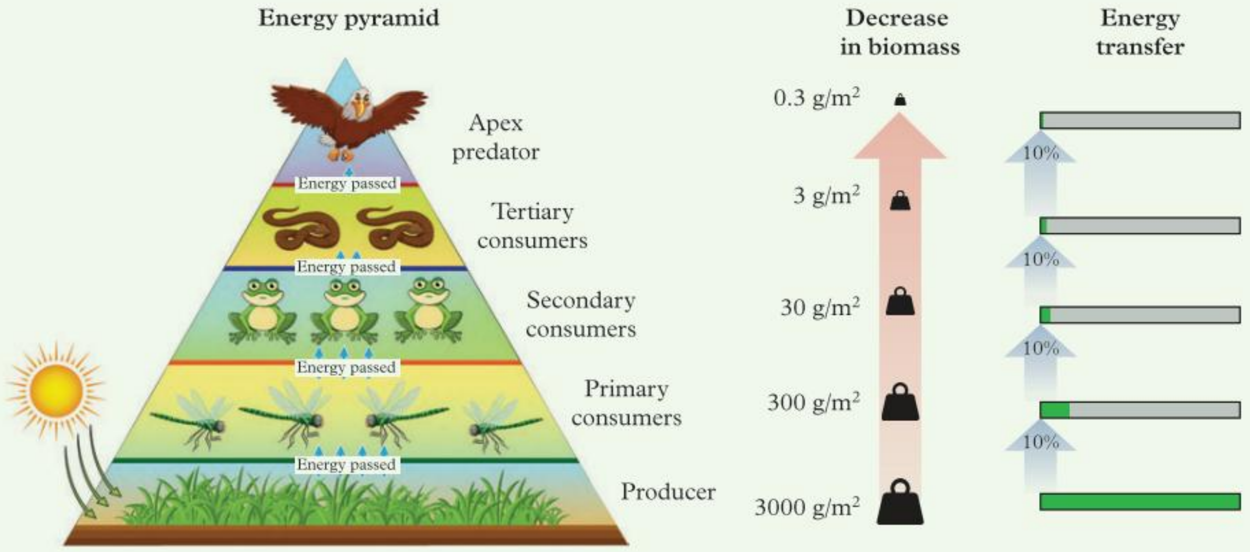


Figure 1 Combined energy and biomass pyramid

2. Structure of energy pyramid

- Describe the general shape of an energy pyramid with reference to the 10% rule of energy transfer.
- Identify the organisms found at different trophic levels in your ecosystem.

3. Trophic levels, energy transfer and biomass

- Explain the role of each trophic level (e.g. producers, primary consumers, secondary consumers, tertiary consumers and apex predators).
- Construct an energy pyramid that includes the estimated biomass values for each level of your ecosystem, illustrating the decrease in energy and biomass as you move up the pyramid.
- Discuss the concept of energy transfer between trophic levels.

4. Importance of energy pyramids

- Explain the significance of energy pyramids in understanding ecological relationships and energy flow.
- Discuss how energy availability affects population sizes and the overall health of an ecosystem.

5. Conclusion

- Summarise the key points made in the text.
- Emphasise the importance of energy and biomass pyramids in ecology to illustrate the interconnectedness of ecosystems and the impact of energy availability on different organisms.
- Highlight the importance of understanding energy pyramids for ecosystem preservation.

6. References (if applicable)

Include a reference list for any sources or textbooks referenced in the text.

Lesson 9.9

Impact of introduced species on ecosystems

Learning intentions and success criteria

Key ideas

→ Introduced species can change the amount of food available for other organisms.

→ New species can cause a new equilibrium in an ecosystem.

→ Biological control is the deliberate introduction of a new species to control a non-native plant or animal.

Balanced populations

There is a balance between all organisms in a food web. If more grass grows, the number of animals that eat the grass will also grow. In time, the amount of grass available will decrease, which will be balanced by a decrease in the animals who eat the grass. This increase–decrease population cycle is a balance that can be disrupted by a range of factors, including **introduced species** or the removal of predators.

introduced species an organism that has been brought to and has established itself in an area it is not native to

Cane toads

Scarab beetles are a family of beetles that can range in size from 2 to 70 millimetres in length. One species from this family, *Dermolepida albohirtum*, can cause a lot of damage to the sugarcane crops in Queensland. The female of this species lays eggs in the soil of the sugarcane. When the larvae hatch, they eat the roots of the cane plant, causing it to die.

Figure 1 Cane toads were introduced to Australia to control scarab beetles in 1935.

In 1935, a little over 2,000 cane toads (*Rhinella marina*) were introduced to Queensland in an attempt to control the beetle population (Figure 1). While the cane toads did eat the scarab beetles, they preferred other insects. Cane toads also lacked natural predators in Australia (Figure 2). This meant that the typical **pattern** seen in a predator–prey graph was not observed (Figure 4 in Lesson 9.1 All organisms have a role in an ecosystem, page 390). When larger animals such as freshwater crocodiles, quolls or goannas tried to eat the toad, they were killed by the poisonous toxin on the toad's back. With a lot of food available to cane toads and few predators, there has been a trend of rapid population growth, with the population front of cane toads expanding at 50 km per year (Figure 3). Estimates now place the number of cane toads in Australia at over 200 million.

pattern when a set of data repeats in a predictable way

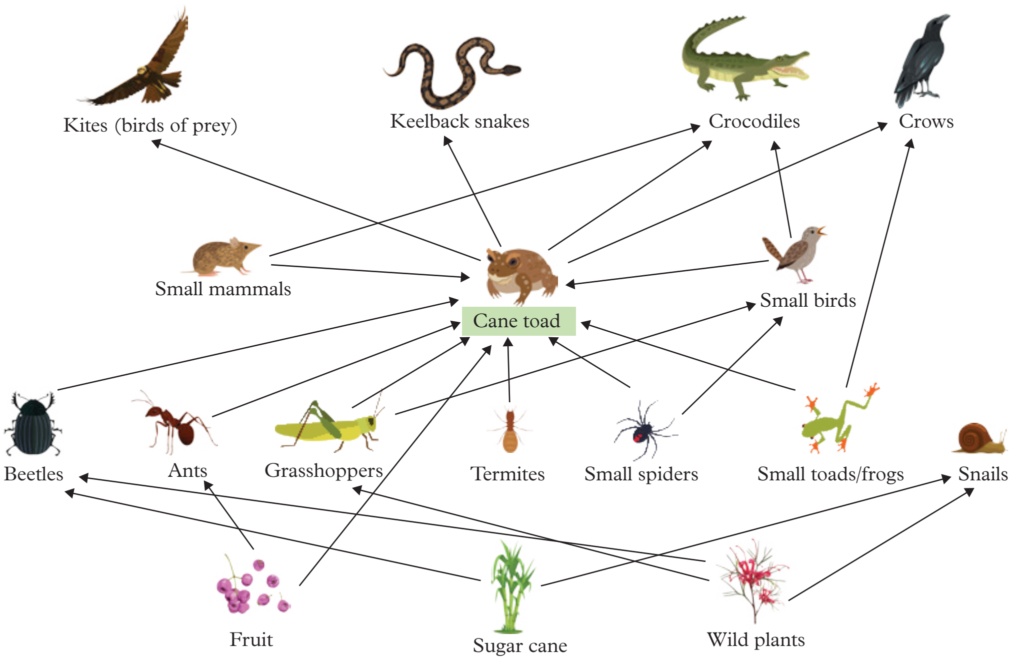


Figure 2 The introduction of the cane toad into this food web has affected many other animals.

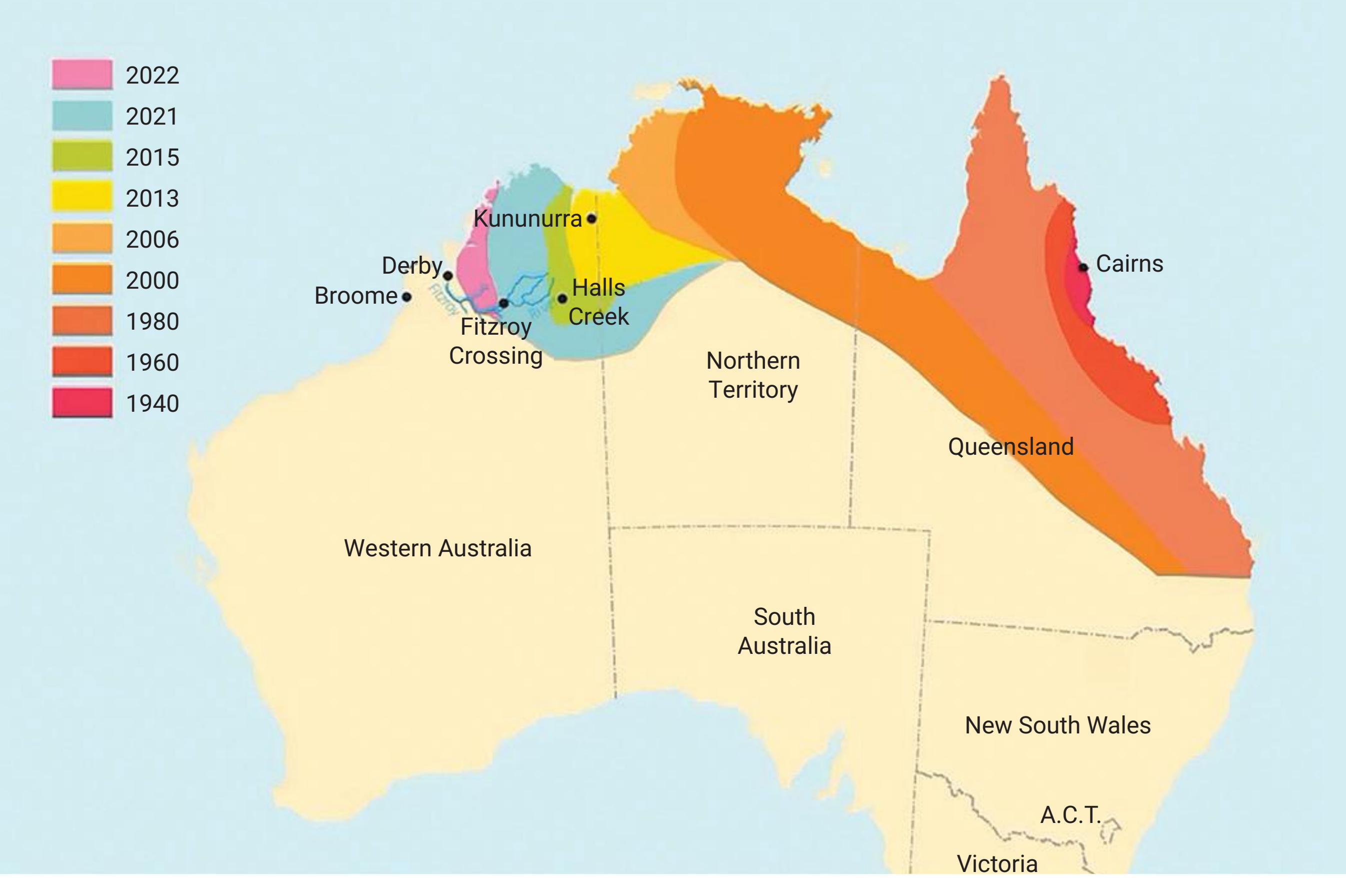


Figure 3 Cane toad distribution across northern Australia over time

Figure 4 Freshwater crocodile that died after attempting to eat the toxic cane toad.

The introduction of cane toads has also had negative social effects on Aboriginal and Torres Strait Islander Peoples who rely on the local ecosystem for food. By the early 2000s, cane toads had made their way to the Northern Territory. Local Aboriginal and Torres Strait Islander communities observed a direct relationship between the arrival of the cane toads and the decline of many native species such as freshwater crocodiles and the yellow-spotted monitor goanna – both important meat and protein sources for the local communities. The crocodiles and goannas are opportunistic feeders and were killed when they tried to eat cane toads (Figure 4).

Figure 5 shows a declining trend of goannas on the Adelaide River floodplain, 50 km south-east of Darwin. This is linked to the arrival of cane toads in 2005. From 2001 to 2005, the number of goannas captured for food was stable at approximately two per day (Figure 5A). Between 2005 and 2010, there was a 10-fold decline in the number caught. This coincided with a large number of dead goannas being observed in 2005 (Figure 5B).

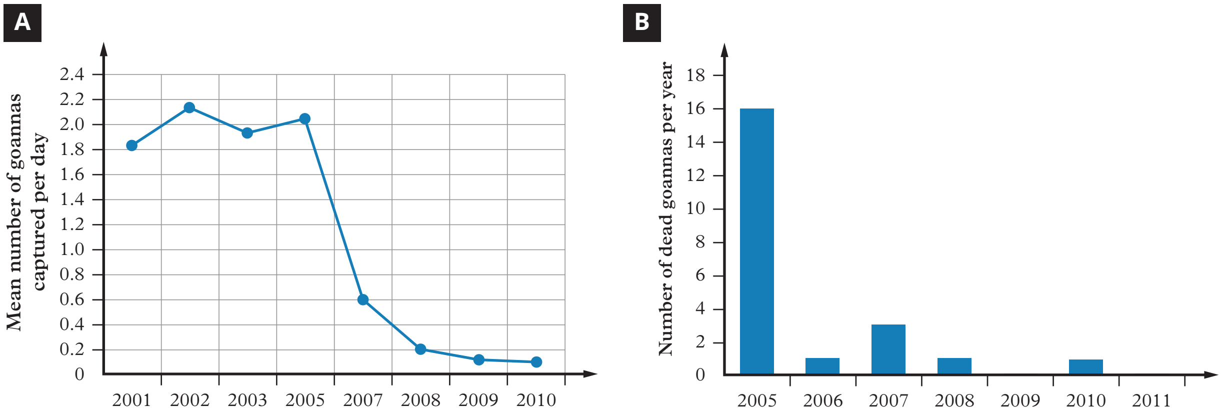


Figure 5 Impact of cane toad invasion on large varanid lizards. Toads arrived at this site in February 2005. (A) Mean annual numbers of goannas (yellow-spotted monitors, *Varanus panoptes*) captured per day in the years preceding and following cane toad (*Rhinella marina*) arrival in 2005 (no fieldwork was conducted in 2004 and 2006); (B) opportunistic observations of numbers of dead *V. panoptes* found per year since the arrival of toxic invasive cane toads

Figure 6 shows the relationship between the density of freshwater crocodile hatchlings at four locations along the Daly River in the Northern Territory before and after the arrival of cane toads. At all four locations, there has been a decline in the number of crocodiles, linked to the presence of cane toads.

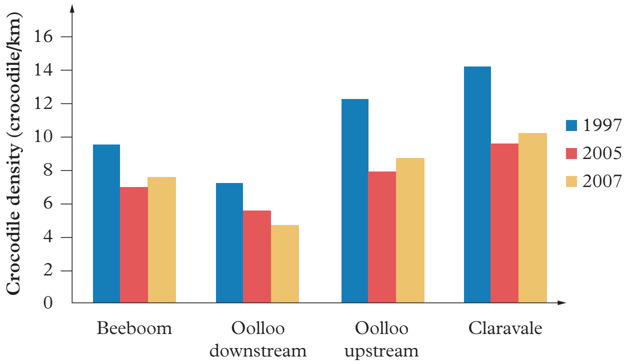


Figure 6 Non-hatchling crocodile density before (1997) and after (2005, 2007) the arrival of cane toads, at four sites on the Daly River, Northern Territory

Gamba grass

In the 1930s, farmers were concerned about the lack of grass in the dry parts of Australia, so they brought gamba grass from the tropical savannahs of Africa (Figure 7). This grass grows very quickly, taking over land that would usually grow native Australian grasses. Because gamba grass grows so quickly, it produces a lot of vegetation that burns in a bushfire.

It also has the potential to prevent small tree seedlings from growing, changing woodlands to a grassland. While cattle farmers might like the increase in grass for their cattle to eat, it has an environmental impact on the plant and animal life in Kakadu National Park. This means it also has an impact on important food sources and medicines for Aboriginal and Torres Strait Islander Peoples who live in that area.

Figure 7 Gamba grass

Macquarie Island rabbits

Not all relationships in a food web are easily predicted. In 1985, scientists on Macquarie Island (halfway between Australia and Antarctica) devised a plan to eradicate the cats that had been introduced to the island since the early nineteenth century. The scientists thought that if the cat population decreased, there would be an increase in the native burrowing bird populations on the island. However, the cats were also predators of rabbits. When the cats were gone, the rabbits were no longer hunted. This allowed the rabbits to survive, destroying native plants and affecting many other organisms that were native to the island (Figure 8). Scientists needed to find a way to control the rabbits.

Figure 8 (A) Before: This slope on Macquarie Island had vegetation as recently as 2007; (B) After: The same slope a few years later – it has been ravaged by rabbits since cats were eradicated.

Biological control

In mainland Australia, all efforts to control the rabbit population by physical means were unsuccessful. In 1938, CSIRO scientists studied a way to control the population using a living organism (**biological control**). They tested a virus called *Myxoma* for its ability to cause **disease** in rabbits. This virus causes myxomatosis, a disease with symptoms including fever and swelling around the head of the rabbit. Death occurs within 14 days. *Myxoma* was eventually released in the wild and quickly killed almost all the rabbits that caught the infection. This had a positive impact on many native plant species that were eaten by the rabbits and on the animals that were competing with the rabbits for food (Figure 9).

A small percentage of rabbits were unaffected by the disease. These rabbits survived and bred a new population of rabbits that were **immune** to the disease. New viruses, such as the rabbit haemorrhagic disease virus (RHDV), were tested on the mainland (Figure 10) producing similar effects on the rabbit population as the *Myxoma* control strategy.

biological control a method of controlling a population by releasing a living organism into an ecosystem

disease a disorder or condition that interrupts the normal functioning of an organism

immune able to fight an infection as a result of prior exposure

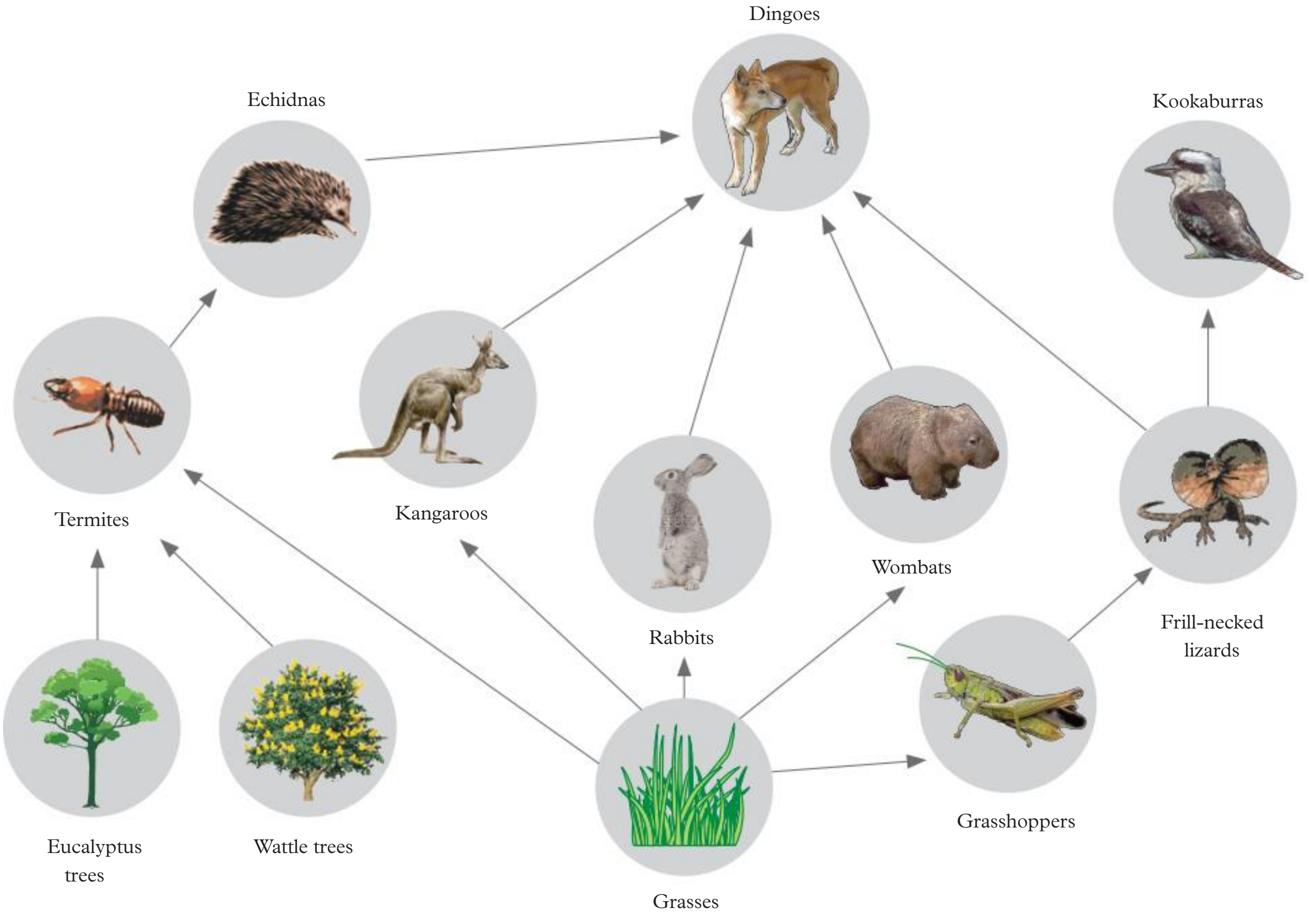


Figure 9 Rabbits compete with grasshoppers, wombats and kangaroos for grass.

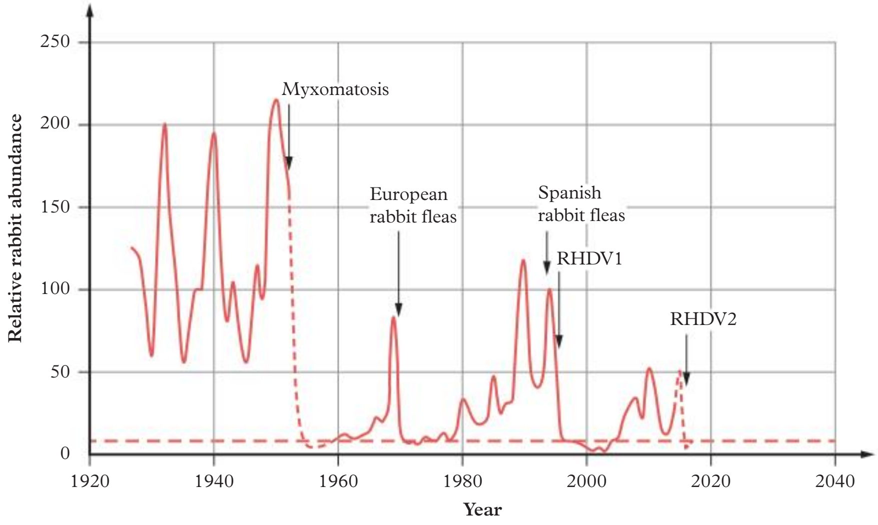


Figure 10 Introduction of different biological controls to reduce rabbit populations

In contrast, the small size and isolated nature of Macquarie Island meant biological control of the rabbit population was more successful there. In early 2011, RHDV was released into the rabbit population, and within one year, the population fell from 150,000 to zero. Figure 11 shows the seasonal pattern in rabbit numbers prior to the introduction of RHDV. There is a direct relationship between the introduction of RHDV and the drop in rabbit population size.

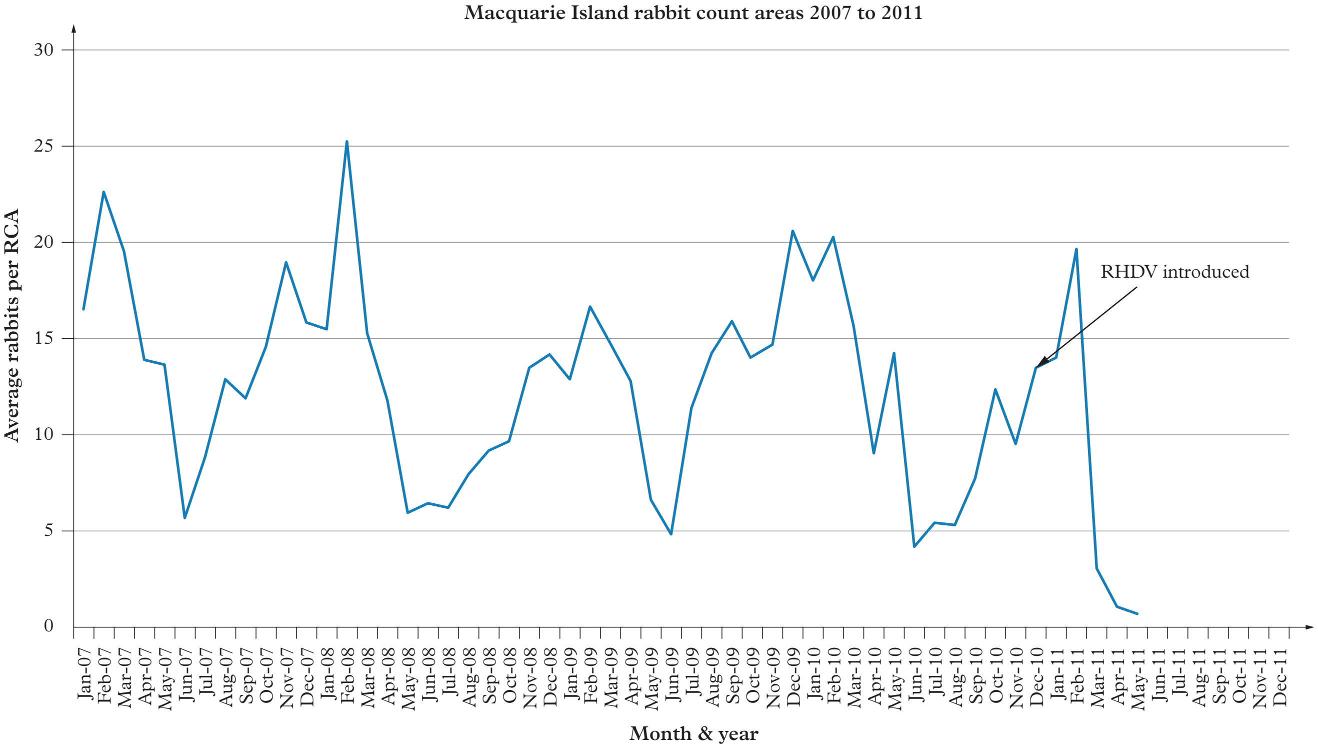


Figure 11 Seasonal patterns of rabbit populations on Macquarie Island and the impact of RHDV introduction in 2011.

Check your learning 9.9

Check your learning 9.9

Retrieve

1 Identify one native species that has declined due to the introduction of cane toads.

2 Identify the primary method used to control the rabbit population in mainland Australia.

3 Describe the effects of gamba grass on the native Australian ecosystem.

Comprehend

4 Explain how the balance between producers and consumers can be disrupted in an ecosystem.

5 Explain why cane toads were unsuccessful at controlling the scarab beetle population.

Analyse

6 Analyse what patterns emerge when comparing the population trends of freshwater crocodiles before and after the arrival of cane toads, and what do these patterns indicate about ecosystem health?

7 What insights can be drawn from the contrasting outcomes of biological control methods used on the mainland versus Macquarie Island regarding ecosystem resilience?

Apply

8 In what ways can the introduction of a biological control agent, such as a virus, impact an ecosystem beyond its intended target species?

9 Considering the decline in native species due to cane toads, what conservation measures could be put in place to protect and restore these populations?

10 Apply the concept of balanced populations to predict what might happen if a new predator is introduced to an ecosystem with an abundant prey population.

Lesson 9.10

Ecosystems can be disrupted

Key ideas

→ Competition for resources, seasonal changes and natural disasters change and disrupt populations.

→ Human activities have a significant impact on ecosystem dynamics.

Learning intentions and success criteria

Limited resources

Animals use resources such as food and water, and in turn, become food for other organisms. The amount of resources in an ecosystem is always limited. As the size of a population reaches its maximum **carrying capacity** (the ability of the environment to support it), some of its resources, such as food, space and shelter, will become more limited. This means some organisms will either die or need to emigrate (leave). Once the population decreases, there will be enough resources for those remaining. When this occurs, the population will stabilise (reach its maximum size). The population will find a new balance or equilibrium (Figure 1). Natural events, such as seasonal changes or natural disasters, and human impacts – including climate change – can disrupt the balance between the biotic (living) and abiotic (non-living) factors in an ecosystem.

carrying capacity the maximum number of organisms in a population that can be sustained by an ecosystem

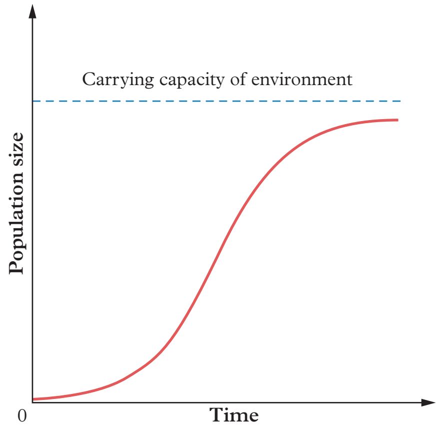


Figure 1 A carrying-capacity graph. A population will continue to grow until resources become limited, at which point the carrying capacity is reached.

Seasonal changes

When the weather becomes colder, many animals migrate to warmer areas (Figure 2). As a result, their populations decrease in one environment and increase in another. During the breeding season, usually spring, the numbers of animals will increase. Flowering plants are pollinated and form seeds that spread throughout the environment and later germinate into seedlings. As the population increases, so does competition for resources. As a result of this competition, some members of the population survive and others die, allowing the population to maintain its balance.

Figure 2 Short-tailed shearwaters leave their burrows on Montague Island on the southern coast of NSW and fly to feeding grounds in the Bering Sea (between Russia and Alaska) during the northern hemisphere summer. They return to Montague Island to breed in late September.

Natural disasters

Australia has a widely fluctuating environment. Years of drought can be followed by flooding rains. When extreme natural changes affect humans, we call these changes **natural disasters**.

natural disasters natural events, such as floods, volcanic eruptions, tsunamis and earthquakes, that can cause severe damage and fatalities

flood the overflow of a large body of water

Impacts of flood and drought

Floods are an overflow of water onto dry land, which has an immediate effect on the growth of plants and the germination of seeds. Marine ecosystems do not benefit from floods. When the water runs off the land into the sea, it brings sediment, pesticides and fertilisers into the marine ecosystem, causing some algal species to dominate the environment. Algal blooms are often deadly to other animals living in the ocean environment.

Floods can be a hazard for some animal life. Small mammals often escape to higher ground. Snakes are flushed out of their cover, as witnessed in the 2022 Queensland floods (Figure 3), and become a potential danger to humans. Some aquatic animals benefit enormously from floods. Fish can breed in waters such as lakes. The increase in fish, insects and waterweeds provides a food source for

Figure 3 Flooding in Queensland in 2022

Figure 4 Drought poses a great threat to life.

water birds. The extra food encourages the water birds to breed in great numbers, temporarily changing the balance in populations.

Droughts pose an even greater challenge than floods (Figure 4). During a drought, animals migrate to find water. Some animal populations "hang on" during drought, but many populations will decrease until the land looks almost bare. Wind can blow the dry topsoil away from the drought-affected area, removing many of the nutrients in the ecosystem.

drought a period in which an area experiences water shortage

Human impacts

In an ecosystem with limited resources, humans must compete with other organisms for food and shelter. The human population has grown quickly over the last 200 years. This means we have needed to change the environment so that we can grow more food, build more homes and find more resources. Many of these changes can affect the local environment (environmental impacts), how people live (social impacts) and how people work or earn money (economic impacts). Understanding the causes of these impacts will allow us to prevent further damage in the future.

Deforestation

Our landscape was once covered by patches of different types of landscapes, such as swamps, grasslands, forests and heaths. This variety of vegetation supported many species of animals that moved, reproduced and spread throughout their territories and beyond.

Today, over 44 per cent of Australia's original bushland has been cleared since European settlement. Much of that land is used for housing, to grow food or to manufacture products. The food webs that existed in these areas have been changed as new predators (such as dogs and cats) move in and the number of producers decreases.

Figure 5 The eastern quoll is a medium-sized marsupial that was considered extinct on the Australian mainland due to changes to their habitat, such as the clearing of native vegetation and the introduction of predators, in particular the red fox. The species was reintroduced to sanctuaries in Victoria in 2003.

Land degradation

Human activities have led to a degradation of the physical environment. Soil erosion is a major problem caused by the clearing of land for agriculture. In ecosystems with many trees, the soil is stabilised by a dense mat of plant roots. Its surface is covered by a layer of leaf litter, which protects the soil surface from erosion by wind and water. Water from rainfall is quickly absorbed through the top layers of soil.

Once land is cleared of trees for agriculture, there is little to protect the soil from the action of wind and water. Grazing by animals with hard hooves, such as cattle, compacts (squashes) the soil. This slows the absorption of water into the soil and increases the amount of water run-off. This in turn erodes the soil. Wind also contributes to the removal of the nutrient-rich topsoil (Figure 6).

Figure 6 In 1983, large amounts of topsoil were carried across Melbourne and into the Southern Ocean because of wind erosion.

Urban sprawl

urban sprawl the spreading and expansion of cities and houses into undeveloped land

More than half of the world's population lives in cities. The population in the world's urban areas has grown by more than one billion people since the 1970s. Much of this growth has contributed to a phenomenon or process known as **urban sprawl**.

Urban sprawl means the spreading out of urban areas into rural areas such as farmland, forests and coastal lands that lie on the outer edges of cities. Urban sprawl increases the distance between the city centre and its outer edge (Figure 7).

Figure 7 Urban sprawl around many of Australia's capital cities is on the rise.

Urban sprawl is common in rapidly developing cities or those with large populations. Some of Australia's cities rate among the world's worst in terms of their sprawling nature, particularly because everyone wants their own garden and local parks.

A changing climate

Human activities are contributing to more significant changes to weather and climate. These changes can have a huge impact on ecosystems.

In alpine areas, changing rainfall and temperature patterns alter the amount of suitable wet alpine habitat. This has made it difficult for animals that need the cool environments to survive.

Figure 8 Alpine areas are reducing as the climate changes.

Check your learning 9.10

Check your learning 9.10

Retrieve

1 Define the term "carrying capacity".

Comprehend

2 Describe two ways in which you could negatively impact a local ecosystem.

3 Describe the possible economic impacts of a drought.

4 Describe a possible social impact that would occur if the environment surrounding a city was protected so that no new houses could be built.

5 Each winter, the cold weather causes the mountain pygmy possum to hibernate (deep sleep). This allows the possum to save energy when food supplies are low during the winter. Describe how a warming climate could affect the mountain pygmy possum's ability to hibernate and survive each winter.

Figure 9 Mountain pygmy possum

Apply

6 Create a two-column table with the headings “Problems” and “Solutions”. In the Problems column, list the types of things that people do that affect wildlife, such as building homes and roads and cutting down trees.
In the Solutions column, propose solutions to each problem.

Skills builder: Questioning and predicting

7 Choose one of the issues outlined in this topic, such as urban sprawl. Identify a question that you could investigate using secondary sources. (THINK: What would you like to know more about? Is the question specific enough to answer objectively?)

Lesson 9.11

Science in context: Species can become endangered or extinct

Introduction

Australia is home to a unique and diverse variety of flora and fauna. Many species are **endemic** to the continent, which means they are only found in Australia. Approximately 70 per cent of the world's marsupial species are found only in this country, including kangaroos, koalas and wombats (Figure 1A). In addition to marsupials, Australia is only one of two places that are home to monotremes. Of the five known species of monotremes, the platypus (Figure 1B) and one species of echidna (the short-beaked echidna) are found in Australia, while the other three species of echidna are native to New Guinea.

endemic found only in a specific country or region

Of the approximately 700 species of *Eucalyptus* (gum trees), over 600 are found only in Australia. Similarly, there are more than 1,000 species of *Acacia* (wattles) worldwide, with an estimated 950 species native to Australia (Figure 1C and Figure 1D).

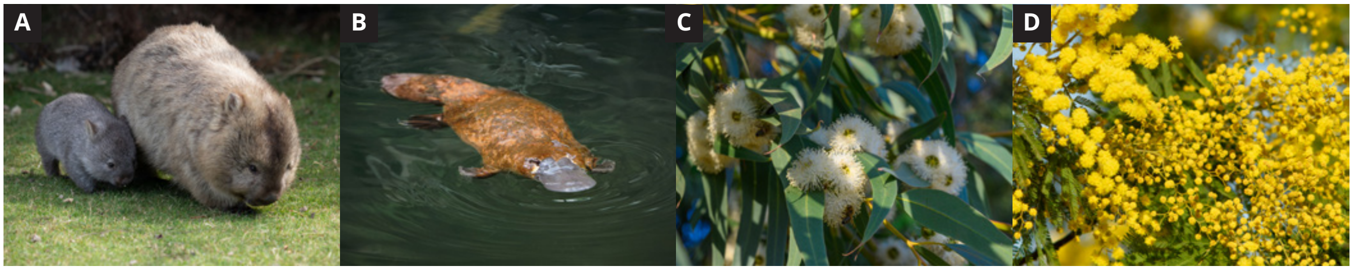


Figure 1 (A) Wombats, (B) platypuses, (C) *Eucalyptus* and (D) *Acacia* are mostly endemic to Australia.

The high percentage of endemic flora and fauna species is largely due to Australia's unique evolutionary history and isolated environment. The isolation over time has allowed for the diversification of species, as they have been able to adapt and evolve in the absence of significant competition.

However, Australia's ecosystems are particularly vulnerable due to a combination of factors, including habitat loss, climate change, introduced species and human activity. These pressures have resulted in one of the highest rates of extinction in the world. According to the World Wildlife Fund (WWF), approximately 30% of the world's mammal extinctions since 1788 (which equals around 39 species) have occurred in Australia, despite having only about 6% of the world's mammal species. Australia also ranks highly for bird, reptile and amphibian extinctions, with at least 24 bird species and four reptile species declared extinct in Australia since the arrival of Europeans, along with several species of amphibians.

Case study Thylacine (Tasmanian tiger) – extinct

The thylacine was a carnivorous marsupial that was native to Tasmania, Australia and New Guinea. It went extinct on mainland Australia approximately 3,000 years ago. While an estimated 5,000 thylacines remained in Tasmania at the time of European arrival, their numbers quickly declined due to habitat destruction and overhunting, as it was believed they posed a threat to livestock. Despite being granted protection status in early 1936, it was too late. In September 1936, the last known thylacine died in a Hobart Zoo.

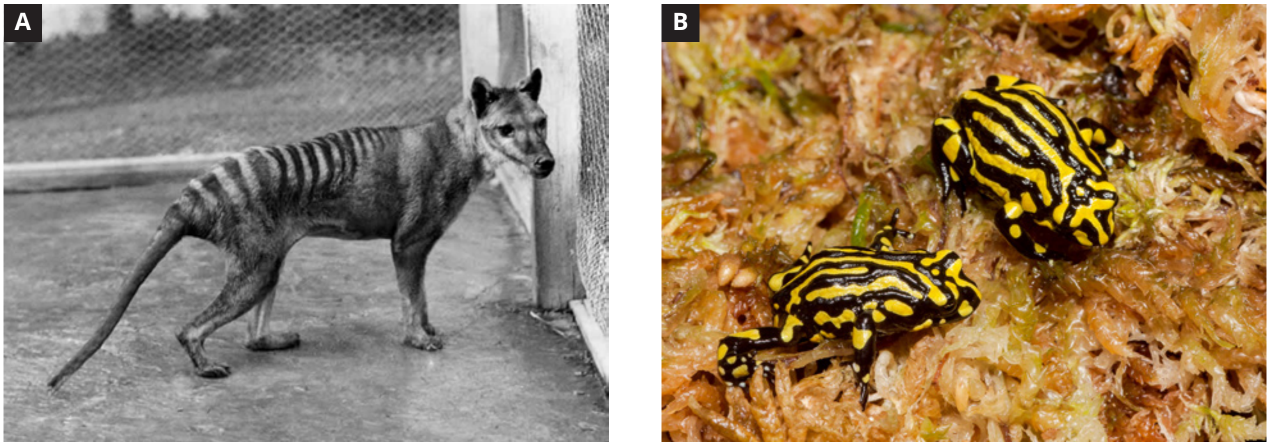


Figure 2 (A) Benjamin, the last known thylacine, died in a Hobart Zoo in 1936. (B) Only 50 southern corroboree frogs are left in the wild.

Case study Corroboree frog – critically endangered

There are two species of corroboree frog: the southern corroboree frog and the northern corroboree frog.

The southern corroboree frog is larger and more brightly coloured with a vivid black-and-yellow-striped pattern, compared to its northern counterpart which is slightly smaller and typically has a duller, greenish tint. Both species are found only in the alpine habitat of Kosciusko National Park, but they inhabit slightly different ecological niches.

Both species have experienced a rapid decline in recent years and are now critically endangered due to habitat loss, climate change and the spread of chytridiomycosis, a deadly fungal disease affecting amphibians worldwide. It is estimated that there are fewer than 1,200 mature northern corroboree frogs remaining in the wild. While these numbers are concerning, what is even more alarming is that only 50 southern corroboree frogs are believed to still exist in the wild.

While conservation efforts are underway to protect the remaining populations of both species of corroboree frogs and restore their habitats, it is unknown whether their numbers will recover. They too may be headed the way of the thylacine.

Test your skills and capabilities

Test your skills and capabilities 9.11

Research an endangered species

Research and present on one of the following endangered Australian species.

1 Identify how many remain in the wild.
2 Describe their natural habitat.
3 Explain the factors that led to the species becoming endangered.
4 Discuss the conservation efforts that are currently in place to protect this species.
5 Analyse the role of the species in its ecosystem and how its decline affects the environment.

Mammals

- Black-flanked rock-wallaby
- Eastern quoll
- Leadbeater‘s possum
- Mountain pygmy-possum
- Northern hairy-nosed wombat
- Numbat
- Woylie
- Yellow-footed rock-wallaby

Birds

- Black-breasted button-quail
- Black-browed albatross
- Buff-breasted sandpiper
- Eastern curlew
- Gouldian finch
- Orange-bellied parrot
- Purple-crowned fairy-wren
- Regent honeyeater

Amphibians

- Giant barred frog
- Green and golden bell frog
- Kroombit tinker frog
- Kuranda tree frog
- Magnificent brood frog
- Armoured mist frog
- Baw baw frog
- Yellow-spotted tree frog

Reptiles

- Adelaide pygmy blue-tongue skink
- Australian snapping turtle
- Blue Mountains water skink
- Fitzroy River turtle
- Loggerhead sea turtle
- Melville leaf-tailed gecko
- Mount Surprise slider
- Woma python

Lesson 9.12

Review: Ecosystems

Summary

Lesson 9.1 All organisms have a role in an ecosystem

- An ecosystem is a community of living organisms and their surroundings.
- Predators eat prey.
- Symbiotic relationships are long-term relationships.

Lesson 9.2 Population size depends on abiotic and biotic factors

- All populations are in a constantly changing equilibrium.
- Deaths and emigration can decrease a population.
- Births and immigration can increase a population.

Lesson 9.5 Matter is recycled through an ecosystem

- Scientists use food chains and food webs to show the flow of food and energy in an ecosystem.
- Producers are found at the start of a food chain.
- Consumers need to gain their energy from eating other organisms.
- Food webs have many interlinking food chains.

Lesson 9.6 Energy flows through an ecosystem

- Energy flows in one direction from the Sun through producers to consumers, with energy loss at each level of the food chain. The hierarchical levels of the food chain are known as a “trophic levels”.
- Energy pyramids show that approximately 10% of energy is passed between each trophic level.

Lesson 9.9 Impact of introduced species on ecosystems

- Introduced species can change the amount of food available for other organisms.
- New species can cause a new equilibrium in an ecosystem.
- Biological control is the deliberate introduction of a new species to control a non-native plant or animal.

Lesson 9.10 Ecosystems can be disrupted

- Competition for resources, seasonal changes and natural disasters change and disrupt populations.
- Human activities have a significant impact on ecosystem dynamics.

Review questions 9.12

Review questions Module 9

Retrieve

1 Identify the organism in Figure 1 that is the producer in the food chain.

A Corn
B Mouse
C Snake
D Owl

2 Identify the organism that is the second-order consumer in Figure 1.

A Corn
B Mouse
C Snake
D Owl

Figure 1 A food chain

3 Identify the organism that is the herbivore in Figure 1.
  A Corn
  B Mouse
  C Snake
  D Owl

4 Define the term "endemic".

5 Define the term "urban sprawl".

Comprehend

6 Compare how matter and energy move through an ecosystem.

7 Describe one example of how humans, especially after European settlement, have changed ecosystems because of an introduced species in Australia.

8 Describe an example of an abiotic condition in an Australian ecosystem that could limit the populations of a living organism.

9 Explain the relationship between a named introduced species and its impact on a specific ecosystem.

10 Explain how carrying capacity affects population dynamics in an ecosystem and discuss the potential consequences when a population exceeds its carrying capacity.

11 With a growing population, humans require more from the land around them. Summarise three ways in which humans are changing the environment.

Analyse

12 How do mutualism, parasitism and commensalism differ in terms of their effects on the organisms involved, and what are some specific examples of each interaction in different ecosystems?

13 Classify the following as either abiotic or biotic factors.
  a Salinity
  b Bacteria present
  c Temperature
  d Plant species present
  e Water availability

14 Describe the role producers and consumers play within a food web and explain how their differences in energy acquisition influence ecosystem dynamics.

15 Analyse the Antarctic marine food web in Figure 2. Describe the relationship between:
  a orca whales and fur seals
  b emperor penguins and fur seals.

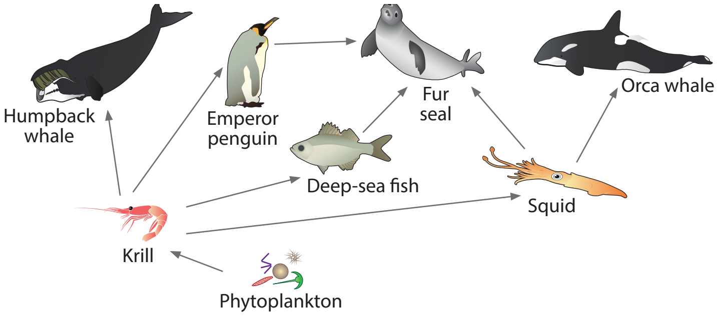


Figure 2 Antarctic marine food web

Apply

16 Consider the food web in Figure 3 in Lesson 9.5 Matter is recycled through an ecosystem (page 402). If the potoroos were to become extinct locally, list the possible changes to the other organisms in the food web.

17 Discuss what happened when the cane toad was introduced into Australian ecosystems. Explain how this impact might have been different if the cane toad had more successful predators.

Figure 3 *Rhinella marina*, the cane toad

18 Analyse the food web shown in Figure 4 that shows organisms from the Yellowstone National Park ecosystem in America. While coyotes can eat larger elk, this usually only occurs when an elk is injured or sick.
  a Identify one example of a producer and one example of a consumer in this food web.
  b Predict what would happen to the population of elk in this ecosystem if the grey wolf was removed.

c Use your answer from question **b** to describe what would happen to the populations of grasses, grains and fruits in the park if the grey wolf was removed.

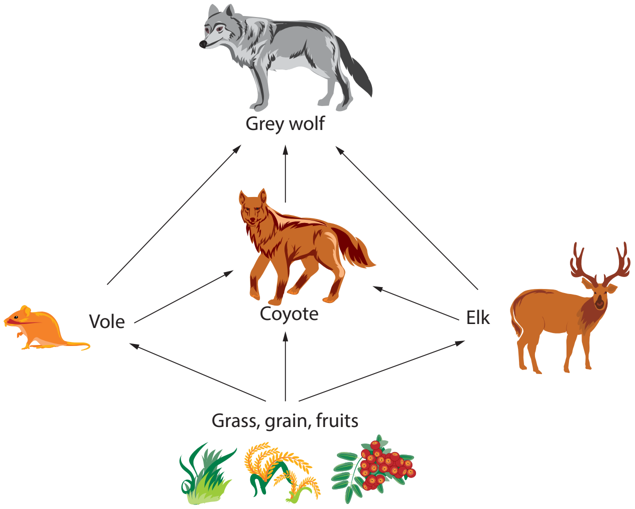


Figure 4 A Yellowstone National Park food web

19 Apply your understanding of energy pyramids to assess the implications of energy loss at each trophic level in a specific terrestrial (on dry land) ecosystem. In your response, discuss how this energy transfer affects the population sizes of producers, primary consumers and secondary consumers, and consider the potential consequences for biodiversity and ecosystem stability when one trophic level is significantly impacted.

Critical thinking

20 Imagine a world without spiders. Discuss what the world would be like. In your answer, consider what spiders eat and which organisms eat spiders.

21 In some cases, introduced animals fail and never become established. In other cases, introduced animals are a spectacular "success", such as rabbits and foxes across much of southern Australia. In terms of the environment in which these animals live and their interactions with other animals, explain why some animals succeed and others do not.

22 Humans compete with other organisms for resources, and as the human population grows, this competition intensifies. Discuss how your actions contribute to the impact on ecosystem biodiversity, and explore measures that can reduce this impact. Consider both individual choices and broader community initiatives that promote sustainability and conservation.

23 The balance of nature is very delicate, and changes to the environment or to any member of a food web bring about changes throughout the whole system. Food webs are graphical ways of showing the relationships in ecosystems created by what is eaten by animals and organisms. If the food web is changing, so is the ecosystem. Decide which would be more resistant to change:

- big, complicated ecosystems with numerous species interacting
- simple ecosystems with relatively few species interacting.

This can be done by:

a describing an example of how both environments could be disrupted by the same event

b deciding which environment would be most disrupted and least likely to recover.

24 In this module, you have learnt about the Earth's growing population. Create a visual representation (sketch, drawing, poster or similar) to represent the Earth's changing population 50 years ago, now and 50 years into the future.

Social and ethical thinking

25 Prior to 1950, most scientists thought that the size and make-up of a population never changed. There were two parts to this. In human populations, the poor people in society would stay poor, and the rich would stay rich. In the animal world, some animals would survive, and some would die, but the population would stay the same. In the 1960s, ecologist Richard Levin started researching ecology and populations. He thought that all populations could change if there was enough change in the environment.

a Decide if you agree or disagree with Richard Levin.

b Describe two arguments from the paragraph above that support your argument.

26 Humans have tried a number of methods to reduce rabbit numbers in Australia, including the introduction of a virus that caused serious deformities and led to a slow and painful death of the rabbit. Discuss if the result (reducing the number of introduced rabbits so that other native wildlife survive) justifies how it was achieved (the painful death of the rabbits).

Figure 5 The introduction of rabbits to Australia has resulted in considerable environmental damage.

Research

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

Mars biosphere

Earth is particularly special because, as far as we know, it is the only planet that sustains life – our biosphere. The biosphere concept has been looked at as a means of long-distance space travel and as a way to colonise planets such as Mars. As a class project, explore how to set up a biosphere on Mars.

This means we will need to identify the abiotic conditions that exist on Mars and consider the biotic factors that we will need to survive.

- Research the abiotic conditions that exist on Mars.
- Explain whether these conditions are suitable for human habitation. If not, describe how we could survive in these conditions (what would we need to take with us).
- Describe the most basic food web that we would need to survive on Mars.
- Describe the abiotic conditions that each of these organisms would need to survive.
- Use the information you have gathered to evaluate the chances of success for a colony to exist on the surface of Mars.

Science communication causing change

Dame Jane Goodall first travelled from England to Tanzania to study chimpanzees at the age of 26, even though she was not a trained ecologist at the time. Gradually, she was accepted by the chimpanzees. This allowed her to experience the way they behaved and how they were affected by changes in their environment. Her regular communication with other groups about her work increased our understanding of the balance between the needs of humans and chimpanzees.

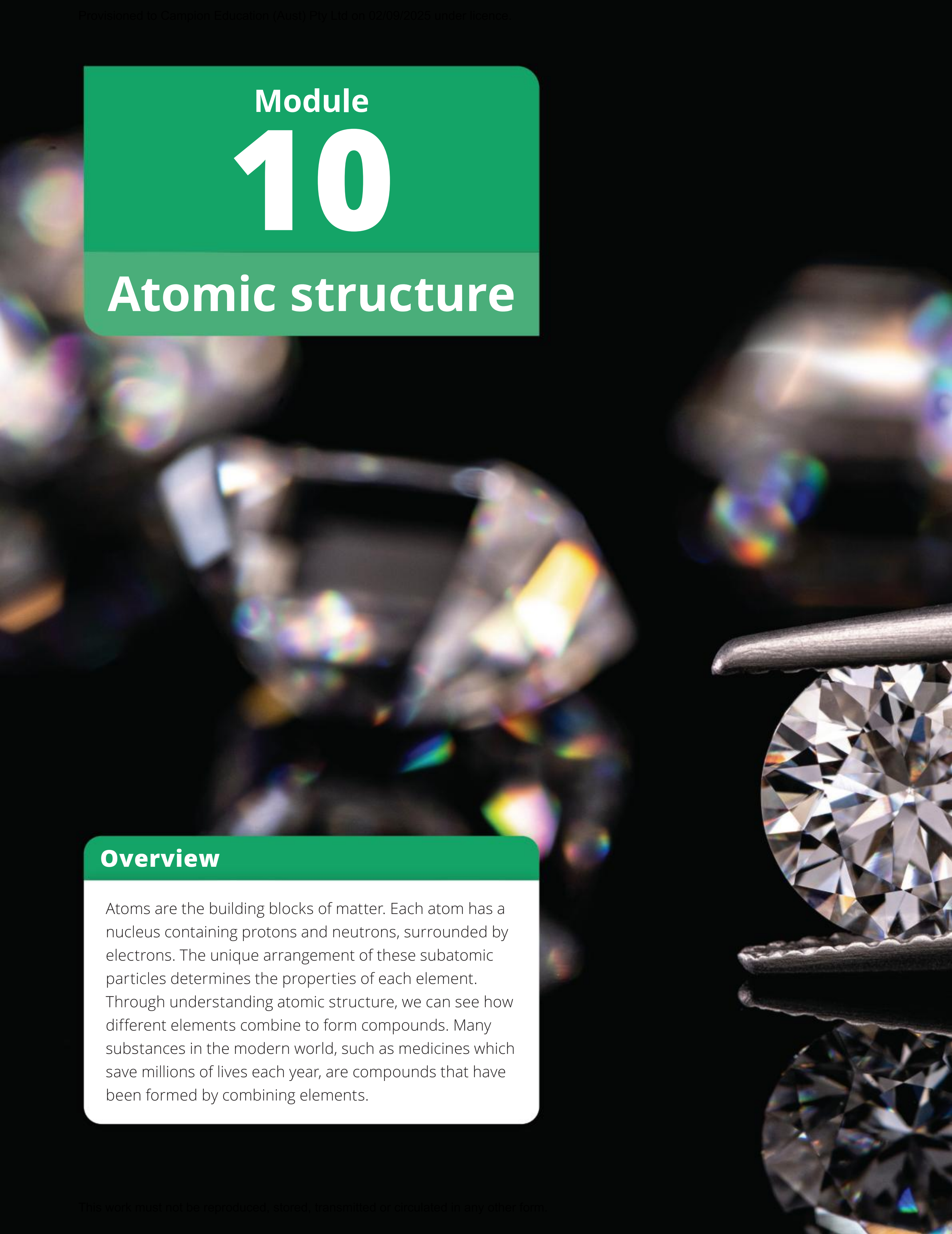
Research how Dame Jane Goodall was able to change people's view of chimpanzees, and describe people's attitudes before and after her discoveries were shared.

Figure 6 Dame Jane Goodall studied the behaviour of chimpanzees and shared her research widely, leading to a greater understanding of chimpanzees.

Laboratory-grown meat

In Australia and many other countries, land is still being cleared so that sheep and cows can be farmed for meat. To prevent this, some laboratories are attempting to grow meat in a Petri dish.

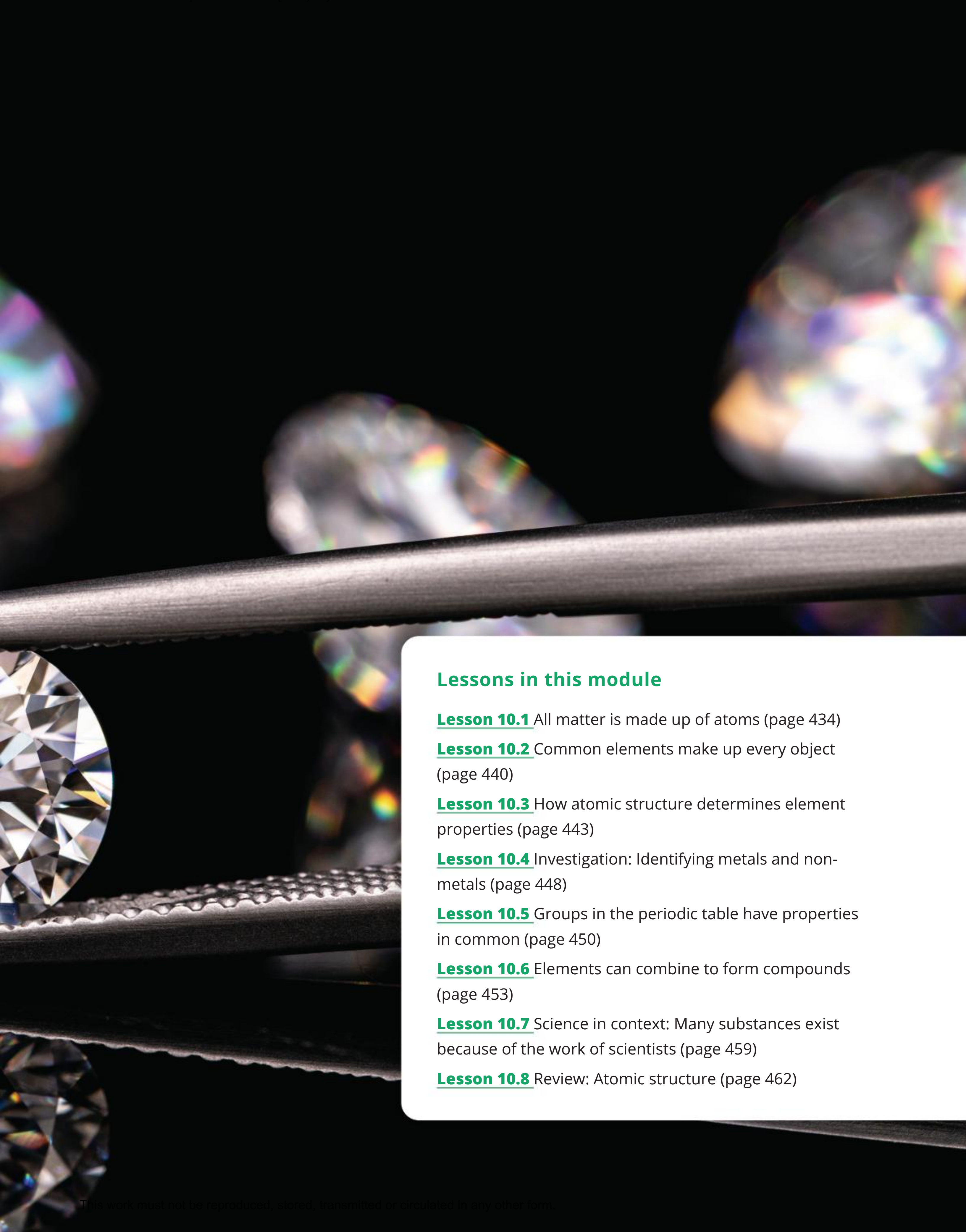
- Explain how the lab-grown meat could reduce the impact on the environment.
- Describe how the lives of the sheep and cattle farmers could be affected.
- Decide if you would eat lab-produced meat in the future.



Module
10
Atomic structure

Overview

Atoms are the building blocks of matter. Each atom has a nucleus containing protons and neutrons, surrounded by electrons. The unique arrangement of these subatomic particles determines the properties of each element. Through understanding atomic structure, we can see how different elements combine to form compounds. Many substances in the modern world, such as medicines which save millions of lives each year, are compounds that have been formed by combining elements.



Lessons in this module

Lesson 10.1

All matter is made up of atoms

Learning intentions and success criteria

Key ideas

→ An element is a pure substance with one type of atom.

→ The periodic table organises elements according to their chemical and physical properties.

What are atoms?

atom the smallest particle of matter; cannot be created, destroyed or broken down (indivisible)

The ancient Greeks used the word *atomos* to describe those particles that could not be divided up any further. The concept of the **atom** was also described in ancient Indian texts over 2,000 years ago. Although we cannot see atoms, there is much evidence that this basic form of matter exists.

In around 450 BCE, the Greek philosopher Democritus said:

> "By convention there is colour, by convention sweetness, by convention bitterness, but in reality there are atoms and the void."

atomic theory the theory that all matter is made up of atoms

Democritus was a natural philosopher. He did not carry out experiments, but proposed hypotheses based on thought and reasoning. Over the next 1,500 years, scientists tried many experiments to detect these invisible particles that make up all life on Earth.

By the 1780s, French chemists Antoine Lavoisier and Marie-Anne Lavoisier were convinced that matter could not be created or destroyed (Figure 1). Like many scientists of the time, they were interested in the study of mixtures in "invisible" air. They used a series of tests to divide the different "atoms" into metals and non-metals.

English scientist John Dalton was fascinated by this research, and in 1810 he stated:

> "Matter, though divisible in an extreme degree, is nevertheless not infinitely divisible. That is, there must be some point beyond which we cannot go, in the division of matter … I have chosen the word 'atom' to signify these ultimate particles."

Dalton was one of the first scientists to consider the link between elements and atoms. He was the originator of what is now called the **atomic theory**.

Figure 1 French chemists Antoine Lavoisier and Marie-Anne Lavoisier were convinced that matter could not be created or destroyed.

Dalton's atomic theory

One of the pieces of evidence that Dalton published was that all atoms had different weights. Although the weight of an atom is too small to measure, Dalton was able to compare the weight of the lightest atom (hydrogen) to all the other atoms that were then known. He assigned comparison weights to atoms such as oxygen, carbon and nitrogen, using the results of chemical analysis carried out by other chemists.

Evidence supports atomic theory

A scientific theory aims to explain existing evidence and observations. A good theory supported by evidence is used to make testable predictions. Ever since Dalton proposed his atomic theory, it has been used to make predictions. Today, evidence that was not available in Dalton's time supports his theory.

- Elements can join together to form new substances.
- Water always contains twice as much hydrogen as oxygen.
- When chemicals react with each other, the total mass of the chemicals does not change.
- Pure oxygen has the same properties wherever it is found on Earth or even in space.
- Gases – some of which are invisible – have mass, and different gases have different masses.
- Modern scanning tunnelling microscopes produce images of surfaces that look "bumpy".
- Under a microscope, tiny particles of pollen in water move in strange ways as if bumping into invisible objects.

Discovering more about atoms

A century after Dalton proposed his theory, in the early twentieth century, the physicist Joseph John Thomson discovered that atoms were in fact divisible and were made up of even smaller **subatomic particles** (particles that are smaller than atoms). His experiments showed that inside the atom are far smaller, negatively charged particles, which we now call **electrons**.

He also showed that an atom contains positively charged material, although it was not yet clear what this material was. From this discovery, and knowing that oppositely charged objects attract each other and move towards each other, Thomson suggested that the atom is like a plum pudding in which the positively charged material is the "cake" and the electrons are the "fruit". The positive and negative charges are mixed uniformly throughout the atom in what was called the **Thomson plum pudding model** of the atom (Figure 2).

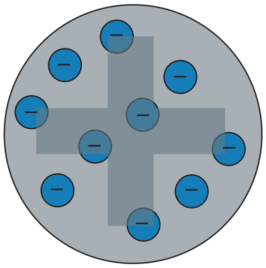


Figure 2 Thomson's plum pudding model of the atom

subatomic particle a particle that is smaller than an atom

electron a negatively charged particle in the nucleus of an atom

Thomson plum pudding model an early model of the atom in which the positively charged nucleus has negatively charged electrons scattered through it, like a plum pudding

Rutherford’s experiments on atoms

Ernest Rutherford was born in New Zealand in 1871. His experiments changed the way people thought about the inside of the atom. In 1911, he supervised Hans Geiger and Ernest Marsden, who carried out what is known as the “gold foil” experiment (Figure 3). They set up a very thin layer of gold foil and fired a stream of alpha particles at it. Alpha particles are very small, positively charged radioactive particles that contain energy. Detectors were set up around the gold foil to record the path of the radioactive particles. This would identify whether the particles had gone straight through the foil or had been deflected (made to change course) by the gold atoms in the sheet of gold foil. If the plum pudding model was correct (that the positive and negative charges were distributed uniformly throughout the atom), then the alpha particles should shoot straight through the neutral (no charge) gold foil by passing through the gaps between the gold atoms (Figure 4).

Two aspects of the results surprised the scientists. The first evidence was that, while most of the alpha particles did pass straight through the gold foil, some alpha particles were deflected in different directions (Figure 5). Even more surprising was the second piece of evidence. A small number of the alpha particles bounced straight back in the direction that they had come from.

Rutherford concluded that, instead of being like a plum pudding, a gold atom must contain a lot of space, with a small positive charge in the centre that deflected the positive alpha particles. With his gold foil experiment, Rutherford had discovered a small, positively charged nucleus in the centre of the gold atoms.

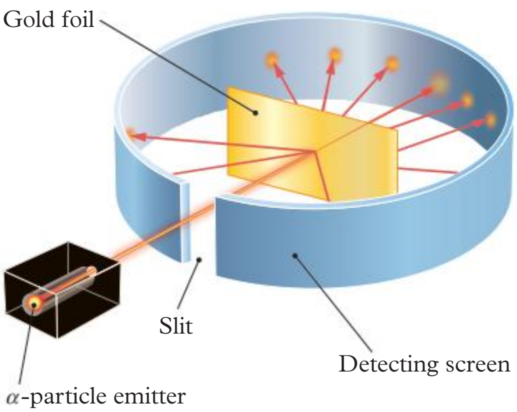


Figure 3 Rutherford’s gold foil experiment. Note the large deflection of some particles.

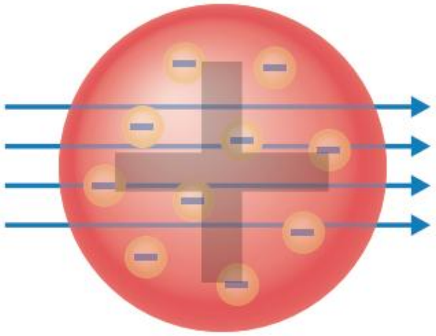


Figure 4 If the “plum pudding” model of the atom were correct, it would be expected that most of the alpha particles would move through the gold with only minimal deflection.

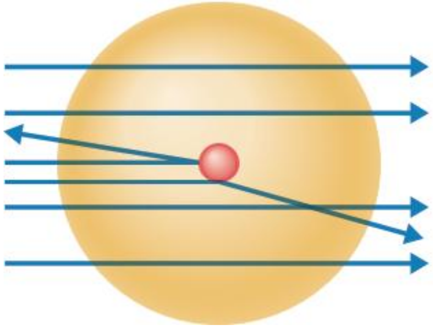


Figure 5 The gold foil experiment showed that some alpha particles were deflected.

Rutherford’s model of the atom

Rutherford’s model has been supported by further research on the structure of the atom. The current accepted model of an atom is as follows.

- The **nucleus** of an atom is made up of protons and neutrons.
- **Protons** carry a positive electric charge.
- **Neutrons** are neutral – they have mass but no electric charge.
- Electrons have a negative electric charge.
- The mass of the atom is almost entirely due to the mass of the protons and neutrons in the nucleus; electrons have very little mass in comparison.
- Electrons move around in the space outside the nucleus.

Huge parts of atoms are empty space. If you expanded one atom to the size of the Homebush Olympic grounds, the nucleus of that atom would be no bigger than a pinhead.

nucleus a membrane-bound structure in cells that contains most of the cell's genetic material

proton a positively charged subatomic particle in the nucleus of an atom

neutron a neutral (no charge) subatomic particle in the nucleus of an atom

An important thing to know is that, overall, an atom has no electrical charge. In other words, there are always the same number of positive protons as negative electrons in any atom.

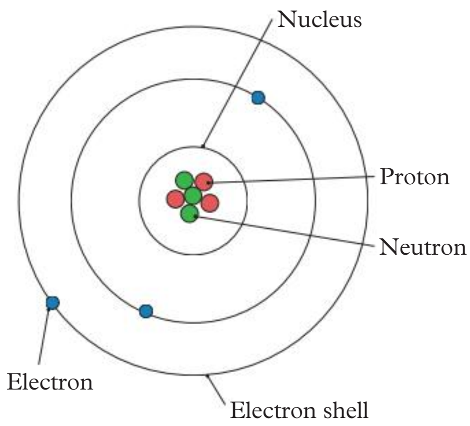


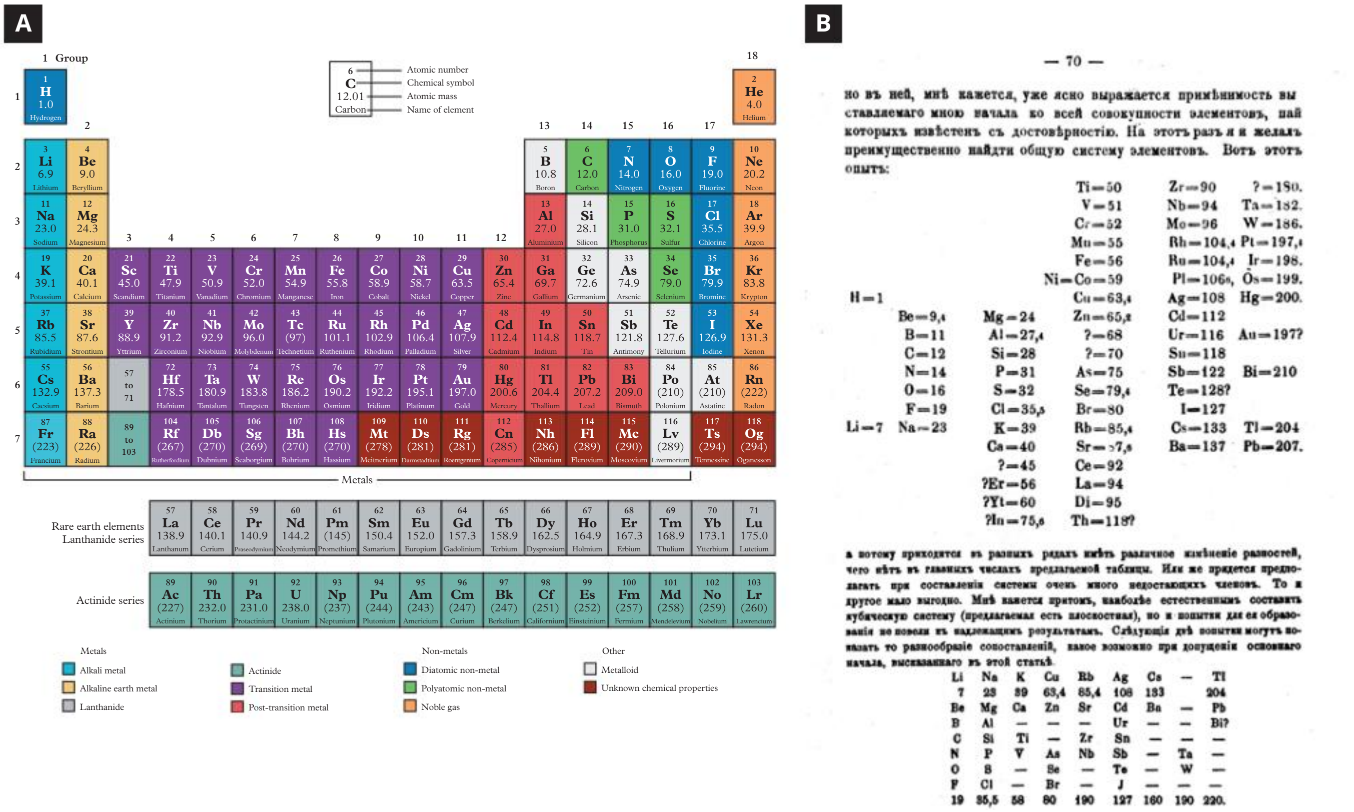
Figure 6 A two-dimensional model of an atom of the element lithium.

Mendeleev organises atoms

By 1869, up to 56 atoms had been discovered by chemists around the world. In 1865, British scientist John Newlands published a paper that described how these atoms could be arranged into groups of eight atoms with similar properties. He called this the Law of Octaves. While many scientists did not agree at the time, Russian scientist Dmitri Mendeleev was preparing a textbook for his university students when he dreamed of patterns of atomic properties. When he woke up, he drew the pattern of atoms in a table (Figure 7B). This table was so accurate, he was able to predict the properties of atoms that had not yet been discovered. This table became known as the **periodic table**. The periodic table we use today (Figure 7A) identifies the many different properties of every atom that has been discovered or created so far. Both tables have:

- elements arranged in groups and periods
- hydrogen in the first row
- the same second row of elements
- the metals in a group
- the non-metals in a group.

periodic table
a table in which elements are listed in order of their atomic number, and grouped according to their similar properties



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H 1.0 Hydrogen																	2 He 4.0 Helium
2	3 Li 6.9 Lithium	4 Be 9.0 Beryllium											5 B 10.8 Boron	6 C 12.0 Carbon	7 N 14.0 Nitrogen	8 O 16.0 Oxygen	9 F 19.0 Fluorine	10 Ne 20.2 Neon
3	11 Na 23.0 Sodium	12 Mg 24.3 Magnesium											13 Al 27.0 Aluminium	14 Si 28.1 Silicon	15 P 31.0 Phosphorus	16 S 32.1 Sulfur	17 Cl 35.5 Chlorine	18 Ar 39.9 Argon
4	19 K 39.1 Potassium	20 Ca 40.1 Calcium	21 Sc 45.0 Scandium	22 Ti 47.9 Titanium	23 V 50.9 Vanadium	24 Cr 52.0 Chromium	25 Mn 54.9 Manganese	26 Fe 55.8 Iron	27 Co 58.9 Cobalt	28 Ni 58.7 Nickel	29 Cu 63.5 Copper	30 Zn 65.4 Zinc	31 Ga 69.7 Gallium	32 Ge 72.6 Germanium	33 As 74.9 Arsenic	34 Se 79.0 Selenium	35 Br 79.9 Bromine	36 Kr 83.8 Krypton
5	37 Rb 85.5 Rubidium	38 Sr 87.6 Strontium	39 Y 88.9 Yttrium	40 Zr 91.2 Zirconium	41 Nb 92.9 Niobium	42 Mo 96.0 Molybdenum	43 Tc (97) Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
6	55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57 to 71	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.8 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po (210) Polonium	85 At (210) Astatine	86 Rn (222) Radon
7	87 Fr (223) Francium	88 Ra (226) Radium	89 to 103	104 Rf (267) Rutherfordium	105 Db (270) Dubnium	106 Sg (269) Seaborgium	107 Bh (270) Bohrium	108 Hs (270) Hassium	109 Mt (278) Meitnerium	110 Ds (281) Darmstadtium	111 Rg (281) Roentgenium	112 Cn (285) Copernicium	113 Nh (286) Nihonium	114 Fl (289) Flerovium	115 Mc (290) Moscovium	116 Lv (289) Livermorium	117 Ts (294) Tennessine	118 Og (294) Oganesson

Rare earth elements Lanthanide series	57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm (145) Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.1 Ytterbium	71 Lu 175.0 Lutetium
Actinide series	89 Ac (227) Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np (237) Neptunium	94 Pu (244) Plutonium	95 Am (243) Americium	96 Cm (247) Curium	97 Bk (247) Berkelium	98 Cf (251) Californium	99 Es (252) Einsteinium	100 Fm (257) Fermium	101 Md (258) Mendelevium	102 No (259) Nobelium	103 Lr (260) Lawrencium

Metals
- Alkali metal
- Alkaline earth metal
- Lanthanide
- Actinide
- Transition metal
- Post-transition metal

Non-metals
- Diatomic non-metal
- Polyatomic non-metal
- Noble gas

Other
- Metalloid
- Unknown chemical properties

Figure 7 (A) The periodic table as it is today and (B) Dmitri Mendeleev's periodic table which he created after dreaming of the patterns of atomic properties.

