VICTORIAN
CURRICULUM
VERSION
2.0

POWERED BY
oxforddigital

OXFORD

OXFORD SCIENCE 9

Victorian Curriculum

Third Edition

Helen Silvester
Anna Hawthorne
James Andersen

VICTORIAN CURRICULUM VERSION
2.0

POWERED BY oxforddigital

Third Edition

OXFORD SCIENCE 9

Victorian Curriculum

Helen Silvester
Anna Hawthorne
James Andersen

OXFORD UNIVERSITY PRESS

Oxford University Press is a department of the University of Oxford.
It furthers the University's objective of excellence in research, scholarship
and education by publishing worldwide. Oxford is a registered trademark
of Oxford University Press in the UK and in certain other countries.

Published in Australia by
Oxford University Press
Level 8, 737 Bourke Street, Docklands, Victoria 3008, Australia.

First published 2016
Third edition

ISBN: 978 0 1903 5050 5

Edited by Karen Jayne
Typeset by Q2A Media Services Pvt. Ltd., Noida, India
Proofread by Lorna Hendry
Indexed by Puddingburn Publishing Services
Printed in Singapore by Markono Print Media Pte Ltd

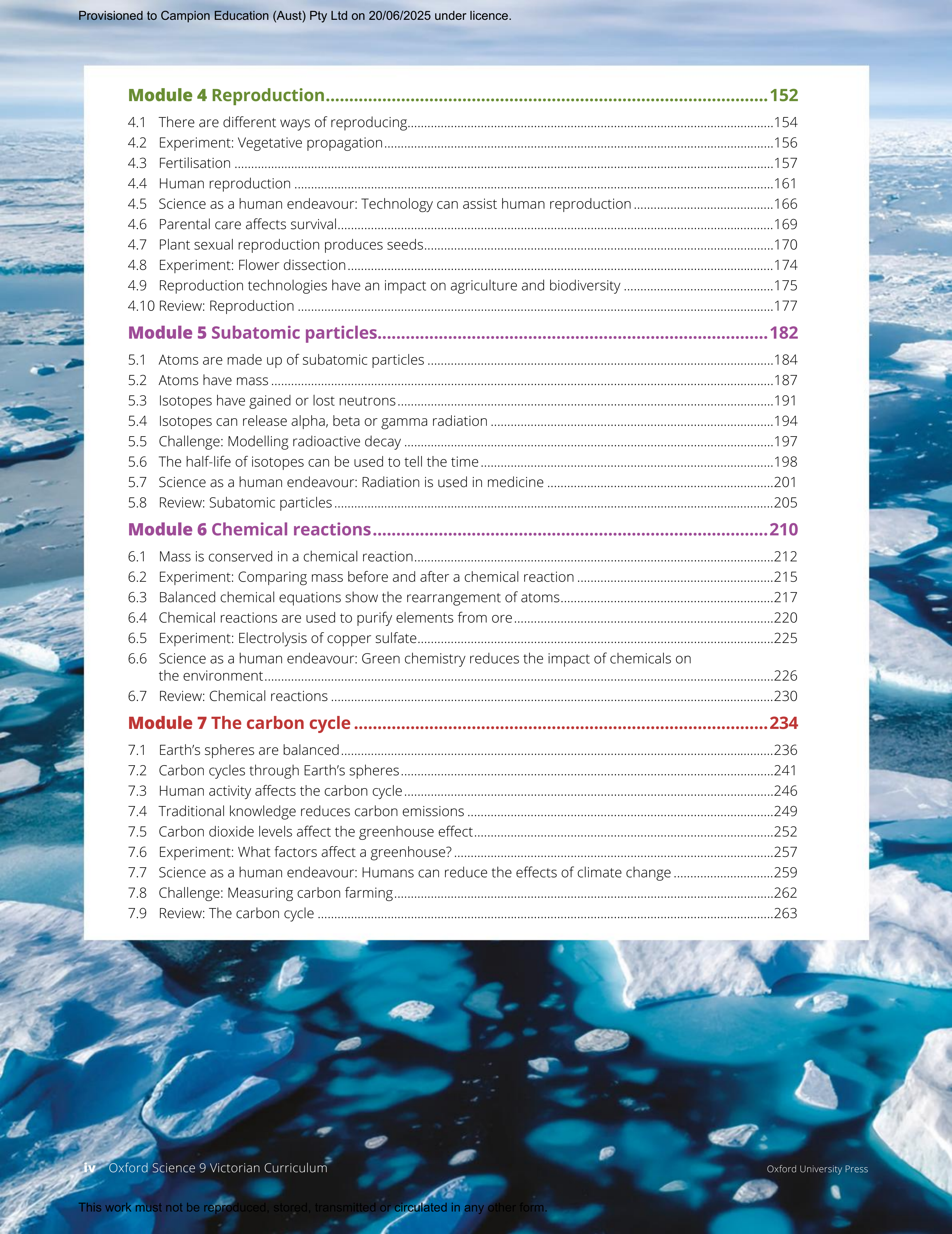
Oxford University Press Australia & New Zealand is committed to sourcing paper responsibly.

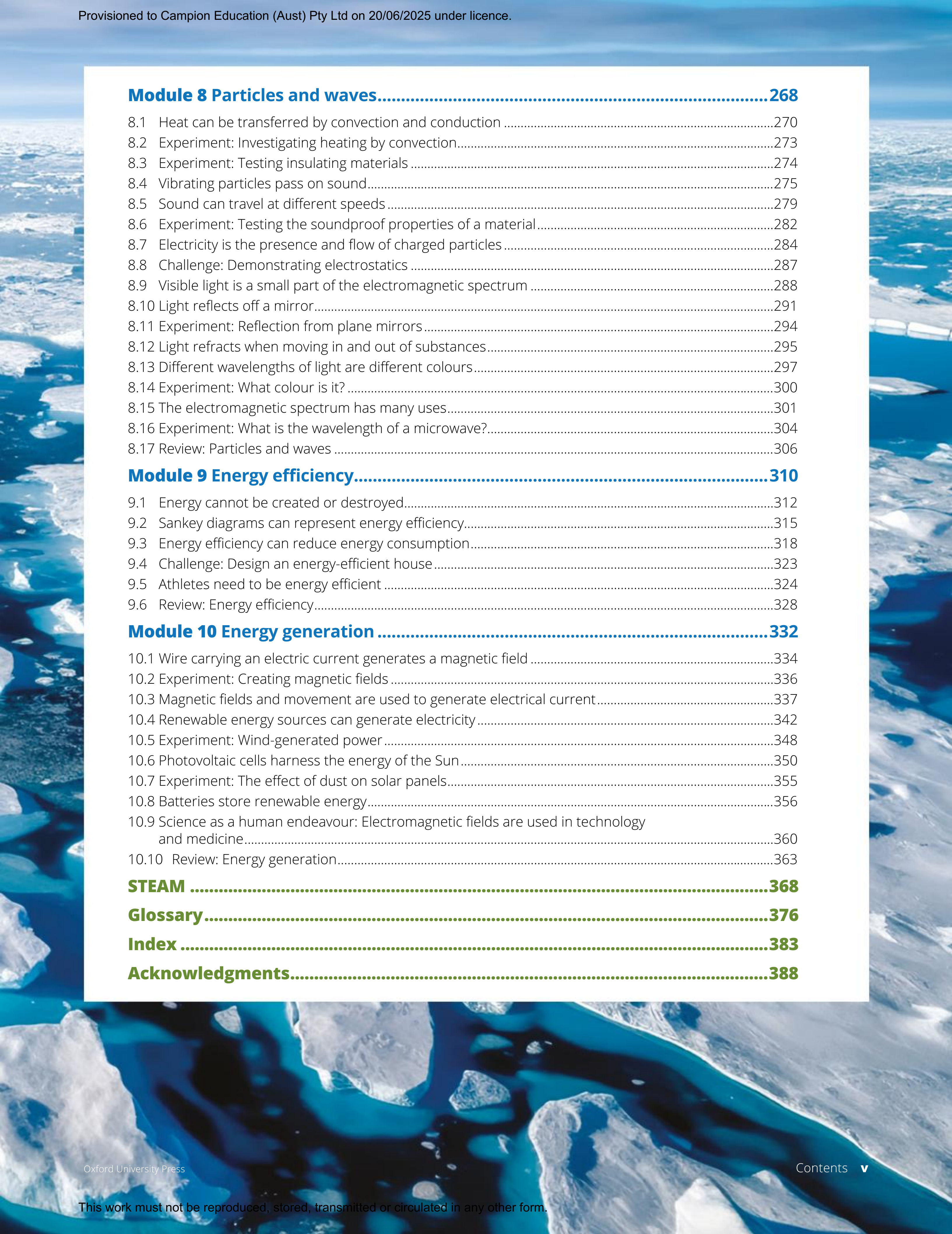
Acknowledgement of Country
Oxford University Press acknowledges the Traditional Owners of the many lands on which we create and share our learning resources. We acknowledge the Traditional Owners as the original storytellers, teachers and students of this land we call Australia. We pay our respects to Elders, past and present, for the ways in which they have enabled the teachings of their rich cultures and knowledge systems to be shared for millennia.

Warning
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 9 Victorian Curriculum* (Third edition)

Congratulations on choosing *Oxford Science 9 Victorian Curriculum* (Third edition) as part of your studies this year!

Oxford Science 9 Victorian Curriculum (Third edition) has been purpose-written to meet the requirements of the Victorian Curriculum Version 2.0 Science. 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 **Science toolkit** 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.

Lesson 1.1

Scientists value the knowledge and skills of Aboriginal and Torres Strait Islander Peoples

Key ideas

→ Aboriginal and Torres Strait Islander Peoples have developed sophisticated science skills that enabled them to survive and thrive some of the most challenging environments in the world for tens of thousands of years.

→ Indigenous science sees everything as connected – the land, water, plants, animals and people are all part of one big system that remains in balance.

→ The scientific knowledge and skills of Aboriginal and Torres Strait Islander Peoples is now recognised and valued by Western scientists.

Learning intentions and success criteria

Australia is home to many Aboriginal and Torres Strait Islander Peoples

Australia is home to over 250 different Aboriginal and Torres Strait Islander Peoples, each with their own culture, customs, language, laws and knowledge systems.

Aboriginal and Torres Strait Islander Peoples – also known as First Nations Peoples – hav lived in Australia and the islands of the Torres Strait for at least 65,000 years, making them the oldest surviving cultures in the world. Aboriginal and Torres Strait Islander cultures in Australia are incredibly rich and diverse. Although these groups are different and distinct, they share a deep connection to **Country**.

Country a term used by Aboriginal and Torres Strait Islander Peoples to describe the connections between land, water, sky, animals, plants, people, stories, songs, cultural practices and spiritual beliefs that make up a traditional area

The scientific knowledge and skills of Aboriginal and Torres Strait Islander Peoples developed as part of their connection to Country over tens of thousands of years. They a wide range of areas, such as:

- detailed local knowledge of weather patterns, seasons and tides (Figure 1)
- knowledge of the stars and astronomy
- bush food, medicine and healing
- detailed knowledge of natural resources and how to manage them sustainably
- the physics required to design, make and use a variety of tools.

The knowledge and traditions of Aboriginal and Torres Strait Islander Peoples suff significantly after the English colonised Australia from 1788. Over many decades, gover policies have had a devastating impact on Aboriginal and Torres Strait Islander Peoples. policies have directly (and indirectly) removed people from their traditional lands, broken families up and prevented culture, knowledge, skills and language from being passed do from generation to generation. This includes passing down scientific knowledge and skill

Despite the negative impacts of colonisation, the cultures, languages, beliefs, knowle and skills of Aboriginal and Torres Strait Islander Peoples have survived and are still practised today. In fact, this knowledge is gaining recognition for its scientific rigour an relevance to modern-day challenges such as climate change and sustainability.

Oxford University Press

4 Oxford Science 9 Victorian Curriculum

Lesson 1.8

Scientists keep a logbook

Key ideas

→ A logbook is used by scientists in the laboratory and in the field to record the details and results gathered during experiments and research.

→ A logbook provides evidence of the planning, changes and results of an experiment.

Learning intentions and success criteria

A logbook is used to record essential data and observations

There are many different types of science and even more types of science investigations. Some investigations last a few minutes, while others can last many years.

An example of a long investigation is an ecologist recording how the population numbers of dolphins in Port Phillip Bay change over a decade (i.e. 10 years).

All investigations rely on the scientists collecting and recording data and observations in an electronic or physical **logbook**. Logbooks contain all of the information that will eventually be used to write a formal report (i.e. a written report used to communicate the results of an experiment with other scientists).

logbook a detailed recording of observations and data from a scientific investigation

Figure 1 Logbooks contain important data and observations from experiments conducted in the laboratory or in the field.

Oxford University Press

Module 1 Science toolkit **41**

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.

Lesson 7.1

Earth's spheres are balanced

Key ideas

→ Earth is made up of the lithosphere (solid crust), atmosphere (air), hydrosphere (water) and biosphere (living organisms).

→ Interaction between Earth's spheres maintains global temperatures and climate.

Learning intentions and success criteria

Introduction

The solid crust of Earth (lithosphere) interacts with the atmosphere (air) and hydrosphere (solid, liquid and gaseous water) to influence temperature and therefore the climate in mountains and deserts, as well as the ocean currents. In return, these three spheres affect all the living organisms in the biosphere. A balance must be maintained to ensure the survival of all life on this planet.

The lithosphere

The outermost rocky layer of Earth is the **lithosphere**. It is made up of the upper mantle and the crust (Figure 1). Although the crust and upper mantle are approximately 80 km thick, they actually form a very thin layer compared to the other layers of Earth.

lithosphere the outermost layer of Earth, consisting of the upper mantle and crust

The rocky crust of Earth is made from magma (molten rock), which cools very slowly and at different times all over the surface of Earth. The heat from the magma escapes into the air and water surrounding it. The cooled crust settles as uneven giant plates of rock that are mismatched and butt up against their neighbours, covering the entire surface of Earth. The giant pieces are called **tectonic plates**. These plates float on the semi-liquid magma at the top of the mantle. The heat in the mantle creates currents that slowly stir through the molten rock, moving the tectonic plates as well. The tectonic plates move about 2 to 10 cm per year – a similar rate to the growth of your fingernails.

tectonic plate a large layer of solid rock that covers part of the surface of the Earth; movement of tectonic plates can cause earthquakes

The outermost area of the lithosphere is the soil in which plants grow and many insects and animals live (Figure 2). The weathering of rocks produces small particles that can move into the waterways (hydrosphere) or provide essential nutrients for plants and animals (biosphere).

The lithosphere is the slowest of Earth's systems to change. Small changes can take thousands, even millions, of years.

Figure 1 Earth is made up of layers.

Oxford University Press

236 Oxford Science 9 Victorian Curriculum

7.1

Figure 2 Volcanoes are part of the lithosphere.

The atmosphere

The **atmosphere** is a layer of gases that we commonly call air. The atmosphere is relatively thin compared to the size of Earth. If Earth were the size of a party balloon, the atmosphere would only be as thick as the rubber skin of the balloon.

atmosphere the layer of gases surrounding the Earth

Earth is the only planet in our solar system that has an atmosphere that sustains life. The atmosphere helps keep us warm, controls our weather, protects us from the dangers from space and carries sounds.

The most important gas for humans and other animals is oxygen (O_2), which makes up 21 per cent of the atmosphere. Oxygen in Earth's atmosphere allows organisms to respire (use oxygen to produce energy), which is essential for almost all life on Earth. Other gases in the atmosphere include ozone (O_3), which offers protection from the Sun's ultra-violet radiation; carbon dioxide (CO_2); water (H_2O) and other greenhouse gases, which trap heat to keep us warm; and nitrogen (N_2), which makes up 78 per cent of the atmosphere.

Layers in the atmosphere

The atmosphere is more dense at ground level and thins out as you go higher above Earth's surface: 99 per cent of all the air in the atmosphere is found within 80 km of Earth's surface. There is not really a top to the atmosphere – the air just thins out, with decreasing pressure, until you reach the relative emptiness of space. These changing conditions are identified as several atmospheric layers (Figure 3).

Earth and Space

Oxford University Press

Module 7 The carbon cycle **237**

Lesson 10.9

Science as a human endeavour: Electromagnetic fields are used in technology and medicine

Key ideas

→ A changing magnetic field generates a current in a wire that can recharge a battery.

→ Magnetic Resonance Imaging uses a changing magnetic field to generate internal images of the body.

Learning intentions and success criteria

Introduction

Current moving through a coiled wire generates a magnetic field. If the direction of the current continually changes (alternating current, AC), so too does the direction of the magnetic field. A constantly changing magnetic field can generate a current in a nearby wire coil. This process occurs in transformers and wireless chargers.

Transforming current

The movement of a wire or coil in a magnetic field or vice versa is not the only way to generate electricity. Michael Faraday was a poorly educated book binder who developed an interest in science by reading the books he was working on. In 1831, Faraday began a series of experiments on electromagnetic fields. He wrapped two insulated coils of wire around opposite ends of a large iron ring and found that when a current was passed through one coil of wire, a current appeared briefly in the other coil of wire. This current only lasted while the first wire's current was turned on or off. If the current in the first coil constantly changed direction, such as in an alternating current (AC), the current in the second wire also constantly changed direction. Therefore, electricity could be passed between wires without the wires touching each other. If the first coil of wire had more turns of wire than the second coil of wire, the voltage passed on would be less in the second coil.

This is what happens in a transformer (Figure 1) – the current and voltage are changed or transformed. Many electrical devices operate on less than the 240 volts that come from an electrical power point in Australia. For example, many computers have an electrical cord with a small black box attached, which transforms the 240 volts into a smaller voltage that the computer can use (Figure 2).

Figure 1 A transformer

360 Oxford Science 9 Victorian Curriculum

Oxford University Press

Wireless charging

The process of transferring an electric current through coils of wire is used in wireless charging devices. Alternating current flows through coils of wire in the charging device. The resulting magnetic field generates a current in a coil in the receiving device, such as a mobile phone. When the current is converted into a direct current, it recharges the battery in the device. Although wireless chargers are convenient, the current generated is lower than when charging devices directly with a cord. If the coils of wire on the wireless charger are not directly aligned with the coils in the phone, most of the energy is lost as heat. Figure 3 shows the process of wireless charging for a mobile phone.

Figure 2 A laptop computer has a transformer in its power cord.

Magnetic resonance imaging (MRI)

Magnetic resonance imaging (MRI) involves placing a human body inside a strong, stable magnetic field. The magnetic field is usually generated by a large cylindrical coil of specially made wire in a bath of liquid helium, and the patient is positioned in the centre of the coil (Figure 4). The liquid helium is kept at –269°C. This very low temperature decreases the resistance of the wire to electric current so that it can conduct electricity indefinitely without any loss. Once current is flowing in the coil, it produces a strong magnetic field. The magnetic field causes the protons in the water (H_2O) in the person's body (we consist of 60 per cent water) to align with it.

Figure 3 Wireless charging.

ⓐ **Transmitter circuit**: Alternating current flows through coils of wire in the charging device.

ⓑ **Receiver circuit**: A magnetic field is generated around the recharging device.

ⓒ **Receiver coil**: When a mobile phone is within range of the magnetic field, a current is generated in coils within the phone.

ⓓ **Transmitter coil**: The current is converted to direct current and the battery starts recharging.

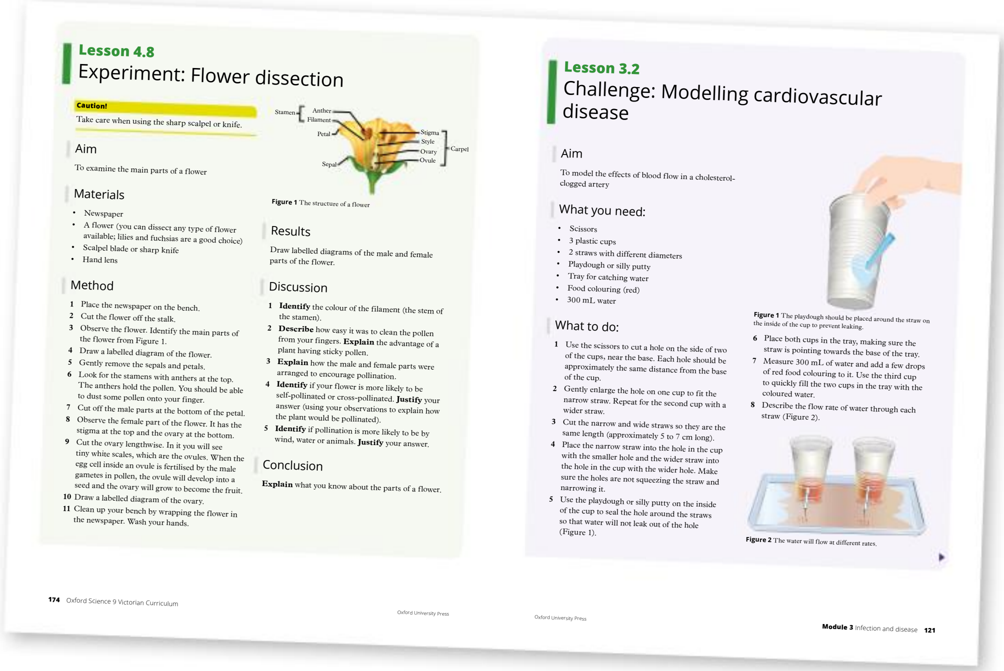
Figure 4 An MRI machine uses a magnetic field to generate images of the body's internal structure.

Oxford University Press

Module 10 Energy generation 361

Science as a human endeavour 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.



Lesson 4.8

Experiment: Flower dissection

Caution!

Take care when using the sharp scalpel or knife.

Aim

To examine the main parts of a flower

Materials

- Newspaper
- A flower (you can dissect any type of flower available; lilies and fuchsias are a good choice)
- Scalpel blade or sharp knife
- Hand lens

Method

1 Place the newspaper on the bench.
2 Cut the flower off the stalk.
3 Observe the flower. Identify the main parts of the flower from Figure 1.
4 Draw a labelled diagram of the flower.
5 Gently remove the sepals and petals.
6 Look for the stamens with anthers at the top. The anthers hold the pollen. You should be able to dust some pollen onto your finger.
7 Cut off the male parts at the bottom of the petal.
8 Observe the female part of the flower. It has the stigma at the top and the ovary at the bottom.
9 Cut the ovary lengthwise. In it you will see tiny white scales, which are the ovules. When the egg cell inside an ovule is fertilised by the male gametes in pollen, the ovule will develop into a seed and the ovary will grow to become the fruit.
10 Draw a labelled diagram of the ovary.
11 Clean up your bench by wrapping the flower in the newspaper. Wash your hands.

Figure 1 The structure of a flower

Results

Draw labelled diagrams of the male and female parts of the flower.

Discussion

1 **Identify** the colour of the filament (the stem of the stamen).
2 **Describe** how easy it was to clean the pollen from your fingers. **Explain** the advantage of a plant having sticky pollen.
3 **Explain** how the male and female parts were arranged to encourage pollination.
4 **Identify** if your flower is more likely to be self-pollinated or cross-pollinated. **Justify** your answer (using your observations to explain how the plant would be pollinated).
5 **Identify** if pollination is more likely to be by wind, water or animals. **Justify** your answer.

Conclusion

Explain what you know about the parts of a flower.

174 Oxford Science 9 Victorian Curriculum

Oxford University Press

Lesson 3.2

Challenge: Modelling cardiovascular disease

Aim

To model the effects of blood flow in a cholesterol-clogged artery

What you need:

- Scissors
- 3 plastic cups
- 2 straws with different diameters
- Playdough or silly putty
- Tray for catching water
- Food colouring (red)
- 300 mL water

What to do:

1 Use the scissors to cut a hole on the side of two of the cups, near the base. Each hole should be approximately the same distance from the base of the cup.
2 Gently enlarge the hole on one cup to fit the narrow straw. Repeat for the second cup with a wider straw.
3 Cut the narrow and wide straws so they are the same length (approximately 5 to 7 cm long).
4 Place the narrow straw into the hole in the cup with the smaller hole and the wider straw into the hole in the cup with the wider hole. Make sure the holes are not squeezing the straw and narrowing it.
5 Use the playdough or silly putty on the inside of the cup to seal the hole around the straws so that water will not leak out of the hole (Figure 1).

Figure 1 The playdough should be placed around the straw on the inside of the cup to prevent leaking.

6 Place both cups in the tray, making sure the straw is pointing towards the base of the tray.
7 Measure 300 mL of water and add a few drops of red food colouring to it. Use the third cup to quickly fill the two cups in the tray with the coloured water.
8 Describe the flow rate of water through each straw (Figure 2).

Figure 2 The water will flow at different rates.

Oxford University Press

Module 3 Infection and disease 121

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 **Experiments** provide students with opportunities to use problem-solving and critical thinking, and apply science inquiry skills.

Find out more

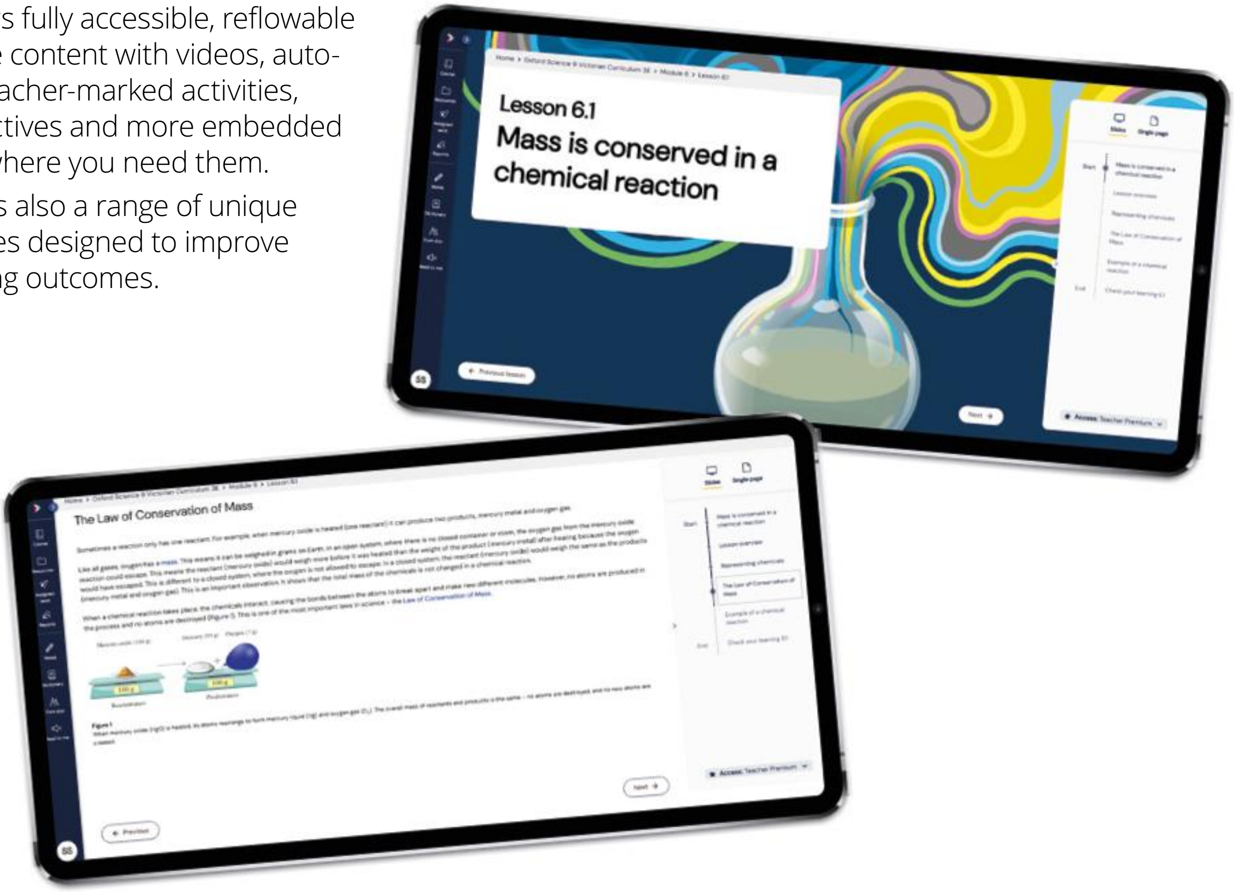
For a complete overview of all the features and benefits of this Student Book:

> activate your digital access (using the instructions on the inside front cover of this book) and click on "Introducing *Oxford Science 9 Victorian Curriculum* (Third edition)" 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 6.1

Mass is conserved in a chemical reaction

The Law of Conservation of Mass

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

> **highlight, take notes, bookmark pages**, or define words with the built-in **Australian Oxford Dictionary**

> **watch hundreds of concise key content videos** to help you revise anything you don't understand, catch up on things you've missed, or help you with your homework

> **complete** hundreds of interactive questions and quizzes as you work through the content and get the answers and results sent to you.

As a teacher, you can:

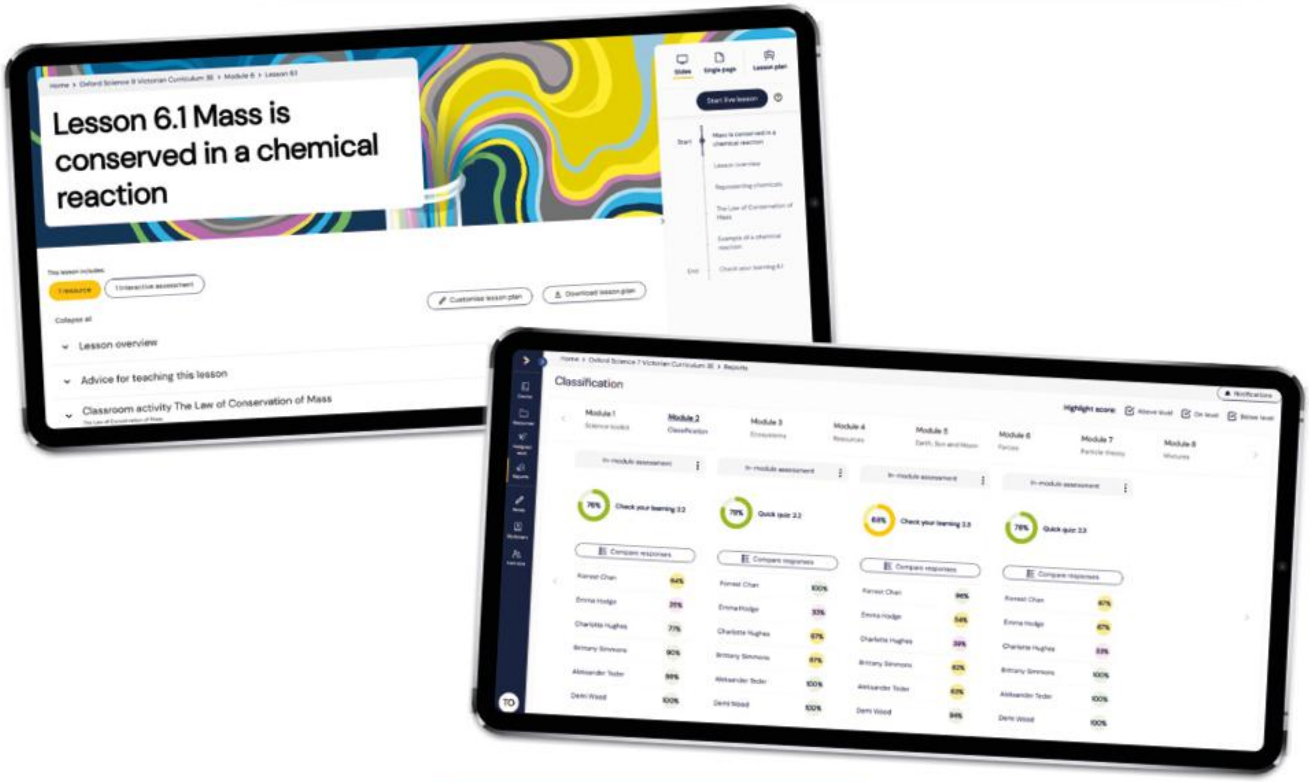
> **elevate** your teaching and **reduce planning and preparation time** with **Live Lesson mode**. This is an Australian first that lets you upgrade from traditional print-based lesson plans to **fully interactive, perfectly sequenced and timed interactive lessons complete with classroom activities** that are ready to go

> **personalise** learning for every student and **differentiate** content based on student strengths and weaknesses. Assign support or extension resources to any student using a range of differentiation resources

> begin every lesson with ready-made **learning intentions** and **success criteria**

> **revolutionise** your planning, marking and reporting with powerful analytics on student performance and progress.

- **Assessment report** shows how students are performing in each online interactive assessment, providing feedback for teachers about areas of understanding
- **Curriculum report** summarises student performance against specific curriculum content descriptors and curriculum codes



Lesson 6.1 Mass is conserved in a chemical reaction

Lesson overview

Advice for teaching this lesson

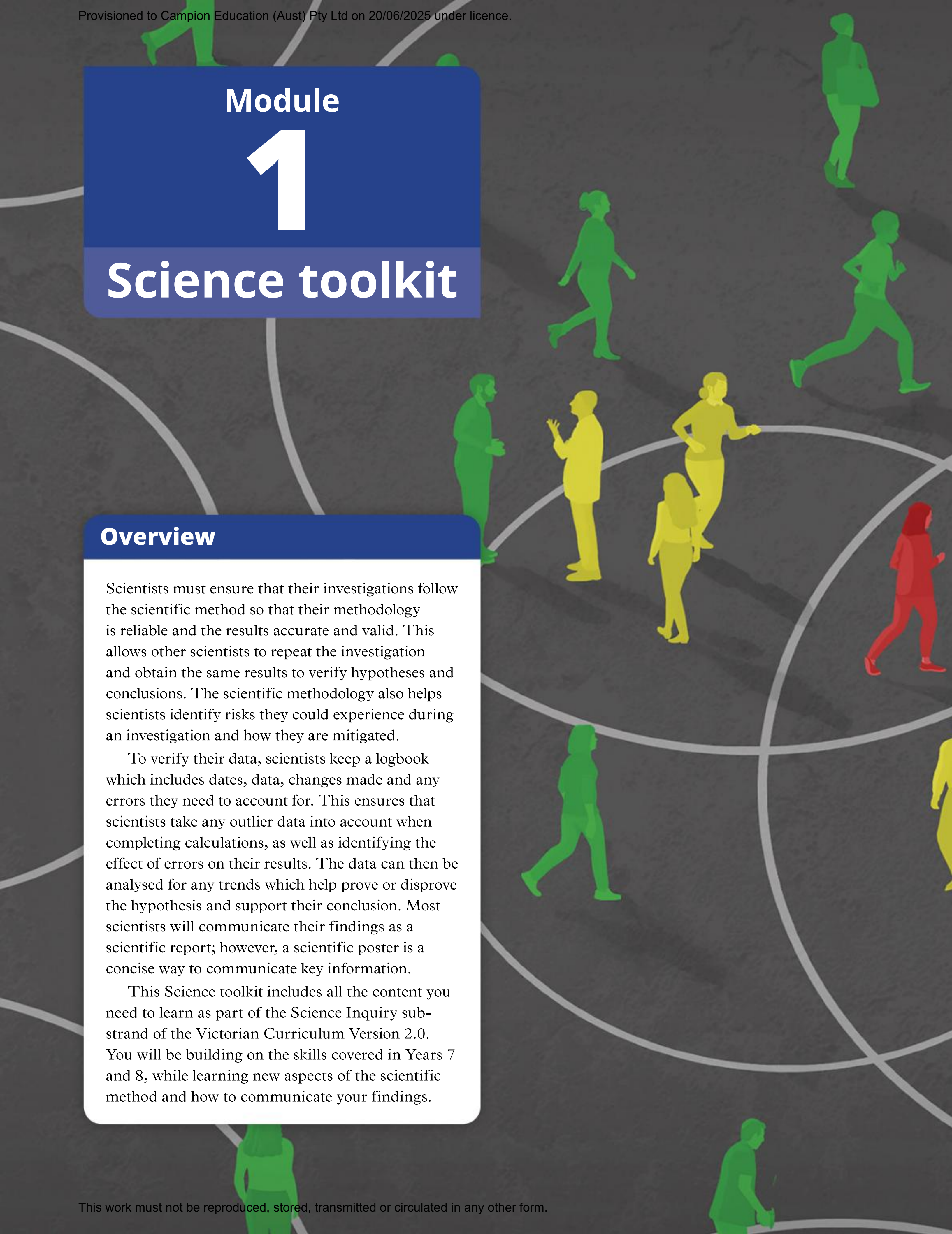
Classroom activity The Law of Conservation of Mass

Classification

Find out more

For a complete overview of all the features and benefits of Oxford Digital:

> activate your digital access (using the instructions on the inside front cover of this book) and click on "Introducing *Oxford Science 9 Victorian Curriculum* (Third edition)" in the "About this course" menu.



Module 1

Science toolkit

Overview

Scientists must ensure that their investigations follow the scientific method so that their methodology is reliable and the results accurate and valid. This allows other scientists to repeat the investigation and obtain the same results to verify hypotheses and conclusions. The scientific methodology also helps scientists identify risks they could experience during an investigation and how they are mitigated.

To verify their data, scientists keep a logbook which includes dates, data, changes made and any errors they need to account for. This ensures that scientists take any outlier data into account when completing calculations, as well as identifying the effect of errors on their results. The data can then be analysed for any trends which help prove or disprove the hypothesis and support their conclusion. Most scientists will communicate their findings as a scientific report; however, a scientific poster is a concise way to communicate key information.

This Science toolkit includes all the content you need to learn as part of the Science Inquiry sub-strand of the Victorian Curriculum Version 2.0. You will be building on the skills covered in Years 7 and 8, while learning new aspects of the scientific method and how to communicate your findings.

Lessons in this module

Lesson 1.1

Scientists value the knowledge and skills of Aboriginal and Torres Strait Islander Peoples

Key ideas

→ Aboriginal and Torres Strait Islander Peoples have developed sophisticated science skills that enabled them to survive and thrive some of the most challenging environments in the world for tens of thousands of years.

→ Indigenous science sees everything as connected – the land, water, plants, animals and people are all part of one big system that remains in balance.

→ The scientific knowledge and skills of Aboriginal and Torres Strait Islander Peoples is now recognised and valued by Western scientists.

Learning intentions and success criteria

Australia is home to many Aboriginal and Torres Strait Islander Peoples

Australia is home to over 250 different Aboriginal and Torres Strait Islander Peoples, each with their own culture, customs, language, laws and knowledge systems.

Aboriginal and Torres Strait Islander Peoples – also known as First Nations Peoples – have lived in Australia and the islands of the Torres Strait for at least 65,000 years, making them the oldest surviving cultures in the world. Aboriginal and Torres Strait Islander cultures in Australia are incredibly rich and diverse. Although these groups are different and distinct, they share a deep connection to **Country**.

Country a term used by Aboriginal and Torres Strait Islander Peoples to describe the connections between land, water, sky, animals, plants, people, stories, songs, cultural practices and spiritual beliefs that make up a traditional area

The scientific knowledge and skills of Aboriginal and Torres Strait Islander Peoples developed as part of their connection to Country over tens of thousands of years. They cover a wide range of areas, such as:

- detailed local knowledge of weather patterns, seasons and tides (Figure 1)
- knowledge of the stars and astronomy
- bush food, medicine and healing
- detailed knowledge of natural resources and how to manage them sustainably
- the physics required to design, make and use a variety of tools.

The knowledge and traditions of Aboriginal and Torres Strait Islander Peoples suffered significantly after the English colonised Australia from 1788. Over many decades, government policies have had a devastating impact on Aboriginal and Torres Strait Islander Peoples. These policies have directly (and indirectly) removed people from their traditional lands, broken families up and prevented culture, knowledge, skills and language from being passed down from generation to generation. This includes passing down scientific knowledge and skills.

Despite the negative impacts of colonisation, the cultures, languages, beliefs, knowledge and skills of Aboriginal and Torres Strait Islander Peoples have survived and are still practised today. In fact, this knowledge is gaining recognition for its scientific rigour and relevance to modern-day challenges such as climate change and sustainability.

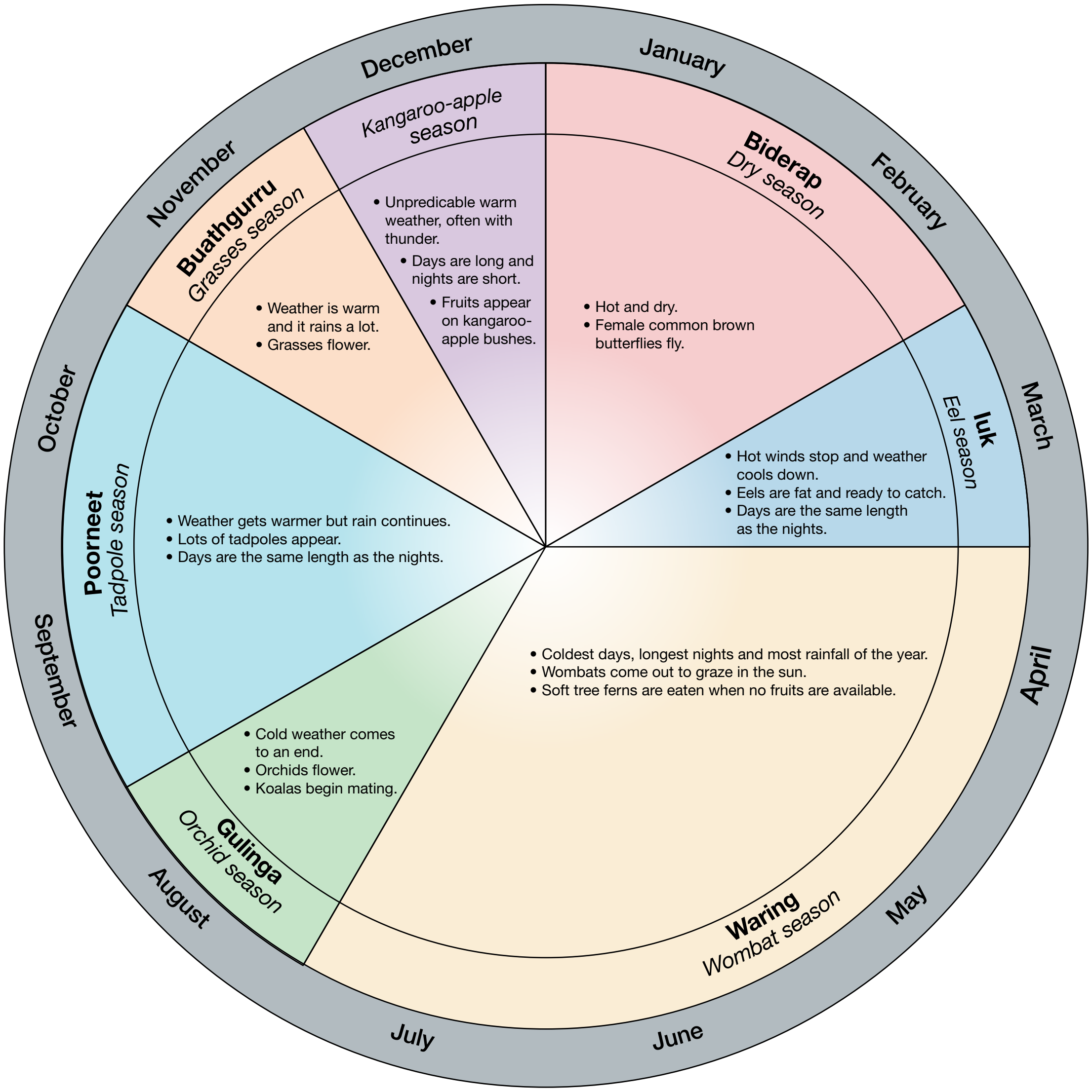


Figure 1 The Wurundjeri people of the Kulin Nation in Victoria identify seven seasons in their calendar. These seasons are marked by changes in the weather, the life cycles of plants and animals, and the position of the stars in the sky at night.

Indigenous science

Aboriginal and Torres Strait Islander Peoples have developed sophisticated science skills that enabled them to survive and thrive some of the most challenging environments in the world for tens of thousands of years.

Over this time, Aboriginal and Torres Strait Islander Peoples created sophisticated systems for closely observing Country, identifying the similarities and differences between the individual parts and how they work together to create a balance. This approach to close observation, grouping and classification to identify patterns and balance has been passed down through storytelling that often models the consequences if balance is not maintained. Today, this body of knowledge and skills is referred to as **Indigenous science**.

While **Western science** often relies on comparative testing, it is recognised that the Indigenous approach to science – observation, classification, identification and modelling – is a unique way to approach the investigation of the natural world that is place-specific, producing knowledge that is tailored to a particular environment.

Indigenous science a system of knowledge developed by Aboriginal and Torres Strait Islander Peoples over tens of thousands of years that combines careful observation and testing of the natural world with cultural understanding to explain how things work and are connected in nature

Western science a system of knowledge based on careful observation, measurement, testing and experimentation (known as the scientific method) to develop and test hypothesis to explain how things work

The scientific knowledge and skills of Aboriginal and Torres Strait Islander Peoples is now recognised and valued by Western scientists. It is integral to current conversations and collaborations around some of the biggest scientific questions of today, such as sustainability, management of natural resources, food security and climate change.

Examples of Indigenous science

Aboriginal and Torres Strait Islander Peoples developed advanced scientific knowledge and skills that were integral to survival, cultural practices and management of the environment.

Astronomy

Aboriginal and Torres Strait Islander Peoples have a rich tradition of using the stars for navigation, timekeeping and cultural storytelling. Today, there are many Aboriginal and Torres Strait Islander Peoples who are sharing their knowledge with the wider community including Krystal de Napoli and Karlie Noon.

- **Navigation**: The stars, moon and constellations are used to navigate large distances across land and sea. For example, Torres Strait Islander Peoples use star maps for navigation at sea.
- **Seasonal calendars**: Many Aboriginal and Torres Strait Islander Peoples developed complex seasonal calendars based on the appearance of certain stars or constellations. For example, the Wardaman people of the Northern Territory associate the appearance of a star cluster known as the “Seven sisters” with the start of the wet season.
- **Predicting events**: Knowledge of lunar cycles and eclipses is used to predict environmental changes, such as tides and animal migrations.

Ecology and land management

Aboriginal and Torres Strait Islander Peoples developed sophisticated land and water management practices that have sustained ecosystems for thousands of years. Today there are Aboriginal and Torres Strait Islander Peoples who keep this traditional knowledge alive and collaborate with communities to teach traditional practices, including Victor Steffensen (Figure 2).

- **Cultural burning**: Aboriginal and Torres Strait Islander Peoples use controlled burning to manage landscapes, promote new growth and encourage biodiversity (Figure 3). This practice (also known as “cool burning” and “fire-stick farming”) has shaped Australia’s ecosystems.
- **Using resources sustainably**: Knowledge of plant and animal life cycles has ensured sustainable harvesting. For example, certain plants are only harvested at specific times to allow time for them to regrow.
- **Water management**: In dry regions, Aboriginal and Torres Strait Islander Peoples have developed techniques to locate and manage water sources, such as digging soakage wells or using natural indicators (e.g. bird behaviour) to find water.

Figure 2 Victor Steffensen, a Tagalaka man, is deeply committed to teaching cultural burning practices, through workshops and initiatives like the Firesticks Alliance. He shares this knowledge with both Indigenous and non-Indigenous communities, emphasising the importance of understanding the land’s needs and fostering a healthier relationship with nature.

Medicine

Aboriginal and Torres Strait Islander Peoples have an extensive knowledge of medicinal plants and healing practices, developed through observation and testing.

- **Plant-based medicines**: Plants like eucalyptus, tea tree and kangaroo apple are used for their antiseptic, anti-inflammatory and healing properties (Figure 4). For example, eucalyptus leaves are used to treat respiratory conditions. Aboriginal and Torres Strait Islander Peoples also understood the dosage and preparation of medicinal plants, such as boiling, crushing and infusing, to maximise their effectiveness.
- **Healing practices**: “Ngangkari” (traditional healers) of the Ngaanyatjarra, Pitjantjatjara and Yankunytjatjara lands (in the remote western desert of Central Australia) combined physical treatments with spiritual healing to set broken bones and care for wounds.

Figure 3 Cultural burning in Kakadu National Park

Figure 4 Tea tree (*Melaleuca)* leaves and seeds are used for their antiseptic, anti-inflammatory and healing properties.

Engineering

Aboriginal and Torres Strait Islander Peoples developed tools, structures and technologies suited to their environments.

- **Tools and weapons**: Boomerangs, spears and spear-throwers were designed using principles of aerodynamics and physics. Boomerangs, for example, were crafted to return to the thrower or travel long distances, depending on their purpose (Figure 5).
- **Fish traps and aquaculture**: The Gunditjmara people of Victoria created traps and dug channels to catch and farm eels at Budj Bim Cultural Landscape – a UNESCO World Heritage site near Warrnambool in western Victoria (Figure 6).
- **Housing and shelter**: Structures like bark huts, stone houses and windbreaks were designed for insulation, ventilation and protection from the elements, reflecting an understanding of materials science and environmental conditions.

Figure 5 The Luritja and Pertame Peoples in Central Australia design and craft boomerangs, spears and spear-throwers.

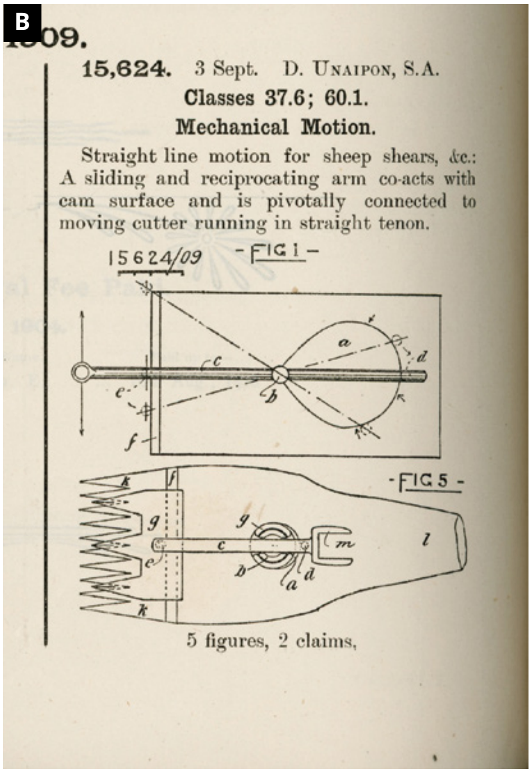
Figure 6 The Gunditjmara people of Victoria dug these channels to catch and farm eels. These channels are at least 6,600 years old.

David Unaipon

The Australian $50 note features David Unaipon (Figure 7A), born in 1872 on the Lower Murray in South Australia, who was a member of the Ngarrindjeri people and is recognised for his contributions to science and technology and improving the lives of Aboriginal Australians.

Between 1909 and 1944, Unaipon submitted 19 provisional patents for his inventions; he could not afford to patent all of them. His inventions included a modified hand piece used in sheep shearing (Figure 7B), a centrifugal motor, a multi-radial wheel and a mechanical propulsion device (helicopter).

Even into old age, he worked to unlock the secrets of perpetual motion.



09.

15,624. 3 Sept. D. Unaipon, S.A.

Classes 37.6; 60.1.

Mechanical Motion.

Straight line motion for sheep shears, &c.: A sliding and reciprocating arm co-acts with cam surface and is pivotally connected to moving cutter running in straight tenon.

5 figures, 2 claims.

Figure 7 (A) David Unaipon features on the $50 bank note. (B) David Unaipon's patent for the modified hand piece used in sheep shearing.

Agriculture

Aboriginal and Torres Strait Islander Peoples practiced sustainable agriculture and developed methods to store and preserve food.

- **Cultivation**: Evidence suggests that some Aboriginal Peoples in Victoria and New South Wales cultivated yams, grains and other plants. Grinding stones that date back 30,000 years indicate the processing of seeds and grains.
- **Food preparation**: Techniques like roasting, crushing and soaking were used to treat certain plants, such as cycads, so that toxins were removed, making them safe to eat (Figure 8).
- **Food preparation and preservation**: Smoking, drying and fermentation were used to preserve meat, fish and plants. For example, Torres Strait Islander Peoples preserved fish and dugong meat for long-term storage.
- **Seasonal harvesting**: Knowledge of seasonal cycles ensured that food resources were harvested sustainably, preventing overuse.

Figure 8 Aboriginal Peoples across Far North Queensland observed that the seeds and stems of cycad plants could be poisonous. They planned and conducted tests to discover ways to make them safe to eat.

Different approaches, similar goals

Indigenous science and Western science both aim to understand the natural world, but they can use different paths to get there. Indigenous science sees everything as connected – the land, water, plants, animals and people are all part of one big system that remains in balance. Western science, on the other hand, has often broken things down into smaller parts to study them separately in controlled experiments before reconstructing the whole. Table 1 shows some of the different approaches taken by Indigenous and Western science to achieve similar goals and outcomes.

Table 1 A comparison of Indigenous science and Western Science

Indigenous science	Western science
• Science is passed down orally through stories, songs and direct teaching. • Knowledge is integrated with cultural and spiritual systems. • Everything is viewed as interconnected and part of one system. • Methods are specific to local environments and contexts. • Knowledge is developed and modelled in local environments by the whole community over generations. • Its focus is on understanding specific places and ecosystems in detail.	• Science is written down in formal documents, papers and textbooks. • Knowledge is considered separate from cultural and spiritual systems. • Focus is on breaking things down into separate parts to study them (e.g. fields such as Biology, Chemistry and Physics). • Methods used are standardised so that they can be repeated anywhere. • Knowledge is often developed by specialist experts in laboratories. • It usually aims to find universal laws (rules that apply everywhere).

Check your learning 1.1

Check your learning 1.1

Retrieve

1 **Define** Indigenous science.

2 **Identify** one way in which Indigenous science is similar to Western science and one way in which it is different.

Comprehend

3 **Describe** why it is important to refer to Aboriginal and Torres Strait Islander Peoples as “Peoples” and not “people”.

4 **Describe** one example of Aboriginal and Torres Strait Islander Peoples observing the world.

5 **Describe** one example of an experiment that Aboriginal and Torres Strait Islander Peoples may have conducted thousands of years ago.

6 **Explain** why it is important to communicate the results of an experiment to produce clean water or identify plants that are safe to eat.

Apply

7 **Identify** the Aboriginal and Torres Strait Islander nations in your local area. Carry out some research to investigate one or two examples of scientific knowledge and skills used by one or more of these groups.

8 **Compare** and **contrast** two differences between Indigenous science and Western science. In your answer, **use** specific examples from both knowledge systems to support your comparison.

Lesson 1.2

Scientists follow the scientific method

Key ideas

→ The scientific method is a framework that helps scientists figure out how things work by asking questions and testing ideas. It is an essential tool to guide scientific inquiry and research that is valid and reliable.

→ There are five stages to the scientific method.

→ Pseudoscience is a term used to describe theories, beliefs or claims that seem scientific but aren't backed by any real evidence or results from experiments.

Learning intentions and success criteria

Introducing the scientific method

Being a scientist means that you need to use the scientific method. The scientific method is a framework that helps scientists figure out how things work by asking questions and testing ideas. It is an essential tool to guide scientific inquiry and research that is valid and reliable.

At each stage of scientific inquiry, the scientific method outlines what a scientist must do in order to ensure their findings can be trusted. It also helps scientists evaluate and test the claims and findings made by other scientists. This is known as "peer review", and helps to ensure all scientific findings are **valid**.

valid where a test investigates what it sets out to investigate

There are five stages to the scientific method (Table 1). In this module, you will develop the science inquiry skills needed at each stage of the scientific method. These skills will ensure you can investigate ideas, solve problems, draw valid conclusions and develop evidence-based arguments.

inference a conclusion based on evidence and reasoning

hypothesis a proposed explanation for a prediction that can be tested

Table 1 The five stages of the scientific method

Stages of the scientific method	What happens at each stage	Lessons in this module
Stage 1: Questioning and predicting	A curious scientist has questions about the world. Observations lead to asking questions, making **inferences** and forming **hypotheses** to be tested.	• Lesson 1.3 Scientists form hypotheses that can be tested (page 15)
Stage 2: Planning and conducting	There are many different ways to test a hypothesis. They could use information or data that already exists, design a controlled experiment or complete field work to generate their own data. This approach allows them to collect and organise reliable information that can be trusted by everyone in the community. When conducting an investigation, appropriate safety precautions must be taken, risk assessments completed and specialised equipment selected so precise and accurate data can be collected.	• Lesson 1.4 Scientists plan and conduct investigations (page 18) • Lesson 1.5 Scientists always take safety precautions (page 23) • Lesson 1.6 Scientists use specialised equipment (page 29)

Stages of the scientific method	What happens at each stage	Lessons in this module
Stage 3: Processing, modelling and analysing	Data collected and any changes made should be recorded in a logbook. Patterns in the data might provide evidence that the hypothesis is supported, so scientists need to process and analyse the data so they can create models that can be tested further. Once the data has been collected, it must be checked to make sure it tells the full story of what has happened. Scientists look for patterns and trends that might show a predictable relationship to support the hypothesis.	• Lesson 1.7 Scientists use tables, graphs and models to record and process data (page 33) • Lesson 1.8 Scientists keep a logbook (page 41) • Lesson 1.9 Scientists analyse trends in data (page 45)
Stage 4: Evaluating	Once the data has been processed and analysed, scientists need to compare the new information with the hypothesis or other experiments. Does it answer the original question? Does the information tell the same story as other scientific investigations? Can it be used to explain the original observations? This process is different to processing and analysing data. Evaluating the science means that scientists must consider the accuracy and importance of their work. Scientific investigations can only be used to make decisions or design solutions to problems if they can be trusted.	• Lesson 1.10 Scientists evaluate conclusions (page 50)
Stage 5: Communicating	The work of scientists is only important if people know about it. Consider the safety features of a car. Seatbelts, airbags and braking systems are only included in cars today because scientists communicated the results of their scientific process to car manufacturers and the public. Scientists must be able to explain what they do to many different audiences. Good science communication explains a complex scientific idea in simple language that everyone can understand. This allows science to influence environmental, social and economic change.	• Lesson 1.11 Scientists communicate their findings (page 57) • Lesson 1.12 Command terms identify the tasks in a question (page 63)

As shown in Figure 1, the scientific method is often presented as a cycle because the results from one scientific inquiry can lead to new questions, prompting further investigation and greater understanding of the scientific explanations. This means scientists often loop back to earlier stages of the process to refine understanding and continue their research. Most of the time, science inquiry is not a linear progression where you simply follow steps once and reach a final result.

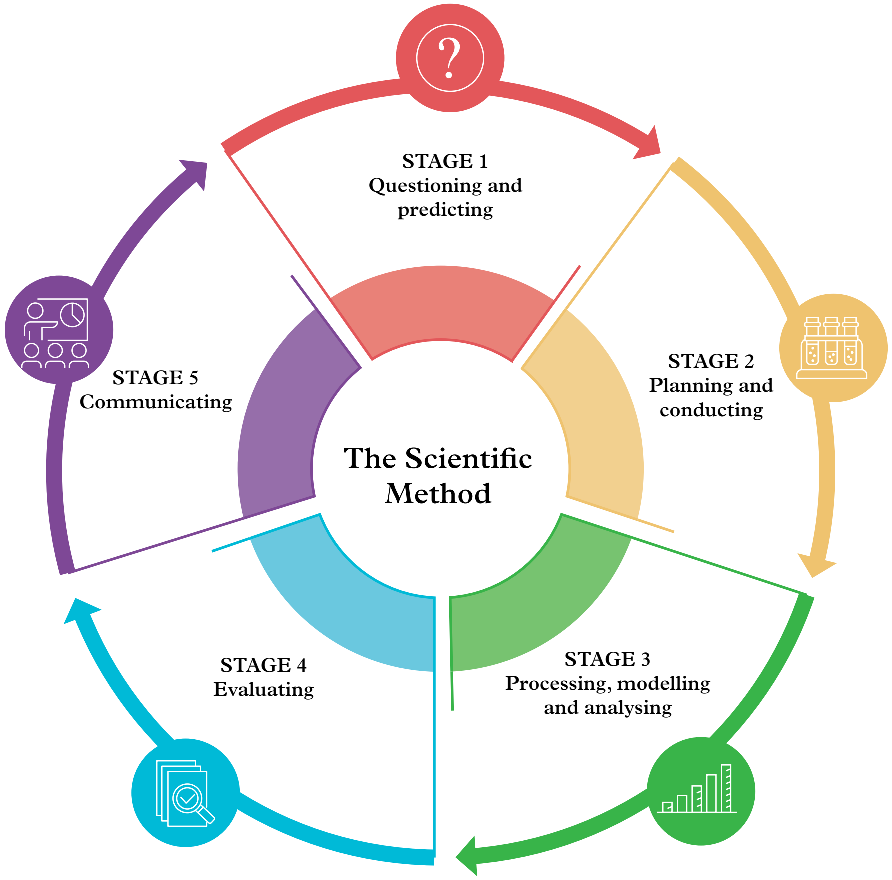


Figure 1 The scientific method

Why the scientific method is important

The scientific method is important for several reasons.

It helps us tell the difference between claims that have reliable evidence and claims that have no evidence. Instead of guessing or believing rumours, scientists use the scientific method to test a claim. For example, if someone says "Eating carrots helps you see in the dark", rather than just believing them, we can use the scientific method to check if this claim has evidence to support it.

It allows other people to check our work. When scientists do experiments, they write down exactly how they did everything. This means other scientists can try the same experiment to see if they get the same results. It's like a very detailed recipe – anyone can follow it, and they should get similar results.

It teaches us to be curious and think critically. Instead of just accepting what we're told, the scientific method encourages us to ask questions, look for evidence, and come to our own conclusions based on careful observation and testing.

Pseudoscience

pseudoscience
a claim that has not been tested using the scientific method

Pseudoscience is a term used to describe theories, beliefs or claims that seem scientific but aren't backed by any real evidence or results from experiments (Table 2 (page 13)). The word "pseudo" (pronounced *SYOO-doh*) comes from an Ancient Greek word that means "false".

Table 2 Common pseudosciences

Type of pseudoscience	Description
Astrology	The belief that the positions of stars and planets at the time of your birth determine your personality and future. While astronomy is a real science that studies planets and stars in the universe, astrology makes predictions without any scientific evidence.
Crystal healing	The belief that different crystals have healing powers. Crystals are beautiful minerals that are studied by geologists, but there is no scientific evidence that they can cure illnesses or are beneficial to our health.
Flat Earth idea	The belief that Earth is flat rather than spherical. This contradicts centuries of scientific observations, satellite imagery and physics.

Unlike real science, pseudoscience doesn't follow the scientific method. This means it doesn't involve carefully collecting evidence and testing ideas over and over. One example of a popular pseudoscience is astrology (Figure 2).

Figure 2 Although many people enjoy reading their stars, astrology is a pseudoscience.

Check your learning 1.2

Check your learning 1.2

Retrieve

1 **Identify** the five stages of the scientific method.

2 **Define** the term "pseudoscience" and give one example of a pseudoscience.

Comprehend

3 **Explain** why it is so important for scientists to follow the scientific method.

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

Analyse

5 **Compare** (the differences between) these two stages in the scientific method: "Processing, analysing and modelling" and "Evaluating".

Apply

6 It is often said that science is never "finished". **Evaluate** this statement (by providing examples of science that are never finished and deciding if this statement is true).

7 Look carefully at Figure 3.

a **Propose** a possible question about the local environment that a Wurundjeri scientist may have investigated.

b **Describe** the investigation that the scientist may have completed to answer their question.