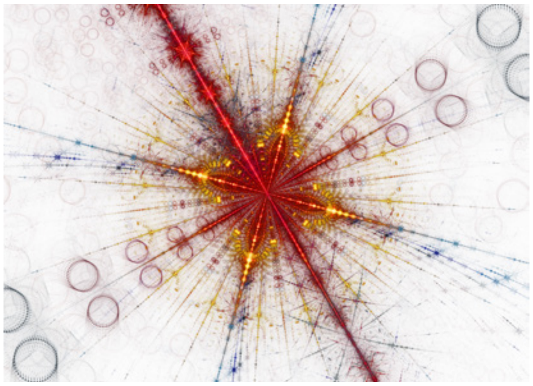


Figure 8 Image of a particle splitting apart in the Large Hadron Collider

Figure 9 The Large Hadron Collider at CERN (The European Organisation for Nuclear Research) in Geneva, Switzerland.

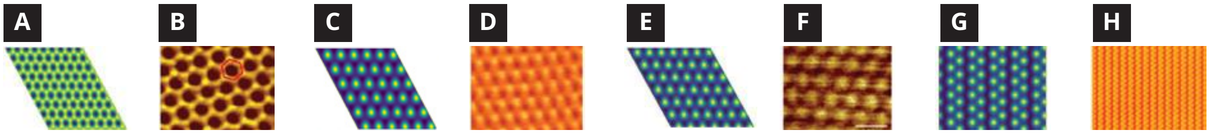


Figure 10 Different scanning tunnelling microscopy (STM) images: (A) DFT-STM image of graphene; (B) experimental STM image of graphene; (C) DFT-STM image of 2H-NbSe$_2$; (D) experimental STM image of 2H-NbSe$_2$; (E) DFT-STM image of 2H-MoS$_2$; (F) experimental STM image of 2H-MoS$_2$; (G) DFT-STM image of black phosphorous; (H) experimental STM image of black phosphorous.

Modern technologies

Advances in technology have allowed scientists to learn more about subatomic particles in atoms. Particle accelerators, such as the Large Hadron Collider located in Switzerland and invented in the mid-twentieth century (Figure 9), help scientists study atoms by smashing them together at super high speeds. These collisions revealed smaller particles, like **quarks** and **gluons**, which are inside protons and neutrons. This discovery showed that protons and neutrons, the particles in the atom's nucleus, are made of even smaller pieces, helping scientists understand the forces that hold the nucleus together.

Another important tool is the electron microscope, which lets scientists actually see atoms. These microscopes use beams of electrons to capture images of atoms on the surface of materials or inside structures. With techniques like scanning tunnelling microscopy (STM) and transmission electron microscopy (TEM), scientists can study how atoms are arranged and how they bond with each other. This gives a clearer picture of how atoms behave and how materials are built at the atomic level.

Lastly, new technology like quantum computing and powerful simulations help scientists understand atomic behaviour in ways that experiments alone

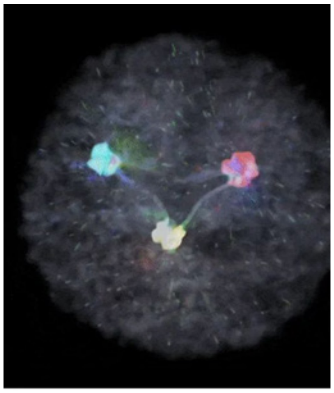


Figure 11 A team of physicists, filmmakers and animators has collaborated to create a new visual representation of the subatomic world. Developed for educational use, this animation provides a dynamic view of the proton, helping to make complex physics concepts more accessible to secondary students. It has been presented at scientific conferences and community events to engage both researchers and the public in a deeper understanding of particle physics.

can't show. These tools allow researchers to model how electrons and subatomic particles act in complex systems. By simulating these behaviours, scientists gain deeper insights into how atoms work according to the rules of quantum mechanics, which helps improve our understanding of atomic and subatomic structures.

Models have limitations

Models are useful as they allow scientists to visualise molecules and atoms that are too small to be seen with the naked eye. Models can make some patterns and trends easier to observe and explain. Unfortunately, it is difficult for models to include everything we know about atoms. As we discover more and more, models cannot include all the complex details. Although the simple models can make it easier for us to learn about particles, they do not tell the full story. For example, the particle model does not acknowledge that particles in different substances can have different properties, or that particles can be different shapes.

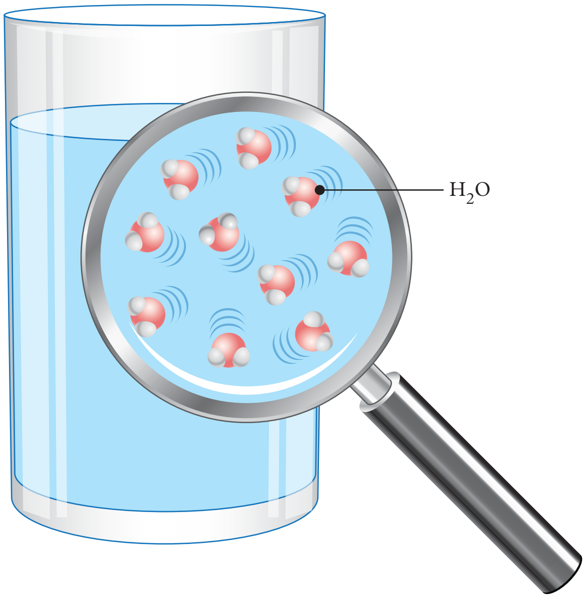


Figure 12 A glass of water is made of molecules. This model shows that each molecule contains two hydrogen atoms and one oxygen atom. The model has limitations, however, because it doesn't show how the molecules move around.

Check your learning 10.1

Check your learning 10.1

Comprehend

1 Use the evidence in this lesson to explain why Rutherford concluded that:
  - **a** an atom contains a lot of space
  - **b** there is a central area of positive charge.

2 Describe Thomson's "plum pudding" model of the atom.

3 Describe the most important new understanding of the structure of the atom that Rutherford inferred from his experiment with alpha particles.

4 Identify and describe three types of particles we now know are inside an atom.

Analyse

5 Compare (the similarities and differences between) a philosopher such as Democritus and a scientist such as John Dalton.

Apply

6 Working with a partner, create a three-dimensional model of an atom from modelling clay or other suitable materials. Make sure you label all parts correctly and state which model of the atom you are representing.

Skills builder: Questioning and predicting

7 Write two of your own scientific questions about atoms. (THINK: What would you like to know more about?)

Lesson 10.2

Common elements make up every object

Learning intentions and success criteria

Key ideas

- → The atom is the smallest unit of an element.
- → Elements, compounds and alloys are important, and they make up everyday materials.
- → Understanding the structure and properties of these substances helps us choose materials for specific uses (e.g. lightweight materials for aeroplanes and rust-resistant metals for kitchen appliances).

What are elements?

element a pure substance that only contains one type of atom

An **element** is a pure substance made of only one type of atom. All the atoms in the element are identical. For example, the element carbon is only made up of carbon atoms; oxygen is only made up of oxygen atoms.

There are 94 to 98 different elements that are found naturally on Earth. Each element is made up of its own type of atom. Another 20 or so atoms have been made artificially, but these are highly reactive and unstable.

Elements cannot be broken down into other substances because they are already the simplest substances. They can be thought of as being "elementary", which is the origin of the name element.

Difference between elements and atoms

An atom is the smallest unit of matter, made up of protons, neutrons and electrons. It is the building block of all substances. An element is a pure substance made up of only one type of atom. The key difference is that atoms are the individual units, while elements are made from many identical atoms combined together.

Elements, compounds and alloys – their uses in everyday life

Some elements are so common in everyday objects that we don't even realise they're there. There are many that you can identify now, just by looking around! For example, iron is found in nails, tools and the cars we drive. Carbon is in the food we eat and the fuel we burn. Oxygen makes up the air we breathe and is also part of water, which is essential for life. Elements combine in different ways to form compounds or alloys, which are the materials we see and use.

Elements

By understanding the elements that make up common items, we can better understand the world around us and how things are built. In Lesson 10.3 How atomic structure determines element properties (page 443) you will explore elements in greater detail.

Compounds

Compounds are substances formed when two or more different elements chemically combine in fixed proportions. Unlike **mixtures**, the elements in a compound are bonded together in a way that changes their individual properties, creating something new with unique characteristics (you will learn more about compounds in Lesson 10.6 Elements can combine to form compounds, page 453). For example, water (H_2O) is a compound made from hydrogen and oxygen, and its properties are completely different from the gases hydrogen and oxygen alone. Many of the things we use every day are made from compounds because they have specific properties that make them useful. Sodium chloride (NaCl), commonly known as table salt, is a compound made from sodium and chlorine and is used for seasoning food and preserving it. Carbon dioxide (CO_2), made from carbon and oxygen, is used in carbonated drinks and is also produced by our bodies when we breathe out. Ammonia (NH_3), a compound made from nitrogen and hydrogen, is found in many cleaning products due to its ability to dissolve grease and dirt. Compounds play a vital role in making the materials we need for food, medicine, cleaning and much more.

compound a substance made up of two or more types of atoms bonded together (e.g. water)

mixture a substance made up of two or more pure substances mixed together

Table 1 lists some examples of everyday objects and the elements that are found in them.

Table 1 Common objects and their elements and uses

Object	Elements	Some uses
Water	Hydrogen (H) and oxygen (O)	Drinking, cooking and cleaning
Iron nail	Iron (Fe)	Construction and tools
Copper wire	Copper (Cu)	Electrical wiring and electronics
Aluminium foil	Aluminium (Al)	Cooking and packaging
Salt	Sodium (Na) and chlorine (Cl)	Flavouring or preserving food

Alloys

An alloy is a mixture made from two or more elements, where at least one element is a metal. Alloys are created to combine the best properties of different metals, making them stronger, more **durable** or more resistant to **corrosion**. By mixing metals in specific proportions, we can create materials that are better suited for particular uses than the individual elements alone. For example, adding carbon to iron makes steel, which is much stronger and more durable than pure iron. Alloys are used in many everyday objects, from jewellery to machinery, because they offer a range of useful properties that make them more effective for different tasks.

durable able to withstand wear, pressure, or damage over time without breaking or deteriorating easily

corrosion the gradual destruction of a material, usually metal, due to chemical reactions with its environment, often involving moisture and oxygen (e.g., rusting of iron)

rust a specific type of corrosion that occurs when iron or steel reacts with oxygen and water, forming iron oxide, which weakens the metal

Some common alloys are made by mixing metals with other elements like carbon, nickel or copper. These combinations can change the metal's hardness, resistance to **rust** or ability to conduct heat or electricity. For example, bronze – made of copper and tin – is harder and more resistant to corrosion than pure copper, which is why it is often used for making coins, statues and tools. Brass – made from copper and zinc – is often used for musical instruments and decorative items because it has a bright, shiny finish and is resistant to tarnishing. Alloys are essential in many industries, such as construction, electronics and transportation, where specific material properties are needed.

Table 2 Common alloys, their main elements, properties and common uses

Alloy	Main elements	Properties	Common uses
Steel	Iron (Fe) and carbon (C)	Strong and durable, and can be made to resist rust	Building materials, tools, machinery
Bronze	Copper (Cu) and tin (Sn)	Hard, corrosion-resistant	Coins, statues, tools
Brass	Copper (Cu) and zinc (Zn)	Strong, rust-resistant, durable	Plumbing, jewellery, musical instruments
Stainless steel	Iron (Fe), carbon (C) and chromium (Cr)	Strong, rust-resistant, durable	Kitchenware, medical instruments, appliances

Check your learning 10.2

Check your learning 10.2

Retrieve

1 Identify the key differences between an atom and an element.

Comprehend

2 Describe how common elements like oxygen and carbon are essential for life and are found in many everyday substances.

3 Explain the difference between elements, compounds and alloys.

4 Identify some common elements (try to find different examples to the ones listed in this lesson) found in everyday objects and explain their uses.

Analyse

5 Analyse the following list of elements and identify how each one is used in daily life. Explain why it is important to use these specific elements for those purposes.

- **a** Silicon
- **b** Gold
- **c** Nitrogen
- **d** Sulfur
- **e** Calcium

6 Research a common alloy (e.g. brass, bronze or steel) and analyse how its elements are combined to improve the properties of the material. Present your findings in a poster, including the alloy's uses and advantages over its individual elements.

Lesson 10.3

How atomic structure determines element properties

Key ideas

- → An element's atomic number and name are determined by the number of protons in its nucleus.
- → The relative atomic mass is the sum of protons and neutrons.
- → Electrons have almost no mass and move around the nucleus in electron shells.
- → The valence shell (outermost electron shell) influences an element's properties and reactivity.
- → The number of valence electrons determines an element's position in the periodic table.

Learning intentions and success criteria

Introduction

Elements can be classified into two main groups: metals and non-metals. In the solid state, atoms of metals are held in a lattice (Figure 1). Most other elements which are not metals are called non-metals. Most non-metals are gases at normal temperatures. Some gases, such as neon and helium, are **monatomic**. This means that each gas particle is a single atom (mono = one). However, the atoms in other gases, such as oxygen, hydrogen and nitrogen, are **diatomic** molecules. The atoms of these elements join together in pairs (di = two).

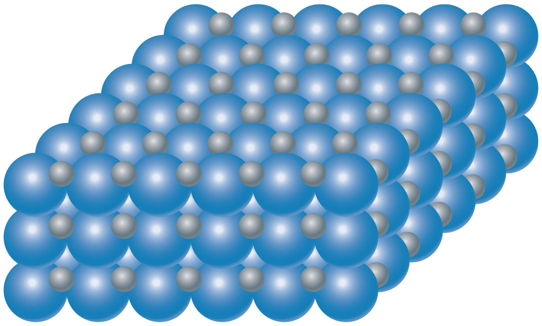


Figure 1 A metallic lattice

Elements and the periodic table

The **periodic table** organises elements (or types of atoms) in rows and columns (Figure 2). The horizontal rows are called **periods**. The **atomic number** increases by one for each element as you go across a period (from left to right). The vertical (up–down) lists of elements are called **groups**. The elements in a vertical group often have similar properties, such as the way they look or how they behave.

Metals are found to the left of the grey zig-zag line of elements in Figure 2 and the non-metals are found to the right of the line.

Elements can also be classified based on their chemical properties. These include how they react with other substances, such as acids and the oxygen in the air.

monatomic consisting of a single atom

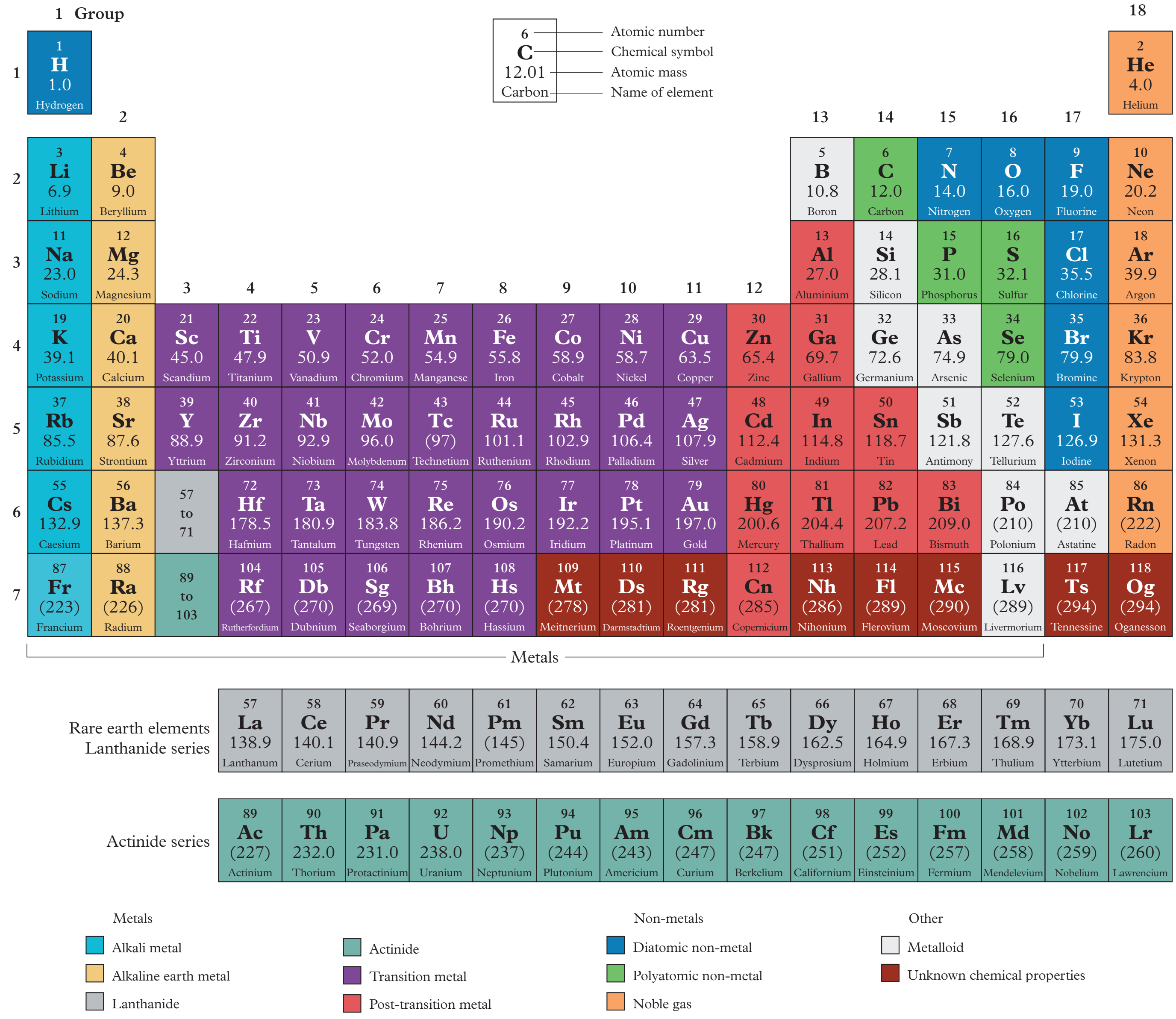
diatomic consisting of two atoms

periodic table a table in which elements are listed in order of their atomic number, and grouped according to their similar properties

period (in chemistry) a horizontal list of elements in the periodic table

atomic number the number of protons of an atom

group (in chemistry) a vertical list of elements in the periodic table that have characteristics in common



6
C
12.01
Carbon

- Atomic number
- Chemical symbol
- Atomic mass
- Name of element

	1 Group	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H 1.0 Hydrogen																	2 He 4.0 Helium
2	3 Li 6.9 Lithium	4 Be 9.0 Beryllium											5 B 10.8 Boron	6 C 12.0 Carbon	7 N 14.0 Nitrogen	8 O 16.0 Oxygen	9 F 19.0 Fluorine	10 Ne 20.2 Neon
3	11 Na 23.0 Sodium	12 Mg 24.3 Magnesium											13 Al 27.0 Aluminium	14 Si 28.1 Silicon	15 P 31.0 Phosphorus	16 S 32.1 Sulfur	17 Cl 35.5 Chlorine	18 Ar 39.9 Argon
4	19 K 39.1 Potassium	20 Ca 40.1 Calcium	21 Sc 45.0 Scandium	22 Ti 47.9 Titanium	23 V 50.9 Vanadium	24 Cr 52.0 Chromium	25 Mn 54.9 Manganese	26 Fe 55.8 Iron	27 Co 58.9 Cobalt	28 Ni 58.7 Nickel	29 Cu 63.5 Copper	30 Zn 65.4 Zinc	31 Ga 69.7 Gallium	32 Ge 72.6 Germanium	33 As 74.9 Arsenic	34 Se 79.0 Selenium	35 Br 79.9 Bromine	36 Kr 83.8 Krypton
5	37 Rb 85.5 Rubidium	38 Sr 87.6 Strontium	39 Y 88.9 Yttrium	40 Zr 91.2 Zirconium	41 Nb 92.9 Niobium	42 Mo 96.0 Molybdenum	43 Tc (97) Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
6	55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57 to 71	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.8 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po (210) Polonium	85 At (210) Astatine	86 Rn (222) Radon
7	87 Fr (223) Francium	88 Ra (226) Radium	89 to 103	104 Rf (267) Rutherfordium	105 Db (270) Dubnium	106 Sg (269) Seaborgium	107 Bh (270) Bohrium	108 Hs (270) Hassium	109 Mt (278) Meitnerium	110 Ds (281) Darmstadtium	111 Rg (281) Roentgenium	112 Cn (285) Copernicium	113 Nh (286) Nihonium	114 Fl (289) Flerovium	115 Mc (290) Moscovium	116 Lv (289) Livermorium	117 Ts (294) Tennessine	118 Og (294) Oganesson

Metals

Rare earth elements Lanthanide series	57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm (145) Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.1 Ytterbium	71 Lu 175.0 Lutetium
Actinide series	89 Ac (227) Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np (237) Neptunium	94 Pu (244) Plutonium	95 Am (243) Americium	96 Cm (247) Curium	97 Bk (247) Berkelium	98 Cf (251) Californium	99 Es (252) Einsteinium	100 Fm (257) Fermium	101 Md (258) Mendelevium	102 No (259) Nobelium	103 Lr (260) Lawrencium

Metals
- ■ Alkali metal
- ■ Alkaline earth metal
- ■ Lanthanide
- ■ Actinide
- ■ Transition metal
- ■ Post-transition metal

Non-metals
- ■ Diatomic non-metal
- ■ Polyatomic non-metal
- ■ Noble gas

Other
- ■ Metalloid
- ■ Unknown chemical properties

Figure 2 The periodic table

Using universal symbols

You will notice that elements are represented by their symbols which consist of one or two letters: for example, hydrogen has the symbol “H”, and helium has the symbol “He”. Other elements (and their symbols) are oxygen (O), carbon (C), nitrogen (N), sulfur (S), gold (Au) and silver (Ag).

In 1828, Swedish scientist Jöns Jakob Berzelius (1779–1848) introduced letters as a way of simplifying the representation of elements. Berzelius chose the first letter of the Latin name for each element. Some symbols make more sense to us in English, such as “O” for oxygen. But “Ag” comes from the Latin word *argentum* for silver, and gold is *aurum* in Latin, therefore it has the symbol “Au”. If elements start with the same letter, subsequent letters (in lower-case) are sometimes used. For example, carbon is “C”, and copper is “Cu”, which has the Latin name *cuprum*.

This same set of chemical symbols is recognised and used around the world, making it easier for scientists to communicate their ideas across languages. For example, Table 1 shows the word silver represented in four different languages. Imagine a group of scientists trying to research and share their findings about silver (Ag) if they are all using a different words and characters to describe it. By using the same shared symbols, scientists can collaborate with one another around the world.

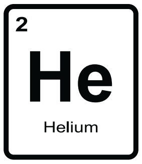


Figure 3 Letter symbols are used to represent elements.

Table 1 The word "silver" written in different languages

French	Argent
English	Silver
Mandarin	銀
Arabic	ضة

Atoms and their electrons

The protons and neutrons of an atom are located within the nucleus. These subatomic particles are responsible for most of the mass of the atom and therefore have a strong influence on the properties of the atom. The number of protons is called the atomic number and is used to order the elements in the periodic table.

In contrast, electrons have a "negligible" mass, meaning the mass is so small it is ignored; it is almost too small to measure. Electrons affect the way the atoms bond with other atoms, however, because electrons orbit the nucleus.

Electron configurations

Danish physicist Niels Bohr (1885–1962) concluded that electrons move about the nucleus in spaces that are at set distances from the nucleus. These spaces are known as **electron shells**. There is a limit to the number of electrons that can be in any of the shells. This special arrangement of electrons around an atom is called the **Bohr model of the atom**.

Table 2 shows that the further an electron shell is from the nucleus, the more electrons it can contain. The maximum number of electrons a shell can hold is related to its shell number by the simple formula $2n^2$, where n represents the number of the shell from the nucleus. For example, the maximum number of electrons that the third shell from the nucleus can hold is $2 \times 3^2 = 18$.

electron shell the area of space around a nucleus where a specific electron may be found

Bohr model of the atom a way to represent the electrons of an atom in a series of shells around the atomic nucleus

Table 2 The Bohr model of the atom

Shell number (from the nucleus outward) (n)	Maximum number of electrons in the shell ($2n^2$)
1	2
2	8
3	18
4	32

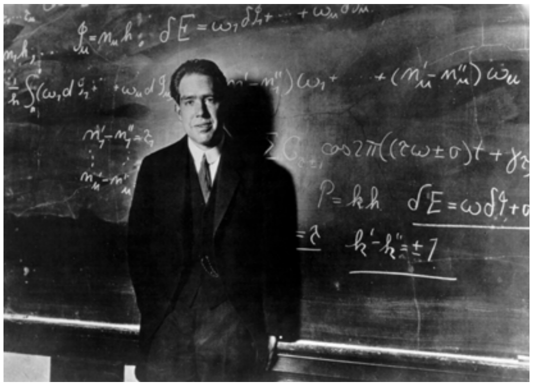


Figure 4 Danish physicist Niels Bohr proposed the idea of electron shells.

electron configuration the distribution of electrons of an atom or molecule in atomic or molecular orbitals

shell diagram a diagram that shows the arrangement of electrons and electron shells in an atom

valence shell the outermost electron shell in an atom that contains electrons

emission spectrum the pattern of wavelengths (or frequencies) that appear as coloured lines in a spectroscope; it is unique to each element

The formula $2n^2$ works for most atoms until we get to atomic number 19 (potassium). Once the third electron shell has eight electrons, the remaining electrons start moving into the fourth shell.

Bohr also stated that the electrons of an atom are normally located as close to the nucleus as possible, because this is a lower-energy state and is more stable. Electrons, therefore, fill the shells closest to the nucleus first. Shells that are further from the nucleus need more energy to stay in the high-energy shell.

The arrangement of electrons in an atom is called its **electron configuration**. Electron configurations are often represented by simple **shell diagrams** that show the electron shells as circles. The electrons are presented in pairs. The outermost occupied shell of uncharged atoms is known as the **valence shell**. The number of electrons in the valence shell of an atom determines the chemical properties of the element and affects how the atom will bond with other atoms. The electronic configurations of oxygen and calcium are compared in Figure 5.

Evidence for electron shells

Many substances give off coloured light when a small sample is introduced into a flame. This light can be seen through a **spectroscope** – an instrument that breaks the light up into its colours. A pattern of coloured lines is observed.

This pattern is known as an **emission spectrum** and is unique for each element. Bohr explained this by saying that a particular atom is given energy in a flame. The electrons absorb the exact amount needed to jump from their normal shell to one further out from the nucleus. He described the electrons as being “excited”. Because this higher energy state is unstable, the electrons then jump back to their normal levels almost instantly. The extra energy that the electrons no longer need is released as light energy. The wavelength of the light (and therefore its colour) represents the energy difference between each electron shell. This unique combination of colours (or spectrum) is linked to a particular type of atom (element) with its unique number of electrons arranged in shells. This spectrum is therefore like the “fingerprint” of that element. This is how flame tests work.

Electrons and properties of elements

The electron configurations of the elements can explain the properties of the elements. Being able to confidently navigate the periodic table enables you to identify trends in electron shell arrangements,

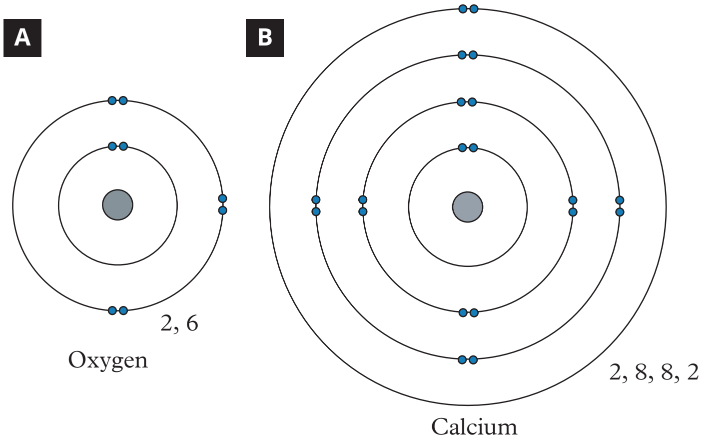


Figure 5 The electron configurations for (A) oxygen and (B) calcium are shown as simple shell diagrams.

the properties of elements and the types of bonds that form in their compounds.

Groups and valence electrons

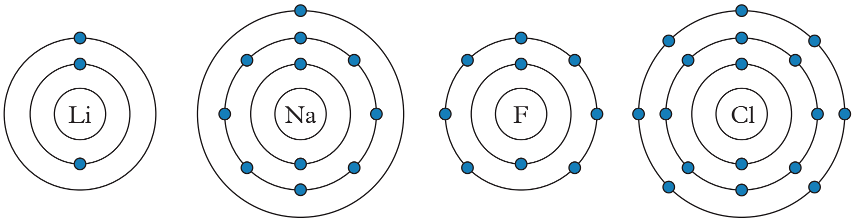


Figure 6 In elements from Group 1 of the periodic table, the atoms have one electron in their outer valence shell. For example, the electron configuration of lithium is 2, 1, whereas that of sodium is 2, 8, 1. Elements in Group 17 (e.g. fluorine and chlorine) have seven valence electrons.

The vertical groups of the periodic table are numbered 1 to 18. Elements in the same group have similar chemical properties, which we now know are due to the arrangement of their electrons. Elements in the same group have the same number of electrons in their valence (outermost) shell. For example, all the elements in Group 13 have three electrons in their valence shells, which means they have very similar properties. Outer valance shells with eight electrons are more stable than electron shells with fewer electrons. The valence-shell electrons often interact with other atoms.

Check your learning 10.3

Check your learning 10.3

Retrieve

1 Identify the key feature of an atom that determines its atomic number. Use an example of two different elements to illustrate your answer.

2 For the Bohr model of the atom, identify the maximum number of electrons that the fourth electron shell can contain.

Comprehend

3 Explain why the second electron shell can contain more electrons than the first shell.

4 Describe the valence shell of an atom.

Analyse

5 Copy and complete Table 3.

6 Identify the element that is in period 3, group 1. Draw its electron configuration.

Apply

7 A potassium atom contains 19 protons.

- **a** Identify the number of electrons in a potassium atom. Justify your answer by explaining how the atomic number of potassium determines the number of electrons.
- **b** Use the Bohr model to identify the electron configuration of a potassium atom.

Table 3 Elements and their properties

Element	Atomic number	Electron configuration
Beryllium		
	9	
Magnesium		
Neon		
		2, 8, 3
	11	
		2, 8, 7
Sulfur		

c From the electron configuration of potassium, it is clear that electrons do not normally occupy the fifth shell. Propose how the electrons in a potassium atom could be moved into this shell.

Skills builder: Communicating

8 Explain why internationally recognised symbols are used for common elements. (THINK: How will you describe this concept clearly?)

Lesson 10.4

Investigation: Identifying metals and non-metals

Purpose

To distinguish between metals and non-metals based on their properties through inquiry. You will be given a selection of "unknown" elements that are either metals or non-metals. These will be labelled A, B, C, etc. Using a selection of tests (see those available below), you will need to categorise them into metal or non-metal

Materials

Materials and chemicals

- A series of "unknown" samples. These may include (your teacher will provide you with a list of available samples):
  – Aluminium (Al)
  – Copper (Cu)
  – Iron (Fe)
  – Zinc (Zn)
  – Magnesium (Mg) ribbon (cut into small pieces)
  – Carbon (C) in the form of graphite
  – Sulfur (S)
- Dilute hydrochloric acid (HCl, 1 M) – 100 mL
- Litmus paper (red and blue) – 10 strips each

Equipment

- Hammer
- 10 test tubes
- Test tube rack
- Bunsen burner
- Heatproof mat
- One pair of tongs
- Crucible and lid
- Metal spatula
- Five beakers (100 mL)
- Two beakers (250 mL)
- Measuring cylinder (100 mL)
- Digital scale (for density test)
- Water container (for density test)
- Battery (9V)
- Four connecting wires with alligator clips
- Small light bulb (low voltage)
- Metal rod holder or clamps
- Thermometer
- Dropper or pipette

Procedure

1. Lustre test (shininess)

- **Metals:** Typically have a shiny or metallic lustre when polished or freshly cut
- **Non-metals:** Often have a dull appearance, lacking the shine found in metals
- **Test:** Observe the surface of the element under light. Metals will reflect light, appearing shiny, while non-metals will appear dull.

2. Malleability test (shape deformation)

- **Metals:** Malleable, meaning they can be hammered or rolled into sheets without breaking
- **Non-metals:** Brittle, meaning they tend to break or shatter when hammered
- **Test:** Use a hammer to gently hit the sample. If it flattens or bends without breaking, it is likely a metal. If it shatters or cracks, it is a non-metal.

3. Electrical conductivity test

- **Metals:** Good conductors of electricity due to the presence of free-moving electrons
- **Non-metals:** Poor conductors (insulators), except for a few like graphite (carbon)
- **Test:** Set up a simple circuit with a battery, wires and a bulb. Place the sample in the circuit. If the bulb lights up, the sample is a metal. If not, it is likely a non-metal.

4. Heat conductivity test

- **Metals:** Good conductors of heat
- **Non-metals:** Poor conductors of heat
- **Test:** Heat one end of the sample and observe how fast the heat travels through it. If the other end becomes hot quickly, it is likely a metal. If the heat transfer is slow, it is a non-metal.

5. Reaction with acid

- **Metals:** React with acids like hydrochloric acid (HCl) to produce hydrogen gas and a salt
- **Non-metals:** Generally do not react with acids
- **Test:** Place a small piece of the sample in dilute hydrochloric acid. If bubbles (hydrogen gas) form, this indicates the presence of a metal. Non-metals typically do not react in this way.

6. Density test

- **Metals:** Generally denser (heavier) than non-metals
- **Non-metals:** Usually less dense
- **Test:** Compare the weight of samples of similar size or place them in water to observe whether they sink or float. Metals usually sink, while some non-metals may float.

Discussion

1. Write a method you will use to complete your investigation. Have your teacher check it before you begin.
2. What sort of table will you need to draw to show your results? Construct a suitable table before starting.
3. Copy and complete Table 1 and show it to your teacher.

Table 1 Results table

Element	Metal or non-metal	Justification
A		
B		
C		
D		
E		

Lesson 10.5

Groups in the periodic table have properties in common

Learning intentions and success criteria

Key ideas

→ Metals are shiny, and they conduct heat and electricity. They are malleable and ductile and they react with oxygen, water and acids.

→ Metals are grouped into alkali metals, alkaline earth metals, transition metals, actinides and lanthanides, with reactivity increasing down a group.

→ Most metals are solid at room temperature (except mercury) and are opaque when flattened.

→ Metalloids are located between metals and non-metals in the periodic table and have properties of both, including electrical conductivity.

→ Non-metals lack metallic properties and are often gases or liquids at room temperature. They have a wide range of melting and boiling points.

→ Noble gases are unreactive, colourless, odourless and non-flammable. They are found in Group 18 of the periodic table.

Metals

metals a collection of elements found on the left-hand side of the periodic table that are malleable, lustrous, ductile and highly conducting

Nearly three-quarters of all elements are metals. **Metals** are defined by their lustrous appearance and their ability to conduct heat and electricity.

Metals have many properties in common. Pure metals are:

- lustrous (shiny)
- able to conduct heat and electricity
- malleable (able to be beaten into a new shape)
- ductile (able to be drawn into a wire)
- very reactive and can react with oxygen, water and acids.

There are different groups of metals – alkali metals, alkaline earth metals, transition metals, actinides and lanthanides. Typically, as you move down a group of metals in the periodic table, they become more reactive. Metals are solid at room temperature (with the exception of mercury) and when they are a flattened into a thin sheet, they are opaque (meaning we cannot see through them).

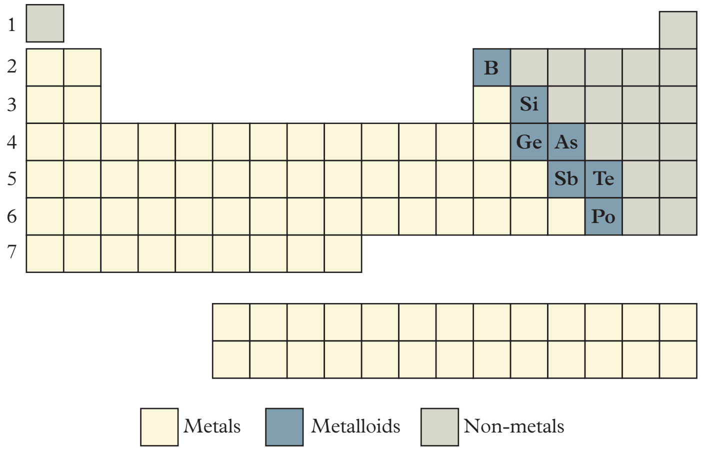


Figure 1 Regions of the periodic table

Figure 2 Not all metals are the same.

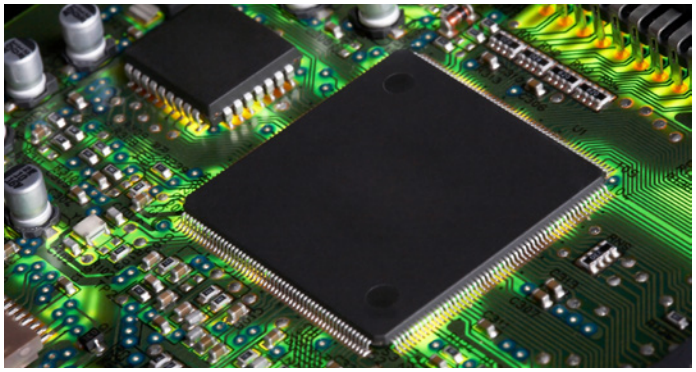


Figure 3 Silicon and germanium are widely used in electronic devices because of their semiconductor properties – they conduct electricity in a very controlled way.

Metalloids

Metalloids are the small set of elements along the "staircase" diagonal boundary of the periodic table between the metals and non-metals (Figure 1). As might be expected from this location, metalloids exhibit properties between those of metals and non-metals. Most of their properties would be considered "un-metallic"; however, metalloids conduct electricity like the metals.

metalloids a small collection of elements that have a mixture of characteristics of metals and non-metals

Non-metals

Non-metals, as the name suggests, are elements that do not have the set of properties common to all metals. None are lustrous (shiny) and none are ductile (easily manipulated); however, a small number of non-metals are coloured and some are brittle. In addition, non-metals have a much larger range of melting points and boiling points than the metals do. At room temperature, several non-metals are gases and one (bromine) is a liquid, whereas all the metals except for one (mercury) are solids at room temperature.

non-metals a collection of elements that are found on the right-hand side of the periodic table

The noble gases

The **noble gases** are found in Group 18. The noble gases are so called because they are all gases at room temperature and are unchanged if mixed with other elements. They are colourless, odourless and non-flammable. They include:

- helium (He)
- neon (Ne)
- argon (Ar)
- krypton (Kr)
- xenon (Xe)
- radon (Rn)
- oganesseon (Og).

noble gases a collection of gaseous elements found in Group 18 of the periodic table

Common elements used today

Today, we can harness the properties of different elements. We can also use elements in different ways if they come in different forms. These different forms of the same element are known as **allotropes**. For example, carbon can come in the form of graphite (which is very soft) or diamond (which is the hardest substance on Earth). In fact, diamond is so hard that it is often used to coat cutting tools such as saws. Table 1 outlines some other uses of common elements.

allotrope different structural forms of the same element, where atoms are arranged in distinct ways, resulting in different physical properties. For example, carbon exists as graphite, charcoal, and diamond, each with unique characteristics

Table 1 Common elements and their uses

Element	Metal/Non-metal	Chemical symbol	Atomic number	Uses
Carbon	Non-metal	C	6	• Coal for fuel • Diamond jewellery • Graphite pencils
Aluminium	Metal	Al	13	• Foil • Kitchen utensils • Aeroplane parts
Sulfur	Non-metal	S	16	• Matches • Fireworks • Insecticide

Check your learning 10.5

Check your learning 10.5

Retrieve

1 Recall the dominant state of matter within the groups of non-metals.

2 Identify the properties of non-metals.

3 Identify what proportion of the periodic table is composed of metals.

Analyse

4 Examine the periodic table.

  a Identify the period and group for each of the following elements: fluorine, bromine, tin, radium, potassium, platinum, arsenic.

  b Are any of the elements in part **a** in the same group? Explain what this would tell you about them.

  c Are any of the elements in part **a** in the same period? Explain what this would tell you about them.

Apply

5 Design a way to represent the different groups of metals clearly and informatively, identifying the distinguishing properties of each group.

6 Why could the term “metal-like” be used to describe metalloid elements? Suggest a better name for this group of elements. Justify your answer.

Skills builder: Planning investigations

7 A student found three unlabelled jars, each containing one element. They wrote down some observations about each, as shown in Table 2.

  a Identify whether you think each of the elements listed is a metal, non-metal or metalloid.

  b Identify a test for each substance that could confirm your prediction. (THINK: What do you know about the properties of metals and non-metals that could help you to devise a test?)

Table 2 Observations of each element

Observations	Metal, non-metal or metalloid?	Test
Shiny metal on the outside and soft		
Brown liquid		
Shiny, brittle solid		

Lesson 10.6

Elements can combine to form compounds

Key ideas

→ Atoms are neutral because the number of protons (positive) equals the number of electrons (negative).

→ When an atom gains or loses electrons, it becomes an ion, a charged particle with an unequal number of protons and electrons.

→ Ionisation occurs when atoms form chemical bonds or are exposed to radiation, affecting electrons in the outer (valence) shell.

→ A stable valence shell has eight electrons, making the atom less likely to gain or lose electrons (e.g. a chloride ion with full shells of 2, 8, and 8 electrons).

→ Ions can be negative (anion) if electrons are gained or positive (cation) if electrons are lost; the charge depends on the imbalance between protons and electrons.

Learning intentions and success criteria

Atoms and ions

Atoms are neutral. This means that the amount of negative charge within the atom is always the same as the amount of positive charge. This is because the number of protons (positive) is always the same as the number of electrons (negative). If electrons are lost or gained from the outside of the atom, however, there will no longer be the same number of protons and electrons. When this happens, the atom becomes an **ion**. The process of forming ions is called **ionisation**.

ion an atom that is charged because it has an unequal number of electrons and protons

Ionisation can happen when atoms come together to form chemical bonds. It can also happen when atoms are exposed to radiation. When ions are formed, it is the electrons in the outer electron shell (the valence shell) that are affected. A valence shell is stable if it has all of its electrons or if it has eight electrons. This means the electron shell is less likely to gain or lose electrons. For example, the first three shells of a chloride ion are full, with 2, 8 and 8 electrons respectively.

An atom that originally had two electrons in its outer valence shell – such as magnesium – would lose both these electrons to achieve a full outer shell; it is easier to lose two electrons than to gain six (Figure 1).

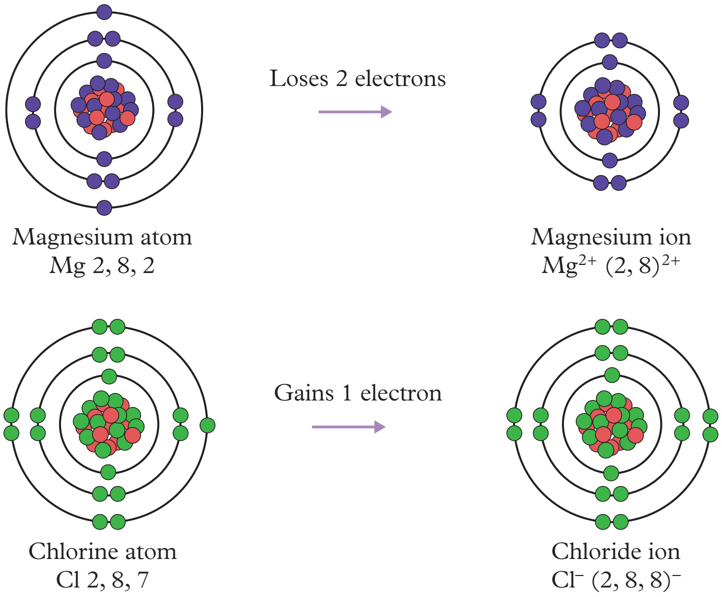


Figure 1 How magnesium and chloride ions are formed

In contrast, an atom with seven electrons in its outer valence shell – such as chlorine – would gain one electron, making eight electrons to complete this outer shell; it is easier to gain one electron than to lose seven to have a stable outer valence shell (Figure 1).

Elements in the same group (column) of the periodic table have the same number of valence electrons. For example, all elements in Group 1 (alkali metals) have one valence electron, while elements in Group 17 (halogens) have seven valence electrons. This concept can be used to predict ion formation and understand atomic behaviour.

Figure 3 shows the formation of sodium and chloride ions.

Figure 2 To remember the difference between cations and anions, think of a positive CATion.

Calculating ion charge

When an ion is formed, the number of protons in the atom stays the same because protons are located in the nucleus and are not affected by changes occurring on the outside of the atom. When electrons are gained or lost, an imbalance is formed between the number of positive charges and the number of negative charges.

Electrons are negatively charged, so when an atom gains an extra electron, the charge on the whole atom becomes negative. If two electrons are gained, then there is an overall charge of negative two. A negatively charged ion is called an **anion**.

If an electron is lost from an atom, the resulting ion will have a charge of positive one because there are more protons than electrons. One electron lost means there is effectively one extra proton. A positively charged ion is called a **cation**.

Table 1 contains some examples of anions and cations.

anion a negatively charged ion formed when an atom gains electrons

cation a positively charged ion that results from an atom losing electrons

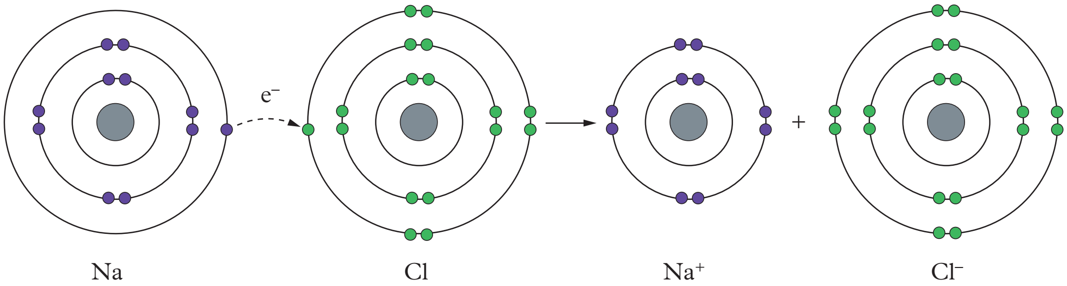


Figure 3 A sodium atom (Na) loses an electron to become a positively charged cation. Chlorine (Cl) gains an electron to become a negatively charged anion. In this way, salt (sodium chloride, NaCl) is formed.

Table 1 Examples of positive and negative ions

Name and symbol of atom	Electron configuration of atom	Electron configuration of ion	Metal or non-metal?	Change	Charge of ion	Name and formula of ion
Oxygen (O)	2, 6	2, 8	Non-metal	Gained 2 electrons	–2	Oxide (O^{2-})
Chlorine (Cl)	2, 8, 7	2, 8, 8	Non-metal	Gained 1 electron	–1	Chloride (Cl^{-})
Sodium (Na)	2, 8, 1	2, 8	Metal	Lost 1 electron	+1	Sodium (Na^{+})
Calcium (Ca)	2, 8, 8, 2	2, 8, 8	Metal	Lost 2 electrons	+2	Calcium (Ca^{2+})

Worked example 10.6A Calculating the charge of atoms

Determine the likely charge of the following atoms:

a sodium ion
b oxygen ion
c neon atom.

Solution

Steps	What to do	Working out
a.	Use the periodic table to identify the group the atom belongs to.	**a** Sodium atoms are in Group 1. **b** Oxygen atoms are in Group 16. **c** Neon is a noble gas (in Group 18).
b.	Identify the number of valence electrons the atom has.	**a** Sodium has one valence electron. **b** Oxygen has six valence electrons. **c** Neon has eight valence electrons.
c.	Deduce how many electrons the atom would need to gain or lose to have a stable outer shell to determine the charge.	**a** It is easier to lose one electron than to gain seven electrons. This means the sodium ion will have one less negatively charged electron and have one more positive proton than electrons. Therefore, the sodium ion will have a charge of 1+. **b** It is easier to gain two electrons than to lose six electrons. This means the oxygen ion will have two extra electrons and have a charge of 2–. **c** Neon atoms already have eight valence electrons (a stable outer shell) and does not need to gain or lose electrons. This means the neon atom will be neutral.

Ionic compounds

Forming ionic compounds

Metallic elements are usually found on the left-hand side of the periodic table before Group 14. This means they have fewer than four electrons in their valence shell. Therefore, metallic atoms tend to lose electrons and become positively charged cations.

In contrast, most non-metal atoms have almost-full valence shells. This means they need to gain only a few electrons to achieve a full valence shell. As a result, non-metal atoms will become negatively charged anions.

Positively charged cations are attracted to negatively charged anions. A cation with a 2+ charge is likely to combine (bond) with an anion of 2– charge or with two anions each with a charge of 1–. The positive charge is balanced by an equal negative charge. The bonds that are formed when ions interact are referred to as **ionic bonds** (Figure 4).

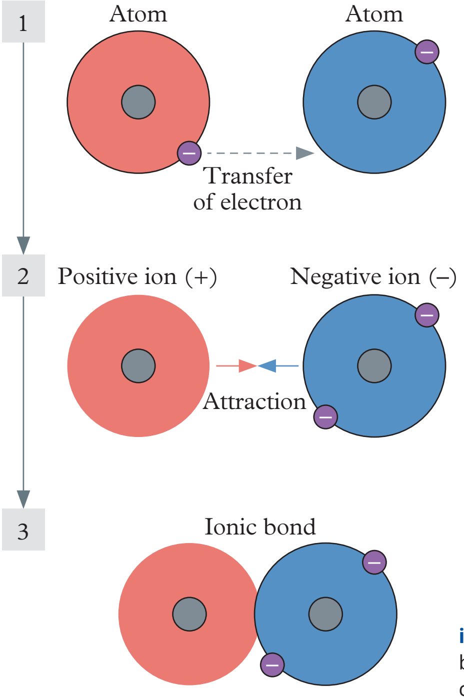


Figure 4 Ionic bonds form when a positive cation is attracted to a negative anion.

ionic bond a bond between a negatively charged anion and a positively charged cation

Properties of ionic compounds

ionic compound a substance made up of a negatively charged anion and a positively charged cation

Compounds that are held together by ionic bonds are called **ionic compounds**. As an ionic compound forms, the like-charged ions repel or push each other and the oppositely charged ions attract each other. After all the pushing and pulling, the ions settle into alternating positions, as shown in Figure 5, because this is the most stable arrangement. The particles are held together by strong forces of attraction, called **electrostatic forces**, between the positively charged ions and the negatively charged ions. These forces bind the ions together, so this is known as **ionic bonding**.

A lot of energy is required to move the ions out of their positions. This means that ionic compounds are hard to melt. At room temperature, they are in the form of hard, brittle crystals. The most commonly known example of an ionic compound is sodium chloride (table salt). Its melting point is 801°C. If you use a salt grinder at home, you will be aware of how hard and brittle salt crystals are.

When naming ionic compounds, the cation is always written before the anion. For example, a sodium cation (Na^+) combined with a chloride anion (Cl^-) is written as NaCl.

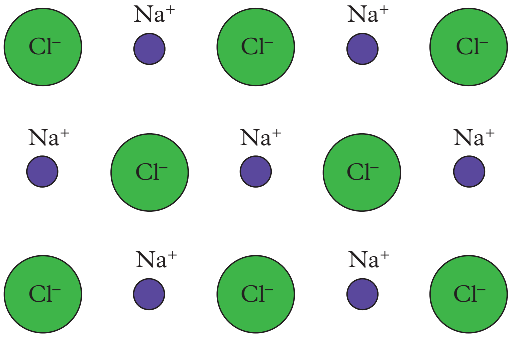


Figure 5 In an ionic compound, such as sodium chloride, the ions are arranged in alternating positions.

Polyatomic ions

polyatomic ion a charged ion that consists of two or more atoms bonded together

A number of ions are made up of more than one atom. These are termed **polyatomic ions**. Figure 6 shows some examples.

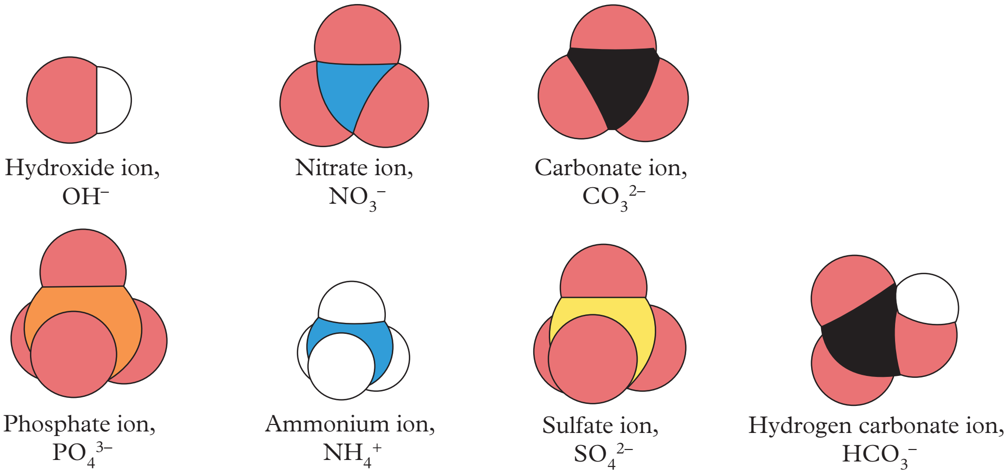


Figure 6 Some common polyatomic ions: the charge number indicates how many electrons have been lost. A negative charge number indicates how many electrons have been gained.

These clusters of atoms have a charge because the total number of protons does not equal the total number of electrons present. For example, in the hydroxide ion which is made up of two ions (one each of oxygen and hydrogen), there are nine protons and ten electrons. This means the two atoms that form the ion have an overall negative charge of 1–.

Calcium carbonate, the main constituent of chalk, is an example of an ionic compound that contains a polyatomic ion. Calcium carbonate contains calcium ions (Ca^{2+}) and carbonate ions (CO_3^{2-}). These ions must be present in the ratio 1 : 1 so that the total positive charge equals the total negative charge. The formula of calcium carbonate is $CaCO_3$.

Ammonium carbonate is used in smelling salts. It contains ammonium ions (NH_4^+) and carbonate ions (CO_3^{2-}). In this case, the ions need to be present in the ratio 2 : 1 (two NH_4^+ for every CO_3^{2-}). The formula of ammonium carbonate is $(NH_4)_2CO_3$.

Covalent compounds

You have seen that when electrons are transferred from one atom to another, positive and negative ions are produced and ionic compounds are formed. However, two non-metals that complete their outer shells of electrons by sharing electrons can also bond together. We can see this with the smallest, lightest atom: hydrogen.

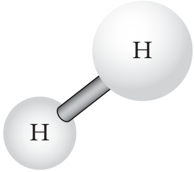


Figure 7 The ball-and-stick model is often used to show atoms (balls) and the bonds (sticks) between them. This image shows a ball-and-stick model of a hydrogen (H_2) molecule.

Hydrogen molecules

An uncharged (neutral) atom of hydrogen has just one electron in the first shell. If it could gain one more electron, this shell would contain its maximum number of electrons – two. If hydrogen was in contact with a reactive metal such as lithium, the hydrogen atom could gain that extra electron from a lithium atom. An ionic compound would form as a result. But what if only other uncharged hydrogen atoms are present? The only way each hydrogen atom can gain an extra electron is by sharing its electron with another.

As two uncharged hydrogen atoms come close together, the electrons are drawn into the region between the two nuclei. The atoms partially merge into one another, with the nuclei of both atoms now sharing the two electrons in a **covalent bond**. The electrons travel in the spaces surrounding the nuclei of each atom. In effect, each atom now has a stable electron configuration because its outer shell is full.

covalent bond a bond formed when two or more atoms share electrons

The particle produced has two hydrogen atoms bonded strongly together and is called a **molecule**. A molecule is a particle produced when two or more atoms combine so that the atoms share electrons.

molecule a group of two or more atoms bonded together (e.g. a water molecule)

A molecule has no overall charge because the total number of electrons and the total number of protons is the same.

The hydrogen molecule is given the formula H_2 because there are two hydrogen atoms present in the molecule.

The hydrogen molecule is an example of a molecule of an element. It is called a diatomic molecule because it is made up of two atoms. Other examples of diatomic molecules of non-metals are fluorine (F_2), chlorine (Cl_2), oxygen (O_2) and nitrogen (N_2).

In a molecule such as the hydrogen molecule, there is strong electrostatic attraction between each positively charged nucleus and the negatively charged electrons that they share. The electrons spend a considerable part of their time between the two nuclei. This electrostatic attraction is termed covalent bonding. The two shared electrons create a strong bond between the two atoms.

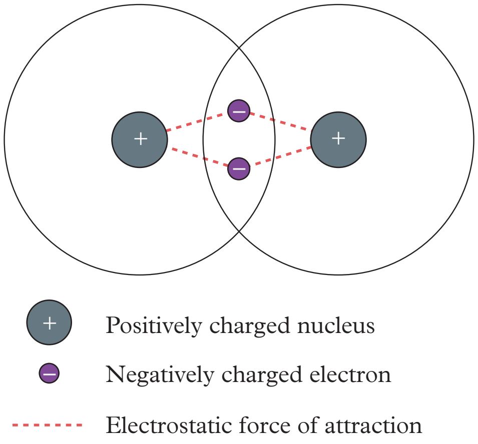


Figure 8 Some diagrams of molecules can show the electrons being shared between the atoms.

Molecular compounds

molecular compound a molecule that contains two or more different atoms bonded together

Molecules can also be formed by combining different types of atoms into compounds. Water is an example of a **molecular compound**. Its formula is H_2O. To gain a more stable electron configuration, an:

- uncharged hydrogen atom, which has one valence electron, requires a share of one more electron
- uncharged oxygen atom, which has six valence electrons, requires two more electrons.

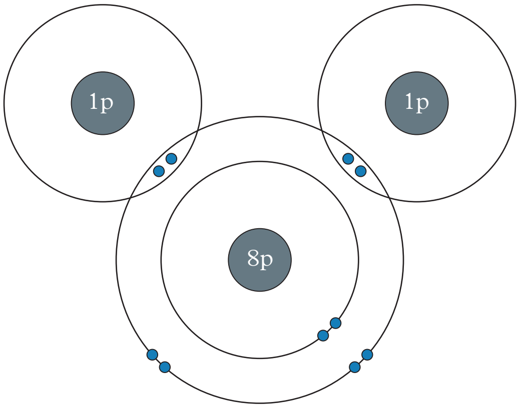


Figure 9 A shell diagram of a water molecule (H_2O)

A single hydrogen atom cannot supply the two electrons the oxygen atom needs, but two hydrogen atoms can supply one electron each. This is why there are two hydrogen atoms and just one oxygen atom in a water molecule. An oxygen atom now effectively has eight electrons in its valence shell, and each hydrogen atom has two electrons. This is shown in Figure 9. Notice that each atom now has a full, stable outer shell of electrons.

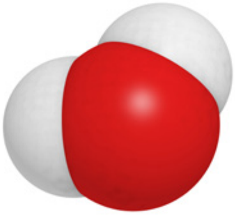


Figure 10 A 3D model is often used to show the arrangement of atoms in a molecule of water (H_2O).

There are other ways of representing the structure of molecules, including with three-dimensional models (Figure 10). Remember that in any representation, however, a single chemical bond holding the molecule together is a pair of negative electrons, shared between two atoms, attracted to the positive nuclei of both atoms.

Check your learning 10.6

Check your learning 10.6

Retrieve

1 Define the term "cation".

2 Define the term "ionic compound".

Comprehend

3 Describe a covalent bond.

4 Use an example from the periodic table to explain how an anion is formed.

5 Describe the patterns you observe in Table 1 for each of the following.
  a Names of the negative ions
  b Electron configurations of the ions
  c Differences between the metals and non-metals

6 Explain why the elements neon (atomic number 10) and argon (atomic number 18) do not normally form ions.

7 Explain the relationship between the groups in the periodic table and the ions that are formed.

8 Describe why the group of an element can be used to quickly identify one or more of its properties.

9 Use your knowledge of atomic structure and valence electrons to explain why many ionic compounds are made up of a metal and a non-metal.

Analyse

10 Carefully examine the periodic table.
  a Identify the groups that are likely to form positively charged ions.

- **b** Identify the groups that are likely to form negatively charged ions.
- **c** Explain why elements from Group 1 and Group 17 are likely to form ionic compounds.

11 Compare ionic bonding and covalent bonding.

12 Calculate the likely charges of the following.
- **a** Calcium cation
- **b** Chloride anion
- **c** Magnesium cation
- **d** Argon atom

13 Use the groups in the periodic table to identify the charges on the following ions.
- **a** Potassium (atomic number 19)
- **b** Aluminium (atomic number 13)
- **c** Nitride (produced from nitrogen atoms with atomic number 7)

Apply

14 Use the information from Figure 2 to determine the formula of the ionic compound that contains a phosphate ion and a potassium cation.

15 Calculate the maximum number of electrons that can be gained or lost by any atom. Justify your answer (by contrasting how elements in Group 13 and Group 15 form ions, explaining why it can be difficult to determine the charge on elements in Group 14, and explaining how this allowed you to calculate the maximum).

Lesson 10.7

Science in context: Many substances exist because of the work of scientists

Introduction

It is easy to forget just how much we rely on manufactured products in our lives. Increasingly, many substances and materials are processed (changed) or manufactured before they are used. These substances, such as medicines, electronic components and composite materials in aircraft and polymers, only exist because of the work of scientists changing them from their original state to one that you can use.

Figure 1 Pharmacists are chemists with a specialisation.

Pharmaceuticals

Pharmacies (also called "chemist shops") are where medicines are prepared and dispensed. A pharmacist (also called a "chemist") has studied chemistry, but has specialised in the study of medicines and their effect on the body (called "pharmacology").

Figure 2 Many everyday items are the result of carefully considered chemistry.

Figure 3 All these products come from petroleum.

Oil refinery

Petroleum, or crude oil, is an important product in our society. Oil is pumped from the ground and is carried in pipelines or tankers to refineries, where it is separated into its many different components. The crude oil mixture is converted into high-value products, such as petrol, diesel, vitamins, medicines, paint, putty and ink, as well as a very large number of different plastics. “Plastic” is the common name for all the different polymers used in construction, clothes, shoes, furniture, surfboards, phone cases and many more products.

Glues and adhesives

Glue was used in ancient Babylon, 3,500 years ago, when King Nebuchadnezzar used bitumen (also called “asphalt”) to hold building stones together. Later, plant gums, egg whites and animal products (such as gelatine) were used for gluing paper and wood. The paints used historically by master painters were made using egg whites, which helped to hold the parts of the paint mixture together.

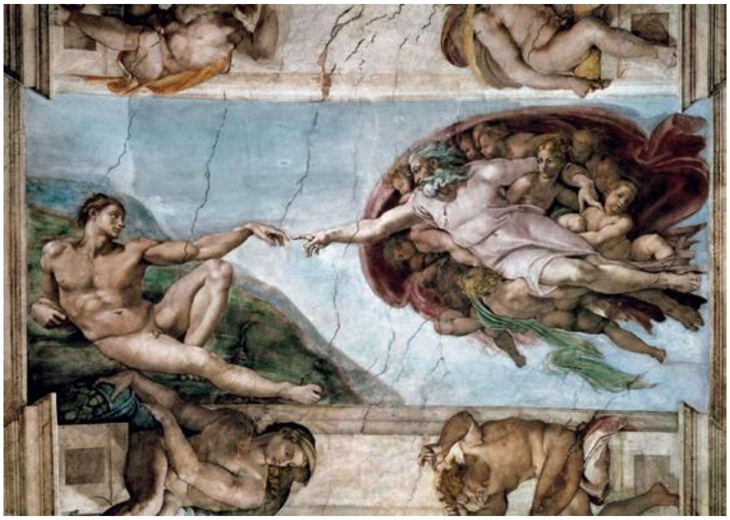


Figure 4 Paints used by the famous artist Michelangelo to paint the ceiling of the Sistine Chapel in Rome contained egg whites to help hold the paint together.

In the First World War, aircraft were made of wood. The wood was glued with casein glue (casein is a protein in milk) and albumin (a protein in egg white).

Nowadays, many synthetic glues are used. Once, shoes were made of layers of leather nailed and sewn together; now these layers are mostly glued. Glue is used to hold many things together, including the chips in chipboard, the layers in MDF board and plywood in a lot of furniture. Even the brake linings in cars are glued (bonded).

Dyes

Before the use of dyes, all clothes had the same colour – the off-white colour of natural fibres, such as raw cotton, silk and wool.

The first dye was obtained from the shells of murex whelk sea snails. It took 12,000 snails to make only 1.4 g of purple dye, which was just enough to colour the edge of one Roman emperor's toga. For this reason, purple clothes were traditionally reserved for high-ranking officials. The whelk sea snail almost became extinct as a result of being hunted for its dye.

The soldiers in the British Army used to be known as "redcoats" because their uniform included a red coat, which was dyed red using liquid extracted from scale insects. This red dye, called carmine, is still available today in supermarkets, but it is now made synthetically.

The first synthetic (or artificial) dye was discovered accidentally by William Perkin in 1856. He named his dye after its colour, mauve. Soon, many other coloured dyes were discovered and manufactured.

Computer printers use dyes when they print photographs. Modern inks do not fade, so modern photographs last longer than paintings made many years ago.

Figure 5 A glue is any substance that sticks things together.

Test your skills and capabilities

Test your skills and capabilities 10.7

Using design thinking to solve problems

Making casein glue requires you to use science inquiry skills and design thinking.

Not all glue needs to be super strong. Dr Spencer Silver was a chemist who researched glues for the 3M company. His job was to make new, stronger glues. Another scientist who worked at 3M, Art Fry, used to sing with his church choir once a week. Each week he would become frustrated that the bits of paper that marked the songs he was going to sing would fall out of his book. When Art and Spencer were talking one day, they came up with the idea of small bits of paper that could be glued to the pages of a book (using a glue that wasn't too strong) and then peeled off when they were finished. They tried many different chemical reactions until they found one that produced the right product. Post-it notes were invented!

The cycle of design thinking involves empathy (understanding someone's problem from their point of view), ideation (thinking of possible solutions to a problem), building and testing the prototype and communicating the results. Identify each of these stages in the invention of Post-it notes.

Figure 6 Dyes, like the colour in this British soldier's coat, originally came from living organisms. Today, colour dyes are mostly synthetic.

Lesson 10.8

Review: Atomic structure

Summary

Lesson 10.1 All matter is made up of atoms

- An element is a pure substance with one type of atom.
- The periodic table organises elements according to their chemical and physical properties.

Lesson 10.2 Common elements make up every object

- The atom is the smallest unit of an element.
- Elements, compounds and alloys are important, and they make up everyday materials.
- Understanding the structure and properties of these substances helps us choose materials for specific uses (e.g. lightweight materials for aeroplanes and rust-resistant metals for kitchen appliances).

Lesson 10.3 How atomic structure determines element properties

- An element's atomic number and name are determined by the number of protons in its nucleus.
- The relative atomic mass is the sum of protons and neutrons.
- Electrons have almost no mass and move around the nucleus in electron shells.
- The valence shell (outermost electron shell) influences an element's properties and reactivity.
- The number of valence electrons determines an element's position in the periodic table.

Lesson 10.5 Groups in the periodic table have properties in common

- Metals are shiny, and they conduct heat and electricity. They are malleable and ductile and they react with oxygen, water and acids.
- Metals are grouped into alkali metals, alkaline earth metals, transition metals, actinides and lanthanides, with reactivity increasing down a group.
- Most metals are solid at room temperature (except mercury) and are opaque when flattened.
- Metalloids are located between metals and non-metals in the periodic table and have properties of both, including electrical conductivity.
- Non-metals lack metallic properties and are often gases or liquids at room temperature. They have a wide range of melting and boiling points.
- Noble gases are unreactive, colourless, odourless and non-flammable. They are found in Group 18 of the periodic table.

Lesson 10.6 Elements can combine to form compounds

- Atoms are neutral because the number of protons (positive) equals the number of electrons (negative).
- When an atom gains or loses electrons, it becomes an ion, a charged particle with an unequal number of protons and electrons.
- Ionisation occurs when atoms form chemical bonds or are exposed to radiation, affecting electrons in the outer (valence) shell.
- A stable valence shell has eight electrons, making the atom less likely to gain or lose electrons (e.g. a chloride ion with full shells of 2, 8, and 8 electrons).
- Ions can be negative (anion) if electrons are gained or positive (cation) if electrons are lost; the charge depends on the imbalance between protons and electrons.

Review questions 10.8

Review questions Module 10

Retrieve

1 Name three common elements found in everyday objects.

2 List three physical properties that can be used to compare metals, non-metals and metalloids.

3 Identify the three subatomic particles in an atom. State the charge of each of these particles.

4 Identify the scientist who first proposed the concept of the atom.

5 Recall which of the following scientists generated the modern version of the periodic table.

A Democritus
B Dalton
C Mendeleev
D Lavoisier

Comprehend

6 Define an element, compound and alloy.

7 Explain why some elements are classified as metalloids.

8 Explain how the periodic table is arranged in terms of groups and periods.

9 Describe how new technologies have contributed to changes in atomic models.

10 Explain why elements in the same group of the periodic table have similar properties.

Analyse

11 Compare and contrast the atomic structure of two elements from different groups in the periodic table.

12 Analyse how the historical development of the periodic table improved our understanding of element properties.

13 Analyse how the properties of an alloy differ from the properties of the pure elements it is made from.

14 Compare the reactivity of alkali metals and noble gases using their positions in the periodic table.

Apply

15 Use the periodic table to determine the number of protons, neutrons and electrons in a neutral atom of magnesium.

16 Predict whether an unknown element with a high melting point and good electrical conductivity is a metal, non-metal or metalloid.

17 Apply your understanding of atomic structure to explain why neon is unreactive.

Social and ethical thinking

18 What are the ethical and environmental implications of mining metals and non-metals for use in everyday products?

Critical and creative thinking

19 If a new element were discovered, how would you determine whether it is a metal, non-metal or metalloid?

20 Imagine you are designing a new type of battery. What properties would you look for in the elements used to make it?

Research

21 Investigate how the availability and properties of metals, alloys and compounds have influenced technological developments in modern society.

Data analysis

Copper and aluminium are widely used in household wiring and kitchen utensils due to their physical properties. Table 1 shows some key properties of these metals.

Using the data provided, explain why copper is often preferred for electrical wiring while aluminium is commonly used for cookware.

Table 1 Key properties of copper and aluminium

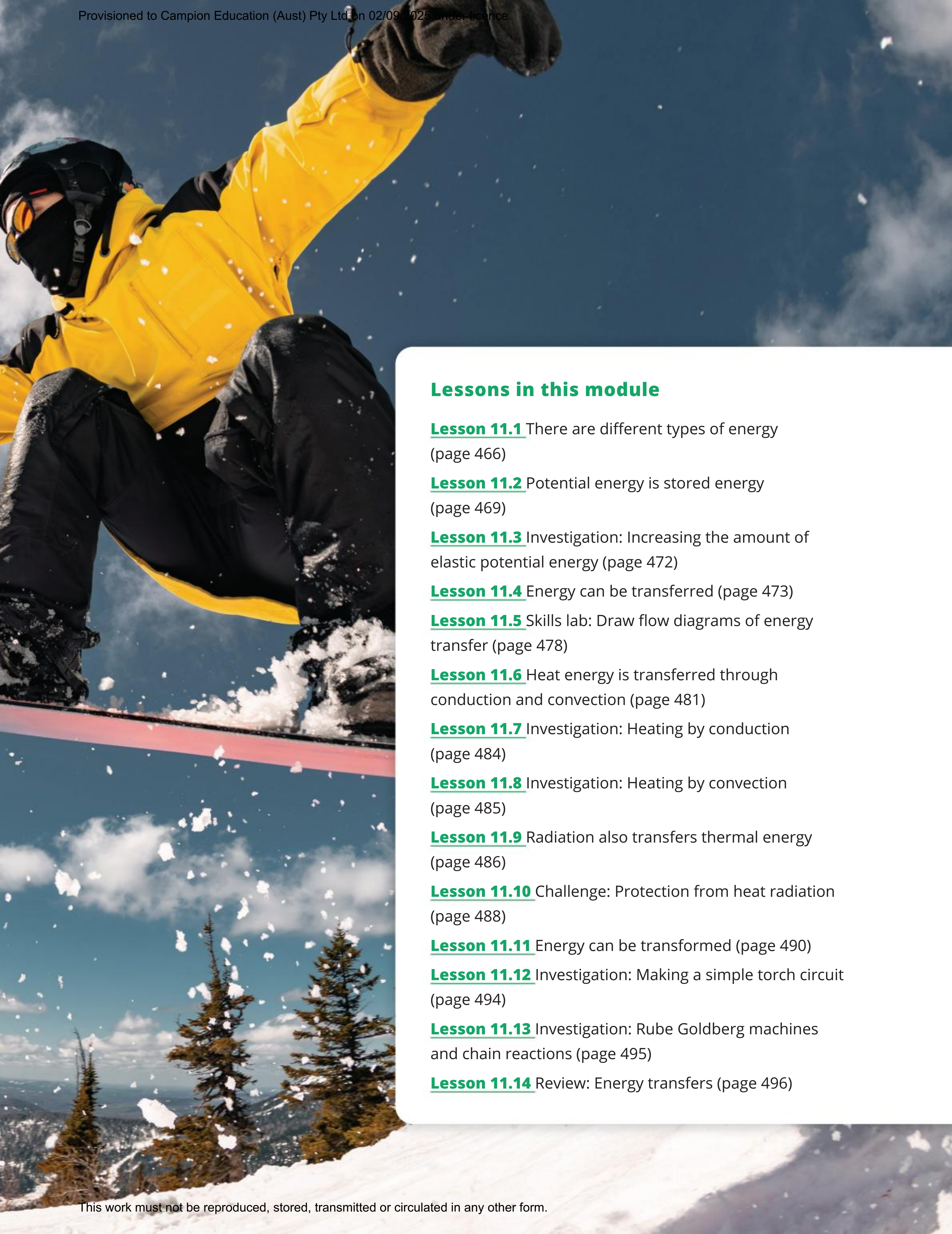
Metal	Melting point (°C)	Electrical conductivity (S/m)	Density (g/cm³)	Corrosion resistance
Copper	1,085	5.96×10^7	8.96	High
Aluminium	660	3.77×10^7	2.70	Moderate

Module 11

Energy transfers

Overview

Scientists define energy as the ability to do work. There are many types of energy, such as light energy, which allows us to see in the dark, and heat energy, which can keep us warm on a cold winter's night. Energy is transferred through heat, light and sound. Understanding how energy moves allows engineers to design more efficient manufacturing materials, such as for cars or energy-efficient homes.