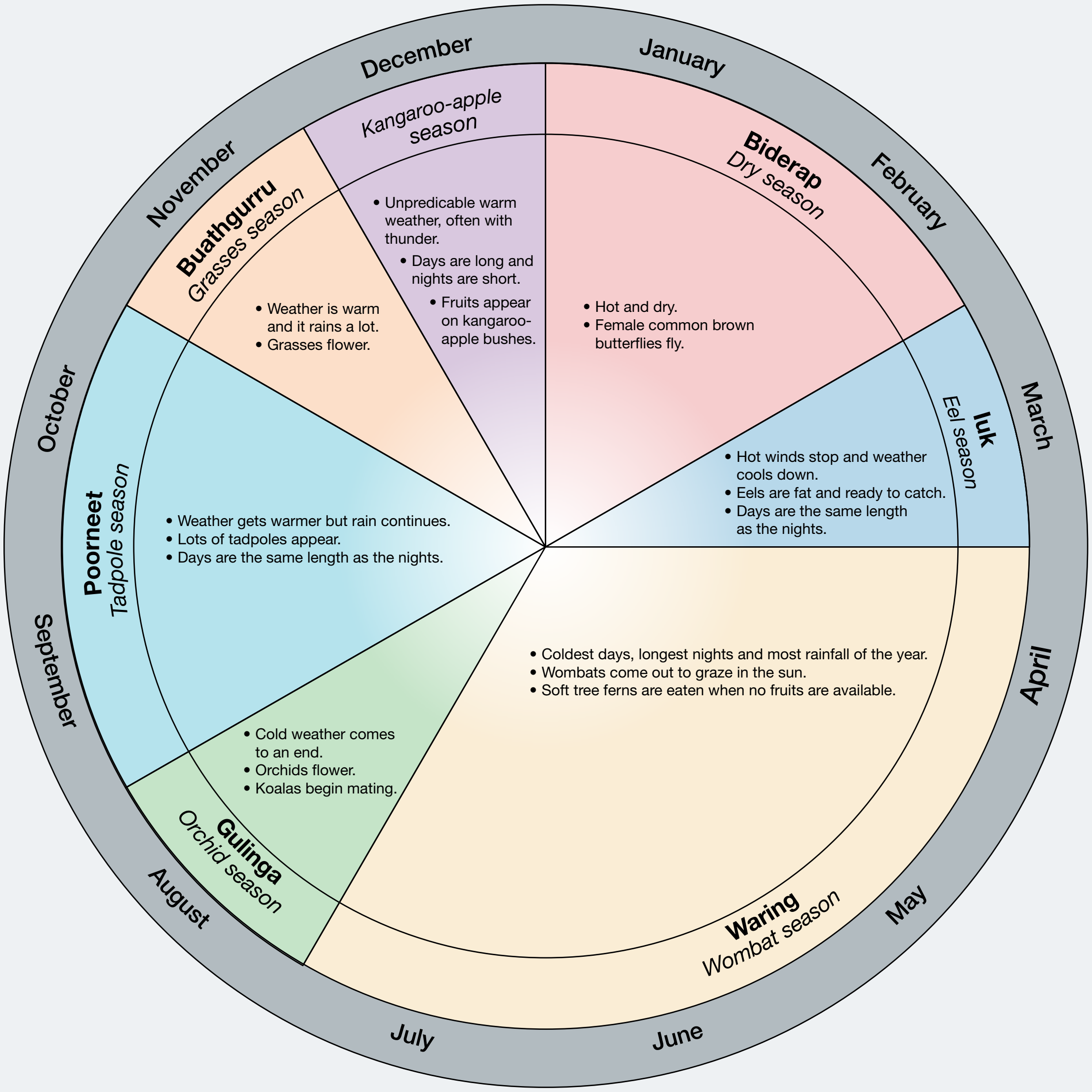


Figure 3 Repeated observations and analysis of patterns by the Wurundjeri people in Victoria identified the different seasons in their environments.

8 Research the prediction of your star sign for the next day or week. **Evaluate** the truth of this prediction (by identifying how many star signs there are, describing the number and ages of people in the world that would be affected by this star sign and deciding if this prediction could be true for all these people).

Lesson 1.3

Scientists form hypotheses that can be tested

Key ideas

- → There are variables that must be considered when trying to answer a question and formulate a hypothesis. This includes independent, dependent and controlled variables.
- → A **prediction** is a specific statement about **what** you expect to observe when you try to answer your question.
- → A **hypothesis** is a proposed scientific explanation for a question. It should try to explain **why** something happens based on previous observations, research or your reading on the topic. It is often written as an "If... then...because..." statement.

Learning intentions and success criteria

The best way to learn is by observing

Following the scientific method means that all scientists follow the same general set of rules and processes when conducting inquiries and research. This helps to ensure that all scientific research and findings are based on careful testing and reliable evidence.

Stage 1 of the scientific method involves making observations, making inferences and asking questions (Figure 1).

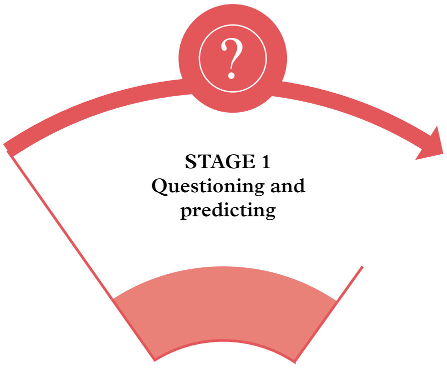


Figure 1 Stage 1 of the scientific method is **Questioning and predicting**.

Questions lead to hypotheses

All scientific investigations start by asking a question. Questions can be big, such as "How did the universe start?", or they can be small, such as "What will happen if acid is mixed with metal?".

For instance, the broad question "How does climate change affect ecosystems?" can be divided into smaller, testable questions:

- What is the current temperature trend in specific regions?
- How are plant growth patterns changing over time?
- What changes are occurring in animal migration patterns?

Breaking questions down into measurable parts is essential. Scientists do this by operationalising their questions, which means designing them in a way that specifies what will be tested or measured. For example, instead of asking, "What happens if plants get more water?" a scientist might ask, "What happens if I water plants with 200 mL of water daily compared to 50 mL?"

Now that you know how scientists observe and ask questions, we will learn about how they make predictions and form hypotheses.

Understanding the role of variables

Once a scientist has made an observation and decided on the inquiry question they want to investigate, it is time to make predictions and form a hypothesis to test. Before planning an experiment, they need to think about all of the things that might affect the result. These are known as **variables**. When a variable is changed, the results of the experiment might change.

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

Types of variables

Variables can be independent, dependent or controlled (Table 1).

- An **independent** variable is the one thing you choose to change in your experiment. They are called "independent" because they don't depend on anything else in an experiment or situation – they stand on their own.
- A **dependent** variable is the thing you measure at the end of an experiment. They are called "dependent" because the results "depend" on the independent variable.
- **Controlled** variables are all the other factors that must be kept the same throughout your experiment. They are called "controlled" because you control them during the entire experiment.

Table 1 Different types of variables in an experiment

Experiment scenario	Type of variable
To test the growth rate of tomato plants, you choose three identical plants and change the amount of sunlight each one receives every day.	The number of hours of sunlight each plant receives every day is the **independent** variable.
After two weeks, the height of the plants are different.	The height of the tomato plants is the **dependent** variable.
Any factors that aren't related to the amount of sunlight the plants are receiving must be the same for all plants. This includes the: • amount of water they receive • type of soil they are planted in • room temperature • levels of fertiliser in the soil • size of the pots.	These are all **controlled** variables.

Once the question is testable, the scientist can predict the outcome of the test and state the reason for their **prediction**. A hypothesis can then be developed and tested in the investigation. It is written as a statement that is based on the scientist's prior knowledge and reasoning. The easiest hypothesis to use is an "If... then... because…" statement. For example:

prediction an outcome that is expected based on prior knowledge or observation

"If more yeast suspension is added to 2 mL hydrogen peroxide, then more gas will be produced because more yeast suspension increases the rate of reaction."

This hypothesis includes the variables to test (assuming all other variables are controlled):

- independent variable – amount of yeast suspension used
- measured dependent variable – volume of gas produced
- the reasoning behind the prediction – scientific knowledge about rates of reaction.

Hypotheses like this can guide investigations and help scientists focus on gathering the correct data to draw conclusions.

Check your learning 1.3

Check your learning 1.3

Retrieve

1 **Define** the term "hypothesis".

2 **Identify** the name given to the variable that is being tested (and is therefore changed on purpose).

3 **Identify** the two variables contained in a hypothesis.

Comprehend

4 **Explain** why most variables need to be controlled.

5 **Explain** the difference between a hypothesis and a prediction.

Analyse

6 Justin decided to conduct an experiment to find out whether his cats preferred full-cream or low-fat milk. He gave one cat a saucer of full-cream milk and the other cat a saucer of low-fat milk and then left them alone. When he returned an hour later, the low-fat milk was gone and there was a small amount of full-cream milk left. Justin concluded that his cats preferred low-fat milk.

  a **Explain** why you agree or disagree with Justin's conclusion.

  b **Explain** whether Justin conducted a reasonable experiment. (Did he control all other variables? Would he have seen the same results if he repeated the experiment? Was the experiment fair?)

  c **Identify** two variables that should have been controlled. **Explain** how these variables could have affected the results.

  d **Describe** two ways Justin could improve his experiment so that his results were more reliable.

Apply

7 **Create** a hypothesis for an investigation that looks at the stopping distances of cars in different conditions.

8 List some variables you would control if you were investigating the energy efficiency of a bouncing tennis ball.

Lesson 1.4

Scientists plan and conduct investigations

Key ideas

→ The type of data being collected will determine what investigation method is used.

→ When planning and conducting an investigation, it must be reproducible by others.

→ Ethics considers "Should we?" when determining whether an investigation should be carried out on people, animals or the environment.

→ When conducting field work, scientists must seek permission from the land owner or organisation to access the land.

→ If research is being conducted at culturally significant sites, appropriate protocol must be followed to access the site, not damage any sacred objects, and limit access to people who have permission to be there.

→ The results obtained from investigations must be reliable, as this indicates the investigation method is sound.

Learning intentions and success criteria

A goal without a plan is just a wish

Stage 2 of the scientific method involves **planning** scientific investigations and **conducting** experiments (Figure 1).

In this lesson, you will learn about the ways in which scientists plan and conduct experiments so that:

- they are reproducible
- the equipment and technologies chosen will collect accurate and reliable data
- the results are reliable
- any risks are recognised and managed
- they consider any ethical issues
- they follow necessary protocols (especially when accessing Aboriginal and Torres Strait Islander Peoples' cultural sites and artefacts on Country).

Figure 1 Stage 2 of the scientific method is **Planning and conducting**.

The aim of an investigation

The aim of an investigation is to explore a scientific question, test a hypothesis, or solve a problem by collecting and analysing data. It helps scientists understand how or why something happens by conducting experiments in a controlled and systematic way. Investigations can confirm existing knowledge, discover new information, or provide evidence to support or refute a hypothesis.

For example, if you are investigating how the concentration of an acid affects the rate of a chemical reaction, the purpose of your investigation could be: “To determine how changing the concentration of hydrochloric acid affects the rate at which it reacts with magnesium ribbon”. This clear purpose guides the experiment by focusing on what you aim to learn and what variables to measure, such as the time it takes for the magnesium to dissolve.

Investigation methods

To collect reliable data, the best investigation method must be selected as some are more suited to collecting certain types of data.

Field work

Scientists collect data directly from natural environments, rather than in a laboratory. Data collected from field work can include quantitative measurements such as temperature or population numbers, as well as qualitative observations, such as habitat conditions and the behaviour of organisms (Figure 2).

Figure 2 In the field, scientists are able to collect more accurate data from the environment.

Laboratory experimentation

Within a laboratory setting, controlled investigations can be conducted to explore hypotheses and manipulate variables. Data collected from these investigations include quantitative measurements including reaction times, change in temperatures or energy outputs, as well as qualitative observations such as colour changes or smell.

Figure 3 Investigations completed in a laboratory allow for precise control and replication of findings.

Investigations must be reproducible

Once the hypothesis has been written, it's time to plan how to carry out the experiment.

An experiment must be a **reproducible** test to ensure accurate and reliable results. A reproducible test is one in which only one variable is changed at a time, and all other conditions are controlled. This means the test can be reproduced and should achieve the same results. This helps scientists trust the effect of the variable being tested.

reproducible the ability to repeat and replicate a test exactly

For example, if you are testing how sunlight affects plant growth, you should keep the type of plant, the amount of water, and the soil the same for all the plants, and only change the amount of sunlight each plant receives (Figure 4). By doing this, you can be confident that any differences in plant growth are due to the amount of sunlight and not other factors.

This approach helps scientists make valid conclusions and advances our understanding of the world.

Figure 4 If you are testing how sunlight affects plant growth, you should control all other variables like water, soil, temperature and pot size.

Ethics

ethics a system of moral principles about what is good, bad, right and wrong

Ethics are a set of principles that provide a way to think when making decisions. Sometimes when you make a decision, you use the rules that are written down, such as the school rules or the laws of the government. At other times, you use rules that are not written down. Some rules are set according to what is normal to the people around you. For example, the unwritten rules in your science classroom may be different to the rules in a physical education class. When playing sport, it might be normal to yell to a team member, whereas yelling in a science classroom is not normal. Neither of these rules are written down; however, everyone in the class will know them and behave accordingly. The expectation that you should behave according to the values of those around you is called the **cultural norm**.

cultural norm expectations (often unspoken) about one's behaviours and beliefs

Ethical approaches

When answering the question "Should we?", scientists can use a variety of ethical approaches. Two of the most common approaches are consequentialist ethics and deontological ethics.

Consequentialist ethics

The consequentialist approach to ethics considers the consequences of an action in order to decide whether an action is good or bad. This approach can also be described as "the end justifies the means".

If this approach was used by Alfred Nobel, a Swedish chemist, engineer and inventor, he might have considered that his dynamite invention (patented in 1867) was bad, because it had been used to kill many people, and that the science should therefore not have been investigated. Alternatively, if the consequence was setting up the Nobel Prize that led to increased recognition of science and scientists, and the promotion of peace, then the overall action could be considered good.

Deontological ethics

In contrast, the deontological approach to ethics considers each action taken according to a set of rules or duties. If an individual did the "right thing" at the time, then ethically it is "good", regardless of the outcome.

Using this approach, Alfred Nobel did the ethically right thing because he wanted to stop people becoming hurt by unstable nitroglycerine. The consequences of this decision are not as important when using this approach.

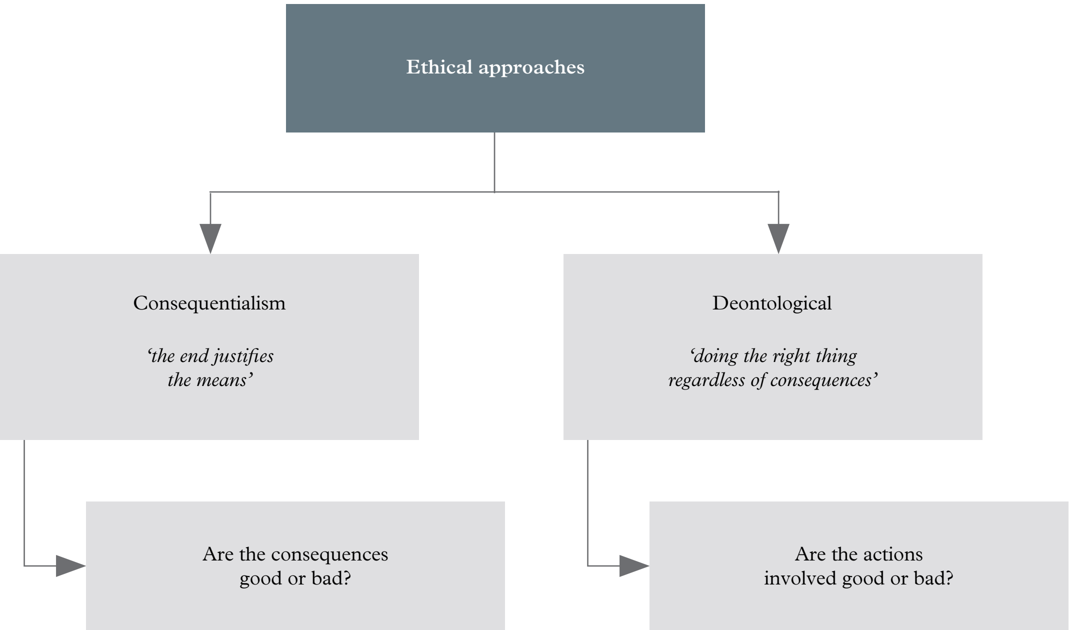


Figure 5 A consequentialist approach to ethics considers the consequences. A deontological approach considers duties and rules.

Ethical issues must be considered

Ethical issues in science are the questions and decisions that scientists face about what is right or wrong when doing research. These issues involve making choices that could affect the wellbeing of people, animals or the environment.

When planning and conducting an inquiry, a simple way for a scientist to consider ethical issues is by asking "Should we?" rather than just "Can we?". For example:

- Should we test new medicines on animals?
- Could this research harm anyone?
- Do the potential benefits of this research outweigh the risks?
- Should we share this discovery if it could be used in harmful ways?
- Are we being completely honest about our results?

These questions don't always have clear right or wrong answers. This is why it is important to discuss and think about them carefully before, during and after scientific research is conducted.

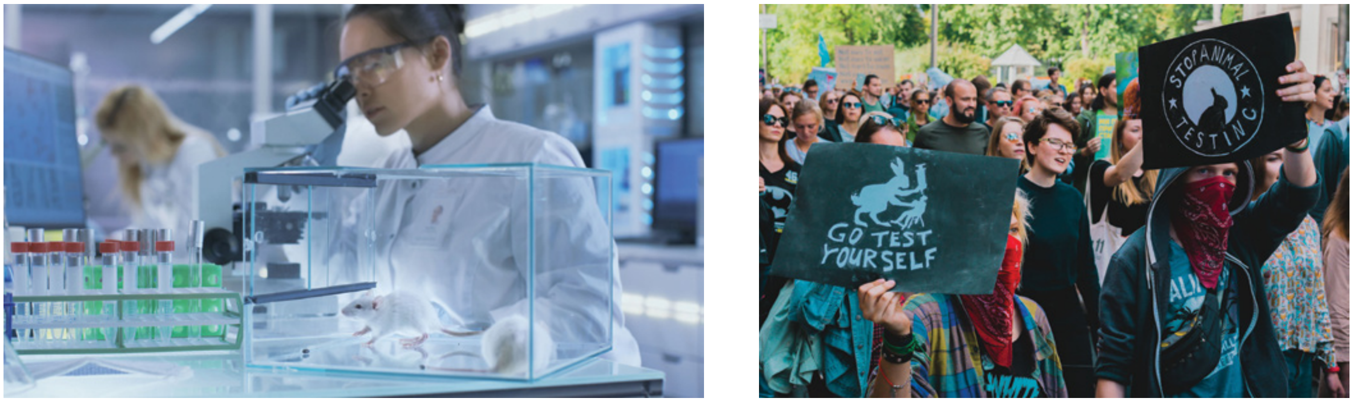


Figure 6 There are many ethical issues related to animal testing, including whether animals should have more legal rights and how to balance the wellbeing of animals against the benefits of developing safe medicines for humans and other animals.

Protocols must be followed

When planning and conducting scientific research in the field (i.e. outside the laboratory), it is important that scientists do their research and seek permission from the person or organisation that owns the land they will be using to conduct their research. This could be a private landholder; a company that holds a lease to the land; or a local, state or federal government organisation.

When conducting research on culturally significant sites in Australia, key protocols need to be followed. These include:

- requesting and receiving consent from the Traditional Owners of the land on which the research is being done
- respecting cultural sensitivities and engaging with Elders and community leaders to ensure these are understood
- not disturbing sacred objects
- limiting access to the site to people who have permission to be there
- ensuring the Traditional Owners understand the aims, methods and possible impacts (both positive and negative) of the research
- ensuring data is shared appropriately with the community.

Hamersley Gorge (Figure 7) is located in the Pilbara region of Western Australia. There are many sacred sites in the Pilbara region including nearby Juukan Gorge. In 2020, mining company Rio Tinto legally destroyed a 46,000-year-old cave in the Juukan Gorge to expand one of its iron ore mines, despite its cultural significance to Traditional Owners. The event led to global outrage, a parliamentary inquiry, and changes to Western Australian cultural heritage laws.

Figure 7 When conducting scientific research on sites in Australia that are culturally significant, it is essential that scientists seek permission and follow all protocols carefully.

Results must be reliable

reliable
consistency of a measurement, test or experiment

It is extremely important that the results of an experiment are **reliable**. Reliable results are those that are consistent and can be trusted because they are repeatable under the same conditions.

If you do an experiment once, following your plan exactly, you will probably get a set of results you think are accurate and reliable. But what if you try the experiment again the next day and the results are different? You would probably ask:

- Did I do things in a different order?
- Did the conditions change? (For example, hotter or cooler weather.)
- Did I use different materials? (For example, a different brand of vinegar or a slightly different variety of plant.)

Repeating the experiment until you get the same results at least three times helps to ensure your results are reliable. Another way to ensure your results are reliable is to ask someone else to perform the same experiment multiple times to confirm that they get the same results. This consistency is crucial for making sure your findings are precise and trustworthy.

Check your learning 1.4

Check your learning 1.4

Retrieve

1 **Explain** what it means for an investigation to be “reproducible”.

2 **Define** what ethics means.

Comprehend

3 List some advantages and disadvantages of field work and laboratory experimentation.

4 **Explain** why results must be reliable when planning and conducting an investigation.

5 **Explain** why scientists must seek permission before conducting field research on private or culturally significant land. Support your answer with two examples from the text.

Analyse

6 **Analyse** the events that resulted from the destruction of Juukan Gorge by Rio Tinto in 2020. You will need to conduct some additional research online for this. In your response, **identify** three specific protocols that were not followed by Rio Tinto.

Apply

7 **Examine** one ethical issue of your own choice that scientists might face when conducting medical research. In your response, consider both the potential benefits and risks of the issue.

Lesson 1.5

Scientists always take safety precautions

Key ideas

→ When working in the laboratory, is important to follow all safety rules to keep yourself and others safe.

→ All risks must be recognised and managed when conducting investigations.

→ Safety data sheets are used to communicate information about how to handle and store the substance, as well as first aid information in the event of an accident.

→ Pictograms are symbols used to communicate the specific type of hazard the substance presents.

→ A risk assessment is created before beginning an investigation. It helps identify risks and describes how to prevent and mitigate them if they occur.

→ When working with chemicals, they must be safely disposed and not poured down the sink, as they can be toxic for the environment.

Learning intentions and success criteria

Safety in the laboratory

A science laboratory is not like a normal classroom. When completing investigations in the laboratory, all laboratory rules must be followed and you must work in a safe manner and understand what to do in an emergency. Before starting your investigation, any protective equipment must be put on including safety glasses, lab coat and gloves. When setting up your work bench, ensure there is sufficient space for you to work. As you perform your procedure, you must keep in mind any safety risks identified on your risk assessment as well as storing equipment and any chemicals in a safe manner on your bench to minimise chemical spills and equipment damage and breakage. Most safety is common sense – common sense can prevent many dangerous situations.

In the laboratory, do:

- wear a lab coat for practical work
- keep your workbooks and paper away from heating equipment, chemicals and flames
- tie back long hair 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 investigation
- listen to and follow the teacher's instructions
- 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.

Risks - anticipate, recognise and eliminate

risk exposure to danger

Scientists work with many hazardous materials when completing experiments. As a result, they need to be aware of **risks** – anything that might affect their health or safety in the laboratory. The laboratory is a safe place, as long as hazards are anticipated, recognised, and eliminated or controlled.

Risks must be recognised and managed

When planning and conducting scientific experiments, managing risks is crucial for everyone's safety. Before starting any experiment, scientists need to identify what could go wrong (e.g. harmful chemical reactions, dangerous equipment or toxic materials).

They must put safety measures in place to prevent accidents and minimise harm. This includes:

- using protective equipment (e.g. goggles, gloves and lab coats)

- carefully following safety instructions and warnings for chemicals (and other dangerous materials)
- working in well-ventilated areas
- knowing emergency procedures (including proper disposal of hazardous materials).

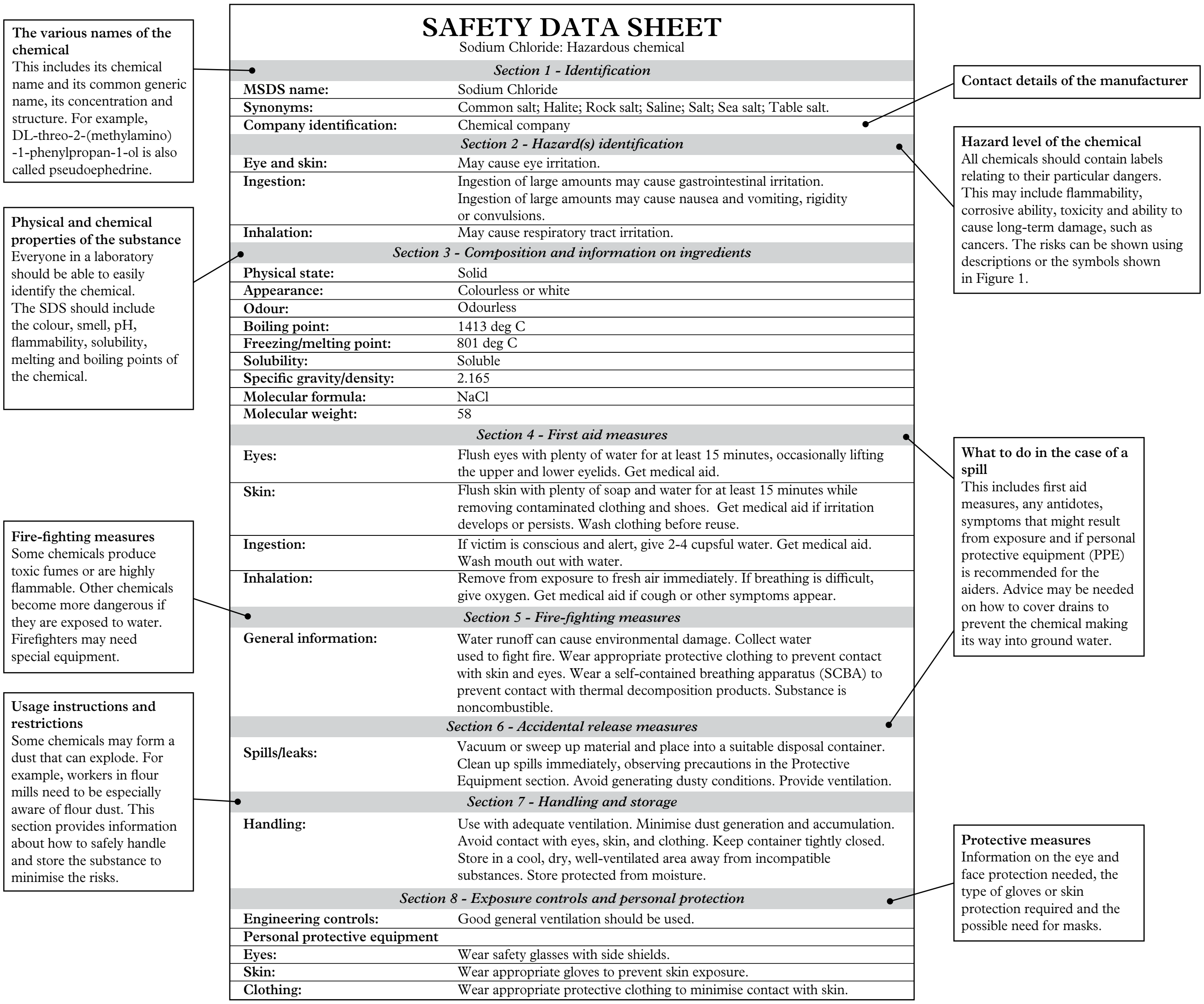
It is also important to consider risks not only to the people doing the experiment, but to others nearby (e.g. animals involved in research) and the environment. For example, if an experiment requires strong acids, the scientists need safety materials and equipment nearby and must know how to safely clean up spills.

A well-planned experiment includes thinking ahead about safety. Missing one small thing could lead to an accident. The goal is to get good scientific results while keeping everyone and everything safe.

Safety data sheets

A **safety data sheet (SDS)** provides scientists and emergency personnel with information on how to use a particular substance. An SDS also helps scientists understand more about how the chemical should be used during an experiment (Figure 1).

safety data sheet (SDS) a document that details health and safety information about a material including safe handling and its properties



The various names of the chemical
This includes its chemical name and its common generic name, its concentration and structure. For example, DL-threo-2-(methylamino)-1-phenylpropan-1-ol is also called pseudoephedrine.

Physical and chemical properties of the substance
Everyone in a laboratory should be able to easily identify the chemical. The SDS should include the colour, smell, pH, flammability, solubility, melting and boiling points of the chemical.

Fire-fighting measures
Some chemicals produce toxic fumes or are highly flammable. Other chemicals become more dangerous if they are exposed to water. Firefighters may need special equipment.

Usage instructions and restrictions
Some chemicals may form a dust that can explode. For example, workers in flour mills need to be especially aware of flour dust. This section provides information about how to safely handle and store the substance to minimise the risks.

Contact details of the manufacturer

Hazard level of the chemical
All chemicals should contain labels relating to their particular dangers. This may include flammability, corrosive ability, toxicity and ability to cause long-term damage, such as cancers. The risks can be shown using descriptions or the symbols shown in Figure 1.

What to do in the case of a spill
This includes first aid measures, any antidotes, symptoms that might result from exposure and if personal protective equipment (PPE) is recommended for the aiders. Advice may be needed on how to cover drains to prevent the chemical making its way into ground water.

Protective measures
Information on the eye and face protection needed, the type of gloves or skin protection required and the possible need for masks.

SAFETY DATA SHEET

Sodium Chloride: Hazardous chemical

Section 1 - Identification	
MSDS name:	Sodium Chloride
Synonyms:	Common salt; Halite; Rock salt; Saline; Salt; Sea salt; Table salt.
Company identification:	Chemical company
Section 2 - Hazard(s) identification	
Eye and skin:	May cause eye irritation.
Ingestion:	Ingestion of large amounts may cause gastrointestinal irritation. Ingestion of large amounts may cause nausea and vomiting, rigidity or convulsions.
Inhalation:	May cause respiratory tract irritation.
Section 3 - Composition and information on ingredients	
Physical state:	Solid
Appearance:	Colourless or white
Odour:	Odourless
Boiling point:	1413 deg C
Freezing/melting point:	801 deg C
Solubility:	Soluble
Specific gravity/density:	2.165
Molecular formula:	NaCl
Molecular weight:	58
Section 4 - First aid measures	
Eyes:	Flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. Get medical aid.
Skin:	Flush skin with plenty of soap and water for at least 15 minutes while removing contaminated clothing and shoes. Get medical aid if irritation develops or persists. Wash clothing before reuse.
Ingestion:	If victim is conscious and alert, give 2-4 cupsful water. Get medical aid. Wash mouth out with water.
Inhalation:	Remove from exposure to fresh air immediately. If breathing is difficult, give oxygen. Get medical aid if cough or other symptoms appear.
Section 5 - Fire-fighting measures	
General information:	Water runoff can cause environmental damage. Collect water used to fight fire. Wear appropriate protective clothing to prevent contact with skin and eyes. Wear a self-contained breathing apparatus (SCBA) to prevent contact with thermal decomposition products. Substance is noncombustible.
Section 6 - Accidental release measures	
Spills/leaks:	Vacuum or sweep up material and place into a suitable disposal container. Clean up spills immediately, observing precautions in the Protective Equipment section. Avoid generating dusty conditions. Provide ventilation.
Section 7 - Handling and storage	
Handling:	Use with adequate ventilation. Minimise dust generation and accumulation. Avoid contact with eyes, skin, and clothing. Keep container tightly closed. Store in a cool, dry, well-ventilated area away from incompatible substances. Store protected from moisture.
Section 8 - Exposure controls and personal protection	
Engineering controls:	Good general ventilation should be used.
Personal protective equipment	
Eyes:	Wear safety glasses with side shields.
Skin:	Wear appropriate gloves to prevent skin exposure.
Clothing:	Wear appropriate protective clothing to minimise contact with skin.

Figure 1 Example of a safety data sheet (SDS) from a manufacturer or certified provider

Safety data sheets can contain a lot of information, including the type of protective equipment that must be worn (Figure 2 and Figure 3) and the specific hazards of chemicals (Figure 4). An SDS can also include:

- How to dispose of the chemical safely. This section should include what disposal containers should be used, the effects of sewage disposal and the special precautions that may be needed to ensure the safety of individuals and the environment.
- How to transport the chemical. Information should include any special precautions for transporting this chemical. This may include the Hazchem code (the code provided by the government for each class of chemical).
- An Australian telephone number of the Office of Chemical Safety.
- The date the SDS was last reviewed. The hazards identified in the Safety Data Sheet are often used by industries to create safety signs which they display around the work environment.

Figure 2 The hazards identified in safety data sheets (SDSs) are displayed by many industries, including the mining industry.

Figure 3 Emergency workers in sealed positive-pressure protective suits communicating with each other

Figure 4 Pictograms such as these are often seen on the labels of chemicals to communicate specific hazards.

Writing a risk assessment

Including a **risk assessment** is a crucial part of any scientific investigation. It helps the person conducting the experiment to identify potential risks and plan how to prevent or manage them if they occur.

risk assessment the process of identifying and evaluating potential risks, including how they can be mitigated and what to do if there is exposure to the risk

A risk assessment table provides a summary of possible hazards and outlines safety precautions, making the investigation safer and more organised. Important details to include in a risk assessment table are the mass of solids, the volume and concentration of solutions, and any equipment used, as these factors can significantly impact the safety and risks associated with the experiment. An example of a risk assessment table is shown in Table 1.

Table 1 A risk assessment table for an experiment involving a reaction between a magnesium ribbon and hydrochloric acid

Chemical	Risk	Precaution	Management
200 mL of 1M HCl	HCl is corrosive and can cause chemical burns.	Wear goggles and gloves to protect the eyes and skin.	If contact occurs, rinse immediately with plenty of water. Seek medical help if necessary.
Mg ribbon	When reacted with HCl, heat and hydrogen gas is produced.	Use a small amount of magnesium ribbon and control the rate of the reaction.	Conduct the experiment in a well-ventilated area. If the reaction is still too vigorous, dilute the acid.
Hydrogen gas produced by the reaction	Hydrogen gas is flammable.	Perform the experiment away from open flames or sparks.	In the case of a fire, use a fire extinguisher to handle any ignition of gas.

Your teacher should provide you with a template to create your risk assessment, or you may have access to programs that will create your risk assessment for you, such as RiskAssess.

Safety in the field

When scientists work in the field (i.e. conduct research and practical work in the natural environment), they need to take important safety measures to protect themselves and their research.

This includes wearing appropriate protective clothing and equipment specific to the location they are working in – for example, closed-toe shoes, long pants or weather-appropriate clothing to guard against hazards like sharp rocks, thorny plants or extreme temperatures (Figure 5).

Scientists working in the field should carry first aid kits, satellite phones and special equipment like GPS trackers in case of emergencies. They should also work in pairs or teams whenever possible rather than on their own.

It is crucial to research potential dangers in advance, such as dangerous local wildlife, extreme weather conditions or terrain challenges, and plan accordingly.

Taking these precautions helps ensure that scientists can focus on their research without putting themselves at risk.

Experiments conducted in a laboratory are easier to control than those conducted in the field because external factors like weather conditions and natural disasters don't influence the results.

Figure 5 Volcanologists are scientists who study volcanoes. When they are out in the field, they wear heat-resistant silver suits to protect themselves against heat, ash and molten rock.

Safe disposal of chemicals and other materials

Safely disposing of chemicals is just as important as safely using them. Not everything can be poured down the sink. Some schools have acid-neutralising traps in the drains that allow diluted acids to be disposed of in this way. Other chemicals can react with the acid traps or can be toxic for the environment. As a result, these chemicals must be collected at the end of the class and disposed of appropriately by your teacher. These chemicals include **corrosive** liquids, grease and oils, biohazardous wastes and toxic solids. Table 2 lists the safe disposal techniques for various materials.

corrosive a substance that can damage or destroy other materials

Table 2 Examples of how various materials can be disposed of safely

Material	Examples	What to do with it
Biohazardous waste	Animal cells and tissue	Solids should be collected by your teacher. Deactivate liquid with bleach (1 part bleach to 9 parts water) for 30 minutes before pouring down the drain.
Grease and oils	Vegetable oils Machinery oil	Collect in a bottle and place in regular rubbish. Dispose of as hazardous chemical waste.
Corrosive liquids	Weak acids Strong acids or alkalis	Pour down the drain. Neutralise the acid or alkali and pour down the drain.
Solids	Play dough	Place in regular rubbish.
Hydrogen peroxide	> 8%	Dilute before pouring down the drain.

Check your learning 1.5

Check your learning 1.5

Retrieve

1 **Describe** what a risk is.
2 **Explain** what information is found on a safety data sheet.
3 **Explain** the purpose of a risk assessment.
4 **Identify** five things you should do to stay safe in the laboratory.
5 **Identify** the three safety symbols shown in Figure 6. Describe the meaning of each symbol.

Figure 6 Three safety symbols

Comprehend

6 **Explain** why you should not mix chemicals that have not been described in the method.
7 **Explain** why it is dangerous to drink from laboratory glassware.

Analyse

8 A student has created a risk assessment for an investigation related to the effect of salt concentration on the boiling point of water (Table 3) but has not completed all aspects of it. **Analyse** this risk assessment and **identify** the information that is missing.

Table 3 Risk assessment for an upcoming investigation

Equipment	Risk	Precaution	Management
Bunsen burner	Burn, fire hazard	Keep area around the Bunsen burner clear and allow equipment to cool before handling	
Thermometer (alcohol)	Cuts, slipping		Alert your teacher and clean up the spill immediately. If there is broken class, use a brush and dustpan.
Beaker		Inspect the beaker for cracks or chips before use and handle carefully when taking it off the Bunsen burner.	Alert your teacher and clean up immediately using a brush and dustpan.

Apply

9 In an investigation, some equipment you will be using includes distilled water, hydrochloric acid, beakers and a Bunsen burner. **Describe** the risks, precautions and management that should be taken with each piece of equipment.

Lesson 1.6

Scientists use specialised equipment

Key ideas

- → When conducing investigations, select suitable materials, equipment and technologies that will provide accurate and precise results.
- → In an investigation, multiple trials are conducted to ensure the method is reliable and the data is accurate and precise.
- → Errors in an investigation can affect the outcome, so you must be aware of how systematic errors can occur.

Learning intentions and success criteria

Materials and technologies

Selecting suitable materials and technologies is a critical aspect of successfully conducting scientific investigations. It is important that when choosing tools and materials that they are safe, reliable and appropriate for the task.

When completing an investigation involving chemistry, the correct chemicals at the appropriate concentration must be used, as well as technology such as digital probes to record temperature or pH more accurately (Figure 1).

In physics, motion sensors or electrical circuit kits are used to measure variables including speed or resistance with precision, while in biology, sensors that monitor environmental conditions all day would provide more accurate conditions.

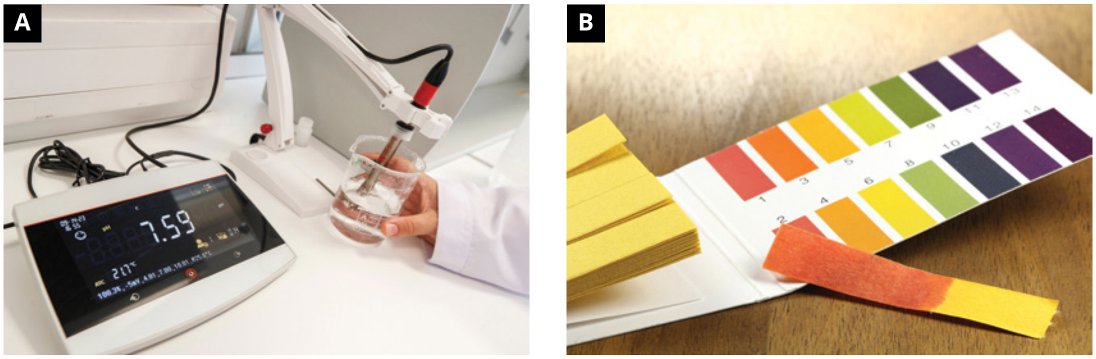


Figure 1 (A) A pH meter is able to accurately determine the pH of a solution. (B) Universal indicator only provides an approximate pH value based on the colour of the paper.

Scientific equipment

Equipment is the term used to describe the beakers, Bunsen burners, conical flasks, retort stands and other items used by scientists to conduct **experiments** (Figure 2). Using the correct equipment ensures accurate and precise **results** and the safety of scientists.

equipment items used in the laboratory to conduct experiments

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

results the measurements and observations made in an experiment; often presented in a table or graph

Figure 2 Types of equipment used in the laboratory

Repeating trials

Repeating trials is a crucial step for ensuring accuracy, precision and reliability in the results and the method as it allows you to identify and reduce errors.

Reliable

A reliable science investigation is dependent on the ability to repeat the investigation with the same scientist and same materials (**repeatable**) or with another scientist in another laboratory (**reproducible**) and achieve the same results. For an experiment to be reliable, all the variables that can affect the dependent variable must be identified and controlled for.

Reliable data means the experiment has been repeated numerous times and the mean calculated for the results. This ensures that the results were not due to errors.

repeatable the same results and observations can be made under the same conditions and using the same method

reproducible the ability to repeat and replicate a test exactly

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

Accuracy

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 errors, 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.

Precision

Precision refers to how consistent your measurements are, even if they aren't accurate. Precision reflects the reliability of your experimental procedure and the quality of the equipment or method you use for measurement.

Imagine you are trying to calculate the value of gravity (where $g = 9.8 \text{ m/s}^2$) by dropping an object from a height and measuring the time it takes to fall.

- If you calculate values like 4.7, 12.5, 5.3 and 9.2, the results are neither accurate nor precise. This indicates significant errors in your method and/or data collection, as the values are far from 9.8 m/s^2 and inconsistent with each other.
- If you calculate values like 8.7, 9.5, 8.2 and 10.7, the results are accurate but not precise. While they are generally close to 9.8 m/s^2, they vary significantly and lack consistency, indicating errors in your data collection.
- If you calculate values like 12.2, 12.9, 11.9 and 12.4, the results are precise but not accurate. Although the measurements are consistent, they are far from the true value of 9.8 m/s^2. This indicates an error in your method.
- If you calculate values like 9.7, 9.4, 9.9 and 9.6, the results are both precise and accurate. These measurements are consistently close to 9.8 m/s^2, showing a reliable and accurate method.

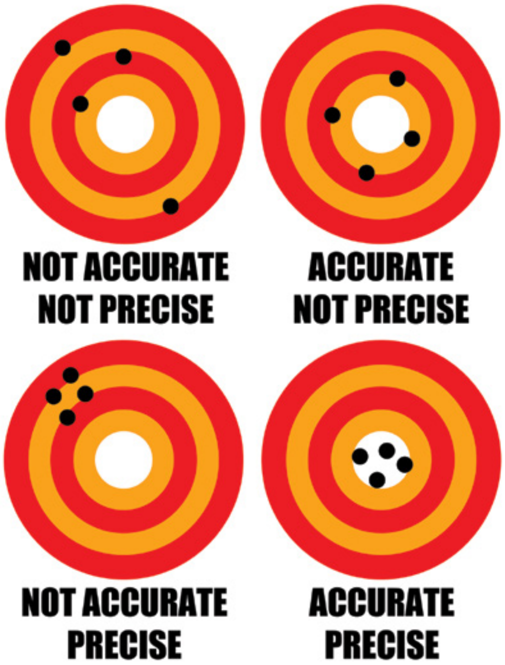


Figure 3 The reliability of your scientific method will affect the accuracy and precision of the data collected.

Errors

There are many different variables that can affect the outcome of an experiment. Something as simple as measuring the mass of an object on scales can change if someone breathes on the scales, or if a person generates a small breeze by walking past quickly. These small unpredictable variations in measurements are called **random errors**. Random errors can be reduced if the measurements or experiments are repeated.

random error
unpredictable variations in measurements that are not the same every time

systematic error
predictable variations in measurements due to faulty equipment or method

Another error that can occur is a **systematic error**. These errors occur when there is an error in the equipment that is used (such as scales that constantly measure the wrong mass) or in the way the experiment is completed.

Repeating the experiment will not remove these errors. Instead, checking the accuracy of the scales with a known weight (Figure 4) or carefully checking that there are no other variables in the method that will affect the outcome will minimise these errors.

Figure 4 Checking the accuracy of scales will minimise errors in data.

Check your learning 1.6

Check your learning 1.6

Retrieve

1 **Explain** the difference between accuracy and precision.
2 **Describe** how repeating trials improves the results and method.
3 **Explain** the difference between a random error and systematic error.

Comprehend

4 **Explain** the advantage of using digital equipment over their analogue counterparts.
5 **Justify** when you would use a beaker or measuring cylinder for a volume of liquid.

Analyse

6 An investigation is conducted on the conservation of mass in a chemical reaction using the following method:
    1 Measure 5 g of baking soda and place it in a sealed plastic bag.
    2 Measure 100 g of vinegar and add it to a separate container.
    3 Carefully pour the vinegar into the plastic bag with the baking soda and quickly seal the bag to prevent any gas from escaping.
    4 Observe the reaction and measure the total mass of the sealed bag and its contents before and after the reaction.
    5 Record the mass measurements and any observations.

Analyse the method used in this investigation to determine its reliability, and the precision and accuracy of the data collected.

Apply

7 From an experiment you have previously completed, **identify** a random error and systematic error that could have occurred.

Lesson 1.7

Scientists use tables, graphs and models to record and process data

Key ideas

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

→ Tables and graphs allow scientists to identify patterns in their results.

→ 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.

→ Keys help scientists interpret or identify information in scientific diagrams, maps and data.

→ Models are representations that help explain scientific concepts or can be used to test explanations.

→ Mathematical relationships show connections between variables and pieces of data, and express them as numbers or equations.

→ The data presented in some graphs can be extrapolated or interpolated to make predictions.

→ If using data from secondary sources, you need to check they are reliable sources.

Learning intentions and success criteria

Without data, you're just another person with an opinion

Stage 3 of the scientific method involves processing, modelling and analysing data generated during a scientific inquiry (Figure 1). This can be done using:

- data tables
- graphs
- keys
- models
- formulas.

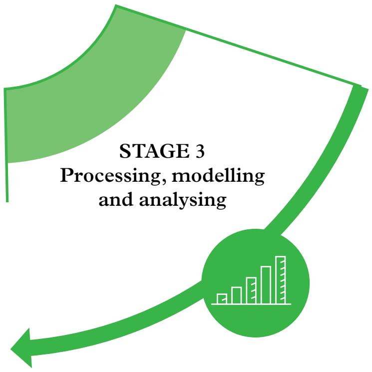


Figure 1 Stage 3 of the scientific method is **Processing, modelling and analysing**.

Representations to organise data

Once data has been collected from an investigation, how to effectively organise and represent the data is crucial for interpreting and communicating scientific findings. Representations such as keys, tables, graphs, models and diagrams allow us to visualise patterns, trends and relationships within data sets. These tools not only help in making sense of complex information but also in presenting it clearly to others.

Data tables

During the investigation, you will be collecting and recording qualitative and quantitative data into your logbook (Lesson 1.8 Scientists keep a logbook (page 41)) for later analysis. This is essential for drawing valid conclusions and evaluating the outcomes of the investigation.

For example, you may be required to collect data at regular intervals using consistent units of measurement, such as temperature every minute or height every day. To be accurate in this data collection and to minimise errors, measurements should be double-checked before being recorded and the data should be presented in a clear and structured manner, such as a table, including units (Table 1). Qualitative data can also be recorded in a table or as a list in your logbook.

There are four steps for constructing a table:

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

A spreadsheet can also be used to create a table.

Table 1 Data presented in a table is easier to read and analyse.

Time (minutes)	Temperature (°C)	Observations
0	15	6 ice-cubes in the beaker with water.
1	18	
2	25	
3	32	3 of the ice-cubes have melted and the remaining 3 are now half their original size.
4	40	
5	49	
6	56	The Bunsen Burner went out. Had to relight it.
7	58	
8	63	Small bubbles appearing in the solution. All the ice-cubes have melted.

Graphs

There are two main types of data that are recorded and graphed by scientists so they can be analysed efficiently.

- **Categorical data** is a collection of information that can be divided into named groups (e.g. colours, types of animals, types of vehicles).
- **Numerical data** is a collection of information that can be represented as numbers (e.g. temperature, wind speed, height).

Numerical data can be divided into two smaller groups.

- **Discrete data** is data that can only take a specific and separate value. It is usually counted in whole numbers that cannot be broken down into smaller parts. For example:
  - the number of students in a class
  - the number of votes in an election.

categorical data information that can be divided into groups or categories

numerical data information in the form of numbers

discrete data information that can only take on specific and distinct values, such as whole numbers

Discrete data is often represented in a column graph.

- **Continuous data** is data that can take any value within a range. It can be divided into smaller parts. It is measured, not counted. For example:
  - measuring the speed and acceleration of a runner over the course of a 100 m sprint
  - measuring the rate at which water is poured into a glass
  - measuring temperature and wind speed over the course of a day.

Continuous data should always be represented in a line or scatter graph.

continuous data information that can be any value, including decimals and fractions that are measured

Table 2 Summary of the data type and how it can be represented

Type of data	Description	Representations
Discrete data	distinct, separate values like the number of students in a class	bar graphs, tables or pie charts
Continuous data	values within a range, such as height or temperature	line graphs or histograms (to show fluctuations over time or a range of values)
Qualitative data	description of characteristics like colour or texture	categorical tables or bar chart
Quantitative data	numerical values like weight or time	line graphs, scatter plots or histograms (to allow for precise measurement and analysis)

Choosing the appropriate representation for each data type allows for clearer interpretation of patterns, trends and relationships.

Line graphs

Line graphs are used when both the independent variable and the dependent variable are continuous data (Figure 2). This includes changes in variables such as temperature, speed or population growth over time. Patterns are more easily observed as well as the relationship between the independent and dependent variable.

line graphs individual data points that are connected and that change over time

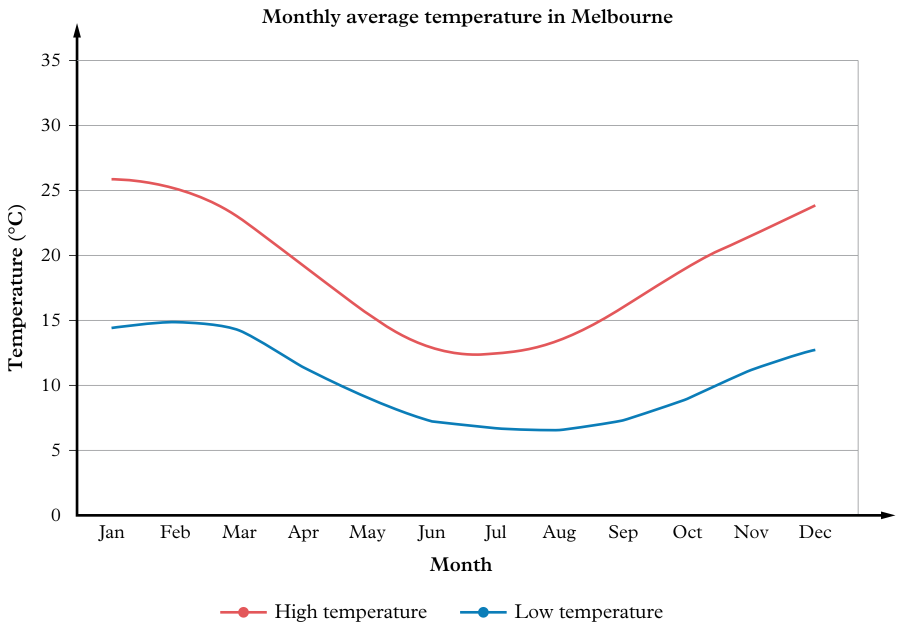


Figure 2 A line graph plots continuous data. In this graph, two data sets are included and are represented by different colours to make it easier to interpret.

Column graphs

column graph vertical bars used to compare data

In a **column graph**, the height of each column represents a value that you have measured. This type of graph is good for showing discrete data.

Imagine that a scientist is recording the number of insects at different locations. In this experiment, the independent variable (the variable that is changed) is the location, and the dependent variable (the variable that is measured) is the number of insects.

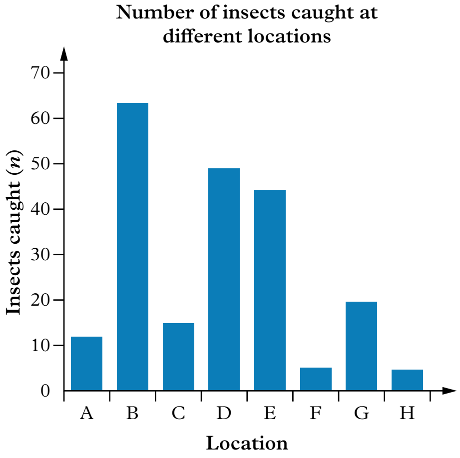


Figure 3 An example of a column graph

Scatter plots

scatter plot a type of graph that displays the relationship between two sets of numerical data

line of best fit a straight line that goes through the middle of all the scatter points to minimise the distance between the line and the scatter points

Scatter plots are used when both the independent variable and the dependent variable are continuous and may not be connected by a line. Occasionally, a **line of best fit** can be used to show the trend or direction of the relationship. A line of best fit is a straight line drawn through a group of data points, and it can show the positive or negative relationship (correlation) between two variables (Figure 4).

Imagine that a scientist is investigating how temperature changes over time. In this experiment, the independent variable (the variable that is changed) is time, and the dependent variable (the variable that is measured) is temperature.

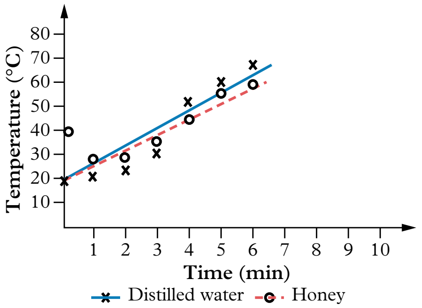


Figure 4 An example of a scatter plot

Keys

A key is a guide that helps a scientist to interpret or identify information in scientific diagrams, maps and data. Examples include:

- a legend on a graph to explain what different coloured lines represent
- a colour key on a weather map to indicate temperature ranges
- a symbol key on a geological map to indicate different types of rock
- a dichotomous key to identify plants or animals based on their characteristics (Figure 5).

Models

Models are representations of systems, structures or processes, and are often used when the actual system is too large, too small or too complex to study directly. Models can be physical (like a model of the solar system), mathematical (such as a formula) or conceptual (like a flow chart). Models help us understand how things work by simplifying complex ideas into something easier to study and experiment with. They include:

- a physical model of the solar system
- a diagram showing how the water cycle works
- a computer simulation of weather patterns or ozone levels (Figure 6)
- a mathematical model predicting population growth
- a scale model showing the relative sizes of different atoms.

Models are not just used for communication. Some models (such as physical or computer models) can be used to test hypotheses about how a system might behave differently if a variable is changed.

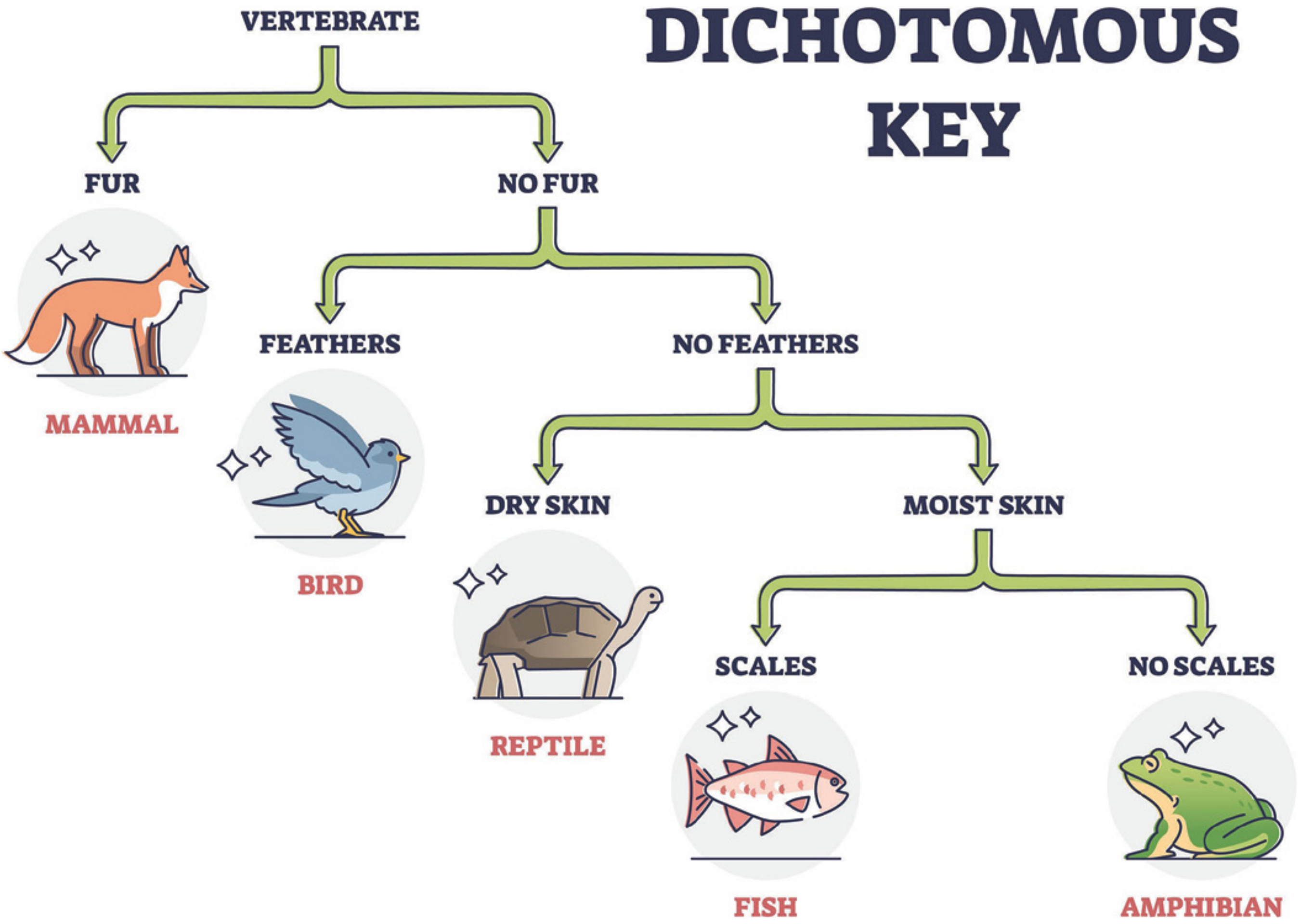


Figure 5 A dichotomous key can be used to identify animals based on their characteristics.

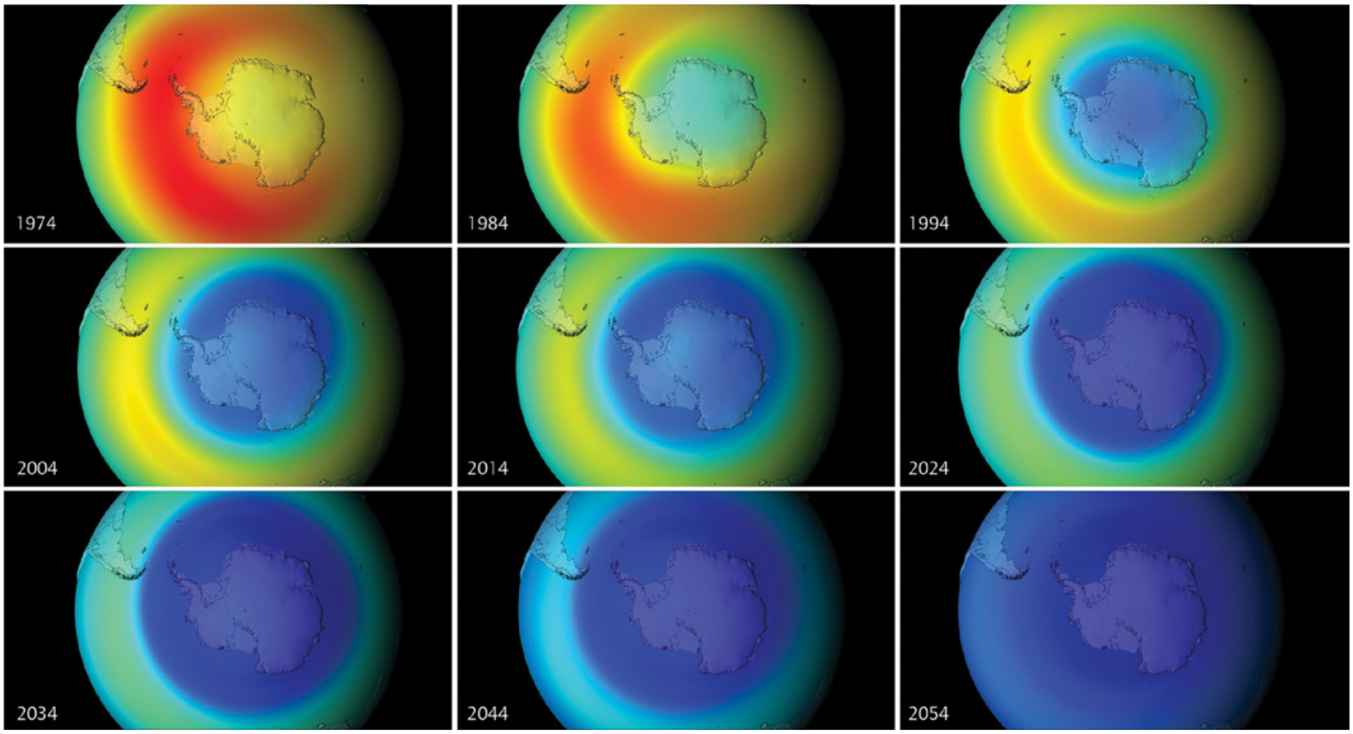


Figure 6 Computer modelling can make predictions about the future, such as Antarctic ozone levels.

Mathematical formulas

Mathematical formulas show connections between independent variables and dependent variables and express them as numbers or equations. Examples include:

- distance travelled = walking speed × time spent walking
- graphing the relationship between the amounts of water given to plants and their growth
- temperature changes throughout a day
- how the weight of a bag changes as you add more items
- finding patterns in measurements (e.g. analysing daily rainfall over a month).

Mathematical relationships can sometimes be used to predict how things may change in the future.

Extrapolating graphs

Graphs can be used to show data that has been collected, but it can also be used to analyse data and to make conclusions. When drawing a graph, it is important to:

- label each axis (with units)
- scale the axis so that it uses the space available
- consider if the line should pass through the origin (0, 0)
- plot the graph and draw the line of best fit
- identify and explain any outliers.

extrapolation
estimating unknown values from trends in known data

Extrapolation occurs when data are estimated outside the known values. Extrapolating a graph occurs when a line is drawn to estimate values beyond the available data. This can introduce errors to the data, because there is no data collected to support the conclusions that have been made (Figure 7).