Lessons in this module

Lesson 11.1

There are different types of energy

Learning intentions and success criteria

Key ideas

→ Kinetic energy is the energy found in a moving object.

→ When objects move at the same speed, heavier objects have more kinetic energy than lighter objects.

→ The faster an object moves, the more kinetic energy it has.

Introduction

Every time something moves, heats up, stretches or changes, energy is being used. Energy is the ability to do work and all objects have energy.

Kinetic energy

kinetic energy the energy possessed by moving objects

The energy of movement is scientifically called **kinetic energy** (KE). Whenever objects or people move, they have kinetic energy. It takes energy to force an object, such as a car, to start moving. Once it is moving, the energy has passed to the car and it has kinetic energy. The faster the object is moving or the more mass the object has, the greater the kinetic energy. Even objects too small to be seen can have kinetic energy.

Figure 1 Kinetic energy is the energy of movement.

Figure 2 Sound energy is the kinetic energy produced when guitar strings vibrate.

Light energy

Light energy is essential to our lives, and historically people have invented lots of devices to help us see in the dark, including oil, gas and kerosene lamps (Figure 3). The humble electric light bulb revolutionised the world in the late 1800s and led to the development of easily portable light sources such as torches. But the best source of light is, of course, the Sun.

Light energy is one type of energy that our eyes can usually detect. It moves in small packets of energy called **photons**. We can see a range of colours (red, orange, yellow, green, blue and violet) in the visible spectrum, but the light we see is part of a larger group of lights that we can't see that is called **electromagnetic radiation**. This large group includes ultraviolet light, microwaves and X-rays. The study of light energy is known as **optics**.

Figure 3 Kerosene lamps were used for many years before the invention of electricity.

The main reason life exists on Earth and not on other planets is because our atmosphere allows the right amounts of light energy from the Sun to reach Earth's surface. Plants rely on the light and heat from the Sun to make their own food, and the plants then become food for animals and humans.

We are now trying to capture light energy as efficiently as plants do. **Solar cells** turn light from the Sun directly into electricity. They are used to power many devices, such as calculators, street lights and even cars.

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

solar cell a device that transforms sunlight directly into electrical energy; is usually in the form of a panel; also known as a solar panel

thermal energy the scientific term for heat energy

Heat energy

Heat energy is scientifically known as **thermal energy**. Thermal energy can be generated by friction, such as by rubbing your hands together or by the rubbing of a car's tyres on the road (Figure 4). It is also commonly generated by burning chemicals or by electrical devices. We experience heat energy being transferred from a higher temperature to a lower temperature as we heat up or cool down. For example, an ice block feels cool because it takes the thermal energy away from our hands.

Figure 4 The heat of a burn-out creates great clouds of smoke.

Electrical energy

All substances are made up of positive and negative electric charges that, when separated, have **electrical energy**. This means that they are in a state of "excitement" and are trying to get back together again. If the positive and negative charges are locked together in one area, such as in a wire, the separated charges can easily move back together. As they try to connect, the electrical energy they had when separated gets changed into light, heat or movement that we see in electrical lights, heaters or motors.

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

Sound energy

sound energy a type of kinetic energy produced when things vibrate, causing waves of pressure in the air or some other medium

Have you been at a very loud concert and stood near the huge speakers? If so, you will remember that you not only heard the deep bass sound but also felt it in your body. You can feel the same vibrations in the car if you put your hand on the dashboard when the sound system is on full volume. Sound is made when things vibrate. Every time you make a sound – whether it be playing the drums, speaking, singing or even whispering – you are making vibrations (Figure 5). Vibrations are simply tiny movements back and forth. Vibrations can occur in gases, liquids and solid things, such as speakers. Energy is needed to make sound. For example, unless a drummer uses energy to hit the drums, the drum skin will not start to vibrate and will not make a sound. So, do you think **sound energy** is a type of kinetic energy?

Figure 5 Musical instruments use kinetic energy to produce sound.

Check your learning 11.1

Check your learning 11.1

Retrieve

1 Define the term "energy".

2 Recall the scientific term for "movement energy".

3 Identify what is moving in electrical energy.

4 Identify what is moving when a guitar produces sound energy.

5 Recall another name for heat energy.

Comprehend

6 Describe how solar cells are used in the transfer of energy.

Analyse

7 Identify the features of a car that would absorb the driver's kinetic energy in a collision.

Skills builder: Planning investigations

8 Propose the type of information you think should be collected for each of the following research questions: first-hand or secondary sources. (THINK: Would you be able to plan and conduct an investigation yourself to find the answer to the question? If not, you may need to get information from a secondary source.)
   - a Which state or territory produces the most solar energy in Australia?
   - b Which solar panels produce the most electrical energy?
   - c Which remote-control car has the most kinetic energy?

Lesson 11.2

Potential energy is stored energy

Key ideas

- → An object that has the potential (future ability) to do work has potential energy.
- → Elastic potential energy is stored when an elastic object is deformed.
- → Gravitational potential energy is stored when an object is lifted away from the Earth's surface.
- → Chemical potential energy is the energy stored when atoms are bonded to each other.
- → Nuclear potential energy is the energy stored inside the centre of an atom.

Learning intentions and success criteria

Introduction

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

potential energy energy that is stored in objects

Elastic potential energy

A trampoline can "store" energy. The springs and the mat of the trampoline stretch under our weight and hold this stored energy. The more they stretch, the more energy they hold. The energy is returned to our bodies when the springs and mat return to normal and throw us into the air. Energy that is stored through stretching or squashing is called **elastic potential energy**.

Figure 1 Jumping stilts rely on elastic potential energy.

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

Gravitational potential energy

If we lift an object to a height, it gains energy in a gravitational field. This type of energy is called **gravitational potential energy** (abbreviated to "GPE").

The larger the mass and the larger the height, the more GPE the object gains. Have you ever noticed that falling a greater distance produces a greater "thud" and can hurt more? This is because of the amount of GPE. As an object falls, the object's

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

Figure 2 This kettlebell has GPE (gravitational potential energy) when raised above the ground.

Figure 3 Plastic slides are great at zapping us with static electricity, although it depends on the weather and the clothes we wear.

GPE can be transformed into other forms of energy. This happens when a person plays on a slide at the playground. The higher they climb, the more GPE they get. When they slide down, the GPE decreases. The person gains movement energy. They may also feel heat from the friction of the slide or even a zap of static electrical energy.

Chemical potential energy

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

Fuels such as natural gas and petrol provide us with energy too. A Bunsen burner uses the burning of natural gas to provide heat for laboratory experiments. Petrol has chemical energy stored in it, as do explosives and batteries.

These devices all contain **chemical potential energy** (CPE) that can be released when we need it. Some batteries can be recharged – the chemical potential energy can be replaced.

chemical potential energy energy stored in chemicals due to their chemical bonds, e.g. in food, fuel, also known as simply chemical energy

Figure 4 Energy drinks contain chemical potential energy.

Nuclear energy

Although nuclear energy is used throughout the world, it is not used in Australia. **Nuclear energy** involves the reaction in the nucleus or centre of atoms. When atoms react in chemical reactions, they usually release only small amounts of energy. If the centres or nuclei of those atoms can be made to react, however, the amount of energy released is much, much larger. In fact, the amount of energy released is so huge that it can cause massive amounts of destruction.

Figure 5 Nuclear explosions can cause catastrophic damage.

nuclear energy energy stored in the nucleus of an atom and released in nuclear reactors or explosions of nuclear weapons; much greater than the chemical energy released in chemical reactions

Check your learning 11.2

Check your learning 11.2

Retrieve

1 Define the term "potential energy".

2 Identify four examples of devices or situations that involve potential energy.

3 Recall the type of energy that is stored in a battery.

4 We get our energy from the chemicals in food. Identify the type of energy found in food.

Analyse

5 Biofuel is an alternative source of energy that comes from burning plants to release the energy stored in them. Identify the type of potential energy released in biofuel.

6 Identify four devices, other than those mentioned already, that can be given elastic potential energy.

7 Describe how a person might use a bow to shoot an arrow. Identify the type of potential energy used in this process.

8 Compare (the similarities and differences between) kinetic energy and potential energy.

Skills builder: Problem solving

9 Evaluate the following claim: "Nuclear energy is good for the environment."
  a Investigate the advantages and disadvantages of using nuclear energy by using secondary resources to fill in Table 1.
  b Using your PMI table, assess the above claim. (THINK: Do you think this claim is correct, somewhat correct or incorrect? What evidence do you have to support this?)

Table 1 PMI table

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

Lesson 11.3

Investigation: Increasing the amount of elastic potential energy

Purpose

To investigate how increasing amounts of elastic potential energy can be used to power a cardboard boat

Materials

- Waxed cardboard (fruit boxes work well)
- Scissors
- Rubber band
- Butterfly pins
- Water bath or swimming pool
- Measuring tape

Procedure

1 Cut out the waxed cardboard to match the diagram in Figure 1.

2 Put the rubber band around the propeller and attach it to the boat using butterfly pins.

3 Wind the propeller anticlockwise once (when viewed from the right side of the boat), place the boat in the water and release it.

4 Measure how far the boat travels.

5 Record your results in Table 1.

6 Repeat Steps 3 to 5 two more times.

7 Repeat Steps 3 to 6, increasing the number of propeller windings to two, three, four and five times.

Inquiry: What if more elastic potential energy was stored in the propeller?

1 Write a prediction or hypothesis for your inquiry.

2 Identify the (independent) variable that you will change from the first method.

3 Identify the (dependent) variable that you will measure and/or observe.

4 Identify two variables that you will need to control to ensure a fair test. Describe how you will control these variables.

5 Draw a table to record your results.

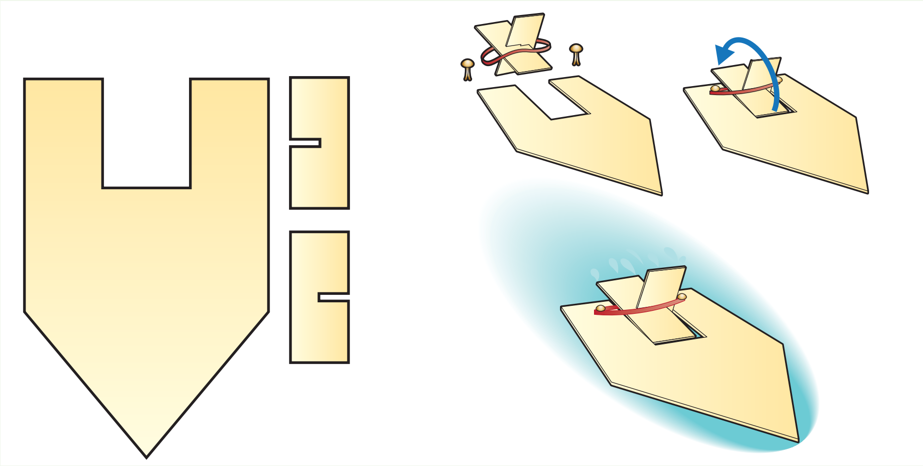


Figure 1 The parts and method of assembly for a rubber-band boat

Results

1 Copy and complete Table 1.

2 Draw a line graph showing the effect of increasing the elastic potential energy of the propeller on the distance the boat travelled.

Discussion

1 Identify the type of data as either qualitative or quantitative. Justify your answer (by defining each term and comparing it to your data).

2 Explain why you made three attempts at each propeller winding to determine the average distance travelled.

3 Identify the type of energy that the elastic potential energy was transformed into.

4 Your hands provided the energy to wind the propeller. Describe where this energy came from.

Conclusion

Describe the relationship between the potential energy given to the propeller and the distance the boat moved.

Table 1 Potential energy experiment

Number of rotations of the propeller	Distance the boat travelled Attempt 1	Distance the boat travelled Attempt 2	Distance the boat travelled Attempt 3	Average distance the boat travelled
1				
2				
3				
4				
5				

Lesson 11.4

Energy can be transferred

Key ideas

→ Energy is the ability to do work. It is how things change and move.

→ Energy cannot be created or destroyed.

→ When energy is passed from one object to another, it is said to be transferred.

Learning intentions and success criteria

Introduction

For hundreds of years, scientists (and some mystics) have been developing theories about energy. While scientists like Nikola Tesla (1856–1943) were able to control different forms of energy in the development of radios, electrical devices and X-ray photographs, mystics such as Tesla's friend Swami Vivekananda collaborated to examine the links between the mass of an object and its energy.

Energy cannot be created or destroyed. When energy is passed from one object to another, it is said to be **transferred**.

transferred when energy is passed from one object to another

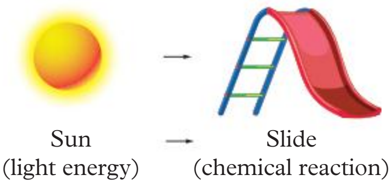


Figure 1 The heat energy from the Sun is transferred to playground equipment.

Sometimes energy will also change its form from one type to another when it is transferred. We looked at the different forms of energy in Lesson 11.1 There are different types of energy (page 466) and Lesson 11.2 Potential energy is stored energy (page 469). When energy is changed from one form of energy to another form, it is said to be **transformed**. This will be discussed in Lesson 11.11 Energy can be transformed (page 490).

transformed when energy is changed from one form to another form

Open and closed systems

system a group of components that work together

surrounding everything outside of a system

boundary either a real or an imaginary line that separates a system from its surroundings

open system a system that exchanges both energy and matter with its surroundings

closed system a system that exchanges only energy with its surroundings

A **system** is a group of components that work together. For example, a bottle of water can be considered a system, with everything outside of it acting as its **surroundings**. A real or imaginary line that separates a system from its surroundings is called the **boundary**. If a system exchanges both energy and matter with its surroundings, it is referred to as an **open system**. For example, when you open a bottle of water, it becomes an open system. Water can evaporate or spill out, exchanging matter with the surroundings, while energy can also transfer in or out of the bottle, which makes the water warmer or cooler.

On the other hand, if a system exchanges only energy with its surroundings, but not matter, it is called a **closed system**. For example, when you seal the bottle of water, it becomes a closed system. No matter can enter or leave, but energy can still be transferred in or out of the bottle.

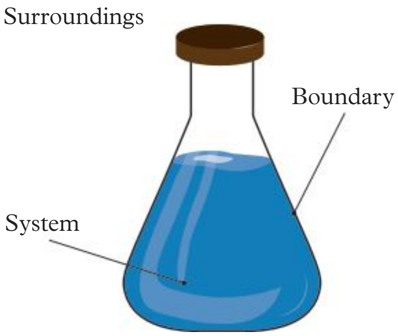


Figure 2 Everything inside the conical flask is the system, while everything outside of the flask is considered the surrounding. The boundary separates a system from its surroundings.

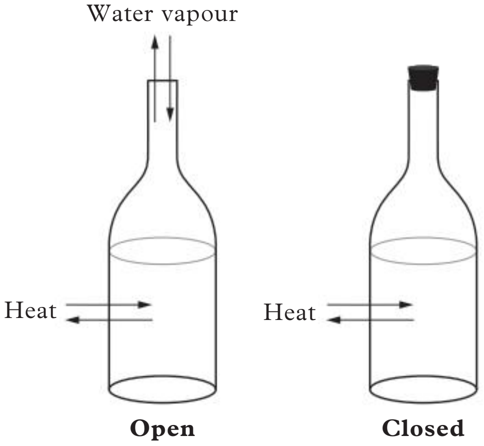


Figure 3 An open system can exchange both matter and energy with its surroundings. A closed system can only exchange energy with its surroundings.

The flow of energy

We have all felt the energy of the Sun on a hot day. It can warm anything left in the Sun including our skin.

Plants are very efficient at absorbing the energy of the Sun. The energy is transferred from the Sun to the plant. This can be shown using an energy flow diagram, where an arrow shows the direction of energy flow. The plant uses the energy to grow. Eventually, animals (including us) eat the plants and the energy is transferred to the animals (Figure 4). When animals die, the nutrients in their bodies return to the soil, helping new plants grow. This creates a cycle, allowing energy to flow continuously through the system.

We use the energy for moving, including walking (Figure 5). This also produces heat that then warms up the air around us (Figure 6).

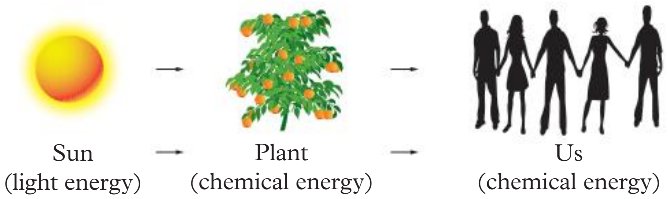


Figure 4 The flow of energy begins with the Sun. Plants absorb energy from the Sun, which then flows to the animals that eat the plants.

Figure 5 We need energy to walk and carry things.

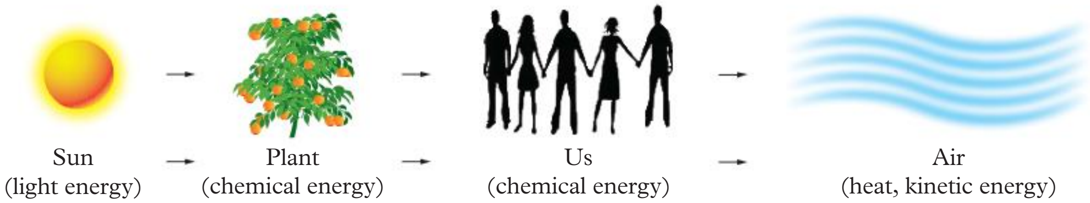


Figure 6 Heat energy generated by walking around can be transferred from us to the air.

Energy transfers for movement

Electric cars are designed to transfer the energy stored in batteries to power an electric motor that makes the wheels turn, rather than using petrol. This can be shown using a flow diagram (Figure 8).

Public transport transfers energy too. Trams and metropolitan trains transfer the energy from overhead wires into the motor that makes the wheels move (Figure 9).

Figure 7 Hybrid cars use both a petrol engine and an electric motor to send power to the wheels.

Trains that travel to country areas or interstate usually run on diesel fuel and don't need overhead electrical wires. The engines in these trains burn diesel fuel, transferring the energy into wheel movement via the motors (Figure 10). Ships and planes use a similar process in their engines.

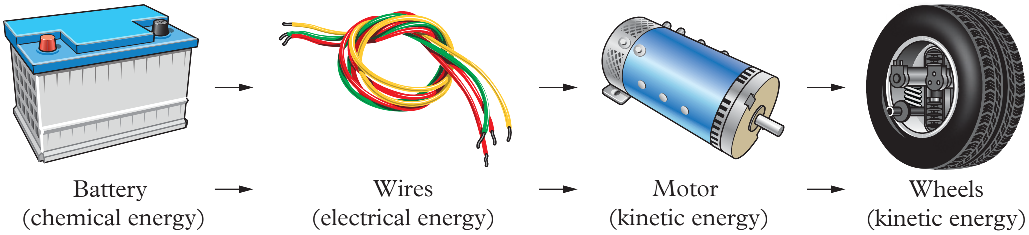


Figure 8 The energy stored in a battery is transferred to the wires, then to the motor and finally to the wheels of a car.

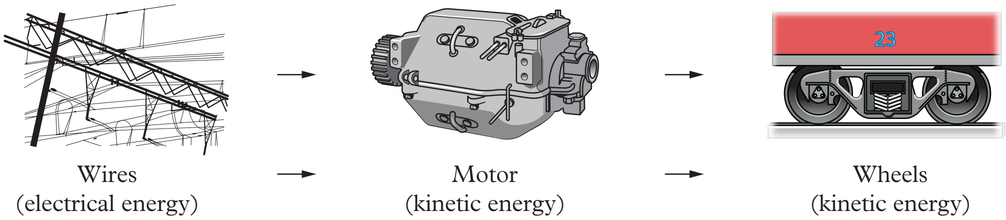


Figure 9 Energy in the wires transfers to the motor and then to the wheels of some trains.

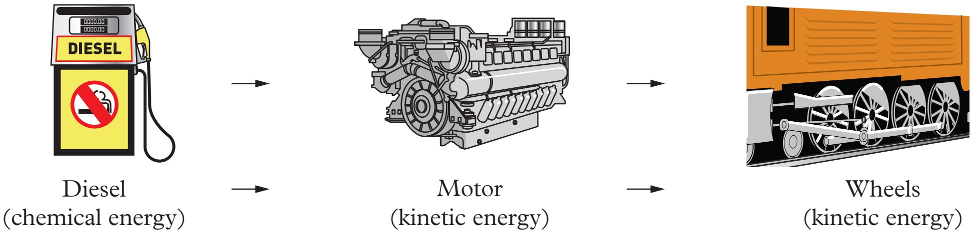


Figure 10 The energy of the diesel fuel is transferred to the motor and then to the wheels of some trains.

Figure 11 Powerlines provide electrical energy for public transport.

Figure 12 Aircraft use higher-quality fuels than road transport vehicles to minimise weight and waste.

Figure 13 Powerlines are not practical in rural areas, so diesel fuel is used.

Energy transfers for entertainment

A mobile phone uses a speaker to produce the sound of a person's voice or the various ring tones and beeps that the phone makes (Figure 15). Home phones use a speaker too, as do sound systems, headphones, radios and many other devices. They all transfer energy from a battery to the wires inside the speaker, then the energy is transferred to the speaker to make sound.

A television **remote control** transfers energy from the device as light energy through the air and into the television set. In fact, most remote controls use infrared light, which is the invisible type of light usually associated with heat. (Figure 16) The remote control sends a pulse of infrared light that represents a particular command, such as changing the channel or increasing the volume. An infrared light detector on the television receives the light signal and transfers it back into electrical energy, which then carries out the command (Figure 17).

Figure 14 Headphones transfer energy in batteries to the wires and the speakers. The speakers transfer the energy to the air so we can hear the sound.

Figure 15 The internal components of a mobile device

remote control an electronic device used to operate a machine remotely (i.e. at a distance)

Figure 16 A television remote control uses an infrared light-emitting diode (LED) to operate the television.

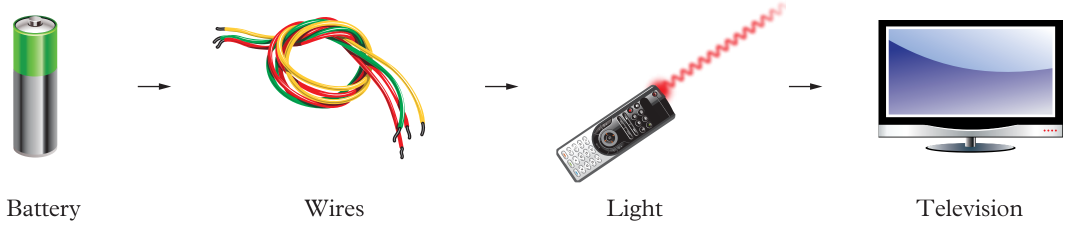


Figure 17 Television remote controls transfer small amounts of energy to the television to carry out commands.

Check your learning 11.4

Check your learning 11.4

Retrieve

Describe the term "transfer of energy".

Comprehend

2 Describe why the direction the arrows point in a flow diagram is important.
3 Explain why country trains mostly use diesel instead of electrical wires.

Analyse

4 Identify the type of devices that the following energy flow diagrams could represent.
  a Wires → motor → air
  b Battery → wires → light globe
  c Food → muscles → bicycle
5 Recreate Figure 18 and draw arrows to indicate the direction the energy flows between each object in an energy flow diagram.

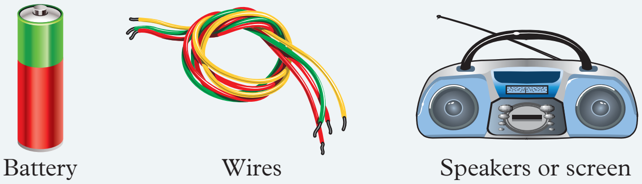


Figure 18 Flow diagram

Apply

6 Determine the ultimate source of all energy.
7 Summarise the entertainment devices mentioned in this lesson and create flow diagrams showing the direction the energy is transferred between the different objects.

Lesson 11.5

Skills lab: Draw flow diagrams of energy transfer

Aim

To identify the transfer of energy between objects

Materials

- Station 1: a variety of wind-up toys
- Station 2: battery, wires, small buzzer
- Station 3: tuning fork
- Station 4: plastic cup, water, salt, aluminium strip, copper strip, two wires, multimeter
- Station 5: plastic windmill, kettle
- Station 6: toy car, ramp, measuring tape

Method

Spread around the room are stations with different types of energy. Copy Table 1 into your notebook. Follow the steps below for each station, and identify the object where you first see evidence of the energy (source) and the object where you last see the energy (output).

Station 1

Wind up the toys and watch them move. Identify the source and output energy.

Figure 1 Station 1 What path does the energy take as it is transferred through the wind-up toys?

Station 2

Connect the battery to a buzzer. Identify the source and output energy.

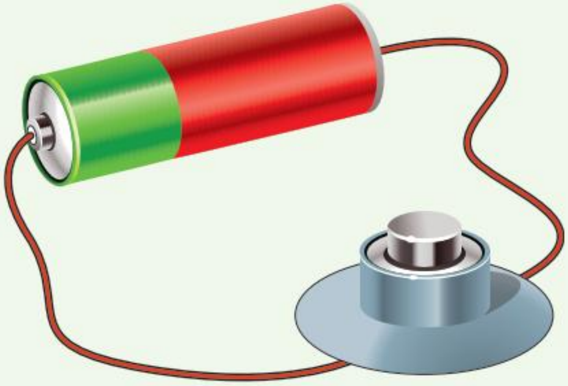


Figure 2 Station 2 Use wires to connect the buzzer to the battery.

Station 3

1 Gently tap the forked end of the tuning fork on a table.
2 All sound is generated by vibrations. Identify the source and output energy.

Figure 3 Station 3 Where does the sound energy come from or transfer from?

Station 4

1 Fill most of the cup with water.
2 Add 1 tablespoon of salt to the water.
3 Fold a strip of aluminium and a strip of copper over opposite sides of the cup so that one end is in the salt water and the other end is on the outside of the cup.
4 Attach wires to the outside edges of the metal strips.
5 Connect the multimeter to the wires and adjust the multimeter so the voltage is measured.
6 Record the voltage generated by your chemical battery. Identify the source and output energy.

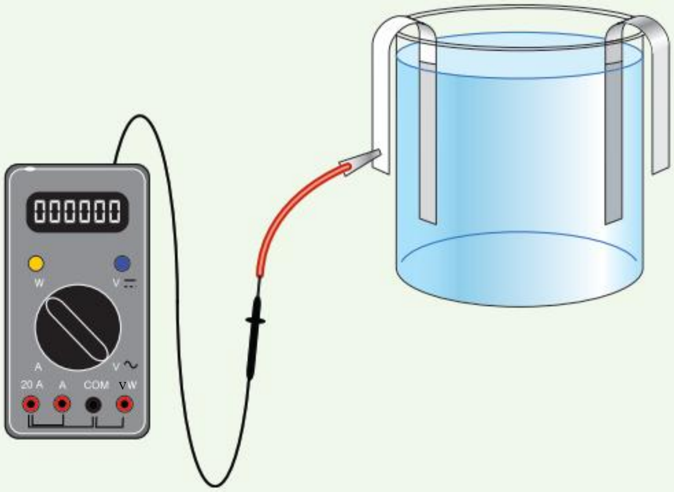


Figure 4 Station 4 Connect the salt water battery to a multimeter.

Station 5

1 Blow on the plastic windmill. Identify the source and output energy.
2 Hold the plastic windmill over a boiling kettle while being careful not to burn

yourself with the steam. Hold your hand as far away as possible from the steam. Ensure there is plenty of water in the kettle so it doesn't boil dry. Identify the source and output energy.

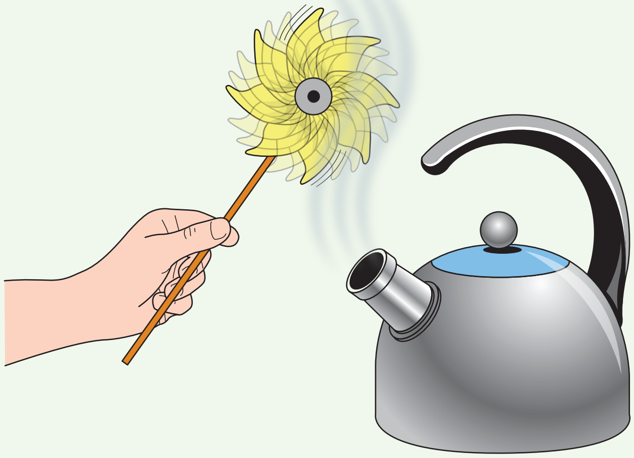


Figure 5 Station 5 A toy windmill acts like an electricity-generating turbine.

Station 6

1 Set up the ramp so that the top end is 10 cm above the ground.
2 Place the car at the top of the ramp.
3 Allow the car to roll down the ramp and along the floor.
4 Measure how far the car rolled. Identify the source and output energy.
5 Describe how you could increase this output energy.

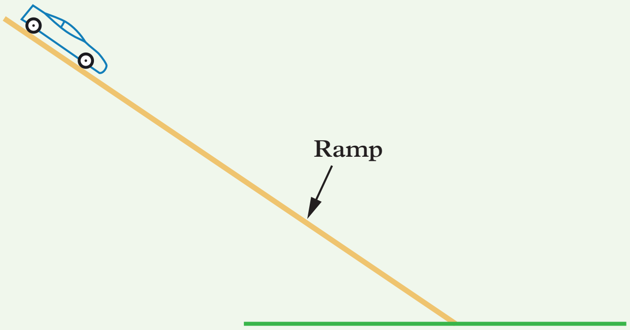


Figure 6 Station 6 What path does the energy take as the car moves down the ramp?

Results

Table 1 Energy transfer

Station	Where does the energy come from?	Which object or part of the object has the energy last?
1		
2		
3		
4		
5		
6		

Questions

1 Describe what is meant by "energy transfer".
2 Identify which stations had energy transfer from one object to another.
3 Draw an energy flow diagram for each station.
4 Describe the original energy source for all of the stations and all objects on Earth.

Lesson 11.6

Heat energy is transferred through conduction and convection

Key ideas

→ Heat is transferred in solids by conduction.

→ Heat is transferred in liquids and gases by convection.

→ Heat transfer by conduction and convection requires particles.

Learning intentions and success criteria

Introduction

Heat (also called **thermal energy**) is a form of energy. Thermal energy moves spontaneously from a hotter substance to a cooler substance. This energy transfer is called heating, even though one substance is being cooled.

Heating by conduction

Heat transfer by **conduction** is the transfer of thermal energy from matter that is warmer to matter that is cooler (Figure 1). This happens spontaneously when two solid objects make direct contact with each other. Eventually, the two objects reach **thermal equilibrium**, meaning that they no longer exchange heat energy because they have the same temperature. Consider what happens when we heat a saucepan of water on a gas burner.

1 When the gas burns, thermal energy is released.

2 The hot particles in the gas flame move quickly and occasionally bump into the atoms of the relatively cold metal of the saucepan.

3 Energy passes to the slowly vibrating atoms in the saucepan so that they vibrate faster.

4 The quickly vibrating atoms in the saucepan bump into other nearby metal atoms, transferring energy to them. This heats the saucepan.

5 When the saucepan heats up, energy is transferred to the water inside it. Although the energy moves through the metal of the saucepan and into the water, the atoms in the metal do not change their positions – metal atoms do not move into the water.

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

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

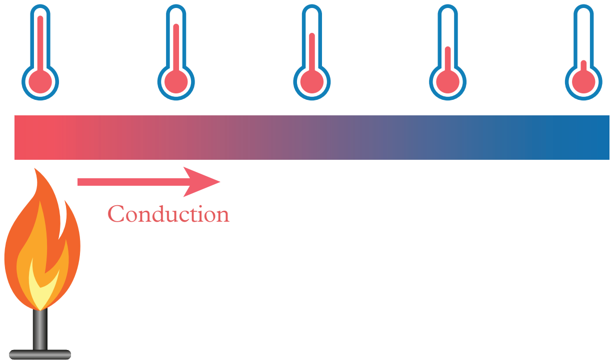


Figure 1 Thermal conduction in a metal rod

Conductors and insulators

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

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

A thermal **conductor** is any material that allows thermal energy to flow through it easily. All metals are conductors, although some are better conductors than others. Thermal **insulators** are materials that slow down the transfer of thermal energy. Insulators such as socks, jumpers and blankets keep us warm in cold weather. They make it difficult for our "body heat" to escape, insulating us against the cold. Insulation in the roof and walls of a house prevents heat gain and heat loss during summer and winter. The insulation can hold heat in or keep it out (Figure 2).

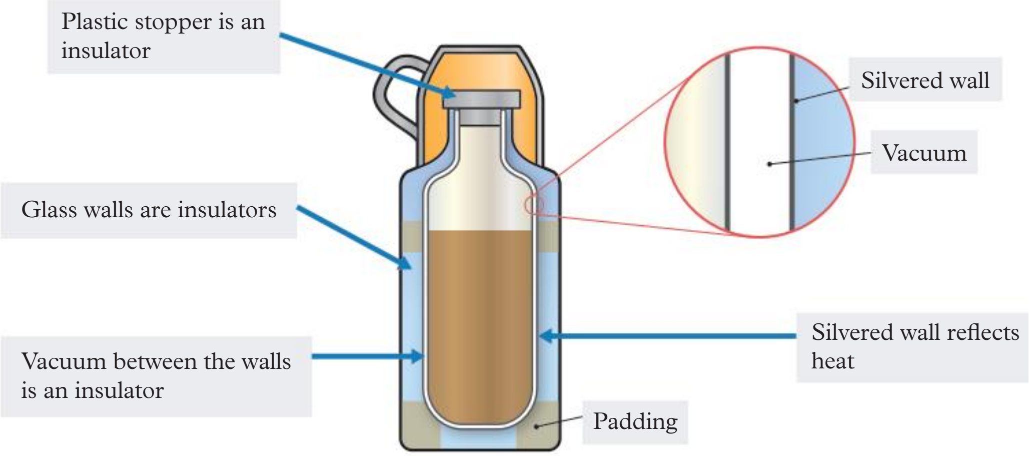


Figure 2 Vacuum flasks use insulation to keep hot substances hot and cold substances cold. The plastic stopper and the vacuum between the walls prevent heat loss or gain through convection and conduction. The glass wall prevents heat loss or gain through conduction and the silvered wall prevents heat loss by radiation.

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

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

Heating by convection

In liquids and gases, thermal energy is transferred by **convection**. Tiny movements within the liquid or gas, called **convection currents**, carry the thermal energy. When water is heated in a saucepan, the following occurs (Figure 3).

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

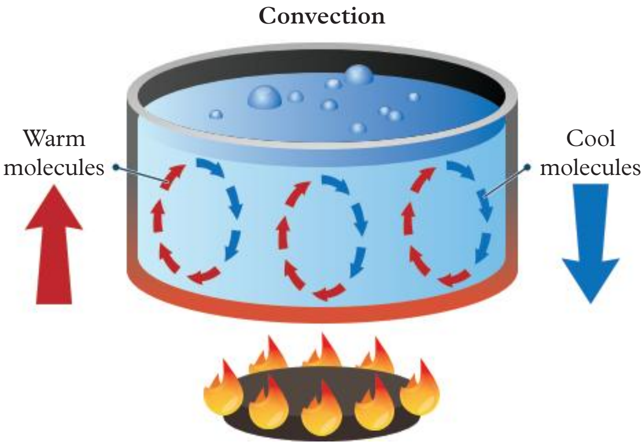


Figure 3 Convection currents are created in a saucepan of water when it is heated. The heated water molecules (shown in red) rise while the cooler ones (shown in blue) sink.

Convection also happens in the air and is responsible for our weather. For example, the Sun heats the ground and the warmed ground then heats the air next to it by conduction. The warmed air, being less dense than the cooler air above, rises, taking the thermal energy with it. This distributes the energy through a much deeper layer of air than could occur just by conduction from the ground. This process of convection in the air is what drives the weather on Earth.

Check your learning 11.6

Check your learning 11.6

Retrieve

1 Identify two examples of situations where thermal energy is transferred by:
   - **a** conduction
   - **b** convection.

2 Identify two examples where good thermal insulators and conductors are needed in everyday life.

Analyse

3 Modern saucepans have a copper bottom, steel sides, a plastic handle and a glass lid. Explain why each of these materials is used for a particular part of the saucepan.

4 Explain why heat energy cannot be transferred in solids by convection.

5 Construct a labelled diagram to explain how heat energy is transferred in water.

Apply

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

Skills builder: Processing and analysing data

7 A student measured the temperature of a saucepan of water as it heated over six minutes. Their results are shown in Table 1.
   - **a** Identify an appropriate type of graph to plot this data. (THINK: Is the data qualitative or quantitative? Is it continuous or discrete?)
   - **b** Construct your graph, including all labels and a title. (THINK: What are the variables in this investigation?)

Table 1 Results from heating a saucepan for six minutes

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

Lesson 11.7
Investigation: Heating by conduction

Purpose

To investigate which metal is the best conductor of heat

Materials

- Three long, thin strips of different metals (e.g. copper, aluminium, iron, brass) each with the same length and width
- Bunsen burner
- Tripod
- Vaseline
- Three 5-cents coins
- Stopwatch

Procedure

1. Attach a coin to the end of each metal strip using a small amount of Vaseline.
2. Position the metal strips on a tripod stand, as shown in Figure 1.
3. Heat the opposite end of the metal strips in the blue (hottest) part of a Bunsen flame.
4. Record the time it takes for the coins to fall off the metals.

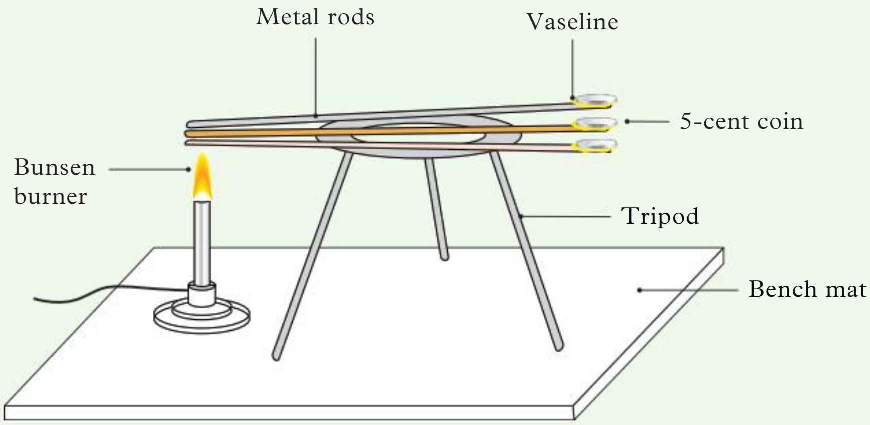


Figure 1 Investigation set-up

Results

Record your results by copying and completing Table 1.

Table 1 Heat conductivity of metals

Metal	Time taken for the coin to fall off (seconds)

Discussion

1. List the metals in order from the least to the most conductive.
2. Explain why metal strips of the same length and width are necessary.

Lesson 11.8

Investigation: Heating by convection

Caution

- Always wear safety glasses, a lab coat and closed-toe shoes, and tie long hair back when using a Bunsen burner.
- Allow all hot equipment to cool before handling.

Purpose

To investigate heating water by convection

Materials

- Water
- Food colouring
- Bunsen burner
- Tripod
- Heatproof mat
- Pyrex 600 mL beaker
- Dropper or pipette

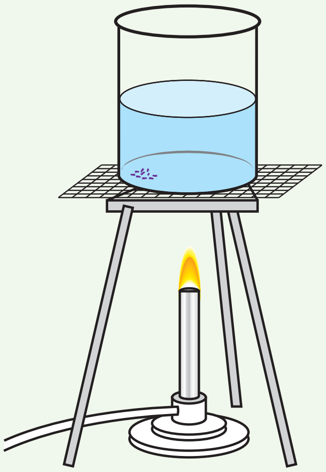


Figure 1 Investigation set-up

Procedure

1. Set up the equipment as shown in Figure 1.
2. Fill the beaker with water. Add a drop of food colouring to the bottom of the full beaker using a dropper or pipette.
3. Heat the water gently over the Bunsen burner and observe the movement of the food colouring. (If possible, use a small flame and no heatproof mat between the Bunsen burner and the beaker – you can do this with Pyrex beakers.)
4. Note the path that the food dye takes from the burner to the top of the water and back down again.

Results

Draw a labelled diagram showing the movement of the coloured water.

Discussion

1. Describe the movement of the coloured water.
2. Why do you think the coloured water moved like this?
3. What was happening to the particles in the water when the water was being heated?

Conclusion

What do you know about heating water by convection?

Lesson 11.9

Radiation also transfers thermal energy

Learning intentions and success criteria

Key ideas

- → There are three methods for heat transfer: conduction, convection and radiation.
- → Radiation is the transfer of heat without the need for matter.

Radiation transfers thermal energy

When you go outside on a sunny day, you experience a particular kind of heating process. Energy from the hot Sun (which has a temperature of about 6,000°C) is transferred to you at a temperature of 37°C. This kind of heating process is different to conduction and convection. Both conduction and convection need the presence of a substance to transfer the energy, and in the process, the substance heats up. But the energy from the Sun travels across many millions of kilometres of space in which there is no substance (because space is empty – it is a vacuum) to reach Earth. It then passes through Earth's atmosphere, hardly heating the air on the way through the atmosphere.

radiation the transfer of thermal energy across empty space or through another substance without the need for particles

Radiation is the transfer of energy across empty space or through another substance, without heating it. Radiation is not necessarily absorbed when it meets a substance – it may be reflected or transmitted. For example, radiation from the Sun is transmitted through the atmosphere, absorbed by the ground and reflected from the tops of clouds (Figure 1).

Objects that have a temperature greater than absolute zero (–273°C) will radiate energy in one or more forms. As the object gets hotter, it will emit visible light and other radiation (e.g. microwaves) depending on the temperature. An electric radiator mainly

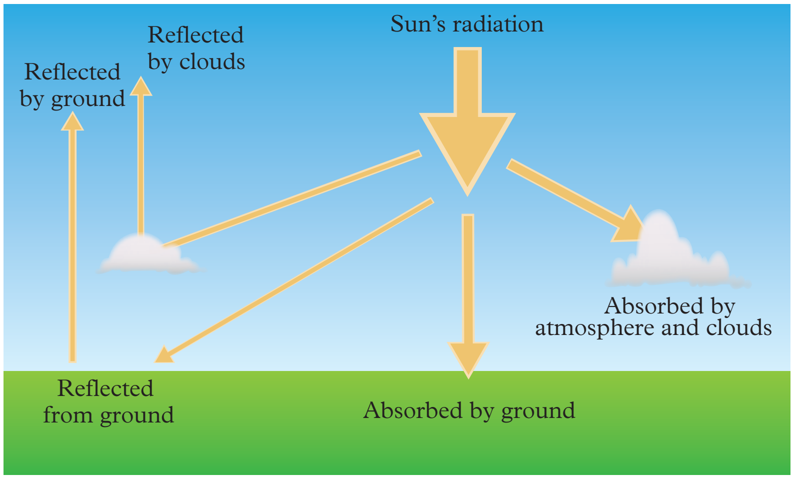


Figure 1 Radiation from the Sun does several things, depending on the weather conditions.

Figure 2 In a household radiator, energy from the movement of particles becomes infrared radiation.

radiates energy in the form of infrared radiation (Figure 2). An incandescent globe radiates some visible light as well as infrared radiation. The gases that are found between the galaxies of our Universe radiate microwaves or radio waves. Radiation can be produced in ways other than by heating an object. For example, radiating radio waves can be produced by a transmitter rather than by heat, and radiating light can be produced in a fluorescent tube (which has little heat energy).

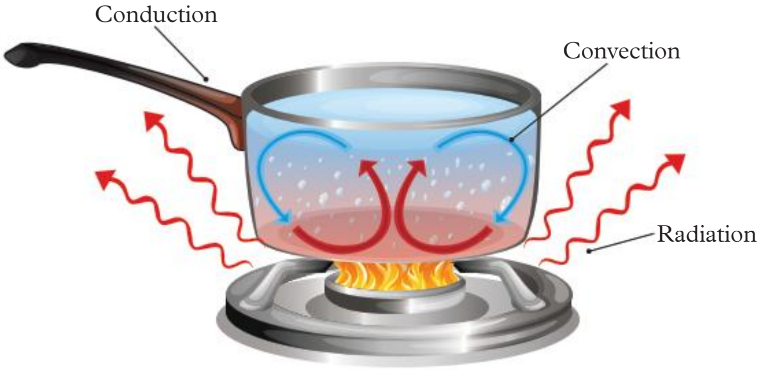


Figure 3 Different methods of heat transfer

Deadly radiation heat

Being outdoors during a bushfire means we can be exposed to large amounts of radiant heat, even if the air around us is cold. The closer we are to the source of the fire, the more radiant heat we are exposed to and the hotter we feel. This heat travels in straight lines out from the bushfire. It can heat up objects so much that they spontaneously burst into flames before the fire has even reached their location (Figure 4). Radiant heat can kill very quickly. Our body cannot absorb large amounts of radiation for very long, and the body's cooling regulation system cannot cope with the large amounts of heat that are generated. The best protection is to put a barrier between our bodies and the source of the radiant heat. Concrete walls and buildings can absorb the radiant heat from a bushfire with little damage – unlike windows, which will shatter, or rubber, which will melt. If you are near a large fire, cover all of your skin and wear sturdy boots, gloves and a hat. Cover your face with a mask or towel and protect your eyes with goggles.

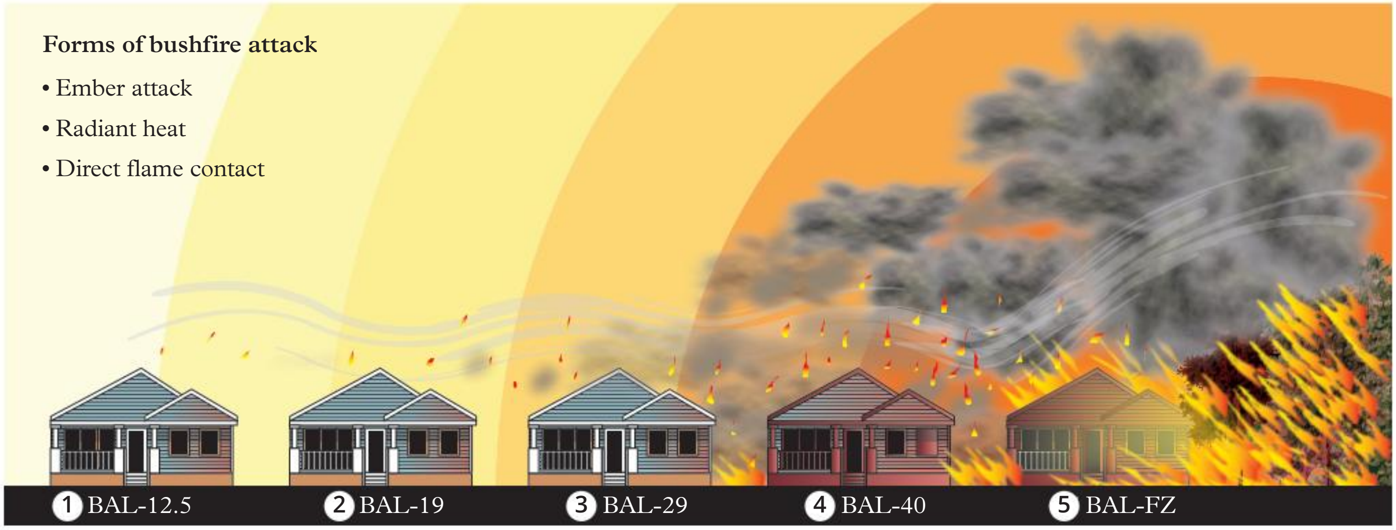


Figure 4 Bushfires radiate intense heat. The following "Bushfire Attack Levels" (BAL) are labelled:

- ❶ BAL-12.5 Ember attack: radiant heat below 12.5 kW/m^2
- ❷ BAL-19 Increased ember attack and windborne debris: radiant heat between 12.5 kW/m^2 and 19 kW/m^2
- ❸ BAL-29 Increased ember attack and windborne debris: radiant heat between 19 kW/m^2 and 29 kW/m^2
- ❹ BAL-40 Increased ember attack and windborne debris: radiant heat between 29 kW/m^2 and 40 kW/m^2. Exposure to flames likely.
- ❺ BAL-FZ Direct exposure to flames, radiant heat and embers from the fire.

Check your learning 11.9

Check your learning 11.9

Retrieve

1 Describe what radiation is.

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

3 Describe three possible pathways for radiation from the Sun.

Analyse

4 Distinguish radiation from convection and conduction.

5 Identify how heat energy is transferred in the following scenarios.

  a A saucepan gets hot when it is on a gas burner.

  b The water in the saucepan gets warm when the saucepan is on a gas burner.

  c You feel the heat when you sit next to an electrical heater.

  d The temperature goes higher when you turn on the air conditioner in winter.

Skills builder: Communicating

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

  a Identify what text type you will use to communicate your message. Justify why you have chosen this format. (THINK: Who is this message for? What text type would they most likely be interested in?)

  b Construct one or two sentences that you could use to get your message across quickly. (THINK: How would you explain it to people who haven't been in class to learn about radiant heat? Keep it simple, but make sure it is scientifically correct.)

Lesson 11.10

Challenge: Protection from heat radiation

Design brief

Test a variety of materials to inform the design of protective equipment that will protect firefighters against the radiant heat of bushfires.

Criteria

Any material must be easily available and be able to be sewn or glued into the required shape. The commercial cost of the material must be within the limit set by your teacher.

Questioning and predicting

Select a range of materials that could be used to design your protective equipment. When selecting your materials consider the following questions which relate to how each material responds to heat and whether each material is feasible for constructing your equipment.

- What are the properties of the material and how might these properties influence its ability to reflect radiant heat?

- What is the cost of the material and how much of this material will you need to construct your garment?
- What colour should your garment be? (Would you need to change the colour of the material and would this make a difference?)
- What added features (such as pockets) will you need? (Is the material suitable for your added features?)
- What other properties in addition to reflecting radiant heat should the material have? (Think about how the equipment is being used.)

Planning and conducting

Once your materials have been selected you will need to design a method of testing each material to measure their ability to reflect radiant heat. When designing your test consider the following questions.

- What equipment is needed? (Is this equipment readily available to use in your science classroom?)
- How will you measure the radiant heat that passes through the material?
- How long will you expose the material to the heat source?
- How will you ensure each material is tested under the same conditions?

Figure 1 shows an example of a general set-up for testing different materials.

Conduct your test and record the results in an appropriate table.

Processing and analysing

1 Use your results to create a graph that shows the rate of temperature increase for all the tested materials.
2 Which material was the most successful at reflecting the radiated heat?
3 What were the limitations of this material? Availability? Cost? Useability?
4 Would it be possible to create a large-scale version of your design for a firefighter? What would be the cost of your design?
5 If you were doing this challenge again, how would you modify your design? Explain.

Communicating

Present the various stages of your investigation in a formal experimental report.

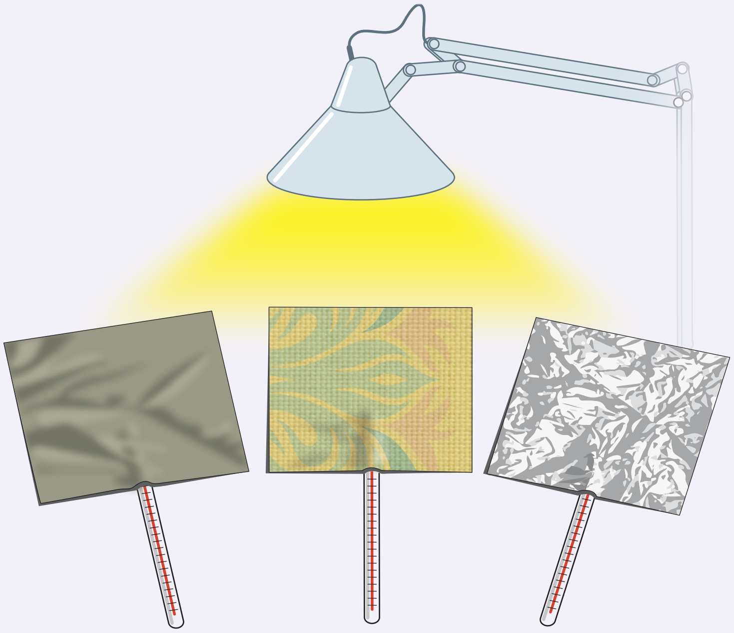


Figure 1 Challenge set-up – place the bulbs of thermometers under the different materials and then place them in the sun (or at 6 cm from a lamp).

Figure 2 Firefighters require specialist equipment to protect them against the radiant heat of bushfires.

Lesson 11.11

Energy can be transformed

Learning intentions and success criteria

Key ideas

→ Energy that changes from one form to another is transformed.

→ Flow diagrams use arrows to show the direction that energy moves.

→ Electricity can be generated when turbines are turned by water, wind or coal-generated steam.

Introduction

Energy cannot be created or destroyed. When energy is passed from one object to another, it is said to be transferred. When energy is changed from one type of energy to another, we say it has been **transformed**.

transformed when energy is changed from one form to another form

Figure 1 In light bulbs, electrical energy is transformed into both light energy and thermal energy.

Energy transformation

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

Energy transformation refers to the way energy changes from one form to another. For example, when the energy in a battery is transferred to the wires in a circuit, the energy is transformed from chemical potential energy into electrical energy (Figure 2). Water at the top of a waterfall has gravitational potential energy. This is transformed into kinetic energy as the water moves down to the bottom of the waterfall. The chemical energy in diesel or petrol can be transformed into kinetic energy when it is used in a car. The electrical energy that powers a microwave can transform into heat (thermal energy) to warm our food. These are all energy transformations because one type of energy is transformed into a different form.

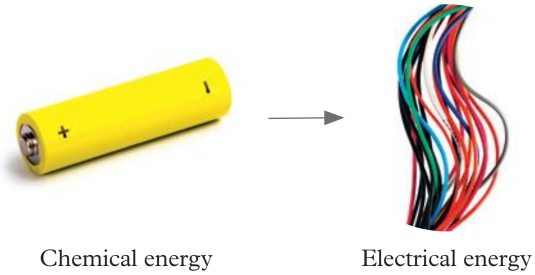


Figure 2 A flow diagram showing how a battery transforms chemical energy into electrical energy.

Flow diagrams

How do we represent an energy transformation scientifically? Flow diagrams that use an arrow to represent the transformation process help with this idea.

1 The arrow points in the direction of the transformation.
2 The starting energy input is written at the back of the arrow.
3 The useful energy output is written in front of the arrow.

Sometimes there is more than one energy output, so we try to concentrate on the main one. The extra energy outputs are known as **by-products**. Think of how you would write the energy transformation in a light bulb. What is the energy input? What is the main energy output? Is there a by-product (wasted energy)?

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

Not all energy transformations are simple. Sometimes there are several energy transformations in a row to get the final energy output. This is called an **energy chain**. For example, the energy chain in a mobile device would be described in the following way. "The chemical energy stored in the battery is transformed into electrical energy. The electrical energy flows through the wires to the headphones, where it is transformed into kinetic energy as the tiny speakers in the headphones vibrate. This is then transformed into sound energy, which our ears pick up."

Figure 3 shows this energy story as a flow diagram.

Chemical energy → Electrical energy → Kinetic energy → Sound energy

Figure 3 Chemical energy in the mobile device battery is transformed into the sound energy that we hear.

Energy cannot be created or destroyed

One of the special characteristics of energy is that it cannot be created or destroyed. All energy must be stored, transferred or transformed. We can see this when we get on a rollercoaster. The first thing that happens is electrical energy is transformed into kinetic energy in the carts as they are moved to the top of the first rise. The carts usually stop temporarily at the top of the first rise. The kinetic energy has been transformed into gravitational potential energy. As the carts start down the first slope, the gravitational potential energy is transformed into kinetic energy again. This process of transforming energy between kinetic energy and gravitational energy continues throughout the whole ride (Figure 4).

Not all energy transformations are 100% efficient. Some of the energy is always transformed into heat energy. The best rollercoasters minimise the friction between the rails and the wheels. This means more energy can be transferred between kinetic energy and gravitational potential energy (and not lost to friction heat energy) and the speed and heights of the carts can be maintained.

Figure 4 Rollercoasters constantly transform kinetic energy into gravitational potential energy and back again.

Generating electricity

There are many ways to generate electricity. Turbines are regularly used to generate electricity, and different technologies use different methods to turn the turbine.

Wind generators use the wind to turn turbines. The kinetic energy of the wind is transferred to the turbines. The turbines then transform this energy into electrical energy (Figure 5).

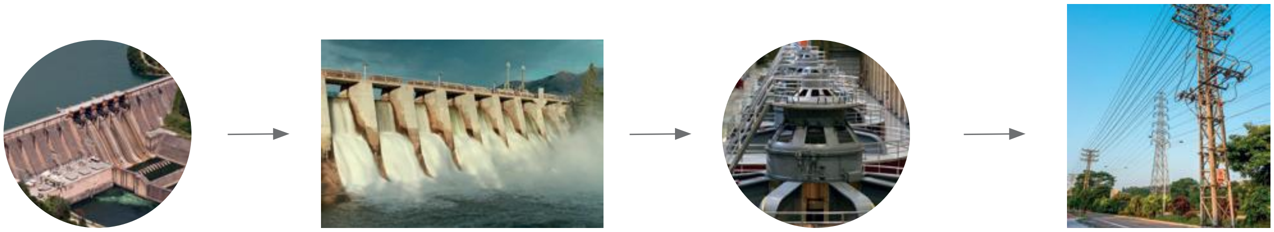
Hydroelectric plants have large dams that store water. The large amount of water is usually located part-way up a hill, therefore, the water has gravitational potential energy. Pipes control the flow of water down through the turbine, transforming the gravitational potential energy into the kinetic energy of the turbines (Figure 6).

Coal-based electricity generators burn coal to heat water. The resulting steam rises, forcing the turbines to turn and transform the kinetic energy into electrical energy (Figure 7).

We use the electrical energy that comes from these energy-generating plants for many different things: charging your mobile phone, cooking dinner and switching on a light. Energy may take many shapes or forms before you can use it.

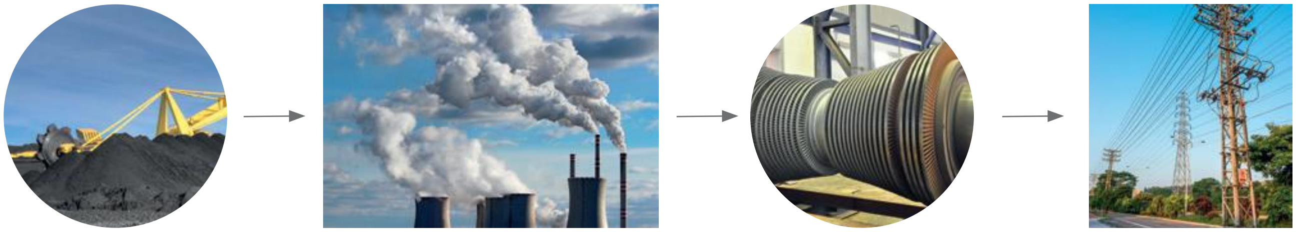
Kinetic energy of air → Kinetic energy of wind generator → Kinetic energy of turbines → Electrical energy of wires

Figure 5 Turbines transform kinetic energy into electrical energy



Gravitational potential energy of water → Kinetic energy of water → Kinetic energy of turbines → Electrical energy of wires

Figure 6 The transformation of gravitational potential energy



Chemical potential energy of coal → Kinetic energy of steam → Kinetic energy of turbines → Electrical energy of wires

Figure 7 The transformation of chemical potential energy

Check your learning 11.11

Check your learning 11.11

Retrieve

1 Identify one way that energy can be transferred without being transformed.

2 Identify where the energy stored in coal comes from.

Analyse

3 Contrast (the differences between) energy transformation and energy transfers.

Apply

4 Create a flow diagram for the main energy transformations in a moving car.

5 Create an energy chain that shows how we get our energy from eating an apple. (HINT:Start with the Sun!)

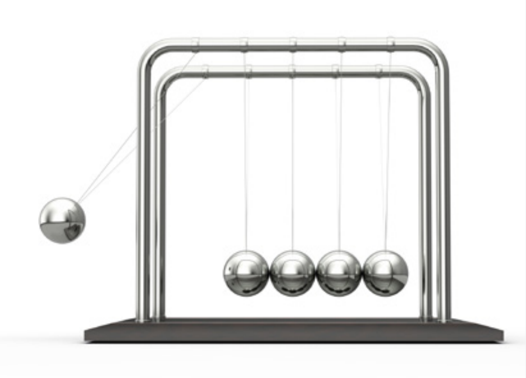


Figure 8 A Newton's cradle

6 A "Newton's cradle" has a series of metal balls suspended on strings (Figure 8). When the ball on one end is pulled back and released, the energy is transferred along the chain to the other end, causing that ball to swing up into the air. Create a flow diagram to show the energy transformation that occurs in a Newton's cradle.

Skills builder: Conducting investigations

7 A student was asked to investigate how the chemical energy in a battery pack transforms to power a lightbulb. When they connected the light bulb to the power source, they observed the bright light energy that was released. The student then decided to feel the light bulb to observe if it had released any heat energy.

  a Identify the safety risks in the student's method. (THINK: Could any of the equipment or how it is handled be dangerous?)

  b Suggest how the student might avoid the identified hazards.

Lesson 11.12

Investigation: Making a simple torch circuit

Purpose

To use a simple circuit to transform electrical energy into light energy

Materials

- Pieces of insulated electrical wire with the ends stripped bare
- 1.5 V battery
- 1.2 V torch globe
- Hand lens

Procedure

1. Try different arrangements of the wires, battery and torch globe to make the globe light up. Draw each arrangement that you tried.
2. Use the hand lens to look carefully at the filament in the globe. The filament is the tiny wire inside the glass of the globe – the part that glows brightly when the globe lights up. Draw what you see.
3. Use the hand lens to look at how a globe holder (the base of a globe) is constructed.

Discussion

1. Select one of the arrangements that did not allow the globe to light up. Explain why this arrangement did not allow electricity to pass through the circuit.
2. Describe how the filament in the light globe can transform electricity into light and heat.
3. Describe how the globe holder connects the light globe to the circuit.
4. Some battery manufacturers claim that their brand of battery lasts longer than other batteries. Design an experiment that you could use to test this claim.

Figure 1 How does a torch work?

Lesson 11.13

Investigation: Rube Goldberg machines and chain reactions

Introduction

Rube Goldberg was an American cartoonist in the early 1900s who drew humorous complex machines that used a series of energy transfers and transformations to perform simple tasks (Figure 1).

Purpose

To create a Rube Goldberg machine

Procedure

1. Work in groups of three to four.
2. Decide on a simple machine to create.
3. Brainstorm to plan the steps (method) and materials needed to create your machine. Ensure your method includes numbered steps.
4. Draw a labelled diagram of your machine.
5. Collect all the materials you need for the machine.
6. Follow your method to build the machine.
7. Test each step to make sure it works before moving on to the next step.
8. When the machine is built, test it from start to finish.
9. Make any adjustments required.
10. Test the machine again.
11. Present your machine to the class

Results

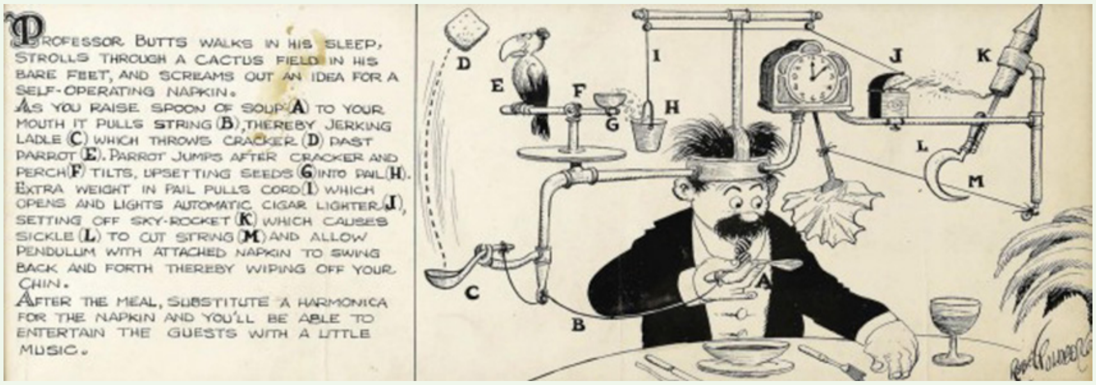
Copy and complete Table 1 for your design.

Table 1 Evaluation of the Rube Goldberg machine

What worked well	Challenges faced

Discussion

1. Describe Rube Goldberg machines.
2. Explain how a Rube Goldberg machine works, using the following terms: the law of conservation of energy, transfer and transformation of energy.
3. Identify each energy transfer and transformation that occurs in your machine.
4. Suggest ways that you can improve your design.



PROFESSOR BUTTS WALKS IN HIS SLEEP, STROLLS THROUGH A CACTUS FIELD IN HIS BARE FEET, AND SCREAMS OUT AN IDEA FOR A SELF-OPERATING NAPKIN.

AS YOU RAISE SPOON OF SOUP (A) TO YOUR MOUTH IT PULLS STRING (B), THEREBY JERKING LADLE (C) WHICH THROWS CRACKER (D) PAST PARROT (E). PARROT JUMPS AFTER CRACKER AND PERCH (F) TILTS, UPSETTING SEEDS (G) INTO PAIL (H). EXTRA WEIGHT IN PAIL PULLS CORD (I) WHICH OPENS AND LIGHTS AUTOMATIC CIGAR LIGHTER (J), SETTING OFF SKY-ROCKET (K) WHICH CAUSES SICKLE (L) TO CUT STRING (M) AND ALLOW PENDULUM WITH ATTACHED NAPKIN TO SWING BACK AND FORTH THEREBY WIPING OFF YOUR CHIN.

AFTER THE MEAL, SUBSTITUTE A HARMONICA FOR THE NAPKIN AND YOU'LL BE ABLE TO ENTERTAIN THE GUESTS WITH A LITTLE MUSIC.

Figure 1 A Rube Goldberg cartoon

Lesson 11.14

Review: Energy transfers

Summary

Lesson 11.1 There are different types of energy

- Kinetic energy is the energy found in a moving object.
- When objects move at the same speed, heavier objects have more kinetic energy than lighter objects.
- The faster an object moves, the more kinetic energy it has.

Lesson 11.2 Potential energy is stored energy

- An object that has the potential (future ability) to do work has potential energy.
- Elastic potential energy is stored when an elastic object is deformed.
- Gravitational potential energy is stored when an object is lifted away from the Earth's surface.
- Chemical potential energy is the energy stored when atoms are bonded to each other.
- Nuclear potential energy is the energy stored inside the centre of an atom.

Lesson 11.4 Energy can be transferred

- Energy is the ability to do work. It is how things change and move.
- Energy cannot be created or destroyed.
- When energy is passed from one object to another, it is said to be transferred.

Lesson 11.6 Heat energy is transferred through conduction and convection

- Heat is transferred in solids by conduction.
- Heat is transferred in liquids and gases by convection.
- Heat transfer by conduction and convection requires particles.

Lesson 11.9 Radiation also transfers thermal energy

- There are three methods for heat transfer: conduction, convection and radiation.
- Radiation is the transfer of heat without the need for matter.

Lesson 11.11 Energy can be transformed

- Energy that changes from one form to another is transformed.
- Flow diagrams use arrows to show the direction that energy moves.
- Electricity can be generated when turbines are turned by water, wind or coal-generated steam.

Review questions 11.14

Review questions Module 11

Retrieve

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

2 Identify which of the following is true about energy.
  A Energy cannot be created or destroyed.
  B Energy is destroyed once it has been used.
  C Energy is created constantly.
  D Energy is precious because it is difficult to find.

3 Identify which of the following correctly describes the energy transformations in a simple electrical circuit containing a battery and a light bulb.
  A Battery → wires → light
  B Battery → light → wire
  C Electrical energy → light energy
  D Chemical energy → electrical energy → light energy

4 Identify which of the following is true or false. Rewrite any false statements to make them correct.
  a Springs only hold stored energy when they are stretched.
  b When an object is thrown up in the air, it gains gravitational potential energy.
  c Sound energy is a type of potential energy.
  d Petrol contains nuclear energy.

5 Identify the main form of energy in each of the following situations.
  a Water flowing slowly over a waterfall
  b A rollercoaster at the lowest point of the ride
  c The Sun coming in through a window on a sunny day
  d Riding a skateboard
  e A stretched rubber band

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

7 A saucepan of water on a stove transfers heat energy by:
  A elastic potential energy.
  B radiation.
  C convection.
  D conduction.

8 Recall the type of energy musical instruments use to produce sound.

Figure 1 Musical instruments use energy to produce sound.

Comprehend

9 Explain why a chemical engineer might be employed to design a new type of solar panel.

10 Describe two different ways electrical energy can be generated.

11 Explain why heat is generated in a light bulb.

12 Describe the energy transformation and energy transfer in a torch.

13 Compare open and closed systems and provide an example for each.

Analyse

14 There are three processes by which energy can be transferred by heating.
  a Use a labelled diagram to explain each type.
  b Explain which of these processes is happening when you touch something hot.

15 Compare conduction and convection.

16 Contrast the number of energy transfers in the generation of electricity in solar panels and hydroelectricity.

17 Compare the energy transformation when electricity is generated by coal and water.

18 Connect the words and phrases in Table 1 with their correct meanings.

Table 1 Words and meanings

Word/Phrase	Meaning
Kinetic energy	The energy stored in a compressed spring
Nuclear energy	Another name for stored energy
Potential energy	The energy of an object when lifted up
Elastic energy	The energy used widely throughout the world to generate electricity from atoms
Gravitational energy	The energy possessed by all moving objects

19 Contrast the terms “transform” and “transfer”.

20 Compare potential energy and kinetic energy.

21 The main job of a car travelling on the road is to produce kinetic energy in its wheels. Identify the other parts of a car that may demonstrate kinetic energy (Figure 2).

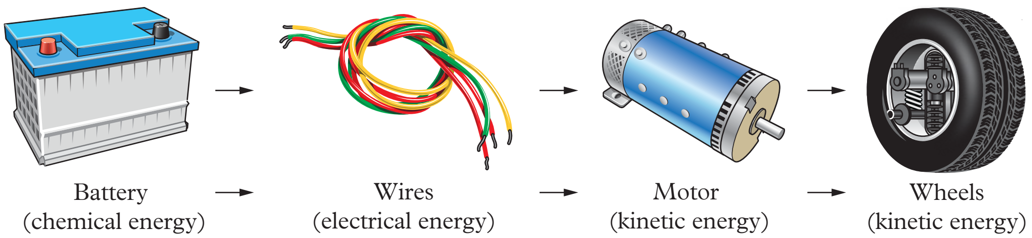


Figure 2 A car produces kinetic energy in its wheels.

22 Think of your day today. Identify the different energy forms you have come across, possessed, used or witnessed. List them in order of use during the day. Consider which energy form was the most common and why.

Apply

23 Visit a local playground and consider the play equipment. Take a photo or draw a picture of a piece of equipment and determine what types of energy are demonstrated as a child plays on the equipment.

24 Create a flow diagram that demonstrates the flow of energy involved in riding a bike. (HINT: Start with the Sun!)

Figure 3 Pedal power

25 Identify the places and structures in your school that you think an engineer was involved with. Justify your decisions (by identifying the role an engineer would have played in the design of the structure).

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

Social and ethical thinking

27 The transformation of chemical energy found in coal and gas into electrical energy has resulted in an increase in the level of carbon dioxide in the air. Despite the advantages of solar (photovoltaic) panels in producing electricity, their production can produce dangerous chemicals such as sodium hydroxide and hydrofluoric acid. Evaluate the effectiveness of using solar panels.

- **a** Identify the advantages and disadvantages of photovoltaic cells.
- **b** Identify the advantages and disadvantages of using another source of energy (i.e. coal or gas).
- **c** Compare (the similarities and differences between) the two methods of producing electricity.
- **d** Identify the different groups of people who will be affected by these two methods.
- **e** Decide which method would be most beneficial to one group.

Critical and creative thinking

28 Aboriginal and Torres Strait Islander Peoples often have no legal input during the planning stages of clean energy projects like wind and solar farms. Evaluate the importance of consulting the Traditional Custodians of the land on which these projects will be situated.

29 Energy comes in many different forms. Create a poster that illustrates each type of energy using visual examples.

30 The massive earthquake and tsunami in Japan in March 2011 caused extensive damage to the Fukushima nuclear power plant, north of Tokyo, and created an emergency. Investigate this disaster and present a 2-minute news report to the class that highlights the issues surrounding the use of nuclear energy.