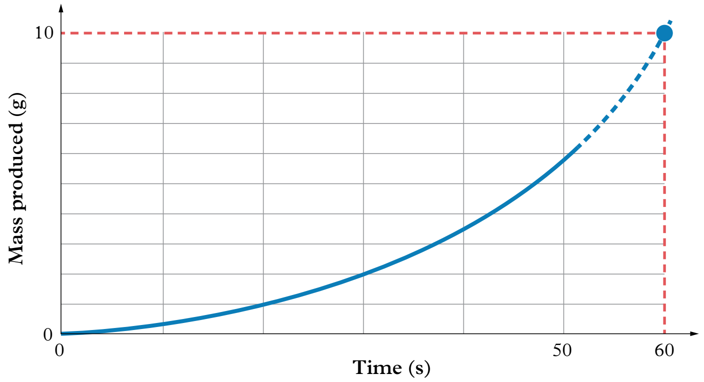


Figure 7 The data were only collected for 50 seconds. Extrapolating the data to 60 seconds can introduce errors.

Interpolation and making predictions

interpolation
determining a value from existing values

While extrapolation involves estimating values outside the known data, **interpolation** is the process of estimating values within the range of the data you have already collected. Interpolation is often considered more reliable than extrapolation because it is based on data points that are within the observed range. To interpolate, you simply use the existing data points on a graph to estimate unknown values between them. For example, if you have data for the mass of an object at 2 g and 5 g, you can interpolate to predict the volume at 2.5 g by drawing a line between the two points and reading the value (Figure 8).

Both extrapolation and interpolation allow us to make predictions based on trends shown in graphs. However, extrapolation should be done cautiously, as it involves estimating data outside the known range, which can lead to less accurate results. Interpolation, on the other hand, uses existing data points and is generally more reliable for making predictions within the known range. It's important to always consider the reliability of the predictions and whether additional data could improve the accuracy of your results.

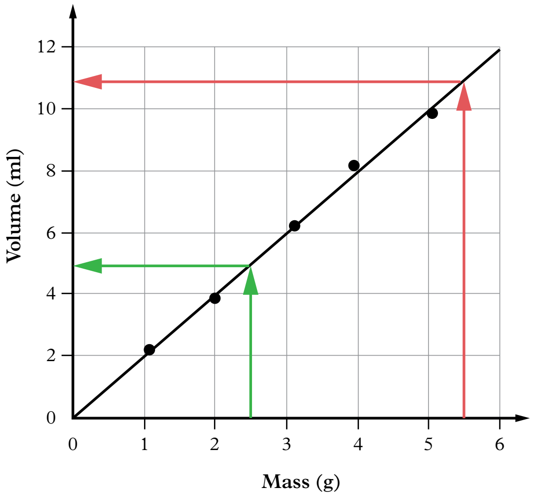


Figure 8 Interpolation uses existing data points to estimate unknown values and is more accurate than extrapolation.

Secondary sources

A reliable secondary source is one that provides accurate, well-researched and credible information derived from primary sources. These sources interpret, analyse and synthesise data and information, offering insights that help deepen an understanding of the research topic. Reliable secondary sources are typically created by experts, are peer-reviewed and are published in reputable scientific journals.

Check your learning 1.7

Check your learning 1.7

Retrieve

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

2 **Identify** which variable (independent or dependent) is located on the x-axis of a graph.

3 **Describe** the type of graph that would be used to show the number of birds found in a particular area each month.

4 **Describe** the main purpose of using data tables.

5 **Identify** the difference between categorical data and numerical data.

6 **Define** what extrapolation and interpolation means.

Comprehend

7 **Classify** the following as discrete or continuous data.
  - **a** Student's favourite colour
  - **b** Height of the members in your family
  - **c** The number of books on a shelf
  - **d** The mass of eggs
  - **e** Amount of liquid in a bottle

8 **Select** the best graph that could be created for the data from the following scenarios.
  - **a** Students conduct an investigation to measure the temperature of water as it is heated over a period of 10 minutes.
  - **b** Students measure the height of plants after 4 weeks of using different types of fertilisers.
  - **c** Students count the number of M&Ms of each colour in a bag.
  - **d** Students measure their reaction time to different stimulis (e.g. visual, auditory).
  - **e** Students measure the pH levels of various solutions (e.g. vinegar, soap, water).

Analyse

9 Students conducted an experiment to measure the growth of bacteria in a petri dish over a period of 10 days. They recorded the number of bacterial colonies each day and created a table with their data (Table 3).
  - **a** Plot the data on a graph with the number of bacterial colonies on the y-axis and the day on the x-axis.

b **Use** the model to predict the number of bacterial colonies on day 12.

c **Use** the graph and model to estimate the number of bacterial colonies on day 7.5.

d **Explain** how the model helps in understanding the growth pattern of bacteria.

e How reliable and accurate do you think the data collected is? What factors could affect the precision of the measurements?

f How does the model help in understanding the growth pattern of bacteria? Are there any limitations to the model?

g **Compare** the growth rate of bacterial colonies between the first 5 days and the last 5 days. What differences do you observe?

h **Interpret** the significance of the steepest part of the graph. What does it tell you about the bacterial growth during that period?

i **Calculate** the average daily increase in the number of bacterial colonies over the 10-day period.

Table 3 The number of bacterial colonies over 10 days

Day	Number of bacterial colonies
1	5
2	12
3	20
4	35
5	50
6	70
7	95
8	120
9	150
10	180

Apply

10 The speed of a car was recorded at regular intervals along a straight stretch of road and the following graph created (Figure 9).

a **Determine** the speed of the car at 2.5 seconds.

b **Justify** if the speed determined in part a is reasonable. HINT: to convert m/s into km/s, multiply your answer by 3.6.

c **Explain** if this is an example of interpolation or extrapolation.

d **Determine** the speed of at car at 12 seconds.

e **Justify** if the speed determined in part d is reasonable. HINT: to convert m/s into km/s, multiply your answer by 3.6.

f **Explain** if this is an example of interpolation or extrapolation.

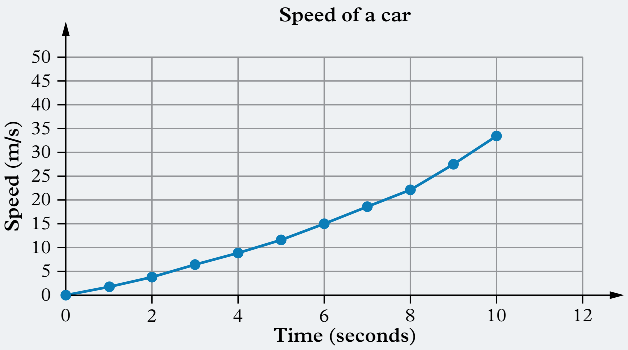


Figure 9 The graph for the speed of a car over time

Lesson 1.8

Scientists keep a logbook

Key ideas

→ A logbook is used by scientists in the laboratory and in the field to record the details and results gathered during experiments and research.

→ A logbook provides evidence of the planning, changes and results of an experiment.

Learning intentions and success criteria

A logbook is used to record essential data and observations

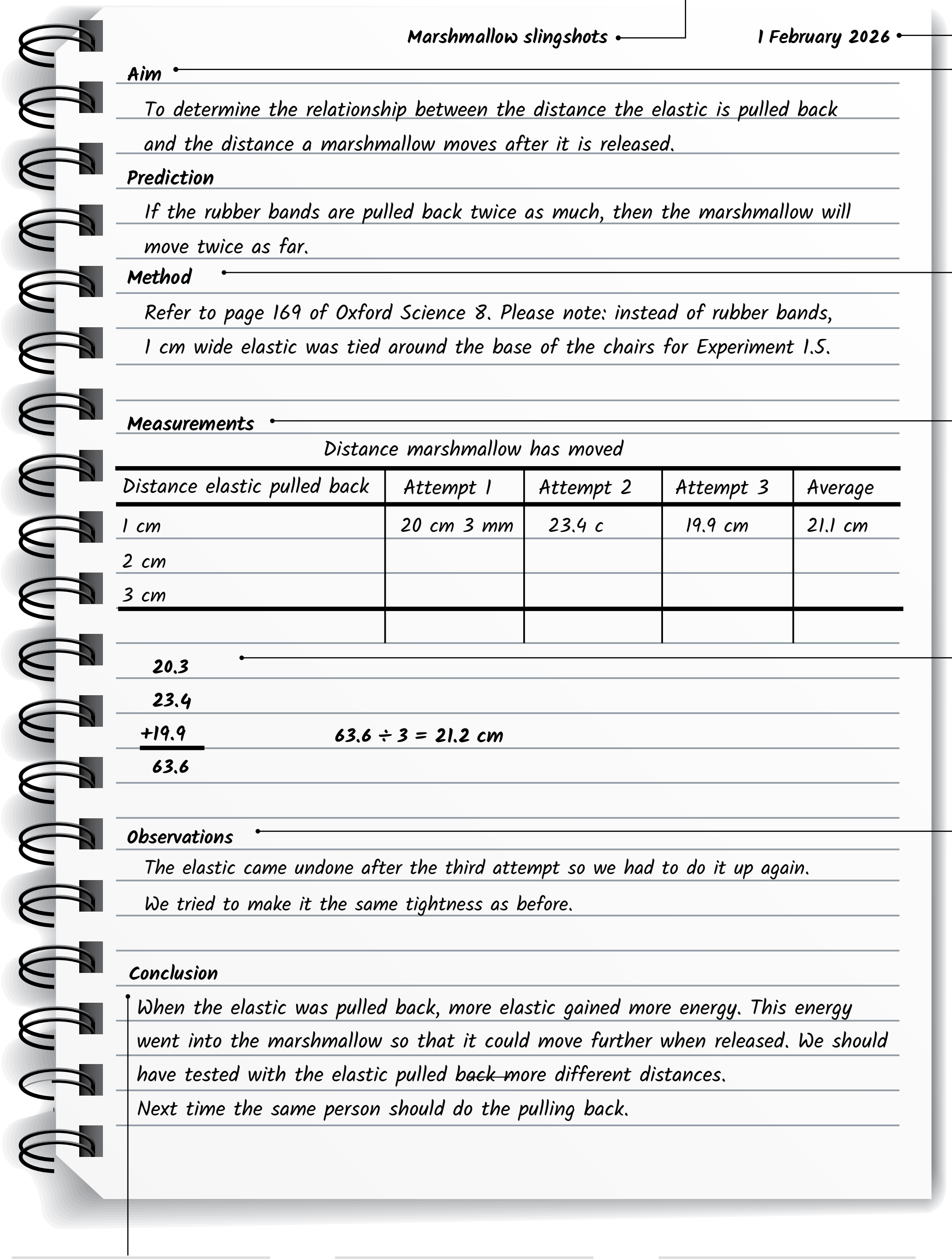
There are many different types of science and even more types of science investigations. Some investigations last a few minutes, while others can last many years.

An example of a long investigation is an ecologist recording how the population numbers of dolphins in Port Phillip Bay change over a decade (i.e. 10 years).

All investigations rely on the scientists collecting and recording data and observations in an electronic or physical **logbook**. Logbooks contain all of the information that will eventually be used to write a formal report (i.e. a written report used to communicate the results of an experiment with other scientists).

logbook a detailed recording of observations and data from a scientific investigation

Figure 1 Logbooks contain important data and observations from experiments conducted in the laboratory or in the field.



Marshmallow slingshots **1 February 2026**

Aim

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

Prediction

If the rubber bands are pulled back twice as much, then the marshmallow will move twice as far.

Method

Refer to page 169 of Oxford Science 8. Please note: instead of rubber bands, 1 cm wide elastic was tied around the base of the chairs for Experiment 1.5.

Measurements

	Distance marshmallow has moved			
Distance elastic pulled back	Attempt 1	Attempt 2	Attempt 3	Average
1 cm	20 cm 3 mm	23.4 c	19.9 cm	21.1 cm
2 cm				
3 cm				

$$\begin{array}{r} 20.3 \\ 23.4 \\ +19.9 \\ \hline 63.6 \end{array}$$

$63.6 \div 3 = 21.2$ cm

Observations

The elastic came undone after the third attempt so we had to do it up again.

We tried to make it the same tightness as before.

Conclusion

When the elastic was pulled back, more elastic gained more energy. This energy went into the marshmallow so that it could move further when released. We should have tested with the elastic pulled ~~back~~ more different distances.

Next time the same person should do the pulling back.

Title of the experiment

The date on which the experiment was conducted

Aim and prediction for the experiment

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

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

Show all calculations (even when adding simple numbers).

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

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

Include a conclusion or reflection for each experiment to make sure you understood what happened and why.

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

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

Figure 2 A sample logbook entry

Creating a logbook

There are some basic rules for creating and using a logbook.

1 Use a bound notebook (Figure 1) or an electronic device that is backed up regularly. Loose papers become lost, and electronic devices can fail. Whether you're using a physical or electronic logbook, ensure that the way you record and store data in your logbook is safe and reliable.

2 Logbooks can be lost, so label your logbook with your name, email address, school and teacher's name. Labelling the logbook with your contact details (and those of your school and teacher) ensures that it will find its way back to you.

3 The second page of the logbook should contain a table of contents (Table 1). Each page should be numbered to help you find the relevant experiments.

4 Always date every entry.

5 Each page should contain the title of the experiment.

Figure 2 shows a sample logbook entry.

Table 1 A table of contents should be included at the start of your logbook.

Unit/subject	Experiment title	Page number
Chemistry	Rates of reactions	2
Biology	Peripheral vision	5
Physics	Newton's first law	10

Check your learning 1.8

Check your learning 1.8

Retrieve

1 **State** the purpose of an experimental logbook.

2 A student made a mistake on a page then ripped that page out of their logbook. **Recall** why this would be the wrong thing to do.

Comprehend

3 **Explain** why an electronic logbook should be backed up regularly.

Analyse

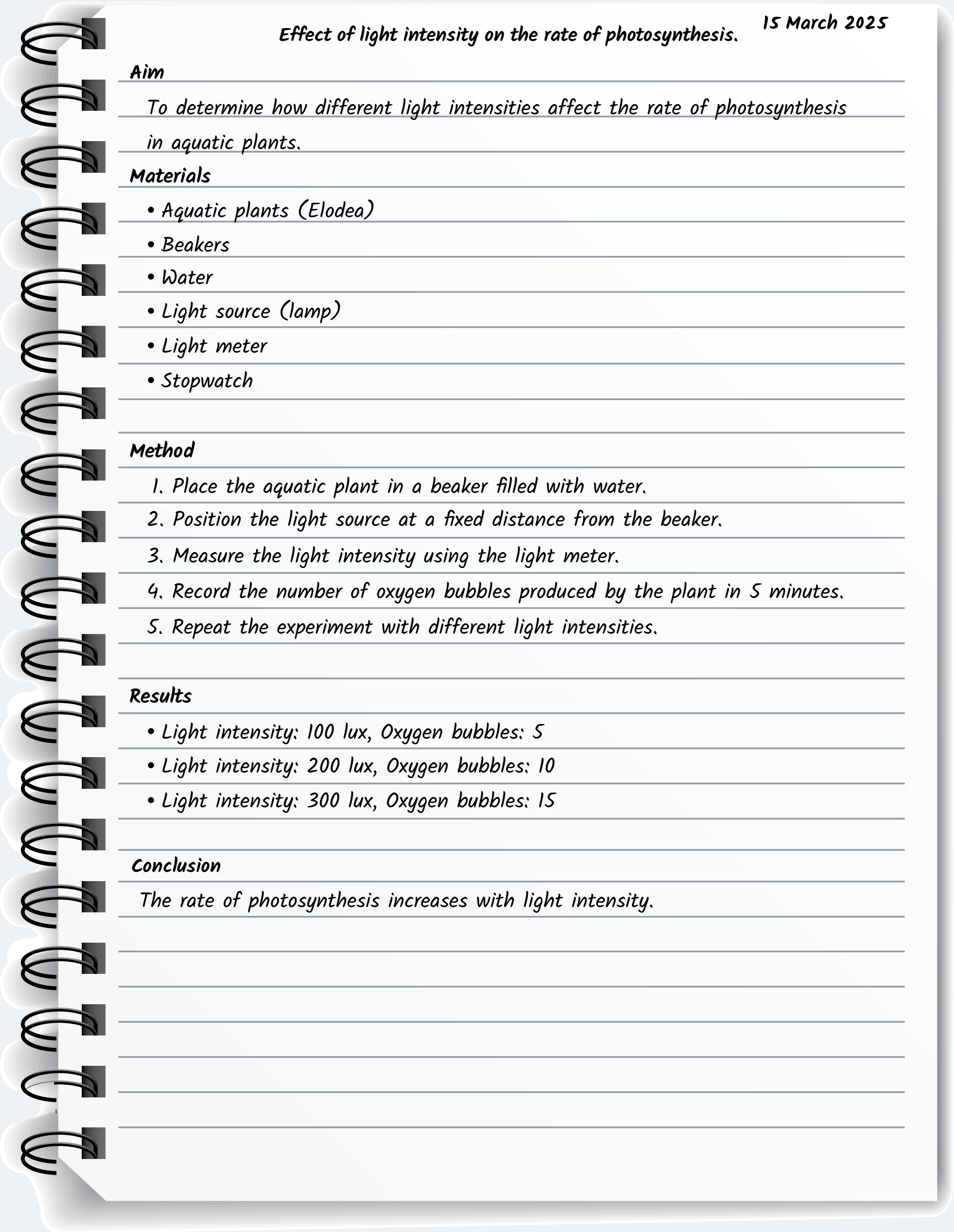
4 **Infer** why it is important to make sure the writing in your logbook is legible (able to be read).

5 **Infer** one reason why it is important to include the date of the experiment in the logbook.

6 **Infer** why you should reflect on each experiment before starting the next experiment.

Apply

7 Use the following logbook entry (Figure 3) to answer the following questions.
   a **Evaluate** the logbook entry and **identify** which pieces of information are missing.
   b **Discuss** why each piece of information is necessary for a complete and accurate record of the investigation.



15 March 2025

Effect of light intensity on the rate of photosynthesis.

Aim

To determine how different light intensities affect the rate of photosynthesis in aquatic plants.

Materials

- Aquatic plants (Elodea)
- Beakers
- Water
- Light source (lamp)
- Light meter
- Stopwatch

Method

1. Place the aquatic plant in a beaker filled with water.
2. Position the light source at a fixed distance from the beaker.
3. Measure the light intensity using the light meter.
4. Record the number of oxygen bubbles produced by the plant in 5 minutes.
5. Repeat the experiment with different light intensities.

Results

- Light intensity: 100 lux, Oxygen bubbles: 5
- Light intensity: 200 lux, Oxygen bubbles: 10
- Light intensity: 300 lux, Oxygen bubbles: 15

Conclusion

The rate of photosynthesis increases with light intensity.

Figure 3 Logbook entry

Lesson 1.9

Scientists analyse trends in data

Key ideas

→ Describing trends in graphs will help determine the relationship between variables.

→ Measures of centre can be used to analyse a data set.

→ To determine the validity and reliability of data, the investigation must have measured the intended variable and the data must be consistent across trials.

→ A conclusion must be included, identifying whether the hypothesis was supported or refuted using evidence.

→ Sources of uncertainty should be considered.

Learning intentions and success criteria

Describing relationships between variables

In science, we often look for relationships between different variables. For example, if you're measuring how the height of a plant changes with the amount of sunlight it gets, the amount of sunlight is the independent variable, and the plant's height is the dependent variable. In this case, you are looking for a relationship between the amount of sunlight and the growth of the plant. Sometimes the relationship might be clear, like when more sunlight leads to taller plants. At other times, the relationship might be more complex or less obvious, and you will need to collect more data or look for other factors that could be influencing the result.

Analysing numerical data

There are many different ways to use mathematics to represent data. The measures of centre of a dataset can be found in a number of ways (outlined in Table 1). Worked example 1.9A shows how to find the measures of centre of a data set.

Table 1 Ways to determine the measures of centre for a data set

Measure	Description
Mean	• The expected or average value of a data set • It is calculated by the formula: • $\text{mean} = \dfrac{\text{sum of all values}}{\text{number of values}}$
Median	• The middle value of the data • It is calculated by placing all the values in order from lowest to highest and then selecting the value in the middle.
Mode	• The most common value in the set of data • It is calculated by tallying how many times each number appears. The number that appears most often is the mode.

mean the average of a data set

median the middle value for data arranged from smallest to largest

mode the value that appears the most in a data set

Worked example 1.9A Calculating mean, median and mode

A car travelled 100 m in the following times:

278 seconds, 167 seconds, 180 seconds, 208 seconds, 3 minutes

Calculate the:

1 mean
2 median
3 mode.

Solution

1 Mean: To calculate the mean, all values must be in the same unit (seconds).

The data should therefore be: 278 seconds, 167 seconds, 180 seconds, 208 seconds, 180 seconds.

$$\text{mean} = \frac{\text{sum of all values}}{\text{number of values}}$$

$$= \frac{278 + 167 + 180 + 208 + 180}{5}$$

$$= \frac{1013}{5}$$

$$= 202.6 \text{ seconds}$$

As all values have three significant figures, the answer should also have three significant figures. 202.6 seconds should be rounded up to 203 seconds.

Therefore, the mean is 203 seconds.

2 Median: To calculate the median, all the values must be placed in increasing order.

167 seconds, 180 seconds, 180 seconds, 208 seconds, 278 seconds

The median value is the middle number, which is 180 seconds.

3 Mode: The mode is the most common number in the data set.

The mode value is 180 seconds.

Interpreting graphs

Line graphs are the most common graphs that are drawn in scientific reports. These graphs are used to show the relationship between the independent variable and the dependent variable. The shape of the graph gives a hint of how the two variables are related (Figure 1).

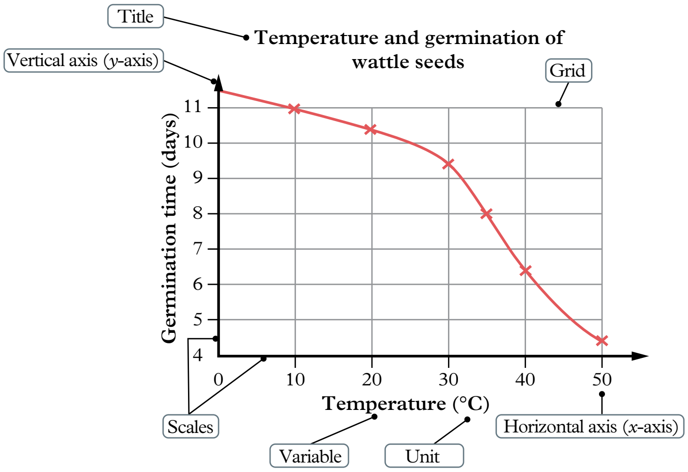


Figure 1 A line graph of germination time of wattle seeds versus temperature

When the line is horizontal, it means the dependent variable is not affected by the independent variable (Figure 2).

If the line is sloped down, the dependent variable decreases as the independent variable increases. This is called an **inversely proportional relationship** (Figure 3).

inversely proportional relationship when one quantity decreases the other quantity increases, or vice-versa

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 of Figure 4) shows an inversely proportional relationship.

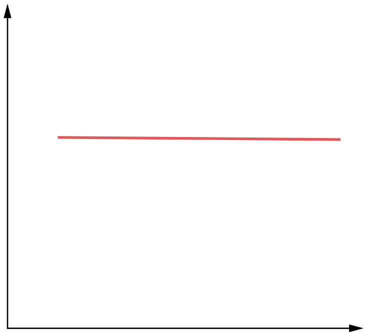


Figure 2 A horizontal line on a graph means the dependent variable is not affected by the independent variable.

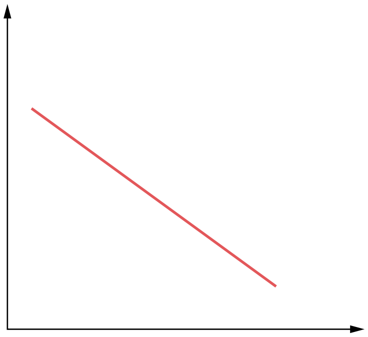


Figure 3 An inversely proportional relationship

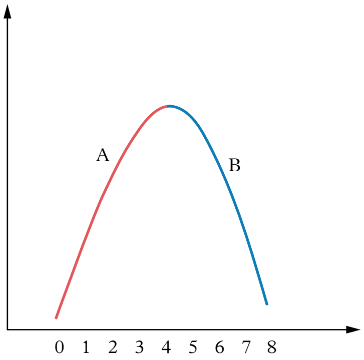


Figure 4 A curved graph is divided into sections that show different relationships.

Describing patterns and trends in data

When analysing data, one of the most important things we do is look for patterns and trends. **Patterns** are regular or repeated arrangements of data points, and **trends** refer to the overall direction or movement of data over time.

pattern a repeated sequence or arrangement of numbers or data points

trend represents the overall direction of the data points

For example, if you're looking at how the temperature changes throughout the day, you might notice a pattern where the temperature rises in the morning and falls in the evening. A trend might be that the temperature generally increases over a week during the summer (Figure 5).

Recognising patterns and trends helps us understand how things are changing and predict what might happen next. However, it's also important to look for inconsistencies in the data – these are points that don't fit the general pattern. For instance, if the temperature suddenly drops during the afternoon when the trend suggests it should continue rising, that could be an inconsistency (or an outlier) that needs further investigation.

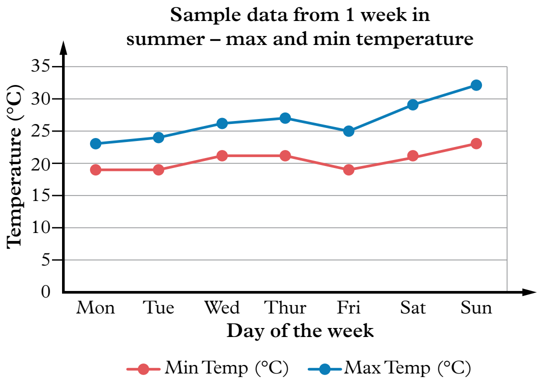


Figure 5 The minimum and maximum temperatures for 1 week in summer

Assessing the validity and reliability of first-hand data

To assess the validity of data, you must consider whether the experiment accurately measures the intended variable and whether external factors were controlled. To assess the reliability of data, check if the data is consistent across multiple trials and if the methods used are precise and repeatable.

Examples of valid and invalid data

- **Valid data**: In an experiment to measure the effect of light intensity on photosynthesis, valid data would show a clear relationship between light intensity and the rate of photosynthesis, with controlled variables such as temperature and carbon dioxide levels kept constant.
- **Invalid data**: If the same experiment is conducted but the temperature fluctuates significantly, the data may show changes in photosynthesis rates that are actually due to temperature variations rather than light intensity. This data would be invalid because it does not accurately measure the intended variable.

Examples of reliable and unreliable data

- **Reliable data example**: When measuring the speed of a chemical reaction at different temperatures, reliable data would show consistent reaction speeds when the experiment is repeated under the same conditions. For example, if you measure the reaction speed at 25°C multiple times and get similar results each time, the data is reliable.
- **Unreliable data example**: If the same reaction speed experiment is conducted but the measurements vary widely each time due to inconsistent timing methods or fluctuating temperatures, the data would be unreliable. This inconsistency makes it difficult to draw accurate conclusions.

Outliers

outlier a data point that differs significantly from the main group of data

Occasionally the data that scientists collect contains a value that is far away from the main group of data. These values are called **outliers** and may be due to inaccurate measurements or experimental errors. An outlier is a value that is outside the normal range of all other results. For example, an outlier may be observed in the data when measuring the height of seedlings after 3 weeks of growth (Table 2).

From the table, it is clear to see that seedling 5 is the outlier as it is outside the normal range when compared to the other results. The mean height of all the seedlings is 3.4 cm. If seedling 5 was excluded, the mean height would be 3.9 cm. This shows how one outlier can affect the results. In this case, the outlier has decreased the mean and so it is not representative of the growth of the seedlings.

Table 2 An outlier can affect the measures of centre. In this case, the mean is lower if seedling 5, the outlier, is included in the calculation.

Seedling number	Height (cm)
1	3.6
2	4.0
3	4.1
4	4.0
5	0.1
6	3.5
7	4.3

Sources of uncertainty

Recognising sources of uncertainty and considering alternative explanations are essential for a thorough analysis of the data. This involves acknowledging limitations in the data and exploring other factors that could affect the results.

Sources of uncertainty in an investigation can include:

- **Measurement errors**: These can occur due to inaccuracies in the instruments used or human error during data collection. For example, if a thermometer is not calibrated correctly, the temperature readings might be inaccurate.
- **Sample variability**: Differences in the samples used for experiments can introduce uncertainty. For instance, if studying plant growth, variations in soil quality or water availability among different samples can affect the results.
- **External influences**: Uncontrolled external factors, such as changes in weather conditions or environmental disturbances, can impact the data. For example, unexpected rainfall during an outdoor experiment can alter the results.

Drawing conclusions

After completing an investigation, you should draw a **conclusion** that aligns with the data and observations collected, ensuring the conclusion is based on accurate and reliable evidence. Here you will explain whether your hypothesis was supported or refuted (using data to support your findings) as well as highlighting the significance of the results.

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

For example, if testing if more salt will be soluble in warmer water, a conclusion could be:

"The experiment investigating the effect of temperature on the solubility of salt in water demonstrated a clear relationship between these two variables. As the temperature increased, the amount of salt that dissolved in the water also increased. This observation is consistent with the scientific concept that higher temperatures enhance the solubility of substances. The data collected supports the hypothesis that temperature positively affects the solubility of salt in water."

Check your learning 1.9

Check your learning 1.9

Retrieve

1 **Define** the following terms in the context of data:
  a pattern
  b trend.

Comprehend

2 **Describe** the factors that contribute to the validity of an experiment.
3 **Explain** what reliable data is.
4 **Describe** what it means if data is valid.

Analyse

5 Look at the following set of data showing the temperature at different times during the day:
  a 8 am: 20°C
  b 12 pm: 25°C
  c 2 pm: 30°C
  d 5 pm: 22°C
  e 7 pm: 18°C

Describe the trend you notice in the temperature data. **Identify** any inconsistencies, and **explain** what could cause them.

6 Below is data from an experiment measuring the growth of plants in two different soil types:
  – Soil A: Plant 1: 15 cm, Plant 2: 14 cm, Plant 3: 16 cm
  – Soil B: Plant 1: 10 cm, Plant 2: 12 cm, Plant 3: 11 cm
  a **Describe** the relationship between soil type and plant growth based on this data.
  b **Explain** if the data is reliable and justify your reasoning.

7 **Use** the following data from an investigation about how different temperatures affected the activity of an enzyme to answer the following questions.

   a **Create** a graph for Table 3.

   b Examine the graph to identify any potential outliers. **Explain** why these data points might be considered outliers.

   c **Interpret** the overall trend of the graph. How does temperature affect enzyme activity?

   d **Discuss** the possible reasons for the decrease in enzyme activity at higher temperatures.

Table 3 How different temperatures affected the activity of an enzyme

Temperature (°C)	Reaction rate (units/min)
10	2
20	5
30	8
40	12
50	15
60	14
70	9
80	3

Apply

8 **Describe** the relationship between the independent variable and dependent variable in Figure 6.

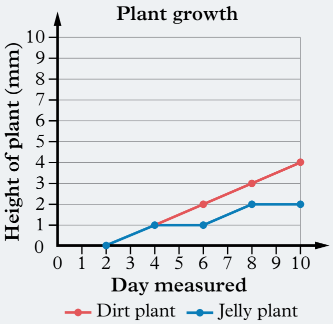


Figure 6 Height of plant versus day measured

9 For the following scenarios, **identify** sources of uncertainty.

   a Students are measuring the speed of a toy car as it travels down a ramp.

   b Students are testing the strength of bridges made from different materials and designs.

   c Students are measuring their reaction times to a visual stimulus using a stopwatch.

Lesson 1.10

Scientists evaluate conclusions

Learning intentions and success criteria

Key ideas

→ To solve a problem, there are different approaches that can be used.

→ Bias can affect all aspects of a scientific investigation and can skew the outcome.

→ Do not take information from secondary sources as true until you check who wrote it, where it has been published and if it's current.

→ Possible alternative explanations for the observed results should be considered.

→ The quality of the data can be improved by repeating trials, having your work peer reviewed, using calibrated digital equipment, analysing sources of error, evaluating the data and improving data recording.

Take a step back and evaluate

Stage 4 of the scientific method involves evaluating the conclusion from the data and findings generated during a scientific inquiry (Figure 1). Scientists do this by:

- evaluating how the problem was solved
- evaluating the validity of information
- suggesting alternative explanations.

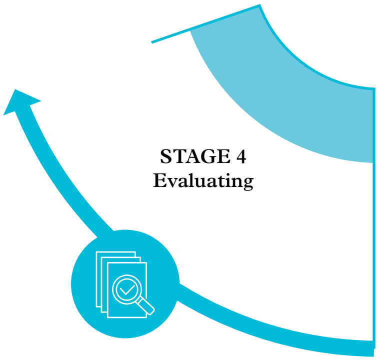


Figure 1 Stage 4 of the scientific method is **Evaluating**.

Approaches used to solve problems

There are various approaches that can be used to solve different problems. Here you need to compare different methods and determine which is most effective based on evidence and scientific principles, while understanding the strengths and limitations of each approach.

These approaches include:

- laboratory experiments
- field work
- modelling and simulations
- comparative analysis
- writing a pros and cons list
- conducting a SWOT analysis
- creating cause-and-effect diagrams.

The strengths and limitations of each approach can be seen in Table 1.

Table 1 A summary of the strengths and limitations of the approaches used to solve problems

Approach	Strength	Limitation
Laboratory experiments	Easy to isolate variables and control the conditions; can produce precise, repeatable results	• Lack real-world context as conditions in the laboratory are not mimicked in natural environments • Can be expensive and time-consuming
Field work	Provides real-world data and makes results more applicable to actual situations	• Cannot control conditions that can introduce variability and challenges in isolating factors • Can be resource intensive and time consuming
Modelling and simulations	Useful for predicting outcomes, testing complex scenarios and analysing patterns without the need for experiments	• Relies on the accuracy of the model and the data used
Comparative analysis	Evidence-based decision-making that identifies similarities, differences and trends in data or case studies	• Requires high-quality, reliable data
Pros and cons list	Simple to use and organises thoughts to evaluate options to make an informed decision	• May rely too much on subjective judgement rather than objective evidence • May oversimplify complex problems
SWOT analysis (Figure 2)	Identifies strengths, weaknesses, opportunities and threats	• May not deeply analyse causes of weaknesses or threats • How factors are categorised can be subjective
Cause-and-effect diagram (Figure 3)	Maps out underlying causes of problems and explores potential solutions	• Can be time consuming to create • May oversimplify interconnected issues

Figure 2 A SWOT analysis grid

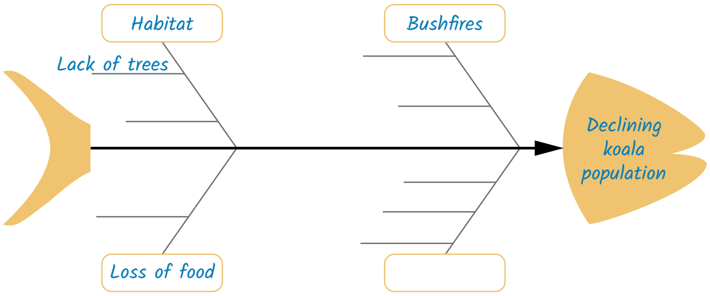


Figure 3 A cause-and-effect diagram

Validity of primary and secondary sources

When analysing the validity of information from primary and secondary sources, it is important to critically evaluate several key aspects to determine its credibility and reliability.

Social media is full of big claims and headlines quoting the latest scientific claim. These claims cannot be trusted unless they pass the validity and credibility tests. There are a number of things to look for before the claim is even read.

Bias

bias discrimination against ideas, against people or in the collection and interpretation of information

If a person is biased, it means they have already made a decision about a person or outcome. In science, **bias** can cause an observer to only notice the information that they expect to occur and to avoid or refuse to acknowledge data that is unexpected. Because biased observations only tell one side of a story, it can sometimes cause inaccurate data and leave a false impression. There are many ways bias can affect a scientific investigation.

Confirmation bias

confirmation bias a preference for information or data that supports pre-existing beliefs or the hypothesis

When a researcher has a hypothesis that they are certain is correct, they may shape their investigation so that the data supports the hypothesis. This is known as **confirmation bias**; it involves favouring information that "confirms" a hypothesis.

Sampling bias

sampling bias the selection of participants is not random and does not represent the larger population

Sampling bias occurs when an experiment tests a small group of subjects (either people or objects) that do not represent the larger group (Figure 4). This has been seen most recently during pre-election surveys where people are asked who they will vote for via landline phone surveys in city regions. These surveys often miss people who are not home during the day or who do not have a landline phone because they only use their mobile phone. This means the predictions of who will win an election may be biased because the sample only represents people who own landline phones.

Channelling bias

When scientists want to test the effectiveness of a new drug, they will carefully select a large group of people and divide them into two smaller groups.

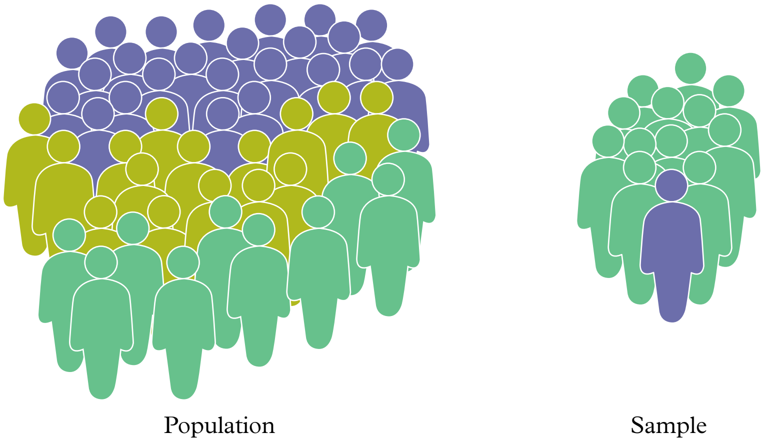


Figure 4 Sampling bias exists when the population of the sample doesn't reflect the actual population.

When selecting which person will be placed into each group, it is tempting for the scientist to place or "channel" the people most affected by a condition into the group that will receive the treatment and the people who are least affected into the non-treatment group. But this can affect the outcome of the trial.

Instead, the two groups should be **randomised** (randomly assigned to a group), and both groups should appear to receive the same treatment. This can be done by giving both groups a pill to take at the same time each day. One group will have the new drug in the pill, while the control group will be given a placebo.

A **placebo** is a substance or treatment that is designed to have no effect, for example, a sugar pill. Some people can be so convinced that the treatment will work that a placebo will make them feel better. In one experiment, a group of patients with osteoarthritis of the knee underwent a placebo operation instead of receiving the real procedure. These patients reported feeling less pain as a result of the fake procedure. When participants do not know if they are receiving the real treatment or a placebo, it is called a randomised **blind study**.

Although a blind study is useful, the doctors treating the participants might also behave differently towards a patient if they know the patient is receiving treatment or a placebo. To avoid this, sometimes the treating doctors are not told which treatment the patient is being given. In these tests, only the scientists know the outcome and can decode which group received the treatment. When there are two layers of people who do not know who received the treatment until it is over, this is called a randomised **double-blind study**.

randomised when participants in a trial are assigned to separate groups by chance

placebo a substance or treatment that has no effect

blind study a study in which participants do not know who is receiving the real treatment and who is receiving a placebo

double-blind study a study in which neither the researchers nor the participants know who is receiving the real treatment and who is receiving a placebo

Who is the author?

It is always worth checking who wrote the article before reading their claims. Is the author qualified in that field? During the COVID-19 pandemic, there were many "doctors" claiming to know about vaccines and the spread of viruses, but many of these people were not qualified in infection, epidemiology or even medicine. It is always worth asking "What are the author's qualifications?".

Why was the article written?

Some big headlines are written by companies that want you to buy their product. Cosmetic companies will make claims that their skin cream will make you look younger, while car companies will claim that their oil will make your car run more smoothly. They may write an article or claim that quotes scientific data that make their product look the best, and often ignore data that disagree with their claim. Always consider why the article was written and if it is biased to a particular view.

Is it current?

A current claim does not just mean the most recently written article. While the date on the article of claim is important, it is worth checking if the data match other available data.

Figure 5 (A) Peer-reviewed articles in science journals are a valid secondary source because they have been checked by other scientists. (B) Posts and articles on social media are not always a valid source because they have not been checked for credibility and posts can often be sponsored by companies with their own agendas.

It is easy for a group of non-scientists to write an article each week with a new claim, but it is important to check if the data are able to be reproduced by other scientists. Does it fit with current research, or is it from the same group of people using the single set of data?

Is the publisher reputable?

Social media has a wide mix of trustworthy as well as untrustworthy publishers. This also happens with some online "scientific" journals. There are some websites that claim to be scientific journals, but they are "pay to publish" sites. These websites will publish any article that is written as long as the authors pay the company. In 2005, MIT students used a computer to generate random science and jargon words in a science paper. They then submitted the paper to a variety of science sites around the world. Some sites published the fake science paper. A good publisher will always peer review a paper before publishing. This means that the paper will be checked by other scientists who have been trained in the area.

Alternative explanations

Considering alternative explanations involves exploring other factors that could potentially explain the observed results. This helps to ensure that the conclusions drawn are not biased.

For example, if an investigation looked at the effects of air pollution on respiratory health, you should also consider other factors that could influence respiratory health, such as allergens, weather conditions and lifestyle factors. These alternative explanations help in understanding that air pollution is not the sole factor affecting respiratory health.

Improving the quality of data

The quality of the data collected from investigations or fieldwork has an impact on the conclusions that can be drawn. To improve the quality of the data, a number of things can be done, including:

- Repeating trials – Completing multiple trials for an investigation ensures results are accurate and precise. Only completing one trial means you would not be able to identify any errors if they occurred.

- Using digital equipment – Digital equipment such as temperature probes and motion sensors, reduce measurement errors and produce more accurate results, as long as they are calibrated and maintained (Figure 6).
- Aanlysing sources of error – Identifying systematic and random errors will help refine your method so these errors can be reduced.
- Peer review – Have a peer review your data and method for any inaccuracies or inconsistencies.
- Evaluation – Critically analyse your data for any patterns, outliers and inconsistencies.
- Improving data recording - All data and observations should be immediately recorded to avoid errors due to memory or miscommunication. The way the data recorded is also important, such as using a table, so it is clear what has been collected and when.

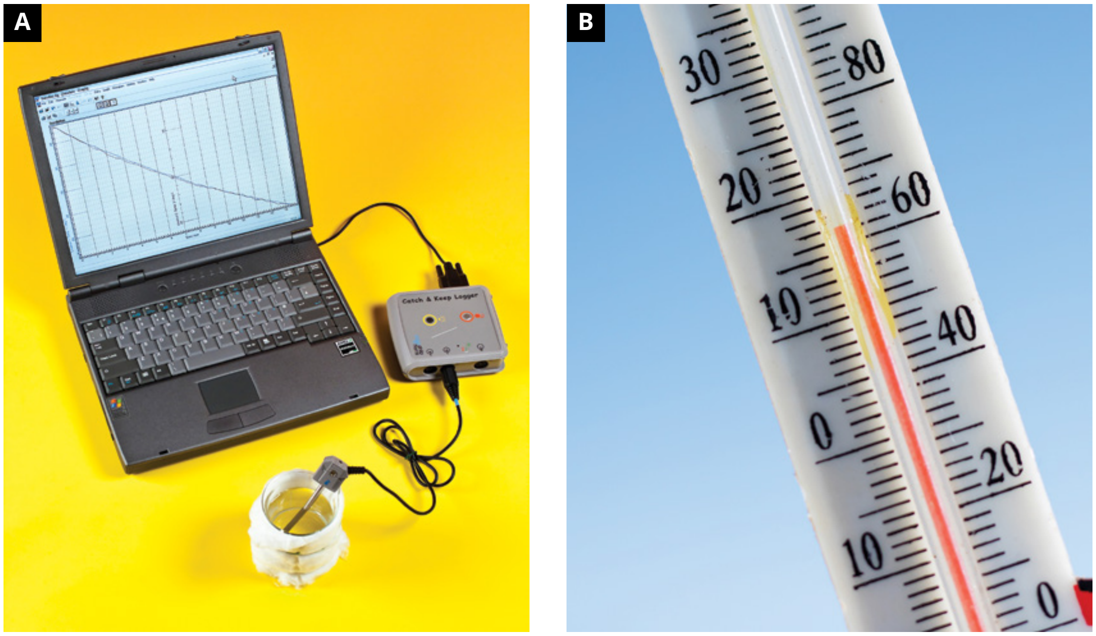


Figure 6 (A) Temperature data collected from a data logger will be more accurate than taking a reading from (B) an analogue thermometer, due to errors that will occur when trying to read the markings.

Check your learning 1.10

Check your learning 1.10

Retrieve

1 **Explain** how bias can affect an outcome.
2 **Identify** three ways the quality of data could be improved.
3 **Identify** three things to look for when evaluating the validity of primary and secondary resources.
4 **Describe** why there are various approaches used to solve problems.

Comprehend

5 **Describe** how not calibrating scales at the start of an experiment could affect the results of the experiment.
6 For each scenario, **determine** what approach would be best to solve the problems.
  a You are investigating the effect of different fertilisers on plant growth.

- **b** You are studying the biodiversity of a local wetland.
- **c** You are comparing the health outcomes of two different diets.
- **d** Your school is planning to implement a new recycling program.

7 Recall two places where you would find reliable research. **Explain** why these sources are reliable.

8 **Explain** how data can be used to draw evidence-based conclusions.

Analyse

9 **Contrast** what is meant by the terms “current” and “recent” in scientific publishing.

10 **Identify** a source of secondary data from social media. **Judge** the validity of the claim made in the information using methods described.

11 Below is data from an experiment measuring the growth of plants in two different soil types:

- Soil A: Plant 1: 15 cm, Plant 2: 14 cm, Plant 3: 16 cm
- Soil B: Plant 1: 10 cm, Plant 2: 12 cm, Plant 3: 11 cm

Scientists concluded that: “Plants grown in Soil A exhibit greater growth compared to those grown in Soil B. The average height of plants in Soil A is 15 cm, while the average height of plants in Soil B is 11 cm. This suggests that Soil A may have more favourable conditions for plant growth, such as better nutrient content or soil structure.”

Given the information provided, write an alternative conclusion that uses the data provided and considers other possible factors influencing plant growth.

Apply

12 A scientist tested how the amount of light in a glasshouse affected the growth of wheat plants. When they analysed their results, they stated that their findings could not be applied to plants growing outside the glasshouse. **Discuss** why the scientist put a limit on how the findings of their investigation could be applied.

13 **Identify** which of the following doctors could be trusted to comment on vaccines. **Justify** your decision (by describing the qualifications of each type of doctor and comparing these to the type of information needed on vaccines).

- A person with a PhD in English literature
- Veterinarian
- Epidemiologist

14 You are part of a research team investigating the impact of urban development on local water quality. Your team needs to determine the best approach to study this issue and how to present your findings.

- **a** **Create** a method for conducting a laboratory experiment to test water samples from various locations within the urban area. Include steps for sample collection, testing procedures and data recording.
- **b** **Discuss** the advantages and disadvantages of using field work to collect water samples directly from different sites within the urban area. Consider factors such as accessibility, environmental conditions and data accuracy.
- **c** **Evaluate** the effectiveness of using computer modelling and simulations to predict future changes in water quality based on current urban development trends. What are the strengths and limitations of this approach?
- **d** **Justify** your choice of using comparative analysis to study the differences in water quality between urban and rural areas. **Explain** why this method is suitable for your research and how it can help identify key trends.
- **e** **Predict** the potential outcomes of implementing a new urban development policy aimed at improving water quality. Use a SWOT analysis to identify the strengths, weaknesses, opportunities and threats associated with this policy.

15 **Create** a fishbone diagram to identify and organise the possible causes of water pollution in the urban area. Include categories such as human activities, industrial processes and natural factors.

Lesson 1.11

Scientists communicate their findings

Key ideas

→ The results and findings of a scientific investigation are communicated using a scientific report or scientific poster.

→ When presenting a scientific argument, you must provide evidence to support your argument, using correct scientific language and terminology.

→ A scientific report should include all common sections and headings to clearly communicate the purpose, hypothesis, method and results and the data analysis that supports the conclusion.

→ A scientific poster is similar to a report, except it is more concise due to space limitations.

Learning intentions and success criteria

Communication is key

Stage 5 of the scientific method is communicating the data and findings generated during a scientific inquiry (Figure 1). This includes asking another scientist to check if they are correct. This process of **peer review** means the second scientist:

- evaluates the methods to identify assumptions, errors and improvements
- evaluates the results to identify outliers and anomalies
- evaluates the patterns or trends that were identified.

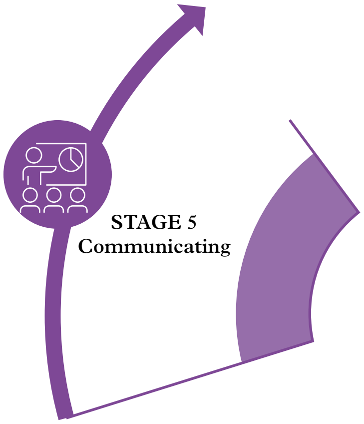


Figure 1 Stage 5 of the scientific method is **Communicating**.

peer review
a process in which experts evaluate the findings of a report before it is published

Introduction

Like all forms of communication, the way we communicate in science depends on the audience. If the audience does not know the key words or concepts that you are discussing, you will need to use simple diagrams, models and language so they understand what you are trying to say. For example, two physicists may say, "Potential energy was added to the rubber band", whereas a teacher may say, "The rubber band was stretched".

How to present a scientific argument

To present an effective scientific argument, you must use evidence to support your argument, correct scientific language and terminology. However, this will depend on your audience and the purpose of your investigation. This will ensure that your argument will be relevant and can be understood by others in the specific community you're addressing.

Evidence

For example, if you are arguing that climate change is affecting local weather patterns, you should present data on temperature changes, precipitation levels and extreme weather events. By using evidence, you can demonstrate the validity of your arguments and persuade the audience to your point of view.

Scientific language and terminology

Using correct scientific language and terminology is essential for precision and clarity. Scientific terms have specific meanings that convey complex concepts accurately. For example, when discussing chemical reactions, you would use terms like "reactants", "products" and "catalysts". This ensures that your arguments are understood by others in the scientific community.

When communicating with non-specialist audiences, explain technical terms when necessary and avoid complex scientific terminology.

Writing scientifically

Writing scientifically is different to writing an English essay. For example, read the next two paragraphs:

> **Descriptive**: The flower was pink with very soft delicate petals. It smelt like spring and filled the laboratory with a lovely scent as it got warmer. As it got hotter, the flower's petals wilted in the steam.
>
> **Scientific**: A beaker containing one rose and water was placed above a Bunsen burner to heat the water. When the water reached its boiling point, some of the water evaporated, producing steam. The heat from the steam caused the rose to wilt.

The descriptive sentence tells us all what was happening, but it does not give a scientific explanation for the behaviour of the flower. The scientific description offers a summary of what was done to the flower and why the flower reacted. It is important that you are concise when writing scientifically and that you do not include information irrelevant to the research.

Writing a scientific report

Scientists write reports so that their investigation and results can be reviewed by their science-trained colleagues or peers. As both the writer and reader are science trained, these reports will contain many terms that have particular meanings. For example, the word "significant" can mean "important" when used by a person in the street. But to a scientist, the word "significant" means that a result is "not due to chance". This means that the words in a scientific report need to be carefully chosen. Clear and detailed writing ensures that others can replicate the experiment and verify the results.

All scientific reports have common sections and headings. Table 1 explains each section that you will need to include in your scientific reports.

Table 1 Sections of a scientific report

Section	Description
Title	• A statement that includes the independent variable and the dependent variable.
Abstract	• Presented on its own page at the start of a report. • Offers a brief summary (no more than 250 words) about the aim, results and conclusion of an experiment. (HINT: You can read this to determine if research is relevant to your topic.)
Introduction	• A summary of any previous experiments that you have completed. • A description of the key concepts being examined and how they are related to your hypothesis.
Aim	• A statement of what you are trying to achieve in the experiment.
Hypothesis	• A prediction of how the independent variable will affect the dependent variable and the reason that supports the outcome. • "If … <how the independent variable will change> … then … <how the dependent variable will change> … because … <reason for the change>".
Method	• A list of the materials, containing the concentrations and brands, should be included in the method. • The method should contain step-by-step instructions or a brief description (in past tense) that would enable someone to repeat the experiment. • Safety advice or a risk assessment should be included. • Relevant labelled diagrams should be included where necessary.
Results	• The data should be presented in a table, graph or diagram. • A written summary of the results (stating facts without conclusions) should also be included.
Discussion	• This section should analyse the results by: – describing the relevant science concepts that occurred in the results – drawing conclusions from the results – comparing the conclusions to the hypothesis – describing how the results could apply in the real world.
Conclusion	• The conclusion should answer the aim of the experiment by: – comparing the conclusions to the aim – describing the limitations of the experiment (by describing situations where these results would not apply) – describing another investigation that could be conducted to confirm or extend the conclusions.
References	• Any sources that you used to research the scientific concepts or definitions should be included here. • There are different ways to write a reference. Check which style is preferred by your school. • Most scientific communications use APA Style (American Psychological Association Style). For example: Silvester, H. (2023). *Oxford Science 10 Australian Curriculum* (2nd ed.). Oxford University Press.

unbiased showing no prejudice for or against something

objective information that is free of prejudices, is based on evidence and is verifiable

When writing reports, scientists also avoid using the first person ("I", "we", "me", "you", "us", etc.). All science should be **unbiased** and **objective**.

Scientific reports and papers are written in the third person so that it is clear that the communication is objective, rather than being based on the opinions or beliefs of individuals.

Scientists usually use past tense when they write a report because they are describing something they have already completed. If results were described in present tense (the now) or future tense (the later on), then the reader or listener would not be sure if the experiment was finished.

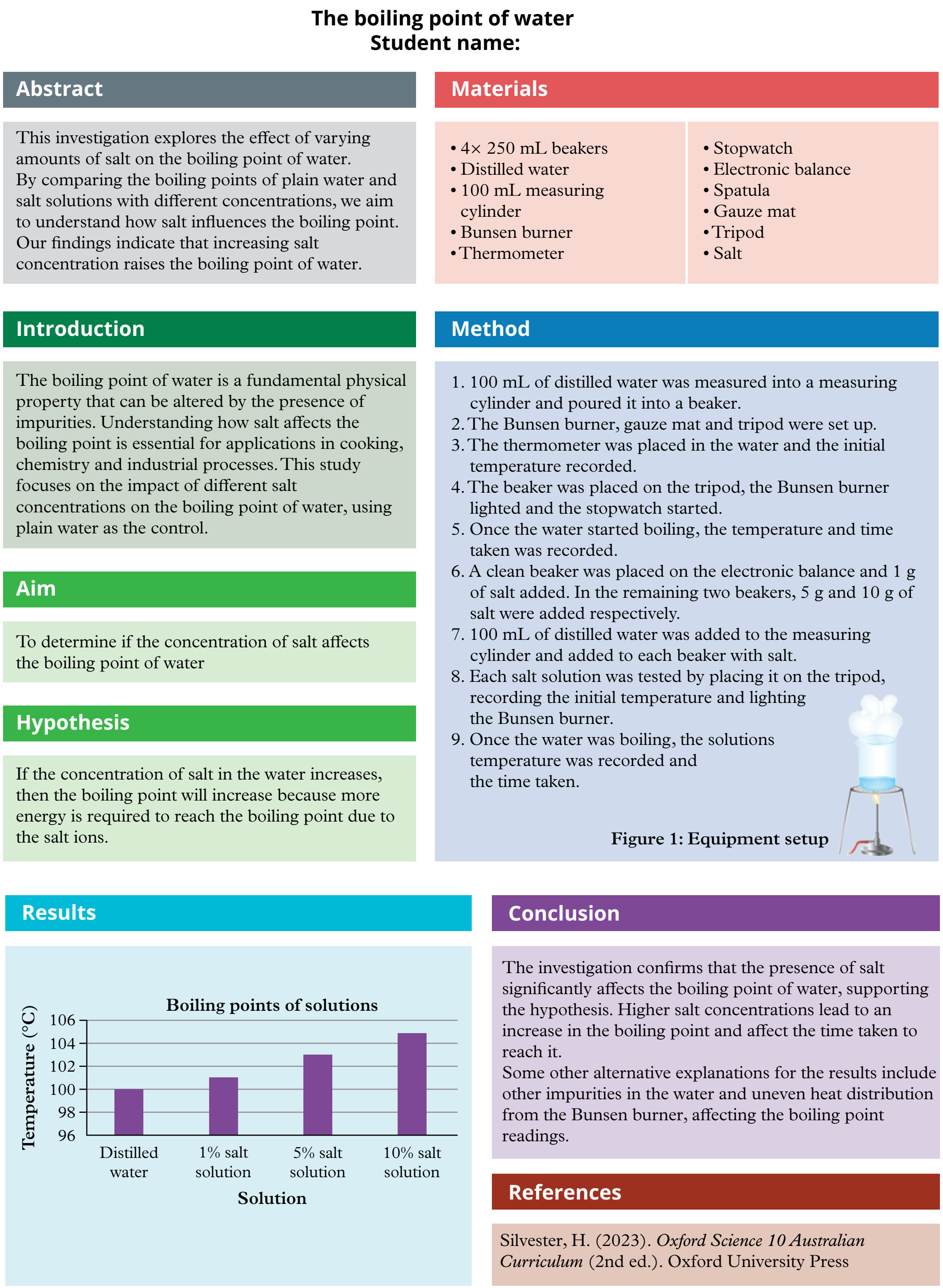
Some examples showing the differences between scientific language and common language are given in Table 2.

Table 2 Examples showing differences between scientific language and common language

Scientific language	Common language
The equipment was set up.	I set up the equipment.
The mass of the beaker was measured.	We weighed the beaker on the scales.
The beakers were heated to 50 degrees Celsius. (Past tense)	Heat the beakers to 50 degrees Celsius. (Present or future instruction)
The two trolleys were pulled apart. (Past tense)	Pull the two trolleys apart. (Present or future instruction)
The metal was malleable.	The metal could be bent into any shape.
At 6:15 am a single magpie sitting on a protruding tree branch called loudly for 30 seconds.	I think it was a magpie that sang the warbling song that woke me up in the morning.
The mass of the sodium bicarbonate was identified as a possible random error.	We could have improved the experiment if we were more organised and measured the amount of bicarb properly.

Creating a scientific poster

Another way to communicate your findings is to create a scientific poster (Figure 2). It contains all the components you would find in a scientific report but is a concise summary of an investigation, communicating the research process, findings and conclusion in an effective manner. Your teacher should be able to provide you with a digital or paper copy of a scientific poster template for you to work with.



The boiling point of water
Student name:

Abstract

This investigation explores the effect of varying amounts of salt on the boiling point of water.
By comparing the boiling points of plain water and salt solutions with different concentrations, we aim to understand how salt influences the boiling point. Our findings indicate that increasing salt concentration raises the boiling point of water.

Materials

- 4× 250 mL beakers
- Distilled water
- 100 mL measuring cylinder
- Bunsen burner
- Thermometer
- Stopwatch
- Electronic balance
- Spatula
- Gauze mat
- Tripod
- Salt

Introduction

The boiling point of water is a fundamental physical property that can be altered by the presence of impurities. Understanding how salt affects the boiling point is essential for applications in cooking, chemistry and industrial processes. This study focuses on the impact of different salt concentrations on the boiling point of water, using plain water as the control.

Method

1. 100 mL of distilled water was measured into a measuring cylinder and poured it into a beaker.
2. The Bunsen burner, gauze mat and tripod were set up.
3. The thermometer was placed in the water and the initial temperature recorded.
4. The beaker was placed on the tripod, the Bunsen burner lighted and the stopwatch started.
5. Once the water started boiling, the temperature and time taken was recorded.
6. A clean beaker was placed on the electronic balance and 1 g of salt added. In the remaining two beakers, 5 g and 10 g of salt were added respectively.
7. 100 mL of distilled water was added to the measuring cylinder and added to each beaker with salt.
8. Each salt solution was tested by placing it on the tripod, recording the initial temperature and lighting the Bunsen burner.
9. Once the water was boiling, the solutions temperature was recorded and the time taken.

Figure 1: Equipment setup

Aim

To determine if the concentration of salt affects the boiling point of water

Hypothesis

If the concentration of salt in the water increases, then the boiling point will increase because more energy is required to reach the boiling point due to the salt ions.

Results

Conclusion

The investigation confirms that the presence of salt significantly affects the boiling point of water, supporting the hypothesis. Higher salt concentrations lead to an increase in the boiling point and affect the time taken to reach it.
Some other alternative explanations for the results include other impurities in the water and uneven heat distribution from the Bunsen burner, affecting the boiling point readings.

References

Silvester, H. (2023). *Oxford Science 10 Australian Curriculum* (2nd ed.). Oxford University Press

Figure 2 A sample scientific poster

Check your learning 1.11

Check your learning 1.11

Retrieve

1 **Identify** what should be included in the discussion section of a scientific report.

2 Outline the correct order for the following items in a scientific report.

- **a** Discussion
- **b** Method
- **c** Results
- **d** Abstract
- **e** Introduction
- **f** Conclusion
- **g** Aim

3 **Explain** the difference between a scientific report and scientific poster.

Comprehend

4 **Explain** why a conclusion is written at the end of an experiment or investigation.

5 **Explain** why personal pronouns are not used in scientific reports.

6 **Explain** why it is important that scientists prepare scientific reports.

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

8 Rewrite the following statements using scientific communication.

- **a** I measured the speed of a skateboard.
- **b** The acid made lots of bubbles appear on the side of the metal.
- **c** When I put my hand in the water, it felt very cold. I think it was 15 degrees.

Analyse

9 **Compare** the information that is written in the results and discussion sections.

10 You are investigating the impact of different types of water filtration systems on the removal of contaminants from urban water sources. You have collected data on the effectiveness of three different filtration systems: System A, System B and System C.

Data:

- System A: Removes 85% of contaminants, costs \$200, lasts 2 years.
- System B: Removes 90% of contaminants, costs \$300, lasts 3 years.
- System C: Removes 80% of contaminants, costs \$150, lasts 1 year.

Analyse the data provided to communicate scientific ideas and information for the purpose of recommending the best water filtration system for urban use. Construct evidence-based arguments and use appropriate scientific language, conventions and representations to answer the following questions:

- **a** **Classify** the filtration systems based on their effectiveness, cost and lifespan.
- **b** **Compare** and **contrast** the advantages and disadvantages of each filtration system.
- **c** **Distinguish** between the short-term and long-term benefits of each system.
- **d** **Interpret** the data to determine which system offers the best balance of cost-effectiveness and contaminant removal.
- **e** **Calculate** the annual cost of each filtration system and use this information to support your recommendation.

Apply

11 You are part of a team tasked with investigating the spread of a new infectious disease in your local urban area. The following data has been collected (Table 3).

Table 3 Data collected from the spread of a new infectious disease

Infection rates	Age distribution of cases	Hospitalisation rates	Recovery rates
Week 1: 50 cases **Week 2:** 120 cases **Week 3:** 200 cases **Week 4:** 350 cases	**0–10 years:** 30 cases **11–20 years:** 70 cases **21–30 years:** 100 cases **31–40 years:** 150 cases **41–50 years:** 200 cases **51+ years:** 170 cases	**Week 1:** 10% **Week 2:** 15% **Week 3:** 20% **Week 4:** 25%	**Week 1:** 30% **Week 2:** 40% **Week 3:** 50% **Week 4:** 60%

Present a scientific argument, providing a clear and concise summary to the city council of your findings. **Use** appropriate scientific language and conventions, including evidence-based arguments and visual aids such as graphs, charts and diagrams to convince the council of the importance of your solution. Some things to consider include:

- your proposed measures to control the spread of the infectious disease
- the potential impact of your proposed measures on public health and the community
- the feasibility of your proposed measures, taking into account factors such as cost, resources and community acceptance
- the long-term outcomes of implementing your proposed measures
- use of scientific language and conventions to explain how your proposed measures will reduce the spread of the disease over time.

Lesson 1.12

Command terms identify the tasks in a question

Key ideas

→ Command terms are instructive words that require specific types of mental processes to perform set tasks.

→ Command terms can be grouped into categories based on the level of cognition required to perform the task.

Learning intentions and success criteria

Command terms

Command terms are instructive words that require specific types of mental processing or “**cognition**” to perform set tasks. For example, the word “explain” is a command term because it requires you to first recall what you understand about something and then reframe that understanding into clearer succinct terms. Command terms are often used in questions, which means you will encounter a variety of different command terms in school as you learn new information and undertake assessments.

command term a “doing word” that requires you to perform a specific thinking task

cognition mental processes that are involved in acquiring, storing, manipulating and retrieving information

Familiarising yourself with different command terms and the tasks and thinking processes behind them can help you determine how to best respond to a question. An understanding of command terms can be the difference between achieving partial or full marks on an important exam or assessment question (Figure 1).

Some command terms require multiple or more complex cognitive processes than others. For example, if you were asked to **name** the two fruits in Figure 2, you may instantly recall "apple" and "orange". However, if you were asked to **compare** the two fruits, you would also need to consider the two fruits and identify at least one similarity and one difference between them. In this sense, "compare" involves more cognitive processes than "name".

Table 1 lists common command terms and their associated tasks. It also shows four categories of thinking processes that can be used to group command terms: retrieve, comprehend, analyse and apply.

"Retrieve" questions come before "apply" questions. This is because retrieve questions ask you to perform a simpler cognitive task – remembering – than apply questions. An apply question requires you not only to recall information but also to interpret that information and determine how it can be used in a specific situation. Performing questions in order of simpler cognitive processes to more complex cognitive processes can support the way you acquire and understand new information.

Figure 1 Familiarising yourself with different command terms can help you answer questions and improve your learning.

Figure 2 Two healthy fruits

Table 1 Common command terms and their tasks

Command term	Task	Category
Define	give the meaning of a word	**Retrieve** – Recall information from permanent memory.
Identify	recognise and state a distinguishing factor or feature	
Name	provide the correct term or noun	
Recall	present remembered ideas, facts or experiences	
Use	operate or put into effect	
Select	pick out	
Describe	give an account of a situation, event, pattern or process, or of the characteristics or features of something	**Comprehend** – Activate and transfer knowledge from your permanent memory to your working memory.
Explain	make an idea or situation plain or clear by describing it in more detail or revealing relevant facts	
Summarise	give a brief statement of a general theme or major point/s; present ideas and information in fewer words and in sequence	

Command term	Task	Category
Calculate	determine or find (e.g. a number, answer) by using mathematical processes	**Analyse** – Use your reasoning to go beyond what was directly taught.
Categorise	place in or assign to a particular class or group	
Classify	arrange, distribute or order in classes or categories according to shared qualities or characteristics	
Compare	display recognition of similarities and differences and recognise the significance of these similarities and differences	
Contrast	give an account of the differences between two or more items or situations	
Distinguish	recognise as distinct or different; note points of difference between	
Interpret	use knowledge and understanding to recognise trends and draw conclusions from given information	
Create	reorganise or put elements together into a new pattern or structure	**Apply** – Use your knowledge in specific situations.
Discuss	examine by argument; sift the considerations for and against; talk or write about a topic	
Evaluate	examine and determine the merit, value or significance of something	
Elaborate	investigate, inspect or scrutinise	
Justify	give reasons or evidence to support an answer, response or conclusion	
Predict	give an expected result of an upcoming action or event	

Check your learning 1.12

Check your learning 1.12

Retrieve

1 **Define** the term "command term".

2 **Identify** the command term that requires you to "use knowledge and understanding to recognise trends and draw conclusions from given information" and **identify** the category of thinking process this verb belongs to.

Comprehend

3 **Explain** in your own words what is required to correctly answer:

- **a** a "discuss" question
- **b** a "calculate" question
- **c** a "predict" question.

Analyse

4 **Compare** the terms "categorise" and "classify".

Apply

5 After conducting an experiment on how temperature affects the plant growth of corn and beet plants, a student was asked: "Identify which plant would be more suitable to grow in a hot environment. Justify your answer". Their response was: "The corn would be more suitable to grow in a hot environment". **Evaluate** whether the student has correctly answered the question.

Lesson 1.13

Review: Science toolkit

Summary

Lesson 1.1 Scientists value the knowledge and skills of Aboriginal and Torres Strait Islander Peoples

- Aboriginal and Torres Strait Islander Peoples have developed sophisticated science skills that enabled them to survive and thrive some of the most challenging environments in the world for tens of thousands of years.
- Indigenous science sees everything as connected – the land, water, plants, animals and people are all part of one big system that remains in balance.
- The scientific knowledge and skills of Aboriginal and Torres Strait Islander Peoples is now recognised and valued by Western scientists.

Lesson 1.2 Scientists follow the scientific method

- The scientific method is a framework that helps scientists figure out how things work by asking questions and testing ideas. It is an essential tool to guide scientific inquiry and research that is valid and reliable.
- There are five stages to the scientific method.
- Pseudoscience is a term used to describe theories, beliefs or claims that seem scientific but aren't backed by any real evidence or results from experiments.

Lesson 1.3 Scientists form hypotheses that can be tested

- There are variables that must be considered when trying to answer a question and formulate a hypothesis. This includes independent, dependent and controlled variables.
- A **prediction** is a specific statement about **what** you expect to observe when you try to answer your question.
- A **hypothesis** is a proposed scientific explanation for a question. It should try to explain **why** something happens based on previous observations, research or your reading on the topic. It is often written as an "If... then...because..." statement.

Lesson 1.4 Scientists plan and conduct investigations

- The type of data being collected will determine what investigation method is used.
- When planning and conducting an investigation, it must be reproducible by others.
- Ethics considers "Should we?" when determining whether an investigation should be carried out on people, animals or the environment.
- When conducting field work, scientists must seek permission from the land owner or organisation to access the land.
- If research is being conducted at culturally significant sites, appropriate protocol must be followed to access the site, not damage any sacred objects, and limit access to people who have permission to be there.
- The results obtained from investigations must be reliable, as this indicates the investigation method is sound.

Lesson 1.5 Scientists always take safety precautions

- When working in the laboratory, is important to follow all safety rules to keep yourself and others safe.
- All risks must be recognised and managed when conducting investigations.
- Safety data sheets are used to communicate information about how to handle and store the substance, as well as first aid information in the event of an accident.
- Pictograms are symbols used to communicate the specific type of hazard the substance presents.
- A risk assessment is created before beginning an investigation. It helps identify risks and describes how to prevent and mitigate them if they occur.
- When working with chemicals, they must be safely disposed and not poured down the sink, as they can be toxic for the environment.

Lesson 1.6 Scientists use specialised equipment

- When conducing investigations, select suitable materials, equipment and technologies that will provide accurate and precise results.

- In an investigation, multiple trials are conducted to ensure the method is reliable and the data is accurate and precise.
- Errors in an investigation can affect the outcome, so you must be aware of how systematic errors can occur.

Lesson 1.7 Scientists use tables, graphs and models to record and process data

- Scientists need to collect data and present it in an organised manner.
- Tables and graphs allow scientists to identify patterns in their results.
- 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.
- Keys help scientists interpret or identify information in scientific diagrams, maps and data.
- Models are representations that help explain scientific concepts or can be used to test explanations.
- Mathematical relationships show connections between variables and pieces of data, and express them as numbers or equations.
- The data presented in some graphs can be extrapolated or interpolated to make predictions.
- If using data from secondary sources, you need to check they are reliable sources.

Lesson 1.8 Scientists keep a logbook

- A logbook is used by scientists in the laboratory and in the field to record the details and results gathered during experiments and research.
- A logbook provides evidence of the planning, changes and results of an experiment.

Lesson 1.9 Scientists analyse trends in data

- Describing trends in graphs will help determine the relationship between variables.
- Measures of centre can be used to analyse a data set.
- To determine the validity and reliability of data, the investigation must have measured the intended variable and the data must be consistent across trials.
- A conclusion must be included, identifying whether the hypothesis was supported or refuted using evidence.
- Sources of uncertainty should be considered.

Lesson 1.10 Scientists evaluate conclusions

- To solve a problem, there are different approaches that can be used.
- Bias can affect all aspects of a scientific investigation and can skew the outcome.
- Do not take information from secondary sources as true until you check who wrote it, where it has been published and if it's current.
- Possible alternative explanations for the observed results should be considered.
- The quality of the data can be improved by repeating trials, having your work peer reviewed, using calibrated digital equipment, analysing sources of error, evaluating the data and improving data recording.

Lesson 1.11 Scientists communicate their findings

- The results and findings of a scientific investigation are communicated using a scientific report or scientific poster.
- When presenting a scientific argument, you must provide evidence to support your argument, using correct scientific language and terminology.
- A scientific report should include all common sections and headings to clearly communicate the purpose, hypothesis, method and results and the data analysis that supports the conclusion.
- A scientific poster is similar to a report, except it is more concise due to space limitations.

Lesson 1.12 Command terms identify the tasks in a question

- Command terms are instructive words that require specific types of mental processes to perform set tasks.
- Command terms can be grouped into categories based on the level of cognition required to perform the task.

Review questions 1.13

Review questions: Module 1

Retrieve

1 **Identify** the most appropriate definition of "independent variable".
  - **A** The variable that is measured
  - **B** The variable that is controlled
  - **C** The variable that is deliberately changed by the scientist
  - **D** The variable that is measured at the end of the experiment

2 **Identify** which of the following statements is correct.
  - **A** Correlation means causation.
  - **B** Data are described in the method section of a scientific report.
  - **C** Data are analysed in the results section of a scientific report.
  - **D** A safety data sheet should include the protective equipment to be used for a chemical.

3 **Identify** which of the following scientists could be trusted to make a claim on the growth rate of plants.
  - **A** General practitioner in medicine (GP)
  - **B** Chiropractor
  - **C** Person with a masters of Botany
  - **D** Person with a PhD in epidemiology

4 **Identify** the main steps used when conducting an experimental investigation by the scientific method.

5 **Define** the term "variable".

6 **Identify** why consumer scientists are interested in what can be observed and tested, rather than in the slogans and claims of manufacturers.

7 A student conducts an experiment where they measure the amount of mass produced over time. They collect data for up to 50 seconds and then create the graph in Figure 1. **Recall** the term that describes what they have done with their graph.

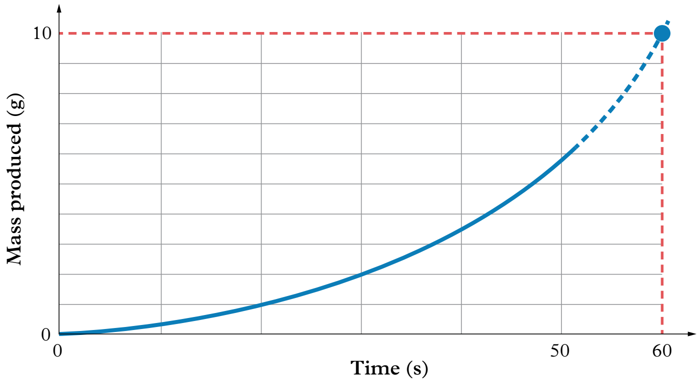


Figure 1 A graph created by a student

8 **Identify** three types of information that should be included on a safety data sheet.

9 **Identify** the most accurate way to measure each of the following in your school science laboratory.
  - **a** Time
  - **b** Mass
  - **c** Length

10 **Define** the following terms.
  - **a** Valid
  - **b** Reproducible
  - **c** Accuracy

Comprehend

11 **Describe** how scientists find out about the safety risks involved in an experiment they are planning.

12 Suppose you are conducting a fair experiment in which you have identified six variables. **Explain** how you can be sure of the effect of one particular variable.

13 **Explain** why beakers are not used to measure volumes.

14 **Explain** why every experiment should have a large sample size.

15 **Explain** why it is important that scientific papers are peer reviewed.

Analyse

16 **Define** and **contrast** independent, controlled and dependent variables.

17 **Contrast** the four categories of command terms and **identify** an example of a command term and its task for each category.

18 A student has written a report using information they read in an article posted on social media by an influencer. **Consider** whether the student has used a valid secondary source.

19 **Calculate** the range of the following measured lengths if two pieces of wood (5.2 ± 0.1 cm and 2.3 ± 0.1 cm) were added together.

20 A student used a measuring cylinder to measure two volumes: 15 mL and 18 mL. The uncertainty for both measurements was 0.2 mL. **Calculate** the final volume and uncertainty if the two liquids were combined.

Apply

21 A consumer scientist wanted to test the effect of a lotion for treating acne. They first tested the lotion on a group of 20 teenagers, all aged 15, but then they decided to conduct more tests. So they then tested 100 more teenagers, all aged 15.

- a **Determine** whether this is an example of experimental repetition or increasing the sample size.
- b **Decide** which result (using 20 teenagers or 120 teenagers) is likely to lead to the most reliable conclusion. **Justify** your answer (by comparing the reliability of the test of 20 teenagers to that of 120 teenagers and deciding which is more reliable).

22 A scientist was commissioned by a jeans manufacturer to test various denims. The manufacturer wanted a more durable fabric than the one they were currently using. **Describe** how the scientist might test a fabric for durability in a valid way. **Discuss** why this is important.

Figure 2 How might a scientist test the durability of different denims?

23 A make-up manufacturer claims that their brand of tinted lip gloss will stay on for at least 6 hours, even during eating and drinking. **Create** an experiment based on the scientific method to test this claim. **State** your hypothesis, and then **identify** the variables you will be considering. **Describe** the measurements you will take and how you will ensure that they are accurate.

- a **Predict** the results you would expect to obtain if your stated hypothesis was correct.
- b **Evaluate** the accuracy of the results that you may measure and suggest what further investigation you could undertake to improve the reliability of your conclusions.
- c Assuming you found that the manufacturer's claim was correct, **create** a scientifically accurate slogan or advertisement for the lipstick based on your findings.

Figure 3 What results would be expected for the hypothesis from question 23?

24 You are investigating the effect of different exercise routines on heart rate recovery times. You have collected the following data on recovery times (in minutes) for two different exercise routines, Routine A and Routine B.

Data:

- Routine A: 5, 6, 7, 8, 5, 6, 7, 8, 5, 50
- Routine B: 10, 12, 11, 13, 12, 11, 10, 12, 11, 13

a **Calculate** the mean (average) recovery time for Routine A and Routine B.

b **Calculate** the median recovery time for Routine A and Routine B.

c **Identify** the mode (most frequent value) of recovery times in Routine A and Routine B.

d **Identify** any outliers in the data for Routine A and Routine B.

e **Explain** how these outliers affect the mean, median and mode.

f **Discuss** the implications of the outliers on the overall analysis of heart rate recovery times for different exercise routines.

Social and ethical thinking

25 Two phrases commonly used in advertising are "Scientists have proved …" and "Recommended by scientists". These are often accompanied by pictures of named scientists who are paid to appear in the advertisement. **Discuss** the ethical implications of using these phrases or pictures of scientists, by completing the following.

a **Describe** why the company may choose to use the phrases or a picture of a scientist.

b **Describe** how a person viewing the advertisement might be affected by the use of the phrases or pictures.

c **Describe** how a person would be affected if the phrases/pictures were not used.

d **Evaluate** whether using the phrases/pictures disadvantage the person viewing the advertisement.

e **Decide** whether the phrases/pictures of scientists should be allowed in advertising.

Critical and creative thinking

26 One source of information for consumers is *Choice* magazine. The magazine reports the results of testing of a variety of brands of consumer products.

a If a consumer scientist was reading a report on the safety of children's pyjamas, **describe** the evidence they might look for to see if the report was fair and objective.

b If the scientist concludes that the report is reliable, **propose** how the public might be convinced to read the report before purchasing children's pyjamas.

Research

27 Choose one of the following topics for a research project. Some questions have been included to help you begin your research. Present your findings in a format of your choosing.

Bottled water

Many people in Australia spend a lot of money on bottled drinking water. Are they doing this because of the way the water is marketed, or are there scientifically supported health benefits in drinking bottled water rather than tap water? Is tap water unsafe to drink? Have there been any cases where water bottlers have been fraudulent in their claims about the water they are selling? Investigate this issue.

- Find out what dentists and medical experts say about bottled water.
- **Describe** the scientific tests that are performed to check that the claims are correct and that the results that have been obtained are valid.
- After researching and comparing a range of evidence, **evaluate** whether we should drink bottled water in Australia or use tap water.
- **Describe** any limitations of your conclusions (for example, does it depend on where you live?).

Figure 4 Why do people drink bottled water?

Mobile phone safety

Research is continuing into the safety of mobile phones, although most people in the Western world have one or use one. You are an advisor to the minister of communications and technology.

- Produce a report, of at least 10 points, detailing research that has taken place into mobile phone safety.
- Make sure you assess the validity of these secondary sources.
- Include the outcomes or conclusions reached in these studies.

Figure 5 People of all ages use mobile phones.

Artificial colourings and flavourings in foods

Some people claim that certain artificial colourings and flavourings in foods can cause problems, such as hyperactivity in children. Use the internet and other resources to investigate this issue.

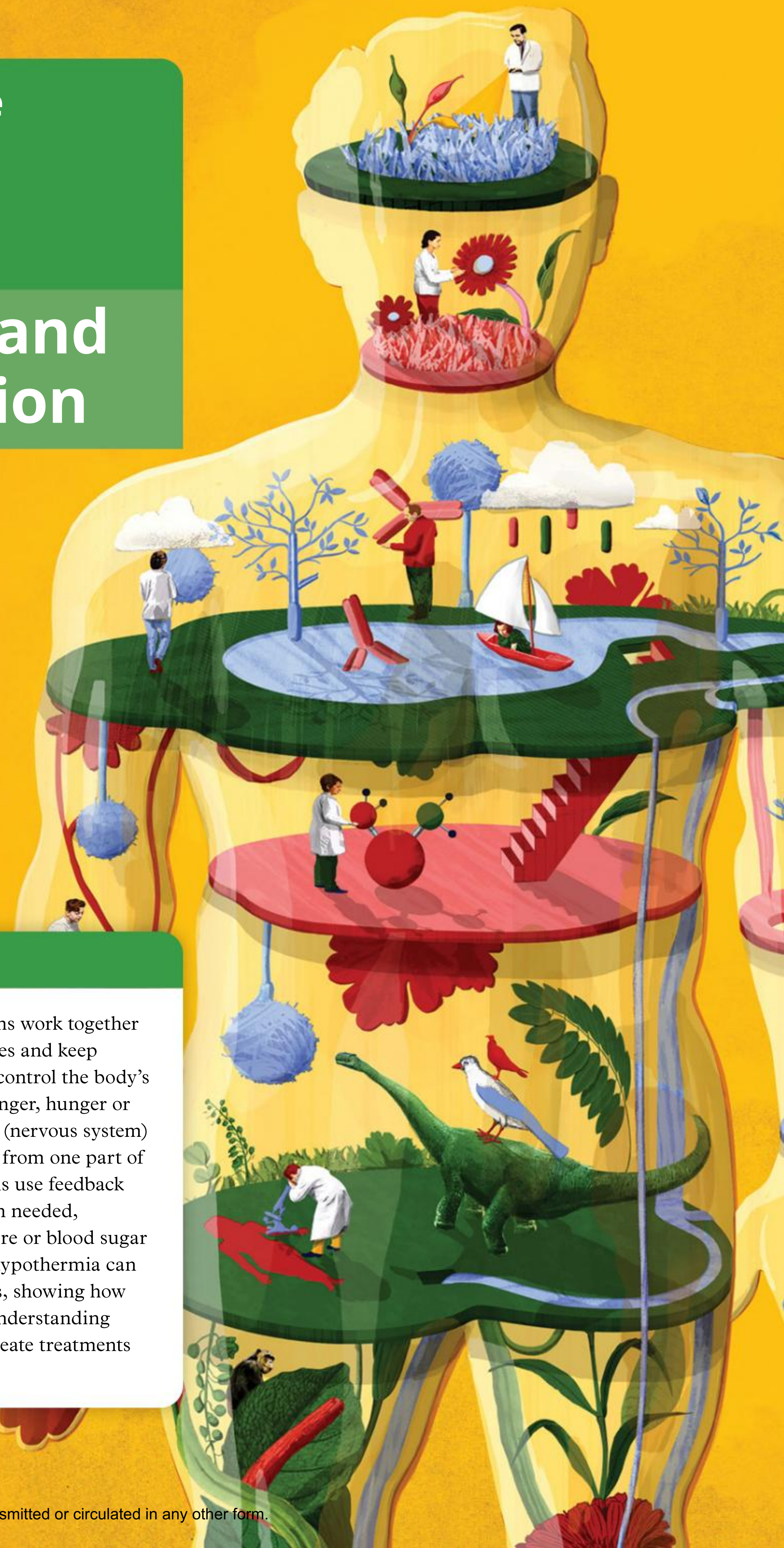
- **Describe** the reliability of each of the sources that you use by identifying the source, the reason for the article and the validity of the data used.
- **Define** the term “opposing evidence”.
- **Identify** whether the warnings are based on anecdotal evidence or scientific evidence.
- **Discuss** whether anecdotal evidence can be of value to scientists.

Figure 6 Are artificial colourings and flavourings in foods bad for us?

Module

2

Control and regulation



Overview

The nervous and endocrine systems work together to help the body respond to changes and keep everything in balance. They help control the body's reactions to temperature, light, danger, hunger or thirst by sending electrical signals (nervous system) and hormones (endocrine system) from one part of the body to another. These systems use feedback loops to adjust and fix things when needed, including keeping body temperature or blood sugar steady. Problems like diabetes or hypothermia can cause problems with these systems, showing how important balance is for health. Understanding these feedback loops has helped create treatments such as insulin for diabetes.

Lessons in this module

Lesson 2.1

Receptors detect stimuli

Key ideas

→ Your body has receptors that detect changes (stimuli) in the environment.

→ The five main types of external receptors detect light, sound, chemicals in the air and in your mouth, and touch.

Learning intentions and success criteria

Introduction

Your body responds to changes in its environment. Receptors detect these changes and pass the information to other parts of the body. A stimulus is any change in the internal or external environment that your body receives that might cause it to respond. For example, touching a hot surface is a stimulus that triggers an immediate response from your body to move your hand away.

Responding to change

stimulus any information that the body receives that causes it to respond

response a change in an organism's behaviour or function in reaction to a stimulus

Within our bodies, we regularly respond to changes without being aware of a **stimulus** and **response**. What makes you aware that you're hungry or thirsty? Something in your body is communicating with your brain to tell you to find food or water (Figure 1). A similar process occurs when you feel tired or have a headache. What is the source of these stimuli?

Other examples of stimuli are less obvious. We are surrounded by bacteria, viruses and fungi. Although many of them are too small to see, our bodies are constantly monitoring their numbers and fighting off harmful microorganisms (Figure 2).

Your body is an amazing combination of cells, tissues, organs and systems, all working together. Each contains cells that play a part in detecting stimuli and passing on the information to other parts of the body. The structures that detect stimuli or changes in the environment are called **receptors**. For example, photoreceptors in your eyes detect light, and thermoreceptors in your skin sense changes in temperature.

receptor a structure that detects a stimulus or change in the normal functioning of the body

Figure 1 We often respond to hot weather by drinking more.

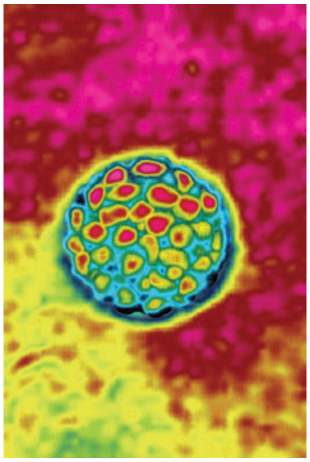


Figure 2 The human papillomavirus (seen here under a microscope) stimulates an immune response in the human body.

The sense organs

Our body can detect five main signals: light (sight), sound (hearing), chemicals in the air (smell) and in our mouth (taste), and touch (pressure, heat and pain). These are external senses because they tell us about the world outside our body. The sense organs – the eyes, ears, tongue, nose and skin – are highly specialised to receive stimuli from the environment.

Sight

Sight tells us more about the world than any other sense. The pupils change size to control how much light enters the eyes (Figure 3). The different types of photoreceptor cells at the back of the eyes transform the light into nerve signals for the brain (Figure 4). Photoreceptors include rods, which are sensitive to low light levels and help with night vision, and cones, which detect colour and work best in bright light.

It is not only your eyes that allow you to see but also your brain! The information from your eyess is transferred to your brain, which then tells you what you are seeing.

Figure 3 A crocodile's eye has an elliptical (oval-shaped) pupil, which helps to protect its sensitive retina from the bright light of day.

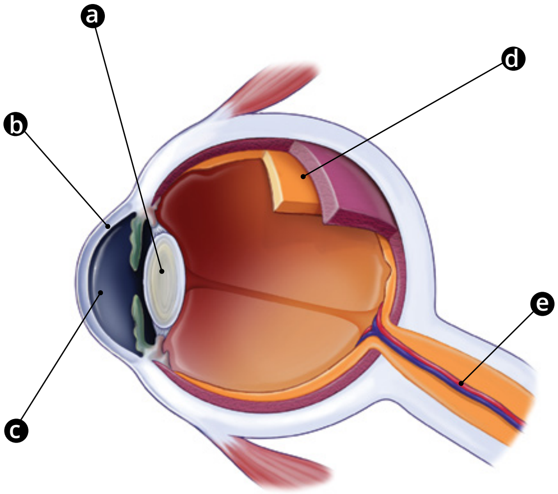


Figure 4 Photoreceptors in the human eye transform light into nerve signals.

- a The lens focuses incoming light.
- b The cornea bends incoming light.
- c The iris controls the amount of light entering the eye.
- d Photoreceptor cells in the retina change light into nerve signals.
- e Nerve impulses travel through the optic nerve to the brain.

Hearing

The strumming of a guitar causes the particles in the air to vibrate. These vibrations are collected by the outer ear, which funnels sound waves into the ear canal and directs them to the eardrum (Figure 5). The eardrum vibrates and transfers the sound energy to the middle ear, where the smallest bones in your body – the hammer, anvil and stirrup – amplify the vibrations and pass them into the cochlea. In the cochlea, the vibrations are converted into nerve impulses by hair cells (Figure 6). The brain then interprets the information, telling you what you are hearing.

Parts of your ear also control your sense of balance. The vestibular system is a group of three tubes filled with fluid and tiny hair cells that detect movement. As you spin, the fluid in these tubes moves, stimulating the hair cells and sending signals to your brain about your position and motion.

When you stop spinning, the fluid continues moving for a short time, even though you are stationary. This confuses your brain, causing you to feel dizzy or unbalanced. This reaction coordinates with your sight (to stabilise your vision) and touch (through pressure receptors in your feet) to help you recognise which way is up and prevent falls.

Figure 5 The large ears of some bats help them use sound waves to locate their prey.

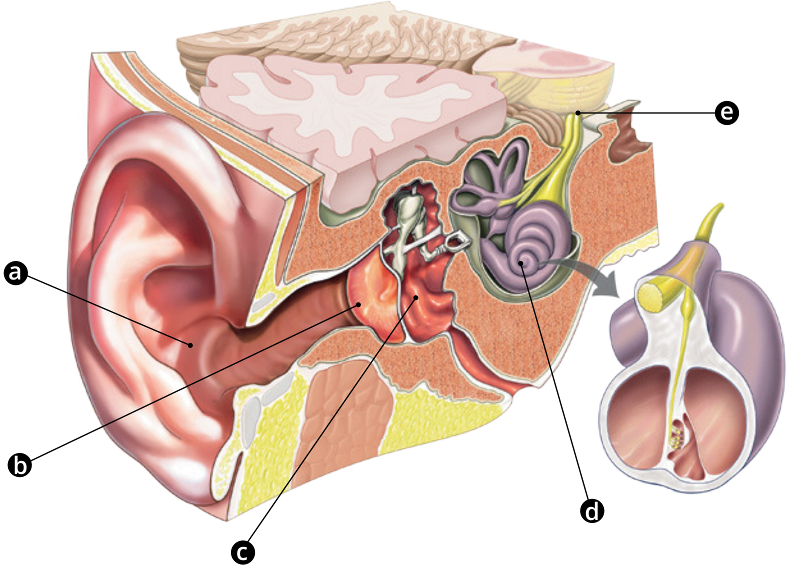


Figure 6 The human ear transfers vibrations to the middle ear. These vibrations become nerve impulses.

- ⓐ Sounds enter the ear through the ear canal.
- ⓑ Eardrum.
- ⓒ Vibrations passing through the middle ear are changed to nerve impulses.
- ⓓ The cochlea contains fluid that moves due to vibrations coming from the middle ear. This motion becomes an electrical signal that is passed to nerve cells.
- ⓔ Nerve impulses travel through the auditory nerve to the brain.

Taste

Your tongue is covered in thousands of tiny taste buds (Figure 7 and Figure 8). You can see this in a mirror. Taste buds contain special receptor cells that react to chemicals in foods. These chemical receptors can recognise basic kinds of taste molecules, such as sweet, salty, sour, bitter and umami (savoury). When you eat or drink, the information from the taste receptor cells is sent to your brain through nerves. It is the mix of chemical molecules that your brain detects as the flavours you are tasting.

Figure 7 A dog uses its tongue for many things, including taste and temperature control. Panting moves cool air over the tongue and lungs, allowing moisture to evaporate, thus cooling the body.

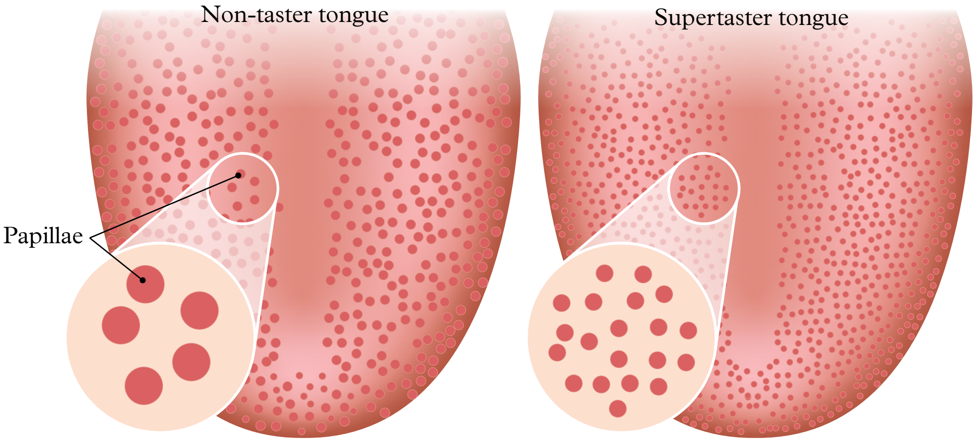


Figure 8 The tongue is covered in bumps, called papillae, which contain tastebuds that enable us to taste. A supertaster has many more papillae than average, and a non-taster has fewer.

Smell

Like taste, our perception of smell depends on chemical receptors (Figure 9). The receptors in our nostrils detect chemicals in the air and then send messages to the brain, which interprets the messages and tells us what we are smelling (Figure 10). Smell is closely linked to taste. If this seems strange, think about the last time you had a bad cold and a blocked nose. Did it affect your ability to taste? A lot of what people think is taste is actually smell.

Figure 9 Elephants use their trunks for a wide range of smelling tasks, such as sensing danger.

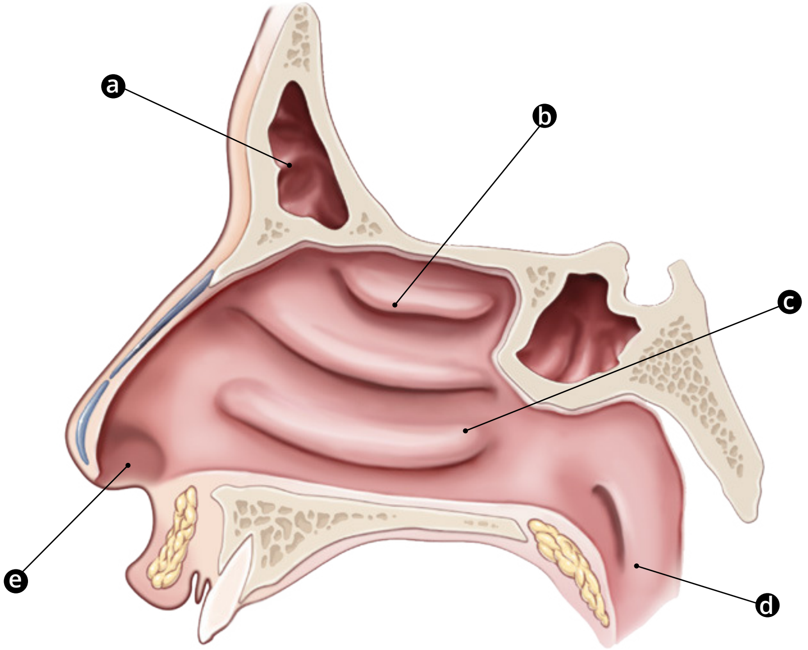


Figure 10 Smell receptors in human nostrils detect chemicals and send messages to the brain.

- ⓐ Mucous provided by nasal sinuses helps to trap bacteria and small particles.
- ⓑ Smell receptors above the nasal cavity stimulate the olfactory bulb, which sends messages to the brain.
- ⓒ Air movies through the nasal cavity to the back of the throat.
- ⓓ Air travels to the trachea and into the lungs.
- ⓔ Air enters the nose through the nostrils.

Touch

While the other four senses are in specific locations, touch is felt all over the body, through the skin (Figure 11). The inner layer of skin, called the dermis, contains many nerve endings that can detect heat, cold, pressure and pain (Figure 12). Information is collected by the different receptors and sent to the brain for processing and reaction.

Figure 11 The skin of a human fingertip has about 100 touch receptors.

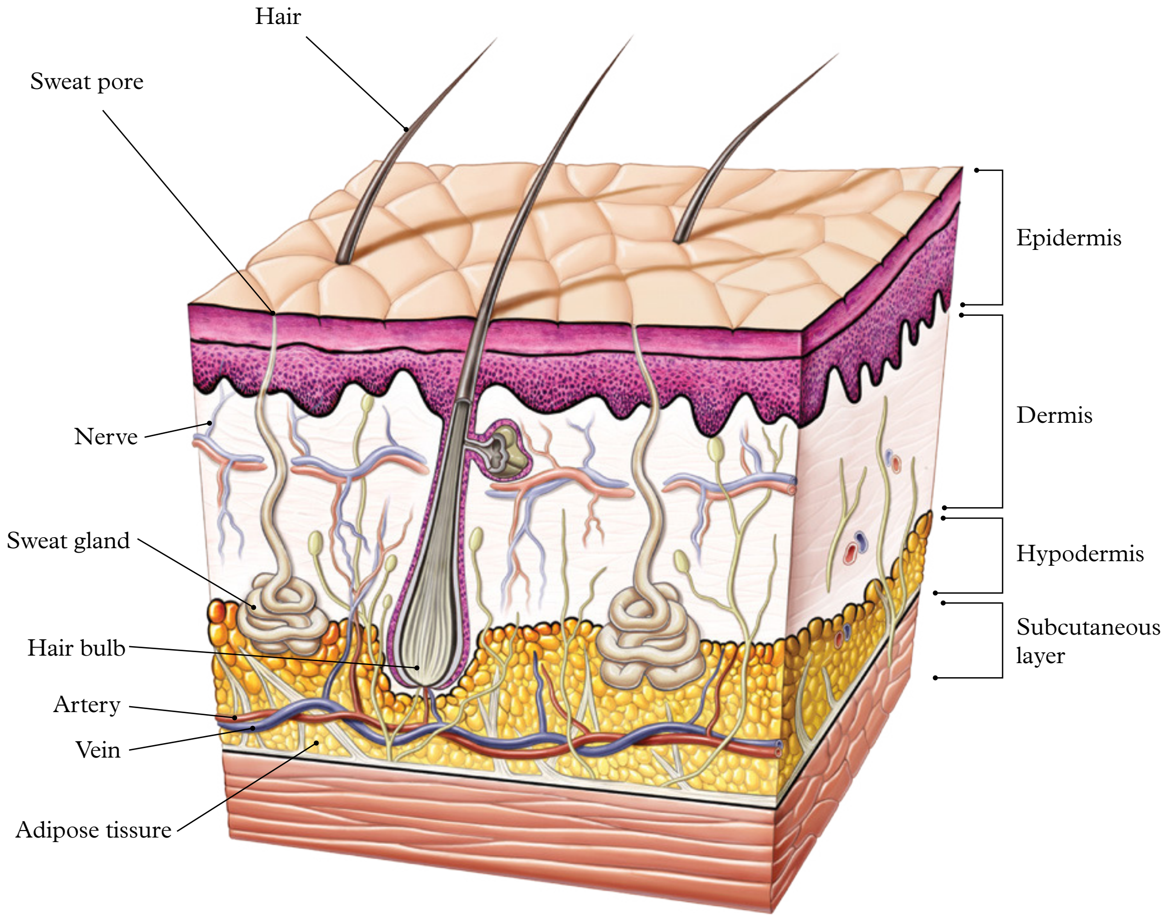


Figure 12 A cross-section of human skin

Check your learning 2.1

Check your learning 2.1

Retrieve

1 **Define** the term "stimulus".

2 **Identify** the five major sense organs.

Comprehend

3 Stimuli can be changes in our immediate environment or changes within our bodies. **Describe** two examples of each.

4 **Describe** two situations in which each sense organ would need to respond.

Analyse

5 **Compare** the way you detect smell and the way you detect taste.

Apply

6 "A person has more than five senses." **Evaluate** this statement by:

- **a** describing the five senses that are being referred to
- **b** describing what happens to your balance when you spin around quickly (sense of balance) and identifying if any of the five senses you listed were part of the reaction
- **c** describing how your body reacts when you are sick (sensing bacteria) and identifying if any of the five senses you listed were part of the reaction
- **d** deciding whether the original statement is correct.

Skills builder: Planning investigations

7 Jacob wants to know if the receptors sensitive to umami are distributed evenly on the tongue or concentrated in particular areas. He wants to give people the following foods to test his theory: sour hard sweets, gummy bears, sea salt crisps, grapefruit and mi goreng.

- **a** **Describe** the experimental method Jacob could use to test his theory. (THINK: What is Jacob trying to test? How many repeats would he need to measure?)
- **b** **List** any additional materials Jacob might need. (THINK: How could he make this experiment safe? How would the flavours be tasted?)
- **c** **Select** two risks associated with Jacob's test. (THINK: Does Jacob need to use people in his experiment? Are there allergies?)
- **d** **Explain** how the risks you identified in part c could be managed. (THINK: What would Jacob need to know about the participants? How could he avoid making people sick?)

Lesson 2.2

Nerve cells are called neurons

Key ideas

- → Neurons are cells in our body that enable messages to be passed quickly.
- → A change is detected by the receptor and an electrical message is passed along the neuron to the synaptic terminal.
- → Chemical neurotransmitters pass the message across the gap to the next neuron.
- → The myelin sheath protects parts of the neuron and increases the speed of messages being sent.

Learning intentions and success criteria

Nerves

The basic unit of the nervous system is the nerve cell, or **neuron**. Scientists believe that we may have up to 100 billion neurons in our bodies, connected in paths called nerves.

Neurons have many highly specialised features. Each neuron has a large **cell body** that connects to a long thin **axon**. An axon carries nerve impulses away from the cell body. The axons connecting your spinal cord to your foot can be up to 1 m long.

At the end of the axon are small bulbs, called synaptic terminals. Each synaptic terminal releases information into the synapse (Figure 1). The next neuron receives these messages from the synapse via its dendrites.

Nerves work just like electrical wires and require insulation in the same way. The axons are covered by a fatty layer called the **myelin sheath**. The myelin sheath helps to protect and speed up a nerve impulse and keep it moving along an axon. People with multiple sclerosis have damaged myelin sheaths. This means that the nerve impulse is disrupted, blocked or unable to move along the length of the axon. A person with multiple sclerosis can therefore have difficulties with movement.

neuron a nerve cell

cell body the main part of a cell that contains the nucleus/genetic material

axon the part of a neuron (nerve cell) that carries an electrical message away from the cell body to the synapse

myelin sheath a fatty layer that covers the axon of a nerve cell

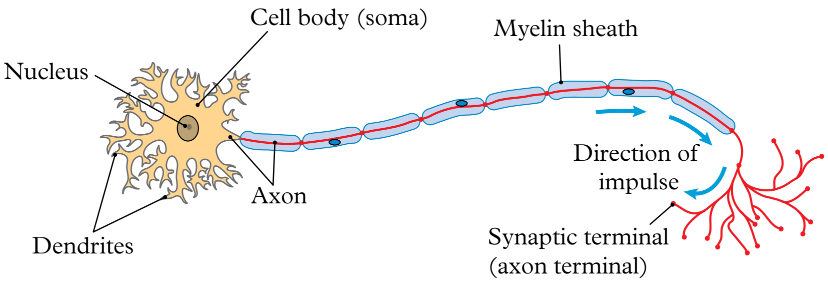


Figure 1 A typical neuron

dendrite the part of a neuron (nerve cell) that receives a message and sends it to the cell body

synapse a small gap between two neurons that must be crossed by neurotransmitters

neurotransmitter a chemical messenger that crosses the synapse between the axon of one neuron and the dendrite of another neuron

Dendrites are nerve endings that branch out of the cell body. These highly sensitive, thin branches receive information from the synaptic terminal of other neurons, allowing nerve impulses to be transmitted.

Dendrites bring information to the cell body and axons take information away from the cell body. Information from one neuron flows to another neuron across a **synapse**. The synapse is a small gap separating neurons. When the message reaches the end of the axon, chemicals called **neurotransmitters** are released from the synaptic terminal and travel across the gap in the synapse to the dendrite of the next neuron (Figure 2). In this way, electrical messages are passed around the body.

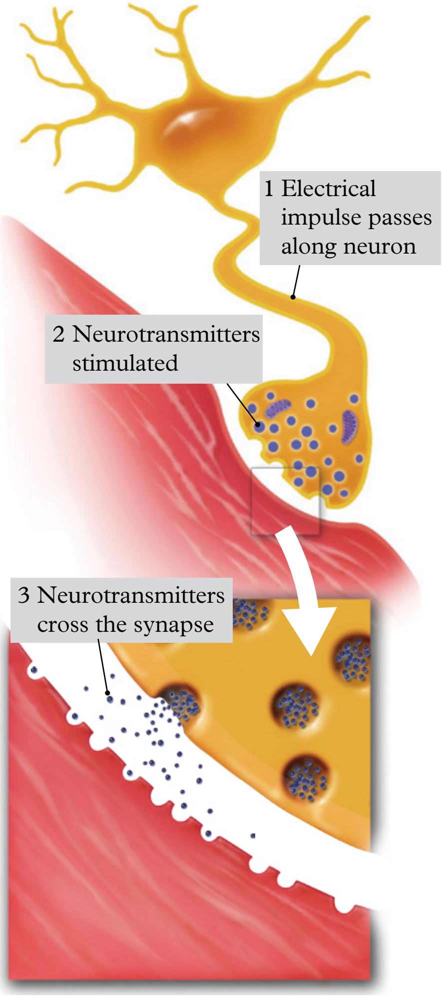


Figure 2 Electrical messages are converted to chemical messages (neurotransmitters), which cross the gap in the synapse.

Types of neurons

There are three specialised types of neurons, all with different jobs (Figure 3).

sensory neuron a nerve cell that carries a message from a receptor to the central nervous system

interneuron a nerve cell that links sensory and motor neurons; also known as a connector neuron

motor neuron a nerve cell that carries a message from the central nervous system to a muscle cell

- **Sensory neurons** (or afferent neurons) are sensitive to various stimuli, collecting information from either the body's internal environment or the outside world. Sensory neurons send the information they have collected to the central nervous system for processing.
- **Interneurons** (or connector neurons) link sensory and motor neurons, as well as other interneurons. Interneurons are the most common neuron in your central nervous system (brain and spinal cord). They only make connections with other neurons.
- **Motor neurons** (or efferent neurons) carry messages from the central nervous system to muscle cells throughout the body, which then carry out the response.

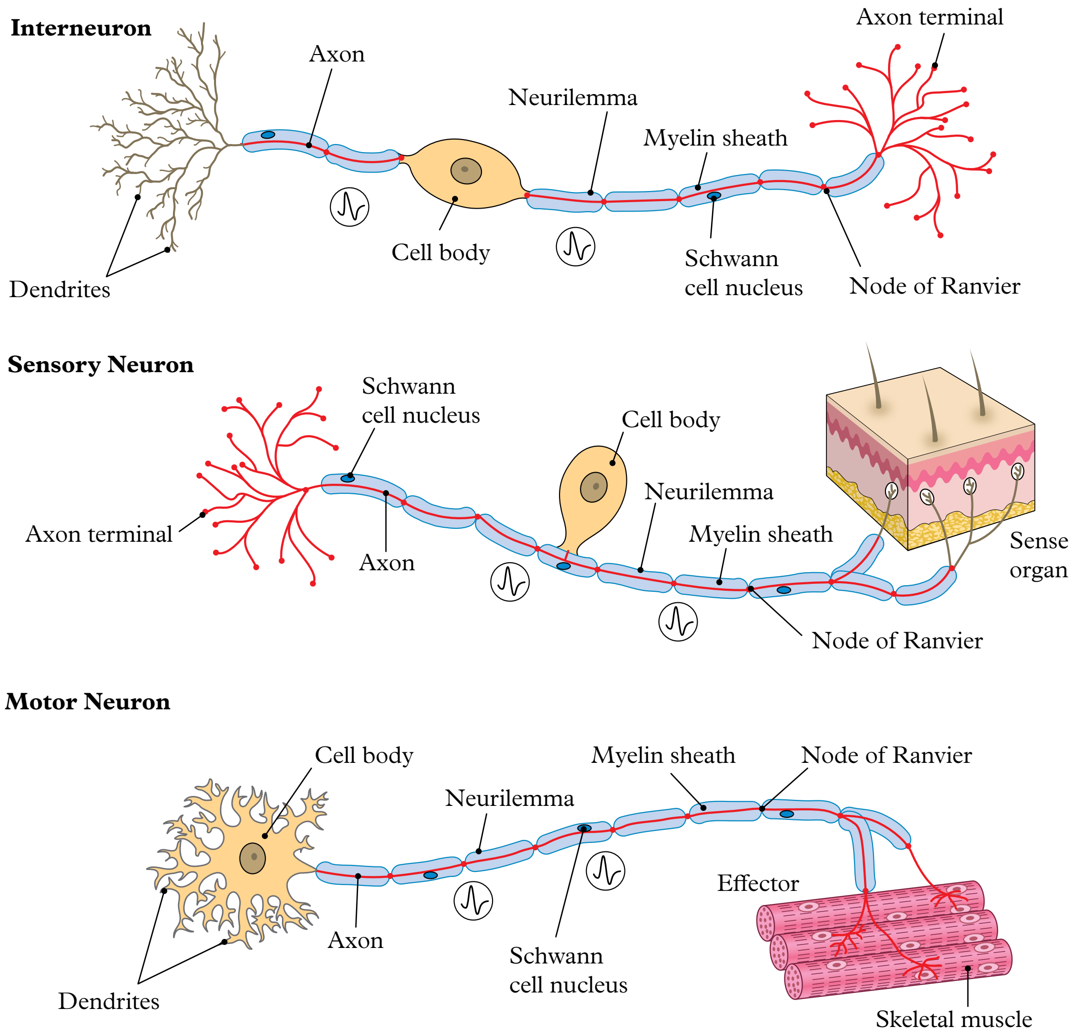


Figure 3 In these examples of an interneuron, a sensory neuron and a motor neuron, you can see how they are structured differently to send and receive different messages.

Check your learning 2.2

Check your learning 2.2

Comprehend

1 **Describe** the features of a neuron that enable it to pass messages on to other neurons.

2 **Describe** where you will find sensory neurons that detect:
  - **a** smell
  - **b** taste
  - **c** sound
  - **d** touch
  - **e** light.

3 **Describe** the role of the myelin sheath.

Analyse

4 **Compare** (the similarities and differences) sensory neurons and motor neurons.

5 **Contrast** (the differences) sensory neurons and interneurons.

Apply

6 With a partner, **create** a way to remember the difference between sensory neurons, motor neurons and interneurons. Be creative! Share your memory trick with the class.

7 **Create** a diagram to **explain** the problem that may result from damage to the myelin sheath.

Skills builder: Problem solving

8 Isadora's myelin sheath is deteriorating. **Describe** the problem that this will cause. (THINK: What does myelin sheath do? How will this impact Isadora's life?)

Lesson 2.3

The nervous system controls reflexes

Key ideas

→ Receptors in the nervous system detect a stimulus and pass it on to control centres.

→ The control centres initiate a message to the effectors, which causes a response.

→ Reflexes are special pathways that allow a response to occur before the brain has time to think.

Learning intentions and success criteria

Stimulus–response model

Stimuli can come in many different forms. A stimulus may be pressure or heat on the skin, or a puff of air or strong light in your eye. The stimulus is detected by receptors and the message gets sent to the spinal cord and the brain via sensory neurons. The spinal cord and brain are the control centre of the nervous system. Interneurons in this control centre pass the message on to other interneurons as your brain thinks about how you should respond to the stimulus. Eventually, you make a decision and the motor neurons pass the message on to the muscles. In this case, the muscles are called the effectors, because they are the cells that cause the body to respond. This simple pathway is called the stimulus–response model (Figure 1).

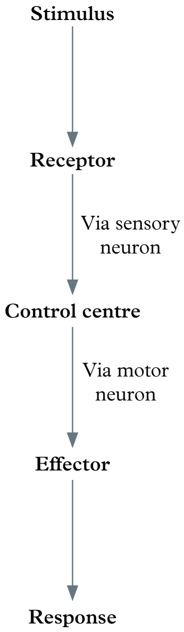


Figure 1 The stimulus–response model

Reflexes

If you have ever accidentally touched something very hot, you will remember how quickly you snatched your hand away. In fact, it would have been so quick that you didn't even have time to think about it – it was automatic.

reflex an involuntary movement in response to a stimulus

A **reflex**, or reflex action, is an involuntary and nearly instantaneous movement in response to a stimulus.

During a reflex action, the sensory neuron carries the message from the receptor to the spinal cord. The interneuron then sends two messages at the same time: one to the brain and the other to the muscles via the motor neuron (Figure 2). This means the muscle is moving at the same time as the brain gets the message (e.g. that the object is hot). This makes reflexes even faster than usual responses. Most reflexes help us in survival situations. Can you think of the advantages of these reflexes (Figures 3 to 7)?

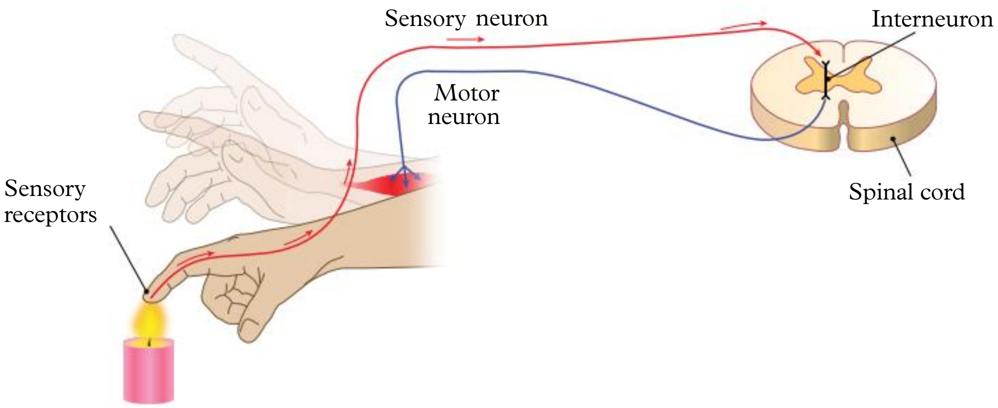


Figure 2 A reflex action ensures that your hand pulls away from the flame very quickly, even before you feel the pain.

Figure 3 Grasp reflex When an object is placed on a baby's palm, their fingers curl over and grasp it.

Figure 4 Sneezing reflex When small particles land on receptors in the back of your nose, the muscles in your diaphragm force air out rapidly.

Figure 5 Startle reflex When a newborn baby is startled, they will fling their arms out wide and grab anything they touch.

Figure 6 Plantar reflex When a blunt object (such as the blunt end of a pencil) is moved along the underside of the foot, the toes usually curl downwards.

Figure 7 Patellar (knee-jerk) reflex When a small section below the kneecap (the tendon that connects the muscle to the bone) is stimulated with a quick, firm tap, the foot will kick out.

Figure 8 Quick reflexes!

Check your learning 2.3

Check your learning 2.3

Retrieve

1 **Define** the following terms.
  - a Receptor
  - b Effector
  - c Response

Comprehend

2 **Describe** the stimulus–response model.

3 **Explain** why the brain is not involved in a reflex action.

4 **Explain** the advantage of a baby having the startle reflex.

Analyse

5 If a person has a damaged upper spinal cord, they may not be able to feel their toes. **Analyse** whether this will affect their knee-jerk reflex (by describing how a person "feels" their toes, describing the role of the spinal cord in a knee-jerk reflex and determining whether damage to the upper spinal cord will affect the messaging in a knee-jerk reflex).

Skills builder: Processing and analysing data and information

6 Seth conducted a reflex test to measure the average time it takes someone to respond to catching a ball. He found that it took people the following amount of time (in seconds) to react: 0.04, 3, 2, 1, 0.9, 2, 4, 3, 2, 1.
  - **a** **Identify** any outliers in the data. (THINK: Is something unusual? Is there a result that seems different to the others?)
  - **b** **Identify** the median and mode. (THINK: What is the most common number? What is the middle number?)
  - **c** **Calculate** the mean. (THINK: What is the average reaction time?)

Lesson 2.4

The central nervous system controls our body

Learning intentions and success criteria

Check the next lesson for a linked practical activity or experiment.

Key ideas

→ Humans are constantly receiving stimuli from their environment through the peripheral nervous system.

→ Neurons use electrical messages that are passed along to neurons in the brain and spinal cord that make up your central nervous system.

Central nervous system

central nervous system the brain and spinal cord

The **central nervous system** is the control centre of the body (Figure 1). All incoming messages from your environment and your responses to them are processed through your central nervous system. The two main parts of the central nervous system are the brain and the spinal cord.

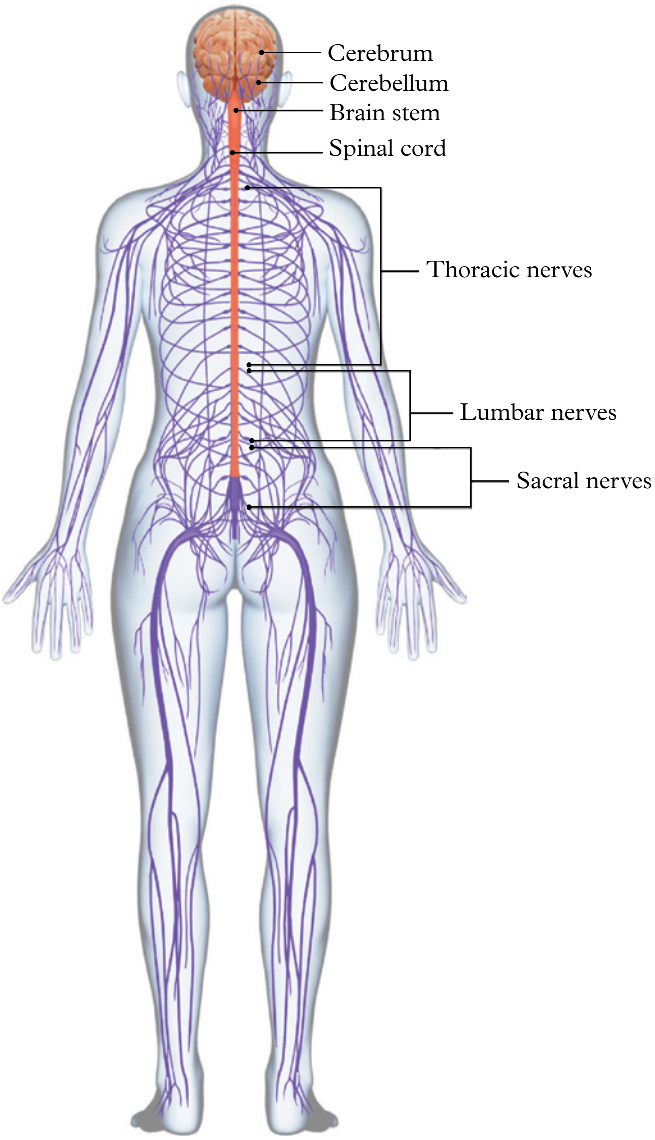


Figure 1 The nervous system of the body is made up of the central nervous system, including the brain and the spinal cord (red), and the peripheral nervous system, including all other nerves of the body (purple).

Brain

The brain is the processing centre of the body and is mainly concerned with your survival. It is a soft, heavy organ surrounded by a tough skull. The interneurons in the brain gather information about what is going on inside and outside the body. It then compares the information to events that have occurred previously, before making decisions about things such as internal changes and movements. The brain is also home to your memories, personality and thought processes.

Lobes of the brain

The **cerebrum**, or outer section of the brain, is divided into four lobes or sections. These lobes have specific functions (Figure 2).

- The **frontal lobe** is at the front of the brain. Its functions include emotions, reasoning, movement and problem solving.
- The **parietal lobe** manages the perception of senses, including taste, pain, pressure, temperature and touch.

cerebrum the largest part of the brain; divided into four lobes called the frontal lobe, the parietal lobe, the temporal lobe and the occipital lobe

- The **temporal lobe** is in the region near your ears. It deals with the recognition of sounds and smells.
- The **occipital lobe** is at the back of the brain. It receives all the information from your eyes. It is responsible for the various aspects of vision.

Parts of the brain

- The **thalamus** processes and carries messages for sensory information such as information sent from the ears, nose, eyes and skin, to the cortex.
- The **cerebellum** is important in the fine control of movement, balance and coordination.
- The **medulla** is the bottom part of the brain stem and controls automatic functions such as respiration (breathing) and digestive system activities.
- The **brain stem** sits mostly inside the brain. At its base, it becomes the spinal cord. The brain stem is made up of three major parts – the medulla, the pons and the midbrain. The pons assists in some automatic functions such as breathing, and also controls sleep and arousal. The midbrain contains areas that receive and process sensory information, such as movement and vision.

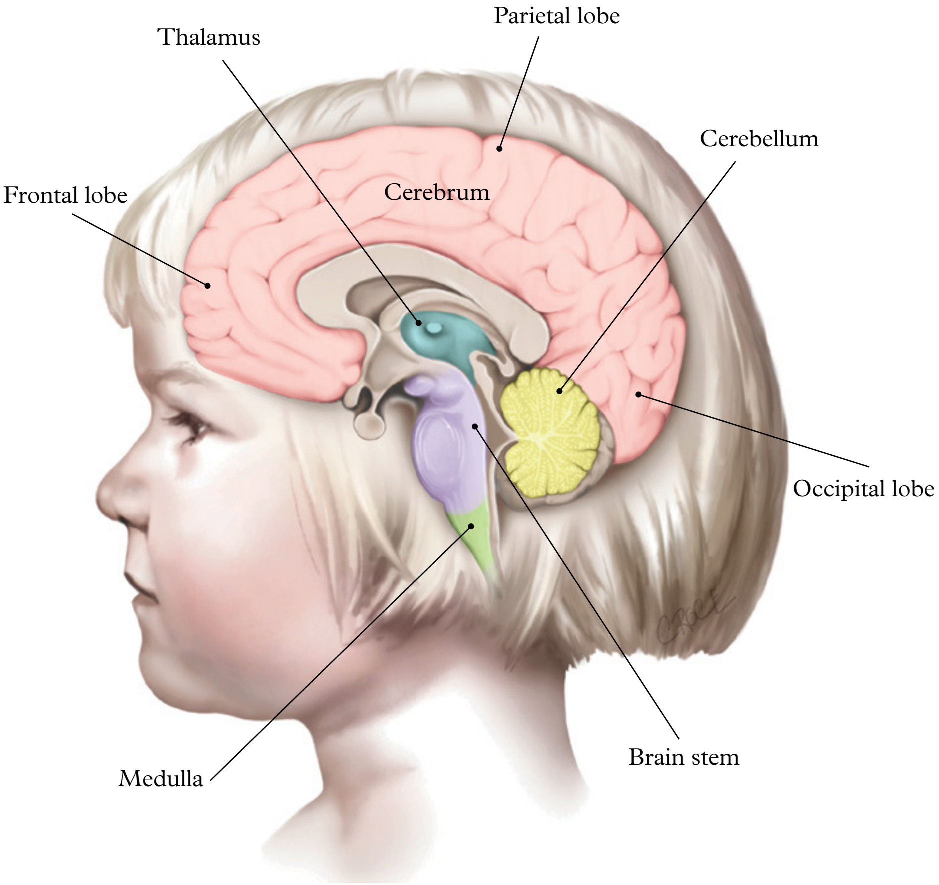


Figure 2 Structure of the human brain. The fourth lobe of the cerebrum, the temporal lobe (not shown here), is near the ears.

peripheral nervous system
all the neurons (nerve cells) that function outside the brain and spinal cord

Peripheral nervous system

The **peripheral nervous system** is a large system made up of all the nerves outside the central nervous system. The peripheral nervous system carries information to and from the central nervous system to the rest of the body, such as the limbs and organs.

The peripheral nervous system is divided into two parts.

- The **somatic nervous system** controls voluntary skeletal muscle movements, such as waving or reaching out to take an object.
- The **autonomic nervous system** controls involuntary actions, which happen without our conscious control. This includes heartbeat, digestion, respiration, salivation and perspiration. The autonomic nervous system maintains your body's internal environment (homeostasis).

The autonomic nervous system also has two parts: the sympathetic division and the parasympathetic division. These two divisions often have opposite effects. For example, the parasympathetic division slows down the heart rate, whereas the sympathetic division speeds up the heart rate. The systems work together to maintain a balance in the body.

somatic nervous system the part of the nervous system that controls the muscles attached to the skeletal system

autonomic nervous system the part of the nervous system that controls involuntary actions such as heartbeat, breathing and digestion

Check your learning 2.4

Check your learning 2.4

Retrieve

1 **Identify** the two parts of the body that make up the central nervous system.

Comprehend

2 **Describe** the role or function of the peripheral nervous system.

3 **Describe** how the peripheral nervous system and the central nervous system work together. Use an example to illustrate your answer.

4 **Explain** why, if you slipped and hit the back of your head, everything might go black.

5 **Describe** the possible effect on behaviour that would occur if a person had damage to the frontal lobe of their brain.