Research

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

Compact fluorescent lights

- Explain how compact fluorescent lights (CFLs) work.
- Explain how they differ from incandescent light globes.
- Explain why CFLs are initially more expensive to buy, but then more economical over time.
- Identify the benefit of using CFLs.

Figure 4 The CFL (compact fluorescent light) is economical to run despite being initially more expensive to buy than regular light globes.

Energy-efficient housing

In previous times, energy efficiency was important because people had limited access to energy supplies compared to today.

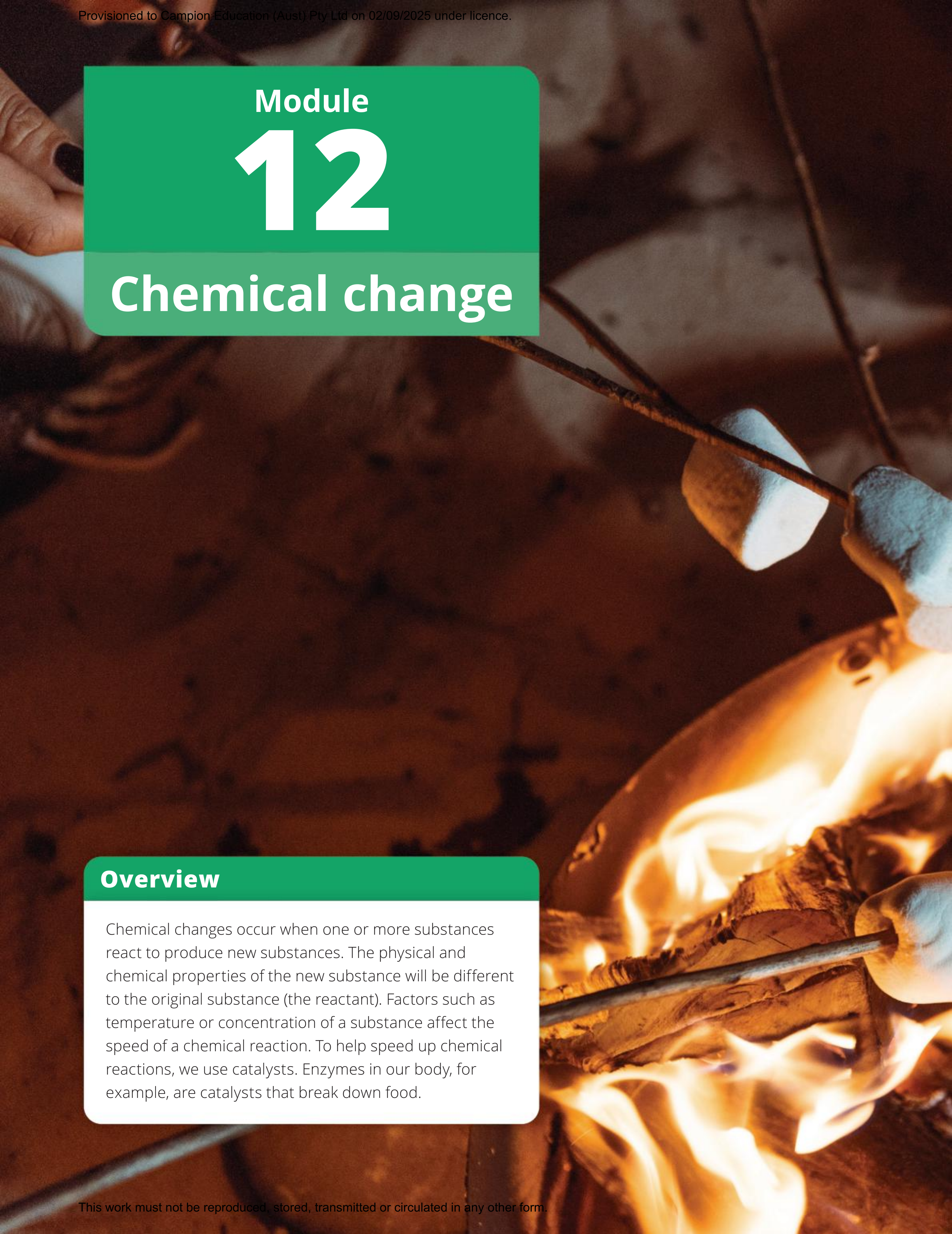
- Research how civilisations in tropical areas designed their homes to keep them cool and damp-free.
- Describe three types of energy-efficient practices that humans have used through the ages.
- Describe three ways modern humans can be energy efficient today.
- Compare the advantages and disadvantages of each energy-efficiency method used in the past and present.

New and specialised engineering fields

Engineers use science, technology and mathematics to solve problems. Select one of the newer fields of engineering such as aerospace, biomedical or nuclear engineering and complete the following tasks.

- Describe what an engineer in that field does.
- Explain what they need to know.
- Identify who they work with.
- Describe where they work.
- Describe the materials they work with.
- Name a significant project that an engineer in the field has worked

Figure 5 Aerospace engineers at work

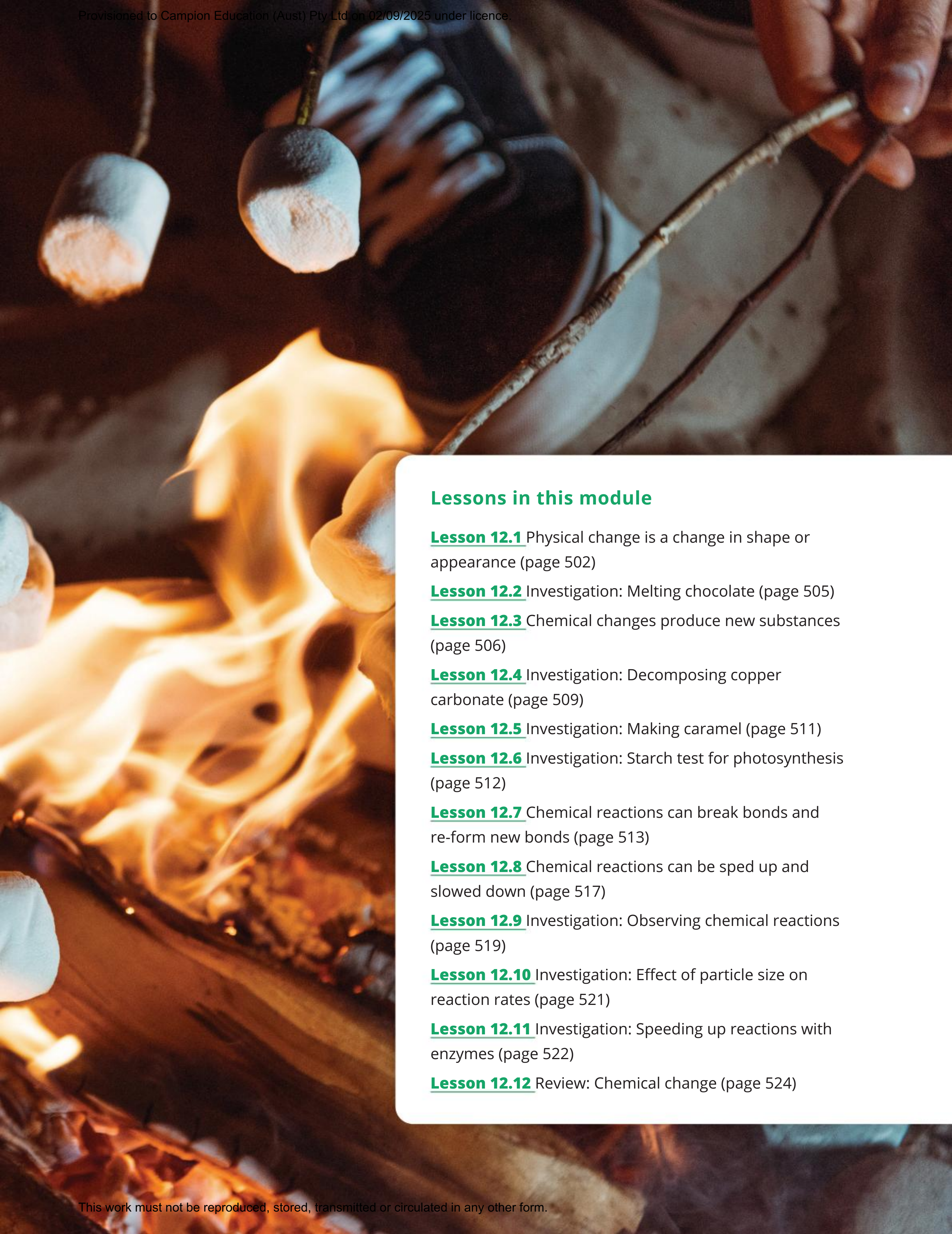


Module 12

Chemical change

Overview

Chemical changes occur when one or more substances react to produce new substances. The physical and chemical properties of the new substance will be different to the original substance (the reactant). Factors such as temperature or concentration of a substance affect the speed of a chemical reaction. To help speed up chemical reactions, we use catalysts. Enzymes in our body, for example, are catalysts that break down food.



Lessons in this module

Lesson 12.1

Physical change is a change in shape or appearance

Learning intentions and success criteria

Key ideas

- → A physical change occurs when a substance has different properties, but the molecules remain the same.
- → A physical change can be a change in state, when a substance changes between a solid, liquid or gas.
- → Most physical changes are reversible.

Physical changes are reversible

Figure 1 Ice melting to water is an example of a physical change.

Most physical changes are reversible, which means the change can be undone and the substance can go back to how it was. When you put water (H_2O) in the freezer, it turns to solid ice (H_2O). When you take the ice out of the freezer, it melts back into liquid water. We can observe that a physical change has taken place (rather than a chemical change) because the water molecules are unchanged and no new substances have been created.

Particles don't change when they change state. A molecule of water, which contains two hydrogen atoms and one oxygen atom (H_2O), is exactly the same when it is a solid, a liquid or a gas. The only difference is how closely packed the water molecules are and how much kinetic energy they have.

In ice, all the water molecules are in a regular arrangement (rows, columns and layers). A three-dimensional arrangement of particles in a regular pattern is called a **lattice** (Figure 2). The water molecules in ice are constantly vibrating. This ice lattice is unique when compared to most other solids. Most solids are denser and more compact than their liquid versions. The solid water (ice) is different because it takes up more space than the liquid water. This is because the 3D bonds between the water molecules take up more space in the solid than the liquid.

lattice a three-dimensional arrangement of particles in a regular pattern

When heat energy is added, the water molecules in the ice vibrate faster, however, the molecules are still held in place in the lattice by other water molecules around them. As the ice warms up more, the water molecules gain more energy and vibrate even faster. Eventually they have so much energy that the water molecules break free of the others around them and are free to move around. The solid ice has melted to become liquid water.

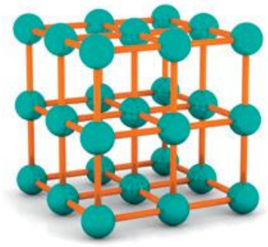


Figure 2 Particles in a solid may be arranged in a lattice.

Changing state

Substances can change between the three states of solid, liquid and gas. We are familiar with seeing water change state (when water boils and ice blocks melt), but other substances may only ever be seen in one state. Theoretically, all substances can be changed into different states if the temperature is hot enough or cold enough. Even gases, such as nitrogen, can be turned into a liquid at very low temperatures. “Dry ice” is solidified carbon dioxide (CO_2).

Vaporisation and condensation

When a liquid evaporates to become a gas, we say it has evaporated or **vaporised**. A **vapour** is the gaseous form of a substance that is normally a solid or liquid at room temperature. For example, when water is turned into a gas, it is referred to as water vapour. Vapours that are smelly are often called **fumes**. Vapours and fumes are gases and behave like gases.

Volatile substances, such as petrol, vaporise easily. Cooking oil does not vaporise if left at normal room temperatures. Cooking oil is not a volatile liquid.

Boiling occurs when we heat a liquid to change it into a gas. Water left in the open at normal room temperature will evaporate very slowly. If the water is heated to its **boiling point**, the water molecules will quickly gain kinetic energy and evaporate or vaporise faster.

When a gas cools down, we say it **condenses** into a liquid. The most common condensation we can observe is in winter when our breath condenses in cold air and we breathe out a white foggy mist. The kinetic energy of the water molecules in our breath passes to the air as heat energy. The water molecules do not change, but they cool down, slow down and **condense** from a gas to tiny liquid droplets in the air that we can see.

vaporise change state from a liquid to a gas; evaporate

vapour gaseous form of a substance that is normally solid or liquid at room temperature (e.g. water vapour)

volatile describes a substance that easily becomes a gas

boiling when a substance changes from its liquid phase to its gaseous phase

boiling point the temperature at which a liquid boils and becomes a gas

condense to become a liquid, from a gas

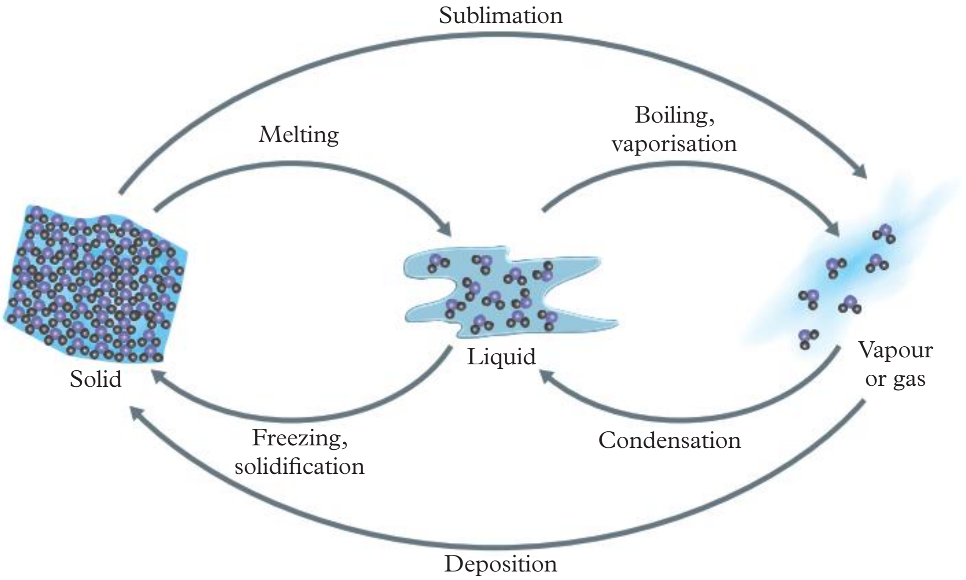


Figure 3 Changing states of water molecules. A solid contains a lattice of water molecules, a liquid contains a loose arrangement of water molecules and a vapour or gas contains separated water molecules.

Melting and solidification

melt change state from solid to liquid

solidification when a substance in its liquid phase changes into a solid state at a fixed temperature

When a solid is heated and changes state to become a liquid, we say it has **melted**. When the liquid loses heat and becomes a solid, this is called **solidification**. When solidification happens to water, it is often called freezing. In both these examples the molecules do not change – only the amount of energy they have changes.

Sublimation

sublimation a change of state from a solid directly to a gas

Some substances don't ever exist as liquids. They just change state from a solid to a gas or from a gas to a solid. The process of a solid becoming a gas is called **sublimation**. Dry ice (CO_2) changes directly from a solid into a gas when it warms up. Dry ice is often used to produce smoke effects on stage at concerts. The "smoke" you see is not carbon dioxide, however, but clouds of water. When dry ice sublimes to form carbon dioxide gas, it cools the air quickly. This drop in temperature causes water vapour in the air to condense and form clouds of water.

Diamond (a form of carbon) is the hardest known substance on Earth. It also sublimes, but only at extremely high temperatures (above 3,500°C).

Figure 4 Dry ice is frozen carbon dioxide gas.

Figure 5 Water vapour in the air has condensed on this cold window.

Check your learning 12.1

Check your learning 12.1

Retrieve

1 Define the following terms.
  a Lattice
  b Condense
  c Sublimation
  d Volatile

Comprehend

2 Explain why physical changes are reversible.

3 Explain why shattering a block of ice is considered a physical change.

4 Explain why all perfumes are volatile liquids.

5 Illustrate the three major states of water. Identify the physical changes the water goes through to form ice and water vapour.

Apply

6 A student claimed that the bubbles in boiling water were oxygen. Evaluate their claim (by describing the kinetic energy changes that occur in boiling water, describing the types of molecules found in the bubbles and deciding if the statement is correct).

Skills builder: Communicating

7 Construct a visual aid to demonstrate the three major states of water and the physical changes water goes through to form ice and water vapour. (THINK: How could you represent this information visually? Would you use a flowchart, a diagram or a table?)

Lesson 12.2

Investigation: Melting chocolate

Caution

- Wear safety glasses, closed-toe shoes and a lab coat, and tie long hair back when using a Bunsen burner.
- Do not touch hot equipment.

Purpose

To examine the physical changes that occur when chocolate is melted

Materials

- Milk, dark and white cooking chocolate buttons (approximately 10 of each)
- Three 100 mL beakers
- Thermometer
- 250 mL beaker (as a water bath)
- Stirring rod
- Bunsen burner and heatproof mat or hotplate
- Timer
- Matches
- Heatproof gloves

Procedure

1 Place four to six buttons of milk cooking chocolate in a 100 mL beaker.
2 Place a thermometer in the beaker.
3 Using a hot plate or a Bunsen burner, heat approximately 150 mL of water in a 250 mL beaker. Wait for the water to start gently boiling before proceeding to the next step.
4 Place the 100 mL beaker in the hot water bath (the boiling water in a beaker) and heat it to 60°C. Do not stir the chocolate.
5 Time how long it takes to melt. Record your observations.

Inquiry: Would another type of chocolate melt faster or slower than milk chocolate?

- Write a prediction or hypothesis for your inquiry.
- Identify the (independent) variable that you will change from the first method.
- Identify the (dependent) variable that you will measure and/or observe.
- Identify two variables that you will need to control to ensure a fair test. Describe how you will control these variables.

- Write in your notebook the method you will use to complete your investigation.
- Draw a table to record your results.
- Show your teacher your planning (for approval) before starting your experiment.

Results

1. Record your observations, including any diagrams and photographs.
2. Draw a column graph of the time it took for each type of chocolate to melt.

Figure 1 Placing the small beaker of chocolate buttons in a beaker of boiling water causes the chocolate to melt.

Discussion

1. Contrast (the difference in) the time it took for each type of chocolate to melt.
2. Compare the pattern of melting for all three types of chocolate. (Inside first or outside edges first?)
3. Describe how a chef could apply your observations in the kitchen.
4. Describe any discolouration or burning of the chocolate that occurred.

Conclusion

Compare the properties of the milk, dark and white chocolate.

Figure 2 A physical change occurs when chocolate buttons are melted.

Lesson 12.3

Chemical changes produce new substances

Learning intentions and success criteria

Key ideas

→ Chemical changes can cause heat or light to be produced.

→ Chemical changes can cause an object to change colour.

→ Chemical changes can cause a new gas or solid to be formed.

→ When a chemical change occurs, a new substance is formed.

Chemical changes

In a chemical change, a new chemical is made. This means that the atoms have been moved around into new arrangements. In some chemical changes, the atoms in a molecule can be separated to make new chemicals. Sometimes atoms and molecules join together to make new chemical substances with larger molecules. New substances have new particles and new properties. Both the physical and chemical properties of the new substance (the product) will be different from those of the original substance (the reactant).

In every chemical reaction, one or more substances are changed into new, different substances with different physical and chemical properties. Chemical changes are not usually reversible – you cannot un-burn toast!

Whether a change is physical or chemical depends on the substances, the temperature and how you mix them.

Physical change or chemical change?

When solid chocolate is heated gradually, it melts and changes shape; when cooled, it goes back to the solid state. It may have a different shape, but the molecules are the same. It is still chocolate. In this situation, a physical change has taken place because the chocolate is still the same substance: it is still made up of the same particles (Figure 6).

If you heat chocolate at too high a temperature, however, it burns. When it cools, it no longer tastes like chocolate – it tastes like burnt chocolate. This is a chemical change, because a new substance is formed that is different from chocolate – you can tell by the taste and the smell! This is why most chocolate recipes suggest heating chocolate over boiling water rather than over a hot plate, so that the chocolate does not get too hot and a chemical change does not take place.

Figure 1 Heating chocolate slowly causes it to melt – a physical change. If it is heated quickly and at a higher temperature, the chocolate will burn – a chemical change.

When you bake a cake, mixing the ingredients together produces a physical change. Baking the cake involves a chemical change.

Cooking often turns food brown. This is due to the sugar in the food caramelising – turning into brown caramel. This is an example of a chemical change. It cannot be reversed easily.

Aboriginal and Torres Strait Islander Peoples use red and yellow ochre in paintings. Ochre is a type of natural clay earth pigment that primarily derives its colour from iron oxide. Carefully controlled heat causes a chemical change to produce the red pigment. The change forms a new substance and is not reversible. It is a chemical change.

We can usually identify a chemical change if one of the things shown in Figures 2–5 occurs.

Figure 2 A gas is produced. We see this either as bubbles or fizz.

Figure 3 A colour change occurs that is non-reversible. Heating an iron nail to red hot is a physical change because the red colour will disappear as the nail cools down; however, if the iron in the nail reacts with oxygen in the air and becomes rusty, it is a chemical change and cannot be reversed.

Figure 4 Light or heat is absorbed or produced. When the atoms in sodium metal and water rearrange themselves during a chemical change, the extra energy is released as light and heat.

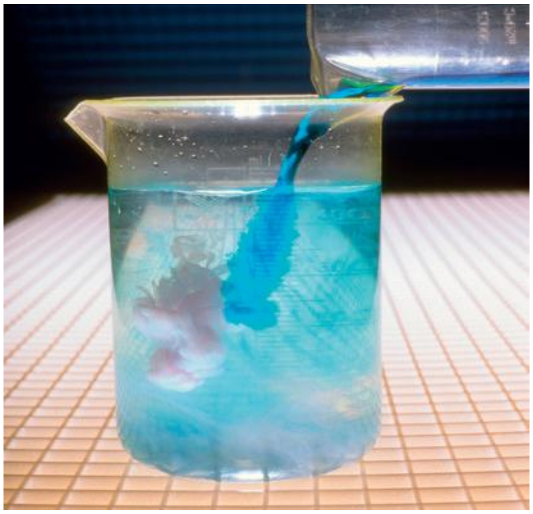


Figure 5 A precipitate forms. A (solid) precipitate is the name given when new solid particles form during a chemical change.

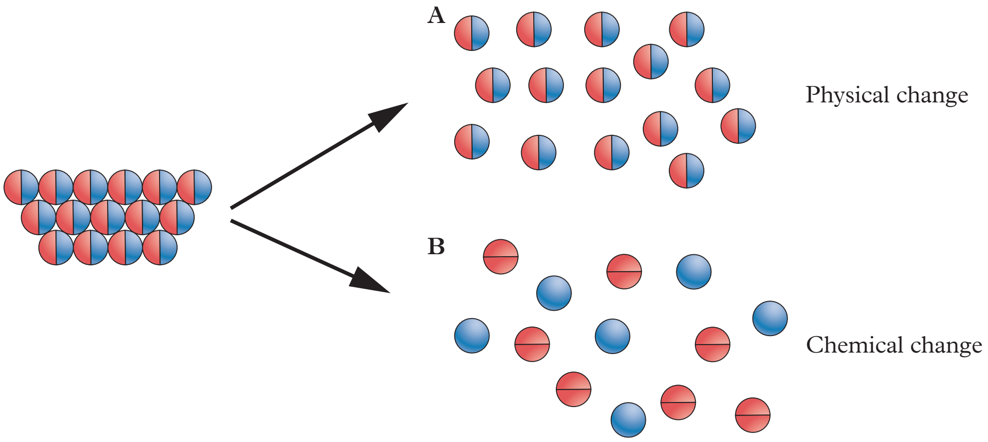


Figure 6 (A) In a physical change, only the appearance of the substance changes because the particles have been rearranged. (B) In a chemical change, atoms are rearranged and new chemicals are made.

Check your learning 12.3

Check your learning 12.3

Comprehend

1 Describe the observations indicating a chemical change has occurred.

2 Sugar turns brown when heated in a process called caramelisation. Explain why caramelisation is considered a chemical reaction.

3 Describe the evidence that baking a cake from egg, flour and butter is a chemical reaction.

Analyse

4 Contrast (the differences between) chemical and physical change.

5 When melted chocolate is put in the fridge, it cools quickly, producing small crystals that were not present before. This changes the taste of the chocolate. Identify this as a chemical or physical change.

6 Identify the following as either a physical or a chemical change.

- **a** Melting cooking chocolate into animal shapes
- **b** Burning magnesium ribbon to form a white ash
- **c** Boiling water and condensing the vapour
- **d** Dissolving magnesium in acid to produce hydrogen gas
- **e** Separating leaves from woodchips using a garden blower

7 Identify the key evidence that suggests that producing a reddish-brown pigment from yellow ochre is a chemical change.

Skills builder: Questioning and predicting

8 A student was asked to investigate the type of change that took place when an egg was heated in boiling water and cooled in cold water.

Write a scientific question for this investigation. (THINK: Is your question specific and can it be tested?)

Lesson 12.4

Investigation: Decomposing copper carbonate

Caution

- Wear safety glasses, closed-toe shoes and a lab coat, and tie long hair back when using a Bunsen burner.
- Use a yellow (cooler) safety flame for this investigation.
- Hold the test tube or crucible securely with the tongs and always point it away from yourself and others.
- Never place hot objects on the balance.

Purpose

To decompose (break into smaller parts) copper carbonate

Materials

- Plastic beaker
- Test tube or crucible
- Electronic balance
- Spatula
- Copper carbonate
- Bunsen burner
- Heatproof mat
- Matches
- Wooden tongsPaper towel

Procedure

1 Place a plastic beaker containing the test tube on the balance. Use the "Tare" button to return the reading to zero.

2 Using a spatula, add approximately 3 g of copper carbonate into the test tube. Record the mass in grams (this mass is named M1).

3 Set up the Bunsen burner on the heatproof mat. Light the flame, ensuring the hole is closed and a yellow (safety) flame is burning.

4 Using the wooden tongs to hold the top of the test tube, gently wave the base of the test tube over the flame twice. Record any changes. Continue to do this for 2 minutes, recording any changes. Be very careful to point the open end of the test tube away from others and yourself.

5 Allow the test tube and copper carbonate to cool. Wipe off any black powder from the outside of the test tube with paper towel.

6 Place the test tube in the original plastic beaker. Reweigh the test tube and beaker and record the mass in grams (this mass is named M2). Note any change in mass.

Results

Record your results in Table 1.

Figure 1 Matches are used to light the Bunsen burner flame

Discussion

1 Describe what happened to the copper carbonate. Consider the colour and any change in mass.

2 Describe the evidence that copper carbonate is a compound and not an element.

3 Describe one possible source of error in this investigation.

Conclusion

Describe what happens when copper carbonate decomposes.

Table 1 Copper carbonate before and after heating

Mass of copper carbonate before heating (M1) (g)	Mass of copper oxide after heating (M2) (g)	Difference (M1 − M2) (g)

Lesson 12.5

Investigation: Making caramel

Caution

- Wear safety glasses, closed-toe shoes and a lab coat, and tie long hair back when using a Bunsen burner.
- Do not touch hot equipment.

Purpose

To identify the chemical change when heating sugar

Materials

- Sugar
- Test tube
- Test-tube holder
- Plastic beaker
- Bunsen burner
- Heatproof mat
- Matches
- Electronic balance

Procedure

1 Place the sugar into the test tube.
2 Place a plastic beaker containing the test tube of sugar on the balance. Use the “Tare” button to return the reading to zero.
3 Wearing safety glasses and using the test-tube holder, gently heat the sugar with the test tube facing away from you and everyone else. Heat the sugar by passing it through the top part of a blue flame.
4 If you are careful, the sugar grains will crumble (they lose water in a chemical reaction) and turn into a brown syrup. This brown syrup is caramel. You may see condensation on the inside of the test tube as the water is driven out of the sugar.
5 If you continue heating or heat too strongly, you will burn the sugar.

Discussion

1 Describe the evidence that a chemical reaction has occurred at Step 3.
2 Describe the chemical change that could occur if you continued heating the caramel in Step 4.

Figure 1 Sugar undergoes a chemical change when heated and produces caramel.

Lesson 12.6

Investigation: Starch test for photosynthesis

Purpose

To investigate and model the balance between photosynthesis and respiration in a native aquatic plant by comparing the changes in CO_2 levels (as indicated by colour shifts in bromothymol blue) under light and dark conditions

Materials

- Two clear glass jars (approximately 9 cm in diameter, 10 cm in height, with a capacity of 250 mL each)
- 200 mL of distilled water
- 100 mL graduated cylinder
- Bromothymol blue indicator
- Two identical specimens of a native aquatic plant, trimmed to approximately 8 cm in length and 2 cm in thickness
- Permanent marker or labels for marking jars
- Access to direct sunlight for the light treatment
- Access to a dark cupboard or opaque box to completely block light
- Stopwatch

Procedure

1. Measure 100 mL of distilled water with the graduated cylinder and pour it into each jar.
2. Add exactly 5 drops of bromothymol blue indicator to each jar and stir gently until the solution is uniformly blue.
3. Place one plant specimen into each jar, making sure they are fully submerged in the solution.
4. Label one jar "Light" and the other "Dark" using the permanent marker or labels.
5. Place the "Light" jar on a window ledge where it receives direct sunlight and immediately put the "Dark" jar into a dark cupboard or opaque box that completely blocks out light.
6. Start the timer and leave both jars undisturbed for 45 minutes.
7. After 45 minutes, observe and record the colour change in each jar.

Note: When CO_2 dissolves in water, it forms a weak acid called carbonic acid. This makes the solution more acidic. If there is less CO_2, the solution becomes either more neutral or basic.

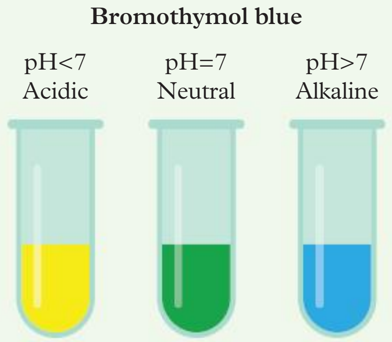


Figure 1 Change in indicator colour with bromothymol blue indicator

Discussion

1. What does the blue (or blue-green) colour in the "Light" jar indicate about the CO_2 levels and pH in the water, and how does this relate to photosynthesis?
2. Why does the "Dark" jar turn yellow, and what does this suggest about the CO_2 concentration due to respiration?

3 What other factors, such as water temperature or light intensity, could influence the balance between photosynthesis and respiration in this set-up?

4 How do these observations help us understand the balance between photosynthesis and respiration in natural aquatic ecosystems?

Communication

Write a scientific report for this experiment. Refer to Lesson 1.17 Skills lab: Writing a scientific report (page 60) on the components of a scientific report.

Lesson 12.7

Chemical reactions can break bonds and re-form new bonds

Key ideas

→ In a chemical reaction, the starting substances are called reactants and the final substances that form are called products and can have new properties.

→ In chemical changes or reactions, the atoms in the reactants separate from each other and bond together in different combinations to form new products.

Learning intentions and success criteria

Chemical reactions

A chemical change can also be described as a **chemical reaction**. The substances that you start with are called **reactants**. They react or change to produce new substances. The substances that you finish with are called **products**. They are produced in the chemical change. There may be more than one reactant and product for each chemical change (Figure 1).

Chemical reactions are all around us. They not only occur in factories but they also take place in our homes and in our bodies. Every process in your body requires a chemical change. Cooking food changes it chemically so it is more edible and easier to digest.

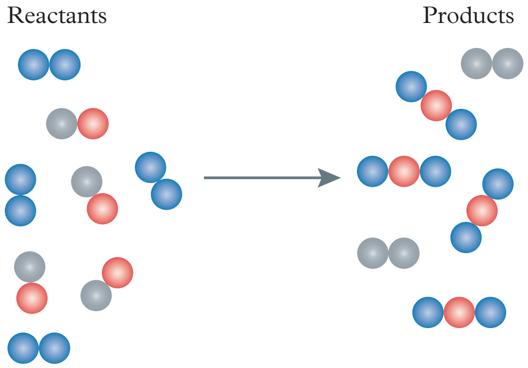


Figure 1 Reactants in a chemical reaction become products.

chemical reaction a procedure that produces new chemicals; same as chemical change

reactant a substance used at the beginning of a chemical reaction; written on the left side of a chemical equation

product a substance obtained at the end of a chemical reaction; written on the right side of a chemical equation

Reactions in cooking

Preparing and cooking food involves many physical and chemical changes to the food. There are other similarities between chemistry and cooking – some of the techniques used in cooking, such as heating, mixing and filtering, are similar to the tasks of a chemist.

There are many chemical reactions in the kitchen. Baked vegetables and meat turn brown as the sugars in them are caramelised. The sugar is the reactant and the caramel is the product. Usually, the sugar comes from the breakdown of starch granules into starch molecules, followed by a chemical change into sugar. Other chemical changes involve the breakdown of proteins in meat. Some vitamins may be destroyed by certain cooking methods.

Some chemical changes are caused by microorganisms. Sour milk forms when a bacterium converts milk sugar (lactose) into an acid (lactic acid). The taste of sour milk is unpleasant and the large numbers of bacteria in the milk may make you sick. Cheese is made by fungi that consume the sugars in milk and cause the protein to thicken. In making yoghurt, the bacteria act as a **culture** (a colony of microorganisms) that is transferred to the new medium (milk).

Other chemicals are added to our food, including flavourings, colourings, antioxidants and preservatives. These help to improve the food's appearance and increase its shelf life. Processed foods usually show a list of these additives on the packet (Figure 2).

Dietary Fiber

INGREDIENTS: ENRICHED FLOUR (WHEAT FLOUR, NIACIN, REDUCED IRON, THIAMIN MONONITRATE, RIBOFLAVIN, FOLIC ACID), WHEAT STARCH, LARD AND HYDROGENATED LARD WITH BHT TO PROTECT FLAVOR, WATER, SUGAR. CONTAINS 2% OR LESS OF: SALT, XANTHAN GUM, YELLOW 5, RED 40, CITRIC ACID AND SODIUM PROPIONATE AND POTASSIUM SORBATE (PRESERVATIVES), SOY FLOUR.

CONTAINS: WHEAT AND SOY.

Figure 2 Some processed foods have artificial chemicals added to them.

Energy in reactions

All chemical reactions, regardless of whether they are breaking bonds or forming new bonds, require energy. The amount of energy needed to kickstart a reaction is called activation energy. Different reactions require different amounts of activation energy. While all reactions require energy to start, not all reactions will release energy. In fact, reactions can be divided into two categories based on whether they absorb energy or release energy.

Endothermic reactions are reactions that absorb energy. This is because in endothermic reactions the reactants have less energy than the products, so to convert the reactants into products, energy must be absorbed from the surroundings. Exothermic reactions are reactions that release energy. This is because in exothermic reactions the reactants have more energy than the products, so as reactants are converted into products the excess energy is released into the surroundings.

One method that can be used to determine if a reaction is endothermic or exothermic is monitoring temperature changes. As endothermic reactions absorb energy, they will result in the surroundings cooling down, as energy (in the form of heat) gets absorbed from the surroundings to allow the reaction to occur. For example, when sodium thiosulfate is reacted in water, the test tube feels cooler as the reaction is occurring because energy is being absorbed and the reaction is endothermic. Alternatively, exothermic reactions release energy (in the form of heat), resulting in an increase in temperature. For example, when magnesium is added to hydrochloric acid, the test tube feels warmer as the reaction is occurring because the reaction is exothermic and is releasing energy.

Combustion

Burning is an exothermic chemical reaction. The scientific word for burning is **combustion**.

combustion a reaction that involves oxygen and releases light and heat energy

Magnesium is a metal that can burn fairly easily, giving off a lot of heat and bright white light. When a magnesium ribbon interacts with oxygen in the air, the reactants are magnesium and oxygen. The chemical reaction takes place when we see the magnesium ribbon burn. After the ribbon has burnt, we are left with a white powder – magnesium oxide – as the product of the reaction.

Figure 3 The Adnymathanha people of the Flinders Ranges in South Australia used charcoal to paint the Yourambulla Rock Shelter.

Aboriginal and Torres Strait Islander Peoples carefully control the burning of plants and wood so that there are only small amounts of oxygen as a reactant. This means that good-quality charcoal is produced (the product) that can then be used for black pigment (Figure 3) or to improve the properties of glues for spears or axe heads.

New products

Many substances that we now take for granted, such as medicines, chemicals used in agriculture and construction, and plastics such as PVC and polythene, are made from chemical reactions with crude oil.

These products are hard to make in a laboratory because they require high temperatures and some specialised conditions. A substance that we can make in a laboratory is nylon – a compound consisting of long molecules (called polymers) (Figure 4).

Figure 4 Nylon thread is made by mixing two solutions.

Chemical equations

Scientists use a shorthand technique to describe what happens to reactants and products in chemical reactions. This is called a **chemical equation**. The reactants are written on the left-hand side and the products are written on the right-hand side. An arrow represents the chemical change.

reactants → products

For magnesium ribbon burning in air, the chemical reaction could be represented by the following chemical word equation and chemical symbol equation:

magnesium + oxygen (burning in air) → magnesium oxide (white powdered form)

$$2Mg + O_2 \rightarrow 2MgO$$

Figure 5 Sodium metal reacts violently with water, undergoing chemical change.

When sodium metal reacts with water (Figure 5) it dissolves and reacts violently, producing heat along with fizzing, caused by the production of hydrogen gas. If there is enough heat, the hydrogen gas catches fire above the sodium metal.

This can be shown using a word equation. The reactants are sodium and water, and they interact to form the products, which are sodium hydroxide and hydrogen gas. The word equation summarises the changes:

sodium + water → sodium hydroxide + hydrogen

In chemical equations, the formulas of all the substances involved are included with the ratio in which they react:

$$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$$

Each representation tells us something different about the changes occurring in the chemical reaction. Chemical equations and chemical formulas will be introduced in Stage 5.

Check your learning 12.7

Check your learning 12.7

Retrieve

1 Define the following terms.
  a Reactant
  b Product

Comprehend

2 Describe the purpose of the arrow in a chemical equation.

3 Explain why it is unnecessary to write an equation for a physical change.

Analyse

4 Contrast (the differences between) reactants and products.

5 Identify the reactants and the products in the following chemical reactions.
  a Iron ore is made into a steel ship.
  b Bread is made from flour.
  c Freezer bags made from polythene are manufactured from ethene.
  d Nitrogen fertilisers are made from nitrogen gas and hydrogen gas.

6 Contrast exothermic and endothermic reactions.

Apply

7 What is one change you might observe at the very beginning of a chemical reaction, and why do you think this happens?

Skills builder: Planning investigations

8 Plan an investigation that explores the rate of one chemical reaction under different conditions (for example, rusting).
  a Identify the dependent variable, independent variable and any controlled variables. (THINK: What are you changing or measuring in your investigation? Which other variables might need to be controlled?)
  b Write a method for your investigation and draw a scientific drawing of the experimental set-up. (THINK: What is a logical order for each step in the method?

Lesson 12.8

Chemical reactions can be sped up and slowed down

Key ideas

→ The rate of a chemical reaction can be sped up or slowed down.

→ Factors that speed up the rate of a chemical reaction include increasing the surface area of the reactants, increasing the temperature and concentration of substances, and adding a suitable catalyst.

Learning intentions and success criteria

The effect of temperature

Figure 1 An increase in temperature causes reactant particles to move faster and to collide with each other more frequently.

In chemical reactions, for substances to react, their particles must collide with each other. This is known as the **collision theory**. In the collision theory, the more collisions that happen between the particles, the more likely it is that they will react.

One way to increase the number of collisions between particles is to increase the temperature (Figure 1). When heat energy is added to the substance, the particles gain kinetic energy and therefore move more quickly. To slow down a reaction, the temperature can be reduced so that the particles have less kinetic energy and have less chance of colliding.

collision theory a theory stating that the particles involved in a chemical reaction must collide in order to react

The effect of concentration

The number of particles trapped in a small area – the **concentration** – also has an effect. More concentrated substances will react more easily, again due to the collision theory. A more concentrated substance has more particles available to collide with particles from another substance (Figure 2).

concentration the number of active molecules in a set volume of solution

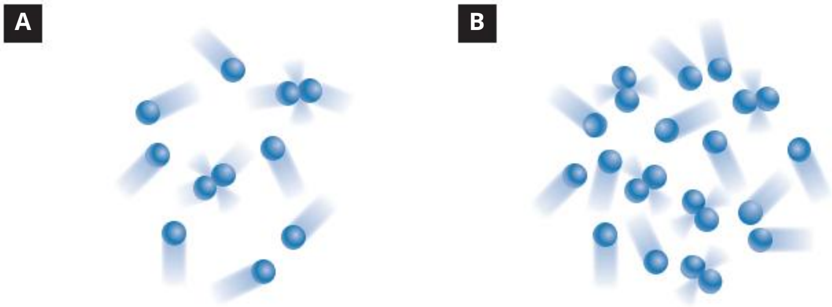


Figure 2 (A) At low concentrations, there are few collisions between particles. (B) At high concentrations, the number of collisions between particles is increased.

To increase the rate of a reaction between a solid substance and a substance in solution, for instance, we can increase the concentration of the solution, meaning that there are more particles in the solution to collide with the particles in the solid.

The effect of surface area

The surface area of reactant pieces affects the rate of a reaction. When a solid reactant is cut into smaller pieces, it will react faster. This is because the smaller reactant pieces have a larger total surface area, which means that the reactant particles have a greater chance of interacting with each other (Figure 3).

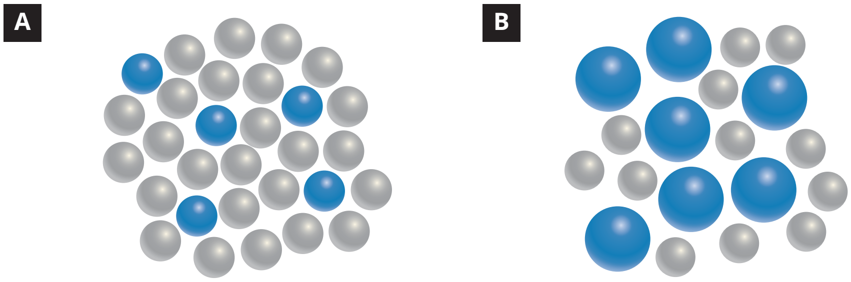


Figure 3 (A) More reactants can interact or touch each other when the reactant pieces are small. (B) Large reactant pieces have less total surface area to make contact with other reactants.

The effect of catalysts

Adding another substance or material may also affect the rate of a chemical reaction. Substances that increase the rate of a reaction without being used up by it are known as **catalysts**.

catalyst a substance that increases the rate of a chemical reaction without undergoing any permanent chemical change

enzymes a protein that helps speed up chemical reactions in the body

Enzymes are types of catalysts that help speed up chemical reactions in living things. They do this by lowering the activation energy needed to start the reaction. We have many enzymes in our bodies that help to speed up chemical reactions. For example, enzymes found in the digestive system help break down food. Enzymes are very "fussy" and only work with one type of reactant and so will only catalyse one reaction each. They act like landing strips for reactants, allowing the chemicals to collide with each other more easily.

Enzymes are responsible for the ripening of fruit. When a piece of fruit is cut and left exposed to the air, enzymes help the oxygen react with the fruit and make it turn brown. This enzyme can be blocked by adding salt or vitamin C (Figure 4).

Figure 4 Adding lemon juice to freshly cut apples prevents them from going brown. Lemon juice contains vitamin C.

Figure 5 Why does roasting a marshmallow make it go brown?

Check your learning 12.8

Check your learning 12.8

Comprehend

1 Explain the "collision" theory in your own words.

2 Describe how the surface area of a solid reactant affects the rate of a chemical reaction.

3 Describe the effect enzymes have on the rate of a reaction.

4 Describe what happens to the number of particles when you increase the concentration of a substance.

5 Explain how increasing the concentration of reactants increases the rate of a reaction.

6 Explain why increasing the rate of a reaction does not change the total amount of product produced.

Analyse

7 Consider how the particle model of matter helps to explain the rate of reactions.

Lesson 12.9

Investigation: Observing chemical reactions

Purpose

To observe the reactants and products in different chemical reactions

Materials

- Spatula
- Copper carbonate (solid)
- Bunsen burner
- Heatproof mat
- Matches
- Three test tubes
- Test-tube holder
- Baking soda (sodium bicarbonate)
- 20 mL of 1 M hydrochloric acid
- Thermometer
- Wooden splint
- Magnesium ribbon (1 cm length)
- 30 mL of 0.5 M copper sulfate solution
- 100 mL beaker
- Tongs
- Piece of steel wool, about thumb size when rolled up

Procedure

Part A

1 Place a large spatula of copper carbonate in a test tube.

2 Set up the Bunsen burner on the heatproof mat.

3 Using a test-tube holder, gently heat the test tube by passing it over the flame twice.

Make sure the test tube is facing away from you and everyone else. Observe any changes and repeat until the powder changes colour.

4 Collect the waste powder in a beaker for disposal.

Part B

1 Place the baking soda in a test tube to a depth of 0.5 cm.
2 Add an equal amount of 1 M hydrochloric acid to the test tube and observe.
3 Conduct a carbon dioxide test by holding a burning wood splint above the tube. If the flame goes out, carbon dioxide is present as one of the products of the chemical reaction.

Part C

1 Pour 5 mL of hydrochloric acid into the bottom of a test tube. Measure its temperature with the thermometer.
2 Add the magnesium ribbon to the test tube. Measure its temperature again.
3 Observe what happens using sight, touch (the outside of the test tube only!) and sound.

Part D

1 Pour 30 mL of copper sulfate solution into a 100 mL beaker.
2 Use the tongs to place the steel wool into the copper sulfate solution.
3 Carefully observe the changes that occur to both the steel wool and the copper sulfate solution.
4 Collect the copper sulfate/steel wool solution in a beaker for safe disposal.

Results

Include your observations here.

Figure 1 When heating a test tube, be sure to point it away from you or anyone else close by.

Discussion

1 Describe what happened to the copper carbonate when it was heated.
2 Describe your observations of the copper carbonate when it was taken away from the heat.
3 Compare the copper carbonate experiment with the melting chocolate experiment (Lesson 12.2 Investigation: Melting chocolate, page 505).
4 Identify what is produced in the baking soda and acid experiment.
5 Explain why the flame on the burning wooden splint goes out if carbon dioxide is present.
6 Explain what happened to the magnesium metal.
7 Design an experiment to test the science question, “What if twice as much magnesium was used in Part **C** of the investigation?”

Conclusion

Explain what you observed about the reactants and products of chemical reactions.

Lesson 12.10

Investigation: Effect of particle size on reaction rates

Purpose

To observe how particle size affects the rate of a reaction

Materials

- Two small pieces of marble
- Mortar and pestle
- Electronic balance
- Pieces of filter paper
- Two small beakers
- 10 mL graduated cylinder
- Dilute hydrochloric acid (1 M HCl)
- Stirring rod
- Stopwatch

Procedure

1. Place a piece of filter paper on the electronic balance and record the mass.
2. Place a small piece of marble onto the filter paper. Measure and record the combined mass.
3. Place the marble piece into a beaker and add 5.0 mL of hydrochloric acid. Record the time.
4. Stir the marble and the acid occasionally.
5. Time how long it takes for the reaction (gas bubbles being produced and the marble piece becoming smaller) to stop.
6. When the reaction stops, filter the remaining solution using the original filter paper.
7. Allow the filter paper to dry overnight and measure the mass.
8. Now select a piece of marble the same size as the first. Grind the marble piece into a fine powder using the mortar and pestle.
9. Place another piece of filter paper onto the electronic balance and record the mass. Place the ground-up marble onto the filter paper. Measure and record the combined mass.

Figure 1 Weighing the marble allows you to calculate the mass lost in the reaction.

Figure 2 Grinding the marble creates smaller particles.

10 Place the ground-up marble into a small beaker and add 5.0 mL of 1 M HCl. Record the time.

11 Stir the marble and the acid occasionally.

12 Time how long it takes for the reaction to stop.

13 When the reaction stops, filter the remaining solution using the original filter paper.

14 Allow the filter paper to dry overnight and measure the mass.

15 Calculate the mass lost in the first reaction by subtracting the mass of the filter paper after the reaction from the combined starting mass.

16 Calculate the percentage of calcium carbonate in the marble using the formula below.

$$\frac{\text{Mass lost in the first reaction}}{\text{Starting mass of marble in the first reaction}} \times \frac{100}{1}$$

17 Repeat these calculations for the ground-up marble.

Results

Draw an appropriate table for your results.

Discussion

1 Identify which type of marble dissolved faster (large chip or ground powder).

2 Explain why small pieces of marble react faster than one large piece.

3 Explain why stirring is necessary.

4 Explain whether grinding up the marble changed the amount of calcium carbonate in the sample.

Conclusion

Explain what you know about how particle size affects the reaction rate.

Lesson 12.11

Investigation: Speeding up reactions with enzymes

Introduction

Hydrogen peroxide breaks down into oxygen and water slowly over time. Yeast enzymes act as a catalyst which speeds up this reaction.

Purpose

To investigate the effect of yeast enzymes in breaking down hydrogen peroxide

Materials

- One packet of dried yeast
- Two 200 mL beakers
- 10 mL hydrogen peroxide (3%)
- Wooden splint
- Matches

Procedure

1. Fill one beaker with 10 mL of hydrogen peroxide.
2. Light a wooden splint and then blow it out. Place the glowing splint in the top half of the beaker.
3. Record your observations.
4. Add the yeast to the second beaker.
5. Add 10 mL of hydrogen peroxide into the beaker containing the yeast.
6. Repeat Steps 2 to 3 for the second beaker.

Results

Record your observations in a table.

Discussion

1. Describe whether the breakdown of hydrogen peroxide into oxygen and water was noticeable.
2. Describe what happened to the rate of hydrogen peroxide breakdown when the yeast was present.
3. Describe the effect the gas produced had on the glowing splint.
4. Identify the gas that would cause this reaction.

Conclusion

Explain what you know about how enzymes affect the rate of a reaction.

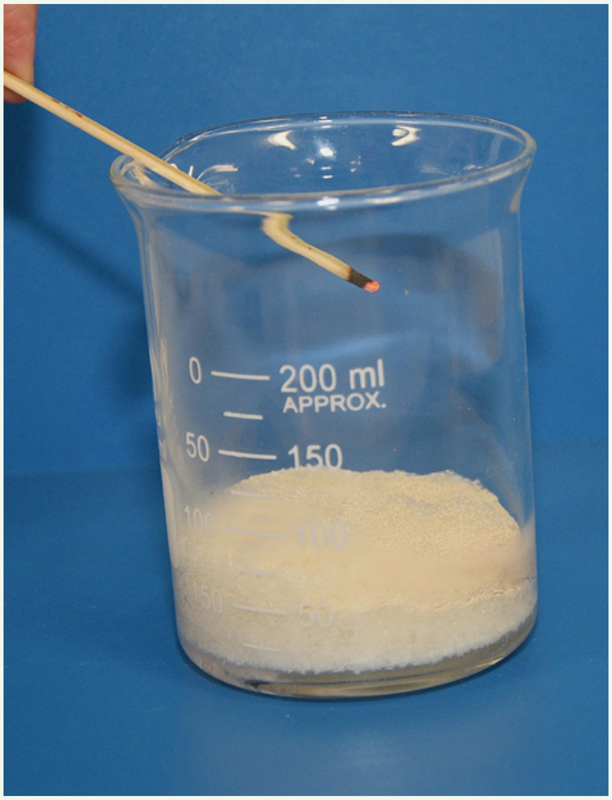


Figure 1 Yeast enzymes can speed up the reaction rate when breaking down hydrogen peroxide.

Lesson 12.12

Review: Chemical change

Summary

Lesson 12.1 Physical change is a change in shape or appearance

- A physical change occurs when a substance has different properties, but the molecules remain the same.
- A physical change can be a change in state, when a substance changes between a solid, liquid or gas.
- Most physical changes are reversible.

Lesson 12.3 Chemical changes produce new substances

- Chemical changes can cause heat or light to be produced.
- Chemical changes can cause an object to change colour.
- Chemical changes can cause a new gas or solid to be formed.
- When a chemical change occurs, a new substance is formed.

Lesson 12.7 Chemical reactions can break bonds and re-form new bonds

- In a chemical reaction, the starting substances are called reactants and the final substances that form are called products and can have new properties.
- In chemical changes or reactions, the atoms in the reactants separate from each other and bond together in different combinations to form new products.

Lesson 12.8 Chemical reactions can be sped up and slowed down

- The rate of a chemical reaction can be sped up or slowed down.
- Factors that speed up the rate of a chemical reaction include increasing the surface area of the reactants, increasing the temperature and concentration of substances, and adding a suitable catalyst.

Review questions 12.12

Review questions Module 12

Retrieve

1 Identify which of the following describes a chemical change.
  A Breaking glass
  B Burning toast
  C Melting ice
  D Mixing sand and water

2 Identify the new substance produced in a chemical reaction.
  A The chemical
  B The result
  C The product
  D The reactant

3 Identify which of the following describes how a physical change is different from a chemical change.
  A A physical change refers to rusting or cooking processes.
  B A physical change requires heat.
  C A physical change is permanent.
  D A physical change is easily reversible.

Comprehend

4 Define the term "reactant" (in a chemical reaction).

5 Use the particle model to explain:
  a melting
  b sublimation
  c freezing
  d condensation.

6 Describe the changes that might be observed during a chemical change.

7 Using your knowledge of particles, explain why most physical changes can be reversed.

8 Describe four ways to speed up a chemical reaction. Use the particle model to explain why each method works.

9 Explain why nylon is described as a synthetic material.

10 Explain why chemists would never write a chemical equation for the melting of chocolate.

Figure 1 Chocolate can be easily burnt.

11 In Lesson 12.9 Investigation: Observing chemical reactions (page 519), you observed the reaction between copper sulfate solution and iron (steel wool) to make copper and iron sulfate solution.
  a Copy and complete Table 1 to summarise the changes observed in this reaction.
  b Use the information in Table 1 to explain why this is an example of a chemical change.

Analyse

12 Analyse the differences between physical and chemical changes by comparing the role of energy and particle interactions in each.

13 Examine the process of sublimation and condensation, and explain how these phase changes affect the arrangement and movement of particles.

Apply

14 The following are descriptions of interactions that occur around us in our daily lives. Describe what the products of these interactions might be and evaluate whether the changes described are useful or harmful.
  a A bike is left out in the rain so that parts of the bike that are made of steel are in contact with water for a few hours.
  b A barbecue fuelled by propane gas is turned on.
  c A hairdresser applies bleach to someone's hair.

15 Create a drawing of a reactant and a product that represents a chemical change.

Table 1 Observations

Names of reactants	Description	Names of products	Description

16 Identify which parts of Figure 2 show:

- **a** a mixture of an element and a compound
- **b** a mixture of two elements
- **c** a pure element.

Justify your decisions (by defining each term and describing how this matches the diagram).

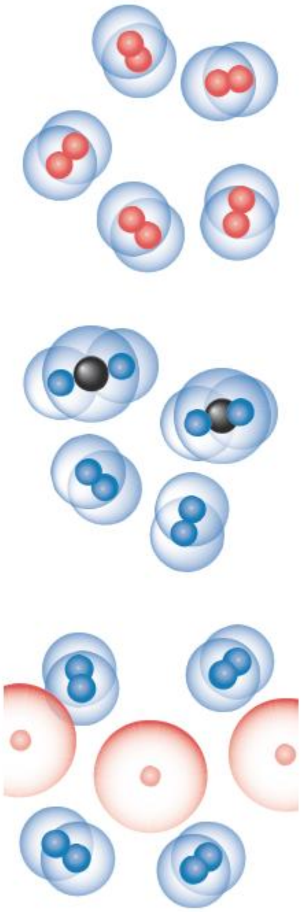


Figure 2 Different types of substances are shown here.

17 Some of the chemical changes that occur with food are described as biochemical reactions. Define the term "biochemical" and use this to evaluate the accuracy of the statement.

Critical and creative thinking

18 The use of chemistry to produce new materials has affected people's lives in a range of ways.

- **a** Discuss how new materials have changed the type of clothes that people wear.
- **b** Discuss how new materials have changed the type of food that people eat.

19 Describe a chemical change that may be harmful to the environment if it is allowed to occur in an uncontrolled way. Create a poster that describes the danger and offers a solution.

Research

20 Choose one of the following topics for a research project. A few guiding questions have been provided for you, but you should add more questions that you want to investigate. Present your research in a format of your own choosing, giving careful consideration to the information you are presenting.

Barbecue fuels

Most home barbecues burn liquefied petroleum gas (LPG) as the fuel. This is the gas that can be bought in cylinders at petrol stations, hardwares and camping stores.

- Identify the chemicals that are present in LPG.
- Compare gas barbecues and solid fuel barbecues.
- Describe the safety precautions that must be followed when storing LPG cylinders.
- Describe what could happen if an LPG cylinder is exposed to high temperatures.

Figure 3 A home barbecue with a gas cylinder.

Magic or chemistry?

Magicians use a range of tricks to misdirect the audience into thinking magic is real. Some of these tricks use chemical reactions.

- Describe the chemical reactions that could be used by magicians.
- Describe the physical changes that could be used in tricks performed by magicians.
- Explain how the "magic" happens.

Explosives

Explosions are chemical reactions that release enormous amounts of light, heat and sound very quickly. Dynamite is one of the first explosive chemical reactions that was controlled.

- Identify the person who developed dynamite from **nitroglycerine**.
- Explain why they were trying to control the chemical reaction.
- Describe how dynamite was used in mining.
- Describe how dynamite was used in war.
- The person who developed dynamite was horrified at how their discovery was used in war. Identify how the money they accumulated was used to "benefit humankind".

Figure 4 Dynamite is an explosive.

Soil testing

Some plants grow better in soils that contain certain amounts of nutrients. Gardeners who know this can test the soil to determine the amount of nutrients in the soil.

- Investigate a soil test that has a colour change if it is positive.
- Investigate the chemical reaction that causes this colour change.
- Identify the name of the nutrient and its chemical formula.
- Describe what will happen to a plant if this nutrient is not present.
- Describe how this nutrient could be added to the soil if it is needed.

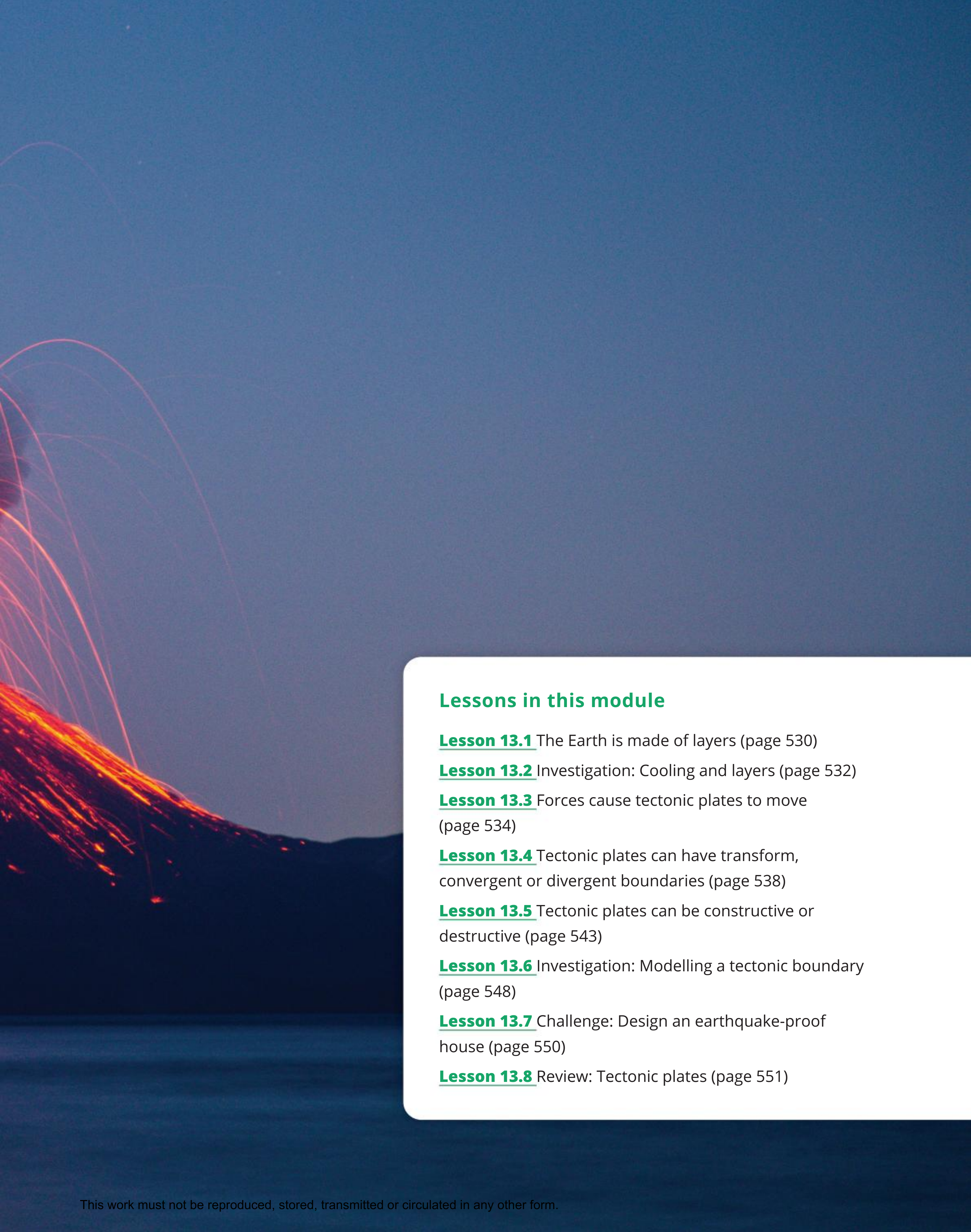
Figure 5 This soil is growing healthy plants.

Module 13

Tectonic plates

Overview

Aboriginal and Torres Strait Islander Peoples' oral histories contain ancient stories of earthquakes and volcanoes, providing evidence that the Earth is constantly changing. Theories explaining these continual changes have evolved as new evidence is discovered and explored by scientists. The Earth's crust is broken up into tectonic plates which move at an extremely slow pace. The impact of these tectonic-plate movements on humans can be significant, but engineering solutions can help reduce their effects.



Lessons in this module

Lesson 13.1

The Earth is made of layers

Learning intentions and success criteria

Key ideas

- → The Earth is made up of several layers.
- → The centre of the Earth, the core, has two layers: the outer core of liquid iron and nickel and the inner solid core.
- → The next layer, the mantle, is made up of molten rock.
- → The outer layer of the Earth that we live on is the crust.

What is the Earth made of?

Although the Earth is described as a solid planet, it began as a ball of molten (melted) materials. Scientists believe the Earth and other planets are the result of an explosion billions of years ago. According to this theory, the Earth began as a molten fragment from this explosion. The Earth's surface has continued to change slowly and is still changing – many rocks have worn down to form soil and sand, mountains and valleys have formed and the land and oceans have changed shape. Some of this change is caused by weathering and erosion at the surface. Other changes are because of the movement of molten rocks from deeper down, which push their way up to the surface and also move sections of the Earth's crust.

If we could journey deep inside the Earth, we would find that it is made up of several layers (Figure 1).

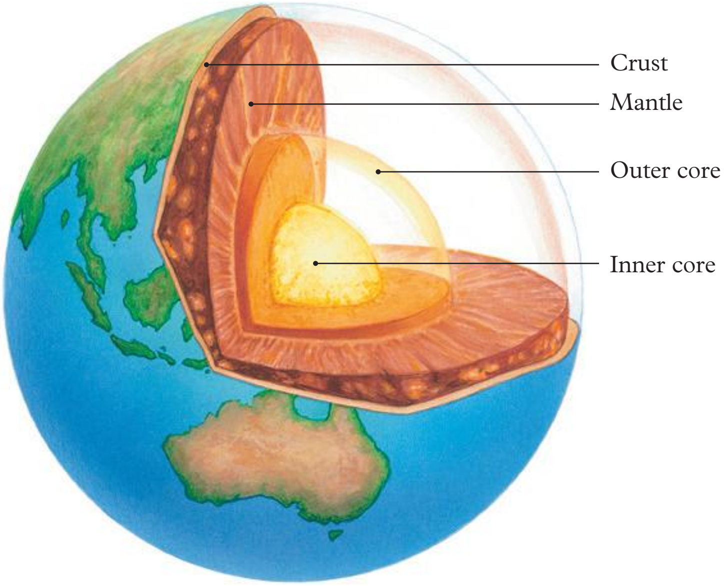


Figure 1 The percentage volume of each layer of the Earth is 1% crust, 84% mantle and 15% core (which includes the inner and outer core).

Core

The **core** is the centre of the Earth. It consists of the outer core and the inner core. The outer core is mainly made of metals, rather than rock. The main metal is iron, possibly with some nickel. The iron is molten (liquid) and very hot, with temperatures ranging from 4,000°C to 6,000°C. The heat comes from nuclear reactions, and some of the heat is left over from when the Earth was formed. The outer core gives the Earth its north and south poles and magnetic field. The temperature of the inner core is almost 10,000°C, but it does not melt or boil because of the force of the rest of the Earth pushing down on it. No geologist has ever seen the core. The deepest mines only penetrate a few kilometres into the Earth's crust, whereas the core is nearly 3,000 km below the Earth's crust.

core the centre of the Earth

Mantle

The **mantle** is between the core and the crust. It is about 2,800 km thick. Temperatures near the crust are about 500°C and at the bottom of the mantle reach 3,000°C. Although the bottom of the mantle is solid, nearer the top, the rock slowly moves and is the source of **magma**. The top part of the mantle is more like modelling clay than solid rock. It is the source of volcanoes and earthquakes.

mantle the layer of molten rock beneath the Earth's crust

magma semi-liquid rock beneath the Earth's surface

Crust

The **crust** is the outer layer of the Earth and is about 7 to 50 km thick. It is a thin, brittle outer coating, like the shell of an egg. The crust is made up of rocks and minerals, and approximately 70 per cent of it is covered by oceans. The crust is not smooth: it has hills, mountains, valleys, oceans and deserts.

crust the outer layer of the Earth

The moving crust

The **lithosphere** is made up of the Earth's crust and the top part of the upper mantle. It is the rigid, rocky outer layer of the Earth. The lithosphere is broken into a number of pieces, called **tectonic plates**. These plates float on the semi-liquid magma at the top of the mantle. The speed of movement is similar to that of fingernail growth: between 1 cm and 10 cm per year. Sometimes the tectonic plates crash into one another, causing one plate to slide under the other. The plate on top buckles under the pressure, pushing the land upwards (Figure 2). The Indo-Australian Plate, for example, is sinking under the Eurasian Plate. This has caused the Eurasian Plate to buckle, pushing up the world's highest mountain range, the Himalayas, in Asia (Figure 3).

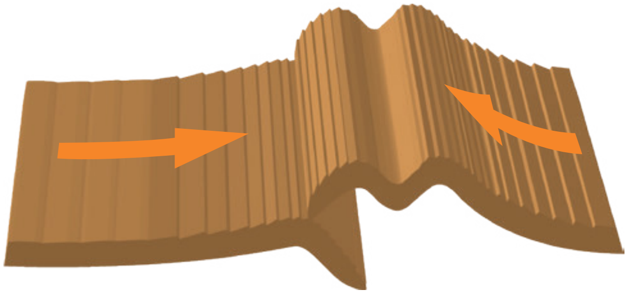


Figure 2 Colliding tectonic plates cause the Earth's surface to buckle and form mountain ranges.

Figure 3 The Himalayan mountains have been pushed up by pressure from beneath the Earth.

lithosphere the rocky outer layer of the Earth's surface that is made up of the crust and uppermost part of the mantle

tectonic plate a large layer of solid rock that covers part of the surface of the Earth; movement of tectonic plates can cause earthquakes

Check your learning 13.1

Check your learning 13.1

Retrieve

1 Identify the part of the Earth that contains tectonic plates.

2 Identify the layer that contains magma.

3 Describe the structure of the lithosphere.

Analyse

4 If the Earth's radius is about 6,370 km, use the information about the crust and the mantle to calculate the thickness of the Earth's core in kilometres.

Apply

5 "The Earth's crust is the same thickness everywhere." Evaluate this statement by comparing the approximate thickness of the Earth's crust at two extremes – the Andes mountains in South America and NSW – and deciding whether the statement is likely to be correct.

6 Examine Figure 2. Evaluate whether this diagram could be used to model the formation of the Andes mountain range (by describing how the Andes are formed, comparing this to the diagram and deciding whether it is an accurate representation).

Skills builder: Questioning and predicting

7 A team of scientists were trying to drill the deepest hole in the world. They planned to dig 20 km down.
  a Predict what it will be like to dig the ground at about 15 km down. (THINK: What layer of the Earth will they reach?)
  b Explain how you made this prediction. (THINK: What scientific knowledge did you use?)

Lesson 13.2

Investigation: Cooling and layers

Purpose

To investigate whether cooling a substance causes layers to form

Materials

- 250 mL beaker
- Copper sulfate
- Spatula
- Glass stirring rod
- Bunsen burner
- Matches
- Heatproof mat
- Tripod
- Gauze mat

Procedure

1 Set up the heating equipment and boil 50 mL of water in the beaker (Figure 1).

Figure 1 Heat the water.

2 When the water is boiling, turn off the Bunsen burner. Using the spatula, add the copper sulfate to the boiled water a little at a time, and stir constantly to make it dissolve (Figure 2). Stop when no more copper sulfate will dissolve.

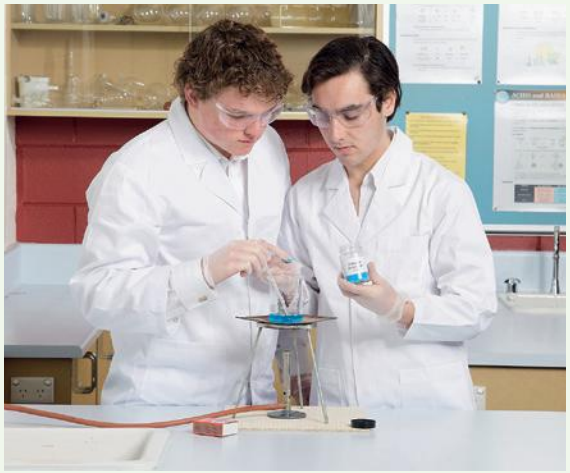


Figure 2 Add copper sulfate.

3 Allow the beaker of saturated copper sulfate solution to cool, undisturbed for about 20 minutes, then carefully place it in the fridge. Examine it after an hour if possible (or the next day).

4 When the beaker has cooled, examine its contents without moving the beaker, and observe where any solid copper sulfate might be located.

Figure 3 Examine the cooled contents.

Results

Describe what happened as the beaker cooled, and record where any solid copper sulfate is located.

Discussion

1 Contrast (the differences between) the density of solid copper sulfate and liquid water.

2 Compare (the similarities and differences between) the formation of solid copper sulfate from a solution to the formation of solid tectonic plates formed from a molten mass.

Conclusion

Explain why layers are formed when a substance cools.

Lesson 13.3

Forces cause tectonic plates to move

Learning intentions and success criteria

Key ideas

- → Continental drift is the continual movement of the continents, which have changed shape and position over millions of years.
- → Sea-floor spreading describes the process by which new oceanic crust is formed as the middle of the ocean pulls apart.
- → Plate tectonics explains how and why the continents are moving.
- → The forces involved in plate tectonics are convection current, ridge push and slab pull.

Introduction

Many theories have tried to explain why there are earthquakes, mountains and deep-sea trenches over the surface of the Earth. One of the first theories was that the Earth was cooling down and therefore shrinking, causing "wrinkles" to form on the surface. Like all theories, this idea was testable and was eventually changed and refined as new evidence became available. In this lesson, you will see how the scientific hypothesis of continental drift was suggested, discounted, modified and then revived as plate tectonics.

Plate tectonics

plate tectonics the theory that the surface of the Earth consists of a series of plates that are continually moving due to convection, ridge push and slab pull

continental drift the theory that the continents are continuously moving over time

sea-floor spreading the theory that the middle of the ocean is spreading apart, forming new oceanic crust

Pangaea a supercontinent that existed on Earth between 300–100 million years ago

Plate tectonics is a combination of two theories: **continental drift** and **sea-floor spreading**. Continental drift is the idea that the continents are continuously moving and have significantly changed shape and position over millions of years. The theory of sea-floor spreading proposes that the middle of different oceans are cracking open and spreading apart very slowly.

Continental drift

Before plate tectonics was fully understood, a German meteorologist called Alfred Wegener (1880–1930) outlined the theory of continental drift in 1912 (Figure 1). He observed that the coastline shapes of Africa and South America seemed to fit together like a jigsaw puzzle (Figure 2). Wegener proposed that all the continents once fit together in a giant supercontinent known as **Pangaea**.

Wegener proposed that Pangaea was a supercontinent that existed 220 million years ago. When it started to break up, the continents slowly drifted apart as they moved through the oceanic crust. He supported his claims with the

Figure 1 Alfred Wegener pioneered the theory of continental drift in his book *The Origin of Continents and Oceans*.

evidence of the way the coastlines of today's continents fit together and the fact that similar-looking landscapes and fossils could be found in continents that were widely separated, particularly those in America and Africa (Figure 2).

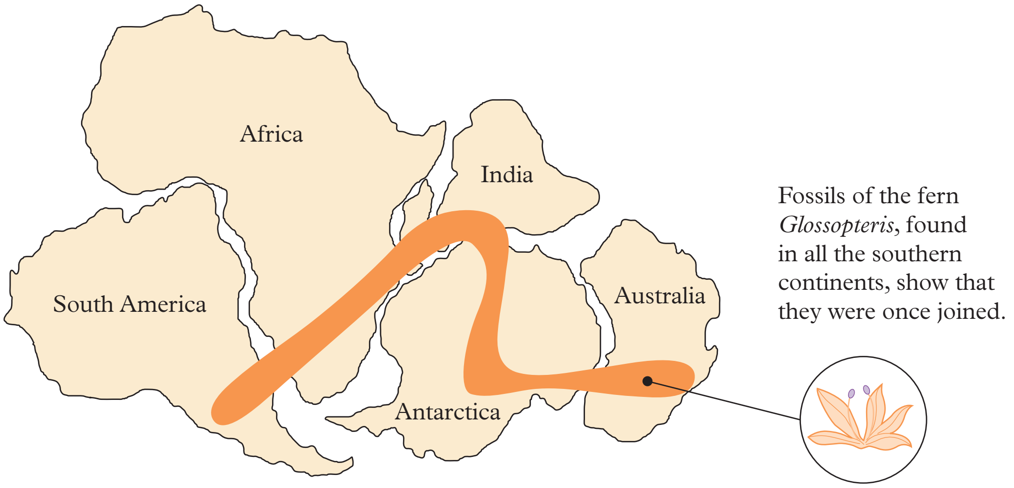


Figure 2 Given that the fossil fern *Glossopteris* cannot walk, swim or fly, how can its isolated occurrence in so many different parts of the world be explained?