Analyse

6 **Contrast** the somatic nervous system and the autonomic nervous system.

Apply

7 **Create** a scientific diagram of the brain that shows the four lobes. In each of the lobes:

   a write the functions that are carried out in that lobe

   b draw something to remind you of the functions carried out in that lobe.

Skills builder: Communicating

8 Create an information pamphlet explaining the difference between the central nervous system and the peripheral nervous system. This pamphlet should help students in your year level understand the differences between and the responsibilities of each system.

   a **Identify** the key information. (THINK: Can you explain the components of each system simply? Why is this important?)

   b **Synthesise** the information you found in question 1 and present this information for your target audience. (THINK: Who is your audience? Is it age appropriate?)

   c **Create** the information pamphlet. (THINK: What is the best way to present this information? Is the language I am using scientific (i.e. clear and concise)? Would including diagrams help?)

Lesson 2.5

Challenge: Sheep brain dissection

Caution!

Wear your lab coat, safety glasses and plastic gloves. Be careful with the scalpel because it is likely to be very sharp. Cut away from your hands and other people.

Aim

To explore the structure of a sheep's brain

What you need:

- Sheep's brain
- Dissecting board
- Scalpel
- Dissecting scissors
- Coloured pins
- Microscope
- Slide
- Cover slip (optional)
- Forceps

What to do:

1 Examine the outside of the brain. Set the brain down so that the flatter side, with the white spinal cord at one end, rests on the board (Figure 1). Using the different-coloured pins, identify the two hemispheres, the four lobes of the brain, the spinal cord, the cerebellum and the cerebrum. Draw a diagram (in pencil) or take a photo that displays the different sections of the brain. Check this with your teacher before continuing.

Figure 1 Step 1: examine the top and sides of the brain.

2 Remove the pins and turn the brain over (Figure 2). Identify the medulla and the pons. Draw a diagram or take a photo that displays these parts of the brain.

Figure 2 Step 2: examine the underside of the brain.

3 Place the brain with the curved top side of the cerebrum facing up. Use a scalpel to slice through the brain along the centre line, starting at the cerebrum and going down through the cerebellum, spinal cord, medulla and pons (Figure 3). Separate the two hemispheres of the brain (Figure 4). Draw a diagram or take a photo that displays these parts of the brain.

Figure 3 Step 3: slice along the brain.

Figure 4 Step 3: separate the two hemispheres.

4 Cut one of the hemispheres in half lengthwise. Record what you see.
5 If a microscope is available, slice a very thin section of the cerebrum and put it on a slide, covering it with a drop of water and a cover slip. Draw a diagram of what you observe at low and high magnifications. Follow the same procedure with a section of the cerebellum, and then compare the two sections of the brain.

Questions

1 **Describe** the texture of the brain (smooth, rough, slippery, waxy, tacky, flimsy, chalky, hard, soft, granular, rubbery).
2 **Compare** the structure of the sheep's brain and what you know about a human brain.
3 **Contrast** the cognitive functions (ability to think and reason) of a sheep and a human. **Describe** how these differences could be reflected in the structure of the brain.

Lesson 2.6

Sometimes things go wrong with the nervous system

Key ideas

→ A slipped disc can press on the nerves in the spinal cord.

→ When the myelin sheath is damaged in multiple sclerosis, the movement of the body can be affected.

→ Motor neurone disease affects messages being passed to the muscles.

→ Alzheimer's disease is caused by progressive damage to neuron functioning.

Learning intentions and success criteria

Introduction

The nervous system plays a very important role in coordinating and regulating your body. Things that can go wrong with the nervous system include the spinal cord being damaged (paraplegia), things pressing on the nerves in the spinal cord (slipped disc), the myelin sheath in neurons being damaged (multiple sclerosis), the motor neurons failing (motor neurone disease) and damage to the neurons in the brain (Alzheimer's disease).

Spinal damage

Spinal injury is a major type of injury in Australia, especially in young men. These injuries commonly result from motor vehicle accidents, everyday falls and sports.

When the spinal cord is damaged, the messages from the neurons below the level of injury can no longer travel to the brain. This means the individual cannot receive messages from the sensors in this part of the body. It also means the messages from the brain cannot reach past the injury. How much of the body is able to move after a spinal injury depends on where the injury is in the spinal cord. If it is high up, most of the body is "cut off" from the brain; if it is lower down, then the upper body and arms may be able to work as they normally would.

People with severe damage to the upper part of the spinal cord have quadriplegia – they are unable to use their arms or legs. If the injury is very high, they may even have trouble breathing on their own. People with severe damage below the arms have paraplegia – they are still able to use their arms but not their legs.

Slipped disc

Your backbone consists of 26 bones, or vertebrae, that surround the nerves of your spinal cord. Between each vertebra is a sac called a disc, which is filled with a thick fluid, or gel, and allows the vertebrae to move. These discs act like shock absorbers, keeping your backbone flexible.

If a disc becomes weak and puts pressure on the nerves entering or leaving the spinal cord, this will cause pain or numbness along the nerve (Figure 1). Treatment usually involves pain relief, along with exercises that strengthen the muscles in the back. Occasionally, surgery is required to remove the damaged part of the disc.

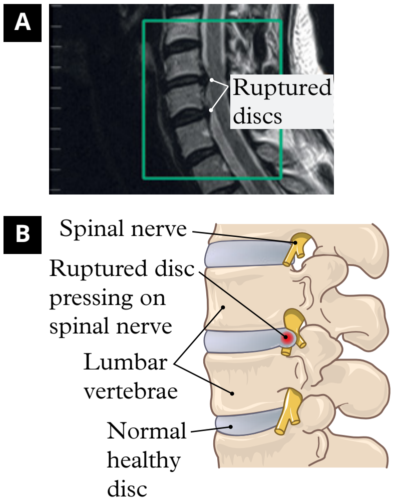


Figure 1 A slipped disc can put pressure on the spinal nerves. (A) X-ray of spine, showing two ruptured discs (B) A ruptured disc presses on the spinal nerve, causing pain.

Multiple sclerosis

The myelin sheath plays a very important role in ensuring the electrical message passes along the axon of a neuron. If the myelin sheath is damaged, the electric signal can be lost, like a broken wire in an electric circuit.

Your immune system usually fights and kills bacteria and viral infections. In multiple sclerosis, the immune system mistakenly recognises myelin sheath cells as dangerous, and attacks and destroys them (Figure 2). This means messages to and from the senses (including the eyes, skin and bladder) and the muscles become lost. Muscles can become weak, and the person can feel dizzy or tired, or have difficulty seeing properly. Most commonly, the symptoms appear for a short time, before disappearing completely, and then returning later on. This is called a relapsing–remitting cycle.

Motor neurone disease

In motor neurone disease (also known as amyotrophic lateral sclerosis, or ALS), the neurons that send messages to the muscles become weak and eventually lose function. As the muscles grow weaker, they can cramp and become stiff. This usually starts in the muscles in the legs and arms, before progressing to the face and chest. This can affect the person's ability to talk and, eventually, to breathe. Neurons in the brain are also affected by this disease. Scientists do not know what causes the motor neurons to lose function. Research in this area is continuing.

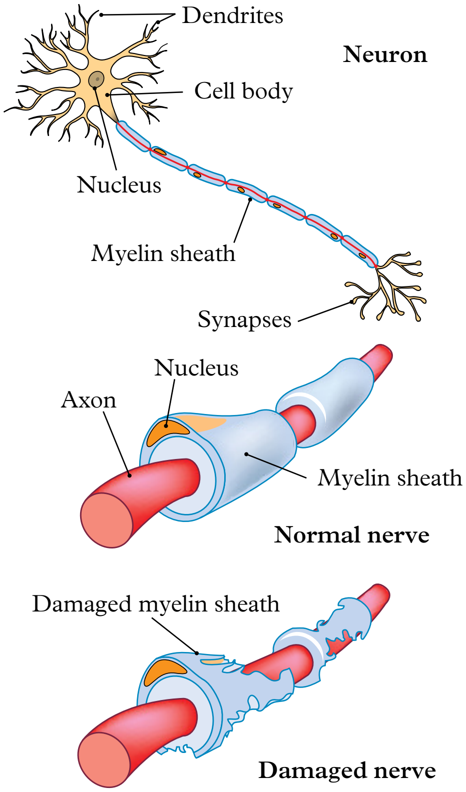


Figure 2 In multiple sclerosis, damage to the myelin sheath prevents the nerves from passing on messages.

Alzheimer's disease

Alzheimer's disease is caused by progressive damage to the neurons in the brain (Figure 4). This gradually affects memory, and the ability to reason or plan and carry out everyday activities. Problems with short-term memory mean that someone with Alzheimer's disease cannot remember what happened a few hours ago, or what they are meant to be doing that day.

The disease also has wider impacts. A person with Alzheimer's disease can forget where they are and how to get home. This makes life very confusing for them and they can become upset very easily. Symptoms can vary from day to day, depending on tiredness or stress.

The cause of Alzheimer's disease is not known. Research suggests that plaques develop around neurons in the brain, making it hard for them to transmit messages. Chemical changes in the neurons may be caused by genetic, environmental and health factors.

Figure 3 AFL legend Neale Daniher was diagnosed with motor neurone disease (MND) in 2013. Daniher's diagnosis has increased awareness and fundraising for MND.

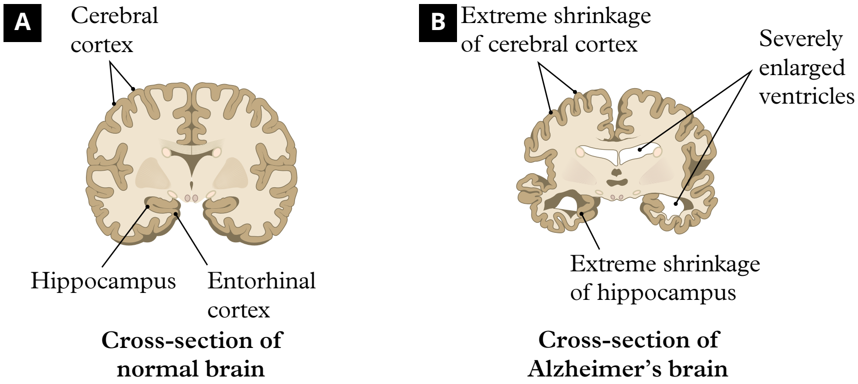


Figure 4 Damage to the neurons in Alzheimer's disease can cause the brain to shrink. (A) Normal brain (B) Brain of a person with Alzheimer's disease

Check your learning 2.6

Check your learning 2.6

Retrieve

1 **Recall** the name of the individual bones that make up the spine.

Comprehend

2 **Describe** the role of a disc in the spinal column.

3 **Explain** why the destruction of the myelin sheath causes symptoms in multiple sclerosis.

4 **Identify** another name for motor neurone disease. **Describe** the role motor neurons usually play in a healthy nervous system.

5 Think about where you were and what you were doing 1 hour ago. **Describe** how you would be affected if you had Alzheimer's disease and could not remember this.

Analyse

6 **Contrast** quadriplegia and paraplegia.

Lesson 2.7

The endocrine system causes long-lasting effects

Learning intentions and success criteria

Check the next lesson for a linked practical activity or experiment.

Key ideas

→ The endocrine system uses chemical messengers called hormones to maintain control and to regulate growth.

→ Hormones travel through the bloodstream to receptors or target cells.

→ The effects of hormones often last longer than the effects of the nervous system.

Introduction

The **endocrine system** is a collection of glands that secrete (release) chemical messengers called **hormones**. The hormones are secreted directly into the bloodstream and then travel around the body through the blood. Some cells in the body have receptors that match the hormone, like a lock to a key. These cells are called **target cells** (Figure 1). It only takes one hormone "key" to cause a change in the target cell "lock".

endocrine system a collection of glands that make and release hormones

hormone a chemical messenger that travels through blood vessels to target cells

target cell a cell that has a receptor that matches a specific hormone

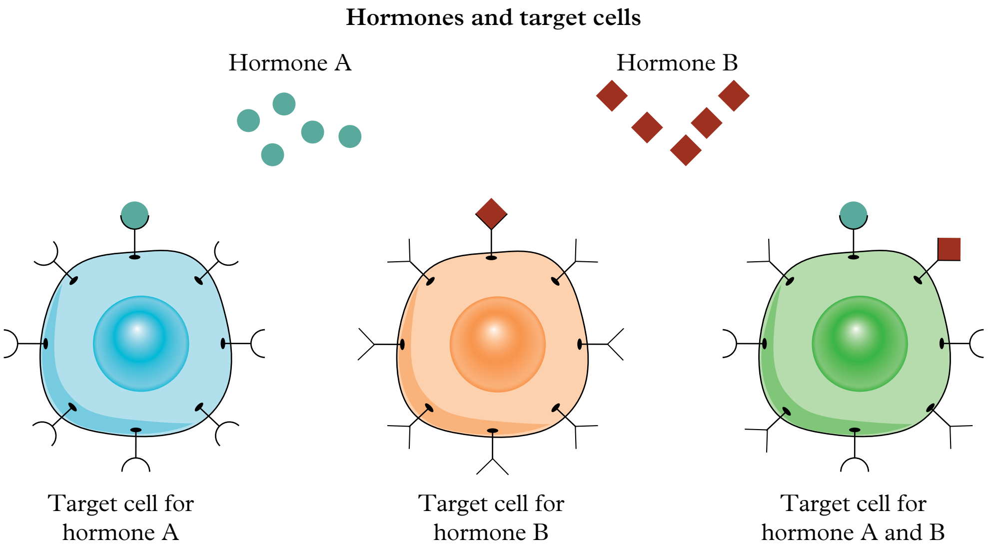


Figure 1 Hormones are chemical messengers that are the key to the target cell's lock.

The glands and organs of the endocrine system are spread throughout the body (Table 1 and Figure 2).

Table 1 Some organs and hormones of the endocrine system

Organ	Hormone	Target tissue	Main effects
Hypothalamus	Wide range of neurohormones	Pituitary gland	Sends messages from nervous system to the pituitary gland to control functions such as body temperature, hunger, thirst and sleep patterns
Ovaries	Progesterone	Uterus	Thickens wall of uterus to prepare for pregnancy
	Oestrogen	Body cells	Development of female sexual characteristics; aspects of pregnancy and foetal development
Testes	Testosterone	Male reproductive system, body cells	Development and control of male sexual characteristics; production of sperm
Pancreas	Insulin	Liver, most cells	Lowers blood glucose level
	Glucagon	Liver	Raises blood glucose level
Pituitary gland	Thyroid-stimulating hormone	Thyroid	Changes the rate of thyroxine release from the thyroid
	Antidiuretic hormone	Kidneys	Increases the amount of water reabsorbed from the kidneys
	Pituitary growth hormone	Bones, muscles	Stimulates muscle growth; controls the size of bones
Thyroid gland	Thyroxine	Body cells	Affects rate of metabolism, and physical and mental development
Parathyroid glands	Parathyroid hormone	Blood	Regulates the amount of calcium in the blood
Adrenal glands	Adrenalin	Body cells	Increases body metabolism in "fight, flight or freeze" response
Pineal gland	Melatonin	Skin cells	Involved in daily biological rhythms

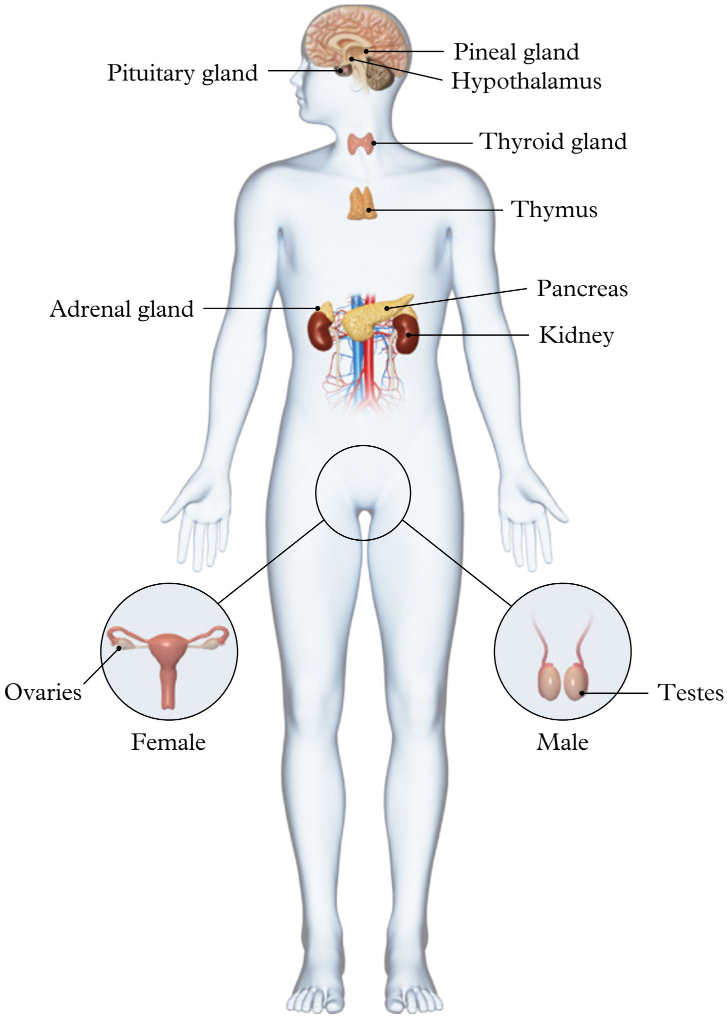


Figure 2 The human endocrine system

Fight, flight or freeze?

If you are ever in a dangerous or frightening situation, you may experience a "fight, flight or freeze" response. You break out in a cold sweat, your heart beats wildly, everything around you seems to slow down and your senses bombard you with information.

Most of these symptoms are triggered by the release of the hormone adrenalin (also called epinephrine). Adrenalin is constantly produced by the adrenal glands in small doses.

Figure 3 Adrenalin is responsible for the "fight, flight or freeze" response in mammals and can help them to survive.

The adrenal glands are located above the kidneys. The usual function of adrenaline is to stimulate the heart rate and enlarge blood vessels. However, when a mammal is in danger, the hormone takes on another role. It floods the system, causing an increase in the strength and rate of the heartbeat, raising blood pressure and speeding up the conversion of glycogen into glucose, which provides energy to the muscles. In this way, adrenalin prepares the animal's body for the extra effort required should it need to defend itself (fight), run away (flight) or hide (freeze).

Panic attacks

Sometimes the "fight, flight or freeze" response can be triggered without any obvious reason. This means adrenalin can flood the body, causing the heart to pound, breathing to become fast and shallow, and a flood of sensory information to stimulate the brain. When this occurs, lights appear brighter, sounds are louder and smells are stronger. These sensory messages can become jumbled as the brain struggles to make sense of all the information. This combination of endocrine and nervous system responses is called a panic attack. These symptoms are not life threatening and will eventually disappear. Support from friends and family can help.

Check your learning 2.7

Check your learning 2.7

Retrieve

1 **Name** the system in your body that is responsible for the production of hormones.

Comprehend

2 **Describe** what is meant by the phrase "fight, flight or freeze" and how it relates to hormones.

3 **Describe** the symptoms of a panic attack.

4 **Explain** why the endocrine system is referred to as a communications system.

5 **Explain** why telling someone to "calm down" during a panic attack will not stop their symptoms. (HINT: Are they able to control their hormones?)

Analyse

6 **Compare** a hormonal response and a nervous response. **Describe** one advantage for each system.

Skills builder: Questioning and predicting

7 A scientist claimed that because modern society has so many processes automated or controlled by artificial intelligence (AI), we don't experience stress that may put our lives at risk. Therefore, we no longer use the fight or flight response.

- **a** **Identify** the assumption made in this claim. (THINK: What is the scientist taking for granted about AI?)
- **b** **Describe** how we could test if someone is stressed. (THINK: What do you expect to happen?)
- **c** **Construct** a scientific question that you could use to test this claim. (THINK: Is this question testable?)

Lesson 2.8

Challenge: Glands and organs of the endocrine system

Aim

To identify the path of a hormone from its gland to the target organ

What you need:

- Large sheet of butcher's paper
- Sticky tape
- Felt-tipped pen
- Coloured pencils or markers

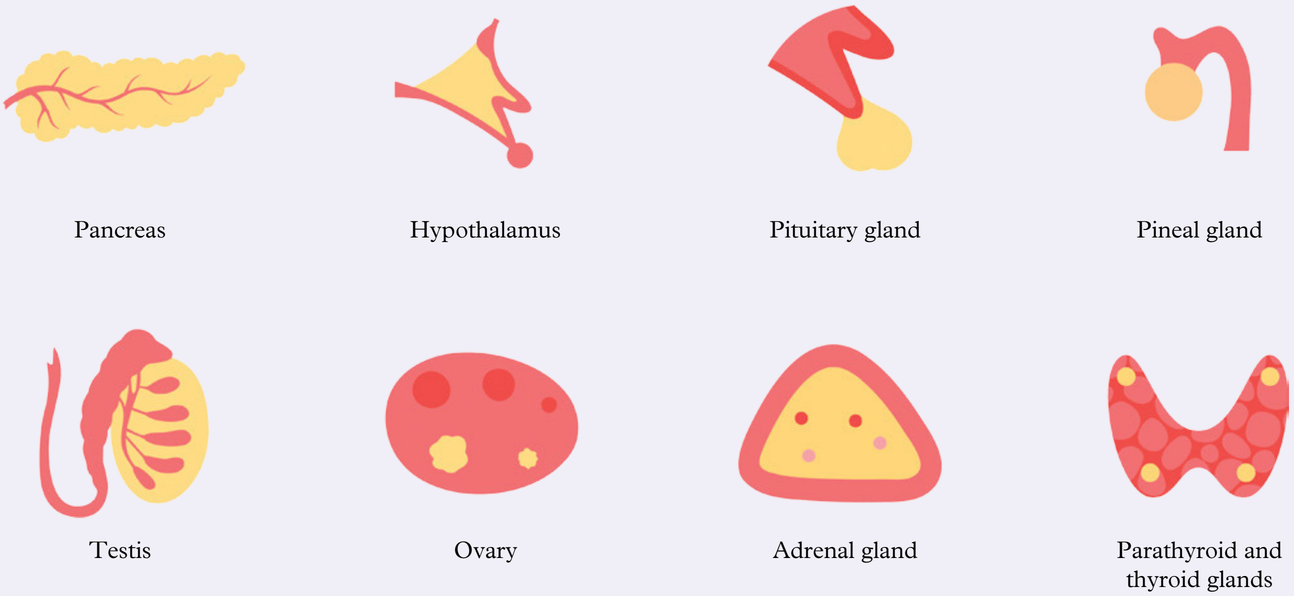
What to do:

1. Working in pairs, draw an outline of your partner's body on the paper.
2. With your partner, draw in the glands and organs of the endocrine system. Using the information in Table 1 of Lesson 2.7 The endocrine system causes long-lasting effects (page 93), annotate each gland with a brief description, in your own words, of what it is responsible for.
3. Use colour coding and arrows to show the path of the hormone(s) produced by each gland to its target organ.

Questions

Choose one gland or organ to research.

1. **Identify** the main hormone the gland secretes.
2. **Describe** how the hormone affects the target cells in the target organ.
3. **Describe** one disorder that results from a malfunction of this organ or gland.



Pancreas

Hypothalamus

Pituitary gland

Pineal gland

Testis

Ovary

Adrenal gland

Parathyroid and thyroid glands

Figure 1 The organs of the endocrine system

Lesson 2.9

Homeostasis regulates through negative feedback

Key ideas

→ The body needs to detect and correct changes in its levels of nutrients, water and temperature to stay healthy.

→ The process of regulating the internal conditions of the body is called homeostasis.

→ Negative feedback occurs when the body responds in a way that removes the initial stimulus.

Learning intentions and success criteria

Check the next lesson for a linked practical activity or experiment.

Introduction

Scientists have not yet discovered another planet that humans could inhabit. Humans can only survive in very specific environments. Our bodies have particular requirements, including the right amount of food, water and oxygen. If you were lost in a desert or in freezing temperatures, your body would try to maintain a temperature of about 37°C at all times, to keep all cells working efficiently. This "business as usual" approach of responding to stimuli to maintain a stable state is called **homeostasis** (Figure 1).

Figure 1 Homeostasis is your body's ability to regulate and maintain a stable condition (balance) inside your body, regardless of changes to the external environment.

homeostasis the process by which the body detects and responds to stimuli to ensure a stable internal state is maintained

Homeostasis

To maintain homeostasis, your body uses a mechanism that is similar to a thermostat in a heater. When temperature receptors on your skin and in the hypothalamus of your brain detect cooling down (stimulus), a message gets sent to a variety of effectors around your body. Effectors are glands or muscles that cause a change in the way your body functions. This may include muscles to make you shiver (to warm up) or blood vessels to redirect the flow of warm blood to the important organs in your body (heart, liver and brain).

If the temperature receptors detect that you are too hot (stimulus), then the effectors include your sweat glands and blood vessels. Your body responds by sending more blood, which is carrying heat, to your skin, where sweat is evaporating, carrying away the heat and cooling you down (Figure 2).

Figure 2 When your body is stimulated by heat, homeostasis ensures you cool down by sweating.

negative feedback mechanism a regulatory loop in which the stimulus causes a response that acts in the opposite direction to whatever is being regulated

This a **negative feedback mechanism** – the stimulus causes the effectors to respond in a way that negates or removes the stimulus. If you are too hot, your body tries to cool you down. If you are too cold, your body works to warm you up (Figure 3).

This doesn't just work for maintaining the temperature of your body. The levels of iron in your body also need to be controlled. Every red blood cell in your body contains iron molecules. If you do not have enough iron in your body, then you will not be able to make enough red blood cells to carry oxygen for energy. Iron in the food you eat is broken down and absorbed by the intestines. It is stored temporarily in the bone marrow (where red blood cells are made), the liver and the spleen (where old red blood cells are broken down). If your store of iron becomes too low, homeostasis ensures that more iron is absorbed from red meat or some plant cells and sent to the bone marrow. Your body only absorbs what it needs.

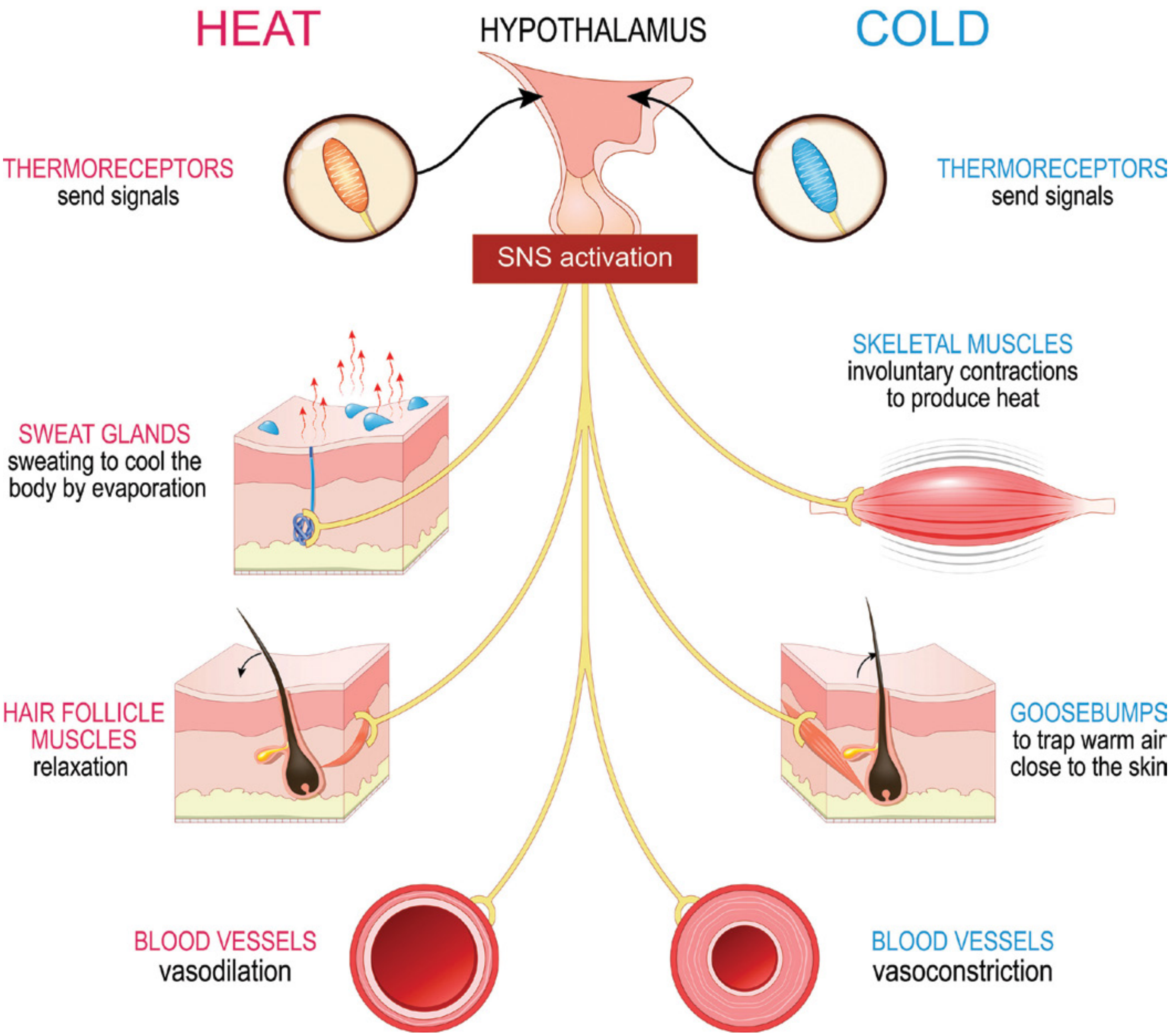


Figure 3 Temperature homeostasis ensures that your body maintains a constant temperature.

Hormones at work

The rate of hormone production and secretion is often regulated by a negative feedback mechanism. If a stimulus is received that indicates something in the body is happening "too much", the body has receptors to detect it. The body responds by producing a hormone to remove the stimulus and return the body to normal.

Blood glucose

As you eat, food gets broken down into smaller nutrients. All carbohydrates get broken down into simple sugars, including glucose. These glucose molecules travel through your blood and provide energy for cellular respiration (the reaction of glucose with oxygen to produce carbon dioxide, water and ATP). Too much glucose in the blood is not healthy, because it causes water to be lost from cells through osmosis. Your body tries to control the amount of glucose in your blood.

If the concentration of glucose in your blood is too high (stimulus), receptors in the pancreas detect it. The receptors release a hormone called insulin into the blood. Insulin travels throughout the body to insulin receptors on the target muscle and liver cells. These cells act as effectors and remove glucose from the blood and store it as glycogen (Figure 4). This causes the blood glucose to decrease, removing the original stimulus. This is an example of negative feedback.

If blood glucose levels are too low, your body will use negative feedback to restore levels to a homeostatic state. Low glucose levels are detected by receptors in the pancreas (stimulus). This time, the hormone glucagon is released into the blood. Receptors for glucagon are also found on the effector cells in the liver and muscles. Glucagon binding to the receptors causes the muscle and liver cells to release stored glucose into the blood (response), increasing the amount of blood glucose once again (Figure 5).

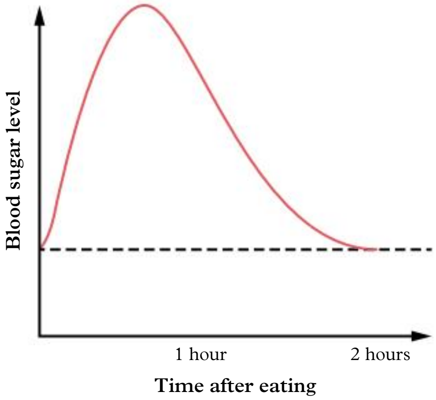


Figure 4 After you eat, your blood glucose levels increase. The body's response is to release insulin, which causes the muscle and liver effectors to remove the glucose and restore homeostasis.

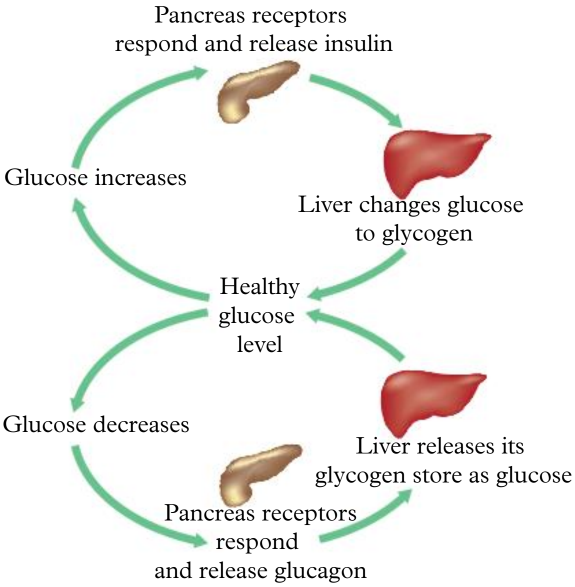


Figure 5 The pancreas and the liver work together to maintain healthy glucose levels in the body.

Water regulation

You may have noticed that when you drink a lot of water, you need to visit the bathroom in the next hour. Your body uses homeostasis to control the balance of water in your body. Water is needed to control all the chemical reactions that occur in the cells. If there is too much or too little water, these chemical reactions will be affected and the cells can become damaged.

The water balance in your body is tightly controlled by the hypothalamus in your brain. If it has been a hot day, or you have been doing physical exercise and sweating, then your body may have lost a lot of water. Receptors in the hypothalamus of the brain detect changes in fluid levels in your blood and send a message to the pituitary gland at the base of your brain. The pituitary gland releases a chemical messenger called antidiuretic hormone (ADH) into your blood.

This hormone travels all around your body until it reaches target effector cells in your kidney. The ADH binds to the receptors on the effector cells, causing them to reabsorb extra water from your urine. This makes your urine more concentrated or darker in colour. The extra water that was reabsorbed goes back into the blood, keeping the blood volume high. This is a form of negative feedback, because the response (reabsorbing water from the urine and returning it to the blood) results in a decrease of the stimulus (restoring water levels in the blood).

Drinking a lot of water causes the blood volume to increase. This is also detected by receptors in the hypothalamus. This time the message from the hypothalamus to the pituitary gland is “STOP producing ADH”. The lack of ADH is detected by the effector cells in the kidney, and they stop reabsorbing water from the urine. This means the urine has more water in it, and it becomes very clear and diluted (Figure 6).

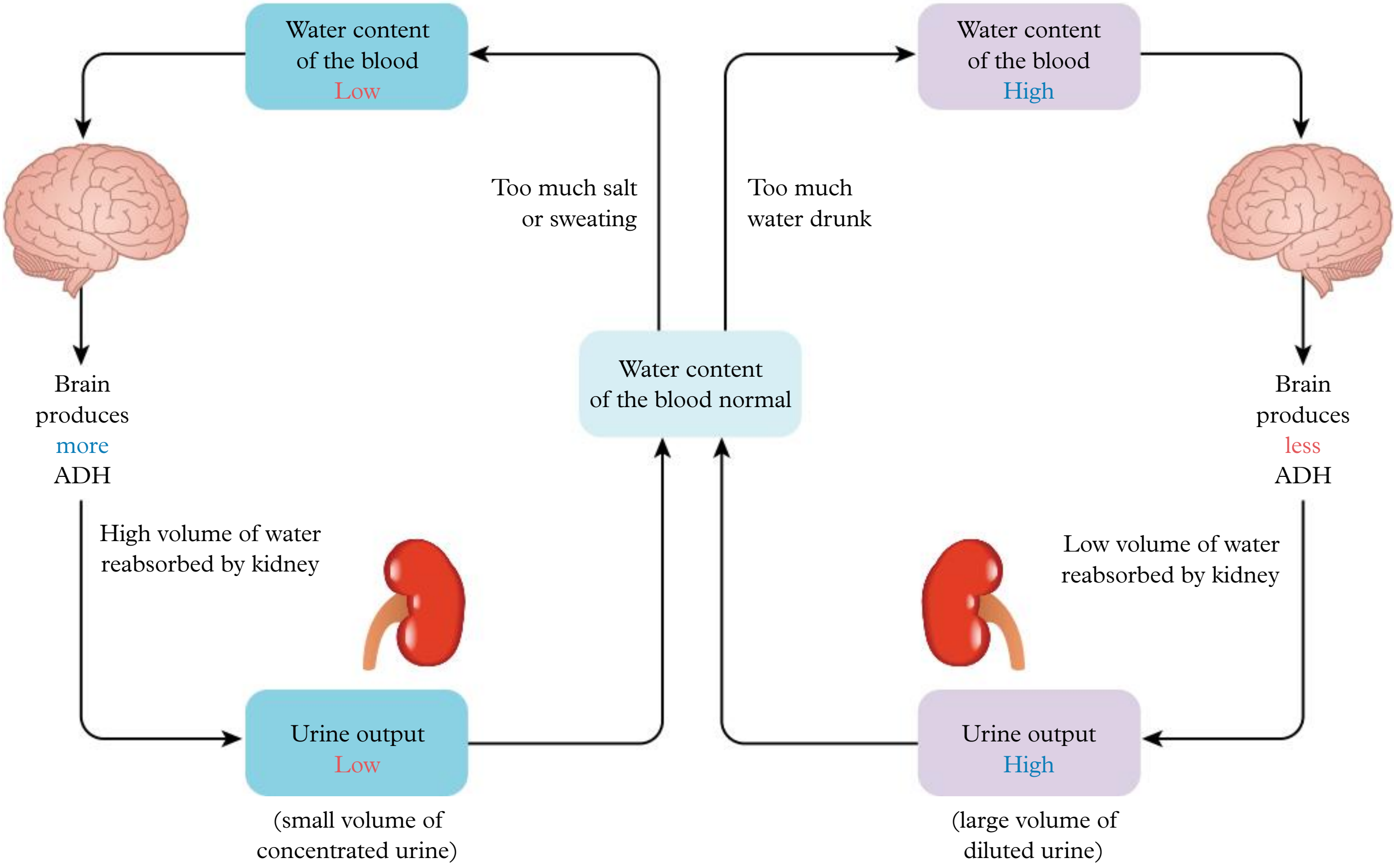


Figure 6 Water regulation in the human body

Oxygen and carbon dioxide homeostasis

Have you ever wondered why you become puffed when running a race? Oxygen and carbon dioxide in the blood are under strict homeostatic control. You need oxygen for the cells in your body to convert glucose into carbon dioxide, water and energy (cellular respiration).

Sprinting during a race causes the muscle cells in your legs to use a lot of glucose and oxygen and to produce a lot of carbon dioxide. The muscle cells release the carbon dioxide into the blood, where it forms carbonic acid. This is not good for your body. The acid content of the blood is measured by receptors in the medulla in the brain stem. If the level is too high from excess carbon dioxide, a message is sent through the nervous system to the muscles that control your breathing. This causes the diaphragm to move faster, increasing the rate of your breathing and making you feel puffed. The message also goes to the heart to make it beat faster. This makes the blood move faster, carrying the carbon dioxide to the lungs where it can be removed by breathing out. These two responses act as negative feedback, removing the stimulus of high levels of carbon dioxide in the blood (Figure 8).

Meditation often involves sitting or lying down and relaxing. This means the level of cellular respiration in muscles is low. Little oxygen is used and little carbon dioxide is produced. As a result, the levels of carbon dioxide in the blood decrease. The receptors in the medulla once again detect the change from the homeostatic state and signal the heart to slow its beat and the lungs to slow their breathing (Figure 9).

Figure 7 Water levels in the body need to be controlled to support the chemical reactions that occur in cells.

Figure 8 After a race, you may be puffed.

Figure 9 When you meditate, the carbon dioxide levels in your body decrease.

Check your learning 2.9

Check your learning 2.9

Retrieve

1 **Define** the term "homeostasis".

2 **Identify** the stimulus, location of receptors, effectors and response to high body temperature.

Comprehend

3 **Describe** how your body responds to cold weather.

4 **Describe** how your blood sugar level changes when you eat.

5 **Describe** how your body responds to low iron levels.

Analyse

6 If a negative feedback loop reduces the effect of a hormone, **infer** what a positive feedback loop should do.

Apply

7 **Discuss** how and why your body responds to the following:
  - a drinking a bottle of water
  - b swimming 15 m under water
  - c swimming in the ocean on a cold day.

8 In type 1 diabetes, cells in the pancreas are unable to produce insulin. **Predict** what effect this would have on blood glucose levels. **Justify** your prediction by providing reasons for your decision.

Skills builder: Planning investigations

9 To investigate homeostasis in humans, scientists may need to test body responses including temperature and heart rate.
  - **a** **Identify** what equipment you would need to measure temperature in humans. (THINK: What is the best device to use?)
  - **b** **Explain** whether taking someone's pulse with your fingers would be as successful as using a device, such as a smart watch. (THINK: What could go wrong measuring a pulse with fingers? Are the results from a device more accurate?)
  - **c** **Recall** why it is important to use the appropriate device to measure a body response. (THINK: How might the wrong device impact your results?)

Figure 10 Digital thermometer

Lesson 2.10

Experiment: Experiencing homeostasis

Aim

To demonstrate how homeostasis maintains control of the heart rate during and after exercise

Materials

- Stopwatch
- Heart rate monitor (optional)

Method

1 While sitting down, find your pulse and count the number of times your heart beats in 15 seconds.

2 Multiply this number by 4 to determine the number of beats every minute.

3 Measure your breathing rate by counting the number of breaths you take in 1 minute.

4 Do repeated step-ups or star jumps for 2 minutes. (Make sure you are wearing appropriate shoes.)

5 Measure your heart rate and breathing rate immediately after stopping exercise.
6 Measure your heart rate and breathing rate every 2 minutes for 10 minutes.

Results

1 Record the data in a table.
2 Draw a line graph showing how your heart rate varied after exercise.
3 Draw a line graph showing how your breathing rate varied after exercise.

Discussion

1 **Describe** how you could ensure that the way you measured your heart rate and breathing rate was accurate.
2 **Describe** how your breathing rate changed during exercise and in the 10 minutes after exercise.
3 **Describe** how your heart rate changed during exercise.
4 **Explain** any changes you noticed in your breathing rate and heart rate.
5 **Describe** what happened to your heart rate in the 10 minutes after exercise.
6 **Compare** your results to others in your class. **Determine** the mean heart rate before the exercise started and immediately after finishing the exercise. **Compare** this to the median and mode values at these times.
7 **Identify** any outliers of the mean heart rate after exercise. **Explain** how these affected the mean value.
8 **Identify** any random or systematic errors that could explain the outliers and how this could be improved if the experiment was repeated.
9 Use the concept of homeostasis to **explain** why your heart rate was different before, during and after exercise.

Conclusion

Describe how homeostasis ensures that our muscles get enough nutrients and remove wastes during exercise.

Figure 1 Heart rate monitor on a smart watch

Lesson 2.11

Sometimes things go wrong with homeostasis

Key ideas

→ Negative feedback can be disrupted.

→ Type 1 diabetes is caused by the disruption of glucose homeostasis.

→ Becoming too cold (hypothermia) can disrupt homeostasis.

Learning intentions and success criteria

Introduction

Homeostasis is important in maintaining the health of your body. When it malfunctions, it can cause other parts of the body to stop functioning properly. If undetected, it can even cause death.

Type 1 diabetes

Diabetes mellitus (type 1 diabetes) is a disease caused when a single hormone (insulin) cannot be produced by the body. As discussed in Lesson 2.9 Homeostasis regulates through negative feedback (page 97), when a person eats, many of the foods are broken down into simple sugars, such as glucose. The glucose is absorbed into the blood stream. If the level of glucose in the blood stays too high, it can cause problems, so the body relies on the release of insulin to remove the glucose and store it in the liver and muscle cells.

Some people are unable to produce insulin because their body has destroyed the pancreas (beta) cells that detect blood glucose levels and produce the insulin. This means that the body is unable to remove the glucose from the blood. When the level of glucose in the blood is not regulated, it can disrupt other functions in the body. Approximately one person in every 183 people between the ages of 0 and 24 has **type 1 diabetes**. The average age of onset is 13 years old.

type 1 diabetes an autoimmune disease in which the immune system attacks the insulin-producing cells in the pancreas

Hyperglycaemia

When the beta cells are destroyed, the amount of glucose in the blood increases to beyond normal levels (4.0 to 7.8 mmol/L). This is called **hyperglycaemia** (hyper – too much, glycaemia – sugar concentration). As the amount of glucose increases, the body tries to remove the sugar in other ways. It can be released in the mouth saliva, causing fruity-smelling breath. It can also cause the mouth to feel dry because the extra sugars pull water from the surrounding tissues.

hyperglycaemia when there are high levels of glucose in the blood which can occur when the body has too little insulin

High blood glucose also affects the kidneys, causing more urine to be produced. This means a person with hyperglycaemia will need to urinate more often. Because they are losing more water in the urine, a hyperglycaemic person will be thirsty all the time. They may feel that they need to drink many litres of water each day. They may also feel tired, have a headache or experiene blurred vision. If the hyperglycaemia is not treated, they may become confused and fall into a coma.

Hyperglycaemia can be controlled by replacing the insulin in the body with an injection or via an insulin pump. This artificial insulin works the same way as the body's normal hormone, causing the liver and muscle cells to take in the glucose.

Hypoglycaemia

hypoglycaemia when there are low levels of glucose in the blood which can occur when the body has too much insulin

Hypoglycaemia (hypo – too low, glycaemia – sugar concentration) occurs when the amount of glucose in the blood becomes too low. This can be caused by not eating enough, or by injecting too much insulin into the body. This causes the liver and muscle cells to remove too much glucose from the blood.

If the amount of glucose in the blood becomes too low, the body will not be able to use glucose to produce energy. This can cause sweating, clamminess, headaches, confusion, tiredness and difficulty speaking. If it is not treated, the person may pass out and could eventually die.

Mostly, hypoglycaemia can be treated simply by consuming glucose-rich foods and drinks like jelly beans and apple juice.

Blood sugar technology

A person with type 1 diabetes needs to be aware of their blood glucose levels so that they can control them through diet and administration of insulin. If blood sugar levels are not controlled, it can cause long-term effects, from kidney damage to blindness. A regular finger-prick test can test the amount of glucose in a drop of blood.

Technology has made it easier for people with type 1 diabetes to maintain near-normal blood glucose levels. Continuous glucose monitors are inserted into the abdomen or arm of the person (Figure 1). This technology can automatically check blood glucose levels and send the information to an app on the person's phone. An alarm will notify the person if their glucose level is too high or too low. They can then administer insulin or eat some glucose-rich foods.

People with type 1 diabetes can also access insulin pump technology that automatically releases insulin into the body (Figure 2). The amount of insulin delivered depends on how much food the person tells the pump they will eat and information about their blood glucose level sent to the pump from their continuous glucose monitor. The use of the monitors and pumps allows people to regulate their blood sugar effectively to achieve glucose homeostasis.

Figure 1 Continuous glucose monitors can be used to automatically detect the amount of glucose in the blood.

Figure 2 Insulin pumps can be programmed to inject insulin automatically.

Hypothermia

hypothermia the condition of having an abnormal, potentially dangerous, low body temperature

Hypothermia (hypo – too low, thermia – temperature) is caused by the body's temperature becoming too low. This can be caused by situations such as wearing clothes that are not warm enough, staying out in the cold (especially in wet clothing) or being in cold water for too long.

When the body's temperature starts to drop, homeostasis will cause the muscles to start moving and the body will start to shiver. The blood moves away from the skin (making it pale) and stays in the important organs, such as the heart, liver and brain. If the body continues to cool below 35°C, the person may become clumsy, slur their speech and become confused (Figure 3). Eventually, there will not be enough energy for the body to keep shivering, and confusion may cause the person to think they are warm again. This is when hypothermia becomes most dangerous, because the body temperature will drop quickly below the life-threatening 32°C.

It is important not to treat hypothermia by putting the person in a warm shower, heater or bath. This can cause the cold blood near the skin to rush back to the heart and brain, causing the person to become even colder. Instead, the person should have wet clothing removed and be warmed up slowly with warm blankets, wrapped warm water bottles or skin-to-skin contact.

Figure 3 Early warning signs of hypothermia

Check your learning 2.11

Check your learning 2.11

Retrieve

1 **Define** the following terms.
  a Hypoglycaemia
  b Hyperglycaemia
  c Hypothermia

2 **Recall** what causes type 1 diabetes.

Comprehend

3 **Describe** how your body responds to high blood glucose levels.

4 **Describe** how your body responds to low blood glucose levels.

5 **Describe** how your body responds to extremely low temperatures.

6 **Describe** why drinking apple juice can help a person with hypoglycaemia.

7 **Explain** why you should not put a person with hypothermia in a hot bath to warm up.

Apply

8 **Identify** if it is one or more of the stimulus, the receptors or the effectors that is lost in type 1 diabetes. **Justify** your decision (by identifying the stimulus, the receptor and the effector in blood glucose homeostasis, describing the function of each in blood glucose homeostasis and comparing this to the effect of type 1 diabetes).

Lesson 2.12

Science as a human endeavour: Hormones are used in sport

Key ideas

→ Erythropoietin is a hormone that causes more red blood cells to be produced.

→ Chemicals can be used to mimic hormones in the body.

→ Increasing the number of red blood cells in the body can artificially enhance an athlete's performance.

Learning intentions and success criteria

Introduction

Erythropoietin is a hormone normally produced by the kidneys to increase the number of red blood cells in the body. Athletes can use this version of a negative feedback mechanism naturally or artificially to increase their performance on the sporting field.

Many athletes and sporting clubs spend months training high in the mountains to help their performance in competitions (Figure 1). The air in the mountains is much thinner. Although the air still contains 21 per cent oxygen, it is harder for a person to fill their lungs as the particles in the air are spread out further. As a result, when a person first arrives at high altitude, their body struggles to get enough oxygen. This can make them feel tired, because they are unable to burn glucose in aerobic cellular respiration.

Figure 1 Training at a high altitude can increase an athlete's performance.

Negative feedback in action

The body normally produces just enough red blood cells to carry oxygen around the body. When red blood cells die, erythropoietin is produced by the kidneys. The erythropoietin travels through the blood to receptors in the bone marrow. The effector bone marrow cells then produce more red blood cells to replace the ones that have been lost (Figure 2).

Exercising at a high altitude stimulates the body to react as though there are not

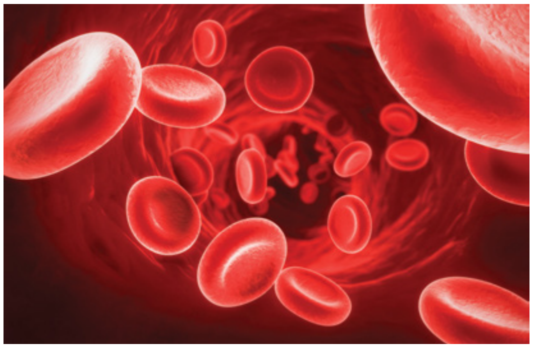


Figure 2 Erythropoietin increases the production of red blood cells.

enough red blood cells to carry oxygen to the muscles. Erythropoietin is produced, causing the bone marrow to make extra red blood cells. It takes about 3 weeks for the extra cells to become noticeable. When the athlete returns to sea level to compete, the red blood cells remain active for up to 1 month. This means the athlete's blood is more efficient at carrying oxygen to muscles, making the athlete less likely to become fatigued (tired). Training at a high altitude uses the negative feedback mechanism to the athlete's advantage.

Drug testing

Some athletes bypass high-altitude training and inject erythropoietin directly into their blood. This is called blood doping (Figure 3). Because the amounts of hormone introduced into the blood are not controlled, it can cause an over-production of red blood cells, which strains the heart. The athlete is at risk of a heart attack or a stroke.

Erythropoietin was first synthesised in the laboratory in the 1990s but it was 10 years before drug testing could distinguish the artificial hormone from naturally occurring erythropoietin. In 2002, at the Winter Olympic Games in Salt Lake City, United States, the first athlete was identified as having a version of erythropoietin in their urine and blood.

Figure 3 In 2013, Lance Armstrong admitted to injecting erythropoietin to help him win world cycling events.

Medical uses of erythropoietin

Erythropoietin is produced in the kidneys. Any disease that affects kidney function will also affect the production of erythropoietin. As a result, a person with kidney disease will also have low levels of red blood cells. This is called anaemia. Symptoms of anaemia are a pale appearance and feeling tired when exercising (Figure 4). Regular injections of erythropoietin will increase the production of red blood cells and improve the person's health.

Figure 4 Anaemia can make you feel tired when exercising.

Test your skills and capabilities

Evaluating the ethics in sports

Sporting competition prides itself on fairness for all competitors. There are many ways to improve an athlete's chances of winning a competition, including training, special diets, shaving body hair and wearing special clothing that reduces air resistance. Some athletes undergo surgery to improve their ability to compete. This can include a golfer having laser eye surgery. A runner who has asthma is allowed to use a Ventolin inhaler, but other athletes are not permitted to use hormones to speed their recovery from an injury.

Evaluate the ethics of cheating in sports by deciding which of the following situations should be allowed and which should be banned. In each situation, **justify** your decision (by describing how the athlete would be advantaged, describing the potential dangers to the athlete, describing whether all athletes would have equal access, and deciding whether the situation could be described as cheating).

1 An athlete takes a dietary supplement that maximises their performance.
2 A swimmer wears an expensive swimsuit that minimises water resistance.
3 An athlete has genetically modified muscles.
4 An athlete takes hormones that increase recovery after injury by increasing muscle mass.

Lesson 2.13

Review: Control and regulation

Summary

Lesson 2.1 Receptors detect stimuli

- Your body has receptors that detect changes (stimuli) in the environment.
- The five main types of external receptors detect light, sound, chemicals in the air and in your mouth, and touch.

Lesson 2.2 Nerve cells are called neurons

- Neurons are cells in our body that enable messages to be passed quickly.
- A change is detected by the receptor and an electrical message is passed along the neuron to the synaptic terminal.
- Chemical neurotransmitters pass the message across the gap to the next neuron.
- The myelin sheath protects parts of the neuron and increases the speed of messages being sent.

Lesson 2.3 The nervous system controls reflexes

- Receptors in the nervous system detect a stimulus and pass it on to control centres.
- The control centres initiate a message to the effectors, which causes a response.
- Reflexes are special pathways that allow a response to occur before the brain has time to think.

Lesson 2.4 The central nervous system controls our body

- Humans are constantly receiving stimuli from their environment through the peripheral nervous system.
- Neurons use electrical messages that are passed along to neurons in the brain and spinal cord that make up your central nervous system.

Lesson 2.6 Sometimes things go wrong with the nervous system

- A slipped disc can press on the nerves in the spinal cord.
- When the myelin sheath is damaged in multiple sclerosis, the movement of the body can be affected.
- Motor neurone disease affects messages being passed to the muscles.
- Alzheimer's disease is caused by progressive damage to neuron functioning.

Lesson 2.7 The endocrine system causes long-lasting effects

- The endocrine system uses chemical messengers called hormones to maintain control and to regulate growth.

- Hormones travel through the bloodstream to receptors or target cells.
- The effects of hormones often last longer than the effects of the nervous system.

Lesson 2.9 Homeostasis regulates through negative feedback

- The body needs to detect and correct changes in its levels of nutrients, water and temperature to stay healthy.
- The process of regulating the internal conditions of the body is called homeostasis.
- Negative feedback occurs when the body responds in a way that removes the initial stimulus.

Lesson 2.11 Sometimes things go wrong with homeostasis

- Negative feedback can be disrupted.
- Type 1 diabetes is caused by the disruption of glucose homeostasis.
- Becoming too cold (hypothermia) can disrupt homeostasis.

Lesson 2.12 Science as a human endeavour: Hormones are used in sport

- Erythropoietin is a hormone that causes more red blood cells to be produced.
- Chemicals can be used to mimic hormones in the body.
- Increasing the number of red blood cells in the body can artificially enhance an athlete's performance.

Review questions 2.13

Review questions: Module 2

Retrieve

1 **Identify** which of the following is the stimulus.
- **A** A target cell that has a receptor
- **B** A hormone released into the bloodstream
- **C** A change in the environment that disrupts homeostasis
- **D** A response by the body that restores the homeostatic balance

2 **Identify** which of the following organs produce insulin.
- **A** Pancreas
- **B** Liver
- **C** Hypothalamus
- **D** Muscle

3 **Identify** which of the following is not part of the nervous system.
- **A** Axon
- **B** Dendrite
- **C** Hormones
- **D** Chemical messengers

4 **Define** the following terms.
- **a** Stimulus
- **b** Homeostasis
- **c** Negative feedback

5 **Identify** the missing labels for the parts of a neuron in Figure 1.

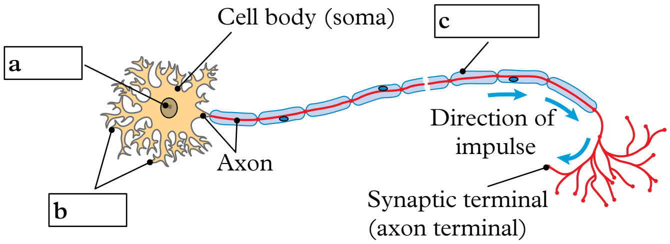


Figure 1 A typical neuron

6 **Identify** the four lobes of the brain and **state** their functions.

Figure 2 The cerebrum (the largest area of the brain) is divided into four lobes.

7 **Identify** the early warning signs of hypothermia that are missing in Figure 3.

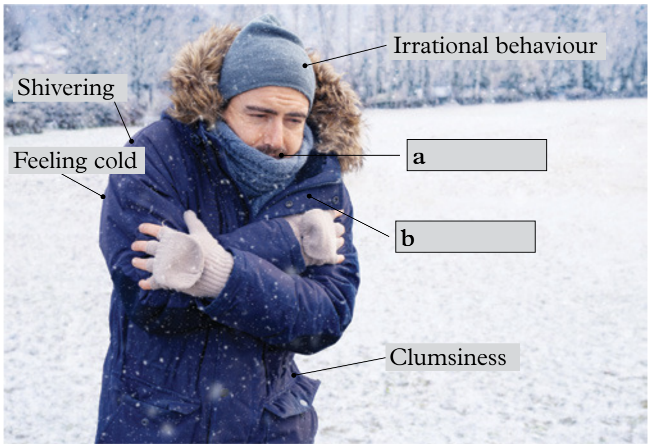


Figure 3 Early warning signs of hypothermia

8 **Name** two glands in humans that produce hormones.

9 **Identify** the missing words in the following sentence. A person with diabetes has a problem with the hormone _______, which is secreted by the _______.

Comprehend

10 **Describe** three ways the human body can receive a stimulus from the environment.

11 **Explain** why the nervous system and the endocrine system are both described as communication systems.

12 **Describe** how hormones are transported in the body.

13 **Describe** three major features of an axon.

14 **Describe** how drinking a sugary drink can cause the release of insulin into the blood stream.

15 **Explain** why it is important to regulate the temperature of the body.

16 **Explain** how the hormone ADH helps to regulate the amount of water in the body.

17 **Use** an example to **explain** how a negative feedback mechanism works.

18 When a person drinks a litre of water, their body produces extra urine. **Use** the concept of homeostasis to **explain** why.

Figure 4 Drinking water after exercising is an important part of homeostasis.

19 **Explain** how the endocrine system assists your body to "respond to the world". **Explain** why your body also needs a nervous system.

20 **Explain** why holding your nose might help you to swallow something that tastes awful.

21 In Canada in 2006, a woman fought off a polar bear with her bare hands when it attacked her son. She literally wrestled the bear and won! **Explain** why this reaction could be attributed to the hormone adrenalin.

22 Reflexes are automotive responses by the body that help the survival of an individual. Select one of the reflexes described in Lesson 2.3 The nervous system controls reflexes (page 82). **Describe** a situation where this reflex would increase the chances of survival.

23 **Describe** how your body controls the level of iron in your body.

Analyse

24 **Compare** the way your body responds to high temperatures and low temperatures.

25 **Contrast** the roles of the somatic and autonomic nervous systems.

26 **Contrast** hyperglycaemia and hypoglycaemia.

Apply

27 Caffeine can reduce feelings of tiredness and fatigue. **Describe** how caffeine could benefit someone competing in an endurance sport.

28 High levels of sugar in the blood can cause water to move from the surrounding tissues into the blood. Use this information to **explain** why people with uncontrolled type 1 diabetes are at risk of losing their vision.

29 Scientists working in the Antarctic experience the coldest and driest environment on Earth. **Explain** the way this environment could impact their bodies and suggest a way they could change their behaviours to minimise this impact.

Critical and creative thinking

30 **Create** a cartoon strip with at least five squares, illustrating a person receiving a stimulus and then responding.

31 **Create** a visual presentation on the role of the pancreas in controlling the level of glucose in the blood.

32 Alcohol blocks the production of ADH. **Use** critical thinking to **predict** the effect this will have on urine volume.

Social and ethical thinking

33 A person with Alzheimer's disease can often forget what has happened in the past 30 minutes. An example of this is forgetting they have already eaten their lunch. This means the person can become very frustrated and upset if they think they are being refused food. Their carers may explain (many times) that the person has already eaten, but this can upset the person more, because they think they are being lied to. Other carers may lie to the person and say that lunch will be ready in five minutes. This settles the person, who will often forget about eating in that time. **Determine** which approach you would use. **Justify** your decision by describing the factors you considered when making your decision.

34 Scientists have been working for over 50 years to make it easier for people with type 1 diabetes to control their blood sugar levels. There are two parts to this process:

- monitoring the level of glucose in the blood, and
- injecting the required amount of insulin as it is needed.

The integration of these two processes would provide an artificial replacement to the pancreas. There are many ethical issues that arise from these separate processes including who has access to the monitoring data (child, young adult, parents, doctors, nurses or other medical specialists); who has duty of care to check that the data is correct; and who is liable if either the monitor (one company) or insulin pump (second company) malfunctions.

- **Describe** how a glucose monitor works and how an insulin pump works.
- **Describe** the data that they need to function.
- **Explain** the consequences if one of these processes were to fail.
- **Explain** why the medical companies may be reluctant to combine these two processes.
- **Research** why and how people have volunteered for a project like this.

Research

35 Choose one of the following topics for a research project. A few guiding questions have been provided, but you should add more questions that you wish to investigate. Present your report in a format of your own choosing.

Leprosy

Leprosy is an old disease that is described in many ancient texts. Investigate how an infection of *Mycobacterium leprae* can affect a person's ability to feel pain stimuli.

- **Explain** why the ability to detect pain is important for the normal healthy functioning of the body.
- **Describe** a possible consequence of not detecting pain when cooking.
- **Compare** the modern treatment of leprosy to the treatment of lepers (people infected with *Mycobacterium leprae*) 100 years ago.

Figure 5 Leprosy is a curable disease that still occurs in more than 120 countries.

Diabetes insipidus

Diabetes insipidus is a disease that is caused by a lack of antidiuretic hormone (ADH). This can affect the body's ability to control the level of water in the body. There are two possible causes for diabetes insipidus: an inability to produce the hormone ADH or an inability for the receptors in the kidney to respond to ADH.

- **Describe** the symptoms of diabetes insipidus. Use your knowledge of the hormone system to **compare** these two causes.
- **Investigate** and **describe** the treatment for this disease.

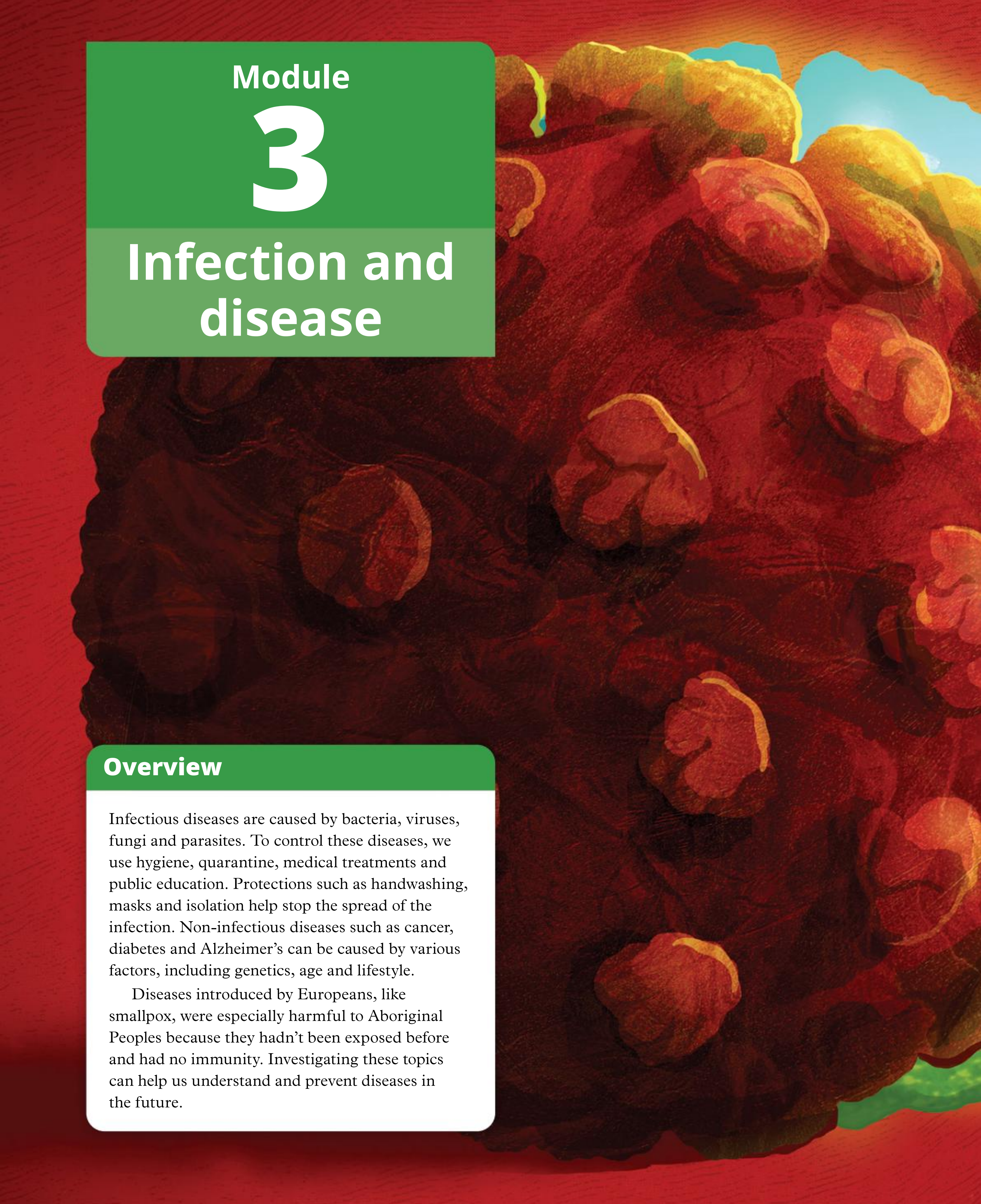
Bionic ears and eyes

Professor Graeme Clark was instrumental in the development of the cochlear implant. This device is able to detect soundwaves through a receiver worn just behind the ear (Figure 6). The information is transmitted to the cochlea, inside the ear, where the message can be passed on to the sensory nerves going to the brain.

- **Compare** the human-made cochlear implant to the way information is normally detected and transmitted by nerves.
- **Investigate** the bionic eye project.
- **Identify** and describe the way light is detected and the information transmitted to the part of the brain responsible for decoding the information.
- **Investigate** why it may take time for the brain to learn to interpret these new signals.

Figure 6 A cochlear implant passes sound signals from the processor behind the ear, to the round transmitter, and to electrodes that have been implanted in the cochlea.

Module
3
Infection and disease



Overview

Infectious diseases are caused by bacteria, viruses, fungi and parasites. To control these diseases, we use hygiene, quarantine, medical treatments and public education. Protections such as handwashing, masks and isolation help stop the spread of the infection. Non-infectious diseases such as cancer, diabetes and Alzheimer's can be caused by various factors, including genetics, age and lifestyle.

Diseases introduced by Europeans, like smallpox, were especially harmful to Aboriginal Peoples because they hadn't been exposed before and had no immunity. Investigating these topics can help us understand and prevent diseases in the future.

Lessons in this module

Lesson 3.1

Non-infectious diseases can be affected by genetics or the environment

Learning intentions and success criteria

Check the next lesson for a linked practical activity or experiment.

Key ideas

→ Infectious diseases can be passed from one person to another.

→ Damage can accumulate as the body ages, causing disease.

→ Too much or too little nutrients can cause disease.

Diseases

A healthy animal relies on their body doing many activities without them even noticing. Their lungs breathe in and out, their heart beats, and their digestive system digests food to supply nutrients to the cells from their head to their toes.

Sometimes the normal everyday activities that occur in the body are changed, causing some parts to stop functioning in a normal healthy way. This disruption in the normal functioning of a body is called a **disease**. There are many different types of diseases. Some diseases can be passed from one person to another (infectious), while other diseases are caused by age, a lack of the right nutrients, factors in the environment, or the way an animal or person lives (non-infectious).

disease a disruption or change in the normal structure or functioning of an animal or plant

Some diseases have the same name but can have many different causes. Epilepsy is a brain condition that results in recurring seizures. Seizures can look very different depending on the part of the brain and the size of the area affected. While some people suffering a seizure may stare blankly for a few seconds, others might twitch their arms and legs in a convulsion. Seizures can be caused by injuries to the head, infections in the brain, or abnormal arrangements of blood vessels or cells in the brain. Because there are different causes of epilepsy, there are also many different ways to treat it, including medication, surgery and diet.

Figure 1 Diseases are diagnosed and treated by the medical profession.

Non-infectious diseases

Every living thing has a unique set of genetic material called DNA. You received half your DNA from your mother, and half from your father. This genetic material that is present in almost all of the cells in your body (except the red blood cells) controls the way the cells, tissues and organs in your body react to the environment. If your parents have brown eyes, there is a strong chance (but not certain) that you will also have brown eyes. If you are tall, it may be that your parents are tall and that you received good food and nutrients to grow. The normal healthy functioning of your body is a result of the genetic material that you inherited and the healthy environment that you live in.

Unfortunately, things can go wrong with both the genetic material and the environment. This can affect the normal function of your body and cause a **non-infectious disease**.

non-infectious disease a disease that cannot be passed between plants or between animals

Age

As a plant or animal grows older, their body ages. This means parts of the body stop functioning normally. This can be due to changes in the genetic material that cause cells to grow abnormally. Cancer is caused by normal cells that change so they will not die, and these changed cells will keep making copies of themselves. As the number of cancer cells keeps increasing, they take up more and more space in the body. This can stop other parts of the body from doing their normal healthy work. The body becomes diseased because it cannot function normally. For example, cancer cells growing and taking up space in the liver can stop the liver from removing toxins and waste from the blood. As a result, the toxins and waste can build up in the body, causing the skin and eyes to have a yellow tinge (jaundice) (Figure 2).

Figure 2 Jaundice (yellowing of the skin and eyes) is caused by a diseased liver.

Sometimes ageing genetic material will cause a group of cells to die. This is what can cause Alzheimer's disease. As a person ages, the cells in their brain can become damaged, changing the normal way a brain works. This can cause a person to stop making new memories or to be unable to think clearly.

While the way that cells age in the body cannot be stopped, it can sometimes be slowed by a healthy lifestyle. Eating healthy food and getting regular exercise can help slow the rate the body ages. Unfortunately, many non-scientists can use this idea to make claims that are based on **pseudoscience** (claims that are not tested scientifically).

pseudoscience a claim that has not been tested using the scientific method

Malnutrition

Malnutrition is another factor that can lead to disease. It is caused by eating too much or too little food, or an imbalance of the type of nutrients the body needs. Nutrients are the chemical molecules that are taken in by the roots of a plant or eaten by animals. Too little nutrients, or not enough of one type of nutrient, can mean the body does not have enough essential molecules to repair damage or to produce new cells. This means a person will feel tired or weak, and they will not be able to grow, fight an infection or repair damaged parts of their body. If the body does not have enough nutrients from food to keep the lungs working or the heart beating, it will start to break down the muscles and other organs in the body and repurpose the nutrient molecules to keep the body alive.

malnutrition a condition caused by too much or too little nutrient intake, or an imbalance of essential nutrients

Sometimes too little of a single nutrient can also cause a disease. Most people are able to make vitamin D when their skin is exposed to short amounts of sunshine each day. Some people who have naturally dark skin or avoid sunshine (through clothing or sunscreen) may have very low levels of this vitamin. Other people have a change in their genetic material that means they have trouble making this nutrient. Both these groups of people can end up with a disease called rickets, which can cause their bones to have very slow growth and break easily. Rickets can also cause their legs to become bowed outwards (Figure 3).

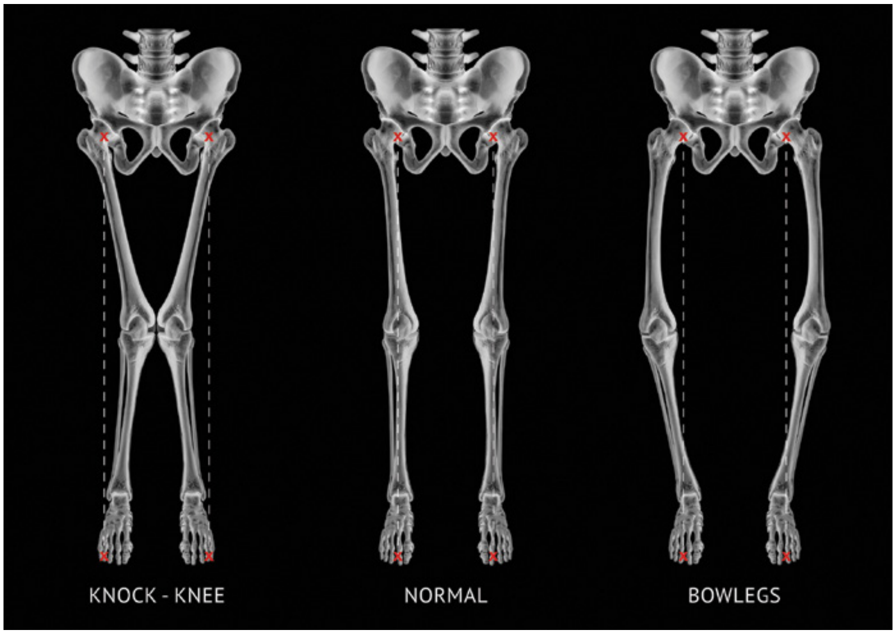


Figure 3 Too little vitamin D can affect the way bones in the legs grow.

Some people try to avoid vitamin deficiency by taking regular vitamin supplements (tablets or pills with extra vitamins). In some countries, pseudoscientific claims that everyone needs to take these supplements can result in one vitamin being in excess. Sometimes the extra nutrient can build up in a body and cause a disease. For example, vitamin A is important in the normal functioning of the body but too much can cause dry, itchy skin; headaches; dizziness; and slow bone growth.

Disease can also result from eating more than your body needs to keep your heart, lungs and muscles working. The excess nutrients from the food are often stored in the body as fat. If the increased nutrients are stored as cholesterol plaques in the blood vessels, it can affect the heart's ability to move blood around the body (Figure 4). This is called cardiovascular disease.

If the excess nutrients are largely sugars it can cause type 2 diabetes. Like type 1 diabetes, type 2 diabetes can cause the body to feel thirsty or tired, affect eyesight, and prevent the body from repairing damaged tissue.

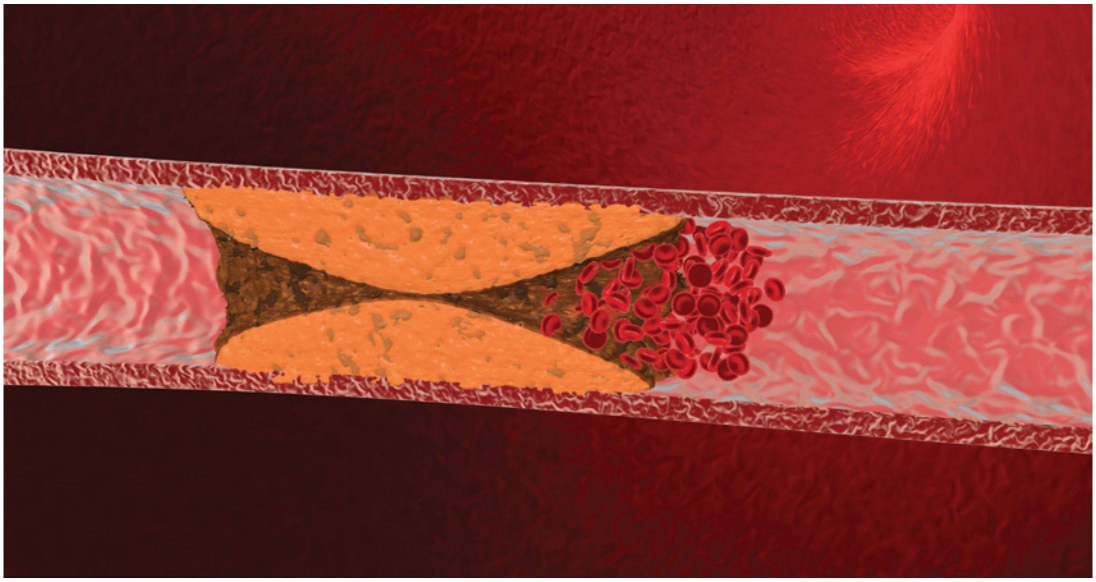


Figure 4 Cholesterol plaques can block the normal flow of blood around the body and cause the heart to work harder.

Environment and lifestyle

Some non-infectious diseases are caused by factors in the environment or the way people live. Australia has one of the highest levels of skin cancer in the world, caused by the high levels of sunshine containing UV radiation. Small doses of sunshine keep us healthy; however, large doses of UV radiation can damage the genetic material (the DNA) in the skin cells and cause sunburn.

DNA controls all parts of a healthy cell, including how big it grows, its interactions with other cells and how often it makes a new cell. While most DNA damage is repaired, too much damage (sunburn) can cause a cell to grow and multiply in an uncontrolled way (cancer). As many Australians spend a lot of time in the sunshine without sunscreen, the rate of skin cancer disease is much higher in Australia. Since public health campaigns in the 1980s that promoted sunscreen use, the incidence of melanoma – the deadliest form of skin cancer – have declined. Consistently using sunscreen, wearing protective clothing and limiting sun exposure are crucial steps in reducing the risk of skin cancer.

Identifying non-infectious diseases

Non-infectious diseases cannot be passed from one person to the next. Despite this, some of these diseases can appear more common in one area than another. For example, a disease cluster (group of people living in a similar location) might suggest that there is a common cause for a particular disease. Once a disease cluster is identified, scientists and medical professionals will start looking for the potential cause. An example of this is the sudden increase in cases of silicosis in stone workers since the year 2000 (Figure 5).

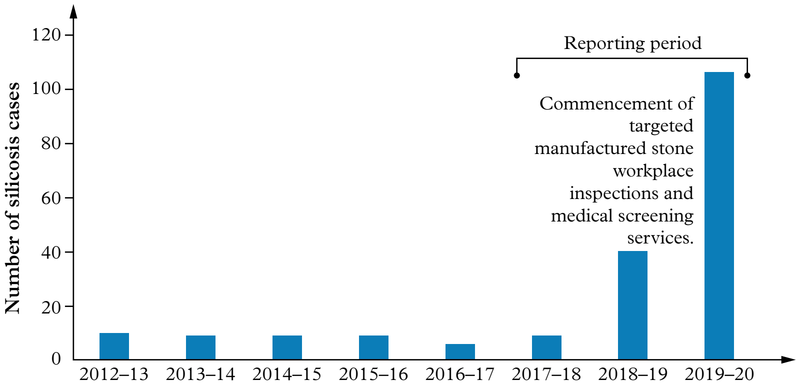


Figure 5 A cluster of silicosis cases in manufactured stone workers was identified in NSW.

Silicosis is a disease that is caused by breathing in small bits of silica dust. Silica is a mineral commonly found in sand and other types of rock. This disease was common in mining workers in the mid-1900s, but it decreased with improvements in workers' safety procedures, such as increased air flow and wearing facial masks. However, in the early 2000s, clusters of silicosis cases were identified in people who worked in the production of manufactured stone benchtops for kitchens and bathrooms. Breathing in the small silica fibres produced during the construction of the benchtops was found to cause difficulty breathing and has also been linked to cancer in other organs of the body. Many companies banned the manufacture of these benchtops in 2024.

Another disease caused by environmental factors is asbestosis. This disease is caused by breathing small naturally occurring mineral fibres that are resistant to heat and corrosion – qualities that made them ideal for use in commercial insulation and fireproof products in the 1900s. The disease was detected when clusters of people working in asbestos mines (and their families) started developing lung disease. It was later discovered that these fibres can cause irreversible scarring in the lungs and result in shortness of breath and eventual death. While the use of asbestos was banned in Australia in 2003, it is still present in many buildings.

Not all clusters of a non-infectious disease have a direct cause. Cardiovascular disease is one of the most common causes of death in Australia. It refers to a group of diseases that affect the functioning of the heart and blood vessels of the body, from preventing blood flowing through the heart muscle to causing blood clots in the legs or arms. People who have unhealthy diets, low levels of physical exercise, drink alcohol or smoke are more likely to develop cardiovascular disease. In some areas, there are more people with cardiovascular disease than others. This does not mean there is a direct cause for the cluster. Instead, there may be more people with an inactive, high-stress and poor-diet lifestyle living in the area.

Check your learning 3.1

Check your learning 3.1

Retrieve

1 **Define** the following terms.
  a Disease
  b Infectious disease
  c Malnutrition

Comprehend

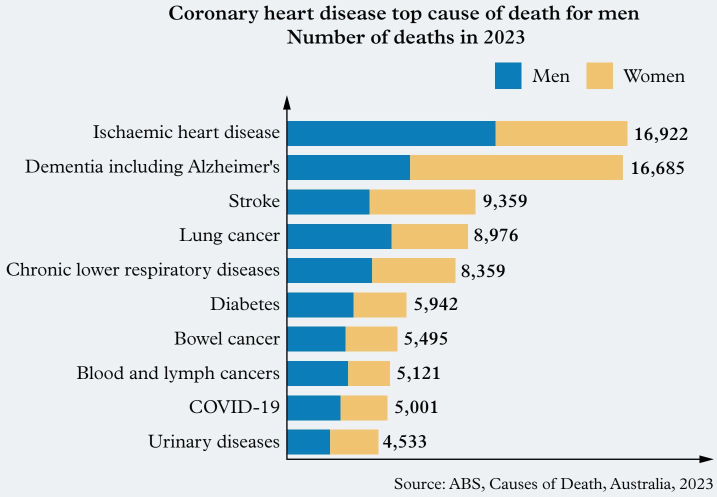
2 **Describe** how age can contribute to a non-infectious disease.

Analyse

3 **Compare** (the similarities and differences between) infectious disease and non-infectious disease.

4 **Compare** pseudoscience and science.

5 Figure 6 shows the leading causes of death in Australia in 2023. **Explain** why the level of:
  a dementia is increasing as Australians start living longer
  b cardiovascular disease decreases as people improve their lifestyle
  c lung cancer decreases as fewer people smoke cigarettes.



Source: ABS, Causes of Death, Australia, 2023

Figure 6 The leading causes of death in Australia in 2023

Apply

6 **Describe** an example of pseudoscience.

7 **Explain** how a person's diet can contribute to disease.

Lesson 3.2

Challenge: Modelling cardiovascular disease

Aim

To model the effects of blood flow in a cholesterol-clogged artery

What you need:

- Scissors
- 3 plastic cups
- 2 straws with different diameters
- Playdough or silly putty
- Tray for catching water
- Food colouring (red)
- 300 mL water

What to do:

1. Use the scissors to cut a hole on the side of two of the cups, near the base. Each hole should be approximately the same distance from the base of the cup.
2. Gently enlarge the hole on one cup to fit the narrow straw. Repeat for the second cup with a wider straw.
3. Cut the narrow and wide straws so they are the same length (approximately 5 to 7 cm long).
4. Place the narrow straw into the hole in the cup with the smaller hole and the wider straw into the hole in the cup with the wider hole. Make sure the holes are not squeezing the straw and narrowing it.
5. Use the playdough or silly putty on the inside of the cup to seal the hole around the straws so that water will not leak out of the hole (Figure 1).

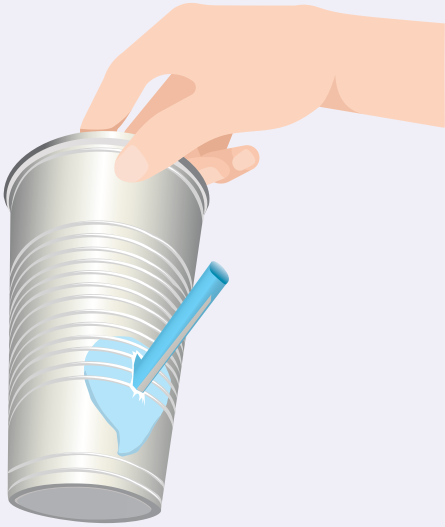


Figure 1 The playdough should be placed around the straw on the inside of the cup to prevent leaking.

6. Place both cups in the tray, making sure the straw is pointing towards the base of the tray.
7. Measure 300 mL of water and add a few drops of red food colouring to it. Use the third cup to quickly fill the two cups in the tray with the coloured water.
8. Describe the flow rate of water through each straw (Figure 2).

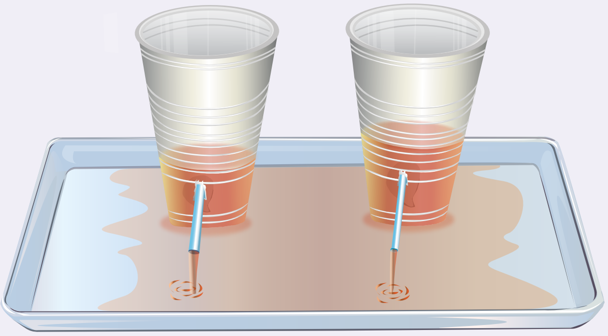


Figure 2 The water will flow at different rates.

Questions

1 **Describe** how modelling can be used to investigate the cause of a disease.
2 **Describe** the differences between the two cups used in the model.
3 **Describe** similarities in the two cups used in the modelling experiment.
4 **Compare** the cup models to a healthy artery and an artery that is clogged by a cholesterol plaque.
5 **Explain** how a cholesterol-clogged artery would affect the normal functioning of the body.
6 **Describe** how environmental or lifestyle factors could reduce a person's chance of developing this disease.

Lesson 3.3

Challenge: Modelling the effects of genetics on heart disease

Modelling the effects of genetics on heart disease

All people inherit their genetic material (DNA) from their parents. Half of a person's DNA comes from their mother, and half comes from their father. Cardiovascular disease can be influenced by factors in the environment and the genetic material that you inherit from your parents. Some of this genetic material can increase your chances of developing type 2 diabetes, high cholesterol in the blood vessels and high blood pressure that stiffens the blood vessels. In this activity, you will model how these different genetic factors are passed from parents to children.

Aim

To model the effects of genetic material that increases the chances of cardiovascular disease being passed from parents to two children

What you need:

- Mother's genetic material in a bag or envelope containing:
  – type 2 diabetes: 5 red beads and 1 blue bead
  – no high cholesterol: 1 red counter and 3 blue counters
  – no high blood pressure: no red buttons and 4 blue buttons
- Father's genetic material in a bag or envelope containing:
  – no type 2 diabetes: 2 red beads and 4 blue beads
  – high cholesterol: 4 red counters and 0 blue counters
  – average blood pressure: 2 red buttons and 2 blue buttons

What to do:

1 Child 1 has half the genetic material from their mother (3 beads, 3 counters and 2 buttons) and half their genetic material from their father (3 beads, 3 counters and 2 buttons). Carefully mix the genetic material from the mother. Without looking, select the appropriate number of beads, counters and buttons from the mother's bag/envelope.
2 Carefully select the genetic material of child 1 from the father's bag/envelope.

3 Combine the genetic material from child 1 and record the results.
4 Place the genetic material of both parents back into the appropriate bags/envelopes and mix.
5 Repeat steps 1 to 3 to determine the inherited genetic material for child 2.

Results

Copy Table 1 into your notebook and record your results.

Questions

1 **Identify** the diseases that child 1 and child 2 are at risk of developing.
2 **Describe** the symptoms of each disease represented in this model.
3 **Describe** the lifestyle changes that child 1 and child 2 can make to reduce their chances of developing these diseases.
4 **Explain** how genetics can affect the development of non-infectious diseases.

Table 1 Results for modelling the inheritance of genetic material that is linked to disease risk. A higher number of red beads/counters/buttons indicates the risk of developing the disease.

Child	Beads (red/blue)	Counters (red/blue)	Buttons (red/blue)	Diseases (type 2 diabetes; high cholesterol; high blood pressure)
1				
2				

Lesson 3.4

Science as a human endeavour: Pathogens cause disease

Key ideas

→ Infectious diseases are caused by microorganisms such as bacteria, fungi and viruses.

→ Koch's postulates provide a process for identifying the cause of an infectious disease.

Learning intentions and success criteria

Introduction

One of the most exciting things about science is the way ideas can change as new evidence is discovered through experimentation. For many centuries, diseases were thought to be a result of supernatural causes (ghosts, fairies, witchcraft) or bad habits and lifestyle.

One of the first people in Western medicine to question the accepted idea of supernatural causes of disease was Hippocrates (460–377 BCE). He concluded that something in the air, soil, water and food caused diseases in humans and animals. His work was followed up by Claudius Galen (131–201 CE), who was a doctor to the gladiators and used animal dissections to explore anatomy.

Girolamo Fracastoro (1478–1553) was an Italian astronomer and doctor who was one of the first to suggest that disease could be transmitted from person to person via small invisible particles. He theorised that these particles could travel through the air, via contaminated clothing or by direct contact with the sick person. It took 200 years and the invention of the microscope to confirm his theories and to develop the "germ theory" used today.

Germ theory states that many diseases are caused by the presence and actions of specific **microorganisms**. These microorganisms are called **pathogens** (Figure 1). Germ theory was confirmed by Louis Pasteur (Figure 2) and Robert Koch.

microorganism a living thing that can only be seen with a microscope

pathogen a microbe that can cause disease

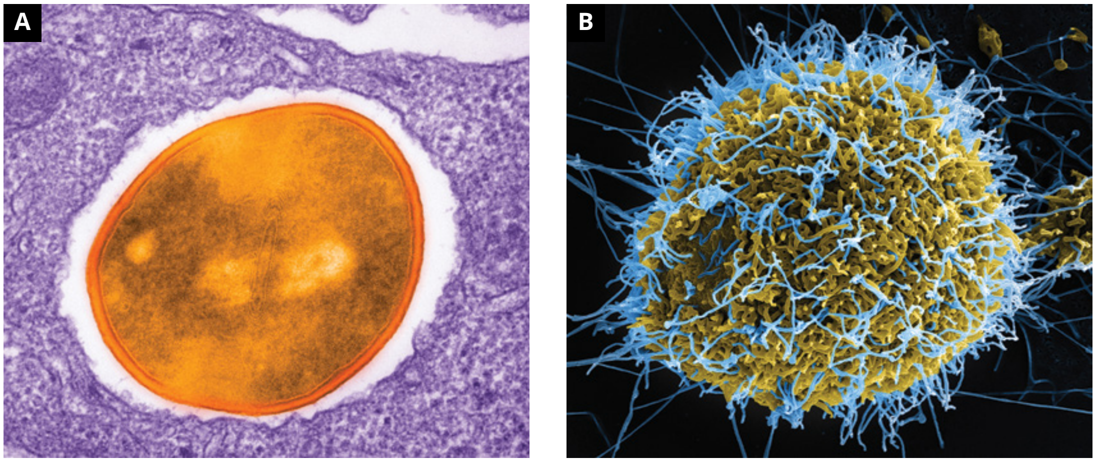


Figure 1 Most infections are caused by microscopic pathogens such as bacteria or viruses. (A) Bacteria (such as those that cause tuberculosis) are very small cells that are able to reproduce by themselves. They can release toxins that affect the normal functioning of our body. (B) Viruses (such as those that cause influenza) are much smaller than bacteria and are unable to reproduce by themselves. Instead they invade the host's cells and use the organelles to make new copies of themselves. This stops the host's cells from functioning properly.

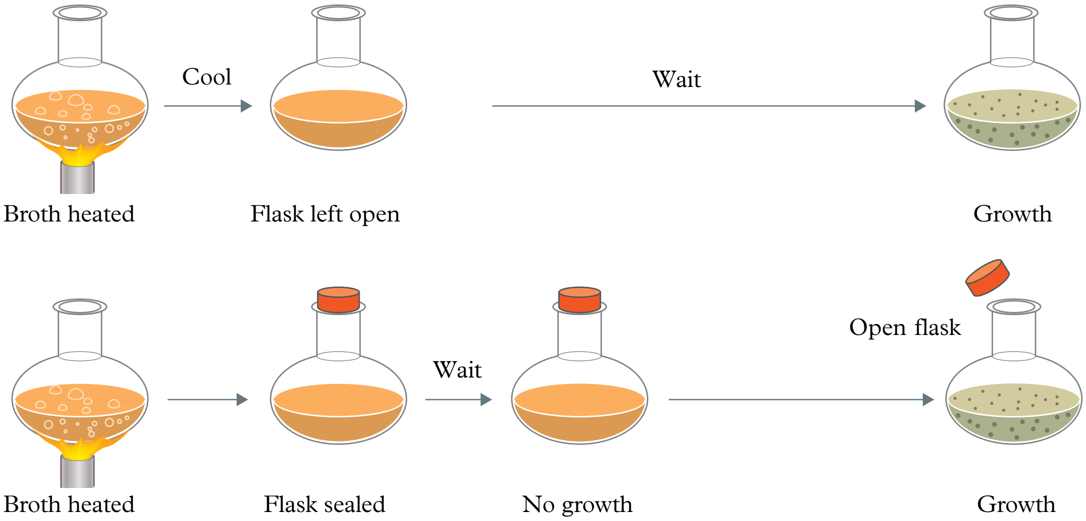


Figure 2 Louis Pasteur's experiments found that microorganisms in milk were killed by heat. This process is called pasteurisation and is still in use today.

Robert Koch went on to develop a set of rules, known as Koch's postulates, that provide evidence that a pathogen causes a disease.

Koch's postulates:

1 The microorganism or other pathogen is present in all cases of the disease.
2 The pathogen can be isolated from the diseased **host** and grown in the laboratory.
3 The pathogen from a pure culture causes the disease when inoculated into a healthy susceptible laboratory animal.
4 The pathogen is re-isolated from the new host and shown to be the same as the originally inoculated pathogen.

host a living organism that provides energy and nutrients to another organism, including a pathogen

Figure 3 Robin Warren (left) and Barry Marshall (right)

Australian scientists Barry Marshall and Robin Warren followed these postulates when they researched stomach ulcers in 1984. Prior to this, stomach ulcers were thought to be caused by stress and bad eating habits. Marshall and Warren discovered that a bacterium (*Helicobacter pylori*) was found in all patients with stomach ulcers. Most doctors at the time thought that no bacterium could survive in the acidic environment of the stomach. Marshall and Warren isolated the bacterium and injected it into mice, causing the disease in the mice. Unfortunately, many doctors still did not believe the research, so Barry Marshall ignored laboratory safety and swallowed a culture of the bacteria, causing the disease in himself. Treatment with antibiotics killed the bacteria and cured his stomach ulcer. Barry Marshall and Robin Warren were awarded the Nobel Prize in Physiology or Medicine in 2005 (Figure 3).

Antibiotics

Before antibiotics were discovered, a single scratch from a thorn on a rose bush could become infected and kill a person.

In 1928, Alexander Fleming was trying to grow bacteria in his laboratory. When he returned from holidays he discovered that some Petri dishes he had left open on the bench were growing a mould similar to that found on bread. There were no bacteria growing near the mould. Being a good scientist, Fleming recognised that further investigation was necessary. He performed some experiments and discovered that the *Penicillium* mould was releasing a chemical that killed bacteria. Australian scientist Howard Florey was then instrumental in developing penicillin into a form that could be mass-produced. Both men were awarded the Nobel Prize in Physiology or Medicine for their work.

Penicillin works by breaking down the cell walls of bacteria. As human cells do not have a cell wall, they are unaffected. This means that penicillin will kill the bacteria in your body but not kill your own body cells. Viruses do not have cell walls. Instead, they have a protein coat that surrounds and protects them. This means penicillin does not affect viruses, such as influenza, coronaviruses or the common cold.

Viruses can be killed or controlled through the use of antiviral medication.

Testing your skills and capabilities

Identifying assumptions

Scientists are always asking questions and challenging what they know. Robin Warren and Barry Marshall asked questions and challenged the assumption that stomach ulcers were caused by stress. Everyone makes assumptions (accepting that something is true or certain without evidence) based on past experiences. It is a way of saving time and thinking space. We assume that the Sun will rise in the morning, that the chair we sit on will not collapse and that food we have cooked will be hot. Making assumptions is not always a bad thing, as long as we are aware that we are making them. Asking questions is a way of identifying assumptions that are not true.

1 **Identify** the question that Robin Warren and Barry Marshall asked about stomach ulcers.
2 **Identify** how Warren and Marshall used each of Koch's postulates to find the cause of stomach ulcers.
3 **Identify** the assumption that other doctors had made about the cause of stomach ulcers.
4 **Identify** one assumption that you have made in the past week.
5 **Describe** the evidence you would need to convince yourself that your assumption in question 4 was incorrect.
6 **Describe** an invention or behaviour you would change if your assumption in question 4 was incorrect.

Skills builder: Conducting investigations

7 Scientists that work with pathogens in the laboratory are at risk of being exposed to extremely dangerous illnesses. You may have seen people in a laboratory wearing full personal protective equipment (PPE). People that work with pathogens typically have all their skin covered and sealed. This is one of the ways scientists manage risk.
   a **Explain** why wearing PPE in the laboratory is important when working with pathogens. (THINK: What are the risks of contracting a virus? What could happen if results were contaminated?)
   b **Identify** one other measure that can help keep scientists safe in the laboratory. (THINK: Should scientists work alone? What can go wrong if you are alone in the lab?)

Lesson 3.5

Experiment: Investigating germ theory

Caution!

Do not open the tape seals on the agar plates.

Aim

To determine what factors affect the growth of airborne microbes

Materials

- 4 agar plates
- Sticky tape or paraffin film
- Permanent marker
- Various disinfectants

Method

1 Open the lid of one agar plate and leave it sitting on the bench for 15 minutes. Have a conversation near the open plate.
2 Place the lid back on top of the agar plate and seal it with sticky tape. Write the label “Open bench” around the edges underneath the plate, so that it does not obstruct the view of the agar.
3 Leave the other agar plate unopened. Seal it with sticky tape. Label the plate “Control”.
4 Incubate the agar plates at 35°C to 37°C for approximately 3 days.
5 Do not open the plates! Examine the closed plates for any growth.

Inquiry: What if the first agar plate was sprayed with a disinfectant before being incubated?

Plan and conduct an experiment that answers the inquiry question.

- **Develop** a hypothesis (If … then … because …) 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 you will need to control to ensure a valid test. **Describe** how you will control these variables.
- **Identify** the materials you will need for your experiment.
- **Develop** a method for your experiment and write it in your logbook.
- **Construct** a table to record your results.
- Show your teacher your planning for approval before starting your experiment.

Results

Record all your results. You could take photos showing the microbe growth on the agar plates.

Discussion

1 **Define** the term “bacterial colony”.
2 **Describe** how a bacterial colony forms on an agar plate.
3 **Explain** why colonies are different colours and sizes.
4 **Compare** the colour and size (diameter) of the different colonies that grew on each plate.
5 **Explain** why you left one agar plate unopened.
6 **Evaluate** whether your results support germ theory (by **explaining** germ theory, **comparing** your results to germ theory, and **deciding** whether your results support germ theory).
7 **Evaluate** whether your results support your hypothesis (by **describing** your results in one to two sentences, **comparing** your results to your hypothesis, and **deciding** whether your hypothesis was supported).

Conclusion

Describe the factors that affect the growth of microbes.

Lesson 3.6

Identification of pathogens allows the treatment of infectious diseases

Key ideas

- → Different types of bacteria need to be treated with different antibiotics.
- → Antivirals are used to treat viral infections.
- → Fungicides are used to treat fungal infections.
- → Multicellular pathogens can cause disease.

Learning intentions and success criteria

Introduction

The phrase “catching a cold” is often used to describe how a person becomes infected with a pathogen. It describes the way the normal functioning of your body is affected. You might have a runny nose, start coughing or even experience an increase in the temperature of your body (have a fever). Sometimes the disease can start changing the way you breathe or the way your heart beats. Severe infections can even cause death.

A disease-causing agent that can be passed from one living organism to another is called a pathogen. The living organism that it infects is called a host. When you have a “cold”, you are hosting a pathogen. When you sneeze, you are passing the pathogen into the air so that it can infect another person or host. Some pathogens can last a long time in the air, while others die very quickly.

Knowing the agent that causes infectious diseases allows scientists to develop treatments that target the pathogen and allow the organism (you) to recover.

Bacteria

unicellular organism a living thing that has one cell

Bacteria are small **unicellular organisms** that can co-exist as a normal part of a healthy living organism. We rely on “good” bacteria to help us digest our food, and to protect our skin from other disease-causing pathogens. However, all bacteria have the potential to cause a disease if their growth becomes uncontrolled. About one person in four carries a strain of bacteria called *Staphylococcus aureus* (golden staph) on their skin or in their throat. Most of the time, it does not cause disease, unless it is able to enter the body through a cut in the skin. The internal parts of the body provide ideal conditions for the bacteria to multiply and cause damage. It can even infect the brain, bones and heart valves.

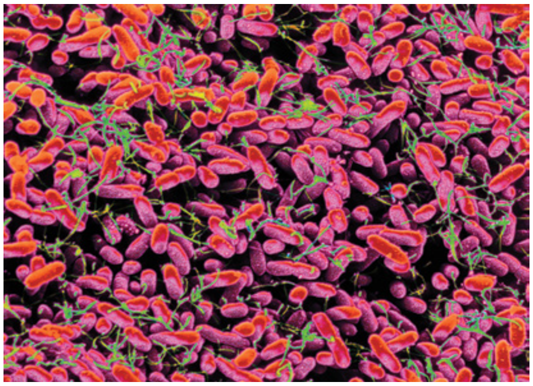


Figure 1 Some bacteria keep us healthy. Other bacteria are pathogens and interfere with the natural functioning of our body.

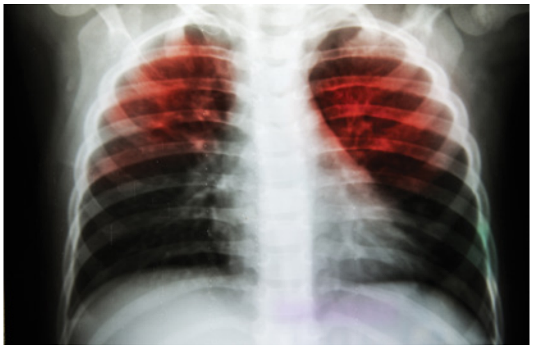


Figure 2 Tuberculosis is a lung disease caused by the bacteria *Mycobacterium tuberculosis*.

Bacteria replicate through binary fission (Module 4 Reproduction (page 152)). This involves a single cell growing longer until it splits into two genetically identical cells. Binary fission can occur very quickly. Some bacteria can replicate every 20 minutes.

Sometimes, the bacteria can be killed by antibiotics (a drug that stops the growth of a bacterium). Antibiotics will only affect the mechanisms that are present in bacterial cells and not the cells in multicellular organisms like animals. For example, the antibiotic penicillin prevents a bacterial cell from growing or being repaired. As animal cells do not have cell walls, penicillin will not affect the animal host of the bacteria.

Unfortunately, some strains of golden staph bacteria are resistant to multiple antibiotics; for example, multi-resistant *Staphylococcus aureus* (MRSA). This means the bacteria cannot be killed and the host is at risk of dying.

Viruses

Figure 3 Viruses such as influenza (or SARS-CoV-2) can only replicate when they are inside another cell.

Viruses are considered non-living pathogens as they are unable to replicate on their own. They are much smaller than bacteria. These viruses often cannot survive on their own and need to invade a living cell (including bacteria) to survive (Figure 3). Some viruses, such as influenza or SARS-CoV-2 (the cause of COVID-19), can survive in sneeze or cough droplets in the air for a short time, before they need to be breathed into the lungs of their next host.

Once inside a host cell, the virus breaks apart and uses the cell's mechanisms to make many new identical virus copies. Sometimes the host cell then breaks apart to release the virus particles. This can cause damage and eventually the disease in the host.

As the virus is often hiding inside cells, and does not replicate by itself, it is not affected by antibiotics (that kill living, replicating cells). This means a person infected with influenza cannot be treated with antibiotics. Instead, antiviral treatments can be used to prevent the virus making new copies inside the cells.

Fungi

Most fungi, such as yeasts or moulds, are **opportunistic** pathogens. This means they are more likely to cause a disease in a host that is already weakened. Fungi cells are larger than bacteria cells and can reproduce both sexually and asexually. You will learn more about these types of reproduction in Module 4 Reproduction (page 152). One type of fungi that produces disease is *Candida albicans*. This yeast fungi can normally be found on the skin,

opportunistic the ability to make the most of favourable conditions to thrive and multiply mouth or throat of a healthy person without causing problems. Sometimes the host becomes weakened by other diseases such as cancer or by taking some medications. When this occurs, *Candida albicans* will replicate quickly and cause redness and pain when swallowing (Figure 4).

Fungicides are chemicals that only affect fungi cells. Echinocandins are a group of chemicals that prevent the growth of fungal cell walls. The cell wall of a fungus is different from a bacterial cell wall. This means a fungicide will kill a fungal pathogen like *Candida albicans* but not a bacterial pathogen such as *Staphylococcus aureus*. This is why it is important to identify which of the pathogens (viruses, bacteria or fungi) is causing a disease.

Figure 4 *Candida albicans* (a yeast) is an opportunistic pathogen that causes disease in already weakened hosts.

From the COVID-19 pandemic to the U.S. West Coast wildfires, some of the biggest threats now are also the most microscopic.

A particle needs to be 10 microns (μm) or less before it can be inhaled into your respiratory tract. But just how small are these specks?

Here's a look at the relative sizes of some familiar particles ↘

Pollen can trigger allergic reactions and hay fever—which 1 in 5 Americans experience every year.

Source: Harvard Health

The visibility limits for what the naked eye can see hovers around 10-40μm.

Respiratory droplets have the potential to carry smaller particles within them, such as dust or coronavirus.

Wildfire smoke can persist in the air for several days, and even months.

Figure 5 Pathogens come in all shapes and sizes.

Multicellular organisms

Some pathogens are **multicellular organisms**. An example of this is a tapeworm that can live in the intestines of animals including humans. This type of flatworm uses the food in the intestine to survive. It has hooks around its head and mouth so that it can stabilise its position and take in the pre-digested food through its mouth (Figure 6). This can interrupt the normal functioning of the digestive system, causing pain, vomiting, diarrhea and weight loss. When the tapeworm replicates, the eggs pass into new hosts through faeces or uncooked meats. The eggs hatch and produce a larval cyst that can live in all parts of the body, including the liver, lungs, heart or brain. The symptoms of the larval cyst disease will vary depending on the location. Treatment involves anti-parasitic drugs.

multicellular organism a living thing that has many cells

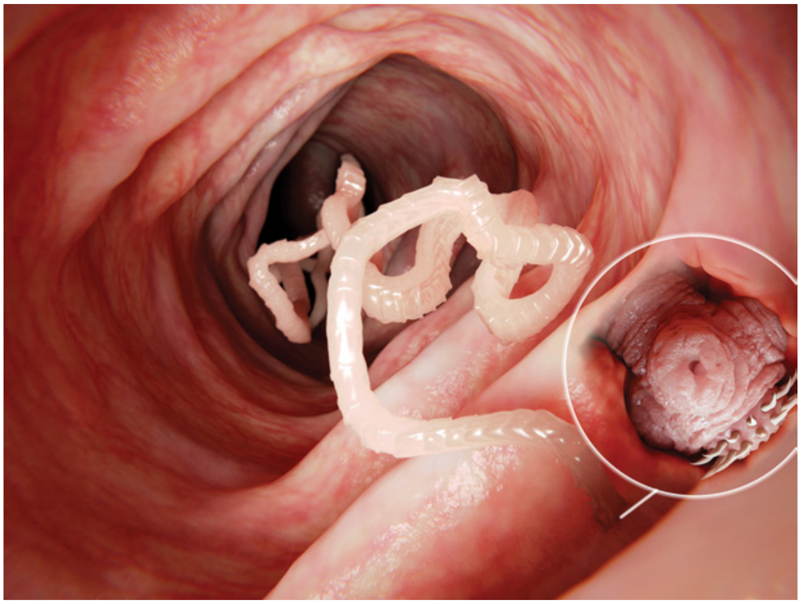


Figure 6 Tapeworms are flatworms that prefer to live in the intestines of their host.

Check your learning 3.6

Check your learning 3.6

Retrieve

1 **Define** the term “opportunistic”.

Comprehend

2 **Describe** how a virus replicates.

3 **Describe** the disease caused by a tapeworm in the intestine.

4 **Explain** why a virus cannot be treated with antibiotics.

Analyse

5 **Compare** (the similarities and differences between) bacteria and viruses.

Apply

6 **Describe** the potential symptoms of a larval cyst in the brain by describing the consequences of interrupting the normal functioning of the brain.

7 **Describe** how a virus can be transmitted from one host to another.

Lesson 3.7

Transmission of infectious diseases can be prevented

Learning intentions and success criteria

Check the next lesson for a linked practical activity or experiment.

Key ideas

→ Pathogens need to be transmitted between hosts for a disease to spread.

→ Transmission of infectious diseases can be prevented by handwashing, mask-wearing, isolation and surface disinfection.

Transmission of infectious diseases

virulent a pathogen's ability to cause damage in a host organism

Pathogens need a host organism in order to survive. Some pathogens are so **virulent** that they quickly infect and kill their host. When the host organism dies, so does the pathogen. To be "successful", a pathogen needs to be able to live inside its host without killing it.

It is also important that the pathogen is not so virulent that the host cannot move. If a human host is sick in bed, the pathogen cannot infect other hosts. The role of a pathogen is to pass copies of itself on to new and healthy hosts so that it can survive.

While many people are healthy enough to eventually defeat the pathogen, there are many people who are already weakened by other diseases, such as cancer, or have impaired immune systems. If they were to be infected by the pathogen, they would be at a greater risk of illness or death. This means that we need to be able to prevent the **transmission** of infectious diseases.

transmission the movement of a pathogen from one host to another

Preventing transmission

Preventing a pathogen from moving to new hosts is dependent on the characteristics of the pathogen and their ability to survive outside the host.

Handwashing

One of the most common ways your body tries to rid itself of a pathogen is to flush it out with mucous produced in the nose. This causes the symptom of a runny nose. If too much mucous is produced, it can move down the back of the throat and cause a cough. Some pathogens cause the tissue in the throat to become itchy, producing a cough with less mucous.

A person who has these symptoms will commonly rub their nose or cover their cough with a hand. This coats the hand with the viral or bacterial particles that are caught in the mucous. If they touch a door handle or table with that hand, the mucous and pathogens are passed on to the surface.

One of the most effective ways to prevent the transmission of these pathogens is to wash your hands after touching your nose or face. Running your hands under warm water can usually flush the pathogen and mucous from the skin. It is even more effective to use an **antiseptic** chemical or soap. While soap does not always kill the pathogen, it does prevent it sticking to your skin. The length of time spent washing your hands is important. The American Centers for Disease Control and Prevention (CDC) recommends that your hands are scrubbed with a soap lather for 20 seconds (Figure 1). This is the length of time it takes to sing the song "Happy Birthday" twice.

antiseptic a chemical that kills a pathogen on your skin

Figure 1 Soap lather rubbed over the hands for 20 seconds is enough to kill most pathogens.

Some chemicals do not need water to be an effective antiseptic. While these substances are not as effective as soap and water, hand sanitisers with at least 60% alcohol will kill many pathogens. These antiseptics need to be rubbed over the surfaces of the hands until the hands are dry in order to kill the bacteria, viruses or fungi.

Surface disinfection

Unfortunately, not everyone is aware of how to prevent the transmission of pathogens. This means that viruses, fungi and bacteria can be easily transmitted to non-living surfaces such as door handles and hand railings. This is usually not a problem, as the pathogens cannot get through the surface of your skin.

The only way most pathogens can enter your body is through a mucous-covered surface such as your mouth, nose or eyes. The cells in these areas are more accessible than your external skin. As the average person touches their face 23 times each hour (every 3 to 4 minutes), it means that there is a chance of transferring a pathogen picked up from a surface to the nose, mouth or eyes.

There are two ways to prevent the transmission of the pathogen in this way – stop touching your face or disinfect the surface.

There are many chemicals that can be used to kill common bacteria, fungi and viruses that may be present on hard surfaces. These chemicals are called **disinfectants**.

disinfectant a chemical that kills a pathogen on non-living surfaces

There are also some materials that can reduce the amount of time that pathogens can survive on a surface. Scientists in Europe tested copper alloy door handles in an aged care home for the presence of MRSA (multi-resistant *Staphylococcus aureus*) over 3 years. They found that the amount of bacterial contamination was significantly less on these surfaces than on stainless steel surfaces (Figure 2).

Figure 2 Copper alloy surfaces can limit the growth of bacteria on the surface.

Isolation

Some infectious diseases such as COVID-19 (coronavirus disease) can have a higher transmission rate than other diseases. This means the virus has an increased chance to infect a new host if an infected person is:

- in the same room for a long period of time
- coughing, singing, shouting or exercising
- experiencing symptoms (fever or runny nose)
- in a poorly ventilated room
- close together with other people.

This is because the virus can survive for some time in the water droplets that are a normal part of a person breathing out (Figure 3). These viral particles can remain suspended in the

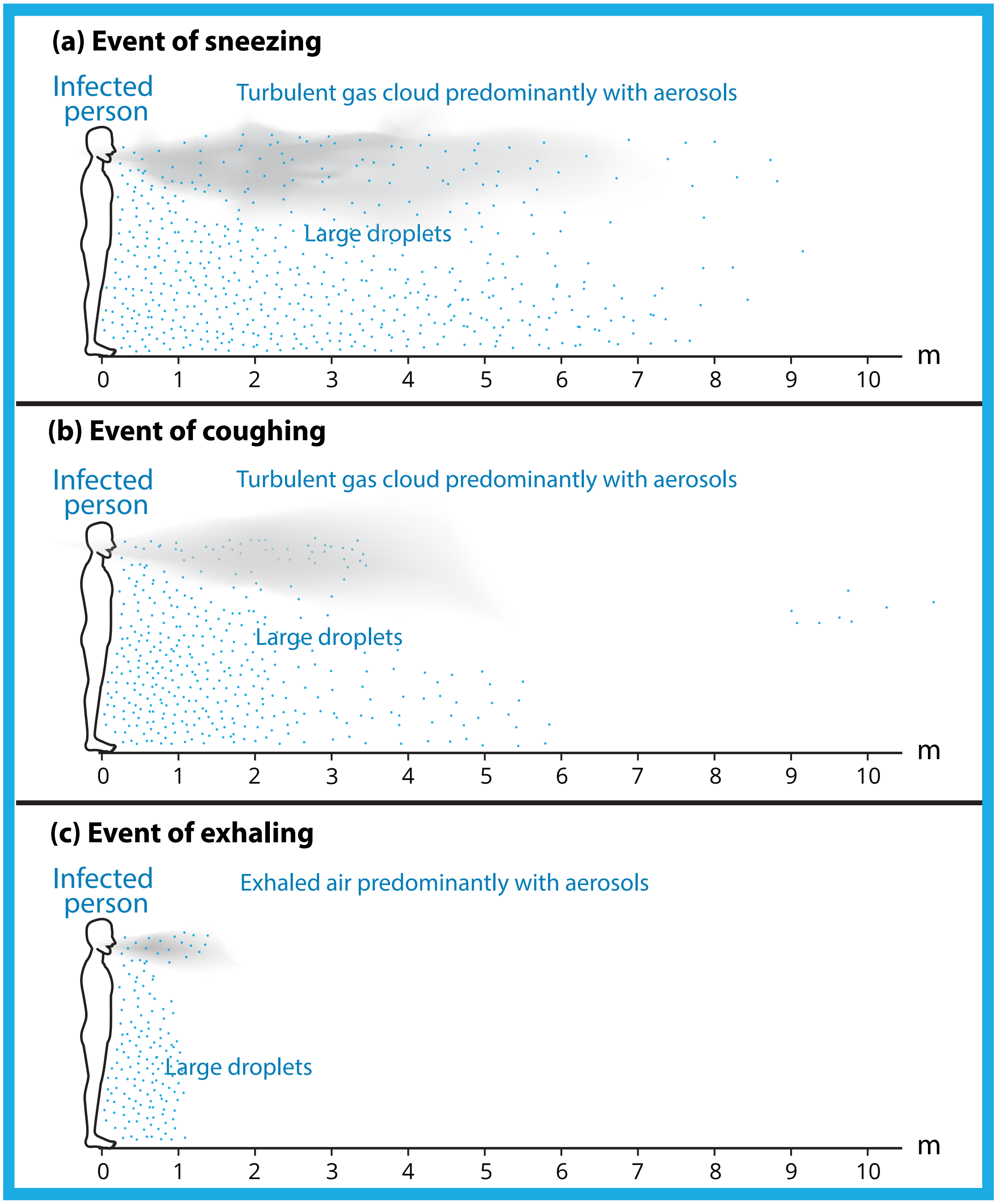


Figure 3 Some pathogens can travel through the air in water droplets.

air for a few hours. One of the most effective ways to stop the transmission of pathogens like COVID-19 is to isolate the infected person and to **quarantine** any people who may have come into contact with them. If an infected person is not exposed to a new host, the pathogen cannot cause another infection.

quarantine the separation and restriction of movement or travel

Mask-wearing

Like quarantine, wearing a mask provides a barrier to a pathogen, preventing it from being transmitted to a new host. The effectiveness of the mask can vary depending on the size of the pathogen (Table 1). Each type of mask is made out of different materials. Most masks have a series of interlacing fibres that form narrow tunnels (N95 mask tunnels = 0.1 to 0.3 micrometres wide). For a pathogen to travel through a mask, the pathogen-carrying water droplet would need to travel through the fibre tunnel without touching any of the fibres. This means a person wearing a tight-fitting mask will not be able to breath in a pathogen. This prevents the transmission of the disease-causing pathogen.

Table 1 The size of different cells and pathogens

Cell	Size
Average cough droplet	8 micrometres
Human cell	8 to 130 micrometres
Fungal cell	3 to 10 micrometres
Bacterial cell	0.3 to 5 micrometres
Viruses	0.025 to 0.35 micrometres

Educating the public

One of the challenges of preventing the transmission of a pathogen is reminding people to wash their hands, disinfect surfaces, wear a mask or remain in isolation. One of the roles of the state and national health departments is to identify a potential risk of infection and to remind the people affected to take appropriate measures. This may include social media campaigns and posters in bathrooms, retail stores or hospitals (Figure 4). Different people respond to different messages. The wording that might appeal to your grandparents will be different to your preferences. The health department needs to consider whose attention they need to attract and how to get them to notice the key message. This is why the posters you see in public bathrooms may be different from the posters you see in your school.

Protect yourself and your family

Cover your cough and sneeze

1 **COVER** your mouth and nose with a tissue when you cough or sneeze.

2 Put your used tissue in the rubbish **BIN**.

3 If you don't have a tissue, cough or sneeze into your upper sleeve or elbow, **NOT YOUR HANDS**.

4 **WASH** your hands with soap and running water. Dry your hands thoroughly with a disposable paper towel or hand dryer.

Stay germ free and healthy

Authorised and published by the Victorian Government, 1 Treasury Place, Melbourne.
© State of Victoria, April 2018 (1804028)

VICTORIA State Government | Health and Human Services

Figure 4 Public health campaigns can help to reduce the spread of infectious diseases by educating the public

Check your learning 3.7

Check your learning 3.7

Retrieve

1 **Define** the terms “virulent” and “transmission”.

Comprehend

2 **Describe** why it is important for a pathogen to not kill its host.

3 **Describe** the best way to wash your hands to prevent transmission of a pathogen.

4 **Explain** why it is important to wash your hands after blowing your nose.

Analyse

5 **Compare** (the similarities and differences between) a disinfectant and an antiseptic.

6 **Compare** the effectiveness of wearing a mask and disinfecting surfaces.

Apply

7 **Explain** how medical personnel might protect themselves from becoming infected from pathogens.

Lesson 3.8

Challenge: Testing the effectiveness of washing hands

Aim

To test the effectiveness of washing hands

What you need:

- Paper and pen
- Newspaper
- Lab coat
- Teaspoon
- Washable paint
- Timer
- Sink
- Blindfold
- Water
- Paper towels (10 sheets)
- Soap

What to do:

1 In groups of three to four, divide the paper into four equal sections. In each section trace an outline around a hand.

2 Create a scale to measure the cleanliness of the parts of the hand. Label each part of the hand as “completely dirty (++++)”, “very dirty (+++)”, “slightly dirty (++)” or “dirty (+)”. Use a pencil or pen to colour in the parts of the outlined hands to match the label.

3 Cover the lab bench with newspaper.

4 Assign each member of the group a role: handwasher, timer or observer(s).

5 The handwasher should place 1 teaspoon of washable paint on the palm of one of their hands. Rub the hands together to spread the paint evenly across both hands, including the

▶

back of the hands and around/under each fingernail. Allow the hands to dry completely (approximately 5 minutes).

6. At the sink, cover the handwasher's eyes with the blindfold. Allow the handwasher to wash with just water (no soap) for 1 second (use the timer).
7. Lightly press the hands with the wet paint onto the paper towel. Do not remove the blindfold or hint to the handwasher if the hands are dirty or clean.
8. The observers should record in their results table the cleanliness (amount of paint) on the blotted handprint under "1 second". Use the handprint ratings decided in step 2 as a guide.
9. Repeat the washing procedure with just water for 4 more seconds. Repeat step 7. This is the result for the 5-second (total) wash.
10. Repeat the washing procedure with just water for 15 more seconds. Repeat step 7. This is the result for the 20-second (total) wash.
11. Draw a line graph of the results (time on the horizontal *x*-axis, and cleanliness "+" on the vertical *y*-axis).
12. Repeat steps 5 to 11 using soap and water.

Results

1. Copy Table 1 into your notebook and record your results.

Table 1 Results for testing the effectiveness of washing hands with water only and soap and water.

	0 seconds	1 second	5 seconds	20 seconds
Water only	++++			
Soap and water				

2. **Compare** your results to the results of other students in the class.

Questions

1. **Compare** the effectiveness of washing hands with only water over the different time periods.
2. **Compare** the effectiveness of washing hands with soap and water over the different time periods.
3. **Compare** the effectiveness of washing hands with just water and with soap and water.
4. Time yourself singing the song "Happy Birthday" twice. **Describe** the effectiveness of using this as a timing method for washing hands.

Lesson 3.9

The immune system protects our body in an organised way

Learning intentions and success criteria

Key ideas

→ The immune system physically prevent pathogens entering your body.

→ Pathogens that enter the body are identified and destroyed by the immune system.

The immune system

The role of the **immune system** is to protect you against foreign invaders by physically stopping them from entering your body, and to identify and attack them if they do manage to enter. The immune system has three lines of defence against pathogens, each with a different role.

immune system a system of organs and structures that protect an organism against disease

First line of defence

The first line of defence is to stop pathogens from getting inside your body (Figure 1). Your body is protected by several layers of waterproof skin cells that are tightly linked to each other. This includes the lining of your digestive system. If a pathogen is detected, the first response is to flush it out with tears, vomiting or diarrhea, to prevent it reaching any surfaces that might be vulnerable to infection.

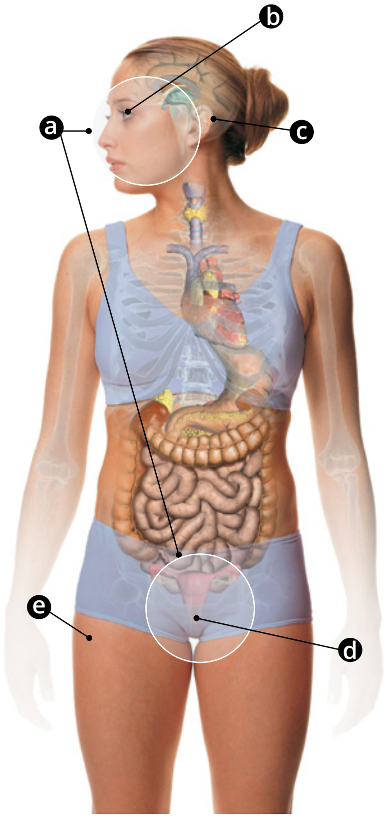


Figure 1 The skin and mucous membranes are the first line of defence against pathogens.

ⓐ Eyes, ears, nose, mouth and genitals are usually exposed to the air and/or environment, so pathogens can enter. Mucous membranes are thin skin-like linings of these entry points. Chemical barriers here assist in defence. Slimy mucous can capture and kill some bacteria.

ⓑ Tears wash pathogens out of the eyes.

ⓒ Ear wax captures pathogens trying to enter through the ears.

ⓓ Urine is slightly acidic, which makes it harder for bacteria to grow.

ⓔ Skin is thick, waterproof and difficult to damage. Oils and sweat help protect the skin. In dry conditions, bacteria are damaged and destroyed by the salt and antimicrobial chemicals in these secretions.

Second line of defence

If there is a break in the first line of defence, such as damage to the skin, a pathogen can enter the body. The second line of defence involves a general "seek and destroy" approach. It does not matter what type of pathogen has entered – the response is always the same. This is called the general or non-specific immune response.

The key elements of the non-specific immune response are:

- blood clotting – to repair the skin break and stop additional infection through skin damage
- inflammation – to increase the number of blood cells reaching an infected area
- fever – some pathogens cannot survive at high temperatures, so heating up the body is one way to destroy them.

Specialised **white blood cells** called **phagocytes** (Greek for "cells that eat") are produced by the body to destroy pathogens. These cells are brought to the infected area by the increased blood supply (inflammation). They surround and absorb the pathogens, destroying them in a process called phagocytosis (Figure 2). The phagocytes may also release chemical messengers that increase the amount of fluid in the infected area, causing even more swelling and blood flow.

white blood cell an immune system cell that destroys pathogens

phagocyte an immune system cell that surrounds, absorbs and destroys pathogens

Other white blood cells (including B cells and T cells) are also produced by the body to fight the infection. Each cell type has its own role, but they all work together to remove the pathogen from the body.