For many years, other scientists did not support Wegener's theory of continental drift. It wasn't until 1950, twenty years after Wegener's death, that science developed the equipment to study smaller earth movements (seismometers) and landforms deep under the ocean (magnetometers). Maria Tharp and Bruce Heezen created the first map of the floor of the Atlantic Ocean. This map identified the Mid-Atlantic Ridge, the longest mountain range in the world, which just happens to be deep under the ocean (Figure 3).

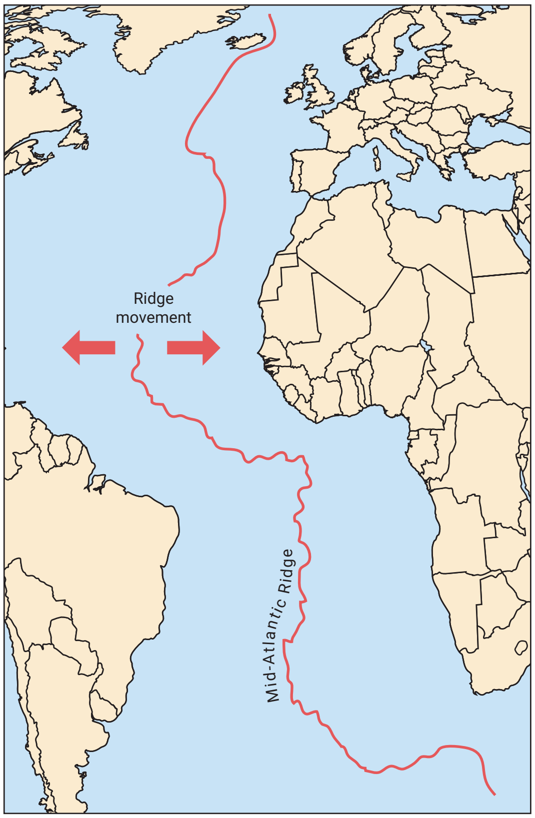


Figure 3 The Mid-Atlantic Ridge provided evidence of sea-floor spreading.

Sea-floor spreading

The idea of sea-floor spreading was proposed by US geologist Harry Hess in 1962. His evidence was based on Tharp and Heezen's discovery of the Mid-Atlantic Ridge. Hess's original hypothesis was that the liquid mantle of melted rock (magma) under the tectonic plates was moving, creating **convection currents**. This moving mantle deep inside the Earth causes magma to rise in ridges under the ocean, enabling the tectonic plates to spread and move apart.

Convection currents

In liquids and gases, thermal energy can move by **convection**. The mantle closest to the Earth's extremely hot core gains thermal energy. This means the molecules in the magma move faster. Because they move faster, they take up more space and become less dense. As a result, the heated magma near the core begins to rise to the surface, leaving room for cooler magma to take its place. The heated magma cools as it reaches the Earth's crust. As it cools, it is pushed to one side as more heated magma arrives. This causes movement

convection the transfer of thermal energy by the movement of molecules in air or liquid from one place to another in the tectonic plates that form the crust. Cool magma is more compact and dense and so it sinks, following the convection cycle. These tiny currents of force are called **convection currents**.

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

Ridge push

If convection currents occur within the Earth's mantle, then rising hot magma pushes up, creating a ridge crest. This usually occurs under the ocean. The crust gets pushed in opposing directions and, with enough force, the oceanic crust splits open, forming a mid-oceanic ridge. Gravity pulls the cooled ridges down and away from the hot magma still rising from the mantle. This pushes the ridges apart, forcing the new edges of the tectonic plate apart. This force is called **ridge push**.

ridge push the force pushing the edges of tectonic plates away from each other when a ridge crest has formed

Oceanic crust versus continental crust

The Earth's crust comes in two types: oceanic crust and continental crust. The crust is thickest under the continents and thinnest under the oceans. As we have learnt, oceanic crust is formed at spreading ridges, where rocks from the mantle are pushed up to the surface. These rocks are dense and are rich in iron and magnesium. Continental crust is made predominantly of silicon and oxygen, and though it is thicker than oceanic crust, it is much lighter.

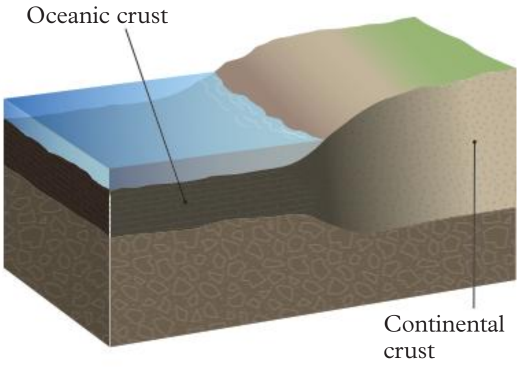


Figure 4 The oceanic crust is thinner than the continental crust, but it is denser.

Slab pull

Sometimes, tectonic plates move towards each other. If one plate is denser (the particles are more tightly packed together), it will sink beneath the other plate. This is known as **subduction**. Sometimes the top, less-dense plate will rise, forming a mountain range such as the Andes. Other times, the sinking plate (slab) will be pulled downwards, dragging down the rest of the tectonic slab due to gravity. This force is called **slab pull**.

subduction the movement of one tectonic plate under another tectonic plate

slab pull the force pulling a tectonic plate beneath a less dense tectonic plate

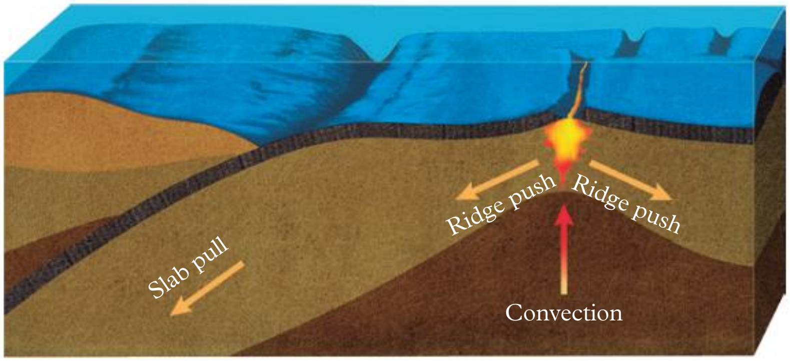


Figure 5 Ridge push and slab pull work together to move tectonic plates.

The movement of the plates explains the existence of landforms such as **continental shelves** and deep trenches in the ocean floor. It also explains how earthquakes and volcanoes are distributed and the very young age of parts of the sea floor.

continental shelf a flat area under shallow ocean water at the edge of a continent

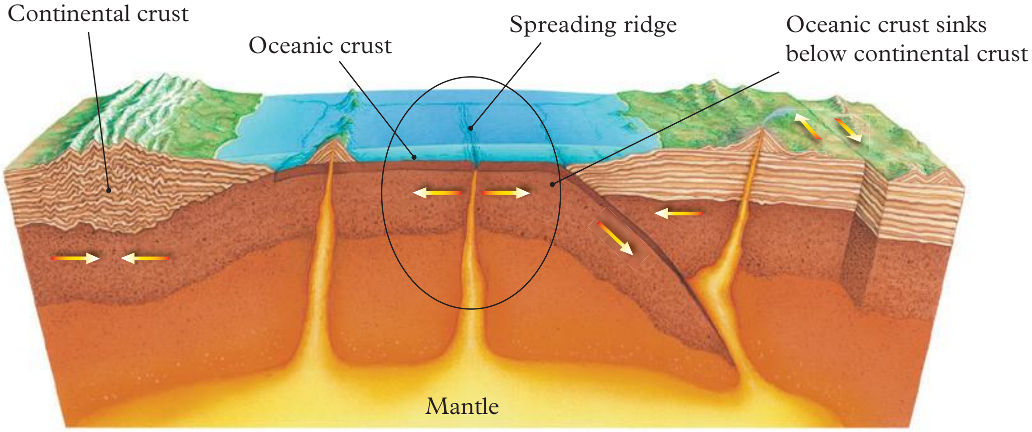


Figure 6 Tectonic plate movement

Check your learning 13.3

Check your learning 13.3

Retrieve

1 Define the term "slab pull".

Comprehend

2 Describe how a ridge crest forms.

3 Use a labelled diagram to describe how convection currents move in the mantle.

Analyse

4 Examine a world map. Apart from Africa and South America, identify the other regions of the world that look as if they could fit closely together.

5 Contrast (the differences between) the continental drift and plate tectonics theories.

Apply

6 Describe the evidence that Wegener presented in support of continental drift. Discuss why many scientists at the time may have rejected the idea.

Skills builder: Problem solving, communicating

7 As a scientist, you must think critically about theories that are presented. Both Wegener and Hess provided a solution to explain the Earth's movement. Consider their theories.

  a Compare their explanations. (THINK: What are the differences in their models?)

  b Evaluate how they developed their theories using "working scientifically" principles. (THINK: Did they conduct tests? Observe data and make predictions? Use problem-solving techniques?)

8 Scientists present their findings in a logical progression. They present ideas in the order they were developed. In this task, you must present the process of how heat and gravity change the Earth's crust. You need to present this as an explanation, including the steps involved in the process. You must present this as a diagram and ensure that you accurately explain the information. (THINK: Why is the process important? What is the key information for each stage in the process?)

Lesson 13.4

Tectonic plates can have transform, convergent or divergent boundaries

Learning intentions and success criteria

Key ideas

- → At transform boundaries, tectonic plates slide past one another.
- → At convergent boundaries, tectonic plates come together and one will subduct under the other, forming mountains.
- → At divergent boundaries, tectonic plates move apart.

Introduction

Plate tectonics explains a wide range of features of the Earth. These features were once studied separately, but they are now unified by a single concept: plate behaviour at plate boundaries (Figure 1). There are three general types of plate boundaries, based on the direction of plate movement.

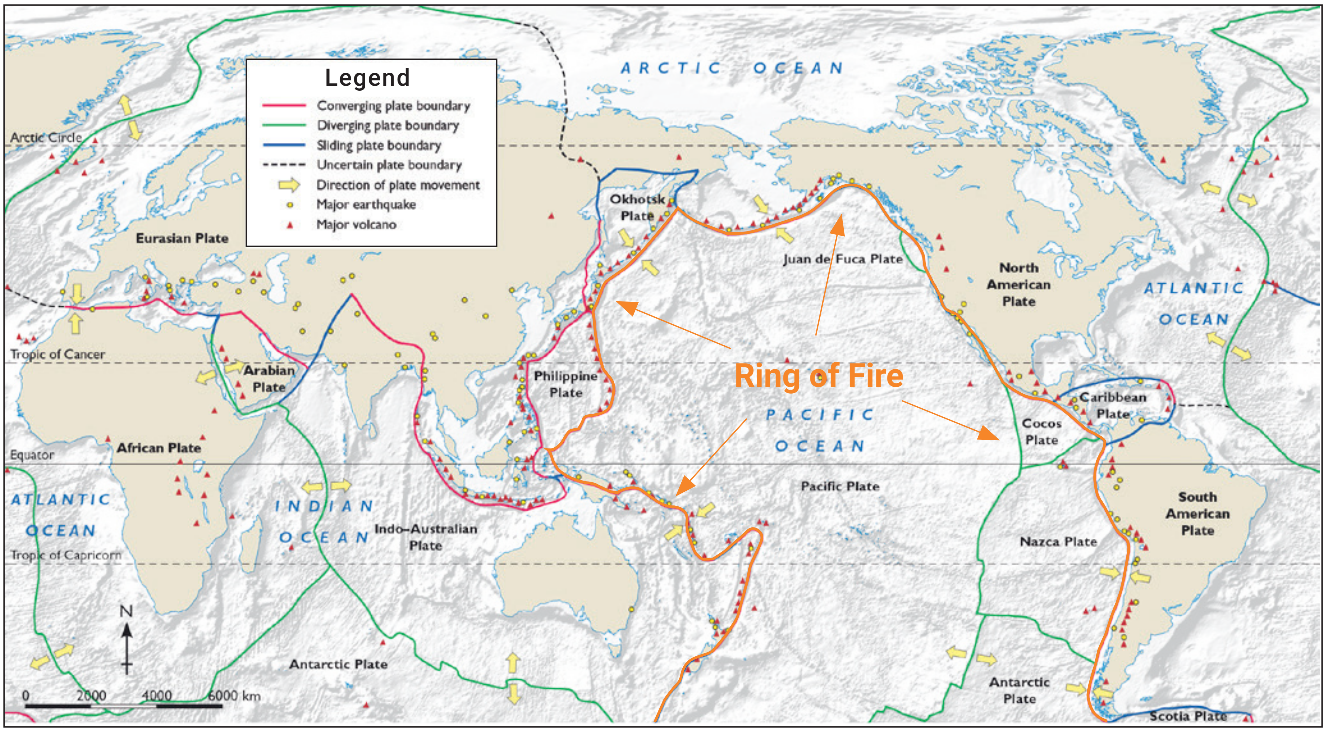


Figure 1 The "Ring of Fire" is an area around the Pacific Ocean where a large number of volcanoes are found. This provides clues as to the location of a tectonic boundary.

Transform boundaries

One plate can slide past another along a single fault line. This is called a **transform boundary** (Figure 3, Figure 4 and Figure 5). A **fault** is a fracture in the rock where movement has occurred.

The two plates involved in a transform boundary can become jammed. Over a period of time, the pressure between the two plates builds up and can lead to the plates slipping. This slipping can cause catastrophic earthquakes, such as the large earthquake that destroyed San Francisco in 1906 when the transform fault line slipped by up to 5 m.

Plate material is not created or destroyed: the plates just slide against each other.

transform boundary the boundary between two tectonic plates that are sliding past each other

fault a fracture in rock where the tectonic plates have moved

Figure 2 The San Francisco earthquake in 1906 destroyed much of the city.

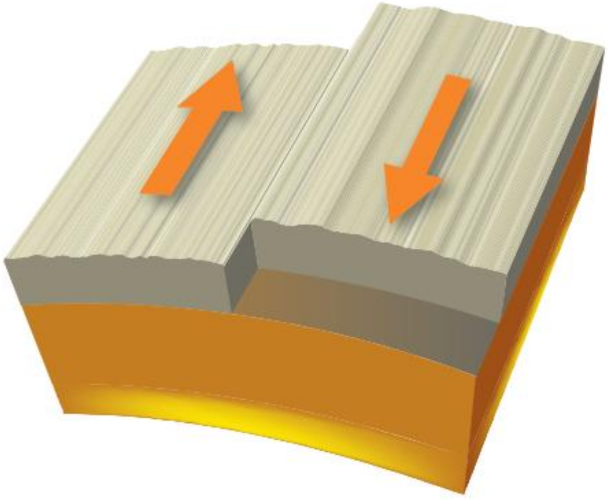


Figure 3 Transform boundary: one plate slides past another

Figure 4 Satellite image of the Southern Alps, New Zealand. The Alpine Fault, a transform boundary, runs along the western edge of the snowline on the South Island.

Figure 5 The San Andreas Fault, which runs along the western coast of California, USA, is created by transform boundaries.

Convergent boundaries

convergent boundary the boundary between two tectonic plates that are moving together

At convergent plate boundaries, two plates move towards each other. There are generally three types of **convergent boundaries**, depending on the plates involved. Mountain ranges, volcanoes and trenches can all be formed by convergent boundaries. Many of the world's major landforms are formed by the collision of plates at convergent boundaries.

Ocean-to-continent collision

ocean trench a deep ditch under the ocean along a tectonic plate boundary

When oceanic crust collides with continental crust, the denser oceanic landform is subducted or pushed downwards into the mantle. The top continental crust is pushed upwards and creates a line of mountains along the crumpled edge (Figure 6). It can also create volcanoes as heat rises through cracks in the crust. A deep **ocean trench** may form at the line of plate contact.

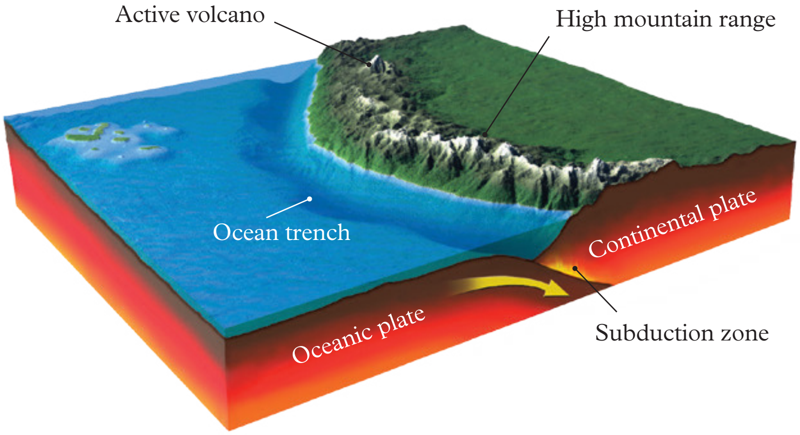


Figure 6 Ocean-to-continent collision causes subduction, and creates mountains, volcanoes and ocean trenches.

Continent-to-continent collision

When two continental plates collide, they have similar densities so no subduction takes place. Instead, the edges of the two plates crumble and fold into high mountain ranges (Figure 7). This is how the Himalayas in Asia formed, when the Indian plate collided with the Eurasian plate about 50 million years ago.

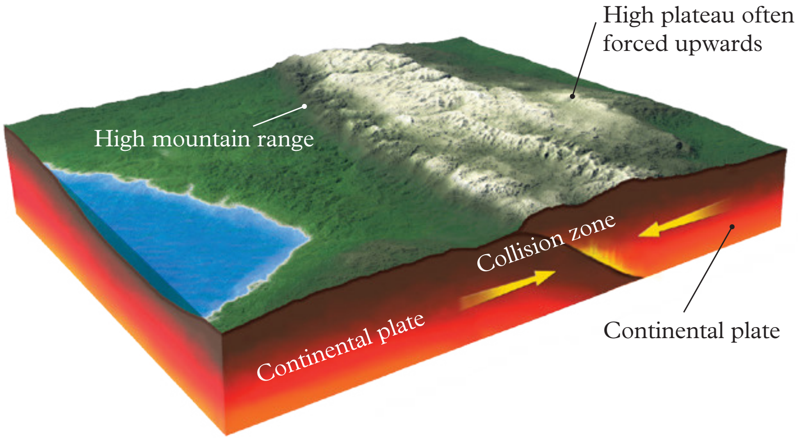


Figure 7 Continent-to-continent collision creates high mountain ranges.

Ocean-to-ocean collision

When two oceanic plates collide, the older, denser crust subducts below the newer crust, creating a deep ocean trench.

The subduction also creates a line of undersea volcanoes that may reach above the ocean surface as an island arc (Figure 8).

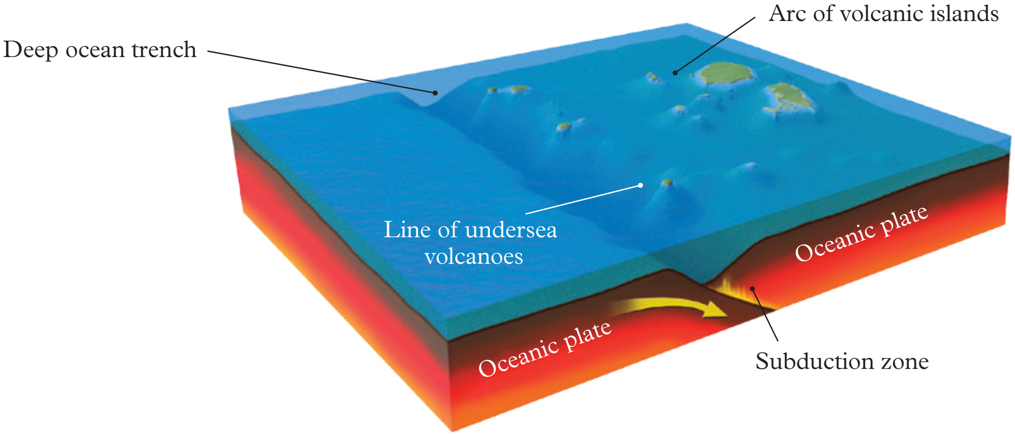


Figure 8 Ocean-to-ocean collision causes subduction and creates a trench and a line of undersea volcanoes. Volcanic islands can be seen when the undersea volcanoes reach the ocean's surface.

Divergent boundaries

Divergent boundaries are plate boundaries that are moving apart. They form different features than those of convergent and transform boundaries. These spreading boundaries can occur in the middle of the ocean or in the middle of land. The break up of the supercontinent Pangaea was probably due to divergent plate boundaries.

divergent boundary the boundary between two tectonic plates that are moving apart

Hot rising mantle rock from deep within the Earth might be the first step in a continent breaking apart. As the mantle rock rises, the continental crust is lifted and thins out. Cracks form and large slabs of rock sink into the Earth, forming a **rift valley** like those found in East Africa (Figure 9).

rift valley a deep valley that forms as a result of tectonic plates moving apart on land

Figure 9 The East African rift valleys may represent the initial stages of the break up of a continent.

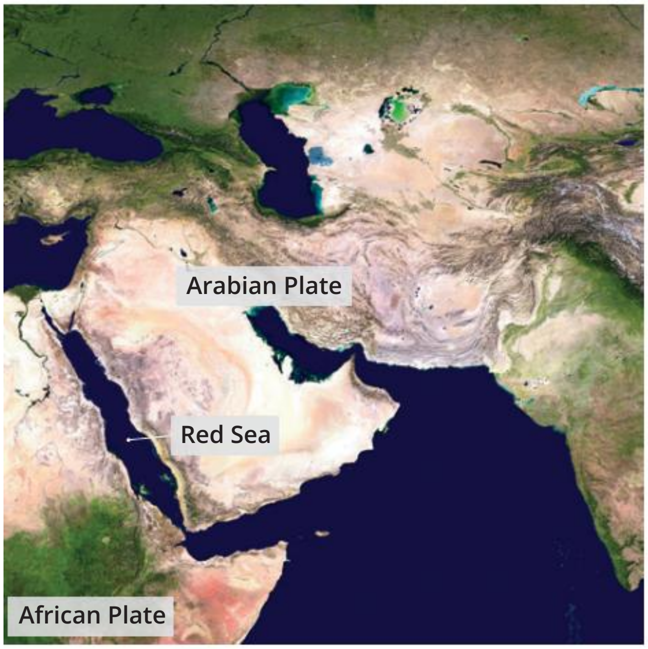


Figure 10 The Red Sea has formed as the African and Arabian Plates have diverged.

Making oceans

As the divergence process continues, the continental crust separates and a narrow sea or lake may form. The Red Sea between the Arabian and African Plates is thought to be a developing divergent boundary (Figure 10). Eventually, oceans are formed and a **mid-ocean ridge** is created (Figure 11).

Mid-ocean ridges are very wide, up to 4,000 km. Sea-floor spreading occurs at a rate of only 5 cm per year, but none of the ocean floor is older than 180 million years.

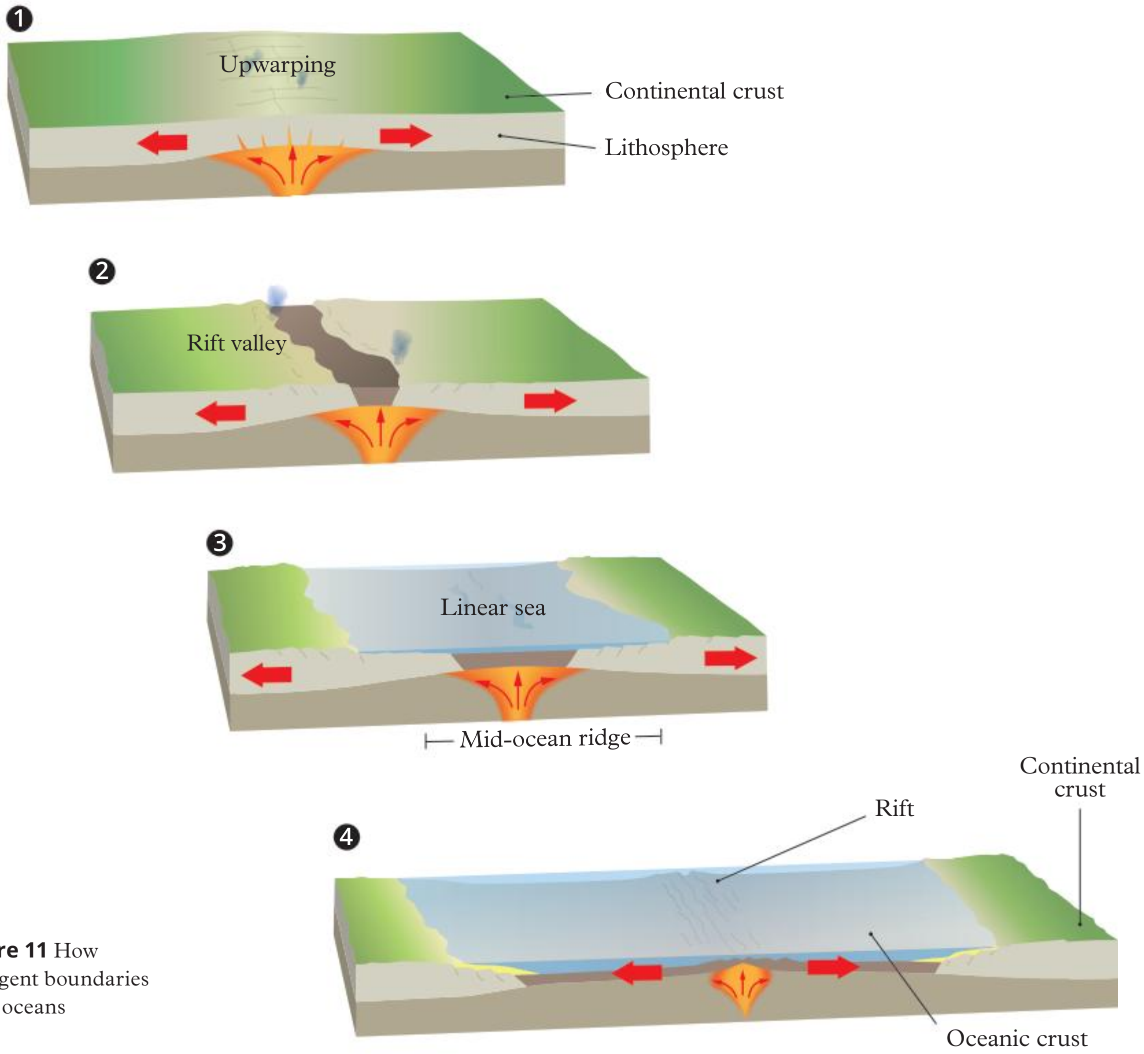


Figure 11 How divergent boundaries form oceans

Check your learning 13.4

Check your learning 13.4

Retrieve

1 Identify the factor that determines which plate subducts at a convergent boundary.

Comprehend

2 Describe the type of plate movement that happens at a transform boundary.

3 Describe what causes the continental crust to spread and break at a divergent boundary.

4 Use Figure 1 to describe where the major mid-ocean ridges are located.

5 Use Figure 1 to describe where the divergent plate boundaries are located.

6 Explain how divergent boundaries can produce earthquakes and volcanic activity.

7 Transform boundaries are sometimes called strike–slip fault zones. Explain why both names are appropriate.

Analyse

8 Use the location of the tectonic plates in Figure 1 to describe the location of volcanoes. Compare (the similarities and differences between) these and the location of earthquakes.

Skills builder: Questioning and predicting

9 Using your knowledge of tectonic plate boundaries, write a scientific question and a prediction for the following scenarios.
  - **a** The "Ring of Fire" is located in the Asia-Pacific region. Because of its location across tectonic plates, it experiences heightened geological activity. (THINK: Look at Figure 1; what geological features are present? Can you write a measurable question for this area?)
  - **b** The Australian Alps run across the NSW and Victorian border. The alps formed after geological activity. (THINK: Look at Figure 1; what geological features are near this location? Is future geological activity likely?)

Lesson 13.5

Tectonic plates can be constructive or destructive

Key ideas

→ Movement of tectonic plates can cause destructive earthquakes or tsunamis.

→ Molten mantle can escape from volcanoes and become lava.

→ Lava can form new islands.

Learning intentions and success criteria

Introduction

The boundaries between the tectonic plates create a lot of pressure as they try to move against each other. This pressure can be released suddenly in the form of an earthquake which in turn can form a tsunami.

Earthquakes can cause tsunamis

tsunami a series of large waves that result from an underwater earthquake

Undersea earthquakes can move the sea floor and push up the water to form a wave known as a **tsunami** (Figure 1). An earthquake in northern Japan in 2011 measured a magnitude of 9.0 on the Richter scale. The earthquake was centred 140 km off the coast of Japan and sent a 10 metre high wall of water towards coastal towns and cities. The force of a tsunami can be enormous – enough to demolish buildings, and to lift cars and even small ships.

The tsunami wave also travelled away from Japan, right across the Pacific Ocean, and was experienced as far away as North and South America and the Pacific Islands. A small wave even reached northern Australia.

Japan lies near the boundaries of three tectonic plates: the Pacific, Eurasian and Philippines plates, and it has the highest amount of earthquake activity (known as **seismic** activity) of any country.

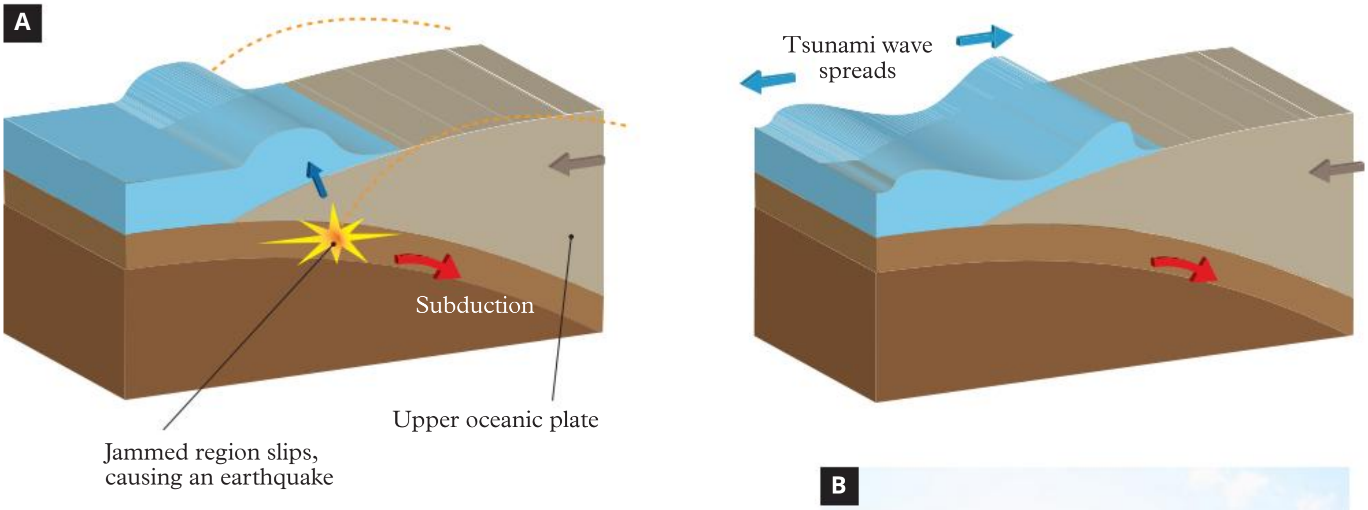


Figure 1 (A) How an earthquake causes a tsunami; (B) the aftermath of the earthquake and tsunami in northern Japan in 2011

Volcanoes and tsunamis

Volcanoes pose great danger to those who live near them. The volcanic eruption of Krakatoa, Indonesia, in 1883 caused a tsunami that raced across the ocean and crashed onto nearby islands. The tsunami killed 36,000 people. Krakatoa's blast was heard 5,000 km away and ash rose 80 km into the atmosphere.

Volcanic eruptions spew lava and ash onto the surrounding land. When this material is broken down by the action of wind and water and mixed with organic material from plants and animals, it forms some of the richest soil in the world, highly suitable for growing all kinds of plants. So, in spite of the dangers, people continue to live near volcanoes because of the fertile soil they provide.

Figure 2 Volcanic eruptions can cause tsunamis.

Hawaiian Islands

The Hawaiian Islands are in the centre of the Pacific Plate. Hawaii has frequent volcanic activity, despite not being located near a mid-ocean ridge. Most geologists believe this volcanic activity is caused by the movement of the Pacific Plate over a **hot spot** beneath the plate. This hot spot is where a plume of hot magma from the mantle comes up through a thin area in the crust and creates a volcano.

In the case of the Hawaiian Islands, the hot spot formed an undersea volcano (Figure 3). Over time, the volcano grows until it pokes above the ocean surface and creates an island. As the plate moves over the hot spot, other islands are formed over millions of years and an island "chain" is created.

The centre of a plate usually lacks earthquakes, volcanoes or folded mountain ranges because it is a long way from a plate boundary, although these landforms are still possible in areas of weakness or thinning. The theory of plate tectonics and what happens at the plate boundaries corresponds with the distribution of earthquakes and volcanoes around the world. Consider Australia's location and the limited number of earthquakes and extinct volcanoes on our continent.

hot spot a region where Earth's outer crust is thin and the magma is hotter than the surrounding area

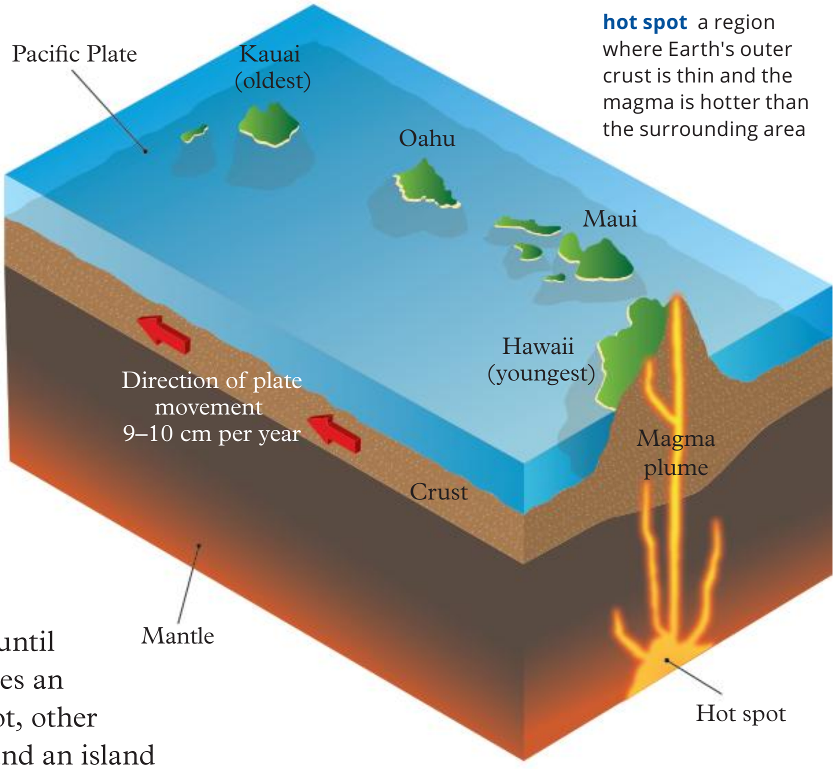


Figure 3 How the Hawaiian Islands were formed. Hot spots result from magma pushing through thin areas of the Earth's crust. (Only the largest islands are shown.)

Figure 4 Evidence of volcanic activity on the Hawaiian islands: (A) rocks that appear to flow into the sea formed from old lava flows; (B) mountains rising out of the sea; (C) and (D) volcanic rock formations; (E) steam rising from craters and (F) lava flowing from active vents

Earthquakes in Australia

Australia is located in the centre of the Indo-Australian Plate. It is thought that the plate formed 43 million years ago when two smaller plates fused. Although we think of tectonic plates as being fixed, two large earthquakes (measuring 8.6 and 8.2 on the Richter scale) beneath the Indian Ocean in 2012 suggest that these two plates may be breaking apart again. The age of the tectonic plate on which Australia is located and Australia's central position on the plate have both resulted in minimal earthquake activity.

There are, however, still more than 300 magnitude 3.0 or greater earthquakes in Australia every year. Our plate, the Indo-Australian Plate, is moving north towards the Eurasian, Philippine and Pacific Plates. This causes stress within our plate, and when this stress is released, it creates earthquakes.

One of Australia's worst earthquakes was of magnitude 5.6 and struck near the city of Newcastle in NSW on 28 December 1989. It killed 13 people and injured 160. Larger earthquakes have occurred in Australia, but the damage depends on how close they are to the surface and to large cities. Figure 5 shows Australia's earthquake and tsunami risk.

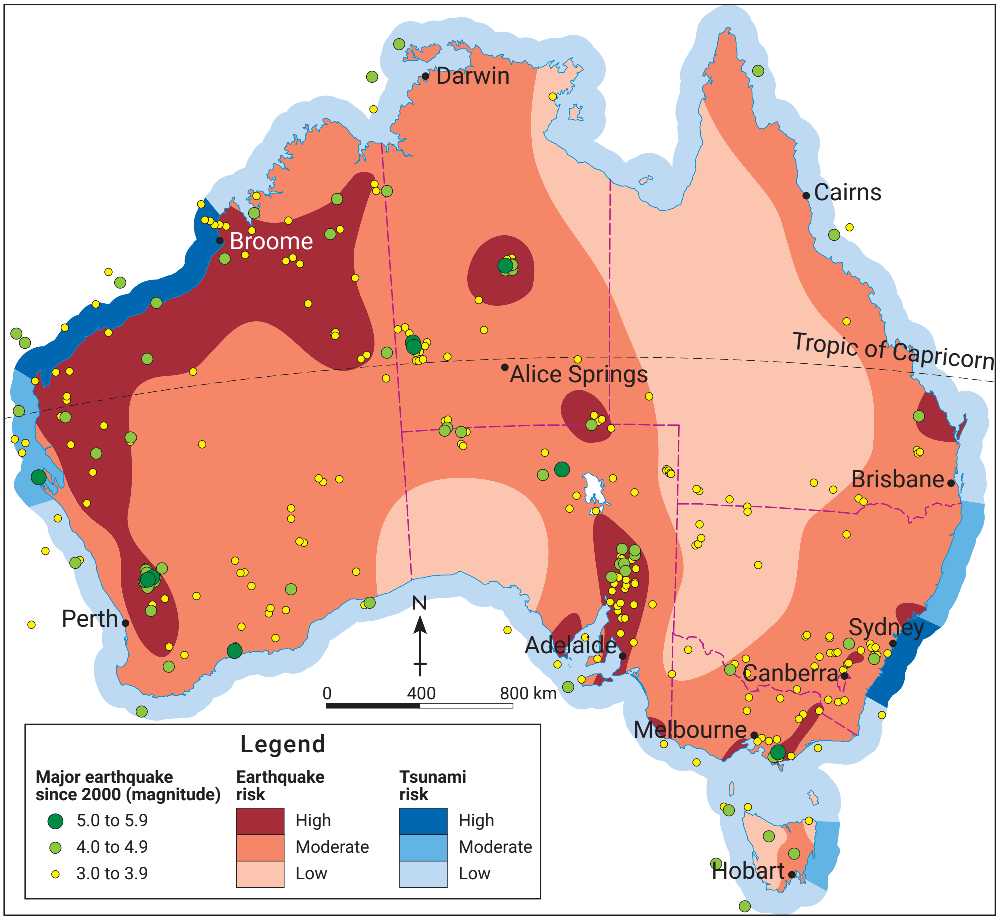


Figure 5 Australia's most recent earthquakes, and our earthquake and tsunami risk

Aboriginal and Torres Strait Islander Peoples provided evidence of earthquakes and volcanoes

The oral traditions of Aboriginal and Torres Strait Islander Peoples provide us with knowledge from many thousands of years ago about volcanic eruptions, earthquakes and tsunamis. These events have shaped Australia's landscape.

Volcanic activity in Far North Queensland created Lake Barrine in Crater Lakes National Park. The Ngadjonjii people of this region have narrated their knowledge of volcanic events in the area. These narratives explain how the volcanic crater lakes formed and how the landscape changed as a result of the volcanic eruption. This knowledge, which has been passed down for over 10,000 years, has been confirmed by modern scientific methods.

The oral traditions of the Awabakal people from the Hunter region of NSW highlight their knowledge of earthquakes in the region. In a similar way, the Gundungarra people in South-Eastern NSW and the Kambure people in the Kimberley region of Western Australia have kept oral records of tsunami events that have impacted the coast.

In addition, there are many stories by Aboriginal and Torres Strait Islander Peoples to explain the cause of these natural events. For example, the Awabakal peoples' story to explain earthquakes describes a giant kangaroo that attacked a wallaby. The angry wallabies chased the kangaroo all the way to Muloobinda (place of the "edible sea fern"). When he neared the sea, the wallabies could not see him and thought he had drowned. However, the kangaroo is still there, and whenever he shakes his giant tail it causes the land to shake.

Check your learning 13.5

Check your learning 13.5

Retrieve

1 Recall two ways that the movement of tectonic plates can be destructive.

Comprehend

2 Describe a tsunami.

3 Describe where most earthquakes occur. Explain why earthquakes occur in these regions.

4 Explain how the movement of tectonic plates can be constructive.

5 Explain why there are few large earthquakes in Australia.

Apply

6 Like Australia, the Hawaiian Islands are in the centre of a tectonic plate. Discuss why the Hawaiian Islands have volcanoes and Australia does not.

Skills builder: Conducting investigations

7 Many geological sites around the world hold cultural significance. Before conducting scientific fieldwork in these areas, this significance must be acknowledged.

   a Select and describe one geological area in NSW. (THINK: What are its features? How was it formed? What is its name?)

   b Identify one ethical consideration you need to check before conducting fieldwork. (THINK: What are the cultural or societal impacts of the fieldwork? Can you conduct the fieldwork elsewhere?)

   c Identify the next steps to take before proceeding. (THINK: Who do I need to contact? Does this need approval?)

Lesson 13.6

Investigation: Modelling a tectonic boundary

Introduction

Scientists can use a variety of equipment to measure the location (latitude and longitude) and strength of an earthquake. The amount of damage that an earthquake can do is dependent on the magnitude and the depth of the plate movement. Table 1 shows a summary of earthquake data from South America.

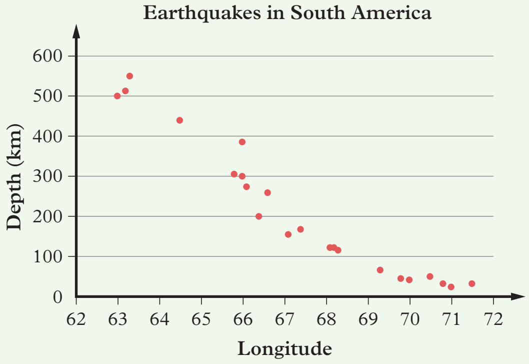


Figure 1 A scatter graph showing the longitude and depth (in km) of earthquakes in South America.

Purpose

To recreate a 2D model of a tectonic boundary

Materials

- Map of South America
- Computer
- Excel (or other spreadsheet software)

Procedure

Part A

1 Make a copy of the map of South America.
2 Map the location of each earthquake (the latitude and longitude) identified in Table 1.

Part B

1 Open an Excel spreadsheet on your computer.
2 Enter the “Longitude” and “Depth (km)” from Table 1 into the spreadsheet.
3 Highlight the two columns on the spreadsheet.
4 Select the “Insert” tab and “Scatter graph”.

Discussion

1 Describe the location of the earthquakes on the South American continent.
2 Explain the location of the earthquakes on the South American coast.
3 Describe the relationship between the longitude of the earthquakes and the depth of the earthquakes.
4 Describe what is happening to the two tectonic plates at that boundary.

Table 1 Earthquake data from South America

Station	Latitude	Longitude	Depth (km)	Magnitude
1	19.8	66.6	259	4.6
2	27.8	63.2	513	5.1
3	26.2	63.3	550	4.8
4	31.2	71.5	33	5.0
5	23.2	66.4	200	4.8
6	23.5	71.0	25	5.0
7	24.5	70.8	33	5.0
8	21.3	68.2	122	4.7
9	23.6	70.0	42	5.0
10	23.5	70.5	50	–
11	22.9	68.3	115	4.8
12	34.1	69.8	45	–
13	22.3	66.1	274	5.0
14	23.2	69.3	67	4.9
15	22.5	67.4	168	4.5
16	19.5	65.8	305	4.5
17	21.4	68.1	123	5.1
18	27.0	63.0	500	4.9
19	27.2	67.1	155	4.7
20	20.4	66.0	300	4.5
21	25.6	66.0	385	5.0
22	22.2	64.5	440	4.8

Lesson 13.7

Challenge: Design an earthquake-proof house

Design brief

Design and build a house that will be stable in an earthquake zone. Test your design by placing the house in a large clear-sided tub of sand and water.

Criteria restrictions

- The house can be built from the materials provided (these might include pipe cleaners, icy pole sticks, sticky tape, paper, aluminium foil, cardboard, plasticine, play-dough or wire).
- The house must be closed-in with walls and a roof.
- The house must have foundations that go into the sand.

Questioning and predicting

- Identify the materials that you will use.
- Identify the properties of the materials that you will use.
- Use your knowledge of earth movement to explain why your house will survive an earthquake.

Planning and conducting

- Fill the tub three-quarters full with fine sand. Pour water into the container until it is just below the surface. Make sure that it does not rise above the surface of the sand.
- Explain how you will measure the effectiveness of your house design.
- Describe the type of earth movement and the length of time of the earthquake.

Processing, analysing and evaluating

1. Describe the movement of your designed house during the model earthquake.
2. Compare the effectiveness of your design against other houses designed by your peers.
3. Describe the limitations of your design (the earth movements that will cause it to collapse).
4. Describe how you could create a large-scale version of your design for a real house.
5. Describe how you would modify your design if you were doing this experiment again.

Communicating

Present the various stages of your investigation in a formal report.

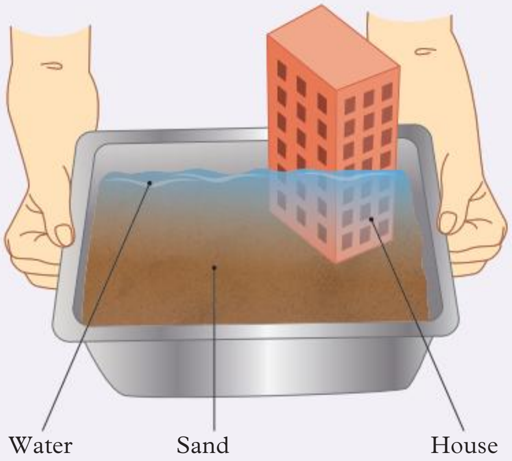


Figure 1 General set-up of experiment

Lesson 13.8

Review: Tectonic plates

Summary

Lesson 13.1 The Earth is made of layers

- The Earth is made up of several layers.
- The centre of the Earth, the core, has two layers: the outer core of liquid iron and nickel and the inner solid core.
- The next layer, the mantle, is made up of molten rock.
- The outer layer of the Earth that we live on is the crust.

Lesson 13.3 Forces cause tectonic plates to move

- Continental drift is the continual movement of the continents, which have changed shape and position over millions of years.
- Sea-floor spreading describes the process by which new oceanic crust is formed as the middle of the ocean pulls apart.
- Plate tectonics explains how and why the continents are moving.
- The forces involved in plate tectonics are convection current, ridge push and slab pull.

Lesson 13.4 Tectonic plates can have transform, convergent or divergent boundaries

- At transform boundaries, tectonic plates slide past one another.
- At convergent boundaries, tectonic plates come together and one will subduct under the other, forming mountains.
- At divergent boundaries, tectonic plates move apart.

Lesson 13.5 Tectonic plates can be constructive or destructive

- Movement of tectonic plates can cause destructive earthquakes or tsunamis.
- Molten mantle can escape from volcanoes and become lava.
- Lava can form new islands.

Review questions 13.8

Review questions Module 13

Retrieve

1 Identify which two of the following have led to our understanding of plate tectonics.

A Continental drift
B Subduction
C Sea-floor spreading
D Magnetometers

2 Identify the type of plate collision where subduction is most likely to occur.

A Continent-to-mantle
B Continent-to-continent
C Ocean-to-ocean
D Ocean-to-continent

3 Identify the type of natural disaster that can be caused by an undersea earthquake.

A Hurricane
B Volcanic eruption
C Tsunami
D Bushfire

4 Recall the evidence that the scientist Alfred Wegener used to support his theory of continental drift.

5 Define the following terms.
- **a** Subduction
- **b** Divergent boundary
- **c** Ridge push
- **d** Sea-floor spreading
- **e** Slab pull
- **f** Convergent boundary
- **g** Convection

Comprehend

6 Describe Pangaea and what happened to it.

7 Describe the three forces that move tectonic plates over the surface of the Earth.

8 Describe the cause of major volcanic eruptions and earthquakes.

9 Most earthquakes occur at plate boundaries. Explain how an earthquake can occur in the middle of a plate.

10 Explain why continental crusts cannot be subducted.

11 Explain how sea-floor spreading accounts for the young age of the sea floor.

Analyse

12 The Himalayas formed when India collided with the Eurasian Plate. Mount Everest, the highest mountain on Earth, is 8,848.86 metres high and continues to be uplifted at a rate of about 1 cm per year. Assuming there is no erosion, calculate the height of Mount Everest in 1 million years if it maintains its current rate of uplift.

Figure 1 Himalayan mountain peaks seen from the Mount Everest Base Camp trek.

13 Examine Figure 2 which shows a topographic image of the Mid-Atlantic Ridge. Consider how this provides evidence of sea-floor spreading.

Figure 2 The Mid-Atlantic Ridge

14 If part of the Pacific Plate is moving at a rate of 10 cm per year, calculate how far it would move in:
- **a** 100 years
- **b** 10,000 years
- **c** 1 million years.

15 Contrast the different layers of the Earth.

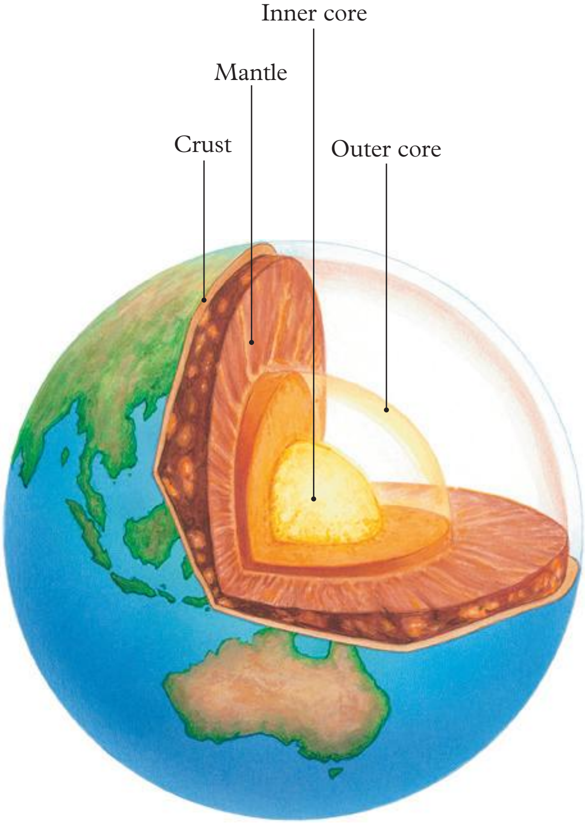


Figure 3 Layers of the Earth

16 Connect the following terms with their definitions in Table 1.

Table 1 Match the terms with their definitions

Term	Definition
Mantle	Central part of the Earth
Crust	Layer of hot, semi-molten rock below the crust
Oceanic crust	Theory that states that the continents move through oceanic crust
Continental crust	Theory that describes why large plates of the Earth's crust gradually move
Plate tectonics	Less dense crust containing continents
Tectonic plate	Hot liquid rock that comes up from the mantle
Continental drift	Thin, semi-rigid outer layer of the Earth
Convection current	Large area that may include continent and sea floor
Magma	Dense crust under the sea floor
Core	Movement of liquids or gases caused by the rising of hot material

Apply

17 If Australia moves north to collide with Indonesia and Malaysia, determine the geographical features that will form and how our climate will change.

18 Once there was one supercontinent called Pangaea. Initially, it split into two. One part, Laurasia, moved north while the other, Gondwanaland, moved south. Laurasia gave rise to Europe, Asia and North America. Gondwanaland gave rise to Africa, South America, Australia, India and Antarctica. Discuss the climate changes each continent faced as it drifted to its current position, and explain why many of today's plants and animals share physical similarities with those that originally inhabited the Gondwanaland subcontinents.

Social and ethical thinking

19 In 2009, there were a series of minor earth tremors in the Italian city of L'Aquila. Six scientists (three seismologists, a vulcanologist and two seismic engineers) provided advice to the city that an ongoing series of small and medium-sized tremors did not necessarily mean a large earthquake was going to occur. As a result, the citizens did not take precautions, and many were indoors on the night a 5.9 magnitude earthquake hit. The scientists were charged with manslaughter for the deaths of 308 people because they had failed to predict the earthquake. Their initial conviction was eventually overturned. Evaluate the fairness of this trial by:

- describing how the local townspeople would have reacted if the scientists had warned of the impending earthquake
- describing how the local townspeople would have reacted if the scientists had not offered any advice
- describing the accuracy of earthquake predictions
- deciding whether the scientists should have offered any advice to the townspeople.

Figure 4 The earthquake that struck L'Aquila in 2009 was one of the deadliest in Italy.

Critical and creative thinking

20 Create a poster or multimedia presentation about a famous earthquake or volcanic eruption. Describe the facts of the earthquake or volcanic eruption and what plate movement caused it, along with the social, environmental and economic impacts and the subsequent recovery process.

21 The Mariana Trench is located where the Pacific Plate is subducting under the Mariana Plate. Its average depth is 11 km below the surface of the water. Surprisingly, ocean explorers have found life at the bottom of the Mariana Trench. Investigate the organisms that live so deep and how they survive.

22 Imagine you could travel into the future to a time when your local environment is drastically different from how it is today. Base your imagined scenario on the plate movements of the Australian continent. Create a travel brochure for a future tourist destination or journey on this new Earth.

Research

23 Choose one of the following topics to research. Some questions have been included to get you started. Present your findings in a format of your own choosing (such as filming a documentary), giving careful thought to the information you are communicating and your likely audience.

The Earth's crust

The lithosphere and the asthenosphere are different internal layers of the Earth.

- Define the term "lithosphere".
- Describe the asthenosphere.
- Describe how the two "spheres" interact.
- Identify and describe other "spheres" of the Earth.
- Explain how they interact with the lithosphere and the asthenosphere.

Subduction zones

The subduction of one plate under another is well understood by scientists today, but how this process begins is not.

- Explain what geologists mean by subduction.
- Identify which plates are involved in subduction.
- Describe what happens to the plates during subduction.
- Describe the geological features that are associated with subduction zones.

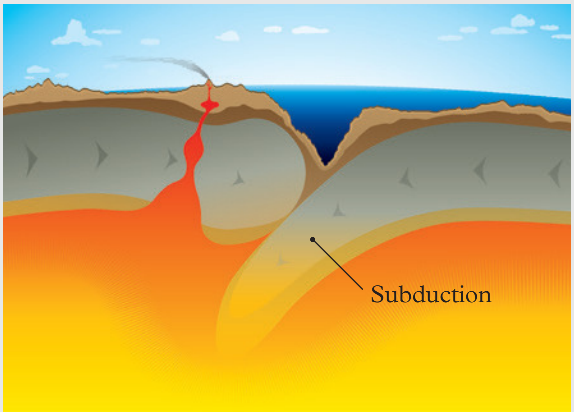


Figure 5 Subduction zone

Magnetic striping

Magnetic striping was considered by some to be the final proof of plate tectonics.

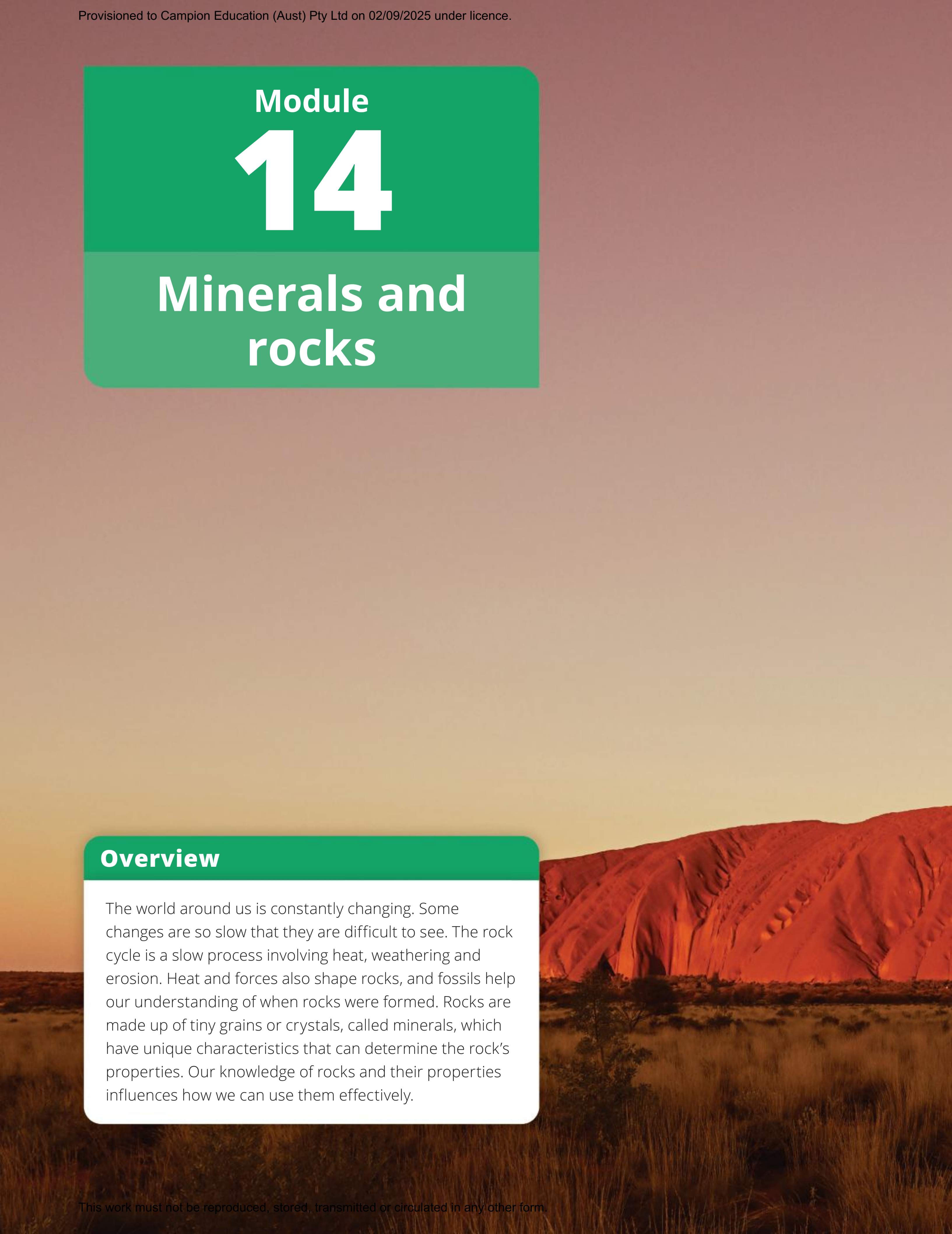
- Explain magnetic striping.
- Identify where it exists.
- Describe how it is linked to sea-floor spreading.
- Explain what it tells us about the age of rocks and Earth's history.

Tsunami warnings

Seismic data (data about earthquakes) is collected and shared by a variety of governments across the Asia–Pacific region.

- Describe how sensors are used to collect earthquake information.
- Describe how information about potential tsunamis is shared between different governments.
- Describe how the information is shared with the population and the actions that may be taken as a result.

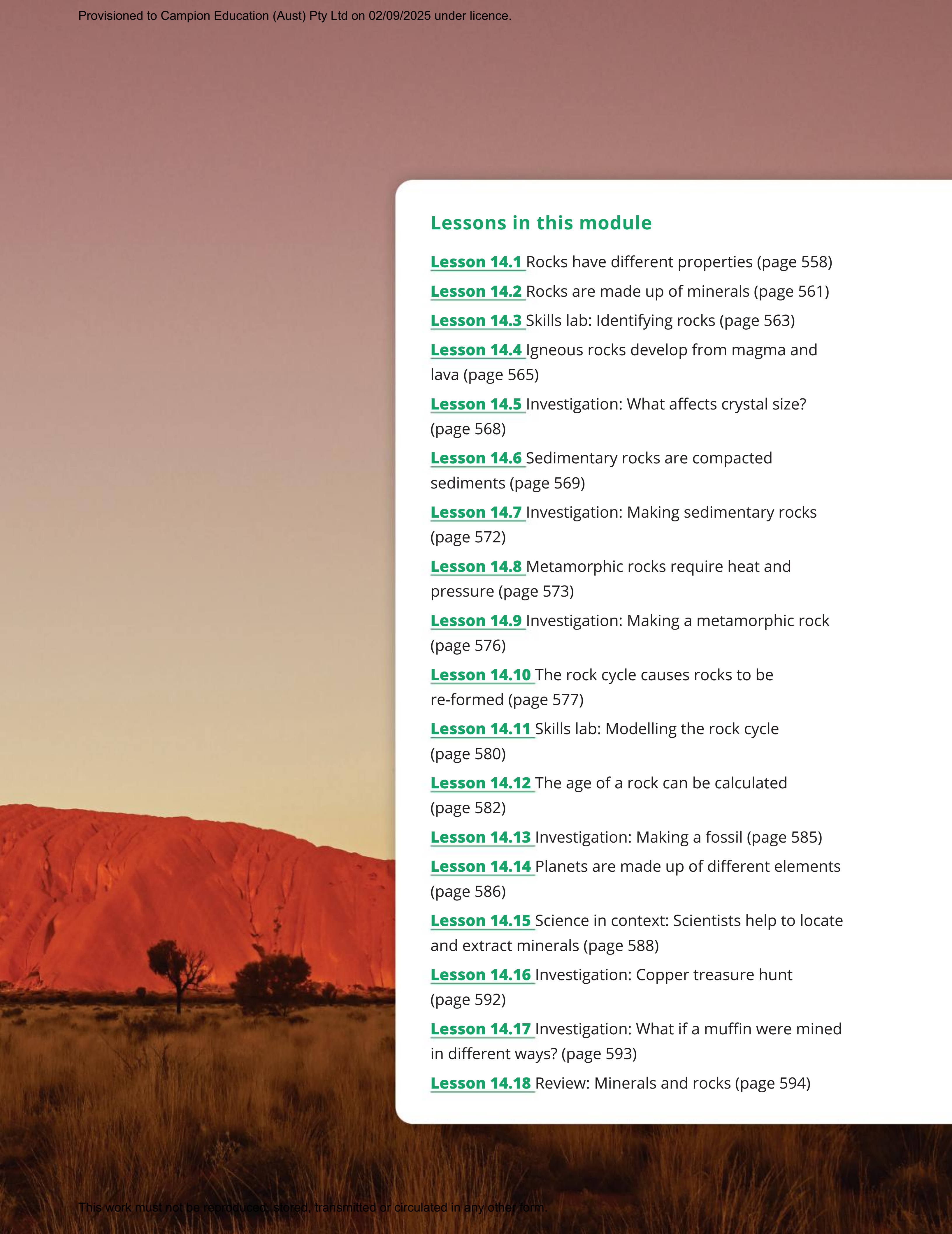
Figure 6 Tsunami warning signs run along the Pacific coastline in California.



Module
14
Minerals and rocks

Overview

The world around us is constantly changing. Some changes are so slow that they are difficult to see. The rock cycle is a slow process involving heat, weathering and erosion. Heat and forces also shape rocks, and fossils help our understanding of when rocks were formed. Rocks are made up of tiny grains or crystals, called minerals, which have unique characteristics that can determine the rock's properties. Our knowledge of rocks and their properties influences how we can use them effectively.



Lessons in this module

Lesson 14.1
Rocks have different properties

Learning intentions and success criteria

Key ideas

→ Geologists are scientists who study rocks.

→ The properties of rocks include colour, presence of layers, hardness, density and crystal size.

Introduction

There are many different types of rocks – they don’t all look and feel the same. Each rock has characteristics that give clues to its identity, such as its colour or hardness. These characteristics are referred to as **properties**. By carefully observing a rock’s properties, **geologists** (scientists who study rocks) can tell where a rock came from and what has happened to it.

properties (in chemistry) the characteristics or things that make a substance unique

geologist a scientist who studies rocks

Identifying and selecting rocks

We select rocks for particular purposes because of their properties. Granite is selected for kitchen bench tops because it is the hardest building stone, it is non porous (it doesn't let liquid through), it is not affected by temperature and it is resistant to damage from chemicals.

Aboriginal and Torres Strait Islander Peoples use their knowledge of different rock properties to make tools. Abrasive rock, such as sandstone, is used to grind seeds and other plant material.

You can identify rocks by how they look. Coal is black or dark brown, and pumice and scoria are covered with holes. Each rock is made up of tiny grains or crystals called **minerals**. These minerals have unique characteristics that can determine the properties of the rock. Granite is made up of large crystals of three minerals – quartz, mica and feldspar. This makes granite very hard. Other rocks can break off in layers of minerals. Some, like **conglomerates**, are made up of individual stones cemented together.

Geologists also use a range of other properties to help identify rocks, such as layering, weight and the presence of crystals or grains (Figures 2–6).

Table 1 lists some types of rocks and how they can be identified.

mineral a naturally occurring solid substance with its own chemical composition, structure and properties

conglomerates rocks made up of gravel size individual stones cemented together

Figure 1 Some of the many different types of rocks

Table 1 Rock identification

Rock	Grain size	Hardness	Usual colour	Density
Basalt	Fine or mixed	–	Dark	2.8–3
Coal	Fine	Soft	Dark	1.3
Conglomerate	Mixed	Hard or soft	–	–
Gneiss	Coarse	Hard	Alternating light and dark bands	2.3–2.6
Granite	Coarse	Hard	Light	2.6–2.7
Limestone	Fine	Soft	Light	2.3–2.7
Marble	Coarse	Soft	Light	2.4–2.7
Obsidian	Fine	Medium	Dark	2.6
Pumice	Fine	Soft	Light	0.6
Quartzite	Coarse	Hard	Light	2.6–2.8
Rhyolite	Fine	Hard	Light	2.4–2.6
Sandstone	Coarse	Hard	Light	2.2–2.8
Schist	Medium to coarse	Medium	Medium	2.5–2.9
Scoria	Fine	–	Dark	0.9
Shale	Fine	Soft	–	2.4–2.8
Slate	Fine	Soft	Dark	2.7–2.8

Figure 2 Weight and density are less if rocks contain large gas holes that were produced when the rock was formed. In pumice, shown above, the holes can be the size of a match head or smaller. In scoria, the holes are often the size of a pea.

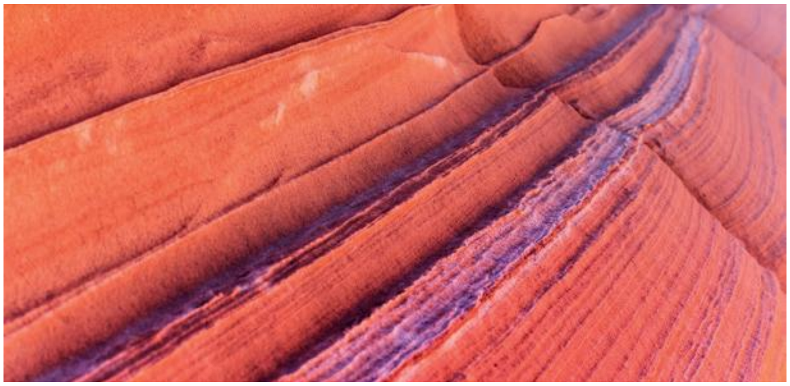


Figure 3 Layers in rocks can look very different. Some rocks have different-coloured layers that line up like ribbons. Gneiss usually has alternating layers of colours, often black and white. Sandstone (pictured) has layers of different-sized grains of sand. Wind or water distributes the sand so that the rock ends up being different shades of the same colour.

Figure 4 Colour is a property that depends on the chemicals in the rocks. For example, some red rocks contain a lot of iron which has reacted with oxygen in the air ("rusted") to form red iron oxide. Other red rocks don't contain iron, so a rock cannot be identified solely by its colour.

Figure 5 Crystals are small pieces of organised particles that have smooth sides and sharp edges. They are usually just one colour and often reflect light off their flat surfaces. Crystals in a rock can be different sizes.

Figure 6 Grains are small pieces of material. The size of the grain can be used to identify the type of rock. Large grains (larger than a grain of rice) are said to be coarse. Smaller grains that can still be seen with the eye are medium grain. Fine grains cannot be seen without a microscope.

Check your learning 14.1

Check your learning 14.1

Retrieve

1 Recall the branch of science that is the study of rocks.

2 Name the properties that are used to identify different types of rocks.

3 Determine whether pumice would be an appropriate material for a kitchen bench (by describing the properties needed for a kitchen bench and comparing these properties to the properties of pumice).

Comprehend

4 Explain why properties other than colour should be used to identify a rock.

Analyse

5 Use Table 1 and Figure 1 to identify these rocks.

  a I am light in colour with a fine grain. I am considered soft.

  b I am light in colour with holes in the surface.

  c I am soft, shiny and dark in colour. I am often used for flooring.

  d I have mixed grains and my colour can vary.

Apply

6 Investigate different uses for three rock types of your choice.

Skills builder: Planning investigations

7 A student was conducting an investigation about the properties of different rocks. They collected a piece each of coal, pumice, sandstone and scoria. They then placed them in a large bucket of water and observed which rocks floated and which sunk. Write an aim for the investigation. (THINK: What property was the student trying to observe? Can you identify the independent and dependent variables in this investigation?)

Lesson 14.2

Rocks are made up of minerals

Key ideas

→ Rocks are made up of one or more types of minerals.

→ The physical properties of rocks can be used to identify minerals correctly.

Learning intentions and success criteria

Introduction

Rocks are made up of one or more minerals. A mineral is a naturally occurring solid substance with its own chemical composition, structure and properties. There are more than 4,000 known minerals, but only approximately 150 of these are common.

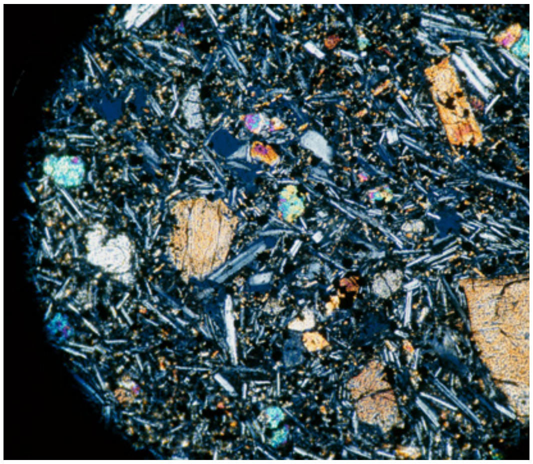


Figure 1 The individual mineral crystals of the rock olivine basalt viewed under a microscope

Properties of minerals

Minerals are found as crystals (Figure 1). The structure of a crystal greatly influences a mineral's properties. For example, diamond and graphite have the same chemical composition – they are both pure carbon. Graphite (which is the "lead" in a grey-lead pencil) is very soft, whereas diamond is the hardest of all minerals. This difference arises because the carbon particles in a graphite crystal are arranged into sheets that can slide past each other, whereas the carbon particles in a diamond crystal form a strong, interlocking unit (Figure 2).

Figure 2 (A) The carbon atoms in the mineral graphite are arranged in sheets. (B) In a diamond, the carbon atoms are interlocked.

Identifying minerals

To identify minerals correctly, geologists carefully examine the properties of rocks. The colour of a mineral is a guide to identifying it, but it cannot be relied on for correct identification. Colour is not a reliable property because many minerals are **impure** (meaning they are combined with other substances). Pure quartz, for example, is colourless; however, if it contains impurities, it can be many colours, such as purple (amethyst), pink (rose quartz) or yellow (citrine). Even in one sample, the colour may vary.

Lustre is the shininess of the surface of the mineral (Figure 3). Some types of lustre are:

- metallic – looks like a shiny new coin
- brilliant – very shiny, like a mirror
- pearly – a bit shiny, like a pearl or fingernail
- dull – not shiny at all
- earthy – looks like a lump of dirt.

lustre the shininess of the surface of a mineral

Oxford University Press

Figure 3 The lustre of a mineral describes its shininess.

streak the colour of powdered or crushed mineral

Streak is the colour of the powdered or crushed mineral. This colour can be seen by drawing with the mineral on a footpath. The colour of the line that the mineral leaves behind is its "streak". Often the colour of the streak is different from the main colour of the mineral.

hardness how easily a mineral can be scratched; measured on the Mohs hardness scale

Hardness is how easily a mineral can be scratched. Some minerals are so soft that they can be scratched with a fingernail. Other minerals are so hard that they can scratch glass. A hard mineral can scratch a soft mineral and not get scratched itself. German geologist Friedrich Mohs (1773–1839) invented a scale to describe the hardness of a mineral. Mohs gave ten common minerals a hardness number from 1 to 10 (Table 1): the softest mineral, talc, has a hardness of 1, and the hardest mineral, diamond, has a hardness of 10. These minerals can be used to find the hardness of any other mineral.

A mineral will scratch another mineral with a lower hardness number, but not one with a higher hardness number. A mineral will be scratched by another mineral with a higher hardness number, but not one with a lower hardness number. So, copper (hardness 3.5) will be scratched by fluorite (hardness 4), but not by calcite (hardness 3). Copper will scratch calcite.

cleavage a number of smooth planes that a mineral breaks along

Cleavage is the tendency of a mineral to break into a number of smooth flat surfaces. Minerals that demonstrate cleavage look like thin slabs stuck together. Mica, for example, breaks in one direction into flat layers, like the

Table 1 The Mohs scale of mineral hardness – every mineral will scratch the minerals above it.

Hardness	Mineral
1	Talc
2	Gypsum
3	Calcite
4	Fluorite
5	Apatite
6	Feldspar
7	Quartz
8	Topaz
9	Corundum
10	Diamond

Figure 4 Mica has one cleavage plane – it breaks into thin sheets of rock.

pages in a pile of papers (Figure 4). Calcite breaks along three cleavage planes: left and right, front and back, and top and bottom.