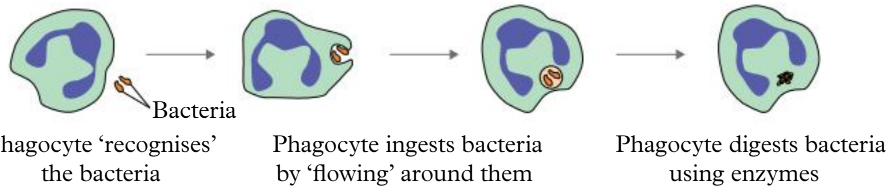


Figure 2 The process of phagocytosis

Third line of defence

Any pathogens that survive the non-specific secondary response are targeted according to their type. This is the third line of defence, and is called the specific immune response.

The specific immune response has two forms of attack. **B cells** produce special molecules called **antibodies**. These antibodies fit exactly onto a specific part of the pathogen (Figure 3). Each antibody will fit only one section of the pathogen. This causes the pathogens to become locked together and stops them from invading other parts of the body.

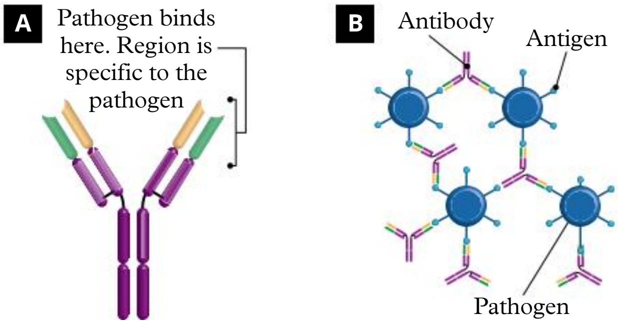


Figure 3 (A) Each antibody has a region that is specific to a particular pathogen. (B) Antibodies cause pathogens to clump together.

T cells then recognise the same specific pathogen and attack and kill it. B and T cells may take up to 1 week to recognise and destroy a pathogen. This is why recovering from an illness takes time.

Both B and T cells keep some **memory cells** alive, just in case the pathogen tries to invade again. This means the pathogen will be attacked and killed before it can cause damage a second time. Your body will be protected from re-infection in the future. You are now **immune**.

Unborn babies obtain some natural immunity by receiving antibodies through the placenta from the mother. This process, known as **passive immunity**, provides protection against certain infections during early development. After birth, antibodies are also passed to babies through breast milk, particularly through **colostrum**, the nutrient-rich first milk produced by the mother. These antibodies help strengthen the baby's immature immune system, providing defense against pathogens until the baby can produce its own antibodies. This natural immunity is crucial in protecting newborns, as their immune systems are not fully developed at birth. Breast milk also contains other immune-boosting substances, such as white blood cells and antimicrobial proteins, which further support the baby's overall health.

b cell an immune system cell that produces antibodies in response to pathogens

antibody a molecule produced by B cells that binds to a specific pathogen

t cell an immune system cell that recognises and kills pathogens

memory cell an immune system cell produced in response to an infection; retains the memory of how to fight the pathogen

immune able to fight an infection as a result of prior exposure

passive immunity temporary protection against disease provided by antibodies transferred from another source, such as from mother to baby or through antibody injections

colostrum nutrient-rich, antibody-packed first milk produced by mammals after giving birth, providing essential immune protection and nutrients to newborns

Check your learning 3.9

Check your learning 3.9

Comprehend

1 **Describe** the body's major first line of defence.

2 **Describe** one other way the body can prevent pathogens from entering.

3 **Describe** in your own words how the non-specific immune response works.

4 **Explain** why babies that are fed breast milk may have more protection against pathogens than those that are not fed breast milk.

Analyse

5 **Compare** (the similarities and differences between) the second and third lines of defence.

6 **Compare** B cells and T cells.

Apply

7 Newborn babies have not been exposed to many diseases. **Explain** why young babies may become sick more often than their parents.

Skills builder: Communicating

8 You have been asked by a teacher at your school to explain the differences between the three lines of defence to Year 7 science students. The teacher has encouraged you to use a diagram to explain this to the students, as they think the class will respond better to this.

  a **Identify** what you need to include in a diagram for the three lines of defence. (THINK: What is the most important information?)

  b **Construct** a scientific diagram(s) to explain the three lines of defence to Year 7 students. (THINK: What do scientific diagrams include? Where should you place labels?)

Lesson 3.10

Vaccination produces memory cells

Learning intentions and success criteria

Check the next lesson for a linked practical activity or experiment.

Key ideas

→ Vaccination pre-activates the third line of defence.

→ Memory cells can last up to 10 years.

Memory cells

When a pathogen escapes the first line of defence, both the non-specific second line of defence (including the phagocytes) and the specific B and T cells in the third line of defence will attack and destroy it. This process takes some time (5 to 10 days), which means the pathogen can cause some damage before it is destroyed. The immune system will be more efficient the next time the same pathogen enters the body.

After each infection, new B and T memory cells are stored in the body. They already know what the pathogen looks like and are ready to make many copies (clones) of themselves. If the same pathogen is detected again, many B and T cells move quickly (sometimes within hours) to destroy the pathogen. This is why you recover quicker, or do not even notice, the second time you are exposed to the same pathogen.

Smallpox

lesion raised bumps that develop on the skin during the infection

For over 3,000 years, the highly contagious smallpox virus was responsible for the deaths of 20 per cent to 60 per cent of those infected with it. Smallpox is a contagious and potentially deadly disease caused by the variola virus. It is characterised by fever, fatigue and a distinctive rash that develops into fluid-filled blisters or **lesions**. During the 1700s, it is thought that smallpox killed 400,000 Europeans each year. Evidence of the disease has even been found in some Egyptian mummies.

In 1796 Britain, Edward Jenner noticed that many young women who milked cows (milkmaids), and had suffered from cowpox as a result, did not get smallpox. Scientists now know that this is because the viruses that cause cowpox and smallpox are very similar. The B and T memory cells that protected the milkmaids from a second infection of cowpox also protected them from a smallpox infection.

However, Jenner did not know this. He just noticed that the milkmaids never had scars from a smallpox infection. In May 1796, to test his theory, he collected fresh cowpox pus and injected it into his gardener's 8-year-old son, James Phipps. Over the next 10 days, the boy had a mild fever and other symptoms, but recovered quickly. Two months later, Jenner deliberately injected James Phipps with pus from a fresh smallpox lesion. James Phipps did not become sick with smallpox. His immune system had the B and T memory cells ready to attack the smallpox virus.

Vaccinations

vaccination an injection of an inactive or artificial pathogen that results in the individual becoming immune to a particular disease

Vaccinations involve exposing the immune system to an inactive or artificial part of a pathogen so that it has a chance to prepare for the real infection.

A vaccine can be made up of:

- the dead pathogen
- a living but non-virulent (weakened) form of the pathogen
- parts of the broken-up pathogen
- genetic material from a viral pathogen.

Through vaccination, a person makes antibodies and memory cells that will recognise the pathogen in the future, which can lead to immunity. The smallpox vaccine (living, non-virulent form) became widespread in the 1800s. By 1958, the World Health Organization (WHO) started a global campaign that resulted in the complete elimination of smallpox worldwide (Figure 1).

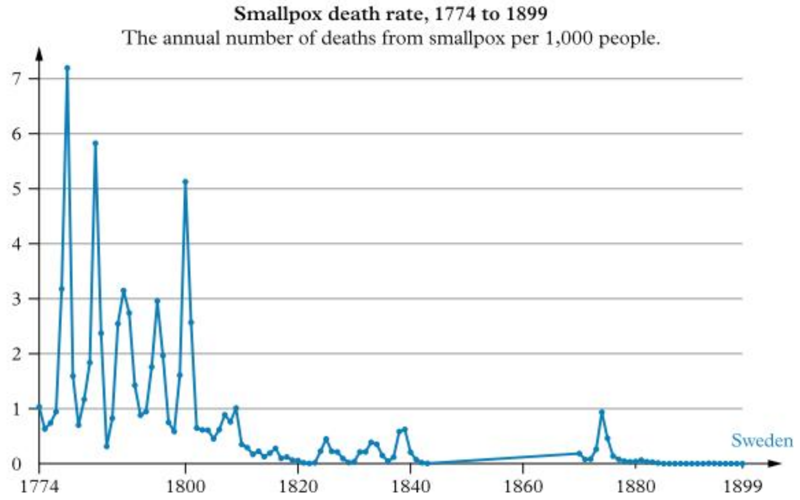


Figure 1 Smallpox is a disease that caused up to seven deaths in every 1,000 people in Sweden until vaccinations were introduced in 1801.

Herd immunity

Vaccines protect more than the person who has been vaccinated. Sometimes it can protect a whole community. Whooping cough is caused by the pertussis virus. It causes long coughing fits that can make it difficult to breathe, and can be infectious for up to 60 days. While most older children and adults recover, very young babies can die from a lack of oxygen. However, if a baby is never exposed to an infected person, they can never catch whooping cough. This can be ensured by vaccinating all the people (the herd) who are around a baby (Figure 2). This is called **herd immunity**.

herd immunity an indirect way of protecting an individual from infection by vaccinating a larger number of individuals in a population

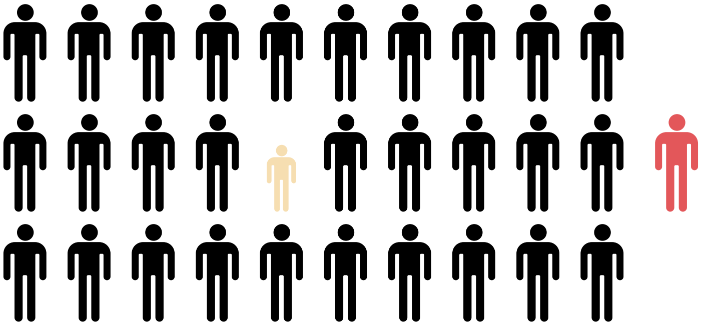


Figure 2 A baby (yellow) is protected from an infected person (red) when they are surrounded by immunised individuals (black).

The number of individuals that need to be immunised for herd immunity is different for each pathogen. Some pathogens, such as the measles virus, are very infectious. The measles virus can survive in the air for up to 2 hours after the infected person has moved away. This means that most of the population (92 per cent to 94 per cent) needs to be vaccinated to prevent the spread of measles in the community. Other diseases, such as polio, only require a vaccination rate of 80 per cent to achieve herd immunity (Figure 3).

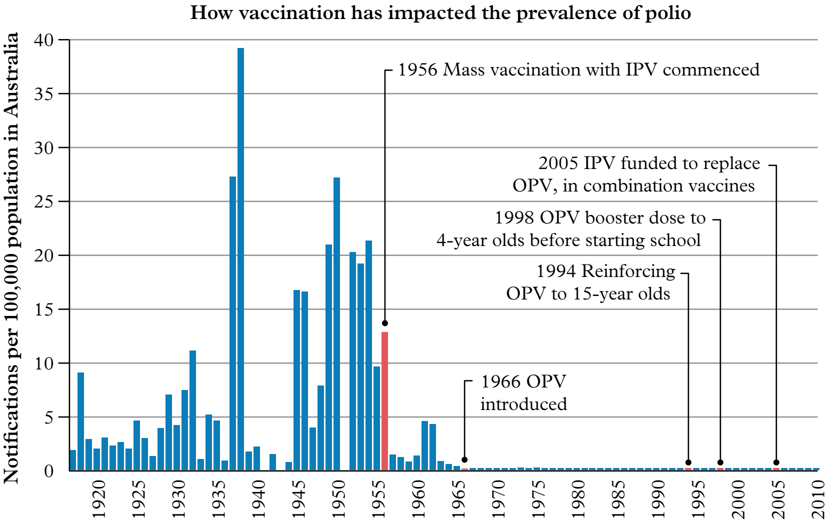


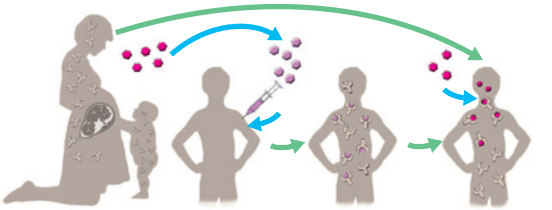
Figure 3 To achieve herd immunity for polio, 80 per cent of the population needs to be vaccinated.

An **epidemic** occurs when there are more cases of a disease than usual in a community. If a disease outbreak spreads to another country and starts infecting people there, it is called a **pandemic**. Examples of a pandemic include the COVID-19 pandemic, the 1918 Spanish flu, HIV/AIDS and others. While many infectious diseases have been almost eliminated from Australia, some countries have **endemic** diseases such as measles, chickenpox and polio.

epidemic the rapid spread of a disease in a community in a short time

pandemic an outbreak of a disease that crosses international borders

endemic a disease that regularly occurs in a community



A virus is killed or weakened, and given to the person.

Antibodies are made by the person but there is no illness.

Exposure to the active virus results in a fast antibody response.

Figure 4 A person can become protected or immune actively through vaccination or passively by antibodies being passed on to them in breast milk from their mother when they are a baby.

Check your learning 3.10

Check your learning 3.10

Retrieve

1 **Identify** the different types of vaccines.

Comprehend

2 **Describe** in your own words how a vaccination prevents a person from suffering from an infectious disease.

Analyse

3 **Compare** (the similarities and differences between) an epidemic and a pandemic.

4 **Describe** how the smallpox vaccine reduced the number of people dying from smallpox.

Apply

5 Newborn babies cannot be vaccinated against whooping cough until they are 2 months old. The antibodies in breast milk are not enough to protect them from this deadly disease. **Explain** why it is important for everyone who is in contact with a newborn baby to be vaccinated against whooping cough.

6 **Describe** the relationship between Edward Jenner and James Phipps. **Explain** why Jenner's actions would not be approved on ethical grounds today.

Lesson 3.11

Challenge: Modelling infection and vaccination

Aim

To model the **epidemiology** of a disease

What you need:

- Measuring cylinder
- Water
- Plastic cup
- 1 M sodium hydroxide
- Pipette
- Phenolphthalein indicator
- 0.1 M hydrochloric acid

epidemiology
study of the distribution, causes and effects of health-related conditions in populations to inform public health practices and disease prevention

What to do:

1. Add 125 mL of water to the plastic cup.
2. Place your cup on a table alongside the other students' cups.
3. Turn your back while the teacher adds 2 mL of sodium hydroxide to one cup. This represents a student having an infection.
4. Collect your cup and use the pipette to exchange 3 mL of water with three other students. This is equivalent to shaking hands. Copy Table 1 into your notebook and record who you "shook hands" with.

Table 1 Results for modelling the spread of infection and the effect of vaccination

Person 1	Person 2	Person 3

5. Add a few drops of phenolphthalein indicator to each cup to determine who caught the disease. A red colour indicates infection.
6. Use the information recorded in Table 1 to determine who the original source of the infection was.
7. Repeat steps 1 to 5, this time choosing whether or not to become "vaccinated". Vaccination is done by adding 2 mL of hydrochloric acid to your cup of water. Redraw Table 1 to record who you shook hands with after some people were vaccinated.
8. Repeat steps 1 to 5, increasing the number of people vaccinated.

Questions

1. **Identify** the number of people who became infected when no one had been vaccinated.
2. **Identify** the number of people who became infected when a few people had been vaccinated.
3. **Identify** the number of people who became infected when more people had been vaccinated.
4. **Explain** why the vaccination affected the number of people who became infected.
5. **Describe** a real-life example of how vaccination can protect vulnerable members of the community.

Lesson 3.12

Sometimes things go wrong with the immune system

Key ideas

→ Allergies result from an overactive immune system.

→ Autoimmune diseases such as type 1 diabetes and rheumatoid arthritis are caused by the immune system attacking body cells.

→ HIV is a virus that specifically attacks T cells, resulting in acquired immune deficiency syndrome (AIDS).

Learning intentions and success criteria

Introduction

The immune system coordinates attacks on pathogens that are trying to disrupt the body. The coordination of all the cells and chemical molecules is very complex, and can easily be disrupted.

Hay fever and other allergies

allergy an overreaction by the immune system in response to pollen, dust or other non-pathogens

Allergies result when your immune system mistakes a harmless substance as dangerous and your body overreacts. A common example is plant pollen, mainly from grass but also from trees, which can cause hay fever. When the pollen gets in your eyes or nose, your second and third lines of defence start attacking it.

Inflammation occurs, resulting in an increased amount of blood reaching the area. Chemical messengers cause fluid leaks out of the blood vessels and the area becomes red and swollen. This also contributes to a runny nose and watering eyes. Your body is trying to flush out the pollen.

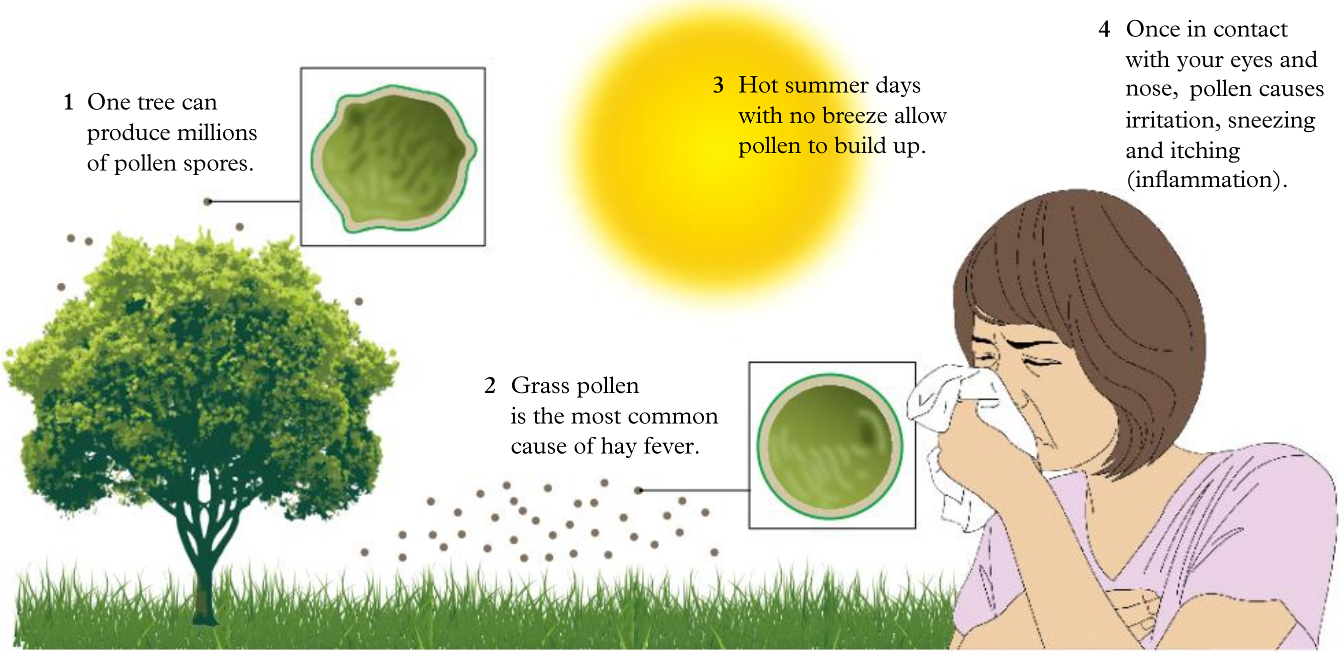


Figure 1 How hay fever develops

anaphylaxis a life-threatening overreaction by the immune system to a normally harmless substance

Phagocytes also invade the area in an attempt to destroy the pollen. If you have been exposed to the pollen before, your body will already have antibodies that speed up this reaction. In extreme cases, the person's throat will swell shut, making it difficult to breathe. The large amount of fluid leaking from the blood vessels can also cause the blood vessels to collapse. This life-threatening response is called **anaphylaxis**.

Figure 2 Epipens deliver adrenalin to people suffering anaphylactic shock.

Autoimmune diseases

autoimmune disease a condition caused by the immune system targeting the body's own cells and tissues

rheumatoid arthritis a chronic autoimmune disorder that causes inflammation, pain, and swelling in the joints

Autoimmune diseases are a group of diseases that result from your body's immune system identifying healthy parts of your own body as a pathogen. **Rheumatoid arthritis** is an autoimmune disease in which the body produces B and T cells that attack the joints of the body. B cells produce antibodies, and T cells try to destroy the synovial membrane that lines the joint. This causes the joint to swell with fluid, which causes heat and pain for the sufferer.

Figure 3 Inflammation causes the joints of rheumatoid arthritis sufferers to swell and become painful.

Type 1 diabetes is also caused by an autoimmune reaction against the cells in the pancreas that produce insulin. As a result of attack by B cell antibodies and T cells, these pancreatic cells are destroyed. This means the person is unable to control their own blood glucose levels and instead must test their glucose levels regularly and inject artificial insulin when it is needed.

HIV causes AIDS

Figure 4 HIV is detected using a blood test.

The human immunodeficiency virus (HIV) infects a special type of T cell in the immune system. This makes the whole immune system ineffective. A person with HIV has a weakened immune system. This causes them to develop a range of infections that a normal immune system would be able to destroy easily. For example, simple fungal infections, viral eye infections and diarrhea (loose bowel motions) can make a person infected with HIV very sick. Collectively these symptoms are called acquired immune deficiency syndrome (AIDS). There are many antiviral drugs that can be used to prevent a person infected with HIV from developing AIDS.

Freddie Mercury, the legendary frontman of the band Queen, died on 24 November 1991 due to complications from AIDS. His death helped raise awareness about HIV/AIDS, a disease that was heavily stigmatised at the time. Freddie Mercury's openness about his diagnosis played a significant role in increasing public understanding of the disease and the need for prevention, treatment and research.

Awareness of diseases is crucial for driving funding and support for research, as it helps highlight the urgency and importance of finding treatments and solutions. Without public and institutional awareness, it can be challenging to generate the financial resources needed for effective research and advancements in health care.

Check your learning 3.12

Check your learning 3.12

Retrieve

1 **Describe** the symptoms of hay fever.

2 **Identify** the cause of swollen finger joints in a person with rheumatoid arthritis.

Comprehend

3 **Explain** why hay fever is always worse the second time you are exposed to pollen.

4 People with type 1 diabetes are unable to produce their own insulin. Use your understanding of autoimmune diseases to **explain** why.

Analyse

5 **Contrast** (the differences between) HIV and AIDS.

Apply

6 **Explain** why eating even a small quantity of peanuts can cause death in some people.

Lesson 3.13

Review: Infection and disease

Summary

Lesson 3.1 Non-infectious diseases can be affected by genetics or the environment

- Infectious diseases can be passed from one person to another.
- Damage can accumulate as the body ages, causing disease.
- Too much or too little nutrients can cause disease.

Lesson 3.4 Science as a human endeavour: Pathogens cause disease

- Infectious diseases are caused by microorganisms such as bacteria, fungi and viruses.
- Koch's postulates provide a process for identifying the cause of an infectious disease.

Lesson 3.6 Identification of pathogens allows the treatment of infectious diseases

- Different types of bacteria need to be treated with different antibiotics.
- Antivirals are used to treat viral infections.
- Fungicides are used to treat fungal infections.
- Multicellular pathogens can cause disease.

Lesson 3.7 Transmission of infectious diseases can be prevented

- Pathogens need to be transmitted between hosts for a disease to spread.
- Transmission of infectious diseases can be prevented by handwashing, mask-wearing, isolation and surface disinfection.

Lesson 3.9 The immune system protects our body in an organised way

- The immune system physically prevent pathogens entering your body.
- Pathogens that enter the body are identified and destroyed by the immune system.

Lesson 3.10 Vaccination produces memory cells

- Vaccination pre-activates the third line of defence.
- Memory cells can last up to 10 years.

Lesson 3.12 Sometimes things go wrong with the immune system

- Allergies result from an overactive immune system.
- Autoimmune diseases such as type 1 diabetes and rheumatoid arthritis are caused by the immune system attacking body cells.
- HIV is a virus that specifically attacks T cells, resulting in acquired immune deficiency syndrome (AIDS).

Review questions 3.13

Review questions: Module 3

Retrieve

1 **Identify** which of the following is a non-infectious disease.

A Candidiasis
B Influenza
C Tuberculosis
D Diabetes

2 **Identify** which of the following cells produce antibodies.

A B cells
B Phagocytes
C T cells
D Viruses

3 **Select** which of the following is not a pathogen.

- **A** Fungi
- **B** Bacteria
- **C** Environment
- **D** Yeast

4 **Define** the following terms.

- **a** Vaccination
- **b** Quarantine
- **c** Pathogen

5 **Identify** two non-infectious diseases.

6 **Describe** one factor that contributes to each of the diseases in question 5.

Comprehend

7 **Describe** three ways the human body can be affected by the environment.

8 **Describe** how the lifestyle of a person can contribute to the development of type 2 diabetes.

9 **Describe** three major features of the body's first line of defence.

10 **Contrast** asbestosis and tuberculosis.

11 **Describe** how an antibody is used by the body to prevent a pathogen from spreading around the body.

12 **Explain** why it is important to have certain vaccinations before travelling overseas. **Identify** two examples of diseases you may need to be vaccinated against.

13 **Explain** how the immune system's third line of defence remembers pathogens when you are exposed to the pathogen a second time.

14 Use an example to **explain** how a person could change their lifestyle to reduce their chances of developing a non-infectious disease.

15 **Describe** the effect of a cholesterol-clogged artery on the function of a heart.

Analyse

16 **Explain** why a viral particle that is 0.03 micrometres in size might be unable to pass through a cotton face mask.

17 **Identify** the most effective way to prevent the transmission of an infectious disease by **comparing** each method described in Lesson 3.7 Transmission of infectious diseases can be prevented (page 132).

18 **Compare** viruses and bacteria.

19 Figure 1 shows the number of cases of silicosis reported in NSW. **Analyse** evidence from the graph (including number of cases and years) and hypothesise a causal relationship.

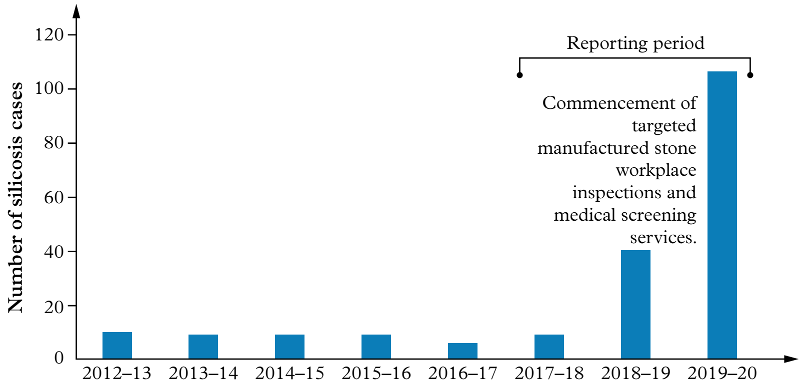


Figure 1 Number of cases of silicosis reported in NSW, 2012 to 2020

Apply

20 Transmission of pathogens can cause mass outbreaks of a disease and affect large numbers of people. Examples are COVID-19, the SARS virus, swine flu, and the outbreak of cholera in Zimbabwe.

- **a** Choose one disease and **explain** how it can spread so quickly.
- **b** **Describe** what can be done to prevent the spread of such diseases.

21 **Explain** why changing the door handles in a hospital to become automatic would prevent the spread of *Staphylococcus aureus*.

22 Given that most people have caught a cold before, **explain** why we continue to catch colds.

23 Your body is constantly monitoring and controlling the numbers of pathogens in and on it. **Describe** what you can do to assist your body in controlling pathogens.

24 **Analyse** the graph in Figure 2 and **explain** why a COVID-19 vaccine is recommended to reduce the strain on the medical system.

Critical and creative thinking

25 **Create** a storyboard for a social media clip with at least five squares, illustrating how a person could prevent the development of Alzheimer's disease.

26 Imagine that you wake up one day and your immune system has stopped working. **Develop** a creative story outlining this day in your life.

27 **Create** a visual presentation on the role of the different types of white blood cells in attacking pathogens.

28 Use critical thinking to **predict** the effect that being vaccinated will have on a coronavirus that was breathed into the lungs.

Social and ethical thinking

29 Babies can be vaccinated against a wide range of diseases in the first months and years of their lives. They are not old enough to choose to be vaccinated, so the decision is made by their parents or guardians.

- **a** **Identify** which vaccinations are available.
- **b** **Describe** at least four secondary sources of information that are consistent with the effectiveness of vaccination for babies.
- **c** **Explain** why your sources of information are valid.

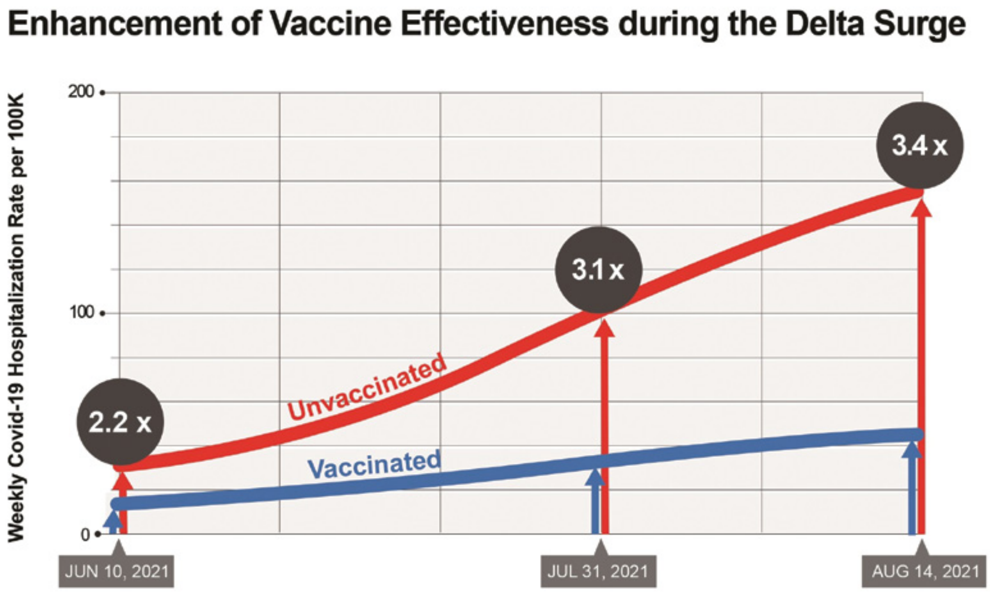


Figure 2 Weekly COVID-19 hospitalisations (rate per 100,000) in unvaccinated and vaccinated people, 10 June 2021 to 14 August 2021

30 Many Australian native plants can be used in the prevention of infection.

- **a** **Identify** how Aboriginal and Torres Strait Islander Peoples use a native plant (emu oil, kangaroo apple, or banksia flowers) in the prevention of infection.
- **b** **Describe** how you identified this knowledge and how widely this knowledge is known.
- **c** **Compare** how this knowledge is used by Aboriginal and Torres Strait Islander Peoples to that of commercial companies.
- **d** **Describe** how you would collaborate with a Aboriginal and Torres Strait Islander community if you were interested in using traditional ecological knowledge.

Research

31 Choose one of the following lessons for a research project. A few guiding questions have been provided, but you should add more questions that you wish to investigate. Present your report in a format of your own choosing.

Preventing childhood diseases

Dr Helen Mayo was one of the first female medical doctors in Australia and made a significant contribution to the reduction of childhood mortality (death).

- **Identify** at least four accomplishments of Dr Mayo.
- **Create** a timeline of her studies, travel and accomplishments.
- **Explain** why Dr Mayo was considered “unusual” for suggesting that mothers needed assistance to raise healthy children. (HINT: consider the level of education of women in 1913.)

HPV: an Australian success story

Human papillomavirus (HPV) is a group of 200 sexually transmitted viruses that can cause several different types of cancers. Prior to 2007, HPV was the leading cause of cervical cancer in adolescent females.

- **Research** the Australian scientist who was responsible for developing the HPV vaccination.
- **Identify** when this vaccine was introduced to both adolescent males and females in Australia.
- **Explain** how this vaccination is able to prevent the virus causing cervical cancer.

Smallpox and the arrival of Europeans

Smallpox is one of the most deadly diseases that affect humans. Regular outbreaks across Europe meant that there was some level of immunity in the community. When Europeans first arrived in Australia, they brought the disease with them. Aboriginal and Torres Strait Islander Peoples were particularly vulnerable to the disease, and a great many died as a result.

- **Describe** the cause and symptoms of smallpox.
- **Identify** the mortality rate of smallpox in European populations in the 1800s.
- **Describe** the impact of smallpox on Aboriginal and Torres Strait Islander Peoples after the arrival of Europeans.
- **Explain** why Aboriginal and Torres Strait Islander Peoples may have been more vulnerable to the disease.

Module 4

Reproduction

Overview

The structures of reproductive cells and organs in plants and animals support the survival of a species. In sexual reproduction, the male and female reproductive organs work together as systems. The individual male and female gametes (reproductive cells) have different structures that help them function. Plants use both sexual and asexual reproduction strategies. Sexual reproduction generates a variety in offspring, while asexual reproduction allows many offspring to be produced quickly. Reproductive strategies in animals depend on the stability of the environment. An animal that has many offspring will not usually provide much parental care, while animals that have few offspring will usually need to give them support to survive and grow.

Lessons in this module

Lesson 4.1

There are different ways of reproducing

Learning intentions and success criteria

Check the next lesson for a linked practical activity or experiment.

Key ideas

→ All living things reproduce, leaving new organisms to carry on when others die.

→ Asexual reproduction involves a single organism making a copy of itself using its own genetic material.

→ Sexual reproduction involves combining the genetic material from two organisms to produce a new organism.

Asexual reproduction

For some organisms, finding a partner is not easy. It takes a lot of energy and time. Some organisms can find partners easily, but for those that live alone or are stuck to the one spot, **asexual reproduction** may be their only chance of continuing the species. Asexual reproduction occurs when an organism makes young copies of itself that only contain its own **genetic material** (DNA), without the involvement of sex cells or fertilisation.

In asexual reproduction, the **offspring** will often have exactly the same genetic material as the parent. If an organism is suited to an environment (they are able to survive in that temperature with that amount of water and type of food), then their identical “children” will also be able to survive and grow. However, if the environment changes in any way that becomes unsuitable for the organism, the entire population or species is at risk of extinction. The simplest version of asexual reproduction is an organism splitting in half to form two new organisms. This occurs in bacteria and is known as **binary fission**.

An amazing asexual reproductive strategy known as **parthenogenesis** involves unfertilised eggs hatching into new organisms. In one zoo, a reticulated python (specific species within the Pythonidae family) that had been kept isolated from other snakes managed to lay eggs that produced six daughters. The zookeepers tested the genetic material (DNA) of the baby snakes and found that it was identical to the mother’s genetic material. The baby snakes were tiny identical clones of the mother. Other animals, such as some species of sea star, are able to form new individuals when they are split into two unequal parts. This is called **fragmentation**.

Figure 1 Parthenogenesis, while common in invertebrates and plants, is less common in vertebrates, however, known cases have occurred in reptiles, fish and sharks.

asexual reproduction type of reproduction in which one parent produces offspring that are all genetically identical to the parent

genetic material information that is stored in DNA and passed onto the next generation by asexual or sexual reproduction

offspring new organisms that are produced by asexual or sexual reproduction; an organism’s young, or child

binary fission a form of asexual reproduction used by bacteria; the splitting of a parent cell into two equal daughter cells

parthenogenesis asexual reproduction where a female fertilises her own eggs

fragmentation asexual reproduction that occurs when a new organism grows from a fragment of the parent

A similar process in plants is called **vegetative reproduction**. “Vegetative” is related to the term “vegetable” (meaning part of a plant), and refers to all non-flower parts of a plant. Vegetative reproduction generally involves a part of the plant breaking off and surviving as a new organism. Like fragmentation, the plant has no need for spores or seeds, just structures that have been grown specifically to be broken off.

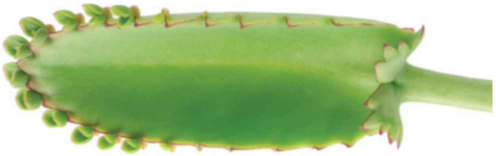


Figure 2 Plantlets are tiny plants that grow on either the parent stem, leaf or root.

Vegetative structures include plantlets (Figure 2), stolons (Figure 3) and rhizomes (Figure 4).

vegetative reproduction a type of asexual reproduction where part of a plant breaks off, forming a new organism with no need for seeds or spores; similar to fragmentation

Figure 3 Stolons (runners) are stems running along the ground.

Figure 4 Rhizomes are underground stems.

Sexual reproduction

The two cells that joined together to make you are called sex cells or **gametes** – an **ovum (egg)** from your mother and **sperm** from your father. Many organisms rely on gametes fusing to make new organisms and this process is referred to as **sexual reproduction**. When this occurs, half the genetic material is from the mother and half the genetic material is from the father. This means each offspring (baby) is genetically different from their parents and siblings.

Sometimes a female produces more than one egg. If both eggs are fertilised, non-identical twins (with different genetic material) can be produced. Occasionally, a single fertilised egg splits into two separate cells. This produces two offspring with identical genetic material – identical twins.

gamete a sex cell; in humans, the sperm and egg cells

ovum the female gamete (sex cell); also called an egg

sperm the male gamete (sex cell)

sexual reproduction type of reproduction in which two parents produce offspring that are genetically different to the parent; the fusion of gametes from two parents

Hermaphrodites

Hermaphrodites are organisms that have both male and female reproductive systems. This means they can reproduce sexually by themselves, but in most cases, it results in organisms that can change sex by “turning off” one system and “turning on” the other. This helps to maintain **genetic diversity** within the species. Earthworms, snails and clownfish are examples of hermaphrodites.

Figure 5 Even though nudibranchs are hermaphrodites, they tend to find a partner to mate with. Whichever nudibranch is fastest at injecting a chemical into the other will get to be the male!

hermaphrodite an organism that has both male and female reproductive systems

genetic diversity the variety of DNA and genes in a population or species

Nature or nurture?

Your genetic material doesn't control how you cut your hair or what you eat, and the same goes for other organisms. Plants cannot control which of their leaves get eaten by predators and animals cannot control the weather. Scientists have had lengthy discussions about "nature versus nurture" – whether DNA is responsible for certain features or whether the features are the result of lifestyle or even upbringing. Your DNA controls your genetic features, such as the colour of your eyes or the length of your nose, whereas the environment (lifestyle, education, etc.) controls everything else and can change regularly. This means genetically identical twins can change slightly (i.e. age faster or slower) if they live in different environments (Figure 6).

Figure 6 Identical twins are only identical according to their DNA at birth.

Check your learning 4.1

Check your learning 4.1

Retrieve

1 **Define** the term "reproduction".

2 **Identify** the substance that is responsible for most family resemblances.

Comprehend

3 **Explain** why organisms that reproduce asexually may look similar.

4 **Describe** one situation where an organism might have difficulty reproducing sexually.

5 **Describe** one situation when parthenogenesis can be useful for organisms that usually reproduce sexually.

Analyse

6 Use a Venn diagram to **compare** sexual reproduction and asexual reproduction.

7 As a class, brainstorm the features of an organism that are genetically controlled (for example, in pugs used for dog breeding) and **compare** with those that are influenced by the environment (for example, wild dogs).

Lesson 4.2

Experiment: Vegetative propagation

Aim

To produce a new plant using vegetative propagation

Materials

- 2 × 500 mL beakers
- Distilled water
- Scissors

- Geranium plant
- Flowerpots with potting mix

Method

1 Fill the beakers three-quarters full with distilled water.
2 Use the scissors to cut four healthy stems with one to two healthy leaves on each stem from the geranium plant.
3 Place the cut ends of the stems into the distilled water.
4 Observe the cut ends of the stems for 2 to 3 weeks.
5 Transfer the cuttings to the flowerpots with potting mix.
6 Water the plants regularly and observe their growth.

Results

Record your observations in a logbook. Take photos of any changes in growth.

Discussion

1 **Identify** this form of reproduction as sexual or asexual. Use evidence from your experiment to **justify** your answer.
2 **Compare** the genetic material in the parent plant to that of the new (daughter) plants.
3 **Identify** if the parent and daughter plants will be identical in shape and size. **Justify** your answer by describing the factors that affect plant growth.
4 A student claimed that they were making plant clones. **Define** the term “clones”. Use your definition to **evaluate** if the student’s claim is correct.

Conclusion

Describe what you know about vegetative propagation.

Lesson 4.3

Fertilisation

Key ideas

→ Sexual reproduction is where half the genetic material comes from a male and the other half from a female, to produce genetically different offspring.

→ Animals may use internal or external fertilisation processes.

→ External fertilisation occurs outside an organism’s body.

→ Internal fertilisation usually occurs inside an organism’s body.

→ The female reproductive system varies between vertebrates depending on the reproductive habits of the species.

Learning intentions and success criteria

Sexual reproduction

Sexual reproduction occurs when two gametes combine to form a single cell. As you learnt in Lesson 4.1 There are different ways of reproducing (page 154), the two gametes come from two parents, each supplying half the genetic material. This means that half your genetic material (DNA) comes from your mother and half comes from your father.

If you have siblings (a brother or a sister), half their genetic material will also come from your mother and half from your father. This does not mean that you have exactly the same genetic material as your siblings (unless you are identical twins). Each time your parents produce an egg or sperm, the genetic material is mixed. This is why siblings look different from one another.

This variation between offspring is one of the key advantages of sexual reproduction. The offspring (babies) are all different from their parents, having new combinations of features. This variation is important for the survival of the entire species. If there are small variations, some organisms will be more likely to survive if the environment changes or a new disease comes along.

Asexual reproduction does not have this advantage. In all forms of asexual reproduction, offspring are genetically identical to their parent. If the parent is affected by a change in an environment, then all of their offspring will also be affected.

Fertilisation is the process where the two gametes fuse to produce a single cell. This process can occur outside an organism's body (**external fertilisation**) or inside an organism's body (**internal fertilisation**).

fertilisation the process where two gametes (sex cells) fuse to produce a single cell

external fertilisation when the egg and sperm meet outside the bodies of the parents

internal fertilisation when the sperm fertilises the egg inside the body of an organism

placental mammal that has a placenta to nourish their offspring during gestation

marsupial mammal that gives birth to immature offspring that complete their development in their mother's pouch

monotreme mammal that lays eggs

Fertilisation

Mammals, such as humans, use internal fertilisation. The mother is responsible for nurturing the growing fetus in the uterus until it is ready to face the world. **Placental** mammals, like humans, keep the fetus in the uterus for this period of gestation, whereas **marsupial** fetuses, such as those of the koala, crawl into the pouch for the final stages of development (Figure 1A).

Monotremes, a rare group of mammals that includes the platypus and echidna, lay leathery eggs instead of giving birth to live young. Leathery eggs have soft, flexible shells made of a tough, leathery material, rather than the hard, calcified shells seen in bird eggs (Figure 1B).

Like monotremes, reptiles and birds lay internally fertilised eggs (Figure 1C). Reptile eggs are leathery, whereas bird eggs have a hard shell. The eggs contain all the nutrients that the fetus needs to develop fully. This is especially important for reptiles, as most reptile species leave their babies to fend for themselves.

Figure 1 (A) Marsupial fetuses finish developing in the pouch. (B) Bird eggs are hard. (C) Reptile eggs are leathery.

External fertilisation

The process of combining gametes can occur outside the body of organisms that live in watery environments. The water allows the gametes to travel towards one another so that they can fuse. An example of this is when a male frog spreads their gametes over eggs laid in the water by a female frog (Figure 2).

Figure 2 Most frogs rely on external fertilisation.

Most corals release their gametes into the water, relying on the current to bring the male and female gametes together so they can be fertilised (Figure 3). However, there is no guarantee that fertilisation will occur – some of the gametes will be eaten by predators or washed away before successful fertilisation can occur. This is why external fertilisation needs many extra gametes to be produced.

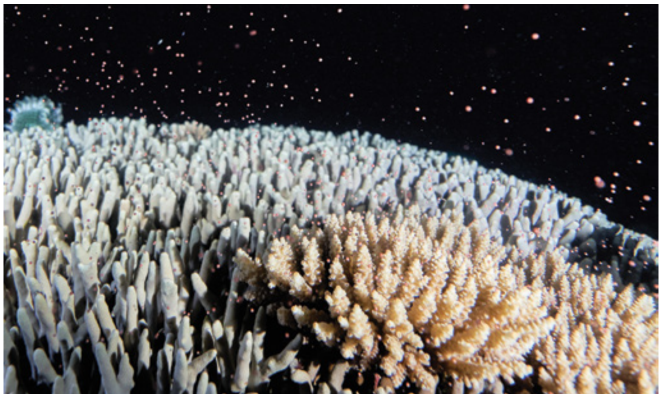


Figure 3 The corals in the Great Barrier Reef coordinate the release of their gametes to increase the chances of fertilisation.

Internal fertilisation

It is much more efficient for male and female gametes to be brought together inside the body of one of the parents. This will occur in the females of most organisms. In seahorses and pipe fish, it is the father that is responsible for fertilising and caring for the offspring before birth. Before two seahorses mate, they perform a courting dance to check that both are ready to produce offspring. The female then places their gametes in the pouch of the male seahorse. The male seahorse adds their gametes and shuts the opening of the pouch while the baby seahorses grow. Approximately 20 days later, the male seahorse gives birth to about 1,000 babies at once (Figure 4).

Figure 4 The male seahorse is responsible for the internal fertilisation and birthing of offspring.

Invertebrates making babies

Invertebrates (animals that do not have a backbone or spine) account for approximately 95 per cent of all animals, so it's not surprising that their reproductive strategies vary quite a lot.

Arthropods, the group that includes insects, spiders and crustaceans, is the largest group of invertebrates.

Terrestrial (land) arthropods generally favour internal fertilisation because of the harsh conditions they often live in. Sometimes the sperm is transferred directly into the female's **oviduct** (fallopian tube in humans) and sometimes the sperm is packaged for delivery to the female in more complex ways. Most arthropods then lay their eggs. Insects and crustaceans tend to hatch as larvae. Spiders hatch as miniature adults.

oviduct the tube through which eggs travel from the ovary

Figure 5 Some fish protect their eggs from predators.

Figure 6 A female fly lays eggs through her oviduct.

Check your learning 4.3

Check your learning 4.3

Retrieve

1 **Define** the term "fertilisation".

Comprehend

2 **Explain** why animals that use external fertilisation usually lay a large number of eggs.

3 **Describe** why it is an advantage for all coral to release their gametes at the same time each year.

4 **Explain** why you may look different from your sibling.

5 **Explain** why sexual reproduction produces variation.

6 **Explain** why variation is important to a species' survival.

7 **Explain** why terrestrial invertebrates fertilise their eggs internally rather than externally.

Analyse

8 **Contrast** internal and external fertilisation.

Lesson 4.4
Human reproduction

Key ideas

- → Human females have a large uterus, two fallopian tubes and two ovaries.
- → Each month an ovary releases one ovum during ovulation as part of the menstrual cycle.
- → Endometriosis is a disease caused by an overgrowth of the endometrium.
- → Male mammals produce sperm in their testes.
- → It takes 9 months for a human baby to form in the uterus before being born.

Learning intentions and success criteria

Introduction

The vast majority of animals reproduce sexually. They are also **sexually dimorphic**, which means that the males look physically different from the females.

The female reproductive system

In humans, girls are born with hundreds of thousands of eggs or ova (singular “ovum”) partially formed in their **ovaries**. Every month, after puberty, a hormone from the brain sends a message to the ovaries to secrete a second hormone called **oestrogen**, which causes one egg to mature and be released. This process is called **ovulation**.

The egg cell is one of the largest cells in the body. This is because it needs to store enough nutrients and energy to travel down the **fallopian tubes** to the **uterus** (Figure 1). If sperm are present in the fallopian tubes, the egg may become fertilised. In the 3 to 5 days it takes for the egg to travel from an ovary to the fallopian tubes, the lining of the uterus (the **endometrium**) becomes thicker. This is to provide a safe place for the fertilised egg, or **zygote**, to grow into a **fetus** (Figure 2).

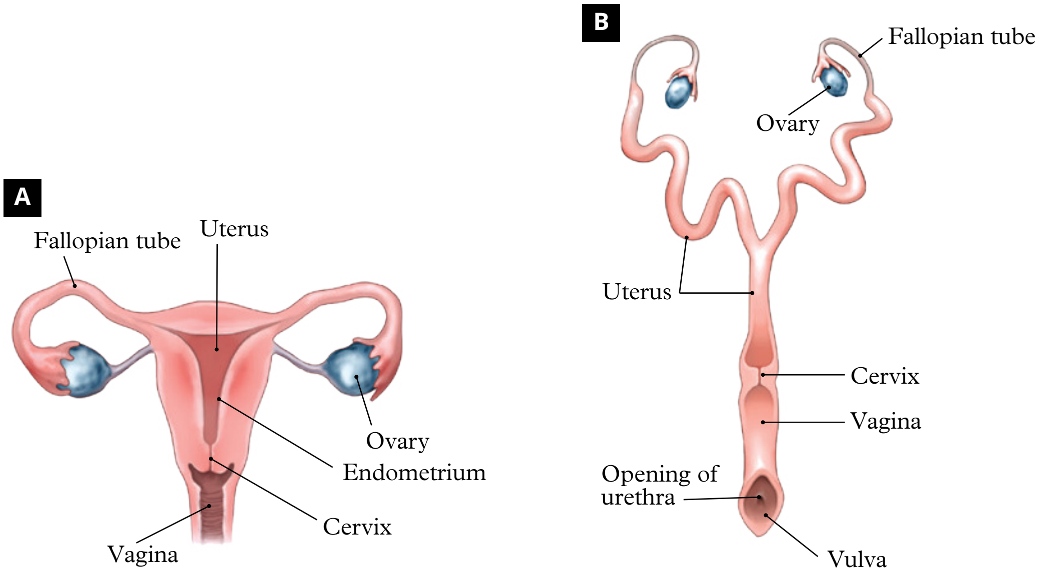


Figure 1 The female reproductive system varies between vertebrates. (A) Human and (B) rabbit reproductive systems

sexually dimorphic describes species in which the male and female organisms look structurally different

ovary the female organ that produces eggs

oestrogen a reproductive hormone in females

ovulation the part of the menstrual cycle when an egg is released from the ovary

fallopian tubes tubes that connect the ovaries to the uterus

uterus an organ in the female reproductive system; where the fetus develops

endometrium the lining of the uterus

zygote a fertilised egg

fetus an unborn animal or human after the embryo stage; in humans this is after 8 weeks of development

cervix	the narrow neck connecting the uterus and the vagina
vagina	a female reproductive organ; a muscular tube connecting the outside of the female body to the cervix
menstruation	also know as a period; the process of the endometrial lining of the uterus breaking down and leaving the vagina
placenta	the organ that connects the developing fetus to its mother
gestation	the length of time between fertilisation and birth

If the egg is not fertilised, the endometrial lining will break down and, 2 weeks after ovulation, will pass through the **cervix** and **vagina** as a period. This monthly cycle is called **menstruation**.

Menstruation usually first occurs in females between 8 and 16 years of age. It can take up to 2 years for menstruation to become a regular cycle. The average length of the cycle is 28 days, but it can vary from 23 to 35 days (Figure 3 and Figure 4).

If the egg is fertilised in the first 3 days after ovulation and develops into a zygote, it attaches to the thick endometrial layer. A special organ called the **placenta** forms between the fetus and the uterus. The placenta allows oxygen and nutrients to pass from the mother to the developing fetus. The length of time between fertilisation and birth is called **gestation** (or pregnancy). In humans, gestation takes 9 months.

Figure 2 An ultrasound image of a human fetus

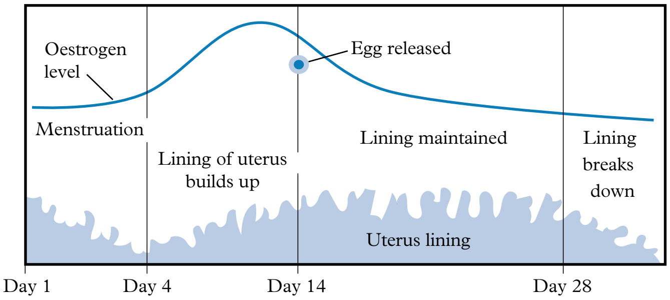


Figure 3 During the average 28-day menstrual cycle, ovulation occurs at day 14.

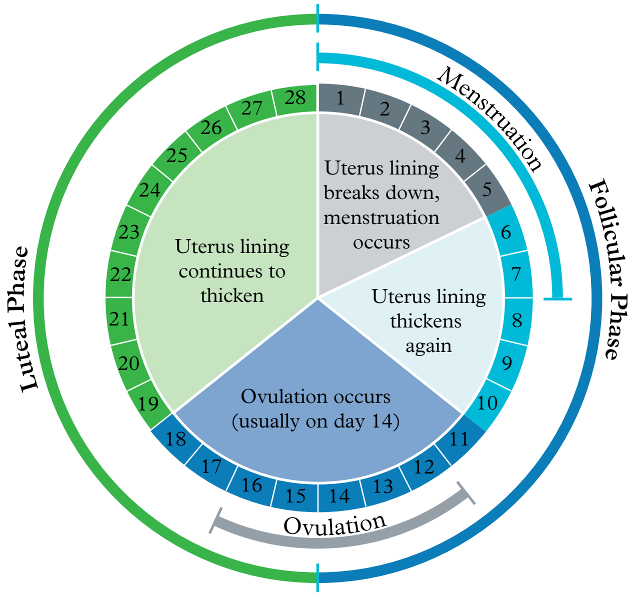


Figure 4 The menstrual cycle begins on the first day of a period.

Endometriosis

Sometimes the lining of the uterus, the endometrium, starts growing outside the uterus. These cells can grow on the outside of the uterus or spread to other organs, such as the ovaries. Each month these endometrial cells grow, and then break down, just as in the menstrual cycle. This can be very painful; it can cause vomiting or prevent a woman from doing her normal activities. Also, the scarring that results can prevent the eggs from moving down the fallopian tubes. This can make it difficult for pregnancy to occur. Anyone who suffers from endometriosis should see their doctor so that it can be treated.

The male reproductive system

In fertilisation, a gamete from the father (sperm) must meet a gamete from the mother (egg or ovum). The sperm cells are produced in special organs called the **testes**. The testes are also responsible for producing a male hormone called **testosterone**. In most mammals, the two testes are kept outside the body in a sack called the **scrotum**. This is to keep the sperm cooler than the rest of the body, which is around 37°C. If sperm get too hot, their form and function may be impaired and this would impact their ability to reach the egg and fertilise it.

Once sperm are produced in the testes, they move to the **epididymis** to mature. When necessary, the epididymis contracts (squeezes tight), and the sperm is moved into the **vas deferens**. The sperm need energy to be activated. **Seminal vesicles** are small pouch-like structures that provide a sugary fluid that is needed for the sperm's journey along the vas deferens tube to the **prostate gland**. The prostate gland is a walnut-sized structure that blocks the flow of urine so that the sperm can move along the urethra and be ejaculated through the penis. The function of the penis is to help the small sperm cells reach the egg (Figure 5).

testis the male reproductive organ that produces sperm (plural: testes)

testosterone a male hormone involved in the reproductive system

scrotum a sac-like structure that contains the testes

epididymis a coiled tube behind the testes that carries sperm to the vas deferens

vas deferens the tube through which sperm travel from the epididymis to the prostate

seminal vesicles a pair of small pouch-like structures that provide a sugary fluid that assists sperm to travel along the vas deferens

prostate gland a walnut-sized structure surrounding the neck of the male bladder that blocks the flow of urine so sperm can move along the urethra

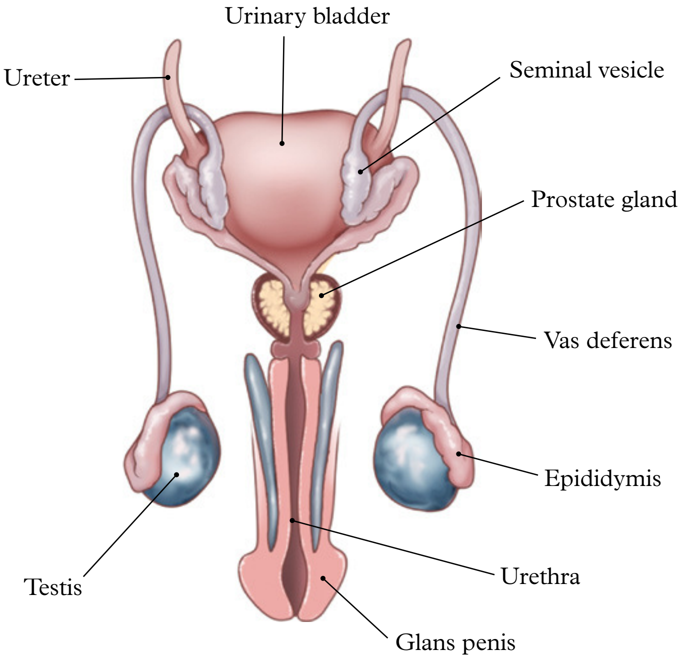


Figure 5 Human male reproductive system

The shape of the sperm cell helps in this process. Each sperm cell has a head containing genetic information and the nutrients needed for survival, and a tail that moves in a circular motion to propel the sperm from the penis, through the vagina and uterus to the fallopian tubes where the large egg cell may be located (Figure 6). Sperm can survive for up to 5 days after ejaculation.

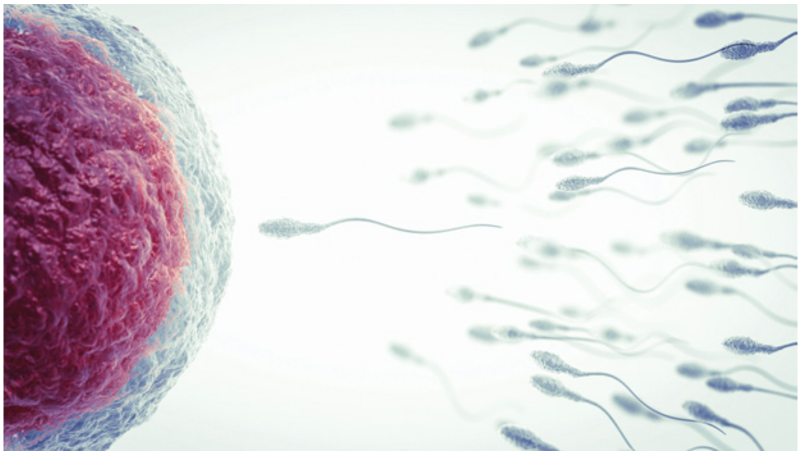


Figure 6 Sperm cells have tails that can be used to move them through the vagina and uterus to the fallopian tube.

Giving birth

Human mothers go through three stages when giving birth (Figure 7). The first stage involves the muscular walls of the uterus contracting, gently squeezing the baby down against the cervix. This causes the cervix to flatten and start dilating (opening). The cervix must open 10 cm before the baby's head can move through the vagina. This is the second stage of birth. When born, the baby is still attached to the placenta, which is inside the mother, via the umbilical cord. The umbilical cord is cut (the baby's belly button will later form where the umbilical cord was attached). The third and final stage of birth is the delivery of the placenta. This is important to prevent infections from developing in the uterus.

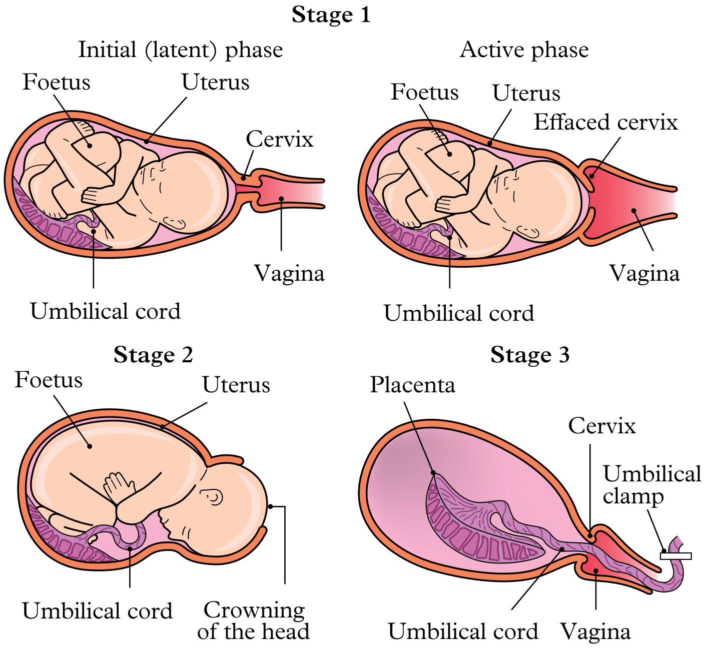


Figure 7 The three stages of childbirth

Check your learning 4.4

Check your learning 4.4

Retrieve

1 **Define** "sexual dimorphism" in your own words.
2 **Name** a hormone involved in male reproduction.
3 **Recall** one hormone involved in reproduction in human females.
4 **Identify** where in the reproductive system the ovum becomes fertilised in humans.
5 **Define** the term "menstruation".
6 **Recall** how often menstruation usually occurs.
7 **Identify** the two vertebrate classes that lay leathery eggs.

Comprehend

8 Use the following table to **explain** why a longer gestation period would be an advantage for the baby.

Averages	Dogs	Humans	Elephants
Gestation period	2 months	9 months	22 months
Number of offspring	5 to 6	1	1
Time to walk	3 weeks	10 to 18 months	1 hour
Reproductive age	~6 months	12 years	10 to 14 years
Lifespan	10 to 13 years	70 to 75 years	60 to 70 years

9 **Describe** the three stages of giving birth.
10 **Explain** how the structure of a sperm cell helps it to achieve its function.

Analyse

11 **Identify** the days (1, 2, 3 …) in the average monthly (menstrual) cycle when the following occur.
  a The first day of a period
  b The usual day of ovulation
  c When the ovum can be fertilised

Apply

12 If an ovum is produced on day 14 of a menstrual cycle, and sperm can survive up to 5 days before fertilisation, **determine** the days of a cycle that a woman can become pregnant.
13 **Describe** the journey a sperm takes from the testes to the ovum.
14 A student said that a baby girl already had all her eggs intact when she was born. **Evaluate** this claim (by describing where all the eggs/ova are located, describing when this organ is fully formed and deciding whether the statement is correct).

Lesson 4.5

Science as a human endeavour: Technology can assist human reproduction

Key ideas

→ Assisted reproductive technologies such as in-vitro fertilisation can help couples have children.

→ Babies can be screened in the womb for any problems.

→ Contraception can be used by males and females to prevent reproduction.

Learning intentions and success criteria

Introduction

The complexity of human reproduction means that many things can affect a couple's ability to have children. Sometimes, physical problems prevent the fertilisation process, and sometimes, the egg or sperm is not fully formed. Scientists have used their understanding of reproduction to develop technologies that can assist the process of having children.