Several minerals have unusual properties. Some minerals **fluoresce** (meaning that they glow brightly) in ultraviolet (UV) light: these minerals absorb UV light, which we cannot see, and emit it as visible light, which we can see. Calcite is a transparent mineral (Figure 5). When you look through it, you see a double image.

Figure 5 Calcite is a transparent mineral.

Check your learning 14.2

Check your learning 14.2

Retrieve

1 Identify a mineral that has a Mohs hardness of 10.

2 Describe:
  - **a** hardness
  - **b** lustre
  - **c** streak
  - **d** cleavage.

3 Explain what it means if a mineral has a hardness of 1 on the Mohs scale.

4 Describe the lustre of gold.

Skills builder: Conducting investigations

5 Two students were asked to observe a piece of calcite and take notes about its cleavage, hardness and streak.
  - **a** Identify two potential hazards that they should be careful of during their investigation. (THINK: What do we know about calcite? How could it be dangerous?)
  - **b** For the two hazards you identified, recommend a strategy to reduce the risk of each. (THINK: Could they change the way they behave or the equipment they use to make the investigation safer?)

Lesson 14.3

Skills lab: Identifying rocks

Aim

To use a key to identify different types of rocks

Materials

- Rock samples (unnamed, perhaps labelled A, B, C, D, etc.)
- Hand lens
- Table 1 Dichotomous key for common types of rocks

Method

1 Examine each rock sample with the hand lens and use the dichotomous key in Table 1

to identify it. Be aware of the following.

- Crystals in rocks have straight edges and flat, shiny surfaces.
- Grains are not shiny – they are jagged or rounded and more like grains of sand.
- Coarse grains are about the size of a grain of rice. Medium grains are smaller but still visible to the naked eye, and small grains are only visible with a hand lens or magnifier.

2 Display your results in a table that identifies the rock sample (e.g. sample A), lists its main properties and gives its name.

Questions

1 Describe any difficulties you had when identifying your rock samples.

2 List any samples that you could not identify.

3 Compare your results with those of another group. Identify any differences between your results and the other group's.

4 Ask your teacher for the names of your rock samples and highlight the rocks that you correctly identified (hopefully all of them).

Figure 1 Rocks can be identified using a dichotomous key.

Table 1 Dichotomous key for common types of rocks

1	Does the rock have layers? (Use a hand lens to check.)	Yes – Go to 3 No – Go to 2
2	Can you see cracks in the rock?	Yes – Go to 4 No – Go to 5
3	Can sand be rubbed off the rock?	Yes – Sandstone No – Go to 8
4	Is the rock a light colour (i.e. mostly white)?	Yes – Marble No – Go to 10
5	Does the rock look like glass?	Yes – Obsidian No – Go to 6
6	Does the rock have a lot of holes that make it light to hold?	Yes – Pumice No – Go to 7
7	Is the rock grey to black?	Yes – Basalt No – Limestone
8	Can you see crystals in the rock?	Yes – Gneiss No – Go to 9
9	Can you see layers of thin, flat pieces of rock? Could the rock be split easily?	Yes – Slate No – Quartz
10	Does the rock have a lot of holes that make it light to hold?	Yes – Pumice No – Granite

Lesson 14.4

Igneous rocks develop from magma and lava

Key ideas

→ Magma (hot liquid rock) flows deep beneath the Earth's surface.

→ When the magma moves above the Earth's surface it is called lava.

→ Igneous rocks form when magma and lava become solid.

Learning intentions and success criteria

Introduction

Rocks are broadly classified according to how they are formed. The three main types of rocks – igneous, sedimentary and metamorphic – form in different ways. **Igneous rocks** form when the magma (hot liquid rock) and lava from volcanic eruptions cool and solidify.

igneous rock rock formed by cooling magma and lava

magma semi-liquid rock beneath the Earth's surface

lava hot, molten rock that comes to the surface of the Earth in a volcanic eruption

intrusive igneous rock rock formed underground by slowly cooling magma

Magma and lava

The term "igneous" comes from the Latin word *ignis*, which means "fire". The hot, molten rock inside the Earth is called **magma** and its temperature can be more than 1,200°C. The magma chamber under a volcano is the source of molten rock for the volcano (Figure 1).

In a volcanic eruption, the red-hot magma rushes out onto the surface of the Earth as **lava**. The cooler conditions at the Earth's surface help to solidify the lava quickly.

Igneous rocks also form from magma under the ground. These igneous rocks look quite different from those formed on the Earth's surface because they cool much more slowly.

Intrusive igneous rocks

Intrusive igneous rocks form slowly beneath the surface of the Earth when magma becomes trapped in small pockets. These pockets of magma cool slowly underground (sometimes for millions of years) to form intrusive igneous rocks. The longer it takes for lava to cool, the bigger the

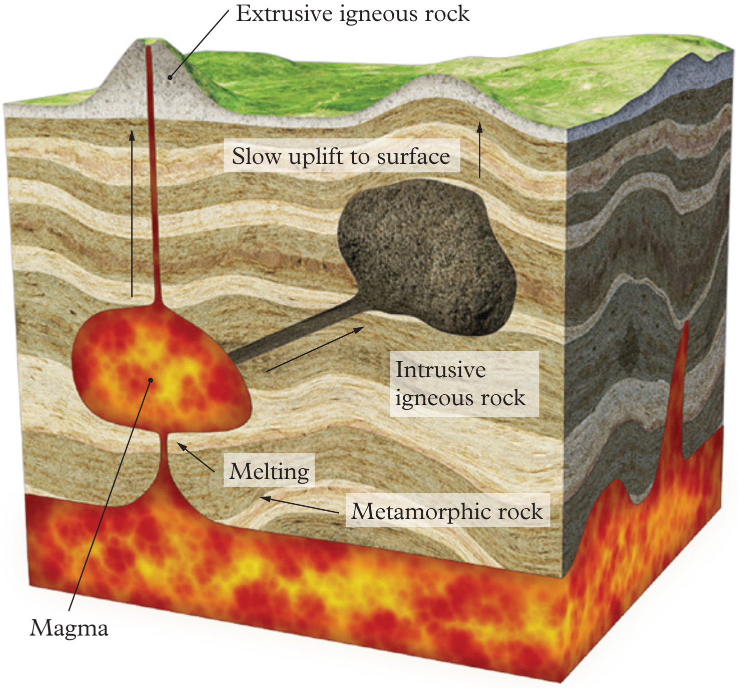


Figure 1 Igneous rocks are formed from volcanic magma.

rock crystals that grow. Intrusive igneous rocks have large crystals locked together. Granite is an intrusive igneous rock in which the crystals can be seen with the naked eye (Figure 2). Although formed underground, intrusive igneous rocks reach the Earth's surface when they are either pushed up by forces in the Earth's crust or uncovered by erosion.

Figure 2 Granite is an intrusive igneous rock.

Extrusive igneous rocks

extrusive igneous rock rock formed at the Earth's surface by quickly cooling lava

Lava cools much more quickly on the surface of the Earth. This causes it to form **extrusive igneous rock**. The crystals formed are smaller because the lava is cooling more quickly than the magma underground. Sometimes, the lava cools so quickly that no crystals are formed. For example, pumice has no crystal structure. Pumice forms when hot, gas-filled lava cools very quickly. The many tiny holes in pumice are formed by volcanic gases escaping from the cooling lava. It has so many holes that it is extremely light and can float on water (Figure 4). Pumice stones are used to scour hard skin from feet, and powdered pumice is found in some abrasive cleaning products.

Obsidian is a smooth, black rock that looks like glass (Figure 3). It is formed almost instantly when lava cools and forms no crystals. Obsidian is used to make blades for surgery scalpels; the resulting blades are much sharper than those made from steel.

Figure 3 Obsidian is an extrusive igneous rock.

Figure 4 Pumice contains many holes that make it light enough to float on water.

The different forms of basalt

Magma can solidify into many different igneous rocks, which can vary in appearance based on how they formed and the minerals they contain.

Basalt is the most common type of rock in the Earth's crust. Most of the crystals in basalt are microscopic or non-existent because the lava cools so quickly that large crystals do not form. Basalt is very hard and has a high **tensile** strength (meaning it can absorb a lot of stress without breaking).

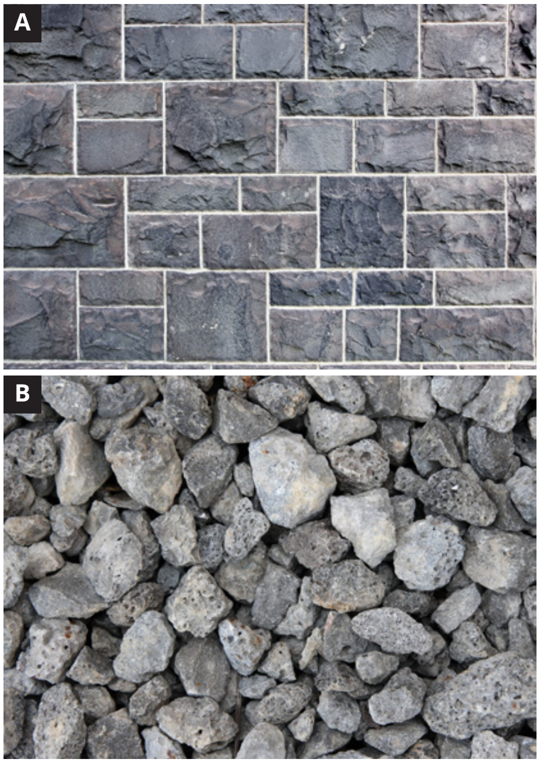


Figure 5 Basalt comes in different forms, such as (A) bluestone and (B) scoria.

We commonly think of basalt as the building product “bluestone” (Figure 5A). Aboriginal and Torres Strait Islander Peoples use basalt in the production of hard stone axes.

Basalt can look different depending on the type of volcanic eruption that produced it and how quickly it cooled. Scoria is a type of basalt that is full of bubble holes (Figure 5B). The lava was filled with gases when it began to cool and the holes in the scoria are where the gas bubbles once were. Scoria is a light rock that is often used for garden paths and as a filler in drainage trenches.

Check your learning 14.4

Check your learning 14.4

Retrieve

1 Define the term “igneous rock”.

2 Name the type of rock that is produced by magma that cools deep below the Earth’s crust.

3 Recall an igneous rock that would float on water.

Comprehend

4 Describe how igneous rocks form.

5 The ancient civilisations that discovered obsidian had a competitive advantage over those who didn’t. Explain a possible advantage of obsidian rock.

Analyse

6 Contrast (the differences between) the properties of intrusive and extrusive igneous rocks.

7 Consider the ways humans use these rocks and how their properties are important for their uses.

Skills builder: Processing and analysing information

8 In this lesson, we have learnt about different types of igneous rocks, including pumice, obsidian, scoria and basalt. Construct a table to organise the information about the properties of the four rock types. (THINK: What information do you have and how can you group it?) Remember that a table should always have a heading and that each column should be labelled.

Lesson 14.5

Investigation: What affects crystal size?

Purpose

To grow crystals and determine what affects their size

Materials

- Alum solution
- Bunsen burner
- Heatproof mat
- Matches
- Tripod
- Gauze mat
- Two Petri dishes
- Evaporating dish
- Safety glasses
- 250 mL beaker
- Tablespoon

Procedure

1. Prepare a solution of alum by mixing 2½ tablespoons of alum with 120 mL of hot water. Stir until the alum is dissolved.
2. Pour roughly equal amounts of alum solution into the evaporating dish and the two Petri dishes.

Figure 1 Different factors can affect the size of a crystal.

3. Put one of the Petri dishes in the refrigerator.
4. Put the other Petri dish on a window sill.
5. Place the heatproof mat under the Bunsen burner and place the evaporating dish on the gauze mat.
6. While wearing safety glasses, gently heat the evaporating dish containing the alum solution over a yellow (safety) flame. The yellow flame is cooler and will allow for gentle boiling.
7. Continue heating the solution until nearly all the water has evaporated. Stand back from the evaporating dish and the solution while heating as the solution may spit and splatter.
8. Observe the size of the crystals formed in the evaporating dish. Turn off the gas when the water is almost gone and allow to cool. Store the crystals in a cool, dry place.
9. After two days, compare the size of the crystals formed by heating quickly to the crystals formed slowly on the window sill.
10. After four or five days, compare the size of the crystals formed by heating quickly to the crystals formed in the refrigerator and on the window sill.

Results

Draw a labelled diagram of the crystals formed in the evaporating dish and in the two Petri dishes. Your diagram needs to show the different sizes of the crystals in the different dishes.

Discussion

1. Identify the independent variable for this experiment.
2. Identify the dependent variable.

3 Identify three variables you needed to control. How were these controlled?
4 Each of these crystals grew over a different time span. Describe how allowing the crystals to form slowly affected the size of the crystals.
5 Compare the results of your crystals to those grown by others in your class. Describe the largest and smallest crystals formed.
6 Identify any factors that could explain any variation in the crystals formed.

Conclusion

Describe what you learnt about the factors affecting crystal size.

Lesson 14.6

Sedimentary rocks are compacted sediments

Key ideas

→ Sedimentary rocks are formed from compacted particles or sediment.

→ Stalactites and stalagmites are forms of sedimentary rock.

Learning intentions and success criteria

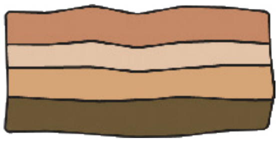
Sedimentary rocks

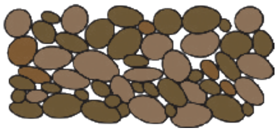
Sedimentary rocks are formed when loose particles are pressed together (compacted) by the weight of the **overlying sediments** (meaning the weight of the sediment layers above) (Figure 1). Sediments are rock particles, such as mud, sand or pebbles, which are usually washed into rivers and eventually deposited on the riverbed or in the sea. Sediments can also come from the remains of living things, such as plants and animals.

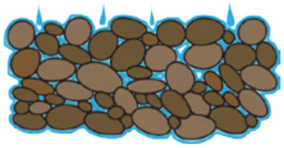
sedimentary rock rock formed from compacted mud, sand or pebbles, or the remains of living things

Formation of sedimentary rocks

Over thousands or even millions of years, sediments form thick layers on the riverbed or sea floor. Pressure from the overlying sediments and water forces out air and any gaps in the bottom layer. Over time, the compacted sediments become sedimentary rocks.


Sediments are deposited in layers called beds.


The grains of sediment in lower layers begin to squash together.


Chemicals that are dissolved in the water can soak into the sediments.

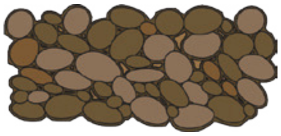

The chemicals help cement the grains together once the water has evaporated.

Figure 1 The formation of sedimentary rocks

The names of some sedimentary rocks are clues to the sediments that formed them – sandstone, mudstone, siltstone and conglomerate are all types of sedimentary rock (Figure 2). Sandstone is made up of sand deposited in environments such as deserts and beaches (Figure 3). Conglomerate is a mixture of all sizes of rocks that have become cemented together (Figure 4).

Figure 2 Shale (or mudstone) is the most common sedimentary rock. Shale is a fine-grained sedimentary rock made up of clay minerals or mud.

Figure 3 Sandstone is a popular building material. This ancient temple of Abu Simbel in Egypt was carved directly into the sandstone rock.

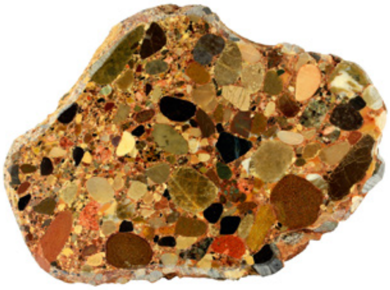


Figure 4 Conglomerate rocks have grains of different sizes.

Biological rocks

Sedimentary rocks are not always formed from the sediments of minerals or other rocks. The remains of living things also break down and are deposited as sediments. Shells and hard parts of sea organisms break down and are deposited in layers on the ocean floor. Eventually, they become cemented together under pressure to form **limestone**.

The compaction of dead plant material can also help to form sedimentary rocks. For example, coal is formed from dead plants that were buried before they had completely decayed. Compression forces from the layers above can change the plant material into coal or oil.

Figure 5 Lake Eyre in South Australia

Chemical rocks

Chemical sedimentary rocks form when water evaporates, leaving behind a solid substance. When seabeds or salt lakes dry up, such as Lake Eyre in South Australia, they leave a solid layer of salt behind. If the layer of salt is compressed under the pressure of other sediments, it may eventually form rock salt.

Limestone caves

When groundwater passes over limestone, it can dissolve calcium carbonate from the limestone. When the water evaporates, it leaves behind the calcium carbonate. Various rock formations in caves are formed by this method.

The amazing long strands of rock found on cave floors and ceilings are composed of calcium carbonate from the limestone ceiling of the cave. A stalagmite grows from the floor towards the ceiling (they "might" reach the ceiling one day) and a stalactite grows down from the ceiling (they hold on "tight") (Figure 6). If these formations meet in the middle, they form a column.

Stalagmites and stalactites form when limestone rocks are dissolved by acids in water. The acid and dissolved limestone form a solution that drips through the ceiling of the cave and is deposited on the stalagmites and stalactites, gradually increasing their width and length.

It is important that visitors to limestone caves do not touch the stalactites and stalagmites because they are generally still forming. Oil from skin can interfere with stalagmite and stalactite formation.

Figure 6 Stalagmites and stalactites form in limestone caves.

Ochre

Ochre is one of the sedimentary rocks greatly valued by Aboriginal and Torres Strait Islander Peoples. It has a high shine that generates a shimmering effect in the light of a fire. It is used in body paint, rock paint and artwork. The colours vary from the deepest chocolate browns, through to orange tones, tobacco and blood reds, and to lighter tones of yellows and creams, where the tones have changed due to white clay in the area. Aboriginal and Torres Strait Islander Peoples have collected and traded sedimentary ochre for thousands of years. Wilgie Mia in Western Australia is 20 metres underground and is the world's oldest continuous excavation operation (Figure 7). This 27,000–40,000-year-old site used tree-pole scaffolding to prevent it from collapsing while thousands of rocks were removed to reach the ochre.

Figure 7 Wilgie Mia ochre mine

Check your learning 14.6

Check your learning 14.6

Retrieve

1 Recall how sedimentary rocks form.

2 Name three different sedimentary rocks.

3 Recall how stalactites and stalagmites form.

Comprehend

4 Explain the link between plants and coal.

Analyse

5 Compare (the similarities and differences between) the formation of biological and chemical sedimentary rocks.

6 Infer why sandstone is often used for carving statues.

Apply

7 A student claims that sandstone is made up of sand. Evaluate their claim (by explaining how sandstone is formed and using this to decide whether the claim is correct).

Skills builder: Communication

8 Imagine that you needed to explain how conglomerate rocks were formed to somebody who had never heard about rocks before. Construct a diagram to explain how conglomerate rocks are formed and include labels to describe the process. (THINK: What do they need to know about rocks to understand? How can you use the diagram to help?)

Lesson 14.7

Investigation: Making sedimentary rocks

Purpose

To make small samples of sedimentary rocks and compare them against real samples

Materials

- Dry clay
- Dry sand
- Plaster of Paris
- Small, smooth pebbles
- Samples of sedimentary rocks
- Water
- Mortar and pestle
- Teaspoon
- Four empty matchboxes
- White tile

Procedure

1 Grind a lump of dry clay with a mortar and pestle until it is fine and powdery.

2 Using the teaspoon, mix the dry ingredients for each rock sample on the white tile according to the recipes in Table 1, but don't add the water just yet. (Note: You will need to prepare two shale samples to use in Lesson 14.9 Investigation: Making a metamorphic rock, page 576.)

3 Pile up your ingredients into a little hill and make a small dip in the centre for the water.

4 Slowly add the water and stir until the ingredients are uniformly mixed. Be careful not to make the mixture too wet.

5 Press your mixture into an empty matchbox, label it with the rock type and your name and leave it to dry for two days.

Table 1 Sedimentary rock experiment

Rock	Number of teaspoons				
	Dry clay	Sand	Plaster of Paris	Pebbles	Water
Sandstone	$\frac{1}{2}$	4	$\frac{1}{2}$	0	2
Shale	5	$\frac{1}{2}$	0	0	2
Conglomerate	$\frac{1}{2}$	1	$\frac{1}{2}$	4	2

6 When your "rock" is dry, peel off the matchbox and examine your sample. Take digital photos of your samples and photos of the "real" rocks for comparison. Keep your two shale samples for Lesson 14.9 Investigation: Making a metamorphic rock (page 576).

Results

Include images of your rocks. Describe what your rocks look like using the terms in Lesson 14.1 Rocks have different properties (page 558).

Discussion

1 Describe how sedimentary rocks are formed.

2 Compare (the similarities and differences between) your rocks and other sedimentary rocks that you have seen.

Conclusion

Describe the characteristics that are unique to sedimentary rocks.

Figure 1 Sedimentary rock cliffs

Lesson 14.8

Metamorphic rocks require heat and pressure

Key ideas

→ Rocks deep underground experience high pressure.

→ High pressure generates high temperatures.

→ High pressures and temperatures cause the rearrangement of minerals to form metamorphic rock.

Learning intentions and success criteria

Introduction

Metamorphic rocks are formed when other types of rock are changed by incredible heat and pressure inside the Earth. Metamorphism means "change in form". When igneous, sedimentary or even metamorphic rocks are heated to extreme temperatures by magma or when they are placed under extreme pressure from the layers of rocks above them, they can change into different types of rock. Limestone, for example, changes to marble (Figure 1).

metamorphic rock rock formed from other rock due to intense heat and pressure

Change in appearance

Figure 1 The Taj Mahal in India is made of marble, the metamorphosed form of limestone. With its dense composition and beautiful patterns, marble is a popular material for sculptures.

The combination of high temperature and pressure causes differences in the appearance of metamorphic rocks. As you go deep underground, the temperature gradually increases. Miners in South Africa's West Wits minefield, who work up to 3.9 km below ground, report temperatures up to 60°C. Temperatures can get much higher anywhere magma intrudes.

The pressure of the Earth above the rock also contributes to the different appearance of metamorphic rocks. Bands can occasionally be seen in metamorphic rocks formed under high pressure. If the pressure is uneven, the rock crystals can twist. This is called **foliation** (Figure 2).

foliation layering in a rock that occurs when the rock is subjected to uneven pressure

Figure 2 Foliation occurs when rock is subjected to uneven pressure.

Change in minerals

Metamorphic rocks also change chemically. Some metamorphic minerals (sillimanite, kyanite and garnet) only form at high temperatures and pressures. They are called **index minerals** because they can tell us the history of what happened to the minerals in the rock – the temperature and pressure they were exposed to.

index mineral a mineral that only forms at a particular temperature and pressure; used to determine the history of the rock that contains the mineral

Other minerals, such as quartz, can withstand the high temperatures and pressures and can sometimes be found in metamorphic rocks. The heat and temperature can cause some crystals to change their size and shape. Recrystallisation occurs when the crystals are squeezed together so tightly that they partially melt and form fewer, but larger, crystals. For example, when granite is squeezed under high pressure, the crystals change and the rock gneiss is formed (Figure 3). This can affect how metamorphic rocks are used.

Metamorphic rocks are stronger than the original material because the particles have been fused together under great pressure or heat. This strength made rocks such as quartzite useful to Aboriginal and Torres Strait Islander Peoples for producing grindstones and millstones (Figure 4). The hard, rough surfaces of the stones made it easier to grind different seeds and produce flour. The Bama people of northern Queensland cut ridges in smooth slate so that the rough surface could be used to grind toxic cycad kernels. Grinding the kernels with water releases the toxins and makes the kernels safer to eat.

The Bama people knew that slate, which absorbs little water, would not absorb the toxins from the ground seed kernels, making the tools safe to use over and over.

Figure 3 (A) When granite, an igneous rock, is subjected to high heat or pressure, it can change into the metamorphic rock known as gneiss. (B) The bands on gneiss show that the crystals have been squeezed together under immense pressure.

Figure 4 A quartzite grindstone used by Aboriginal and Torres Strait Islander Peoples

Check your learning 14.8

Check your learning 14.8

Retrieve

1 State where metamorphic rocks are formed.

Comprehend

2 Describe how metamorphic rocks are formed.

3 Describe a foliated rock.

4 Explain why quartzite is useful for a grindstone.

Apply

5 A student claimed that a rock had to be igneous because it had quartz crystals. Evaluate their claim (by explaining how quartz crystals are formed and using this to decide whether the claim is correct).

a Identify which type of rock is stronger: sandstone or marble.

b Justify your answer (by explaining how each rock is formed, linking this to its properties and deciding which is stronger).

Skills builder: Problem solving

6 A builder was asked to choose between slate or pumice as a building material for the floor of a house.

a Identify the advantages and disadvantages of using pumice and slate. (THINK: What are the properties of both materials? How would these properties impact on their function as a flooring material?)

b Identify which option you think is best.

Lesson 14.9

Investigation: Making a metamorphic rock

Purpose

To make a sample of a metamorphic rock

Materials

- Two shale rock samples from Lesson 14.7 Investigation: Making sedimentary rocks (page 572)
- Bunsen burner
- Matches
- Heatproof gloves
- Tripod
- Pipe clay triangle
- Gauze mat
- Evaporating dish
- Tongs
- Two 250 mL beakers
- Water

Procedure

1. Allow your shale samples from Lesson 14.7 Investigation: Making sedimentary rocks (page 572) to dry for approximately one week.
2. Place one of the shale samples on a pipe clay triangle on top of a gauze mat and heat strongly over a blue Bunsen burner flame for about half an hour. You could place an evaporating dish upside down over the shale to retain more heat.
3. After about 30 minutes of heating, allow the sample to cool for 10 minutes. Then, use the tongs to carefully pick up the shale sample and drop it into a beaker of water.
4. Drop the second, unheated shale sample into another beaker of water and observe what happens to the two rock samples.

Results

Record your observations in Table 1.

Table 1 Observations from the metamorphic rock experiment

Shale sample	Observation after dropping the shale sample into water
Heated	
Unheated	

Discussion

1. Contrast (the differences between) the two rock samples when they are dropped into the water.
2. Explain how strong heat can change the properties of rocks over time.
3. Compare (the similarities and differences between) your new metamorphic rock sample and the original shale sample.

Conclusion

Describe what you know about the formation of metamorphic rocks.

Figure 1 Metamorphic rock

Lesson 14.10

The rock cycle causes rocks to be re-formed

Key ideas

→ The rock cycle describes the formation of sediment, sedimentary rock, compression to metamorphic rock and melting and solidification to form metamorphic rock.

→ Weathering is the breaking down of rocks and minerals through the movement of water and animals, and through the extremes of temperature.

→ Erosion is the movement of sediment to another area.

Learning intentions and success criteria

What is the rock cycle?

The **rock cycle** is an ongoing process that describes the formation and destruction of the different rock types (Figure 1). Over time, igneous, sedimentary and metamorphic rock types can transform into other types. This is due to natural processes, including heat, pressure, physical weathering, chemical weathering, erosion and deposition. These processes also play a role in forming and changing **landforms** on the Earth's surface.

rock cycle the process of formation and destruction of different rock types

landform a physical feature on the Earth's surface

Physical weathering

Weathering is the breaking down of rocks and minerals through the movement of water and animals, and through the extremes of temperature. Mechanical or physical weathering occurs when a physical force is applied to a rock. It includes the breakdown of rocks by non-living things.

In desert areas, the days are very hot and the nights are freezing cold. This daily heating and cooling affects only the outside of the rock. This is because rocks do not conduct heat very well. Sometimes, the outside of the rock can peel off, just like an onion skin. This process is called **onion-skin weathering** and the round rocks produced in this way are called **tors** (Figure 2A).

When water freezes at night, it expands and takes up more space. When water freezes in the crack of a rock, it expands and pushes hard against the rock around it. This can make the crack larger. When the ice melts during the warmer day, water fills the crack again. The next night, ice forms again and makes the crack even larger. This process is repeated many times until part of the rock is split off. This process is called **frost shattering** (Figure 2C).

weathering the breakdown of rocks and minerals by the movement of water and animals, and extremes of temperature

onion-skin weathering weathering of rock whereby the outside of the rock peels off

tor a large, round rock produced by onion-skin weathering

frost shattering a process of weathering in which repeated freezing and melting of water expands cracks in rocks, so that eventually part of the rock splits off

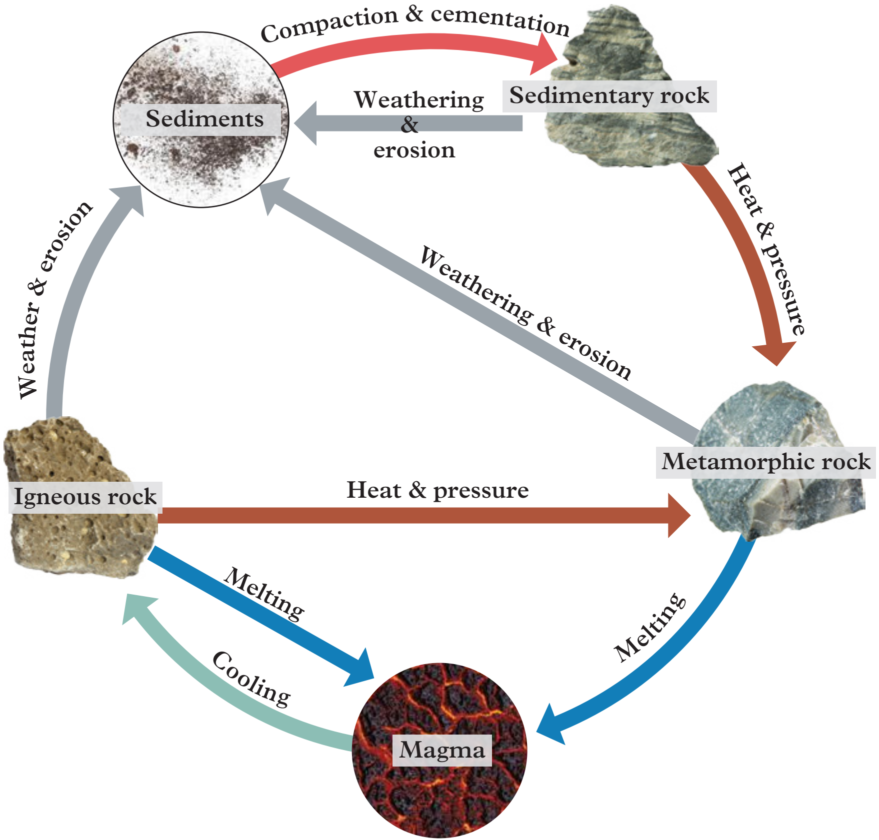


Figure 1 The rock cycle

Figure 2 Physical weathering can include (A) onion-skin weathering, (B) wearing away by water (abrasion) and (C) frost shattering.

Chemical weathering

Chemical weathering changes the minerals in rocks. Carbon dioxide in the air mixes with the water in rain to form a weak acid rain (a much weaker acid than vinegar). When the acid rain falls on rocks such as limestone, a chemical reaction changes the minerals in the rock and the minerals are washed away (eroded). You can see evidence of this type of weathering in old statues (Figure 3).

Biological weathering

Biological weathering can start with a seed falling into a crack in the rock. Soil and water in the rock encourage the seed to grow. As the roots grow, they push on the cracks in the rock, eventually causing the rock to break (Figure 4).

Erosion

Erosion is when sediment that has been broken down by the elements is moved away to another area by wind or water. Erosion can be caused by wind and rain beating at a rock's surface or by water bodies – such as a river or ocean. The Three Sisters natural rock formation in the Blue Mountains, for example, was shaped over many years. In the ancient past there used to be seven pillars; however, erosion by wind and rain has worn the others away over time, leaving the three pillars that we see today.

Figure 3 Chemical weathering can be caused by acid rain.

Deposition

Over time and during the process of weathering, large rocks are broken down into smaller rocks, which are broken down into sediment. The sediment is eroded and carried by wind and water to an area where it accumulates in layers. Over time, many different layers of sediment from the different forms of weathering are built on top of each other. This process is called **deposition**. Gradually, the sediment becomes buried under many layers, re-forming as sedimentary rock.

erosion the movement of sediment to another area

deposition the process whereby sediment from different forms of weathering accumulates in layers

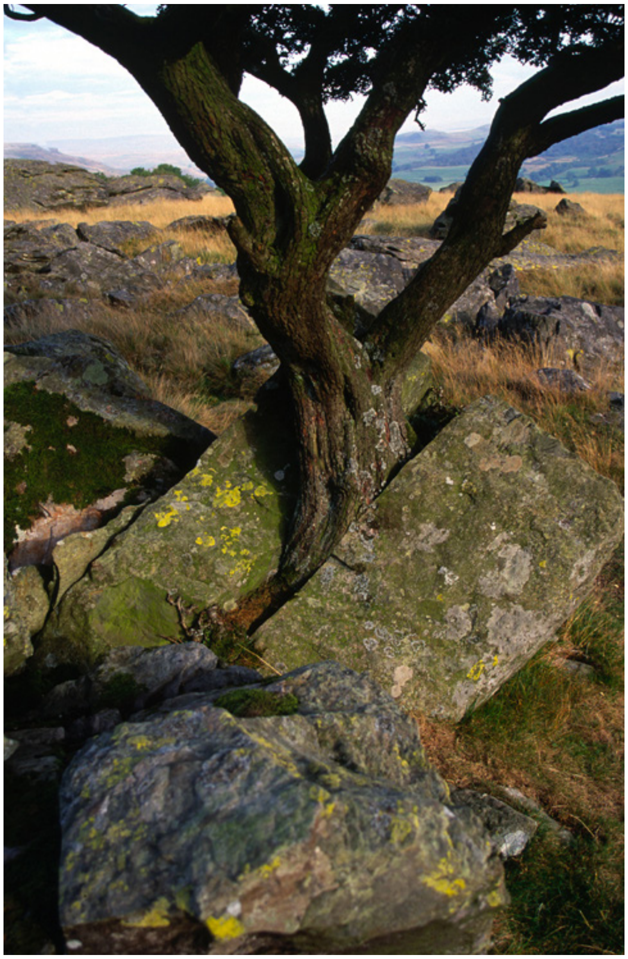


Figure 4 Biological weathering can be caused by plant roots.

Heat and pressure

As more layers form on top of the sedimentary rock, it is put under pressure from the heavy top layers. Over time, the layers sink deeper, putting even more pressure on the deep layers. This can cause the rocks to heat up. Increased temperature and pressure cause physical and chemical changes in the rock, transforming it into metamorphic rock. If the temperature continues to rise, the rock will melt, turning it into its liquid form, magma.

Magma is also put under great pressure, causing it to seek any available space. Gradually it makes its way to the Earth's surface where it can cool as igneous rock. Over time, the rock is uplifted and exposed to wind and water. The rock cycle continues.

Figure 5 The rock cycle can lead to rocks being smoothed.

Check your learning 14.10

Check your learning 14.10

Comprehend

1 Describe how tors are formed.

2 Describe the process of frost shattering.

3 Describe the different stages in the rock cycle. Use the rock cycle diagram in Figure 1 to assist you.

Analyse

4 Use a table to compare (the similarities and differences between) physical, biological and chemical weathering.

5 Contrast (the differences between) weathering and erosion.

Apply

6 Create a story about the "life of a rock". Rocks change with time, as do humans. Unlike humans, however, rocks are never truly "born", nor do they "die" – they can move through the rock cycle, covering the same stage many times in many different ways. Describe the life that your rock experiences. Remember to include the length of time that each step of the process takes.

Skills builder: Planning investigations

7 A student was asked to write a report during a double period about the effect of weathering on landforms in NSW.

  a Propose the type of information they should collect to complete the report on time. (THINK: Should they design their own experiment to collect first-hand data? Or should they collect data using secondary sources online and in the library?)

  b Justify your choice.

Lesson 14.11

Skills lab: Modelling the rock cycle

Caution

- Always wear safety glasses, closed-toe shoes and a lab coat, and tie long hair back when using a Bunsen burner.
- Allow all hot equipment to cool before handling.

Purpose

To model the rock cycle

Materials

- Crayons (three different colours)
- Pencil sharpener
- Two sheets of aluminium foil
- Two wooden blocks
- Beaker
- Bunsen burner or microwave
- Heatproof mat
- Large clamp
- Tripod
- Gauze mat
- Stirring rod
- Matches

Procedure

1. Remove the paper from the crayons.
2. Shave the crayons into small piles using the pencil sharpener. Keep each colour in a separate pile.
3. Cover one wooden block with aluminium foil.
4. Sprinkle a layer of crayon shavings over the aluminium foil to form the first layer.
5. Repeat Step 4 for the remaining colours of crayons.
6. Cover the crayon layers with another sheet of aluminium foil.
7. Place the second wooden block on top of the foil and press down with as much pressure as possible.
8. Remove the top block and aluminium foil and examine the compacted shavings.
9. Place the shavings between the aluminium foil and wooden blocks again.
10. Apply the large clamp around the wooden blocks and shavings. Tighten the clamp as much as possible.
11. Remove the clamp and examine the compacted crayon shavings.
12. Place the compacted crayon shavings into the beaker and place the heatproof mat under the Bunsen burner.
13. Heat the compacted crayon shavings over the Bunsen burner or in a microwave, stirring occasionally until all lumps are removed.
14. Allow the crayon mixture to cool in the beaker.
15. Examine the resulting crayon sample.

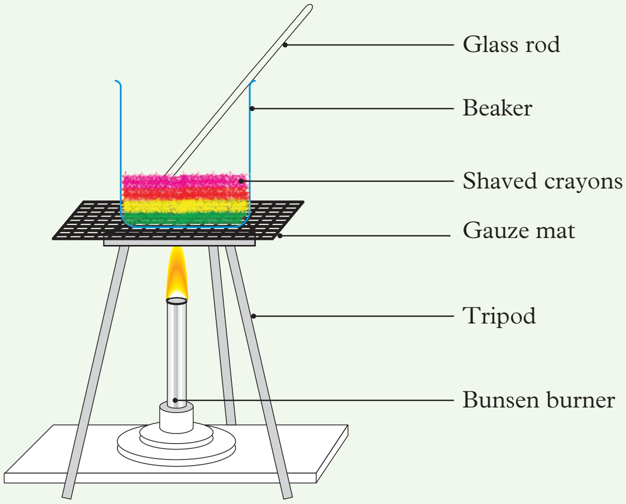


Figure 1 Skills lab set-up

Questions

1. Describe the type of weathering (mechanical or chemical) that took place at Step 2.
2. Identify the term used to describe the movement of the sediment pile of crayon shavings onto the aluminium foil at Step 4.
3. Identify the type of rock formed in Step 8.
4. Identify the type of rock formed in Step 11.
5. Identify the type of rock formed in Step 13.
6. Compare (the similarities and differences between) the three forms of rock you created.
7. Describe one way this rock model did not represent what occurs in the real world. This is referred to as the "limitation of the model".

Lesson 14.12

The age of a rock can be calculated

Learning intentions and success criteria

Key ideas

- → Fossils can tell how and when a rock was made.
- → Fossils can be the remains of an organism preserved in rock.
- → Trace fossils are rock versions of footprints or leaves.
- → Opalised fossils are replicas of a fossil made of opal.

Introduction

Over 95 million years ago, Australia was populated by megafauna. These large animals included a wombat ancestor the size of a rhinoceros (*Diprotodon optatum*) (Figure 1) and a giant monitor lizard, *Varanus priscus*, that was up to 7 metres long (Figure 2).

We know that these animals existed because of the fossils found at Lightning Ridge in NSW and Coober Pedy in South Australia.

What are fossils?

trace fossil traces of an organism that existed in the past

fossilisation the process of an organism becoming a fossil

Fossils are the remains or traces of organisms that are now extinct. A **trace fossil** can include footprints in the mud that become permanent when the sedimentary mud becomes hardened into sedimentary rock. This process can also occur when leaves fall to the ground and leave an imprint or mark in the dirt.

Fossilisation occurs when the footprint or imprint is covered by sediment (Figure 3). This prevents the weathering of the marks. Over time, more layers of sediment are deposited, pushing down on the dry imprinted mud. The pressure allows the sediment to form sedimentary rock.

Aboriginal and Torres Strait Islander Peoples have walked this country for thousands of years. Footprints estimated to be around 20,000 years old have been found preserved in the claypans of Willandra Lakes, NSW. These footprints are the oldest footprints found in Australia and the largest set of Ice Age footprints in the world. The Barkandji/Paakantji, Ngiyampaa, and Mutthi Mutthi peoples have unbroken connection to these footprints, and they continue to walk on Country in the footsteps of their ancestors.

Fossils are only found in sedimentary rock. If sedimentary rock is exposed to too much pressure or heat, then the rock will undergo physical and chemical changes and become metamorphic rock. These changes will usually destroy the fossil. If the sedimentary rock is melted into magma and cooled into igneous rock, the fossils will also be destroyed.

Figure 1 *Diprotodon optatum* is the largest marsupial to have existed.

Figure 2 *Varanus priscus* is an extinct giant monitor lizard.

Opalised fossils

When some Australian megafauna died, their bodies became covered in sediment, such as sand or weathered rocks. This prevented other animals from eating them or bacteria and fungi from decomposing the body. Sometimes, the soft parts of the body would decompose, leaving just the bones to be covered. The bones take longer to break down. If the sediment hardened before the bones decomposed, then a cavity or hole in the shape of the bone would form. Over millions of years, this cavity would become filled with a type of silica, a mineral, that forms opal. This opalised fossil is a copy of the original bones that were buried. Eventually, the sedimentary rock may be uplifted and the surrounding rock weathered and eroded, allowing the opalised fossil to be seen.

Figure 4 *Zygomaturus trilobus* lived 33,000 years ago

Predicting the age of a rock

Knowing how long ago a megafauna such as *Zygomaturus trilobus* lived allows us to work out when a sedimentary rock was made. *Zygomaturus trilobus* was another large wombat-like marsupial the size of a bull (Figure 4). Through a special form of dating that uses the amount of

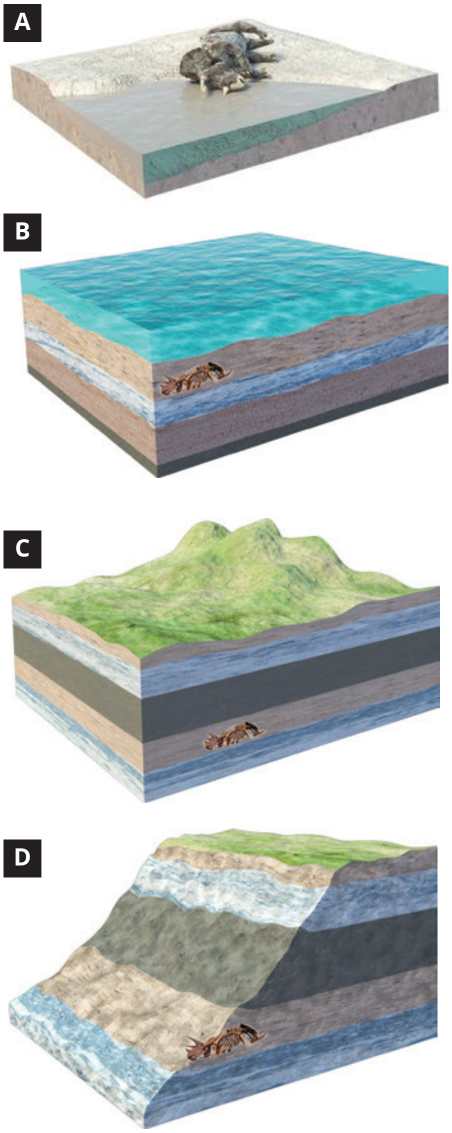


Figure 3 Formation of a fossil: (A) and (B); if an organism dies near water, it has a greater chance of being buried in sedimentary sand. This protects the body from being eaten. (C) Over millions of years, more sediment is deposited, replacing the remains so they are transformed into sedimentary rock. (D) Uplift, weathering and erosion may cause the fossil to be exposed.

radioactive material in the fossil, it was worked out that the animal died about 33,000 years ago. This means that the sedimentary rock surrounding the fossil was 33,000 years old.

law of superposition states that younger sedimentary rock layers lie above older sedimentary rock layers

The **law of superposition** states that, in sedimentary rock layers, the younger layers lie above older layers. This helps scientists to predict the relative age of a sedimentary rock layer. In the example of *Zygomaturus trilobus*, the rock found above the fossil is less than 33,000 years old, and the rock found deeper under the fossil is more than 33,000 years old (Figure 5).

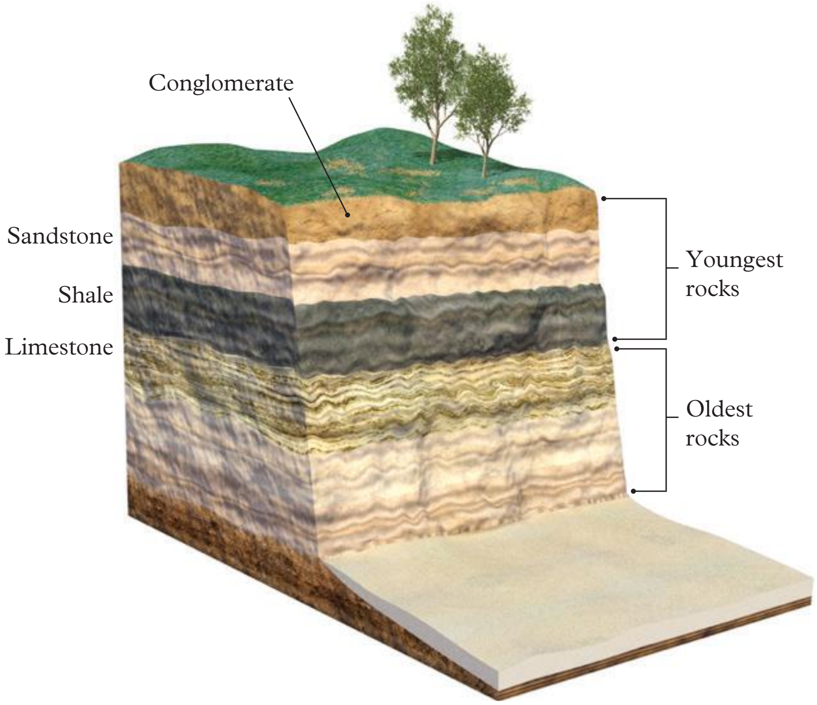


Figure 5 The rock above the fossil must be younger than the fossil. The rock below the fossil must be older than the fossil.

Who killed the megafauna?

For many years, it was thought that all Australian megafauna were hunted to extinction by Aboriginal and Torres Strait Islander Peoples over 50,000 years ago. This is now being questioned, as the discovery of the 33,000-year-old *Zygomaturus trilobus* at Willandra Lakes, NSW, suggests that Aboriginal and Torres Strait Islander Peoples and the large wombat ancestor coexisted (meaning they both lived in the same area) for over 17,000 years.

Check your learning 14.12

Check your learning 14.12

Retrieve

1 Recall two types of fossils.

2 Identify the mineral that is found in opal.

3 Explain why fossils are not found in igneous or metamorphic rocks.

Comprehend

4 Describe how fossilised opals are formed.

5 Explain why Aboriginal and Torres Strait Islander Peoples are no longer thought to have hunted megafauna to extinction in Australia.

Apply

6 Determine how old the rock above a 50,000-year-old fossil would be.

Lesson 14.13

Investigation: Making a fossil

Purpose

To make a trace fossil in sedimentary rock

Materials

- Dry clay
- Dry sand
- Plaster of Paris
- Water
- Mortar and pestle
- Teaspoon
- One empty matchbox
- White tile
- Small objects such as dry leaves, plastic toy animals, etc.

Procedure

1. Grind a lump of dry clay with a mortar and pestle until it is fine and powdery.
2. Use the teaspoon to mix the following dry ingredients for the sedimentary rock on a white tile:
   - $\frac{1}{2}$ teaspoon of dry clay
   - 4 teaspoons of dry sand
   - $\frac{1}{2}$ teaspoon of plaster of Paris.
3. Pile up your ingredients into a little hill and make a small dip in the centre for the water.
4. Slowly add 2 teaspoons of water and stir until the ingredients are uniformly mixed. Be careful not to make the mixture too wet.
5. Press your mixture into the empty matchbox.
6. Gently place the dry leaf or toy animal into the surface of the mixture. Carefully remove the leaf or animal so that an imprint has been left in the surface.
7. Label the “rock” containing the trace fossil with your name and leave it to dry for two days.
8. When your rock is dry, peel off the matchbox and examine your sample. Take digital photos of your trace fossil.

Results

Include images of your trace fossil. Describe what your fossil looks like.

Discussion

1. Describe how fossils are formed.
2. Describe what would happen if the rock containing your trace fossil was exposed to large amounts of pressure or a high temperature.

Conclusion

Describe the formation of a trace fossil.

Figure 1 This dinosaur footprint is an example of a trace fossil.

Lesson 14.14

Planets are made up of different elements

Learning intentions and success criteria

Key ideas

- → The main two elements that make up the Earth's crust are oxygen and silicon.
- → The Earth's core is made up of iron and nickel.
- → The elemental compositions of other terrestrial planets of our solar system are very similar to the Earth.

What is the Earth made of?

silicate a chemical compound made up of silicon and oxygen

terrestrial planets describes the planets Mercury, Venus, Earth and Mars, as they have a rocky surface

The Earth has a layered structure. Its core is made of denser elements such as iron and nickel, while its crust is composed of lighter elements like silicon, oxygen and aluminium. These elements make up about 82% of the Earth's crust. Oxygen is the most abundant element in the crust, followed by silicon. Most of the Earth's crust is made of a chemical called **silicate**, which contains silicon and oxygen atoms. Silicates are the building blocks of many minerals and rocks.

The mantle, which is the layer between the Earth's crust and core, is mainly made up of silicate minerals rich in magnesium and iron. The mantle makes up about 84% of the Earth's volume.

If you consider the Earth as a whole, iron is the most abundant element. This is because the Earth's core, which is very dense, contains a lot of iron (Table 1).

The other **terrestrial planets** in our solar system, such as Mercury, Venus and Mars, have a similar elemental composition to the Earth. Their cores are mostly made of iron, and their crusts and mantles are primarily made of silicate minerals. These similarities suggest that the processes that formed these planets were quite similar.

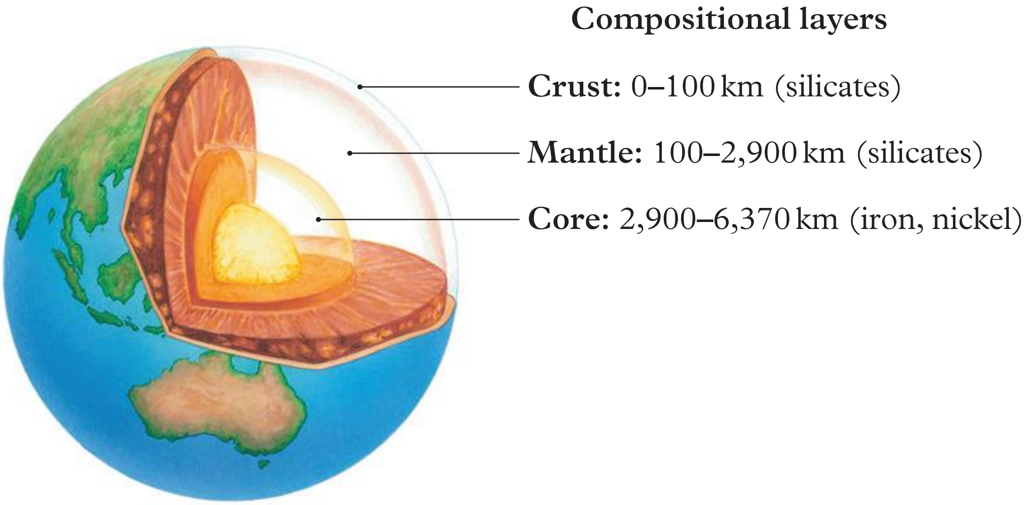


Figure 1 The Earth's crust and mantle are mainly made of silicate, a chemical made up of silicon and oxygen atoms. The core is made up of iron and nickel.

Table 1 Elemental composition of the Earth's crust

Element	Abundance in the crust (%)
Oxygen	47
Silicon	28
Aluminium	8
Iron	5
Magnesium	4
Calcium	2
Potassium	2
Sodium	2
Others	2

Table 2 Elemental composition of the entire Earth

Element	Abundance in the entire Earth (%)
Iron	35
Oxygen	30
Silicon	15
Magnesium	13
Nickel	2
Sulfur	2
Calcium	1
Aluminium	1
Others	1

Check your learning 14.14

Check your learning 14.14

Retrieve

1 Identify the elements that make up the core of the Earth.

2 Explain why we believe terrestrial planets are formed by the same processes.

Analyse

3 Distinguish the primary elements that make up the Earth's composition.

4 Compare the concentrations of different elements in the Earth's layers.

Apply

5 Research to collect evidence in support of the theory that Earth’s elements came from the formation of the solar system.

Lesson 14.15

Science in context: Scientists help to locate and extract minerals

Introduction

Geologists are scientists who study the rocks and particles that make up the Earth. They produce and use geological maps using geophysical methods such as seismic testing, magnetometer testing, electromagnetic testing and gravimetric testing. Geochemistry involves the use of chemistry principles to identify the location and type of minerals in the Earth.

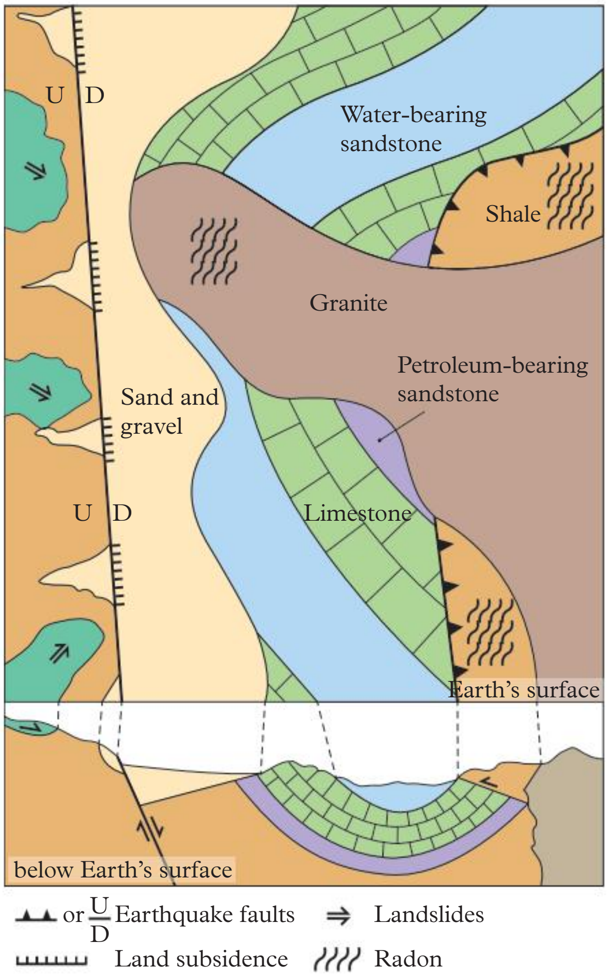


Figure 1 Geological maps allow geologists to determine the location of mineral resources that could be extracted.

Geological mapping

Geological maps show all the rocks and minerals in an area. These maps are a representation of the rock types found under the surface of the Earth. Different colours or symbols are used to indicate the rocks found at each location (Figure 1).

These maps can be used to locate ground water, identify possible contamination risks, predict earthquakes or volcanic eruptions, and identify energy and mineral resources and the costs of mining them.

They can be constructed in different ways. Most are a result of geophysical and geochemical testing.

Geophysical testing

Geophysical testing involves testing the physical properties of the Earth and the atmosphere. This may include oceanography (the study of the ocean), seismology (the study of earthquakes), vulcanology (the study of volcanoes) and geomagnetism (the study of the Earth's magnetic field).

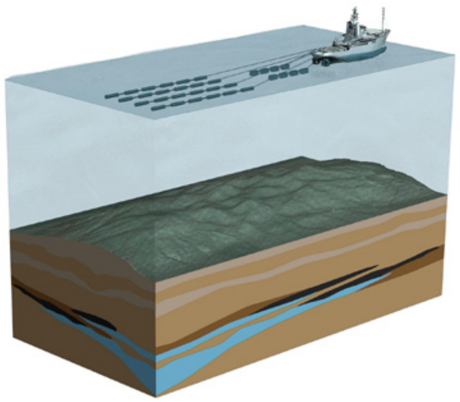


Figure 2 Seismic refraction method, which analyses how the direction and speed of seismic waves change as they move through different layers of Earth

Seismic geophysical testing involves sending vibrations into the Earth. The vibrations move differently depending on the type of rock. The vibrations often bounce off the different layers of rock and travel back to the surface. Special microphones called **geophones** are spread across the surface of the Earth. These geophones record the returning vibrations and a computer uses the data to construct a 3D map.

Oceanography boats will often carry out geophysical surveys to locate geological structures on the ocean floor (Figure 2 and Figure 3).

seismic geophysical testing the collecting of geophysical data such as differences in magnetic fields and gravity fields between different geological locations

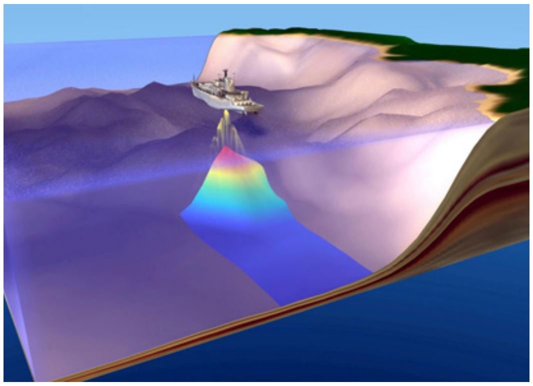


Figure 3 Oceanography boat

The presence of some metals beneath the Earth's surface can cause small changes in the Earth's magnetic field. These small changes can be picked up by **magnetometers** (Figure 4).

Electromagnetic pulses can be sent into the soil to detect different types of minerals. Some rocks contain minerals that do not conduct electricity, whereas others are affected by the electromagnetic signal. This change is detected by specialised metres carried by the geophysicist.

magnetometer a device that detects the difference in a magnetic field between one location and the next

electromagnetic relating to the physical interaction between moving charged particles and the magnetic field that is created as a result

The gravity of the Earth is not constant (Figure 5). Slight changes are caused by the density of the rock under us. We could not pick up these variations in gravity; however, they can be detected by a **gravimeter**. For large-scale surveys, helicopters carrying gravimeters fly in grid patterns across the surface of the Earth (Figure 6).

gravimeter a device that measures the difference in gravity between one location and the next

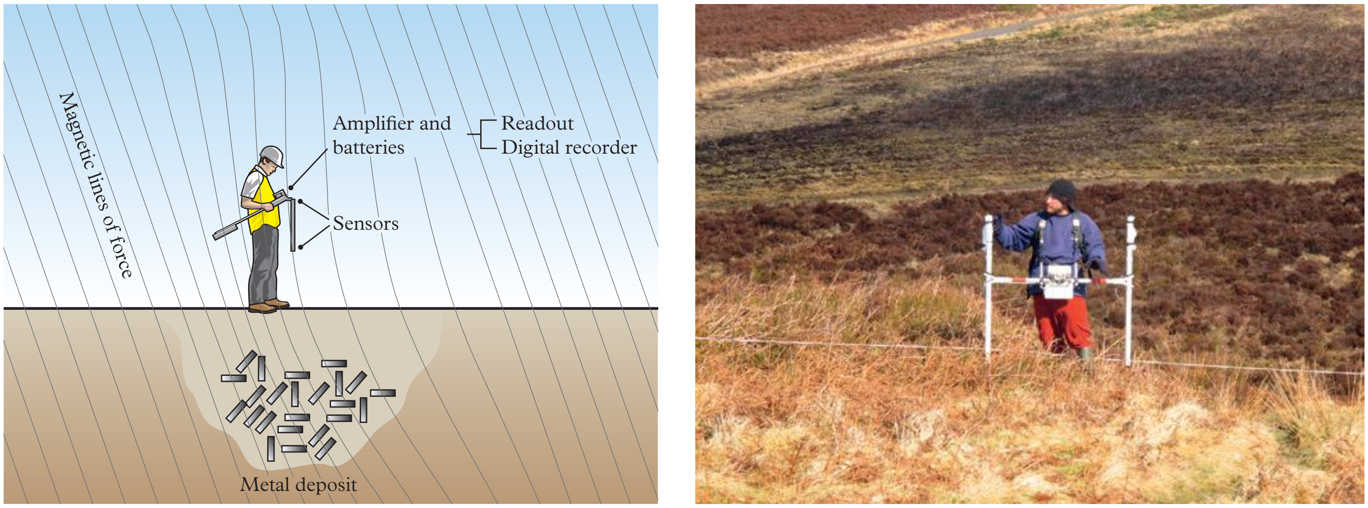


Figure 4 A geophysicist using a magnetometer to pick up slight changes in the Earth's magnetic field

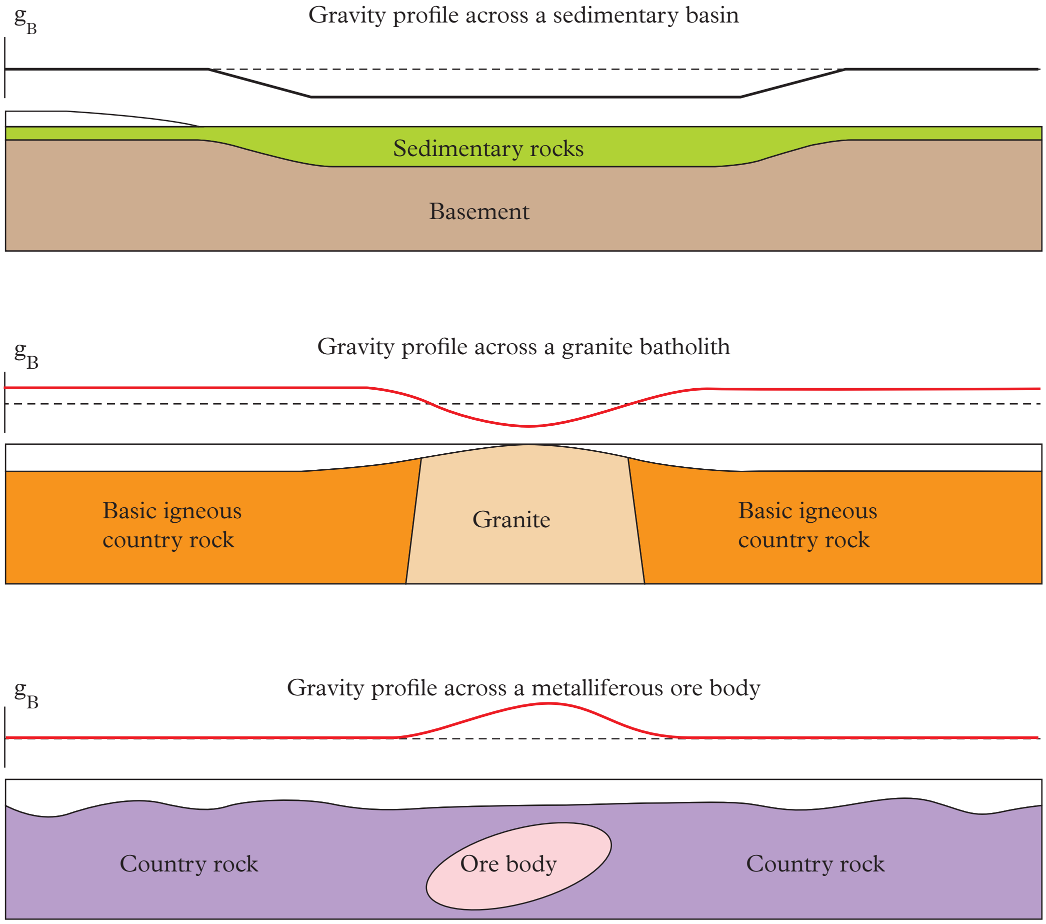


Figure 5 Granite and sedimentary rocks have lower gravitational fields than metal ores.

Geochemical testing

Geochemical analysis is used to determine what chemicals or minerals are in the rocks. It can be used to detect the presence of petroleum products, metals and commercially valuable minerals. It can be like a treasure hunt. Small samples of sediment or rocks are collected at a number of different sites and are taken back to a laboratory for chemical tests. Some samples might show a higher than normal level of a mineral, such as copper. The geochemist will then go back to the site where those samples were located and do further tests to locate the source of the copper.

Figure 6 Helicopter with a front-end gravimeter

Extracting the minerals

Extracting the minerals can be very expensive. If the mineral is close to the surface, open mining may be used. This involves removing the surface of the soil so that the mineral can be extracted easily and taken for processing. If the mineral is deep under the Earth's surface, sub-surface mining – where tunnels or shafts are used to reach the mineral deposits – may be used. Geologists will often prepare reports on the costs of mining the mineral. This will then be compared to the amount of money expected to be made from selling the mineral. If the cost of mining is less than the expected value of the mineral, the extraction will begin.

Test your skills and capabilities

Test your skills and capabilities 14.15

Evaluating the importance of land use

The amount of land available for use is limited. This can cause ethical conflict between the needs of different groups in the community, including:

- mining resources
- food production
- housing
- conservation of native plants and animals.

For each of the needs above:

1. Describe one reason why the need for an area of land may be important.
2. Describe how the use of land in this way could affect your life in a positive way and therefore be important to you.
3. Evaluate which of the four uses of the land is most important by determining which of the reasons is most significant to you and explaining why you made this decision.
4. Consider: if the land surrounding your house was needed for this use, describe how this would change the way you live. Describe whether this changes the decision you made in question **3**. Explain your reasoning.

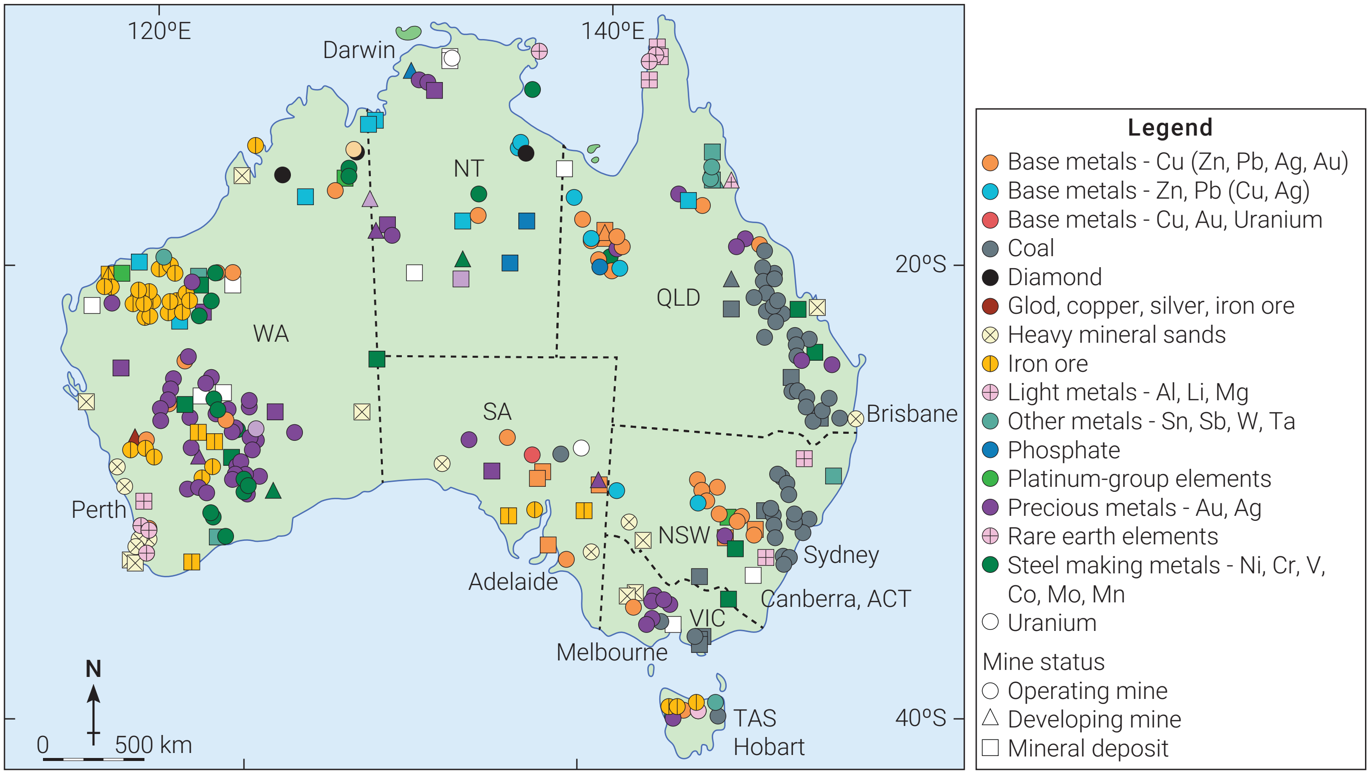


Figure 7 Geolocation has identified many different minerals across Australia.

Lesson 14.16

Investigation: Copper treasure hunt

Figure 1 Copper is an excellent conductor and is highly valued for its ability to conduct heat and electricity.

Introduction

You are a geologist employed to identify the location of new copper sources. You have used geophysical testing to determine a region around Mount Isa that has an intense electrical chargeability. You decide to complete a series of geochemical tests on the river silt to identify a possible source of the metal.

Purpose

To determine the location of a source of copper mineral from samples collected along a river

Materials

- Bunsen burner
- Heatproof mat
- Matches
- Wire loops
- Beaker
- 0.1 M hydrochloric acid
- Soil samples 1 to 6

Procedure

1. Place the Bunsen burner on the heatproof mat and safely light it. Open the collar on the Bunsen burner to produce a blue flame.
2. Take a wire loop and dip it in a small beaker of 0.1 M hydrochloric acid. Flame the loop. This will clean the loop, ready for your soil sample. Avoid getting too close to the flame. Stand back a little.
3. Dip the clean wire loop into a small amount of the soil sample. Place the soil-covered loop into the blue flame and observe the colour of the flame.
   - A green flame suggests copper is in the soil sample.
   - If no green colour appears, this suggests the copper is further downstream.
4. Once you have finished observing the flame, clean the wire loop by dipping it in the 0.1 M hydrochloric acid again and flaming it. This prepares the loop for testing the next sample.

Table 1 Results of copper hunt investigation

Soil sample	Colour of flame
1	
2	
3	

Results

Copy and complete Table 1 to record your results.

Discussion

1. Describe the possible location of the source of copper. Describe the evidence that supports your claim.
2. Explain why you cleaned the loop between each test.
3. Evaluate whether this geochemical method could be used if the copper ore was located deep under the ground (by describing how buried copper ore is different from surface ore and deciding if this would affect the results of the experiment).
4. Describe how you would test for copper ore that was located well below Earth's surface.

Conclusion

Describe what geochemical testing is and how it is used to test for minerals.

Lesson 14.17

Investigation: What if a muffin were mined in different ways?

Purpose

To compare the effectiveness of different methods of mining and their impact on the environment

Materials

- Two homemade chocolate chip muffins (each with the same number of chocolate chips – approximately 20)
- Plates
- Spoons

Procedure

1 Imagine each muffin is an area of land that contains a valuable ore: chocolate.

2 Place a muffin on a plate and use spoons to "mine" the chocolate from the first muffin using the "open mining" method, taking layers off the top and collecting the chocolate as it appears.

Inquiry: What if the muffin was mined using the sub-surface method?

Plan and conduct an experiment that answers the inquiry question.

1 Describe how this muffin can be mined so that the top environment remains intact.

2 Identify the (dependent) variable that you will measure and/or observe to determine which method was more effective.

Figure 1 Equipment for "muffin mining"

3 Identify two variables that you will need to control to ensure that the test is reproducible.

4 Develop a method for your experiment. Write this method in your notebook.

5 Construct an appropriate table to record your results.

6 Show your teacher your planning to obtain approval before starting your experiment.

Results

Draw or take a photo of your two muffins.

Discussion

1 Describe which method recovered the most chocolate ore.

2 Identify which method recovered the chocolate ore in the shortest time.

3 Identify which was the easiest method to recover the chocolate ore.

4 Explain which method would allow the environment to be quickly rehabilitated.

Lesson 14.18

Review: Minerals and rocks

Summary

Lesson 14.1 Rocks have different properties

- Geologists are scientists who study rocks.
- The properties of rocks include colour, presence of layers, hardness, density and crystal size.

Lesson 14.2 Rocks are made up of minerals

- Rocks are made up of one or more types of minerals.
- The physical properties of rocks can be used to identify minerals correctly.

Lesson 14.4 Igneous rocks develop from magma and lava

- Magma (hot liquid rock) flows deep beneath the Earth's surface.
- When the magma moves above the Earth's surface it is called lava.
- Igneous rocks form when magma and lava become solid.

Lesson 14.6 Sedimentary rocks are compacted sediments

- Sedimentary rocks are formed from compacted particles or sediment.
- Stalactites and stalagmites are forms of sedimentary rock.

Lesson 14.8 Metamorphic rocks require heat and pressure

- Rocks deep underground experience high pressure.
- High pressure generates high temperatures.
- High pressures and temperatures cause the rearrangement of minerals to form metamorphic rock.

Lesson 14.10 The rock cycle causes rocks to be re-formed

- The rock cycle describes the formation of sediment, sedimentary rock, compression to metamorphic rock and melting and solidification to form metamorphic rock.
- Weathering is the breaking down of rocks and minerals through the movement of water and animals, and through the extremes of temperature.
- Erosion is the movement of sediment to another area.

Lesson 14.12 The age of a rock can be calculated

- Fossils can tell how and when a rock was made.
- Fossils can be the remains of an organism preserved in rock.
- Trace fossils are rock versions of footprints or leaves.
- Opalised fossils are replicas of a fossil made of opal.

Lesson 14.14 Planets are made up of different elements

- The main two elements that make up the Earth's crust are oxygen and silicon.
- The Earth's core is made up of iron and nickel.
- The elemental compositions of other terrestrial planets of our solar system are very similar to the Earth.

Review questions 14.18

Review questions Module 14

Retrieve

1 Recall the visual properties of rocks that can help identify them.

2 Recall the basis of rock classification.

3 Identify the rock type that is formed from lava.

  A Sedimentary rock
  B Metamorphic rock
  C Igneous rock
  D Marble rock

4 Define the following terms.

  a Extrusive igneous rocks
  b Intrusive igneous rocks
  c Sediment

5 Recall the term used to describe a rock breaking apart because of daily heating and cooling.

  A Physical weathering
  B Chemical weathering
  C Biological weathering
  D Erosion

6 Identify the correct statement. Fossils usually form:

  A in layers of sediment.
  B in layers of igneous rock.
  C as wind erodes layers of rock.
  D as water erodes layers of rock.

Comprehend

7 Copy and complete the following sentences.

  a ________________ are small pieces of organised particles that have smooth sides and sharp edges.

  b ________________ rocks are formed when loose particles are pressed together by the weight of overlying sediments.

  c ________________ rocks are formed when other types of rocks are changed by heat and pressure inside the Earth.

  d ________________ rocks form when magma and lava from volcanic eruptions cool and solidify.

8 Describe the properties used by geologists to identify different rocks.

9 Explain why colour alone is not a reliable guide for identifying rocks.

10 Describe the properties that would allow you to determine the difference between intrusive and extrusive igneous rocks.

11 Explain how sedimentary rocks form at the Earth's surface.

12 Describe the properties of ochre that make it valuable to Aboriginal and Torres Strait Islander Peoples.

13 Describe how the different rock formations found in a cave (stalactites, stalagmites and columns) form.

14 Describe the relationship between weathering and erosion.

15 Explain why and how electromagnetic pulses detect metals.

Analyse

16 Infer why pumice has no crystal structure even though it is a rock.

17 Use Table 1 in Lesson 14.1 Rocks have different properties (page 558) to identify the following rocks based on their properties.

  a A fine grain and no hardness, dark in colour
  b Density of 2.2–2.8, light colour, coarse grain size, hard
  c Fine grain size, soft, dark in colour

18 Examine the rock samples in Figure 1 and Figure 2.

Figure 1 Rock sample 1

Figure 2 Rock sample 2

  a Use Table 1 in Lesson 14.1 Rocks have different properties (page 558) to identify the rocks.

- **b** Explain your responses.
- **c** Recall what type of rock each sample is.
- **d** Consider how their appearance relates to the way in which each was formed.

19 Compare obsidian and scoria rocks.

20 Contrast magma and lava.

21 Some famous works of art are made of marble (Figure 3).

- **a** Recall the properties of marble.
- **b** Categorise the properties of marble as being ideal for artworks and not ideal for artworks.

Figure 3 The famous marble statue of David is over five metres tall and was created by the master Italian artist Michelangelo between 1501 and 1504.

22 Contrast the different ways a rock can undergo weathering.

23 Cave systems in limestone rock follow the course of underground rivers. Infer why water is necessary to form caves.

24 Reflect on why only simple fossils are found in the oldest types of rocks, whereas younger rocks have fossils of larger mammals.

Apply

25 There are no active volcanoes on the mainland of Australia, but there are still examples of igneous rocks throughout the country. Suggest what this implies about the history of volcanic activity in Australia.

26 Determine what types of rocks you would look for if you were a palaeontologist searching for fossils.

27 Explain how chemical weathering impacts a memorial rock located in a town centre at the base of a hill.

Critical and creative thinking

28 Figure 4 shows the Twelve Apostles found along the Victorian coast. Use this image to describe how these rocks were formed. Create a poster to show how the rocks were formed and how they would have changed over time. Describe how they may change over the next 1,000 years.

Figure 4 The Twelve Apostles are located off the coast of Victoria.

29 Create a flowchart showing how fossils are formed.

30 Use the rock cycle (Figure 5) to create a mind map linking the concepts you have learnt about in this module. Include:

- the properties of rocks
- the formation of different rock types
- weathering and erosion
- dating of rocks
- extraction of minerals.

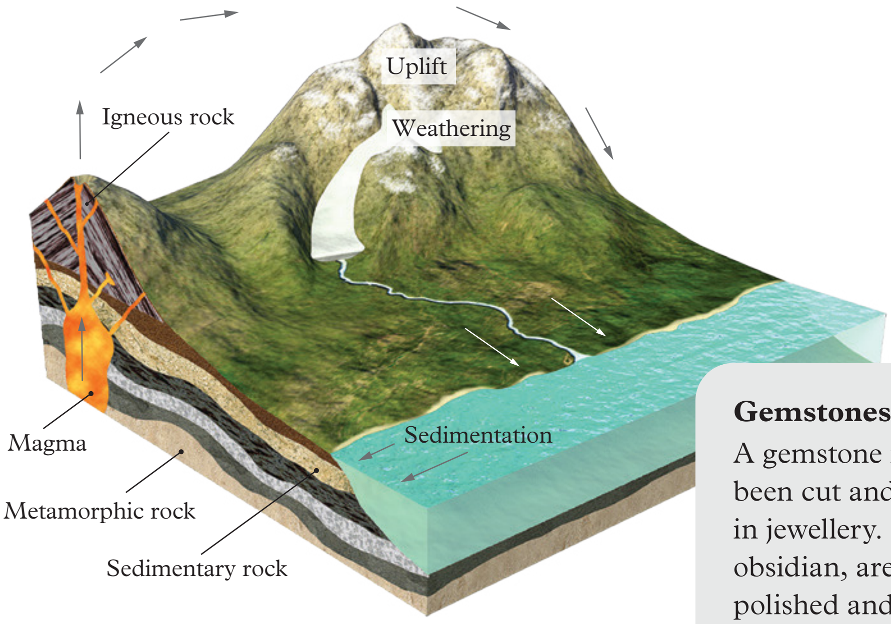


Figure 5 The rock cycle

Social and ethical thinking

31 Some people say that Australia is a huge quarry. This is because Australia mines so many minerals and sells them. Working on your own, determine the advantages and disadvantages of mining and selling minerals. Join with a classmate and combine your lists. Rank your lists in terms of strengths of benefits and risks. Then join with another group and compare your decisions. Prepare another list by considering the ethics involved in mining and justify your three best reasons for mining and the three best reasons against mining.

Research

32 Choose one of the following topics for a research project. Some questions have been included to help you begin your research. Present your report in a format of your own choosing.

Gemstones

A gemstone is a mineral crystal that has been cut and polished. They are often used in jewellery. Some rocks, such as opal and obsidian, are not crystals but can also be polished and used for decoration.

- Describe what gemstones look like.
- Identify which gemstones are found in Australia.
- Select one of these gemstones and identify where in Australia they have been mined.
- Describe how a miner might have extracted this gemstone from the Earth.

Extraction of metals

Metals are extracted from ore using a variety of methods. Some are heated, some are purified using electrical energy and some are extracted using chemical processes.

- Describe why different metals are extracted using different chemical or electrical processes.
- Find out how some metals are extracted, such as copper and aluminium, and design a poster that shows the process of extraction.

Formation of oil

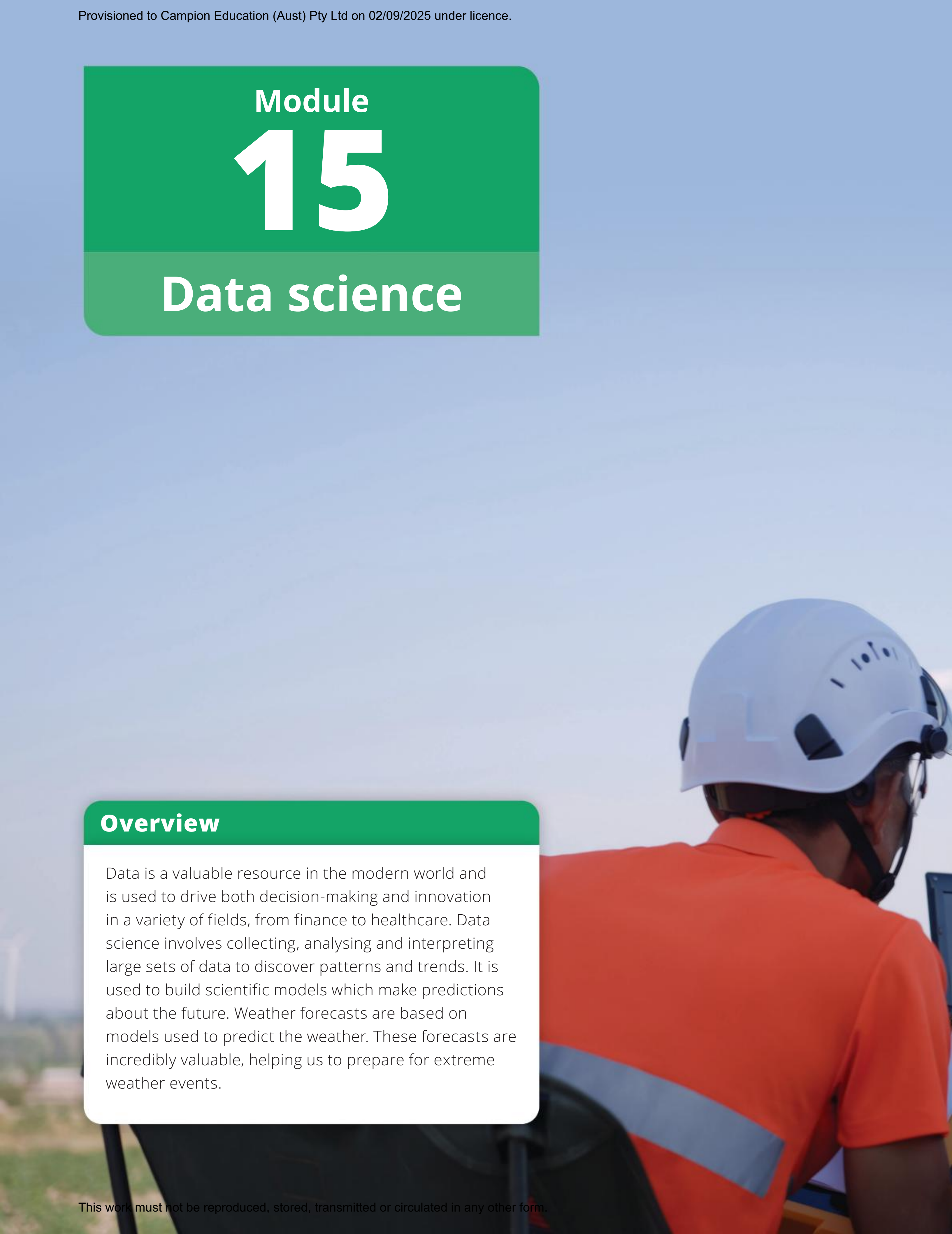
Oil is formed from the compression of dead marine-plant material in mud over millions of years. Oil is made up of hydrocarbons, which are lighter than rock and water, so oil often migrates up through porous rock towards the Earth's surface.

- Describe an oil reservoir.
- Describe the conditions that are needed for an oil reservoir to form.
- Describe how an oil field is formed.

Module

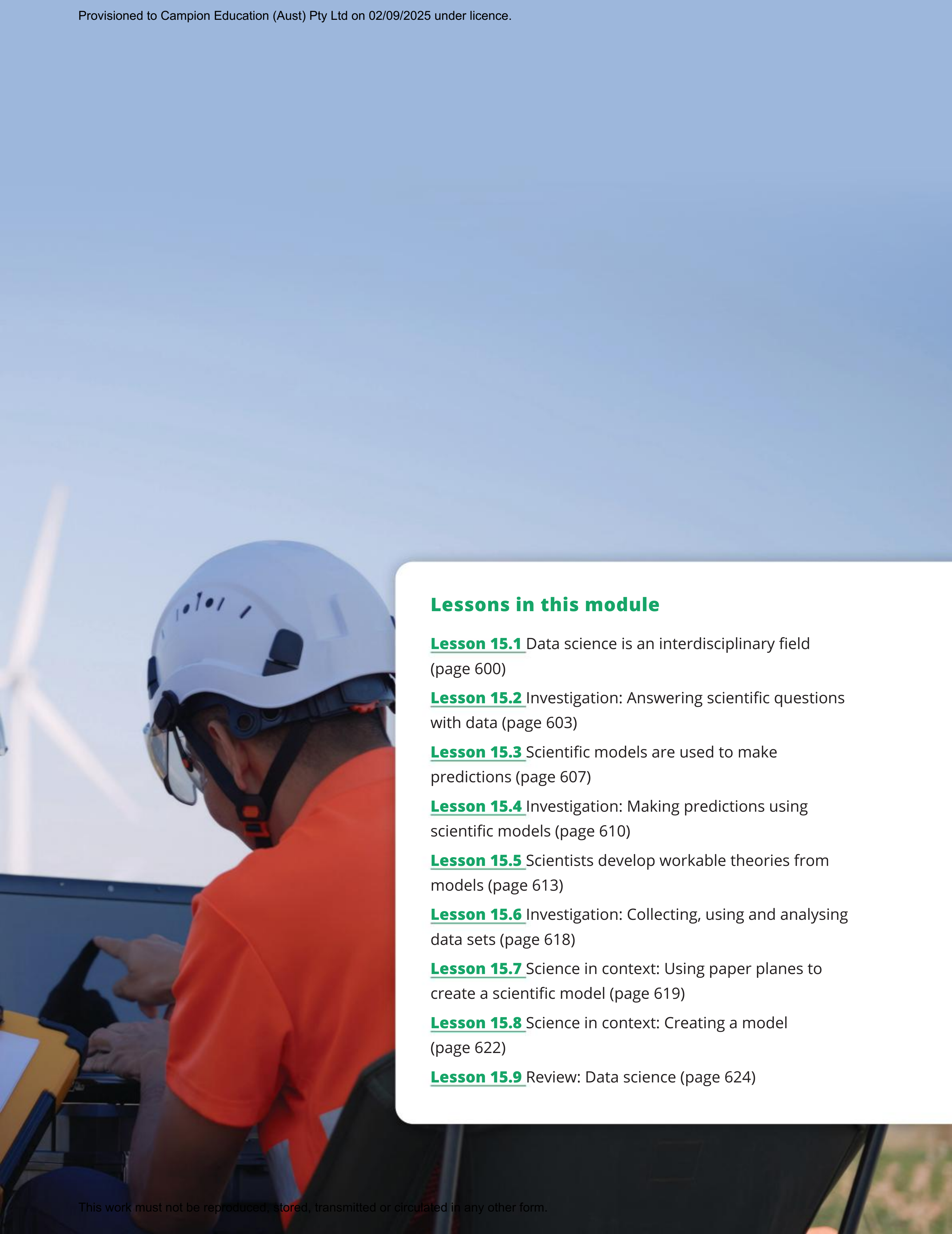
15

Data science



Overview

Data is a valuable resource in the modern world and is used to drive both decision-making and innovation in a variety of fields, from finance to healthcare. Data science involves collecting, analysing and interpreting large sets of data to discover patterns and trends. It is used to build scientific models which make predictions about the future. Weather forecasts are based on models used to predict the weather. These forecasts are incredibly valuable, helping us to prepare for extreme weather events.



Lessons in this module

Lesson 15.1

Data science is an interdisciplinary field

Learning intentions and success criteria

Key ideas

- → Scientists use data to gain knowledge and make predictions.
- → Different types of data are used in distinct ways for specific purposes.

What is data science?

Data science is the scientific study of data and information to gain knowledge and make predictions.

Data is a measurement or an observation. **Quantitative data** is numerical and **qualitative data** is descriptive. Scientists collect data and then process and analyse it to understand more about what they are studying.

Data is the plural of *datum*, which is Latin for “a thing that has been given”. A datum is a single data point that is usually meaningless on its own. When many datum are collected and put together, it is known as data or a **dataset**.

Data scientists collect data from different areas of research and use statistics, scientific methods and processes, algorithms and systems to process, analyse and interpret it. Data that has been analysed and organised to communicate meaning is called **information**. Data and information are used to develop scientific understanding, make predictions, describe relationships and draw conclusions.

When undertaking research in science it is important to have **accurate** and **reliable** data. If the data or sources of data are flawed, then inaccurate conclusions may be drawn from the data.

Answering questions with data

A **data source** is a place where data is obtained. There are two types of data sources: primary and secondary.

Primary data

Primary data (also called first-hand data) is data collected by the person conducting an investigation. Primary data sources include data from experimentation, surveys, measurements and observations. This data is collected to answer a specific inquiry question. Primary data sources allow the researcher to have control of the experiment and are useful for obtaining new data and answering new questions.

For example, if agricultural researchers want to determine how plants grow under certain conditions, they will develop a controlled experiment to measure the growth of plants under these conditions.

data science a field of study which involves collecting, analysing and interpreting large amounts of data to gain insights and make decisions

quantitative data can be measured numerically

qualitative data descriptions and explanations that are not numerical

dataset a collection of data points usually represented in a table or graph

information facts that are provided or learnt

accurate how close information is to the true value

reliable consistency of information across difference sources or measurement

data source the place where data originates from

primary data data that is obtained by the original person doing the research from the original source

Surveys gather data from many people. Scientists develop a hypothesis and conduct a survey to gather results. They analyse the survey data to form a conclusion. Scientists might conduct a survey, for example, to determine how people dispose of their e-waste.

Scientists make observations to count the number of species in an environment. Charles Darwin observed different species of finches in the Galapagos Islands. His observations led him to conclude that the finches were closely related but had evolved to adapt to different environments.

secondary data data which has been collected or analysed based on previous research

credible information that is reliable, trustworthy and based on evidence

Secondary data

Secondary data is data that is collected by others during previous research. Secondary data sources include books, magazines, newspapers, scientific articles, reports and historical records. Using secondary data is less costly than primary data because the information is already available.

During the COVID-19 outbreak, data was collected all over the world. This data included the number of cases, the number of deaths and the countries that had social-distancing policies and vaccine doses. This secondary data and information helped governments of the world to make decisions about how they would manage the COVID-19 pandemic.

How to evaluate the credibility of sources

Currency – When?

- When was the content written?
- When was the information published?
- When will the information be reviewed?

Relevance – What?

- What information is relevant to the topic?
- What is the intention of the publication?
- What language (emotive/factual) and content has been used in the information?

Authority – Who?

- Who is the author(s) and what are their credentials and qualifications?
- Who is the expert in the field and is the author experienced?
- Who is the author affiliated with?

Accuracy – How?

- How is information consistent across different sources?
- How is the content supported by evidence?
- How has the information been peer-reviewed?

Purpose – Why?

- Why has the publication been written? (inform/teach/sell/entertain/persuade)
- Why has the author(s) used this language to convey information?

Figure 1 Not all sources are credible, so it is important to evaluate them before you use their information or data.

Selecting and using data

In the age of digital technology, there is so much data available. It is important for a good scientist to be careful when selecting and using secondary data sources. They must make sure that the data is from **credible** sources and assess if the data is reliable and accurate (Figure 1). Scientists need to look at how the data was collected, the date it was collected, who conducted the primary research and their purpose for obtaining and publishing the data. Data from government (.gov), academics (.edu) and non-profits (.org) can be more reliable than data from commercial (.com) websites. Note that some .org websites may not be credible if they are created by individuals outside of a reputable organisation. Scientists must also correctly **cite** any secondary sources they have used when communicating their research.

cite to reference or acknowledge a source of information

Digital footprint

A digital footprint is the information that a person creates through their actions online. Every person who engages in digital activity leaves a digital trace (Figure 2). In medical research, using data from people's digital footprint can provide personalised medical treatments which are more effective. Using people's digital footprints for research, however, may lead to **ethical** issues, such as breaching privacy and confidentiality, as well as a misuse of the data. The data may also be incomplete or contain **bias**.

It is important for researchers to use, manage and communicate data ethically. Many organisations have rules and regulations about how data is used and communicated.

ethical having a moral character; being truthful, fair and honest

bias leaning towards or against an idea by being prejudiced or unfair

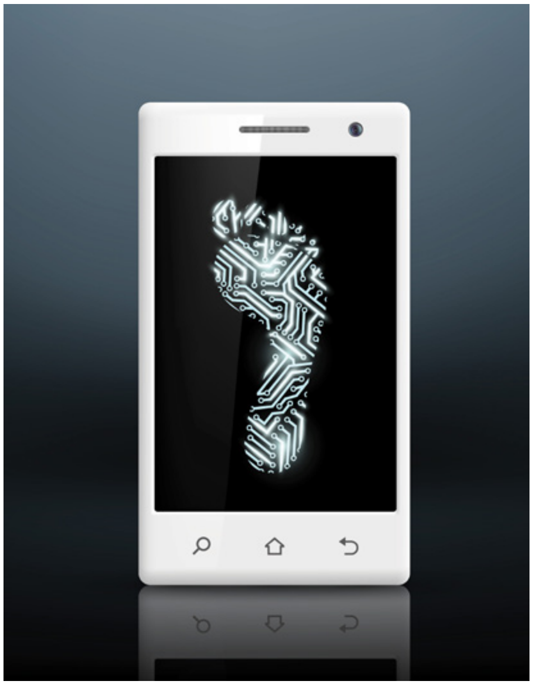


Figure 2 It is important to use digital information ethically and responsibly.

Check your learning 15.1

Check your learning 15.1

Retrieve

1 Define data science.

2 Give an example of qualitative and quantitative data.

Comprehend

3 Describe the difference between primary and secondary data sources. Give an example of each.

4 Discuss why it is important to use data ethically. Explain how this could impact scientific research.

Apply

5 Travel apps use data from a variety of sources. Use a travel app to plan a trip to a place you would like to visit. Answer the following questions.
   - **a** Describe the different types of data that the travel apps provide.
   - **b** Classify the data as quantitative or qualitative data.
   - **c** Outline how this data is obtained or measured.
   - **d** Describe how this data is used. HINT: Recall the reasons that scientists use data.
   - **e** Explain why this data is important.

Lesson 15.2

Investigation: Answering scientific questions with data

Introduction

The average height of a population is an indication of living conditions, including nutrition. Poor nutrition affects human growth. The study of human height allows researchers to examine living conditions of the past and make predictions about future trends in the population.

Purpose

To examine data and draw conclusions based on the data

Materials

The data in this activity is from the link provided.

Weblink: Our world in data

1 Discuss if this is a reputable website for data. HINT: Look at the "About" links and references on the page to consider where the data is sourced from.

2 Identify a question about population height and nutrition that can be answered using this data.

Map of global average height of men aged 18 in 1998 (born in 1980)

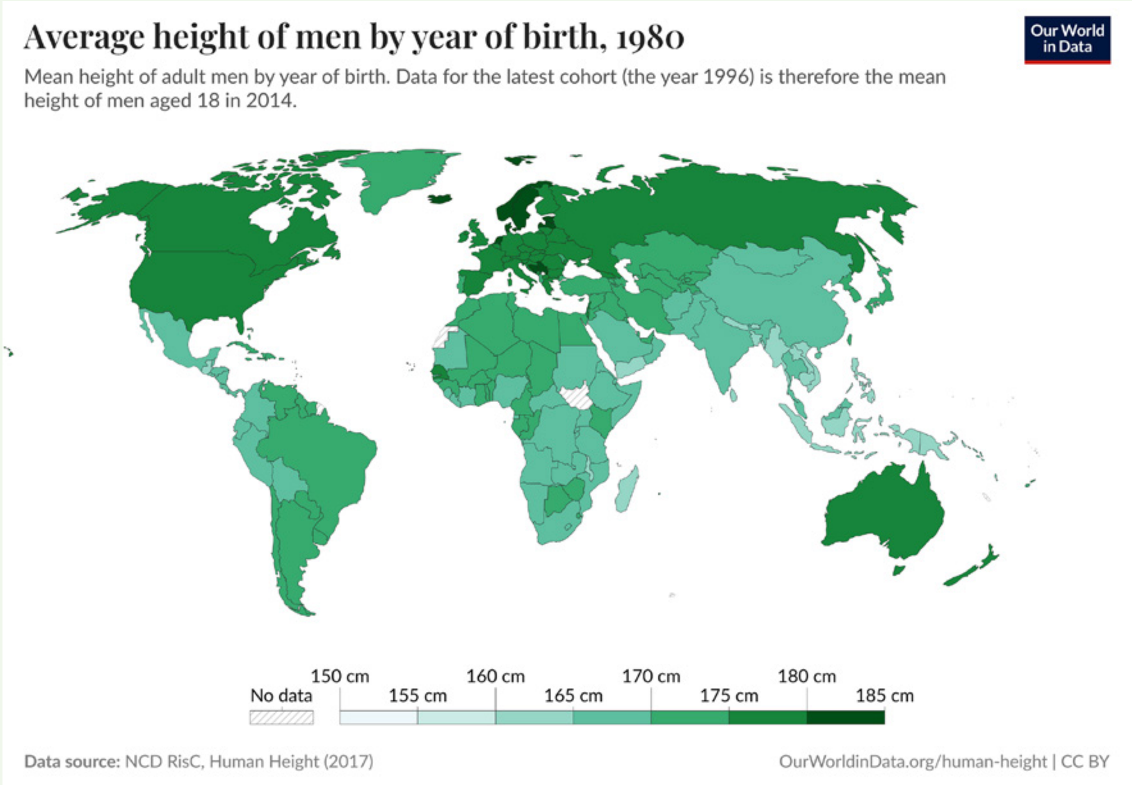
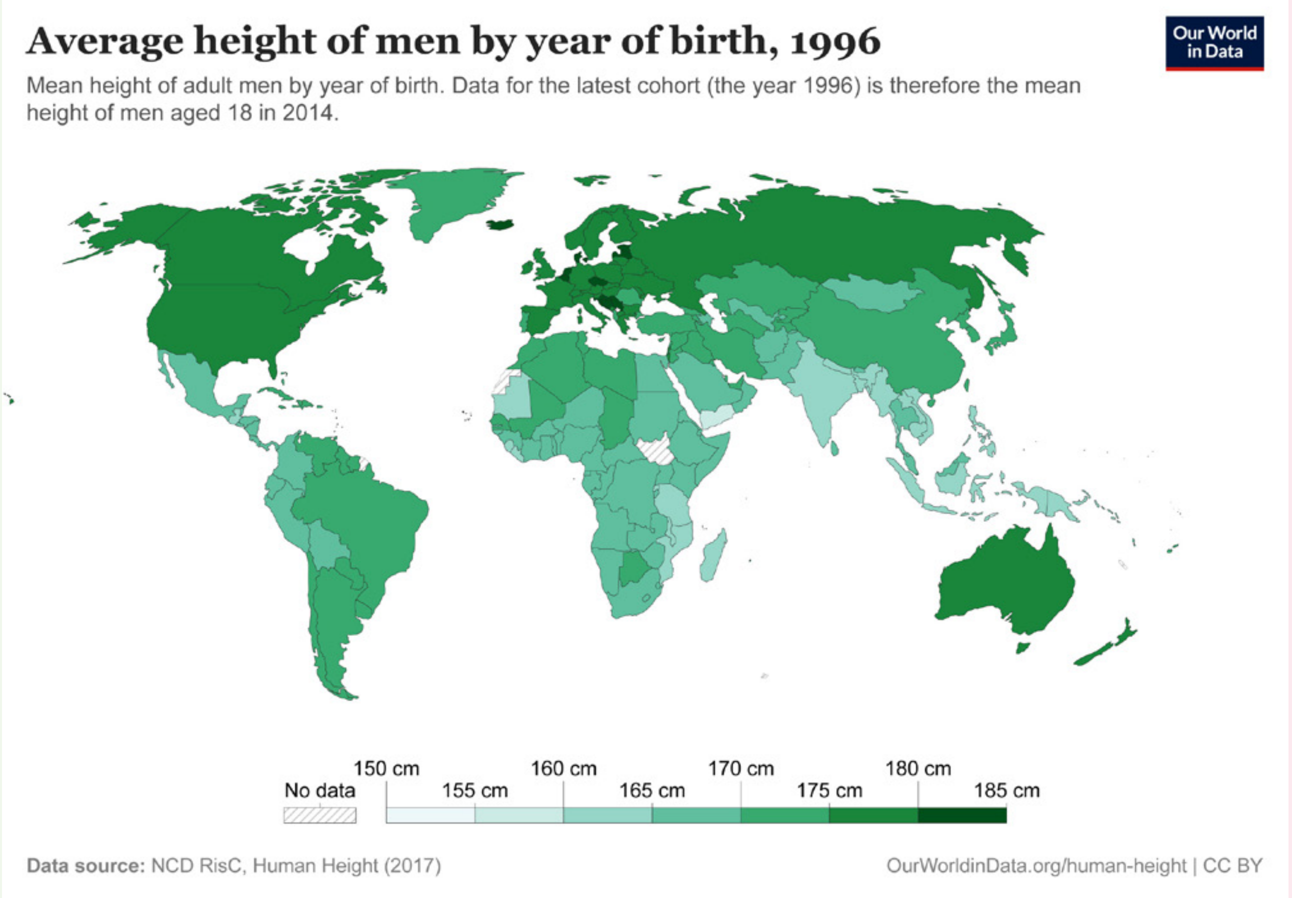


Figure 1 Worldwide average height of men turning 18 in 1998

Discussion

1 Identify the country that has the tallest men.
2 Identify the country that has the shortest men.
3 Discuss if the data in Figure 1 is sufficient to answer the question about the nutrition and height of a population.

Map of global average height of men aged 18 in 2014 (born in 1996)



Average height of men by year of birth, 1996

Mean height of adult men by year of birth. Data for the latest cohort (the year 1996) is therefore the mean height of men aged 18 in 2014.

Data source: NCD RisC, Human Height (2017)

OurWorldinData.org/human-height | CC BY

Figure 2 Worldwide average height of men turning 18 in 2014

Discussion

1 Identify the differences between the maps in Figure 1 and Figure 2.
2 Suggest one or more reasons for these differences.
3 Discuss if there is sufficient data in Figure 2 to answer the question about the nutrition and height of a population.
4 Describe what other data might be needed to answer the question about the nutrition and height of a population.

Graph of global adult height by year of birth

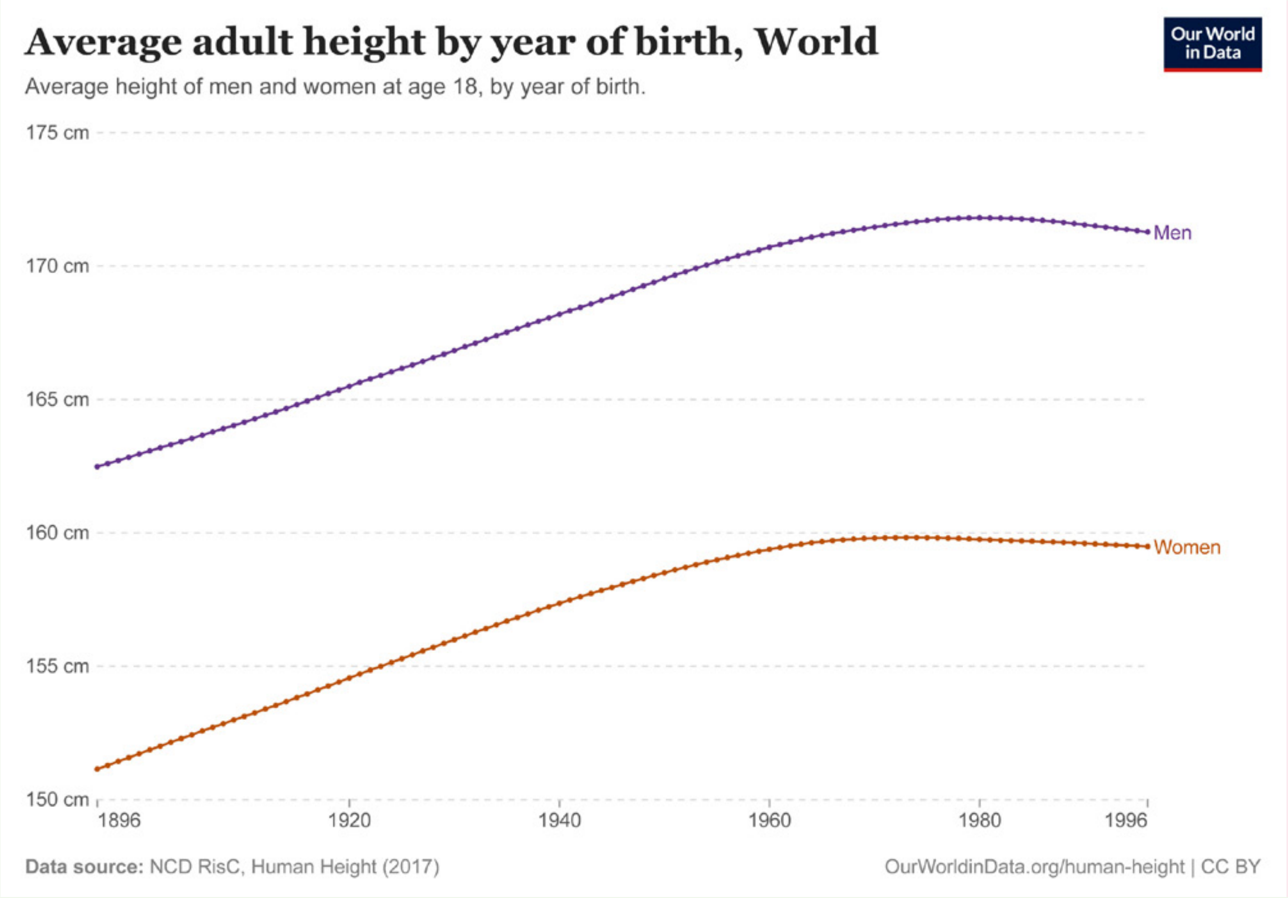


Figure 3 Average global height of 18-year-old women and men from 1896 to 1996

Discussion

1 Describe what the data in Figure 3 is showing.

2 Discuss if there is sufficient data in Figure 3 to answer the question about the nutrition and height of a population.

3 Describe what other data might be needed to answer the question about the nutrition and height of a population.

Graph of total protein calories vs. male height in 1996

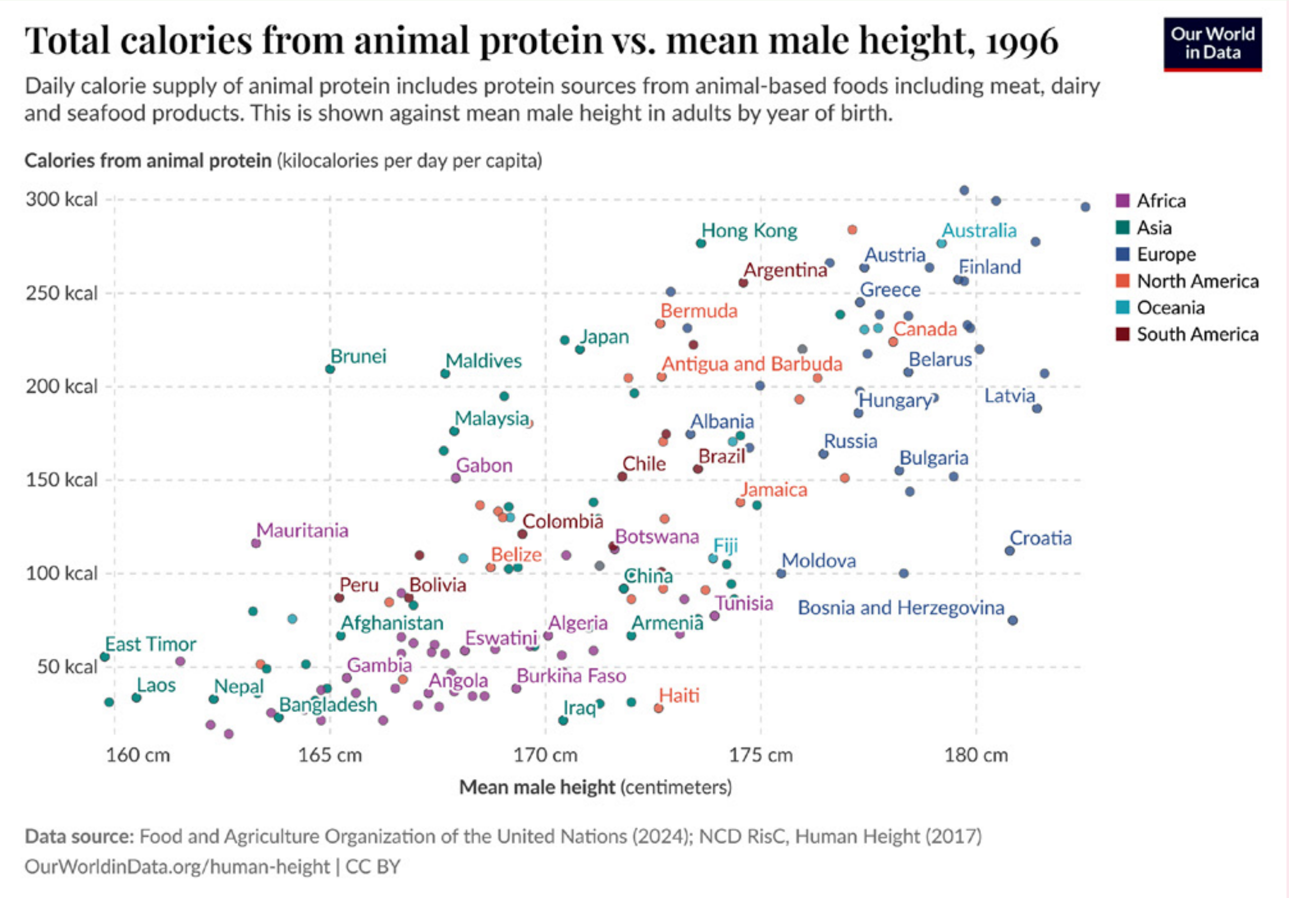


Figure 4 Total calories from animal protein vs. mean male height, 1996

Discussion

1 Describe what Figure 4 is showing.
2 Discuss if there is sufficient data in Figure 4 to answer the question about the nutrition and height of a population.
3 Discuss if height is the only indicator of good living conditions and nutrition.
4 Examine Figure 1, Figure 2, Figure 3 and Figure 4.
   a Describe how the data tells a story.
   b Outline the links between the figures.
5 Describe how the data from the different sources can be useful.
6 Use the data to draw a conclusion about the relationship between nutrition and population height.

Lesson 15.3

Scientific models are used to make predictions

Key ideas

→ Data used in science should be reliable and peer-reviewed.

→ Models are used in science to make predictions and demonstrate complex concepts that are not directly observable.

→ There are different types of scientific models used for distinct purposes.

Learning intentions and success criteria

Introduction

There are different approaches to obtaining data. A scientific approach uses the scientific method and evidence to back up its claims. Data that is obtained using the scientific method should be unbiased and credible. The data should also be repeatable and display consistent results. Experts in the field should check and verify the work of the scientists in a process called **peer-review**.

Unscientific methods of collecting and using data include citing claims and opinions that are not verified by evidence. Collecting and sharing data and information using unscientific methods can lead to incorrect conclusions and predictions. People who do not have scientific knowledge or an understanding of the issues can misinterpret the data or use scientific words or images out of context.

peer-review review and evaluation of scientific research by experts in the field

Scientific models

Scientific models represent objects, events or systems that are difficult to observe directly. Scientific models can be physical, conceptual or mathematical. These models are based on data and observations from real-world phenomena and are used to explain and predict scientific phenomena.

There are different types of scientific models that are used for distinct purposes. Models of atoms or cells, for example, help us to visualise something we cannot see. A model of the planets in our solar system allows us to see things that are too big or far away to be seen (Figure 1). A model of a dinosaur represents something that no longer exists. A prototype is a model of a future invention or application. A **simulation**

Figure 1 A model of the solar system

scientific model a representation of a complex concept or a phenomena that cannot be directly observed

simulation a model that represents a real-world concept can demonstrate a model of tectonic plates moving, which is an event that occurs too slowly for us to observe.

Most scientific models are very useful for helping people understand or visualise scientific ideas. For example, weather apps use data from a variety of sources, including weather stations, satellite data and historical data. The more data that is included in the weather apps, the more accurate the predictions can be. Accurate weather data is important for predicting extreme weather events. This means that governments can ensure that people are safe during these events.

There are some disadvantages, however, of using models. Models use approximations and cannot accurately include all the details of the object or system. Some models may be simplistic and only focus on one aspect of the scientific concept. It is important for scientists and researchers to understand the limitations of the models they are using to communicate ideas and make predictions.

Generating predictions

Scientific models are used to make predictions about complex ideas by applying them to new situations. Models are based on known data or information. Some models are used for predicting climate patterns or agricultural trends. New models are being designed to study ecosystems and even solve crimes.

Scientists can use historical mathematical data and an understanding of how climate events are related, for example, to predict how the climate will change if carbon emissions increase or decrease. Scientists can use computational models or simulations based on mathematical data to predict Earth's climate in the future.

Using models to make predictions is not a new concept. Before the time of computer simulations and animations, athletes would watch videos of games and players to obtain data about the most effective method to kick or throw a ball. Elite athletes can predict with some certainty the outcome of their actions under different conditions. Flight simulations built on data gathered from real flights are used to train pilots before they fly a plane. In theory, pilots should be able to study data to predict the conditions of their flight to manage and fly the plane safely.

Self-driving cars

Currently, self-driving cars are being developed and tested using a variety of factors to ensure they can respond to different driving conditions and scenarios. Different factors are called variables. Variables can change or vary and can affect each other.

Imagine a scenario where a self-driving car detects an object in the middle of the road. Will the car stop in time to avoid hitting the object? The answer depends on different variables. How fast is the car driving? How quickly does it detect the object? Is the ground icy or wet? Can the object be detected at night-time? The answer to the question will change depending on the variables in the scenario.

If the stopping distance depended on one variable, it would be easy to predict the likelihood of the car stopping in time. As soon as different variables are presented in the scenario, then the prediction changes. A computer simulation can account for these variables. It would account for multiple factors that would require the car stopping in time to avoid hitting the object. The simulation would virtually add the impacts of each variable to predict or model how things would be in a real-world scenario. A simulation would also allow scientists to adjust the variables to investigate how that could change the result.

The algorithms in self-driving cars cannot yet predict the behaviour of a jumping kangaroo on the road; however, more research is being done to solve this problem. The adjustment to the algorithms would be based on observation and data collected from kangaroos in order to draw relationships or trends in their movements. This data could then be incorporated into the programs of the self-driving cars, which would make them even safer to drive.

Figure 2 A self-driving car

Using computer models

Computer models are frequently used in science to make predictions. Computational models are used to track the spread of infectious diseases in populations. The models identify the most effective interventions to help prevent the spread of the disease. They are also used in the health system to gather, filter and analyse health information which provides timely and targeted care to patients. Computational models are used to predict the side effects of new pharmaceutical products on the market. This is beneficial in producing the safest medication for patients in a shorter time period.

Check your learning 15.3

Check your learning 15.3

Retrieve

1. Define a scientific model.
2. Outline how different scientific models are used. Give an example for each.

Comprehend

3. Explain how data is used by scientists to model and predict scientific phenomena. Give an example.

Analyse

4. A farmer and a scientist are trying to determine the best fertiliser for increasing crop yield. The farmer observes that crops grow better when using a particular fertiliser and continues using it based on this observation. The scientist conducts an experiment using three different fertilisers on identical plots of land, recording the average crop yields (in kilograms per hectare).
   - **a** Compare and contrast the farmer's and scientist's approaches. How are their approaches similar? How are their approaches different?
   - **b** Describe how their methods differ in collecting and analysing data.
   - **c** Discuss which approach provides more reliable conclusions.
   - **d** Describe how a computer-based model could enhance the scientist's experiment. Outline additional data points that would improve the accuracy of predicting the best fertiliser.

Lesson 15.4

Investigation: Making predictions using scientific models

Introduction

Governments around the world collect climate data. In Australia, the data is collected by the Bureau of Meteorology (BOM) from more than 1,000 sites.

Purpose

To identify data and observations used by scientists for the development of a scientific model

Weather and climate data

- Go to the Bureau of Meteorology (BOM) website.

Weblink: Bureau of Meteorology, The art of the chart: how to read a weather map

- The information in Table 1 summarises the features on a weather map. Use this information to complete the activity.

Discussion

Describe the difference between weather and climate.

Table 1 Summary of the features on a weather map

Features on a weather map	Symbol	Description
Isobars	Shown by plain lines that curve across the map.	Isobars show wind patterns. Wind is strongest when isobars are close together.
High-pressure system	Shown by a H on a weather map.	Air from a high-pressure system means warm and dry weather with light winds.
Low-pressure system	Shown by an L on a weather map.	Air from a low-pressure system means cold, wet and windy weather.
Cold front	Shown by a blue line with small triangles.	A cold fronts bring a drop in temperature and there is cloud and rain.
Warm front	Shown by a red line with semicircles.	Warm fronts bring warmer weather and humid conditions.
Trough	Shown by a dashed blue line.	Troughs separate moist air on one side and dry air on the other side. If the trough is moving towards the moist air, this indicates that showers or thunderstorms can develop. If the trough is moving in the opposite direction, this drags the moist air with it and indicates long periods of heavy rain.

Forecast maps

- Go to the BOM website.

Weblink: Bureau of Meteorology

- Click on "Weather maps".
- Go to "Australian region" and click on "Forecast map for next 4 days".

Discussion

1 Describe the features shown on these maps.

2 Note the position of the high-pressure and low-pressure systems each day. Identify the pattern of movement.

Satellite images

- Return to the BOM homepage and click on "Satellite images".

Weblink: Bureau of Meteorology

- Find the grey tab that says "Animate" and click "Play".
- Watch the animation showing the movement of air in the atmosphere.

Discussion

1 Summarise the movement between high-pressure and low-pressure systems.

2 Predict what the weather will be like tomorrow.

Weather maps

- Return to the BOM homepage and click on "Weather maps".

Weblink: Bureau of Meteorology

- Go to "Numerical weather and ocean prediction maps" and click on "Interactive weather and wave forecast maps".
- Click on the times for tomorrow.

Discussion

Determine if the prediction you made above is correct.

Climate graphs

Climate graphs demonstrate the average temperature and rainfall at a particular place over the course of a year. These graphs include a red line graph to show the average monthly temperature and a blue column graph to show the average monthly rainfall figures.

- Go to the Weather Zone website.

Weblink: Weather Zone

- Type in the city or region you want to look at.
- Go to "More observations" and click on "Climate data".

Discussion

1 Copy the template graph (Table 2) into your notebook.

2 Create a climate graph for your city or region by plotting the average monthly maximum temperature and average rainfall in the template.

Table 2 Climate graph

Climate graph Station: Date:															
	200													40	
	190													38	
	180													36	
	170													34	
	160													32	
	150													30	
	140													28	
	130													26	
	120													24	
	110													22	
Rainfall (mm)	100													20	Maximum Temperature (°C)
	90													18	
	80													16	
	70													14	
	60													12	
	50													10	
	40													8	
	30													6	
	20													4	
	10													2	
	0													0	
	Month	J	F	M	A	M	J	J	A	S	O	N	D		

Regional weather and climate

Go back to the BOM homepage and click on your city or region.

Weblink: Bureau of Meteorology

Discussion

1 Record the high and low temperatures for the last week.

2 Identify which data has more variation – the weather data or the climate data. Provide an explanation for your response.

3 Describe how you would determine if the high temperatures and low temperatures are normal for this time of the year.

4 Identify if the temperature data for this week is warmer, cooler or about the same as the

average temperature from the climate data. Provide an explanation for your response.

5 Describe how weather data and climate data are used to determine how the climate is changing.

Climate model

Go to the UCAR website.

Weblink: UCAR Centre for Science Education

The simulation explores how the rate of carbon dioxide emissions affects the amount of carbon dioxide in the atmosphere and the Earth's temperature. The simulation can also show future scenarios related to climate.

Discussion

1 Use the slidebar to set the carbon emissions to 10 giga tonnes. Press play on the simulation. Describe your observations.
  - **a** Describe trends in the graph.
  - **b** Suggest an explanation for why carbon emissions plateau but carbon dioxide concentration continues to increase after 2020.

2 Use the slidebar to set the carbon emissions to half the emissions, at 5 giga tonnes. Play the simulation again. Describe your observations.

3 Use the slidebar to set the carbon emissions to double the original emissions, at 20 giga tonnes. Play the simulation again. Describe your observations.

4 A large amount of carbon emissions occur in the production of energy. Outline the assumptions about energy consumption if carbon emissions:
  - **a** decrease
  - **b** increase
  - **c** stay the same.

5 Describe how countries could manipulate the variables to stay under the red line (the recommended temperature limit).

6 Explain why a simulation like this is useful for scientists.

Source: This investigation is adapted from "Weather and climate data exploration", UCAR Centre for Science Education.

Lesson 15.5

Scientists develop workable theories from models

Key ideas

→ Scientific models are based on experimental data and observation.

→ Scientific models are continuously changing as more data is gathered.

→ Scientific models need to be consistent and predictable.

→ Ideas can become theories when a hypothesis is supported by a scientific model.

Learning intentions and success criteria

Introduction

Scientific models are designed using a combination of experimental data, observations and scientific understanding of concepts. Models draw together different ideas or information about concepts, events or how processes work. When a model is repeatedly confirmed by reliable scientific evidence, it can become a theory.

Identifying what data to use in a model

When scientists build or develop models, they usually start by using a small amount of known data. This data can be obtained through experimentation or observation. Models are used effectively to predict future scenarios that could result from this basis. Scientists use models when there is uncertainty and they need more information to support their decisions.

The models that scientists develop need to be consistent with observations and inferences that reflect our understanding of the world around us.

The most useful scientific models:

- explain complex ideas
- can be used to make predictions
- are consistent with our understanding of scientific concepts.

As scientists continue to conduct investigations, more data is obtained. As they gain more data, they gain more knowledge. Scientists refine their models by adding new data to them and then they can use the models to test ideas and processes.

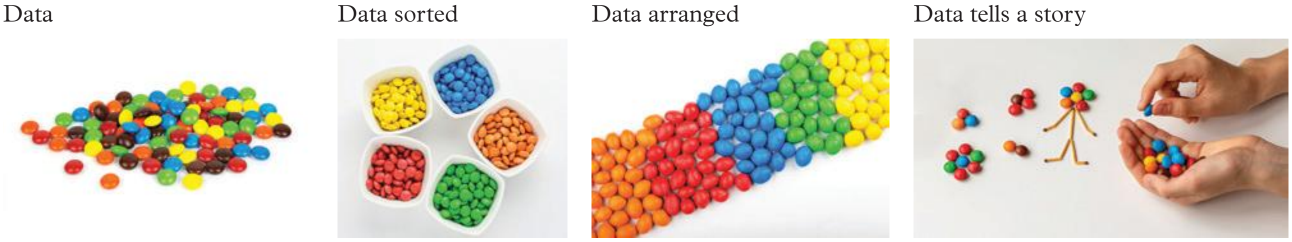


Figure 1 Scientists need to collect data, sort and organise it and then use it to tell a story.

Collecting data from oceans

Argo is an international program that uses nearly 4,000 scientific floats around the ocean. The floats can access very remote areas which could not otherwise be reached by researchers. This provides a better overview of the oceans and helps scientists form a bigger picture using the data obtained (Figure 1).

The Argo floats drift in the ocean about 1,000 m under the surface. Every 10 days, the float will sink to 2,000 m. On the way up, the floats measure depth, currents, temperature and the salinity of ocean water. The data and the location of the float is sent to a satellite to compare the position of the float and where the data was recorded. This technology allows large amounts of data to be collected. This data is then used to build models of the processes in the ocean which help scientists monitor the state of the ocean as well as look for clues that show how it is changing. New floats are being developed which can also measure pH (acidity) and dissolved oxygen. This data will then be added to current models which will identify potential changes in the marine environment, such as ocean acidification and depletion of oxygen.

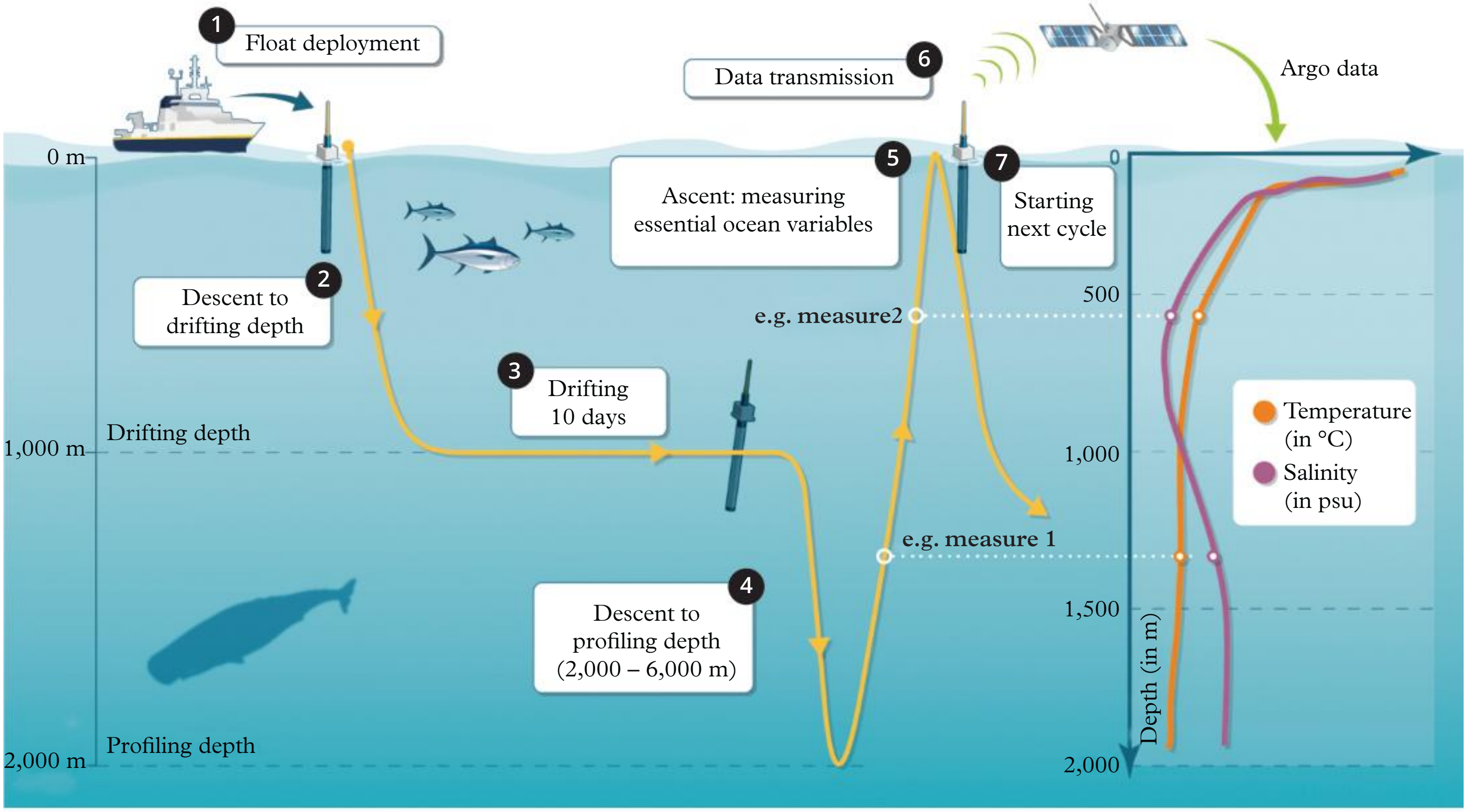


Figure 2 Argo floats drift in the ocean, collecting data that is then transmitted via satellite.

Developing theories from a model

A workable theory in science is a theory that effectively explains phenomena and is consistently supported by evidence. By applying the scientific method, scientists can develop theories from the use of models. The scientific method involves scientists making observations and systematically researching ideas about the observations. Scientists then create a hypothesis that could explain the phenomenon. The hypothesis is tested and the data gathered from the investigation is used to predict other related hypotheses.

A hypothesis is an explanation for an observation. It presents an idea that has not yet been tested. A hypothesis can become a model after it has been tested and verified by other scientists. If the hypothesis is not supported, then it needs to be changed or rejected. If the hypothesis is changed, then further investigation is carried out to determine if the new hypothesis is supported. If a hypothesis is repeatedly supported by multiple investigations conducted by multiple scientists, then it is predictable and may become a theory. A theory is an explanation that is supported by a large body of evidence. A theory can be applied to a wide range of concepts.

Even the most tested theory may be proven wrong because new observations can be recorded. An example of a theory that was once widely thought to be true but has now been disproven is the **miasma theory**. The miasma theory suggested that the bubonic plague and diseases like cholera and malaria were transmitted through "bad air". The theory stated that the diseases were caused by miasma (polluted air) which came from rotting organic matter. It was observed that people who did not sit near swamps or bad air did not contract malaria. It was later discovered that malaria was caused by a pathogen found in mosquitos, which explained why the people who avoided swamps were less likely to contract the disease.

In the 1870s, Robert Koch identified that specific bacteria caused diseases like anthrax, tuberculosis and cholera (Figure 3). He developed the idea that specific germs cause specific diseases. This idea became known as the germ theory of disease, which states that microorganisms (germs) cause diseases. The germ theory was supported by experimental evidence, whereas the miasma theory was based on observation without scientific evidence. The germ theory replaced the miasma theory and led to better public health measures such as sterilisation, better hygiene practices and vaccinations which prevented the spread of diseases.

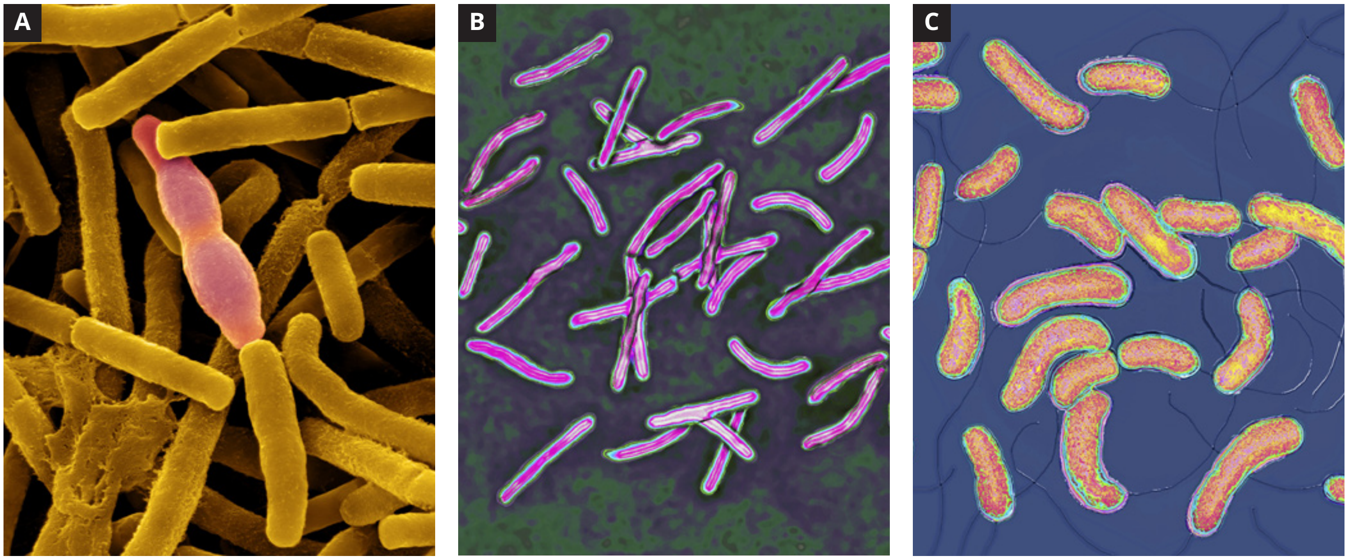


Figure 3 Robert Koch discovered that specific bacteria caused specific diseases. (A) Bacillus anthracis; (B) Mycobacterium tuberculosis; (C) Vibrio cholerae

The reliability of models

If the scientific method is not applied correctly when developing a model, then the predictions and conclusions that are drawn from it can be inaccurate. It is important that scientists undertake valid and reliable experiments and measure and record data accurately.

Limitations of models

Models cannot answer everything. Sometimes there is insufficient data to build a model that explains all the complexities of a concept. In some instances, the technology is not yet powerful enough to deal with the data. This means that scientists need to make decisions about the purpose of the model and the data that is used to generate the model.

Models are adaptable and they can be updated as new data becomes available. This can, however, change the outcomes or the predictions made by the models, making the predictions unreliable.

Models also need to make assumptions about variables. Sometimes these assumptions can be incorrect. In some models, the assumptions can be checked. For example, weather forecasts can be compared to actual weather data. By testing a model's predictions against real observations, the model can be updated to improve its accuracy and reliability.

Different scientists may use different methods or ideas to model phenomena. This does not mean one model is better than the other. If different models can produce similar conclusions or predictions, this makes the models more valid and the conclusions more reliable. For example, weather and climate forecasters will consider the predictions of several different models and compare the data to draw conclusions. The more consistent the data in different models, the more useful the data is in making accurate predictions.

Check your learning 15.5

Check your learning 15.5

Retrieve

1 Describe the factors that make a scientific model useful.

Comprehend

2 Explain how data is used by scientists to model and predict scientific phenomena. Give two examples.

3 Explain how a theory is developed from scientific models.

4 Describe how the germ theory of disease replaced the miasma theory.

Analyse

5 Consider the three different models of heat theory in Table 1.

- **a** Explain how scientists refined their theories as new data and better models became available.
- **b** Describe the role of observation and experimentation in replacing old models with new ones.
- **c** Describe how the caloric theory was replaced by the kinetic theory of heat.
- **d** Describe how the thermodynamic model helps predict heat transfer in everyday life, for example, cooking, insulation and weather patterns.

Table 1 Three different models of heat theory

Model	Key idea	Evidence	Limitations
Caloric theory	Heat is an invisible fluid ("caloric") that flows from hot to cold objects	Heat warms up colder objects	Cannot explain why friction creates heat
Kinetic theory of heat	Heat is the movement of tiny particles	Experiments show that faster-moving particles have more heat energy	Cannot explain changes of state (e.g. boiling)
Modern theory of thermodynamics	Heat is the transfer of energy due to moving particles and differences in temperature	Mathematical models and experiments explain the transfer of heat via conduction, convection and radiation	Need further studies on the transfer of energy in black holes and other extreme conditions

Lesson 15.6

Investigation: Collecting, using and analysing data sets

Introduction

According to a 2019 survey of 2,000 U.S. adults, the most popular Skittles flavour is red, also known as strawberry.

Purpose

To collect and analyse data to test the hypothesis “If red Skittles are the favourite flavour, then there will be more red Skittles in each packet compared to other colours”

Materials

- One bag of Skittles
- Five paper cups to sort the Skittles
- One marker to record the number of Skittles

Procedure

1. Open a bag of Skittles and sort them by colour.
2. Place each colour in a cup.
3. Count the number of Skittles in each colour.
4. Record the number of each colour on the cup.

Results

1. Copy Table 1 into your notebook and record your data.
2. Draw a column graph showing the total number of Skittles in each colour.
3. Collate the data from the rest of the class into your table.

Table 1 The number of Skittles in each colour in a packet

Group	Number of Skittles in each colour					Total number of Skittles
	Red	**Yellow**	**Green**	**Purple**	**Orange**	
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
Mean						
Percentage						

4 Calculate the mean for each colour. Draw a column graph showing the average number of skittles in each colour.
5 Calculate the percentage of each colour and record the data.
6 Draw a pie chart showing the overall percentage of Skittles in each colour.

Discussion

1 Does the total number of Skittles vary across each bag? Provide a reason for this.
2 Use your individual data to:
   a Identify the most common and least common colours.
   b Identify the maximum and minimum number for each colour.
3 Use the class data to:
   a Identify the most common and least common colours.
   b Identify the maximum and minimum number for each colour.
4 Describe how the class results differ from your individual results.
5 Describe any patterns or trends in the group data and the class data.
6 Discuss if this is a reliable investigation.
7 Suggest how this investigation could be made more reliable.
8 Discuss if the results of this investigation are accurate.
9 Describe how the accuracy of the results could be improved.
10 Predict the number of red Skittles in the next bag of Skittles. Justify your prediction.
11 Open another bag of Skittles and count the red Skittles. Discuss if your prediction was correct.
12 Determine if the data supports the hypothesis. Use data from the experiment to justify your response.

Lesson 15.7

Science in context: Using paper planes to create a scientific model

Introduction

There are four main forces acting on a plane. The four forces are weight, thrust, lift and drag (Figure 1).

- Weight is the force that will pull an aeroplane to the ground due to gravity.
- Thrust is the force that helps overcome gravity. It is the force that moves the plane forward. In an aeroplane, the engine provides the forward thrust.

- Lift is the force that keeps the aeroplane in the air. The shape of the wings allows the air to move across the surface of the wing which creates positive and negative pressure, which in turn creates lift.
- Drag is the force that slows down an aeroplane as it moves through the air. Aeroplanes are designed to overcome drag by minimising the surface area exposed to the air.

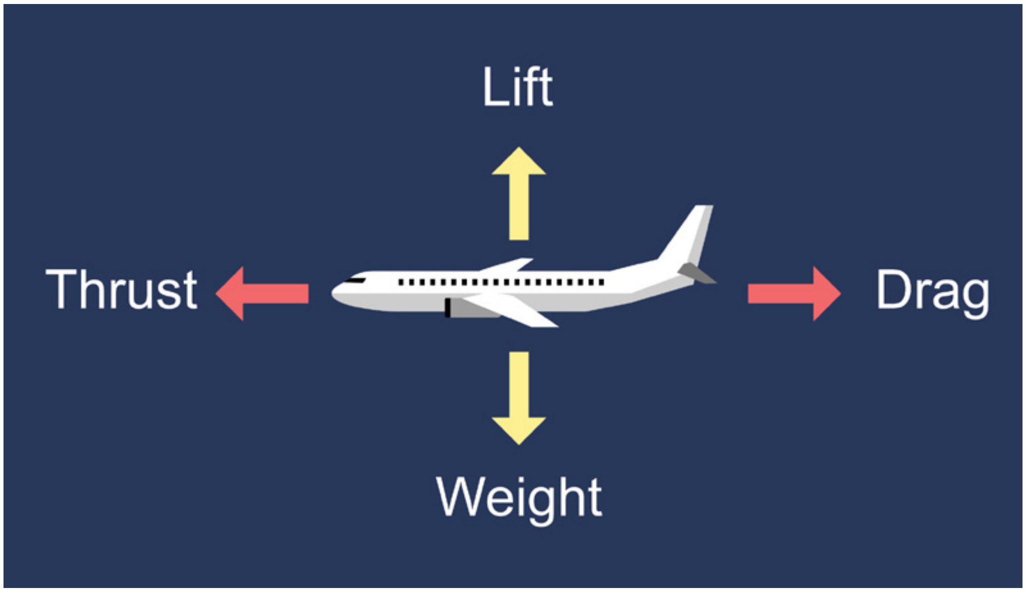


Figure 1 The four forces of flight are weight, thrust, lift and drag.

Test your skills and capabilities

Test your skills and capabilities 15.7

Aims

- To design a paper plane that travels the furthest through the air
- To conduct a valid and reliable investigation to collect data about an aspect of a paper plane design that can minimise drag and allow the plane to travel a further distance

Some ideas for investigation include:

- the shape of the wings
- the length of the wings
- the surface area of the paper plane
- the type of paper used
- the weight of the paper
- cuts or flaps in the wings.

Questioning and predicting

1 Formulate a question about paper planes that can be investigated.

2 Write a prediction for your investigation. Provide scientific reasoning for your prediction.

Planning investigations

3 Outline what data will need to be collected to answer the question.

4 Describe the independent variable in the investigation. You will need at least five variations to the independent variable.

5 Describe the dependent variable in the investigation.

6 Describe the variables that will need to remain constant (the controlled variables). Explain how these variables could affect the results of the investigation if they are varied.

7 Identify any variables that cannot be controlled and may affect the results of the investigation.

8 Outline a reliable and valid method to test your prediction. (Remember, a reliable investigation needs to have a minimum of three trials where the results are consistent.)

Conducting investigations

9 Describe how you will conduct this investigation in a safe manner.

10 Conduct a reliable and valid scientific investigation, following your method to answer your question about paper planes.

Processing data and information

11 Record your results in an appropriate table and calculate the average for your repeat trials.

12 Describe the type of graph that would best represent your results. Draw a graph of your results.

Analysing data and information

13 Discuss the accuracy of your results.

14 Discuss the reliability of your results.

15 Discuss the validity of the investigation.

16 Draw a conclusion which answers your question and prediction. Use data from your investigation to justify your conclusion.

Problem solving

17 Describe any problems that you had with your investigation. Discuss how this may have affected your results.

18 Describe the solutions you developed to solve these problems.

Scientific models

19 Describe how this investigation can be considered as a scientific model.

20 Discuss how your investigation can be used to create models about how planes travel through the air.

21 Describe how the data from your investigation could lead to a theory in the real world.

Lesson 15.8

Science in context: Creating a model

Introduction

Models are an important tool in science as they create visualisations of phenomena that are too difficult to see in real life or real time.

Scientists use models to simplify and explain complex ideas. A model can be a physical representation, a diagram, a mathematical equation or a computer simulation. Models help scientists make predictions, test theories and communicate their ideas to others.

Test your skills and capabilities

Test your skills and capabilities 15.8

Aim

To design and create a scientific model that explains the scientific phenomena

Types of models

Remember the different types of models you can use:

- an image describing the phenomena
- a physical model
- a working model or prototype
- an animation or simulation.

Scientific phenomena

Choose one of the following phenomena (or one of your own).

- The particle theory of matter, showing how the particles interact as a solid, liquid or gas.
- The water cycle, showing how water can be cycled through the Earth's spheres.
- The "Goldilocks principle" of atmospheric gases, showing how a certain amount of carbon dioxide in the atmosphere is "just right".
- Build a model insect, showing how the external and internal features are essential for the survival of the insect.

Communicating

Present your model to the class and use it to explain your chosen scientific phenomena.

Your presentation needs to:

1 outline the scientific phenomena that your model is explaining
2 identify the purpose of the model
3 describe the model and how it works to explain the phenomena
4 discuss the benefits of the model
5 discuss the limitations of the model
6 describe the challenges you faced in designing and creating your model
7 describe the problem-solving strategies that you used to overcome the challenges.

Figure 1 A model of a human heart

Lesson 15.9

Review: Data science

Summary

Lesson 15.1 Data science is an interdisciplinary field

- Scientists use data to gain knowledge and make predictions.
- Different types of data are used in distinct ways for specific purposes.

Lesson 15.3 Scientific models are used to make predictions

- Data used in science should be reliable and peer-reviewed.
- Models are used in science to make predictions and demonstrate complex concepts that are not directly observable.
- There are different types of scientific models used for distinct purposes.

Lesson 15.5 Scientists develop workable theories from models

- Scientific models are based on experimental data and observation.
- Scientific models are continuously changing as more data is gathered.
- Scientific models need to be consistent and predictable.
- Ideas can become theories when a hypothesis is supported by a scientific model.

Review questions 15.9

Review questions Module 15

Retrieve

1 Define the term “data”.

2 Define the term “scientific models”.

3 Primary and secondary data are sources of data.

  a Describe how primary data is obtained.

  b Describe how secondary data is obtained.

  c Compare the use of primary data to secondary data.

4 Which option below completes this sentence? Effective scientific models:

  A do not change over time and can only explain simple ideas.

  B are predictive and explain complex ideas that are consistent with scientific knowledge.

  C only contain one set of data to make predictions.

  D use large amounts of data to explain ideas.

5 Describe what is meant by a digital footprint.

6 Give examples of different types of models that are used by scientists to explain ideas.

Comprehend

7 Explain why the scientific method should be used to obtain data.

8 Discuss the importance of peer-review in developing scientific knowledge.

9 Describe some limitations of using models in science.

Analyse

10 Explore how predictive models are developed and validated. What are the consequences of using an improperly validated model in decision-making?

11 Examine how algorithms might unintentionally reinforce existing biases within a data set. What steps can be taken to identify and reduce such biases?

12 A research team is studying the impact of urban noise pollution on local bird populations. The team collected data on the number of bird species observed across five locations, with varying levels of noise (measured in decibels) over the course of one week (Table 1).

a Identify the relationship between noise levels and the number of bird species observed.
b Evaluate the possible reasons for this trend.
c Suggest methods the research team could use to reduce the impact of noise pollution on bird populations.

Table 1 Data on the number of bird species observed and the average noise level across five locations

Location	Average noise level (dB)	Number of bird species observed
Park A	30	15
Park B	40	12
Park C	50	10
Park D	60	7
Park E	70	4

Apply

13 Table 2 shows education levels and average income of selected countries in 2020.

a Discuss if this is quantitative or qualitative data.
b Discuss if this is primary or secondary data.
c Explain how scientists might use this data.
d Describe the relationships in the data.
e Discuss if there are any contradictions in the data. Provide a possible explanation for this.
f Discuss if higher education always leads to higher income? What other factors could influence economic success?
g Describe how literacy rate impacts income, and why some countries with high literacy still have lower incomes?
h Describe how other variables might explain differences in income despite similar education levels?

Table 2 Education levels and average income of selected countries in 2020

Country	Average annual income (AUD)	Percentage of population who have completed higher education (%)	Literacy rate (%)
Australia	$96,300	52	99
Brazil	$22,120	18	93
Germany	$86,900	42	99
India	$11,060	12	74
Japan	$71,100	50	99
Nigeria	$7,900	9	62
United States	$102,700	50	99

Social and ethical thinking

14 Data can be collected from wearable fitness trackers.

a Describe how these trackers contribute to a person's digital footprint.
b Describe how researchers might use this data.
c Describe the benefits of collecting data from trackers.
d Discuss any issues with collecting data from trackers.

e Discuss if it is ethical for companies to collect and analyse personal health data without explicit consent?

f Suggest how companies can balance innovation in health technology with the need for privacy and security?

g What laws or regulations should be in place to protect individuals from potential misuse of their data?

Critical and creative thinking

15 Propose a solution that could improve the algorithms used in self-driving cars to enable them to better react to unpredictable animal behaviour.

Data analysis

16 Use the data in Table 3 to answer the following questions.

a Copy the table into Excel or Google Sheets.

b Calculate the average number of tsunamis over the 15-year period.

c Plot the magnitude of the earthquake against the maximum wave height. Describe the relationship in the data.

d Plot the magnitude of the earthquake against the total deaths. Describe the relationship in the data.

e Plot the maximum water height against total deaths. Describe the relationship in the data.

Table 3 Tsunami data for Japan over the last 15 years with an earthquake magnitude over six.

Year	Earthquake magnitude	Maximum water height (m)	Total deaths	Total injuries	Total damage ($Mil)	Total houses destroyed	Total houses damaged
2010	7	0.1					
2010	7.4	0.13					
2011	7.3	0.6					
2011	6.3	0.06					
2011	9.1	39.26	18,428	6,167	220,136.60	123,661	280,920
2011	7.1	0.08	3	132			
2011	7	0.09					
2012	6.9	0.2					
2012	7.2	1		11			
2013	7.1	0.4		1			
2014	6.5	0.2					
2015	6.7	0.27					
2015	6.7	0.3					
2016	6	0.01					
2016	6.9	1.44					
2019	6.4	0.11		28			144
2021	7.1	0.1	1	186	7,700	798	19,758
2022	7.3	0.31	4	247	8,800	217	56,718
2023	6.2	0.1	1	34		3	351
2023	6.1	0.3					
2024	7.5	7.23	549	1,393	17,600	29,966	133,758
2024	7.1	0.5		14		1	2
2025	6.8	0.2					

f Choose one of the other parameters and plot it against earthquake magnitude and wave height. Describe the relationship in the data.

g What story does the data tell.

h Describe the limitations of the data set.

Night lights

Your local council is considering replacing street lights in your area with LED lights to reduce energy consumption. There are, however, concerns about how different types of lighting might impact nocturnal animals like possums or bats that are active in your neighbourhood.

- How does the type of artificial light (e.g., LED, halogen or fluorescent) affect the behaviour of nocturnal animals in urban areas.
- Find data to support your response.
- Using the data, describe what you think would happen if the type of artificial light was changed.

Figure 1 Street lights help us to see better in the dark but could be detrimental to nocturnal animals.

Research

17 Choose one of the following topics for a research project, using the questions provided to guide your investigation. Present your research as a poster or PowerPoint presentation, including references for any secondary sources used.

Earthquakes and volcanic eruptions

How can scientific models of tectonic plate movements be used to predict future earthquakes and volcanic eruptions? Investigate the accuracy of these models and the data they use. Provide examples of events to support any of your claims.

Figure 2 Reykjanes Peninsula in Iceland has seen many eruptions occur over a short timeframe, most recently in March 2024.

Bridges

How can data sets on the forces acting on different structures (e.g. bridges and buildings) be collected, analysed and used to improve their design and safety? Explore the methods used to gather this data and the impact of the findings on engineering practices.

Glossary

A

abiotic
all the non-living components of an ecosystem; for example, light, temperature and water

abomasum
the fourth stomach of a cow

accuracy
how carefully, correctly and consistently data has been measured or processed; in science, how close a measured value is to the true value

accurate
how close information is to the true value

adaptation
a characteristic or feature of an organism that assists in its survival and reproductive success

adenosine triphosphate
a compound that is used as the source of energy for cellular activities

adhesion
the attraction between different kinds of molecules that allows them to stick together

aerobic cellular respiration
the chemical reaction between glucose and oxygen that produces carbon dioxide, water and energy

aerobic respiration
the process by which cells convert glucose and oxygen into energy, carbon dioxide and water

aim
the purpose of an experiment

allotrope
different structural forms of the same element, where atoms are arranged in distinct ways, resulting in different physical properties. For example, carbon exists as graphite, charcoal, and diamond, each with unique characteristics

alloy
a mixture of two or more metals, or a metal and another element, designed to enhance properties like strength, durability, or resistance to corrosion (e.g., steel is an alloy of iron and carbon)

alveoli
tiny sacs in the lungs for gas exchange, allowing oxygen to enter the blood and carbon dioxide to be expelled

amino acids
small molecules that are the building blocks of proteins

ammonia
a chemical waste product (NH_3)

amoeba
a type of single-celled organism belonging to the Protista kingdom

analog
a tool that changes smoothly and continuously

anion
a negatively charged ion formed when an atom gains electrons

anomaly
a result that does not fit in with the pattern of data

anther
the part of the stamen (male reproductive organ) in flowering plants that produces and releases pollen

aorta
the major artery that carries oxygenated blood from the heart and divides into smaller arteries around the body

apparatus
equipment placed together for an experiment

artery
a thick, muscular-walled blood vessel that carries blood away from the heart under pressure

arteriole
smaller artery

asthma
a disease caused by narrowing airways

atmosphere
the envelope of gases surrounding the Earth or another planet

atom
the smallest particle of matter; cannot be created, destroyed or broken down (indivisible)

atomic number
the number of protons of an atom

atomic theory
the theory that all matter is made up of atoms

atria
the two smaller, upper chambers of the heart

attraction force
the force that attracts one object to another

autoimmune disorder
a condition in which the immune system mistakenly attacks the body's own healthy cells, treating them as foreign pathogens

autotroph
an organism that produces its own chemical energy through photosynthesis or chemosynthesis

axis
an imaginary straight line joining the North and South Poles of the Earth

B

bacteria
unicellular organisms with a cell wall but no nucleus

balanced forces
two forces equal in size and opposite in direction

bias
leaning towards or against an idea by being prejudiced or unfair

binomial system
a double-name system created by Linnaeus to name organisms; the first name is the genus and the second name is the species

biological control
a method of controlling a population by releasing a living organism into an ecosystem

biotic
all the living organisms in an ecosystem

black hole
a region in space of infinite density where gravity is so strong that nothing, not even light, can escape from it

block and tackle
a group of pulleys mounted together in a frame or block, which provides significant mechanical advantage

blood
connective tissue that carries oxygen, nutrients and waste around the body

blood vessel
a tube or vessel that carries blood around the body

Bohr model of the atom
a way to represent the electrons of an atom in a series of shells around the atomic nucleus

boiling
when a substance changes from its liquid phase to its gaseous phase

boiling point
the temperature at which a liquid boils and becomes a gas

botanist
a scientist who studies plants

boundary
either a real or an imaginary line that separates a system from its surroundings

bronchi
large tubes branching from the trachea into each lung, helping to carry air, and trapping dust and germs with mucus and cilia

bronchioles
small, thin-walled air passages in the lungs that branch off from the bronchi

Bunsen burner
a piece of equipment used as a heat source in the laboratory

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

C

caecum
a small, dead-end pouch that connects the small and large intestines

calibrate
check the accuracy of a metre or measuring device against known measurements

capillaries
the smallest blood vessel in the circulatory system; they are thin-walled, allowing for the exchange of oxygen, carbon dioxide, nutrients and waste between blood and surrounding tissues

capture–recapture
a method of estimating the number of organisms by capturing, marking and releasing a sample of the organisms

carnivore
an animal that eats other animals

carpel
the female reproductive organ of a flower, consisting of the ovary, style, and stigma

carrying capacity
the maximum number of organisms in a population that can be sustained by an ecosystem

catalyst
a substance that increases the rate of a chemical reaction without undergoing any permanent chemical change

cation
a positively charged ion that results from an atom losing electrons

causation
when the independent variable is responsible for the change in the dependent variable

cell
the smallest unit of life

cell membrane
the barrier around a cell that controls the entry and exit of substances into and out of a cell

cell theory
theory describing the properties that all cells have in common

cell wall
a structure that provides support around the cell in some organisms, such as plants and fungi

cellular respiration
the chemical reaction between glucose and oxygen that produces carbon dioxide, water and energy

centrifuging
a separation technique used to separate light particles from heavy particles by rapidly spinning the mixture in a container (called a centrifuge)

chemical digestion
the breakdown of food into absorbable molecules through the action of enzymes and chemicals in the digestive system

chemical potential energy
energy stored in chemicals due to their chemical bonds, e.g. in food, fuel, also known as simply chemical energy

chemical properties
how a substance behaves in a chemical reaction, such as how it reacts with an acid

chemical reaction
a procedure that produces new chemicals; same as chemical change

chemosynthetic
a process by which certain organisms, typically bacteria, convert inorganic compounds into organic matter using chemical energy rather than sunlight

chlorophyll
a green pigment in chloroplasts that absorbs solar energy, which is used by plants in photosynthesis

chloroplast
the organelle in plant cells and some algae that perform photosynthesis

chromatography
a separation technique used to separate substances according to differing adsorption to a surface (e.g. coloured dyes that make up pen ink)

chyme
a mixture of acid, enzymes and digested food that leaves the stomach

cilia
small, hair-like structures found on the surface of some cells

citation
a brief mention within the text of a document that indicates the source of information, ideas, or quotes

cite
to reference or acknowledge a source of information

classification
the systematic process of organising and grouping living organisms or objects based on shared characteristics

cleavage
a number of smooth planes that a mineral breaks along

closed system
a system that exchanges only energy with its surroundings

cohesion
the attraction between molecules of the same kind that allows them to stick together

collision theory
a theory stating that the particles involved in a chemical reaction must collide in order to react

colloid
a type of mixture that always looks cloudy because clumps of insoluble particles remain suspended throughout it – they don't settle as sediment

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

combustion
a reaction that involves oxygen and releases light and heat energy

commensalism
a type of relationship between two organisms of different species in which one organism benefits and the other is not affected

community
different populations living in the same location at the same time

compound
a substance made up of two or more types of atoms bonded together (e.g. water)

compound light microscope
a microscope with two or more lenses

compressibility
the extent to which a substance can be compressed (squashed); gases can be compressed but solids and liquids cannot

compressional strength
the ability of a substance to withstand large forces

concentrated
containing a large number of solute particles in the volume of solution

concentration
the number of active molecules in a set volume of solution

conclusion
a statement that "answers" the aim of an experiment

condensation
the change of state from a gas to a liquid; occurs when a gas cools down

condense
to become a liquid, from a gas

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

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

conglomerates
rocks made up of gravel size individual stones cemented together

connective tissue
the group of cells that provide connections to other parts of the body

consumer
an animal that can't convert the Sun's energy into sugars and instead must eat to get the energy it needs to survive

continental drift
the theory that the continents are continuously moving over time

continental shelf
a flat area under shallow ocean water at the edge of a continent

continuous data
data that are measured and can be any value

controlled experiment
an experiment where all the variables are kept the same except for the independent variable

controlled variable
a variable that is kept constant and unchanged throughout an experiment

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

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

convergent boundary
the boundary between two tectonic plates that are moving together

core
the centre of the Earth

correlation
a relationship between two or more things

corrosion
the gradual destruction of a material, usually metal, due to chemical reactions with its environment, often involving moisture and oxygen (e.g., rusting of iron)

covalent bond
a bond formed when two or more atoms share electrons

credible
information that is reliable, trustworthy and based on evidence

cross-pollination
the transfer of pollen from the anther of one flower to the stigma of a flower on a different plant of the same species, promoting genetic diversity

crust
the outer layer of the Earth

crystallisation
a separation technique used in conjunction with evaporation to remove a dissolved solid from a liquid; after the liquid has been evaporated the solid remains, often in the form of small crystals

cytoplasm
the jelly-like substance inside cells that helps to maintain the structure and facilitate the movement of materials within the cell

D

data
information that is collected, organised and analysed for various purposes; data can be in the form of measurements, numbers, text, images

data science
a field of study which involves collecting, analysing and interpreting large amounts of data to gain insights and make decisions

data source
the place where data originates from

database
structured collections of electronically stored data that allow for efficient storage, retrieval and analysis of large amounts of information

dataset
a collection of data points usually represented in a table or graph

decanting
a separation technique used to separate a sediment from the liquid it is in by carefully pouring the liquid away

decomposer
an organism, such as bacterium, that obtains nutrients by breaking down dead organisms

density
a measure of mass per unit of volume

dependent variable
a variable in an experiment that may change as a result of changes to the independent variable

deposition
the process whereby sediment from different forms of weathering accumulates in layers

dermal
outer protective layer of a plant

detritivore
an organism that obtains nutrients by consuming detritus (decomposing plant and animal parts)

diagrams
visual representations that illustrate concepts, processes or relationships, simplifying complex information for better understanding

diaphragm
a dome-shaped muscle attached to the ribs; moves up and down beneath the lungs

diatomic
consisting of two atoms

dichotomous key
a diagram used in classification; each arm of the key contains two choices

diffusion
the spontaneous spreading out of a substance through a liquid or gas, e.g. the diffusion of perfume in air

digestion
the process of breaking down food into nutrients

digital
a tool that changes in steps or separate values

dilute
containing a small number of solute particles in the volume of solution

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

discrete
data where the numbers can be separated into different groups

discussion
a summary of findings, and an analysis of the design of an experiment, including problems encountered and suggestions for improvement

disease
a disorder or condition that interrupts the normal functioning of an organism

disorder
a condition that occurs when an organ system does not function correctly; the cause is usually not well understood, and symptoms can vary

distance magnifier
a lever that changes a strong force that acts over a short distance into a weak force that acts over a longer distance

distillation
a separation technique that uses evaporation and condensation to separate a solid contaminant and the solvent in which it has dissolved (e.g. to get pure water from salt water)

divergent boundary
the boundary between two tectonic plates that are moving apart

DNA
(deoxyribonucleic acid) a molecule that contains all the instructions for every job performed by the cell; this information can be passed from one generation to the next

domain
a small section of a magnet where the magnetic field of all the atoms is aligned in the same direction

drought
a period in which an area experiences water shortage

durable
able to withstand wear, pressure, or damage over time without breaking or deteriorating easily

E

ecosystem
a community of living organisms and their non-living surroundings

ectotherm
an organism with a body temperature that changes with the environment

effort
the force used to operate a lever

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

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

electromagnetic
relating to the physical interaction between moving charged particles and the magnetic field that is created as a result

electron
a negatively charged particle in the nucleus of an atom

electron configuration
the distribution of electrons of an atom or molecule in atomic or molecular orbitals

electron microscope
a microscope that uses electrons (tiny negatively charged particles) to create images

electron shell
the area of space around a nucleus where a specific electron may be found

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

element
a pure substance that only contains one type of atom

emigrate
refers to when an animal leaves an ecosystem

emission spectrum
the pattern of wavelengths (or frequencies) that appear as coloured lines in a spectroscope; it is unique to each element

emphysema
a disease caused by broken-down alveoli in the lungs

emulsifier
a substance that enables two substances that don't normally combine to form an emulsion; for example: oil and water

emulsion
a colloid made up of two or more liquids

endemic
found only in a specific country or region

endoskeleton
an internal skeleton

endotherm
an organism that has a constant body temperature regardless of the temperature of its environment

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

enzymes
a protein that helps speed up chemical reactions in the body

epiglottis
a flap of skin above the larynx that controls the passage of food and air, preventing food from entering the windpipe

epithelial tissue
the group of cells that cover and protect the body

equinox
a day when day and night are the same length; occurs twice each year

equipment
items used in the laboratory to conduct experiments

erosion
the movement of sediment to another area

error
an inaccuracy or inconsistency in measurement

ethical
having a moral character; being truthful, fair and honest

eukaryotic cell
a complex cell that contains a nucleus and membrane-bound organelles

evaporate
to change in state from liquid to gas; also a separation technique used to separate dissolved solids from water

evaporation
a change in state from liquid to gas; also a technique used to separate dissolved solids from water

evergreen
a type of plant that does not lose it leaves during autumn

exoskeleton
an external skeleton

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

extrusive igneous rock
rock formed at the Earth's surface by quickly cooling lava

eyepiece
where the eye is placed when using a microscope

F

fault
a fracture in rock where the tectonic plates have moved

fermentation
the chemical breakdown of a substance by microorganisms

ferments
the action of fermentation involving the chemical breakdown of a substance by microflora

field
the topic or subject being discussed

filament
the stalk that supports the anther in the stamen of a flower

filter paper
a paper sieve with tiny holes that are too small to see; solutions can flow through, but most solid particles cannot

filtering
a separation technique used to separate solids from liquids or solutions, depending on the size of the holes in the filter used

filtrate
the substance that passes through a filter

first-class lever
a lever that has its fulcrum between the point of effort and the load

first-hand investigation
the direct collection of data through experiments or observations conducted by scientists themselves

first-order consumer
an organism that eats only producers such as plants, algae and bacteria; it does not eat other consumers

flocculant
a chemical added to a mixture to make suspended particles clump together

flood
the overflow of a large body of water

flowchart
a diagram that uses shapes and arrows to represent the steps in a process or the flow of information

foliation
layering in a rock that occurs when the rock is subjected to uneven pressure

food chain
a diagram that shows who eats whom in an ecosystem, and how nutrients and energy are passed on

food web
a system of interlocking and interdependent food chains within an ecosystem

force magnifier
a device that can increase the amount of force available (for example, to shift something); an example is a lever

force of gravity
the force that pulls everything with a mass towards the centre of Earth

fossilisation
the process of an organism becoming a fossil

frost shattering
a process of weathering in which repeated freezing and melting of water expands cracks in rocks, so that eventually part of the rock splits off

fruit
the seed-bearing organ formed from the ovaries of flowering plants

fulcrum
the turning point of a lever

G

galaxy
a system of stars and their solar systems, dust and gas held together by gravitational force

gamete
a sex cell; egg in females and sperm in males

gas
a substance that has no fixed shape or volume, which will freely expand to fill the available space

gas exchange
is the process by which oxygen (O_2) is taken from the environment into the bloodstream, and carbon dioxide (CO_2) is expelled from the bloodstream into the environment

genus
a group of closely related species

geocentric model
a model of the universe that places Earth at the centre of everything

geologist
a scientist who studies rocks

graph
a visual representation showing the relationship between variables, using axes to plot data points for easy comparison and analysis of trends and patterns

gravimeter
a device that measures the difference in gravity between one location and the next

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

group
(in chemistry) a vertical list of elements in the periodic table that have characteristics in common

guard cells
specialised plant cells that surround the stomata, regulating their opening and closing to control gas exchange and water loss

H

habitat
an environment in which an organism lives

hardness
how easily a mineral can be scratched; measured on the Mohs hardness scale

hazard
something that can cause harm, like sharp tools or chemicals

heliocentric model
a model of the universe that places the Sun at the centre of everything

herbivore
an animal that eats only plants

heterogeneous
refers to when a solute does not dissolve in a solvent

heterotroph
an organism that must consume other organisms in order to obtain its energy requirements

high tide
when the ocean covers slightly more land; the highest level that the tide reaches on the shore

homogeneous
refers to when a solute completely dissolves in a solvent

hot spot
a region where Earth's outer crust is thin and the magma is hotter than the surrounding area

hypothesis
a proposed explanation for a prediction that can be tested

I

igneous rock
rock formed by cooling magma and lava

immigrate
refers to when an animal enters a new ecosystem

immune
able to fight an infection as a result of prior exposure

incompressible
unable to be compressed; solids and liquids are incompressible

independent variable
a variable (factor) that is changed in an experiment

index mineral
a mineral that only forms at a particular temperature and pressure; used to determine the history of the rock that contains the mineral

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

inference
a likely explanation of an observation

information
facts that are provided or learnt

insoluble
cannot be dissolved in a liquid

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

interspecific competition
competition between individuals of different species for the same resources

intraspecific competition
competition between individuals of the same species for the same resources

introduced species
an organism that has been brought to and has established itself in an area it is not native to

intrusive igneous rock
rock formed underground by slowly cooling magma

invertebrate
an organism that has an exoskeleton or no skeleton

ion
an atom that is charged because it has an unequal number of electrons and protons

ionic bond
a bond between a negatively charged anion and a positively charged cation

ionic compound
a substance made up of a negatively charged anion and a positively charged cation

K

key
a visual tool used in the classification of organisms

kinetic energy
the energy possessed by moving objects

kingdom
the highest category in taxonomic classification

L

laboratory
a specially designed space for conducting research and experiments

landform
a physical feature on the Earth's surface

lattice
a three-dimensional arrangement of particles in a regular pattern

lava
hot, molten rock that comes to the surface of the Earth in a volcanic eruption

law of superposition
states that younger sedimentary rock layers lie above older sedimentary rock layers

leap year
a year, occurring once every four years, with 366 days

lever
a simple machine that reduces the effort needed to do work

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

light year
the distance light travels in one year. It is 9.46 trillion kilometres per year

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

line graph
a graph used to display continuous data that are connected by a line; typically used to demonstrate trends in data

Linnaean taxonomy
a hierarchical system of classification developed by Linnaeus in which all organisms are grouped into kingdom, phylum, class, order, genus and species, with each individual organism known by its genus and species names

liquid
a substance that has a fluid shape with a fixed volume

lithosphere
the rocky outer layer of the Earth's surface that is made up of the crust and uppermost part of the mantle

load
(in physics) resisting force

low tide
when the ocean covers slightly less land; the lowest level on the shore that the tide recedes to

lustre
the shininess of the surface of a mineral

M

magma
semi-liquid rock beneath the Earth's surface

magnetic
able to be magnetised or attracted by a magnet

magnetic pole
(Earth) the points on Earth where the magnetic field points downwards and a magnetic needle dips vertically
(magnet) the north and south ends of a magnet

magnetometer
a device that detects the difference in a magnetic field between one location and the next

mantle
the layer of molten rock beneath the Earth's crust

marsupial
a type of mammal that gives birth to young that continue to develop in their mother's pouch

mass
the amount of matter in a substance, usually measured in kilograms; the mass of an object never changes, even in space

matter
anything that has space and volume; matter is made up of atoms

mean
the average of a set of numbers

melt
change state from solid to liquid

melting point
the temperature at which a solid changes to a liquid

meniscus
the curved upper surface of a liquid in a tube

metabolism
all the chemical reactions in the body

metalloids
a small collection of elements that have a mixture of characteristics of metals and non-metals

metals
a collection of elements found on the left-hand side of the periodic table that are malleable, lustrous, ductile and highly conducting

metamorphic rock
rock formed from other rock due to intense heat and pressure

metamorphose
to change into a completely different physical form

method
a series of steps explaining how to do an experiment

metric system
a decimal system of measurement; uses metres, kilograms, litres and so on

microbiologist
a scientist who studies microorganisms

microbiology
the science involving the study of microscopic organisms

micrometer
a device that can be used to make precise measurements of very small objects

microorganism
a living thing that can only be seen with the use of a microscope

microscope
a scientific instrument used to magnify the size of an object

microscopy
the study of living things that can only be seen with the use of a microscope

mid-ocean ridge
a series of underwater mountains that form as a result of tectonic plates moving apart and allowing magma to rise to the surface

mineral
a naturally occurring solid substance with its own chemical composition, structure and properties

mitochondria
the organelle in which cellular respiration occurs

mixture
a substance made up of two or more pure substances mixed together

mode
the way information is shared; for example, through speaking or writing

model
a simplified representation of complex phenomena that are usually too big or too small to be seen by the naked eye

molecular compound
a molecule that contains two or more different atoms bonded together

molecule
a group of two or more atoms bonded together (e.g. a water molecule)

monatomic
consisting of a single atom

monotremes
a type of mammal that lays eggs

multicellular
consisting of two or more cells

multimedia resource
a combination of various media types – such as text, images, audio and video – used to enhance learning and engagement by making complex concepts more accessible

muscle tissue
the group of cells that allow the body to move

mutualism
a type of relationship between two organisms of different species in which both organisms benefit

mycologist
a scientist who studies fungi

N

natural disasters
natural events, such as floods, volcanic eruptions, tsunamis and earthquakes, that can cause severe damage and fatalities

neap tide
when the difference between high and low tides is smallest; occurs during the Moon's quarter phase, when the Sun and the Moon pull in different directions

nephron
a tiny structure in the kidneys that filters the blood

nervous tissue
the group of cells that pass on electrical messages

net force
the vector sum of all the forces acting on an object; also known as resultant force

neutron
a neutral (no charge) subatomic particle in the nucleus of an atom

Newton
the unit used to measure force; symbol N

noble gases
a collection of gaseous elements found in Group 18 of the periodic table

non-metals
a collection of elements that are found on the right-hand side of the periodic table

non-vascular
plants that lack a vascular system (xylem and phloem)

nuclear energy
energy stored in the nucleus of an atom and released in nuclear reactors or explosions of nuclear weapons; much greater than the chemical energy released in chemical reactions

nucleus
a membrane-bound structure in cells that contains most of the cell's genetic material

nutrient
a substance that an organism must obtain from its environment for growth and the maintenance of life; examples include carbohydrates, proteins, fats, vitamins, minerals and water

O

objective lens
lens in the column of a compound light microscope

observation
the process of using our senses to gather information about the world around us

ocean trench
a deep ditch under the ocean along a tectonic plate boundary

omasum
the third stomach of a cow

omnivore
an animal that eats both plants and animals

onion-skin weathering
weathering of rock whereby the outside of the rock peels off

open system
a system that exchanges both energy and matter with its surroundings

orbit
move in a curved path around another object

organ
a group of different tissues that are self-contained and have a specific vital function

organ system
a collection of different organs that work together to perform a particular function

organelle
a specialised sub-unit within a cell that has a specific function

osmosis
the movement of water through a semipermeable membrane from an area of low salt concentration to an area of high salt concentration; occurs in root cells

ovary
the enlarged basal portion of the carpel that contains the ovum

ovum
the female gamete or egg cell in plants, located within the ovule

P

Pangaea
a supercontinent that existed on Earth between 300–100 million years ago

parallax error
an error, or inaccurate reading, that occurs as a result of reading a scale from an angle

parasitism
a type of relationship in which one organism (parasite) lives in or on the body of another organism (host) and benefits while the host is harmed

partial solar eclipse
when only some of the Sun’s light is blocked by the Moon

pathogen
a disease-causing agent (e.g. bacteria, viruses, fungi)

pattern
when a set of data repeats in a predictable way

peer-review
review and evaluation of scientific research by experts in the field

periodic table
a table in which elements are listed in order of their atomic number, and grouped according to their similar properties

period
(in chemistry) a horizontal list of elements in the periodic table

peristalsis
the process of swallowed food being moved along the digestive tract by a wave of contractions

pharynx
the throat; connects the mouth to the oesophagus

phases of the Moon
(lunar phases) changes in the shape of the Moon as seen from Earth

philosopher
a “lover of knowledge”; someone who studies ideas, theories and questions

phloem
the vascular tissue in plant stems that carries sugars around the plant

photosynthesis
the chemical reaction used by plants to convert carbon dioxide and water into glucose

physical digestion
the breaking down food into smaller pieces without changing the chemical composition

physical property
a property of a substance that can be measured or observed without changing the substance into something else; examples are colour and boiling point

pie chart
a circular graph used to display data as proportional segments of a whole; each segment represents a category, and its size corresponds to the relative frequency or percentage of that category within the total; the entire chart represents 100% of the data

placental mammal
a type of mammal whose young develop inside the mother’s uterus, and are joined to the uterus via the placenta

plankton
microscopic organisms that float in fresh or salt water

plasma
a straw-coloured fluid that forms part of the blood

plate tectonics
the theory that the surface of the Earth consists of a series of plates that are continually moving due to convection, ridge push and slab pull

platelets
small, disc-like cells in blood that are involved in forming clots

pneumonia
a disease caused by bacterial or viral growth in the lungs

pollen
the fine powder produced by the anther of flowers, which contains the male gametes (sperm)

pollination
the process by which pollen is transferred from the male part (anther) to the female part (stigma) of a flower

polyatomic ion
a charged ion that consists of two or more atoms bonded together

population
a group of individuals of the same species living in the same location at the same time

population dynamics
the study of changes in species population numbers and the factors that may contribute to these changes

potential energy
energy that is stored in objects

precaution
safety measures taken to prevent harm, such as wearing personal protective equipment (PPE)

predator
an animal that hunts and feeds on another (prey) for food

prediction
the expected result of an experiment

pressure
the force something has on a surface; it happens when something pushes on an area; we measure pressure in pascals (Pa)

prey
an animal that is hunted and killed by another (predator) for food

primary data
data that is obtained by the original person doing the research from the original source

producer
a plant or plant-like organism that is at the start of a food chain because it produces its own food, usually using sunlight

product
a substance obtained at the end of a chemical reaction; written on the right side of a chemical equation

prokaryotic cell
a primitive single-celled organism that has no nucleus

properties
(in chemistry) the characteristics or things that make a substance unique

proton
a positively charged subatomic particle in the nucleus of an atom

pure substance
something that contains only one type of substance (e.g. a single element or a single compound)

Q

quadrat
a randomly selected square plot used to estimate the number of organisms

qualitative
descriptive and non-numerical information

qualitative data
descriptions and explanations that are not numerical

quantitative
numerical information that can be measured

quantitative data
can be measured numerically

R

radiation
the transfer of thermal energy across empty space or through another substance without the need for particles

ramp
a sloping surface joining two different levels

range
the difference between the highest and lowest numbers in a set

reactant
a substance used at the beginning of a chemical reaction; written on the left side of a chemical equation

red blood cell
cell in the blood that carries oxygen around the body

reference
a complete entry in a reference list or bibliography that provides full details about a source cited in the text

relationship
the way in which two or more variables interact where changing one variable causes a change in the others

reliable
consistency of information across difference sources or measurement

remote control
an electronic device used to operate a machine remotely (i.e. at a distance)

reproducible
an experiment that can be replicated by other scientists, using the same materials and methods, and produce consistent outcomes

reproduction
the production of offspring by a sexual or asexual process

repulsion force
a force that pushes one object away from another

residue
the substance left behind in a sieve or filter

results
the measurements and observations made in an experiment; they are often presented in a table

reticulum
the second stomach of a cow

ribosome
non-membrane enclosed organelle required for protein synthesis

ridge push
the force pushing the edges of tectonic plates away from each other when a ridge crest has formed

rift valley
a deep valley that forms as a result of tectonic plates moving apart on land

risk
the chance that a hazard will cause harm

risk assessment
a process to identify potential hazards and associated risks in order to take safety precautions

rock cycle
the process of formation and destruction of different rock types

root
a plant organ involved in absorbing nutrients and water

rumen
the first stomach of a cow

ruminant
a hooved animal that has four chambers in their stomachs. Examples include sheep, deer and cows

rust
a specific type of corrosion that occurs when iron or steel reacts with oxygen and water, forming iron oxide, which weakens the metal

S

saturated
describes a solution in which the maximum amount of solute is dissolved in a solvent at a certain temperature

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

science
the study of the natural and physical world

scientific diagram
a clear, labelled, side-view line drawing, usually made using a sharp pencil

scientific model
a representation of a complex concept or a phenomena that cannot be directly observed

scientist
a person who studies the natural and physical world

sclerophyll
a type of vegetation characterised by hard, thick and leathery leaves that are adapted to arid conditions and nutrient-poor soils

screw
a sharp-pointed metal object with a spiral thread running along its length and a slotted head

sea-floor spreading
the theory that the middle of the ocean is spreading apart, forming new oceanic crust

second-class lever
a lever that has its load between the point of effort and the fulcrum

second-order consumer
a carnivore that eats primary consumers

secondary data
data which has been collected or analysed based on previous research

secondary source
information collected and interpreted by others, such as textbooks, articles and documentaries

sediment
something that settles to the bottom in a mixture

sedimentary rock
rock formed from compacted mud, sand or pebbles, or the remains of living things

sedimentation
a process that uses gravity to remove suspended solids from a solution

seismic geophysical testing
the collecting of geophysical data such as differences in magnetic fields and gravity fields between different geological locations

self-pollination
the transfer of pollen from the anther to the stigma of the same flower or another flower on the same plant, leading to fertilisation without genetic mixing from another plant

semipermeable
refers to a membrane that allows certain substances to pass through while blocking others, enabling selective movement of molecules across it

shell diagram
a diagram that shows the arrangement of electrons and electron shells in an atom

sieving
a separation technique used to separate different-sized particles depending on the size of the holes in the sieve used

silicate
a chemical compound made up of silicon and oxygen

simulation
a model that represents a real-world concept

single-celled
an organism that consists of only one cell; also called a unicellular organism

singularity
a point that has infinite gravity and density; the centre of a black hole

slab pull
the force pulling a tectonic plate beneath a less dense tectonic plate

solar cell
a device that transforms sunlight directly into electrical energy; is usually in the form of a panel; also known as a solar panel

solar eclipse
when light from the Sun (as seen from Earth) is blocked by the Moon

solid
a substance that has a fixed shape and volume

solidification
when a substance in its liquid phase changes into a solid state at a fixed temperature

solstice
either of the times when the Sun is furthest from the Equator

solubility
how easily a substance dissolves in a solvent

soluble
can be dissolved in a liquid

solute
a substance that dissolves in a liquid (solvent)

solution
a liquid made up of a solvent with a solute dissolved in it

solvent
a liquid in which other substances dissolve

sound energy
a type of kinetic energy produced when things vibrate, causing waves of pressure in the air or some other medium

species
a group of organisms that look similar to one another, and can breed in natural conditions and produce fertile young

spectroscope
an instrument that separates light into its different colours

spin
rotate around an internal axis or centre

spore
a tiny reproductive structure that, unlike a gamete, does not need to fuse with another cell to form a new organism

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

spring tide
when there is maximum difference between high and low tides; caused by the combined pull of the Moon and the Sun

stain
a substance, such as iodine, used to make cells more visible under a microscope

stamen
the male reproductive part of a flower, made up of the anther and filament

star
a glowing big, hot ball of gases

state
condition or form that something takes based on the arrangement of particles and their movement

stem
an organ that transports materials around a plant

stereomicroscope
a microscope with two eyepieces that uses low magnification

stigma
the part of the female reproductive structure in flowering plants; the tip of the carpel, where pollen is deposited

stimuli
a changes or event in the environment that causes a reaction from an organism

stomata
pores on leaves and stems for gas exchange, allowing carbon dioxide intake and oxygen release, essential for photosynthesis and transpiration

streak
the colour of powdered or crushed mineral

style
the slender stalk within the carpel that connects the stigma to the ovary, providing a pathway for pollen tubes to reach the ovules

subatomic particle
a particle that is smaller than an atom

subduction
the movement of one tectonic plate under another tectonic plate

sublimation
a change of state from a solid directly to a gas

substance
a solid or liquid that can be mixed

supernova
explosion of a star

supersaturated
describes a solution that contains more than the maximum amount of solute that can be dissolved in a solvent at a certain temperature

surface area to volume ratio
the relationship between the area around the outside of a cell and its volume, as a fraction

surface tension
the property of the surface of a liquid that allows it to resist external force, acting as a barrier between the liquid and foreign objects

surrounding
everything outside of a system

suspension
a cloudy liquid that contains insoluble particles

symbiosis
a close, physical relationship between two organisms of different species

system
a group of components that work together

systematic observations
recording observations over time in a structured and consistent way

T

table
organised arrangements of data in rows and columns, facilitating easy access and comparison of specific information

tectonic plate
a large layer of solid rock that covers part of the surface of the Earth; movement of tectonic plates can cause earthquakes

telescope
an optical instrument that uses lenses and mirrors to make distant objects appear closer and larger

temperature
how hot or cold something is. This tells us how much energy the tiny particles in an object are moving. The hotter something is, the faster the particles move. We measure temperature using different scales, like Celsius (°C), or Kelvin (K)

tenor
the people involved in the communication and their relationship

tensile strength
a measure of the flexibility of the bonds between particles in a substance

terrestrial planets
describes the planets Mercury, Venus, Earth and Mars, as they have a rocky surface

theory
an explanation of a small part of the natural world that is supported by a large body of evidence

thermal energy
the scientific term for heat energy

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

third-class lever
a lever that has its point of effort between the fulcrum and the load

Thomson plum pudding model
an early model of the atom in which the positively charged nucleus has negatively charged electrons scattered through it, like a plum pudding

thread
the spiral ridge of a screw

tissue
a group of the same cell type that performs a similar task

tor
a large, round rock produced by onion-skin weathering

total solar eclipse
when the Moon blocks the maximum amount of light from the Sun, as seen from Earth

trace fossil
traces of an organism that existed in the past

trachea
the large tube that connects the throat to the bronchi; carries air in and out of the body

transferred
when energy is passed from one object to another

transform boundary
the boundary between two tectonic plates that are sliding past each other

transformed
when energy is changed from one form to another form

transpiration
the process of water evaporating from plant leaves; causes water to move up through the plant from the roots

trend
the general tendency of a set of data to move in a certain direction

trophic level
the position an organism holds in a food chain or food web

tsunami
a series of large waves that result from an underwater earthquake

type specimen
the specimen used for naming and describing a new species

U

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

unicellular
consisting of only one cell; an example is a bacterium

units
standard measurements

unlike poles
the north and south poles of a magnet

urban sprawl
the spreading and expansion of cities and houses into undeveloped land

urea
a chemical waste product produced in the body and removed in urine

V

valence shell
the outermost electron shell in an atom that contains electrons

valid experiment
where an experiment investigates what it sets out to investigate

vaporise
change state from a liquid to a gas; evaporate

vapour
gaseous form of a substance that is normally solid or liquid at room temperature (e.g. water vapour)

variable
something that can affect the outcome or results of an experiment

vascular
structures or systems composed of blood vessels or plant vessels

vascular bundle
a group of tubes in plant stems that carry water and nutrients around the plant

vascular plants
plants that have vessels (xylem and phloem) used to transport material around the plant

vascular tissue
vessels that transport material around an organism

vein
a thin-walled blood vessel that carries blood back to the heart

ventricles
the two large, lower chambers of the heart

vertebrate
an organism that has an endoskeleton

vesicle
an organelle surrounded by a membrane and used by cells to store materials; a vacuole is a type of vesicle found in plant cells

villi
small ridges in the small intestine that absorb nutrients from chyme

viscosity
a measure of how slowly a liquid changes its shape; the thickness of a liquid

volatile
describes a substance that easily becomes a gas

W

water vacuole
a membrane-bound organelle found in plant cells that primarily stores water and nutrients and provides structural support

weathering
the breakdown of rocks and minerals by the movement of water and animals, and extremes of temperature

wedge
a piece of wood, metal or other substance that tapers to a thin edge and is driven between two objects or parts of an object to secure or separate them

weight
a measure of the gravitational pull on an object and is the same as the force of gravity on Earth

wheel and axle
a type of lever that can rotate about its centre, magnifying force or distance

white blood cell
an immune system cell that destroys pathogens

X

xylem
the tissue in plants that carries water from the roots to the rest of the plant

Z

zoologist
a scientist who studies animals

zygote
the first cell of a new organism created after sexual reproduction

Index

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Lesson 3.1: Fig. 1, Jasper Juinen/Getty Images; Fig. 2, Cary Westfall/Shutterstock; Fig. 3, lzf/Shutterstock; Fig. 4, Vaclav Volrab/Shutterstock; Fig. 5, lev radin/Shutterstock; Fig. 6, David Crausby/Alamy Stock Photo; Fig. 7, Torsak Thammachote/Shutterstock; Fig. 8, vitor costa/Shutterstock; Lesson 3.3: Fig. 1, Mark Dadswell/Getty Images; Fig. 2 , skynesher/Getty Images; Lesson 3.4: Fig. 1, blickwinkel/Alamy Stock Photo; Fig. 2, James Kirkikis/Shutterstock; Fig. 4, sciencephotos/Alamy Stock Photo; Lesson 3.5: Fig. 1, BlueRingMedia/Shutterstock; Fig. 3, Vitalii Nesterchuk/Shutterstock; Fig. 7, Dream01/Shutterstock; Lesson 3.7: Fig. 1, GraphicsRF.com/Shutterstock; Fig. 2, udaix/Shutterstock; Fig. 3, udaix/Shutterstock; Fig. 6, Anirban Basu/Alamy Stock Photo; Fig. 7, redknapper/Shutterstock; Lesson 3.9: Fig. 1, Jakinnboaz/Shutterstock; Fig. 2 (a), PHOTOTAKE Inc./Alamy Stock Photo; Fig. 2 (b), PHOTOTAKE Inc./Alamy Stock Photo; Fig. 2 (c), PHOTOTAKE Inc./Alamy Stock Photo; Fig. 5, Ed Jenkins/Shutterstock; Fig. 6, Science Photo Library/Alamy Stock Photo; Fig. 7, S_E/Shutterstock; Lesson 3.11: Fig. 1, © Look and Learn/Bridgeman Images; Fig. 2 (b), TuktaBaby/Shutterstock; Fig. 3, Nakornthai/Shutterstock; FIg. 4, Hemis/Alamy Stock Photo; Fig. 5 (b), MNI/Shutterstock; Fig. 6 (b), Steve Gorton/Dorling Kindersley RF/Getty Images; Fig. 7 (b), Neale Cousland/Shutterstock; Fig. 8, Robin Smith/The Image Bank/Getty Images; Fig. 10, New Africa/Shutterstock; Fig. 11, Peter Steiner/Alamy Stock Photo; Lesson 3.12: Fig. 1, john photon/Shutterstock; Fig. 6 , NNehring/iStock/Getty Images; Lesson 3.15: Fig. 1, Perihan Can/Shutterstock; Lesson 3.16: Fig. 1, Miiraa/Shutterstock; Fig. 2, Net Vector/Shutterstock; Fig. 3, TommL/E+/Getty Images; Fig. 4, Dorling Kindersley ltd/Alamy Stock Photo; Fig. 5, Geofff/Shutterstock; Fig. 6, Africa Studio/Shutterstock; Fig. 7, Ljupco Smokovski/Shutterstock; Fig. 8, VladyslaV Travel photo/Shutterstock; Lesson 3.17: Fig. 1, studioVin/Shutterstock; Fig. 2, Daniela Pelazza/Shutterstock; Fig. 3, withGod/Shutterstock; Fig. 4, bergamont/Shutterstock; Lesson 3.17: Fig. 1, Glenn Research Centre/NASA; Fig. 3, Ronald Sumners/Shutterstock; Fig. 4, Kidsafe NSW Inc ABN 29 532 079 872 c/o Kidsafe House Westmead NSW 2145 e: schn-kidsafe@health.nsw.gov.au p: 02 9845 0894 w: www.kidsafensw.org; Lesson 3.18: Fig. 7, pavelwp/Shutterstock; Fig. 8, Pike-28/Shutterstock; Fig. 9, Peter Skinner/Danita Delimont/Alamy Stock Photo; Lesson 3.6: Fig. 2, grayjay/Shutterstock; Fig. 3, renklerin kafasi/Shutterstock; Fig. 4, European Southern Observatory (ESO).; Fig. 5, TIM BROWN/SCIENCE PHOTO LIBRARY; Fig. 1, ziggy_mars/Getty Images. **Module 4: Opener:** Roxana Bashyrova/Shutterstock. Lesson 4.1: Fig. 4, Science Photo Library/Alamy Stock Photo; Fig. 1, World History Archive/Alamy Stock Photo; Fig. 2, GL Archive/Alamy Stock Photo; Fig. 3 (a), Science Photo Library/Alamy Stock Photo; Lesson 4.2: Fig. 1 (d), KKT Madhusanka/Alamy Stock Vector; Fig. 3, Choksawatdikorn/Shutterstock; Fig. 2 (b), OMIKRON/SCIENCE PHOTO LIBRARY; Fig. 5 (b), Science Photo Library/Alamy Stock Photo; Fig. 7 (b), DON W. FAWCETT/SCIENCE PHOTO LIBRARY; Fig. 6, Greg Brave/Shutterstock; Lesson 4.3: Fig. 1 (a), Roger Eritja/Alamy Stock Photo; Fig. 1 (b), David J. Green - science/Alamy Stock Photo; Fig. 2 (a), Martin Shields/Alamy Stock Photo; Fig. 2 (b), 77Ivan/Shutterstock; Fig. 3, Science Photo Library/Alamy Stock Photo; Fig. 5, Science Photo Library/Alamy Stock Photo; Lesson 4.4: FIg. 3, David Herraez Calzada/Shutterstock; Lesson 4.5: Fig. 1 (a), Lebendkulturen.de/Shutterstock; Fig. 2 (d), Creative Endeavors/Shutterstock; Lesson 4.8: Fig. 2, udaix/Shutterstock; Fig. 3 (f), Art of Science/Shutterstock; Fig. 3 (g), Designua/Shutterstock; Fig. 4 (a), VectorMine/Shutterstock; Fig. 4 (b), Eli-E-learning/Shutterstock; Fig. 4 (c), Kazakova Maryia/Shutterstock; Lesson 4.10: Fig. 2, WWW.SCIENTRIFIC.COM.AU ; Lesson 4.11: Fig. 1, Baron/Hulton Archive/Getty Images; Fig. 2, Fotosr52/Shutterstock; Fig. 3, Science History Images/Alamy Stock Photo; Fig. 4, age fotostock Spain, S.L./Alamy Stock Photo; Fig. 5, World History Archive/Alamy Stock Photo; Lesson 4.12: Fig. 1 (a), NIBSC/SCIENCE PHOTO LIBRARY; Fig. 1 (b), BIOPHOTO ASSOCIATES/SCIENCE PHOTO LIBRARY; Fig. 1 (c), © Hans Hillewaert; Fig. 1 (d), Science Photo Library/Alamy Stock Photo; Fig. 2 (a), Science History Images/Alamy Stock Photo; Fig. 2 (b), DR JEREMY BURGESS/SCIENCE PHOTO LIBRARY; Fig. 2 (c), J.C. REVY, ISM/SCIENCE PHOTO LIBRARY; Fig. 3, Viktar Malyshchyts/Shutterstock; Fig. 4, Everett Collection/Shutterstock; Fig. 5, STEVE GSCHMEISSNER/SCIENCE PHOTO LIBRARY; Fig. 6, Schira/Shutterstock. **Module 5: Opener:** Steven Porter/Shutterstock. Lesson 5.1: Fig. 1 (a), Maxim Petrichuk/Shutterstock; Fig. 1 (b), sompreaw/Shutterstock; Fig. 2, Claudia Paulussen/Shutterstock; Fig. 3, Susan Flashman/Shutterstock; Fig. 5, Marco Uliana/Shutterstock; Fig. 6, Arm001/Shutterstock; Fig. 7, Blend Images/Shutterstock; Fig. 8, Lmspencer/Shutterstock; Fig. 4, Macrovector/Getty Images; Lesson 5.2: Fig. 1 (a), Ondrej Prosicky/Shutterstock; Fig. 1 (b), TODD G AINSWORTH/Shutterstock; Fig. 1 (c), Andrea Izzotti/Shutterstock; Fig. 2, Photograph taken by Mark A. Wilson (Department of Geology, The College of Wooster).; Fig. 3, crbellette/Shutterstock; Fig. 4, earlytwenties/Shutterstock; Lesson 5.3: Fif. 4 (a), Ken Griffiths/Shutterstock; Fig. 4 (b), Thomas Mesaglio; Fig. 4 (c), © Anders Zimny; Fig. 4 (d), Ken Griffiths/Shutterstock; FIg. 4 (e), Ken Griffiths/Shutterstock; Fig. 4 (f), Matt Jeppson/Shutterstock; Fig. 2, Vicki

Cain/Shutterstock; Fig. 3, rickyd/Shutterstock; Lesson 5.5: Fig. 4, gillmar/Shutterstock; Fig. 1, The Picture Art Collection/Alamy Stock Photo; Fig. 2, Smileus/Shutterstock; Fig. 3, Maks Narodenko/Shutterstock; Lesson 5.6: Fig. 2 (a), Berendje Fotografie/Shutterstock; Fig. 2 (b), Craig Lambert Photography/Shutterstock; Fig. 2 (c), Jaco Visser/Shutterstock; Fig. 3 (a), Nokuro/Shutterstock ; Fig. 3 (b), Sherjaca/Shutterstock; Fig. 3 (c), imageBROKER/Shutterstock; Fig. 4 (a), Andre Nantel/Shutterstock; Fig. 4 (b), Dmitriy Krasko/Shutterstock; Fig. 4 (c), Czintos Odon/Shutterstock; Fig. 5 (a), Ed Reschke/Getty; Fig. 5 (b), Science Photo Library/Alamy Stock Photo; Fig. 5 (c), Science Photo Library/Alamy Stock Photo; Fig. 6 (a), blickwinkel/Alamy Stock Photo; Fig. 6 (b), Choksawatdikorn/Shutterstock; Fig. 6 (c), Ethan Daniels/Shutterstock; Lesson 5.7: Fig. 1 (a), Wako Megumi/Shutterstock; Fig. 1 (b), Skumer/Shutterstock; Fig. 1 (c), Maria Skaldina/Shutterstock; Fig. 1 (d), Liew Weng Keong/Shutterstock; Fig. 1 (e), Medtech THAI STUDIO LAB 249/Shutterstock; Fig. 1 (f), Pentium5/Shutterstock; Fig. 1 (g), kosam/Shutterstock; Fig. 1 (h), Stu Porter/Shutterstock; Fig. 1 (i), Patila/Shutterstock; Fig. 1 (j), ivvv1975/Shutterstock; Fig. 1 (k), smereka/Shutterstock; Fig. 1 (l), Nurlan Kalchinov/Shutterstock; Fig. 1 (m), boonsom/123rf; Fig. 1 (n), Liliana_Cantu/Shutterstock; Fig. 1 (o), Mark Bridger/Shutterstock; Fig. 1 (p), Emily Li/Shutterstock; Fig. 1 (q), Tiplyashina Evgeniya/Shutterstock; Fig. 1 (r), BartTa/Shutterstock; Fig. 1 (s), phungatanee/Shutterstock; Fig. 1 (t), barmalini/Shutterstock; Fig. 1 (u), ART-ur/Shutterstock; Fig. 1 (v), Jacqueline Abromeit/Shutterstock; Fig. 1 (w), yilmazsavaskandag/Shutterstock; Fig. 1 (x), Ivica Drusany/Shutterstock; Fig. 1 (y), Sari Oneal/Shutterstock; Fig. 1 (z), Ethan Daniels/Shutterstock; Fig. 1 (aa), dean bertoncelj; Fig. 1 (ab), Cora M⊠ller/123rf; Fig. 1 (ac), 3d_man/Shutterstock; Fig. 1 (ad), LilKar/Shutterstock; Fig. 1 (ae), deckorator/Shutterstock; Fig. 1 (af), Igor Dutina/Shutterstock; Fig. 1 (ag), Lebendkulturen.de/Shutterstock; Fig. 1 (ah), Christian Musat/Shutterstock; Fig. 1 (ai), Nattika/Shutterstock; Fig. 1 (aj), fusebulb/Shutterstock; Fig. 1 (ak), Ken Solo/Shutterstock; Fig. 1 (al), Lynn Yeh/Shutterstock; Fig. 1 (am), dean bertoncelj/Shutterstock; Fig. 1 (an), Berilova Irida/Shutterstock; Lesson 5.8: Fig. 1, Amanda Cotton/Alamy Stock Photo; Fig. 2 (a), papkin/Shutterstock; Fig. 2 (b), Jolanta Wojcicka/Shutterstock; Fig. 2 (c), Doptis/Shuttertstock; Fig. 2 (d), Natursports/Shutterstock; Fig. 2 (e), Damsea/Shutterstock; Fig. 2 (f), papkin/Shutterstock; Fig. 3, irin-k/Shutterstock; Lesson 5.9: Fig. 1 (a), yevgeniy11/Shutterstock; Fig. 1 (b), NeagoneFo/Shutterstock; Fig. 1 (c), jopelka/Shutterstock; Fig. 1 (d), Fotyma/Shutterstock; Fig. 1 (e), Pan Stock/Shutterstock; Fig. 1 (f), John McQueen/Shutterstock; Fig. 1 (g), Dimijana/Shutterstock; Fig. 1 (h), irin-k/Shutterstock; Lesson 5.10: Fig. 6, Tom Wang/Shutterstock; Fig. 1 (a), Peggy D. Rismiller, Michael W. McKelvey, Frequency of Breeding and Recruitment in the Short-Beaked Echidna, Tachyglossus Aculeatus, Journal of Mammalogy, Volume 81, Issue 1, February 2000, Pages 1–17, https://doi.org/10.1644/1545-1542(2000)081<0001:FOBARI>2.0.CO;2; Fig. 1 (b), Kjuuurs/Shutterstock; Fig. 1 (c), Auscape International Pty Ltd/Alamy Stock Photo; Fig. 2, Four Oaks/Shutterstock; Fig. 3, Ken Griffiths/Alamy Stock Photo; Fig. 4, The Natural History Museum/Alamy Stock Photo; Fig. 5, Kristian Bell/Shutterstock; Lesson 5.12: Fig. 2, Ehrman Photographic/Shutterstock; Fig. 3, Brian Maudsley/Shutterstock; Fig. 4, Taiftin/Shutterstock; Fig. 5, The Natural History Museum/Alamy Stock Photo; Fig. 6, Anne Saarinen/Alamy Stock Photo; Lesson 5.13: Fig. 6, ChameleonsEye/Shutterstock; Fig. 7, N Mrtgh/Shuttterstock; Fig. 8 (a), Taras Vyshnya/Shutterstock; Fig. 8 (b), KarenHBlack/Shutterstock; Fig. 1, dwi putra stock/Shutterstock; Fig. 3, Visual Collective/Shutterstock; Fig. 4, Kristian Bell/Shutterstock; Fig. 5, Chris Watson/Shutterstock; Lesson 5.14: Fig. 1, KAMONRAT/Shutterstock; Lesson 5.15: Fig. 8, Stanislav Fosenbauer/Shutterstock; Fig. 1, P.j.Hickox/Shutterstock; Fig. 2 (a), simona pavan/Shutterstock; Fig. 2 (b), Sergey Malomuzh/Shutterstock; Fig. 3, Cynthia A Jackson/Shutterstock; Fig. 4, Jaroslav Cips/Shutterstock; Fig. 5, Renata Apanavicie/Shutterstock; Fig. 6, John W. Banagan/Getty Images; Fig. 7, ANUJAK JAIMOOK/Shutterstock; Lesson 5.16: Fig. 1, CSIRO; Fig. 3, Reproduced with permission of Anthony Whalen; Fig. 4, Bryan D. Lessard/CSIRO; Fig. 5, Dhugal John Lindsay/JAMSTEC; Fig. 6, NOAA Ocean Exploration; Fig. 7, © Nik Borrow/iNaturalist United Kingdom; Lesson 5.17: Fig. 1, Puwadol Jaturawutthichai/Shutterstock; Fig. 2, Eric Isselee/Shutterstock; Fig. 3, Kristian Bell/Shutterstock. **Module 6: Opener:** Jens Breuer/Shutterstock. Lesson 6.1: Fig. 1, Ph-HY/Shutterstock; Fig. 2, Chaykovsky Igor/Shutterstock; Fig. 3, nnattalli/Shutterstock; Fig. 4, artifex. orlova/Shutterstock; Fig. 5, G A Goulding/Shutterstock; Fig. 6, haveseen/Shutterstock; Fig. 7, Petr Malyshev/Shutterstock; Fig. 10 (a), Africa Studio/Shutterstock; Fig. 10 (b), Pavlo Loushkin/Shutterstock; Fig. 10 (c), sumire8/Shutterstock; Lesson 6.2: Fig. 1, Designua/Shutterstock; Lesson 6.4: Fig. 1, John Sirlin/Alamy Stock Photo; Fig. 4 (a), TarikVision/Shutterstock; Fig. 4 (b), TarikVision/Shutterstock; Fig. 4 (c), TarikVision/Shutterstock; Lesson 6.5: Fig. 2, Pat_Hastings/Shutterstock; Fig. 4, Illustrator76/Shutterstock; Fig. 5, Maleo/Shutterstock; Fig. 8, Avalon_Studio/Getty Images; Fig. 10 (a), NataliaZa/Shutterstock; Fig. 10 (b), MAHATHIR MOHD YASIN/Shutterstock; Fig. 12, Dream01/Shutterstock; Fig. 13, dhamu234/Shutterstock; Lesson 6.6: Fig. 1, ggw/Shutterstock; Fig. 2, PRILL/Shutterstock; Fig. 4, Dream01/Shutterstock; Lesson 6.7: Fig. 2, Nordroden/Shutterstock; Fig. 3, Rendery/Getty Images; Fig. 7, David R. Frazier Photolibrary, Inc./Alamy Stock Photo; Fig. 8, JOE ARMAO/Fairfax; Fig. 9, anmbph/Shutterstock; Lesson 6.8: Fig. 1, xpixel/Shutterstock; Fig. 3, Calum Robertson/Newspix; Fig. 4, FrimuFilms/Shutterstock. **Module 7: Opener:** New Africa/Shutterstock. Lesson 7.1: Fig. 3, Monkey Business Images/Shutterstock; Fig. 6, M. Unal Ozmen/Shutterstock; Lesson 7.2: Fig. 2, bluehand/Shutterstock; Fig. 4, Chris Hondros/Getty Images; Lesson 7.4: Fig. 3, givaga/Shutterstock; Fig. 3, nito/Shutterstock; Lesson 7.5: Fig. 1, Steve Holderfield/Shutterstock; Lesson 7.6: Fig. 1, on9store/Shutterstock; Lesson 7.7: Fig. 1, Brent Parker Jones Photographer; Fig. 2, worradirek/Shutterstock; Fig. 3, Kekyalyaynen/Shutterstock; Fig. 4, egd/Shutterstock; Fig. 5, Robyn Mackenzie/Shutterstock; Lesson 7.8: Fig. 1, Alena Brozova/Shutterstock; Lesson 7.9: Fig. 1, gresei/Shutterstock; Fig. 4, Wessel du Plooy/Shutterstock; Fig. 5, Martin Bergsma/Shutterstock; Lesson 7.11: Fig. 1, Firma V/Shutterstock; Fig. 2, Science Photo Library/Alamy Stock Photo; Fig. 4, anek.soowannaphoom/Shutterstock; Lesson 7.13: Fig. 1, mtaira/123RF; Lesson 7.14: Fig. 1, GIPHOTOSTOCK/SCIENCE PHOTO LIBRARY; Fig. 2, cience Photo Library/Alamy Stock Photo; Fig. 3, Polimerek/ CC 4.0; Fig. 4, Emre Ozcelik/Shutterstock; Lesson 7.17: Fig. 1, Graham Taylor Photography/Shutterstock; Fig. 2, Kekyalyaynen/Shutterstock; Fig. 3, Pyty/Shutterstock; Fig. 4, nostal6ie/Shutterstock; Fig. 6, Avalon/Construction Photography/Alamy Stock Photo; Lesson 7.19: Fig. 3, akepong srichaichana/Shutterstock; Fig. 5 (a), Aiman Chehimi/Shutterstock; Fig. 5 (b), Pif Paf Puf Studio/Shutterstock; Fig. 5 (c), NisanatStudio/Shutterstock; Fig. 7, John Tunney/Shutterstock; Fig. 8, Vera Larina/Shutterstock. **Module 8: Opener:** smereka/Shutterstock. Lesson 8.1: Fig. 1, Nick Brundle Photography/Shutterstock; Fig. 2 (a), Keith Corrigan/Alamy Stock Photo; Fig. 2 (b), Reeed/Shutterstock; Fig. 4, aelzuhry/Shutterstock; Fig. 5, DiBtv/Shutterstock; Lesson 8.2: Fig. 3, homydesign/Shutterstock; Fig. 4, TimeLineArtist/Shutterstock; Lesson 8.4: Fig. 1, The Natural History Museum/Alamy stock photo; Fig. 2, VectorMine/Shutterstock; Fig. 5 (a), Martin Pelanek/Shutterstock; Fig. 5 (b), Ken Griffiths/Shutterstock; Fig. 7 (a), The Natural History Museum/Alamy Stock Photo; Fig. 7 (b), Shutterstock; Lesson 8.5: Fig. 1, Science Photo Library/Shutterstock; Fig. 2, TONY ASHBY/Getty Images; Fig. 3, Phanie/Alamy Stock Photo; Fig. 4 (a), Lightspring/Shutterstock; Fig. 4 (b), logika600/Shutterstock; Fig. 4 (c), Designua/Shutterstock; Lesson 8.10: Fig. 2, Iryna Melnyk/Shutterstock; Fig. 3 (a), Pavel Chagochkin/Shutterstock; Fig. 3 (b), Science Photo Library/Alamy Stock Photo; Fig. 4, Pepermpron/Shutterstock; Lesson 8.8: Fig. 2 (a), Science Photo Library/Alamy Stock Photo; Fig. 2 (b), Science Photo Library ; Fig. 2 (c), RuMax/Shutterstock; Fig. 3 (a), Alice Day/Shutterstock; Fig. 4 , Connect Images/Alamy Stock Photo; Lesson 8.6: Fig. 3, Soleil Nordic/Shutterstock; Fig. 4, Aldona Griskeviciene/Shutterstock; Lesson 8.14: Fig. 1, logika600/SHutterstock; Fig. 3, Asia Evtyshok/Shutterstock; Fig. 4, ANATOLY Foto/Shutterstock; Fig. 2, logika600/Shutterstock; Lesson 8.15: Fig. 1, Ozgur Coskun/Shutterstock; Lesson 8.16: Fig. 3, Science Photo Library/Alamy Stock Photo; Fig. 5, Juergen Faelchle/Shutterstock; Fig. 8, Lev Kropotov/Shutterstock; Lesson 8.17: Fig. 1 (a), sciencephotos/Alamy Stock Photo; Fig. 1 (b), John Boud/Alamy Stock Photo; Lesson 8.18: Fig. 1, Mike Rosecope/ Shutterstock; Lesson 8.19: Fig. 2, eveleen/Shutterstock; Fig. 3, MOLEKUUL/SCIENCE PHOTO LIBRARY; Fig. 4, St Johnston D (2015); Fig. 5 , Shuang Li/Shutterstock. **Module 9: Opener:** Simargl94/Shutterstock. Lesson 9.1: Fig. 1 (a), Ashley Whitworth/Shutterstock; Fig. 1 (b), AustralianCamera/Shutterstock; Fig. 1 (c), ProDesign studio/Shutterstock; Fig. 2 (a), Michelle Sole/Shutterstock; Fig. 2 (b), Fredy Thuerig/Shutterstock; Fig. 3 (a), FiledIMAGE/Shutterstock; Fig. 3 (b), Sergey Uryadnikov/Shutterstock; Fig. 5 (a), Minden Pictures/Alamy Stock Photo; Fig. 5 (b), Holger Ehlers/Alamy Stock Photo; Fig. 6, svetlanaspain/Shutterstock; Fig. 7 (a), Yuttana Joe/Shutterstock; Fig. 7 (b), Nature Picture Library/Alamy Stock Photo; Fig. 8, John Carnemolla/Shutterstock; Fig. 9, Karel Gallas/Shutterstock; Fig. 10, Ken Griffiths/Shutterstock; Lesson 9.2: Fig. 4, Paul Glendell/Alamy Stock Photo; Fig. 5, Shchipkova Elena/Shutterstock; Fig. 6, Pronghorn Productions/Shutterstock; Lesson 9.3: Fig. 1, Frank Martins/Shutterstock; Fig. 2, Eric Isselee/Shutterstock; Lesson 9.4: Fig. 1, dexns/Shutterstock; Lesson 9.5: Fig. 2 (a), detshana/Getty Images; Fig. 2 (b), proxyminder/Getty Images; Fig. 2 (c), clearviewstock/Shutterstock; Fig. 2 (d), THP Creative/Shutterstock; Fig. 3 (a), detshana/Getty Images; Fig. 3 (b), proxyminder/Getty Images; Fig. 3 (c), clearviewstock/Shutterstock; Fig. 3 (d), THP Creative/Shutterstock; Fig. 3 (e), Gary Unwin/Shutterstock; Fig. 3 (f), ozflash/Getty Images; Fig. 3 (g), schnuddel/Getty Images; Fig. 3 (h), redwolfoz/Getty Images; Fig. 3 (i), Cathy Keifer/Shutterstock; Fig. 3 (j), mattabbe/Getty Images; Fig. 3 (k), datmore/Getty Images; Fig. 3 (l), tomasworks/Getty Images; Fig. 3 (m), LisaInGlasses/Getty Images; Fig. 4 (a), tomasworks/Getty Images; Fig. 4 (b), ozflash/Getty Images; Fig. 4 (c), Gary Unwin/Shutterstock; Fig. 4 (d), LisaInGlasses/Getty Images; Fig. 4 (e), schnuddel/Getty Images; Fig. 4 (f), Gary Unwin/Shutterstock; Fig. 5, Rick Ray/Shutterstock; Fig. 6 (a), phildaint/Shutterstock; Fig. 6 (b), Chayut Thanaponchoochoung/Shutterstock; Lesson 9.6: Fig. 1, nadiya_sergey/Shutterstock; Fig. 2, LukaSkywalker/Shutterstock; Fig. 3 (a), Zoe Ezzy/Shutterstock; Fig. 3 (b), Michal Pesata/Shutterstock; Fig. 4, Taras Vyshnya/Shutterstock; Lesson 9.7: Fig. 1, Phillip Wittke/Shutterstock; Lesson 9.8: Fig. 1, Nandalal Sarkar/Shutterstock; Lesson 9.9: Fig. 1, Chris Ison/Shutterstock; Fig. 3, Department of Biodiversity, Conservation and Attractions; Fig. 4, © Mike Letnic; Fig. 5, © 2013 Richard Shine, Thomas Madsen, Beata Ujvari, et al Functional Ecology © 2013 British Ecological Society; Fig. 7, Martin Tobias Aakesson/Shutterstock; Fig. 8, Photographs by Arko Lucieer/University of Tasmania; Fig. 10, Cooke, B. 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Proceedings of the Vertebrate Pest Conference, 25. http://dx.doi.org/10.5070/V425110441 Retrieved from https://escholarship.org/uc/item/6vz1d2bd; Lesson 9.10: Fig. 2, National Geographic Image Collection/Alamy Stock Photo; Fig. 3, Alex Cimbal/Shutterstock; Fig. 4, Anton Prado PHOTO/Shutterstock; Fig. 5, jindrich_pavelka/Shutterstock; Fig. 6, News Digital Media; Fig. 7, Elias Bitar/Shutterstock; Fig. 8, Milosz Maslanka/Shutterstock; Fig. 9, Auscape International Pty Ltd/Alamy Stock Photo; Lesson 9.11: Fig. 1 (a), Tom Wayman/Shutterstock; Fig. 1 (b), Martin Pelanek/Shutterstock; Fig. 1 (c), Mixa74/Shutterstock; Fig. 1 (d), Raksan36studio/Shutterstock; Fig. 2 (a), Historic Collection/Alamy Stock Photo; Fig. 2 (b), Ken Griffiths/Shutterstock; Lesson 9.12: Fig. 3, Chris Ison/Shutterstock; Fig. 6, CherylRamalho/Shutterstock; Fig. 5, John Carnemolla/Shutterstock. **Module 10: Opener:** Levon Avagyan/Shutterstock. Lesson 10.1: Fig. 1, Stocktrek Images, Inc./Alamy Stock Photo; Fig. 7 (b), Ann Ronan Pictures/Print Collector/Getty Images; Fig. 8, sakkmesterke/Shutterstock; Fig. 9, nikonka1/Shutterstock; Fig. 10, Choudhary, K., Garrity, K.F., Camp, C. et al. Computational scanning tunneling microscope image database. Sci Data 8, 57 (2021). https://doi.org/10.1038/s41597-021-00824-y; Lesson 10.3: Fig. 3, magr80/Shutterstock; Fig. 4, Science History Images/Alamy Stock Photo; Lesson 10.5: Fig. 2, CHARLES D. 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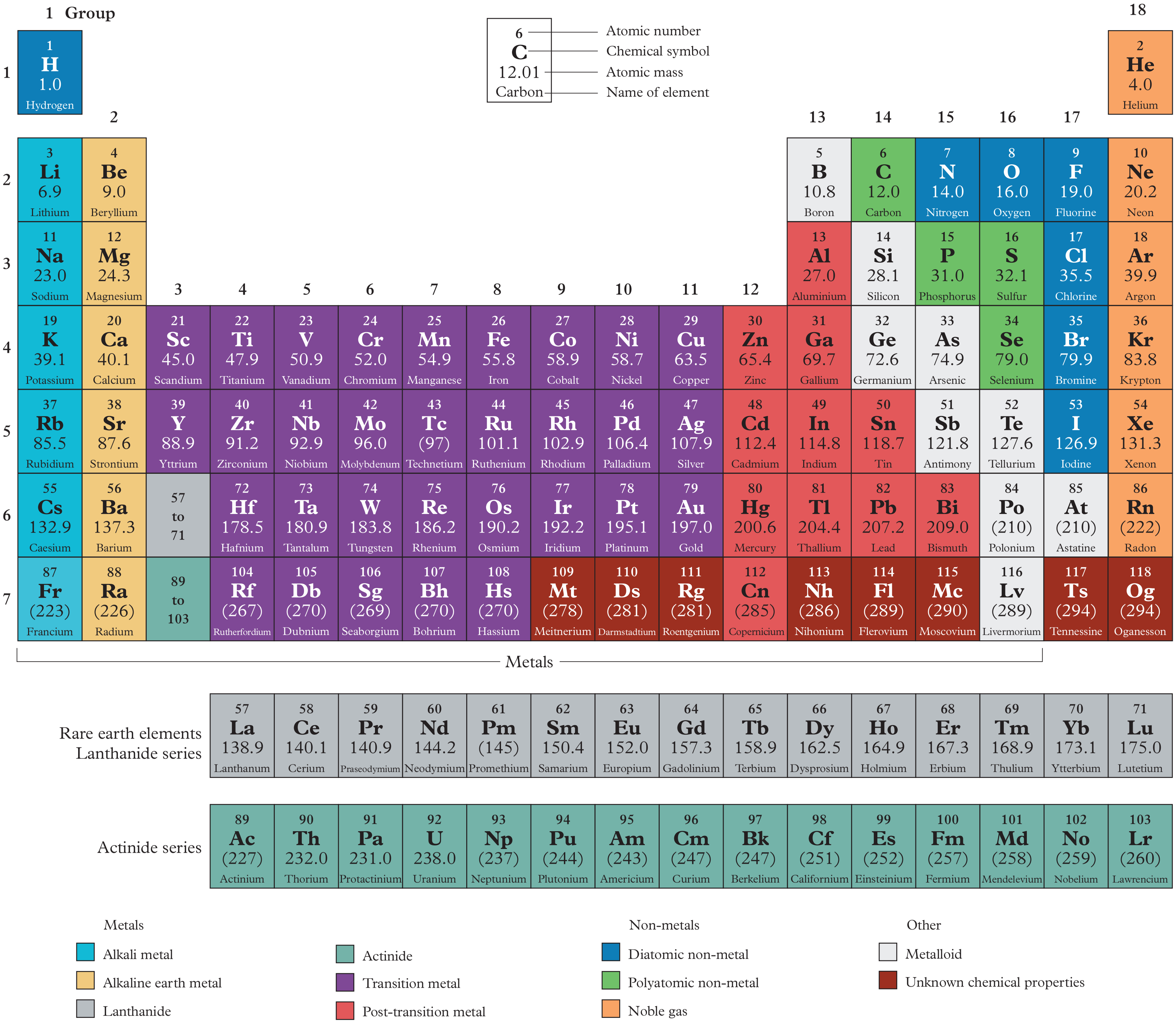
Periodic table



6
C
12.01
Carbon

- Atomic number
- Chemical symbol
- Atomic mass
- Name of element

Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 **H** 1.0 Hydrogen																	2 **He** 4.0 Helium
2	3 **Li** 6.9 Lithium	4 **Be** 9.0 Beryllium											5 **B** 10.8 Boron	6 **C** 12.0 Carbon	7 **N** 14.0 Nitrogen	8 **O** 16.0 Oxygen	9 **F** 19.0 Fluorine	10 **Ne** 20.2 Neon
3	11 **Na** 23.0 Sodium	12 **Mg** 24.3 Magnesium											13 **Al** 27.0 Aluminium	14 **Si** 28.1 Silicon	15 **P** 31.0 Phosphorus	16 **S** 32.1 Sulfur	17 **Cl** 35.5 Chlorine	18 **Ar** 39.9 Argon
4	19 **K** 39.1 Potassium	20 **Ca** 40.1 Calcium	21 **Sc** 45.0 Scandium	22 **Ti** 47.9 Titanium	23 **V** 50.9 Vanadium	24 **Cr** 52.0 Chromium	25 **Mn** 54.9 Manganese	26 **Fe** 55.8 Iron	27 **Co** 58.9 Cobalt	28 **Ni** 58.7 Nickel	29 **Cu** 63.5 Copper	30 **Zn** 65.4 Zinc	31 **Ga** 69.7 Gallium	32 **Ge** 72.6 Germanium	33 **As** 74.9 Arsenic	34 **Se** 79.0 Selenium	35 **Br** 79.9 Bromine	36 **Kr** 83.8 Krypton
5	37 **Rb** 85.5 Rubidium	38 **Sr** 87.6 Strontium	39 **Y** 88.9 Yttrium	40 **Zr** 91.2 Zirconium	41 **Nb** 92.9 Niobium	42 **Mo** 96.0 Molybdenum	43 **Tc** (97) Technetium	44 **Ru** 101.1 Ruthenium	45 **Rh** 102.9 Rhodium	46 **Pd** 106.4 Palladium	47 **Ag** 107.9 Silver	48 **Cd** 112.4 Cadmium	49 **In** 114.8 Indium	50 **Sn** 118.7 Tin	51 **Sb** 121.8 Antimony	52 **Te** 127.6 Tellurium	53 **I** 126.9 Iodine	54 **Xe** 131.3 Xenon
6	55 **Cs** 132.9 Caesium	56 **Ba** 137.3 Barium	57 to 71	72 **Hf** 178.5 Hafnium	73 **Ta** 180.9 Tantalum	74 **W** 183.8 Tungsten	75 **Re** 186.2 Rhenium	76 **Os** 190.2 Osmium	77 **Ir** 192.2 Iridium	78 **Pt** 195.1 Platinum	79 **Au** 197.0 Gold	80 **Hg** 200.6 Mercury	81 **Tl** 204.4 Thallium	82 **Pb** 207.2 Lead	83 **Bi** 209.0 Bismuth	84 **Po** (210) Polonium	85 **At** (210) Astatine	86 **Rn** (222) Radon
7	87 **Fr** (223) Francium	88 **Ra** (226) Radium	89 to 103	104 **Rf** (267) Rutherfordium	105 **Db** (270) Dubnium	106 **Sg** (269) Seaborgium	107 **Bh** (270) Bohrium	108 **Hs** (270) Hassium	109 **Mt** (278) Meitnerium	110 **Ds** (281) Darmstadtium	111 **Rg** (281) Roentgenium	112 **Cn** (285) Copernicium	113 **Nh** (286) Nihonium	114 **Fl** (289) Flerovium	115 **Mc** (290) Moscovium	116 **Lv** (289) Livermorium	117 **Ts** (294) Tennessine	118 **Og** (294) Oganesson

Metals

Rare earth elements Lanthanide series	57 **La** 138.9 Lanthanum	58 **Ce** 140.1 Cerium	59 **Pr** 140.9 Praseodymium	60 **Nd** 144.2 Neodymium	61 **Pm** (145) Promethium	62 **Sm** 150.4 Samarium	63 **Eu** 152.0 Europium	64 **Gd** 157.3 Gadolinium	65 **Tb** 158.9 Terbium	66 **Dy** 162.5 Dysprosium	67 **Ho** 164.9 Holmium	68 **Er** 167.3 Erbium	69 **Tm** 168.9 Thulium	70 **Yb** 173.1 Ytterbium	71 **Lu** 175.0 Lutetium
Actinide series	89 **Ac** (227) Actinium	90 **Th** 232.0 Thorium	91 **Pa** 231.0 Protactinium	92 **U** 238.0 Uranium	93 **Np** (237) Neptunium	94 **Pu** (244) Plutonium	95 **Am** (243) Americium	96 **Cm** (247) Curium	97 **Bk** (247) Berkelium	98 **Cf** (251) Californium	99 **Es** (252) Einsteinium	100 **Fm** (257) Fermium	101 **Md** (258) Mendelevium	102 **No** (259) Nobelium	103 **Lr** (260) Lawrencium

Metals

- 🟦 Alkali metal
- 🟨 Alkaline earth metal
- ⬜ Lanthanide
- 🟩 Actinide
- 🟪 Transition metal
- 🟥 Post-transition metal

Non-metals

- 🟦 Diatomic non-metal
- 🟩 Polyatomic non-metal
- 🟧 Noble gas

Other

- ⬜ Metalloid
- 🟫 Unknown chemical properties

Notes

Notes

Scientific progress in the twentieth century allowed humankind to travel beyond Earth's atmosphere for the first time. To survive even a few minutes in space – where there is almost no atmosphere and the temperature is close to absolute zero (−270°C) – humans must wear a spacesuit.

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