Assisting human reproduction

Assisted reproductive technology (ART) is the name given to any procedure that is used to help a couple have a healthy baby. There are a number of ways this can be done. One of the least invasive processes is to inject the sperm directly into the female's uterus. This processes, called **intrauterine insemination**, shortens the journey the sperm needs to travel and makes it more likely for fertilisation to occur.

intrauterine insemination where sperm is placed directly into the uterus

IVF

Sometimes in men, the sperm levels may be too low, or the sperm may not be able to swim well enough to reach the egg. In women, they can have a low egg count/quality, fallopian tube issues or ovulation disorders where the egg cannot be fertilised or ovulation does not occur regularly or at all. When this occurs, scientists can assist reproduction more directly by removing both the egg and the sperm from the body and using **in vitro fertilisation** (IVF). *In vitro* or "in glass" means the egg and sperm are placed in a glass petri dish reducing the distance the sperm needs to travel even further. A scientist may also use a very fine pipette to inject the sperm directly into the egg (Figure 1). This process of injection is called **intracytoplasmic sperm injection**.

in vitro fertilisation when an egg is fertilised naturally by the sperm in a laboratory, then transferred to a woman's uterus

intracytoplasmic sperm injection a single sperm is injected into the egg and then transferred to a woman's uterus

Reproductive genetic screening

Once the egg has been fertilised, scientists may test the new embryo to make sure the genetic material is undamaged. This can be done by allowing the cells in the embryo to reproduce

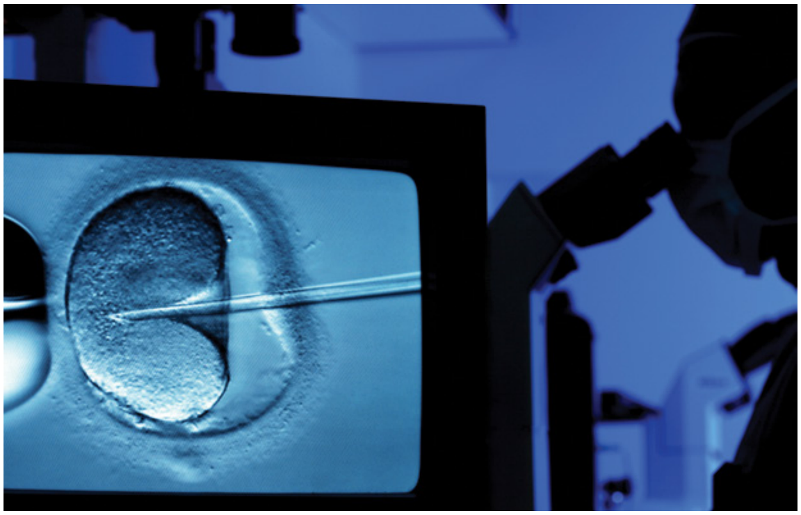


Figure 1 In intracytoplasmic sperm injection, eggs are injected with sperm for fertilisation.

until there are 8 to 16 cells. One of these cells are then removed (which does not damage the embryo) and tested for any genetic diseases. This process is called **preimplantation genetic testing**.

preimplantation genetic testing embryos that are created through IVF that are tested for genetic or chromosomal abnormalities before being transferred to a woman's uterus

Cryopreservation

Once the eggs have been fertilised, the embryos are allowed to grow for 6 to 9 days. Sometimes, a couple may have 4 to 10 embryos produced during this initial stage of assisted reproduction. At this stage the couple needs to make a decision of what to do with the embryos. Only 1 to 2 embryos can be implanted into the mother at a time. This means that the remaining embryos must be stored in liquid nitrogen (–196°C). This process is called **cryopreservation** (cryo = cold, preserve = store).

cryopreservation the preservation of cells for extended periods of time at very low temperatures

Screening tests

Once the embryo has been successfully implanted in the mother's uterus, the unborn baby can be screened for further problems. The amniotic fluid that protects the growing fetus can be tested (amniocentesis), as can the cells of the placenta (chorionic villus sampling). The problem with these tests is that they involve inserting a needle into the belly, which may result in an infection or may interfere with the pregnancy, risking more problems than can be diagnosed. Thankfully, many issues can be spotted in an ultrasound – a picture of what is going on inside, complete with heartbeats (Figure 2).

Figure 2 Ultrasounds allow the developing fetus to be seen.

Contraception

contraception
medical or chemical techniques used to prevent pregnancy

Contraception, also known as birth control, is the term used to describe a variety of methods used to prevent fertilisation or pregnancy. The different ways to avoid reproduction can be divided into physical contraception methods and chemical contraception methods.

Physical contraception methods involve using a physical barrier to prevent the sperm from fertilising the egg. This method includes condoms that cover the penis, diaphragms or cervical caps that form a barrier at the entrance to the cervix. These physical barriers can also limit the transmission of sexually transmitted diseases. Other types of physical barriers are more permanent. A vasectomy is an operation that removes a section of the male vas deferens, preventing the sperm from reaching the penis. A tubal ligation involves an invasive operation where a section of the female fallopian tubes are removed, preventing the egg from reaching the uterus.

Chemical contraception methods use hormones to prevent the formation of a fully developed egg or sperm. For males, a pill or injection can reduce the formation of sperm that can swim. For females, hormone pills, injectable hormone implants, or intrauterine devices (IUD) containing hormones prevent ovulation or thicken the lining of the uterus, preventing a fertilised egg from being implanted.

Test your skills and capabilities

IVF mix-up

While the use of IVF has allowed many couples to have a family, in 2025, a Brisbane woman had the wrong cryopreserved embryo implanted. The process was successful, and a healthy baby was born 9 months later. The error was discovered when the remaining cryopreserved embryos of the genetic parent were being transferred to another IVF clinic, and it was discovered that there was an extra embryo.

1 **Define** the term “genetic parent”.
2 Under the Family Law Act in 2025, a baby born as a result of artificial reproduction technology is biologically the child of the woman who carries it and her partner. **Define** the term “biological parent”.
3 **Construct** an argument for why the biological parents should have the right to adopt the child.
4 **Construct** an argument for why the genetic parents should have the right to visit the child.
5 **Explain** how each of these approaches could affect the wellbeing of the child.

Lesson 4.6

Parental care affects survival

Key ideas

- → Stable environments allow for longer parental care.
- → Producing many offspring reduces the level of parental care.
- → r-strategists produce a lot of offspring quickly, due to their high-risk environment.
- → K-strategists produce less offspring over time, due to their stable environment.

Learning intentions and success criteria

Check the next lesson for a linked practical activity or experiment.

Environment affects parental care

Parenting takes a lot of time and energy in human families. This is why human families are smaller than many families in the animal kingdom. Each species has different approaches to caring for their offspring, and this can be determined by the type of environment that they live in.

Changing environments and rapid breeding

Animals that live in rapidly changing and high-risk environments usually produce a lot of offspring to increase the chances that some will survive. Known as **r-strategists**, these animals rely on short periods of good conditions to mate quickly and produce high numbers of offspring. It is often unsafe for the parents to spend time with their offspring, because that can attract predators, so their offspring need to be independent from birth. They grow rapidly and mature to produce their own children in a short period of time.

r-strategist
organisms living in unstable environments who breed rapidly

Mice are r-strategists. They can produce up to six pups every 3 weeks. The pups grow to adults and are ready to reproduce in 4 to 7 weeks. This gives mice an advantage in a rapidly changing environment.

Stable environments and careful breeding

Animals that live in stable environments, where there is always enough food and warmth, can take more time to care for their young. These animals, called **K-strategists**, usually have long pregnancies to allow the offspring to grow bigger before they are born. Newborn offspring will usually be very immature and rely on their parents to take care of them for more than a year. The parents can do this, because they tend to only have one to two offspring at a time. The environment around them is often close to its carrying capacity (the maximum number of a species that can find food and shelter in that environment). K-strategists only need to have one to two offspring because there is a high chance that they will live to adulthood and produce offspring of their own.

K-strategist
organisms living in stable environments who breed carefully

Humans are K-strategists. We usually only have one or two children in each pregnancy. Our children rely on their parents to survive for up to 15 years. Elephants, whales and eagles also care for small numbers of young over a long time (Figure 1).

Figure 1 Humpback whales are pregnant for 11 months and give birth to a single calf that they rear for up to 1 year.

Check your learning 4.6

Check your learning 4.6

Retrieve

1 **Describe** what parental care is.

2 **Identify** which animals are know for providing:

  a extensive parental care

  b minimal parental care.

Comprehend

3 **Describe** the relationship between parental care and the availability of resources.

4 **Explain** why parental care is important for the survival of their offspring.

Analyse

5 **Discuss** if parental care behaviours is dependent on the number of offspring they have.

6 **Compare** the way r-strategists and K-strategists reproduce.

Apply

7 **Predict** how parental care might change if food sources became scarce.

8 **Design** an experiment that studies the effect of habitat quality on parental care, picking a specific animal.

Lesson 4.7

Plant sexual reproduction produces seeds

Learning intentions and success criteria

Check the next lesson for a linked practical activity or experiment.

Key ideas

→ Flowers help plants to use sexual reproduction.

→ When the male plant gamete lands on the female plant gamete, pollination has occurred.

→ Plants can self-pollinate or be cross-pollinated by another plant.

→ Insects and birds can help pollinate plants.

Introduction

A flower is the reproductive structure of flowering plants (angiosperms). It is responsible for producing seeds and often contains both male and female reproductive organs. Flowers come in all shapes and sizes. Not all of them are attractive and many smell terrible instead of lovely. However, the purpose of a flower is not to be sweet-smelling and beautiful, but to play an important role in plant reproduction by enabling pollination and fertilisation.

Pollination

The female gamete (egg cell) is contained within the **ovule** inside the ovary. The ovule, ovary, **style** and **stigma** are the female parts of a flower and together they are called the **carpel** (Figure 1 and Figure 2). For fertilisation to occur, the male gametes (sperm cells) need to find their way from the top of the male structure (the **stamen**) to the egg cells. The stamen is made up of an **anther** and a long **filament**.

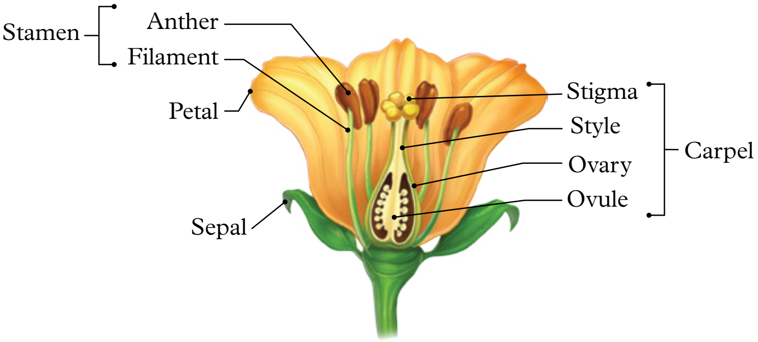


Figure 1 Basic structure of a flower

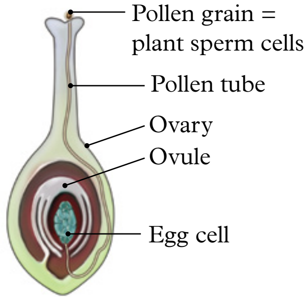


Figure 2 Structure of the carpel with key structures labelled

For the male gametes to find their way to the female gametes, the **pollen** needs to attach to the stigma and "dig" a pollen tube down to the ovary. The transfer of pollen to the stigma is called **pollination**.

Flowers sometimes need assistance from other organisms (insects, birds or mammals) or the environment (wind or rain) for pollination to occur. **Self-pollination** involves pollen from a flower landing on its own stigma or that of another flower on the same plant (Figure 3). **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 4). Just as in animals, the pollen from one flower can only fertilise flowers from the same or a similar species.

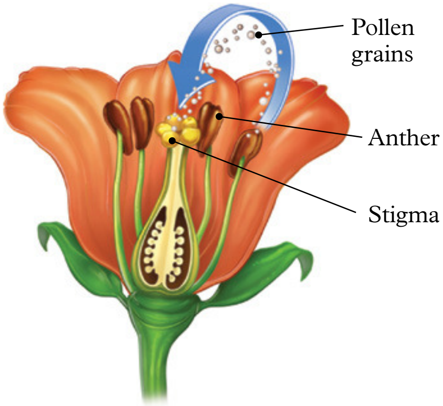


Figure 3 Self-pollination occurs when the male and female gametes (sperm and egg cells) come from the same plant.

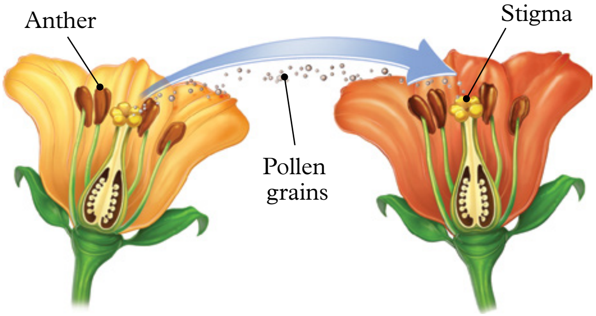


Figure 4 Cross-pollination occurs when the male and female gametes (sperm and egg cells) come from different plants.

ovule structure inside the ovary of seed plants that contains an egg cell; develops into a seed after fertilisation

style female structure in a flower that connects the stigma to the ovary

stigma the top of the carpel; where the pollen from the anther begins its journey to the ovary

carpel the female reproductive organ of a flower; includes the stigma, style and ovary and ovule

stamen the male part of a plant, consisting of a filament supporting an anther

anther the end part of a stamen (male part of a flower); produces pollen

filament male structure in a flower that supports the anther

pollen a powdery substance for transporting the male gametes of flowering plants and cone-bearing plants; contains pollen grains that produce male gametes (sperm cells)

pollination fertilisation of gametes in plants

self-pollination when both gametes come from the same plant

cross-pollination the exchange of pollen and ova between different plants of the same species

After pollination, fertilisation (the fusion of male and female gametes) occurs. The ovule develops into a seed and the ovary takes on a role similar to that of a bird's egg. It swells to become a fruit, which provides nutrition and protection for the zygotes to grow into embryos inside the seeds.

Not all flowers are the same

If a flower smells, it is usually to attract a pollinator – but not all smells are sweet. The flowers of Borneo's *Rafflesia* plant smell like rotting flesh to attract flies for pollination (Figure 5)!

Figure 5 When in bloom, the *Rafflesia* smells like rotten meat to attract pollinating flies.

The colour of a flower is also important for attracting pollinators. Birds tend to pollinate brightly coloured flowers, including red, whereas insects may be more attracted to a wide range of colours. Mammals that feed at night will rely on strong scents and not on colour at all.

Some flowers have modified structures to suit their pollinators. Birds may damage flowers with their sharp beaks when they drink the nectar, so flowers need to be strong. Insects can be small and need to be forced to brush against pollen, followed by the stigma, so the flower may be full of obstacles or simply a tight fit.

Figure 6 Fern sori (the brown patches) produce spores for reproduction.

Sexual spores

If you've ever had a good look at a fern you will have noticed that its leaves are usually quite different from the leaves of flowering plants. You will often see brown patches on the underside of fern fronds (Figure 6). These brown patches, called sori, are made up of specialised cells that make and release **spores** onto the ground. The spores are

spore a tiny reproductive structure that, unlike a gamete, does not need to fuse with another cell to form a new organism tiny reproductive structures that have half the genetic material of seeds. They grow into tiny heart-shaped plants called prothalli that are made up of male and female reproductive organs. Male and female gametes are produced and released when it rains – hopefully, to find a match for fertilisation. The little plant then dies, but the fertilised eggs grow into new ferns (Figure 7).

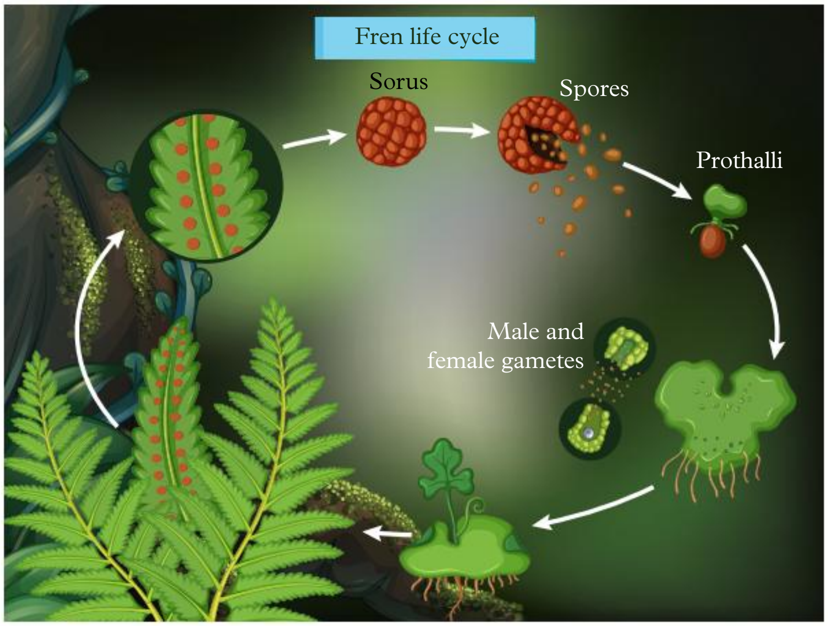


Figure 7 The life cycle of a fern

Check your learning 4.7

Check your learning 4.7

Retrieve

1 **Identify** the structure that contains a plant's sexual reproductive organs.

Comprehend

2 **Explain** why some flowers are large and coloured, and others are tiny and plain.

Analyse

3 **Contrast** self-pollination and cross-pollination.

4 **Compare** fertilisation and pollination.

5 **Describe** the role of a spore in the reproductive cycle of a fern.

Apply

6 Plants that are successful weeds often use both sexual and asexual reproduction. Mint is common in herb gardens and reproduces with little flowers as well as using vegetative reproduction. **Discuss** why it would be difficult to get rid of mint once it has spread through a garden bed.

7 **Create** a circular flow diagram using the following terms: flower, pollen, seed, fruit, pollination, fertilisation, ovule, pollen, ovary, stigma and anther.

Lesson 4.8

Experiment: Flower dissection

Caution!

Take care when using the sharp scalpel or knife.

Aim

To examine the main parts of a flower

Materials

- Newspaper
- A flower (you can dissect any type of flower available; lilies and fuchsias are a good choice)
- Scalpel blade or sharp knife
- Hand lens

Method

1 Place the newspaper on the bench.
2 Cut the flower off the stalk.
3 Observe the flower. Identify the main parts of the flower from Figure 1.
4 Draw a labelled diagram of the flower.
5 Gently remove the sepals and petals.
6 Look for the stamens with anthers at the top. The anthers hold the pollen. You should be able to dust some pollen onto your finger.
7 Cut off the male parts at the bottom of the petal.
8 Observe the female part of the flower. It has the stigma at the top and the ovary at the bottom.
9 Cut the ovary lengthwise. In it you will see tiny white scales, which are the ovules. When the egg cell inside an ovule is fertilised by the male gametes in pollen, the ovule will develop into a seed and the ovary will grow to become the fruit.
10 Draw a labelled diagram of the ovary.
11 Clean up your bench by wrapping the flower in the newspaper. Wash your hands.

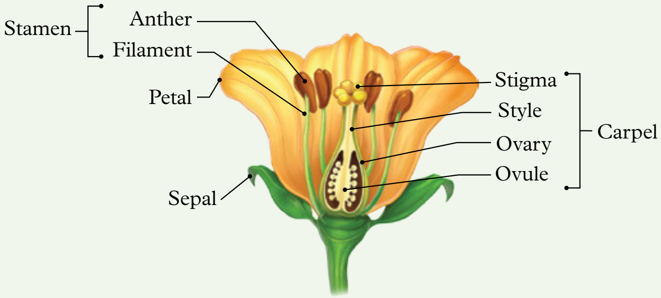


Figure 1 The structure of a flower

Results

Draw labelled diagrams of the male and female parts of the flower.

Discussion

1 **Identify** the colour of the filament (the stem of the stamen).
2 **Describe** how easy it was to clean the pollen from your fingers. **Explain** the advantage of a plant having sticky pollen.
3 **Explain** how the male and female parts were arranged to encourage pollination.
4 **Identify** if your flower is more likely to be self-pollinated or cross-pollinated. **Justify** your answer (using your observations to explain how the plant would be pollinated).
5 **Identify** if pollination is more likely to be by wind, water or animals. **Justify** your answer.

Conclusion

Explain what you know about the parts of a flower.

Lesson 4.9

Reproduction technologies have an impact on agriculture and biodiversity

Key ideas

→ Reproductive technologies can be used in agriculture to improve desired characteristics in plants and animals.

→ Reproductive technologies can have an impact on diversity and increase the risk of inbreeding.

Learning intentions and success criteria

Selective breeding

There are many examples of animals and plants being bred to keep, lose or enhance certain characteristics by people choosing the breeding "partners". For example, a cow that is known to produce a lot of milk could be chosen to breed with a bull that is known to produce healthy, strong offspring. This would result in a greater chance of any female offspring being good milk producers and any male offspring being good meat producers (Figure 1).

Occasionally, animals have difficulty in breeding. This may be due to location (the animals may be on opposite sides of the country) or their owners wanting to have greater control over the animals they breed with. As a result, sperm banks for animals have been developed. Desired characteristics, such as speed or "staying power" in racehorses, or facial shape or coat colour in dogs, are described in a catalogue for owners to examine. The desired frozen sperm can be purchased and sent to the owner of the female animal, where it will be used to create offspring with the desired characteristics.

Figure 1 Some people get a little carried away with selective breeding.

Selective breeding also applies to plants. A type of wheat that is known to survive frost or disease can be deliberately cross-pollinated with a type of wheat that produces high-quality grains; the aim of this is to produce a grain that combines both features (Figure 2).

Figure 2 A healthy wheat crop

Loss of diversity

Diversity in plants and animals refers to the variety of genetic material in a single population or species. When a characteristic, such as milk production in cows, is used for selective breeding, any cow that does not produce “enough” milk is discouraged from breeding. This often means the genetic material from that cow is not passed on to the next generation. Instead, the next generation of calves will only have genetic material from the few cows that meet the milk production criteria. As a result, most of the cows will be related to one another and there is less variation in the genetic material. Although this does not seem like a problem initially, it puts the whole population at risk of disease. If one plant or animal is at risk of a disease, then the rest of that related population, with the same genetic material, is also vulnerable (Figure 3).

An example of this is facial tumour disease in the Tasmanian devil. All Tasmanian devils have very similar genetic material. When one individual devil developed a tumour on its face, it was able to pass it on to another devil that had similar genetics (Figure 4).

Figure 3 In the mid-1800s, the population of Ireland relied very heavily on potatoes for food. When a fungus infected the potatoes, the lack of genetic diversity meant that all potato crops were wiped out and about one million people died of starvation.

Figure 4 Tasmanian devil facial tumour disease is caused by the uncontrolled growth of cancerous cells. The cancerous cells are passed between devils when they bite one another.

Inbreeding

Inbreeding results from closely related animals reproducing. When this happens, rare diseases can show up. For example, some dogs that were chosen to breed because of their particular looks may also have hip problems (Figure 5). Inbreeding has been a problem with some dog breeds, especially when people don't check an animal's ancestry carefully.

Figure 5 Labradors are known to have hip problems as the result of many years of inbreeding.

Check your learning 4.9

Check your learning 4.9

Retrieve

1 **Define** the term "selective breeding". Give one example in your answer.

Comprehend

2 **Describe** the technology that can be used to assist selective breeding.

3 **Describe** an example of how inbreeding could occur.

4 **Explain** why genetic diversity in a population is important.

5 **Explain** why selective breeding is not always a good idea.

Apply

6 **Investigate** pug dogs and **discuss** an issue with selectively breeding the characteristics of this breed of dog.

Lesson 4.10

Review: Reproduction

Summary

Lesson 4.1 There are different ways of reproducing

- All living things reproduce, leaving new organisms to carry on when others die.
- Asexual reproduction involves a single organism making a copy of itself using its own genetic material.
- Sexual reproduction involves combining the genetic material from two organisms to produce a new organism.

Lesson 4.3 Fertilisation

- Sexual reproduction is where half the genetic material comes from a male and the other half from a female, to produce genetically different offspring.
- Animals may use internal or external fertilisation processes.
- External fertilisation occurs outside an organism's body.
- Internal fertilisation usually occurs inside an organism's body.
- The female reproductive system varies between vertebrates depending on the reproductive habits of the species.

Lesson 4.4 Human reproduction

- Human females have a large uterus, two fallopian tubes and two ovaries.

- Each month an ovary releases one ovum during ovulation as part of the menstrual cycle.
- Endometriosis is a disease caused by an overgrowth of the endometrium.
- Male mammals produce sperm in their testes.
- It takes 9 months for a human baby to form in the uterus before being born.

Lesson 4.5 Science as a human endeavour: Technology can assist human reproduction

- Assisted reproductive technologies such as in-vitro fertilisation can help couples have children.
- Babies can be screened in the womb for any problems.
- Contraception can be used by males and females to prevent reproduction.

Lesson 4.6 Parental care affects survival

- Stable environments allow for longer parental care.
- Producing many offspring reduces the level of parental care.
- r-strategists produce a lot of offspring quickly, due to their high-risk environment.
- K-strategists produce less offspring over time, due to their stable environment.

Lesson 4.7 Plant sexual reproduction produces seeds

- Flowers help plants to use sexual reproduction.
- When the male plant gamete lands on the female plant gamete, pollination has occurred.
- Plants can self-pollinate or be cross-pollinated by another plant.
- Insects and birds can help pollinate plants.

Lesson 4.9 Reproduction technologies have an impact on agriculture and biodiversity

- Reproductive technologies can be used in agriculture to improve desired characteristics in plants and animals.
- Reproductive technologies can have an impact on diversity and increase the risk of inbreeding.

Review questions 4.10

Review questions: Module 4

Retrieve

1 **Identify** what type of reproduction occurs when a bacterial cell divides in two equal parts (Figure 1).
  A Cross-pollination
  B Parthenogenesis
  C Fragmentation
  D Binary fission

Figure 1 A cell dividing in two equal parts

2 **Identify** the term used to describe the pollen from one flower being carried to another plant.
  A Cross-pollination
  B Parthenogenesis
  C Fragmentation
  D Asexual reproduction

3 **Identify** the reproductive term used to describe rapid reproduction of many offspring in a changing environment.
  A Internal fertilisation
  B External fertilisation
  C r-strategist
  D K-strategist

4 **Identify** the scientific term used for “making new organisms”.

5 **Define** the term “gamete”.

6 **Identify** the common names for the two gametes in animals.

7 **Recall** which produces greater variation: sexual or asexual reproduction.

8 **Recall** an example of each of the following types of asexual reproduction.
  a Parthenogenesis
  b Fragmentation
  c Vegetative reproduction

9 **Identify** a sexually dimorphic species.

10 **Complete** Figure 2 by **identifying** the missing labels for parts of the flower's reproductive structure.

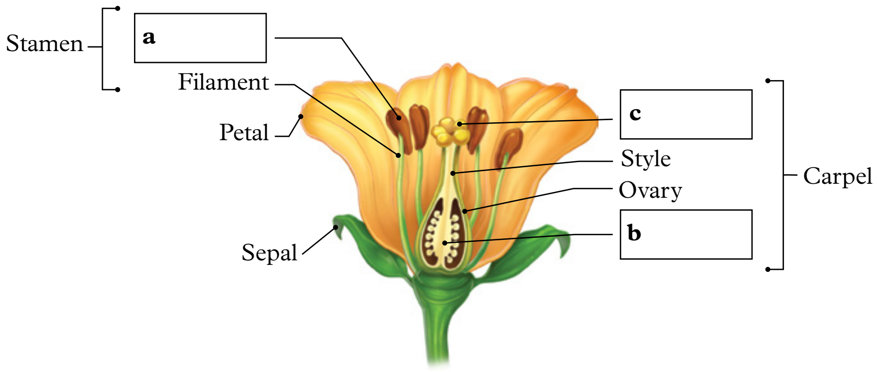


Figure 2 Structure of a flower

Comprehend

11 **Describe** the function of a fruit in reproduction.

12 **Describe** why organisms that fertilise internally tend to produce fewer eggs than those that fertilise externally.

13 **Describe** how reproduction strategies may change in stable or changing environments.

14 **Explain** what happens to the lining of the uterus during the menstrual cycle.

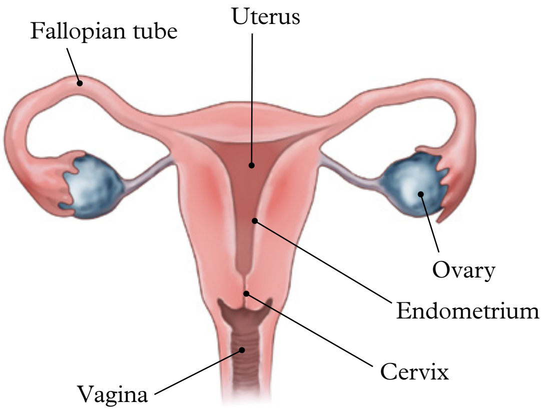


Figure 3 The female reproductive system

15 **Explain** why a hermaphrodite reproducing alone would be considered asexual reproduction.

16 Skinks (a type of lizard) drop their tails when threatened, but their tails can grow back. **Explain** why this is this not a type of asexual reproduction.

Analyse

17 A 13-year-old girl was keeping a record of her menstrual cycle. She found her cycle lasted approximately 28 days (Figure 4). If her last period started on 1 June, **identify** the following:

a when she should ovulate

b when her next period should start.

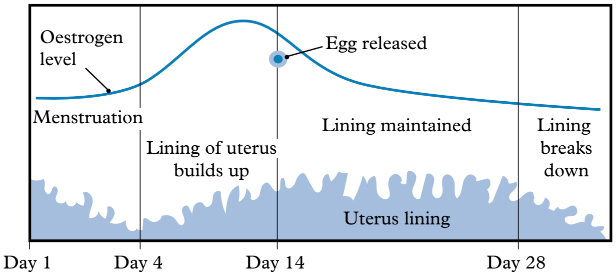


Figure 4 The average 28-day menstrual cycle

18 Examine the images in Figure 5. **Identify** two features that are genetic and two that are environmental.

Figure 5 These dogs are from the same litter.

19 **Compare** the structure of an egg and a sperm cell. **Describe** how the structure helps each cell achieve its function.

20 **Contrast** a spore and a seed.

Apply

21 Some reptile eggs are affected by the temperatures they experience while incubating in the nest (Figure 6). For example, within a single nest, high temperatures will produce female turtles while lower temperatures will produce male turtles. Most nests produce a mixture of turtle sexes. **Discuss** how warmer weather as a result of the enhanced greenhouse effect might impact green sea turtle populations.

Figure 6 Green sea turtle eggs produce female babies when the eggs are warmer and male babies when the eggs are cooler.

22 Use your knowledge of plant reproduction to design a new flower.

- **a** **Describe** how your flower will reproduce (wind, water, insects or birds).
- **b** **Create** a picture of your new flower. Label the stamen (with filament and anther), the carpel (with stigma, style and ovary) and the petals of the flower.

23 **Identify** which is better for maintaining biodiversity: self-pollination or cross-pollination. **Justify** your answer (by defining each term, providing an example of the consequences of each process and deciding which will provide the greatest biodiversity).

24 A farmer grows two types of corn on the farm. One type is affected by the frosts in winter but produces large, juicy corn cobs when it is protected. The other copes in winter without a problem but has produces small corn cobs. **Propose** one way the farmer could improve their crops.

Social and ethical thinking

25 When people are deciding if they agree or disagree on a social or ethical issue, they will often base it on their personal experiences.

- **a** **Discuss** what you know about in vitro fertilisation (IVF) techniques.
- **b** **Identify** where you learnt this information.
- **c** **Identify** reasons why some people may want to use IVF.
- **d** **Identify** two reasons why some people may not want to use IVF.

26 Divide into two groups to **investigate** and debate one of the topics below.

- **a** Selective breeding is essential to maintain food production for humans.
- **b** Reproductive technologies interfere with nature.
- **c** Selective breeding is important in preventing extinction.
- **d** Genetic diversity can be maintained without technology.

Critical and creative thinking

27 Humans don't reproduce asexually – ever.

- **a** **Predict** the possible consequences if a single human was able to reproduce asexually.
- **b** **Predict** the possible consequences if many humans were able to reproduce asexually.

28 The life cycles and reproductive strategies of invertebrates are incredibly diverse. Choose an invertebrate to **investigate** and present your findings to the class in the form of a poster or webpage.

Research

29 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.

Biosecurity

Gamba grass was introduced to northern parts of Australia in the 1930s. It is considered a weed as it competes with native grasses and is highly flammable during the dry season. Aboriginal and Torres Strait Islander Peoples work with research organisations and government agencies to identify and destroy gamba grass in a way that prevents its spread.

- **Describe** how gamba grass can be identified.
- **Describe** how gamba grass reproduces.
- **Explain** why it is important not to burn gamba grass when it has seeds.
- **Describe** how gamba grass can be destroyed.
- **Explain** why it is important to work with local Aboriginal and Torres Strait Islander Peoples when deciding how to control a weed such as gamba grass.

Seed banks

A seed bank stores a large variety of seeds in case a particular species of plant is placed at risk as a result of natural disaster or outbreaks of disease or war (Figure 7).

- **Investigate** a seed bank near your school.
- **Describe** the types of seeds they collect.
- **Identify** who collects the seeds for the bank.
- **Describe** how the seeds are collected.
- **Describe** the conditions that are needed for the seeds to remain viable (alive).

Figure 7 Seed banks store different plant seeds to protect species from endangerment or extinction.

Dog breeding in Australia

Some breeds of dogs are vulnerable to genetic problems, such as difficulty breathing or displaced hips, as a result of decades of inbreeding (Figure 8).

- **Investigate** a breed of dog that has such difficulties.
- **Describe** the features that these pedigree dogs are judged on in dog shows.
- **Describe** the problems that have arisen as a result of the inbreeding.
- **Describe** the measures that the RSPCA and the Australian National Kennel Council are taking to ensure these problems do not continue.

Figure 8 Pugs are one breed of dog that is vulnerable to genetic problems.

Contraception

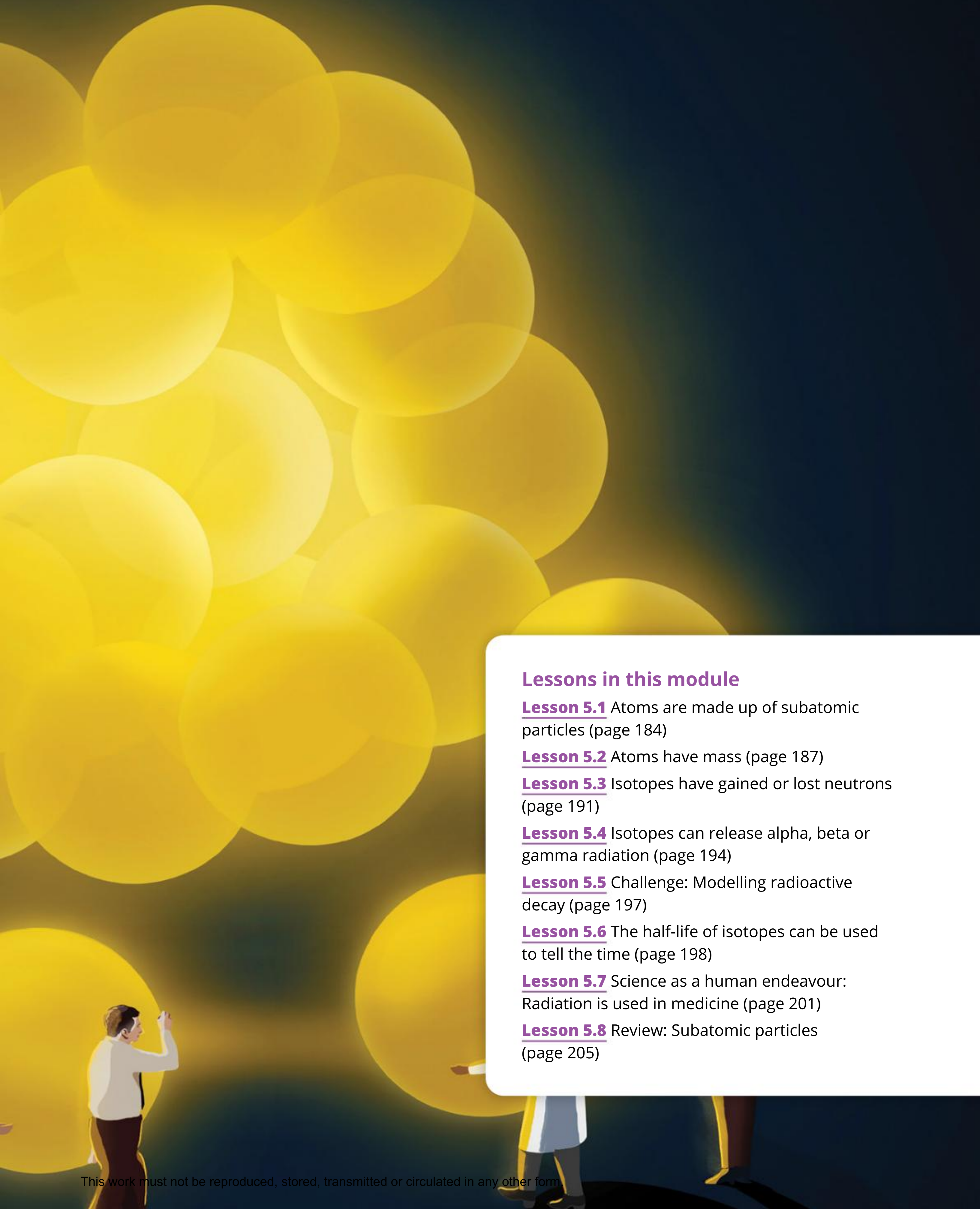
Contraception is the term used for the range of methods and devices that are used to prevent pregnancy. Contraception has been used for thousands of years.

- **Contrast** barrier, surgical and chemical methods of contraception.
- **Investigate** two methods of contraception that can be used by humans.
- **Identify** whether males or females use these methods.
- **Describe** how effective each of these methods are at preventing pregnancy.

Module
5
Subatomic particles

Overview

The model of the atom changed after the discovery of electrons, protons, and neutrons. Atoms of the same element can have different numbers of neutrons, which creates isotopes – some of which are unstable. Radioactive decay occurs when these unstable atoms turn into stable ones over time. Isotopes such as radon-222, iodine-131, and cobalt-60 decay at different rates, known as a half-life. This knowledge helps scientists use techniques like radiocarbon dating to determine the age of ancient objects. Radioactivity also has important uses in medicine and industry, such as treating cancer and checking materials.



Lessons in this module

Lesson 5.1

Atoms are made up of subatomic particles

Key ideas

→ The Rutherford model of atoms suggests that an atom has a central nucleus containing positively charged protons and neutrons with no charge.

→ Negatively charged electrons travel around the space outside the atom's nucleus.

→ Atoms have no overall charge.

Learning intentions and success criteria

Introduction

In 1810, English scientist John Dalton 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**, and he was the originator of what is now called the **atomic theory**.

This theory gave scientists a way to explain the evidence about atoms, and it is now supported by a range of new evidence. Ever since Dalton first proposed his atomic theory, it has been used to make predictions.

element a pure substance made up of only one type of atom

atom the smallest particle that forms the building blocks of matter; the smallest particle that retains the properties of an element

atomic theory the theory that all matter is made up of atoms

subatomic particle a particle that is smaller than an atom

electron a negatively charged particle that moves around in the space outside the nucleus

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

Discovering more about atoms

In the late 1800s, almost a century after Dalton proposed his theory, the physicist Joseph John Thomson discovered that atoms were actually divisible and were made up of even smaller **subatomic particles**. His experiments showed that inside the atom are far smaller, negatively charged particles, which we now call **electrons**.

Thomson 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 1).

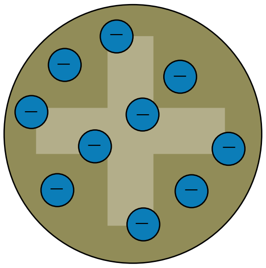


Figure 1 The Thomson plum pudding model of the atom

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 2). 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 3).

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 4). 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.

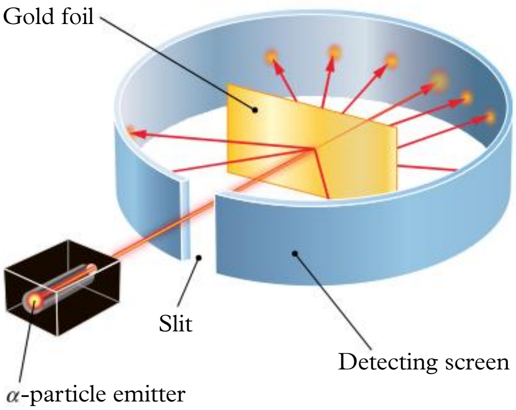


Figure 2 Rutherford's gold foil experiment. Note the way many of the particles changed direction.

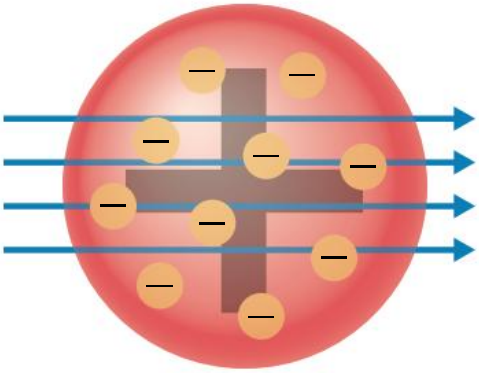


Figure 3 If the "plum pudding" model of the atom was correct, it would be expected that most of the alpha particles would move through the gold foil with only minimal deflection.

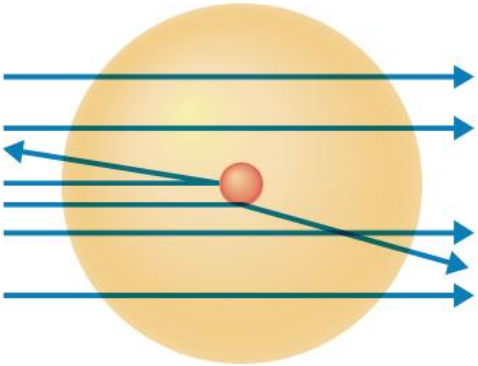


Figure 4 The gold foil experiment showed that some alpha particles were deflected.

Rutherford's model of the atom

nucleus the centre of an atom, containing protons (positive charge) and neutrons (no charge)

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

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.

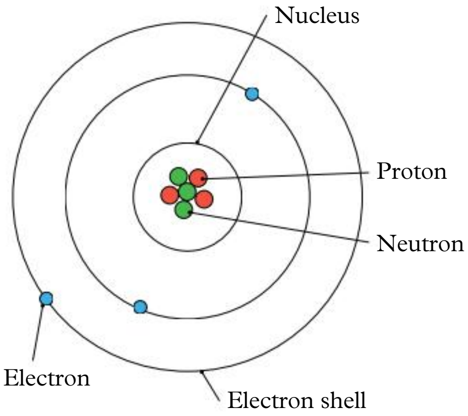


Figure 5 A two-dimensional model of an atom of the element lithium

Huge parts of atoms are empty space. If you expanded one atom to the size of the MCG, the nucleus of that atom would be no bigger than a pinhead.

An important thing to know is that an atom has no overall electrical charge. In other words, there is always the same number of positive protons as negative electrons in any atom.

Check your learning 5.1

Check your learning 5.1

Retrieve

1 **Name** the three types of subatomic particles we now know are inside an atom.

Comprehend

2 Use the evidence described to **explain** why Rutherford concluded that:
  - **a** an atom contains a lot of space
  - **b** there is a central area of positive charge.

3 **Describe** the Thomson plum pudding model of the atom.

4 **Describe** the most important new understanding of the structure of the atom that Rutherford inferred from his experiment with alpha particles.

Analyse

5 **Compare** the different types of subatomic particles that are found inside an atom.

Skills builder: Conducting investigations

6 Rutherford and his assistants conducted experiments by firing radioactive particles at a thin layer of gold. Detectors would then record whether the particles had gone straight through the foil or had been deflected.
  - **a** **Investigate** the method used in the experiment and note any safety risks or hazards. (THINK: How did they manage radioactive materials?)
  - **b** **Select** one of the risks and **assess** how this could be managed to keep future experiments safe. (THINK: What protective measures should be taken? What PPE would assist?)

Lesson 5.2

Atoms have mass

Key ideas

→ The mass of an atom is made up of the protons and neutrons in the nucleus of the atom.

→ Because atoms are so small, their mass is measured using a relative mass scale.

→ Atoms are given their names according to the number of protons in their nucleus.

Learning intentions and success criteria

Size is relative

A gold atom might seem heavy if you compare it to a helium atom. But if you compare it to an elephant, an atom is extremely small! To measure something by comparing it with something else is called relative measurement (Figure 1).

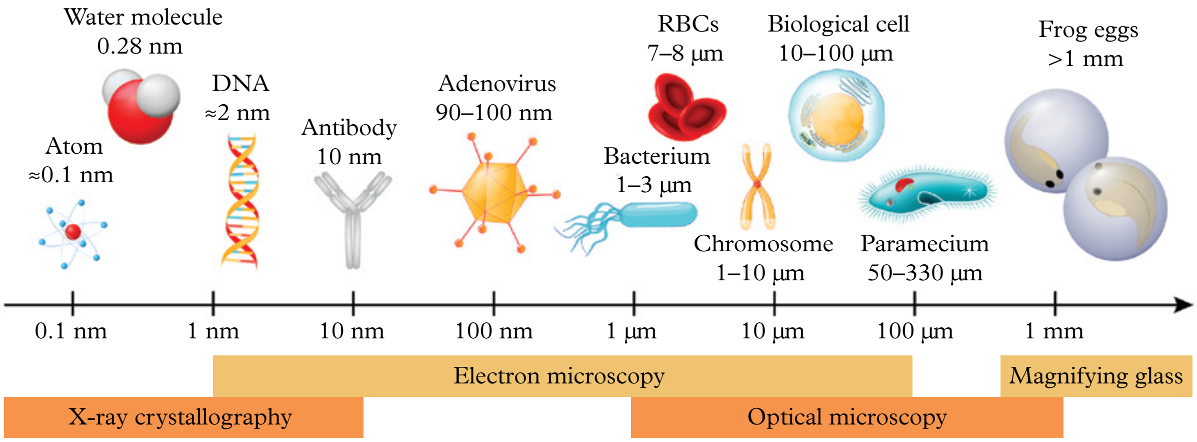


Figure 1 Relative sizes of particles and cells

Relative scales are often helpful when objects or events are being compared. Relative scales are used when it is more important to know the differences between objects and events than the actual measurement (size, mass, time). The following conversation uses relative measurements.

> "Mum, Chloe's been in the shower twice as long as I was."
>
> "I know, but you used three times as much shampoo."

Being able to compare the masses of different atoms is important when investigating the behaviour of different atoms and elements. It is not so helpful to know the actual mass of atoms, partly because the mass is so small.

Mass number

On the relative atomic scale, the mass of a proton is given a value of 1. Neutrons have almost the same mass as protons, so they also have mass of 1 on this scale. Therefore, the mass of an atom can be worked out by counting how many protons and neutrons there are in the nucleus. Remember that electrons are not included in the mass number, because they are so light in comparison to the particles in the nucleus. The total number of protons and neutrons in an atom is called the **mass number**.

mass number
a number that represents the total number of protons and neutrons in the nucleus of an atom

mass number = number of protons + number of neutrons

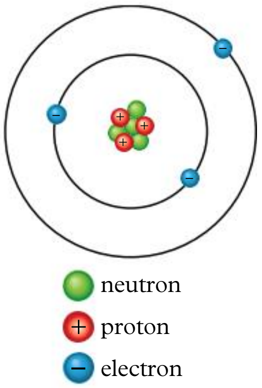
For example, a helium atom that contains 2 protons and 2 neutrons has a relative mass (mass number) of 4. A carbon atom that contains 6 protons and 6 neutrons has a relative mass of 12.

The number of protons in an atom is known as the **atomic number**. Because atoms are always neutral (no overall charge), the number of electrons in an atom is always the same as the number of protons.

atomic number
the number of protons in an atom's nucleus

atomic number = number of protons

Figure 2 and Figure 3 show examples of two common atoms.



Lithium
Number of protons = 3
Atomic number = 3
Number of neutrons = 4
Mass number = 7
Number of electrons = 3

Figure 2 A lithium atom, with mass number 7 and atomic number 3

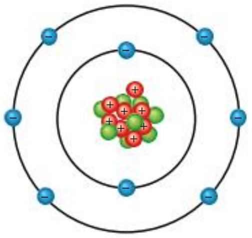


Figure 3 An oxygen atom. Number of protons: 8. Atomic number: 8. Number of neutrons: 8. Mass number: 16. Number of electrons: 8.

Protons determine names

There are many ways to group the different types of atoms. Because the mass of an atom is too small to be easily measured, and some atoms have similar properties, scientists use the number of protons to give an atom its name. An atom with 8 protons is always called oxygen, while an atom with 19 protons is always called potassium.

Representing atoms

When it is important to show the number of particles within each atom, the method of representation shown in Figure 4 can be used. The elements can be presented in a **periodic table** (Figure 5). In a periodic table, the elements are arranged according to the number of

periodic table
a table in which elements are listed in order of their atomic number, and grouped according to similar properties

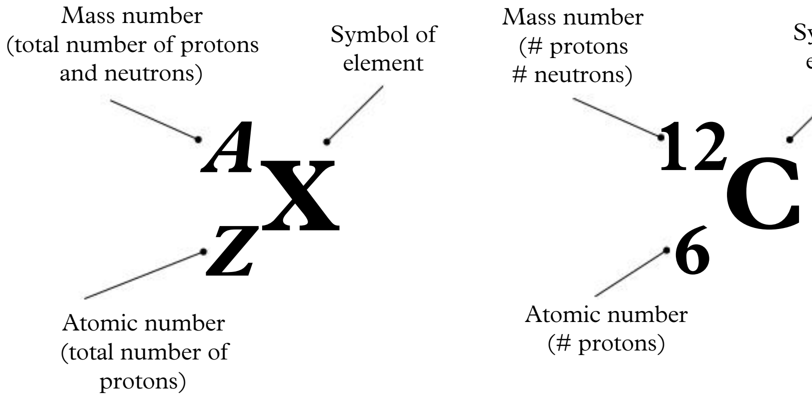
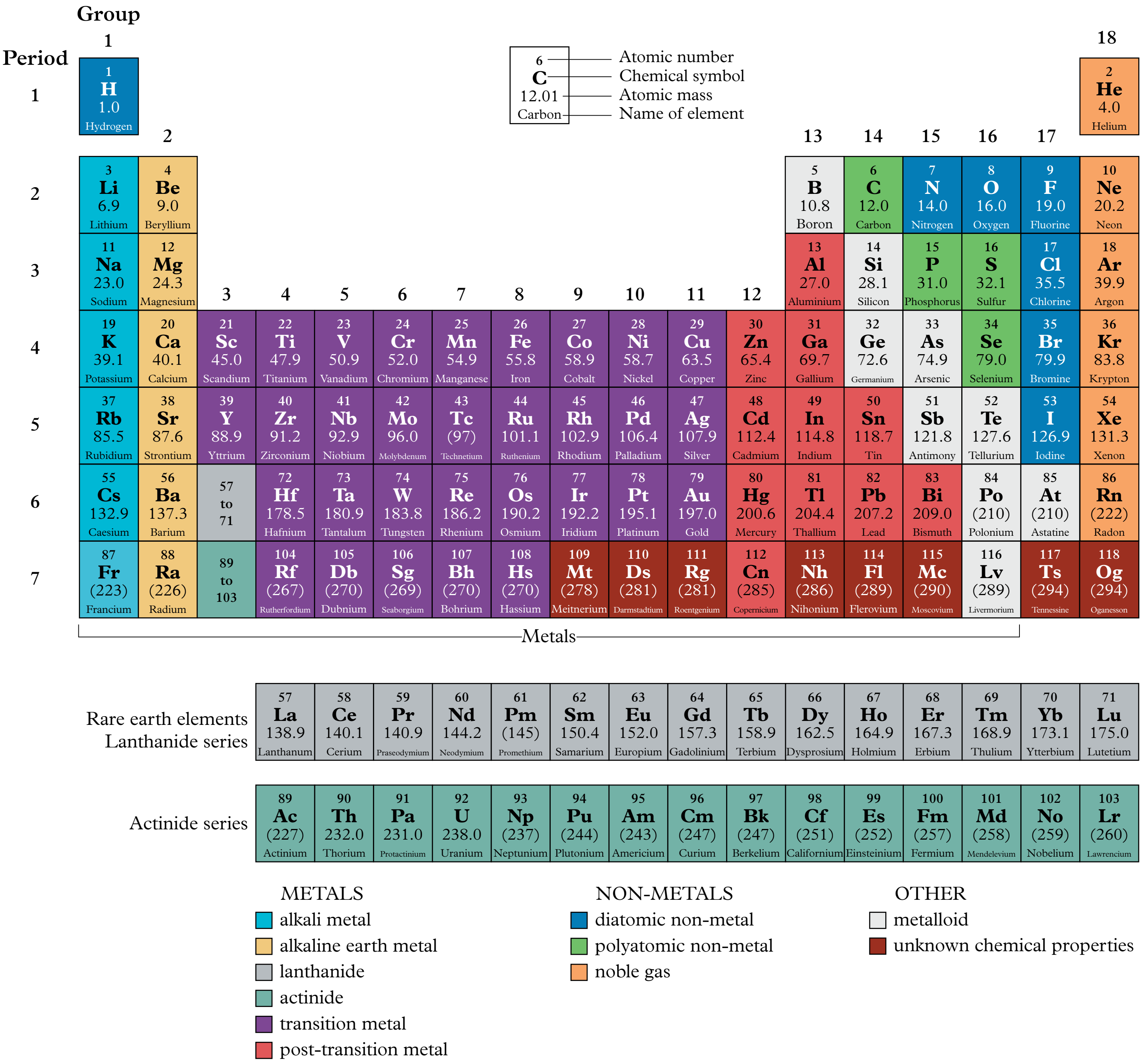


Figure 4 The conventional representation of an element. The mass number is always the largest number shown.

protons in their atoms (their atomic number). The horizontal rows, called **periods**, consist of elements arranged in order of increasing atomic number. Hydrogen (1 proton) is given the atomic number of 1, followed by helium (2 protons), lithium (3 protons) and beryllium (4 protons). The vertical columns, called **groups**, consist of elements that behave in similar chemical ways.

period (in chemistry) a horizontal list of elements in the periodic table

group a vertical list of elements in the periodic table that have characteristics in common



Group

Period	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 5 A periodic table of the elements

Check your learning 5.2

Check your learning 5.2

Comprehend

1 **Identify** the subatomic particle that is not in the nucleus of the atom.

2 Table 1 shows the numbers of subatomic particles in a range of atoms.
  a **Use** the periodic table (Figure 5) to **identify** the missing text in the table.
  b **Explain** how you were able to calculate the number of neutrons in the argon atom.
  c **Explain** how you were able to work out the atomic number and the mass number of the sulfur atom.

Table 1 Atoms and subatomic particles

Atom name and symbol	Atomic number	Mass number	Number of protons	Number of neutrons	Number of electrons
Calcium (Ca)	20	40	20	20	20
	9	19	9		
Sodium (Na)	11		11	12	
Argon (Ar)		40	18		
Sulfur (S)			16	16	

3 The relative mass of a proton is 1. **Describe** what is meant by “relative mass”.

Analyse

4 **Identify** the element that is located in period 3, group 15 of the periodic table.

5 The atomic number of a nitrogen atom is 7 and the mass number is 14. **Calculate** the number of electrons in this neutral atom.

6 **Identify** the atom that has twice as many protons as an oxygen atom.

Apply

7 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 element you are representing.

Skills builder: Communicating

8 **Consider** whether it is more appropriate to use the name, symbol, atomic number or relative atomic mass when you identify an element that will be used in an experiment. (THINK: What information would people require?)

Lesson 5.3

Isotopes have gained or lost neutrons

Key ideas

→ An isotope is a different form of the same element with a different number of neutrons in the nucleus of the atom.

→ The periodic table lists the relative atomic mass of an atom, which represents the weighted relative mass of all the isotopes of that atom.

Learning intentions and success criteria

Atomic mass and isotopes

The periodic table lists the relative atomic masses of the elements. These masses are not whole numbers and are not the same as the mass numbers of the atoms (although they are close). They are a more accurate way of comparing the masses of the atoms of different elements. But why are many of them not whole numbers? We certainly cannot have part of a proton or part of a neutron in an atom. Electrons do have some mass, but not enough to make much difference to the overall mass of the atom. So where do these atomic masses come from?

Generally, not all the atoms within an element have the same mass. This is because they are not identical. Why is this? What do they have in common and what is different?

All the atoms of an element have the same number of protons – their atomic number. The atomic number is used to identify the element. For example, all carbon atoms have 6 protons in their nucleus, so their atomic number is 6. In the periodic table of the elements (Figure 5, page 189), you can see that the elements are listed in order of their atomic number. However, although all the atoms of one particular element have the same number of protons, they may have different numbers of neutrons.

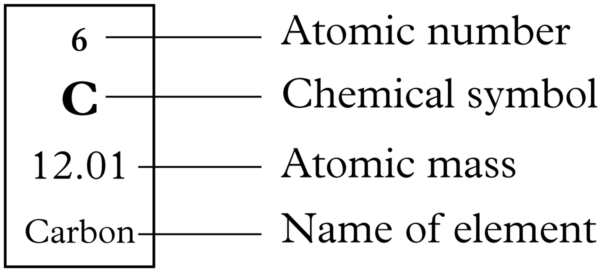


Figure 1 The atomic number and atomic mass of carbon

Isotopes

Neutrons help to make the nucleus more stable. For most elements, the number of neutrons in the atoms can vary. For example, most carbon atoms have 6 neutrons in their nucleus but some have 7 or 8. The different forms of the atoms of an element that have different numbers of neutrons are called **isotopes**.

isotope an atom of a particular element that has more or fewer neutrons in its nucleus than another atom of the same element

Remember, the number of protons in an element never changes. If there is a different number of protons, it is a different element.

Carbon-12 (or ^{12}C) is the most common form of carbon atom in the natural world. It has an atomic mass of 12 (6 protons and 6 neutrons). Of all the natural carbon on Earth, only 1.1 per cent is carbon-13 atoms (6 protons and 7 neutrons), and an even smaller quantity is carbon-14 atoms (6 protons and 8 neutrons).

Like most elements, carbon has more than one naturally occurring isotope (Figure 2). In these cases, chemists use the average mass of the isotopes of the element for calculations. This average mass is termed the **relative atomic mass** of the element. For example, 99 per cent of carbon atoms exist as the carbon-12 isotope and only a very small proportion are present as the two heavier isotopes. Therefore, the relative atomic mass is only just above 12 (12.01). The relative atomic masses of the elements are usually shown in the periodic table, correct to one or two decimal places. Be careful not to confuse atomic masses in the periodic table (which are decimals) with their atomic numbers (which are always integers).

relative atomic mass the average mass of an element, including the mass and prevalence of its different isotopes

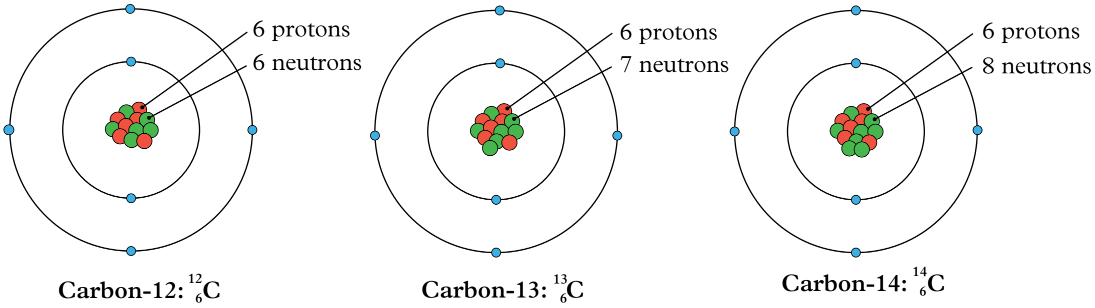


Figure 2 Three of the isotopes of carbon. Almost all of the carbon in the world is carbon-12.

Check your learning 5.3

Check your learning 5.3

Retrieve

1 **Define** the term "isotope".

Comprehend

2 **Explain** the meaning of "mass number" and how this name arose. Use an example to assist your explanation.

3 **Explain** why the atomic number of an element is always a whole number but the relative atomic mass of an element is often not a whole number.

Analyse

4 Using the periodic table on page 189, **identify** which of the following atoms are isotopes of the same element. Also **identify** the name and symbol of the element.

Option 1: 5 protons, 5 neutrons
Option 2: 5 protons, 6 neutrons
Option 3: 6 protons, 6 neutrons

5 **Use** your knowledge of isotopes and a copy of the periodic table on page 189 to complete Table 1.

Table 1 Isotopes

Isotope symbol	Isotope name	Atomic number of element	Number of protons	Number of neutrons	Number of electrons in uncharged atom
${}^{239}_{92}U$					
	Oxygen-16				
			10	20	
				36	29
		30		34	

6 **Compare** the structure of two isotopes of the same element.

Apply

7 One atom has 5 protons and another atom has 6 protons. Is this an example of a pair of isotopes? **Justify** your answer (by providing your reasons).

8 A student wrote that all the atoms of an element are identical. **Evaluate** whether this is correct (by defining the terms "atom" and "element", comparing the isotopes of carbon and deciding whether the isotopes are identical).

Skills builder: Planning investigations

9 Before you can conduct scientific investigations, you need to be familiar with existing information about the topic. **Investigate** one of the natural isotopes of carbon.

- a **Identify** one source that identifies the natural isotope. (THINK: Is this source reliable?)
- b **Explain** what this natural isotope is. (THINK: Can you write this in your own words? Do you need to use a diagram?)
- c **Recommend** whether this is a good source of information. (THINK: Do I understand what this natural isotope is?)

Lesson 5.4

Isotopes can release alpha, beta or gamma radiation

Learning intentions and success criteria

Check the next lesson for a linked practical activity or experiment.

Key ideas

- → Some isotopes are unstable and may decay.
- → Radioactive decay produces alpha, beta and/or gamma radiation.
- → The half-life of an isotope is the time it takes for half the remaining unstable isotopes to decay.

Isotopes and radioactive decay

In Lesson 5.3 Isotopes have gained or lost neutrons (page 191), you learnt about isotopes. Hydrogen, for instance, has three isotopes: hydrogen-1 ($^{1}_{1}\text{H}$), hydrogen-2 ($^{2}_{1}\text{H}$) and hydrogen-3 ($^{3}_{1}\text{H}$).

While the number of neutrons can vary, having too many or too few neutrons results in an unstable nucleus that decays radioactively. In the first 20 elements, stable nuclei have a similar number of neutrons and protons.

Figure 1 Marie Curie was one of the first scientists to study isotopes, some of which are radioactive. Her notebook is still radioactive over 100 years later.

radioactive decay the conversion of a radioactive isotope into its stable form, releasing energy in the form of radiation

radionuclide a radioactive isotope

This process of decay causes the emission of energy in the form of radiation and is known as **radioactive decay** (Figure 1). Hydrogen-1 and hydrogen-2 are stable, but hydrogen-3 is unstable and breaks down. Therefore, hydrogen-3 is a radioactive isotope and is called a **radionuclide**.

Radionuclides occur naturally, but they can also be manufactured in a nuclear reactor. All radionuclides release energy when they break down and form a more stable atom. This energy can be calculated using Einstein's famous equation $E = mc^2$, where E is energy, m is the change in the mass when the radionucleotide converts to its stable form, and c is the speed of light.

Types of nuclear radiation

alpha particle a radioactive particle containing two protons and two neutrons; can be stopped by a piece of paper

Alpha (α), beta (β) and gamma (γ) radiation all originate from an unstable nucleus. An **alpha particle** is identical to a helium nucleus. It contains 2 protons and 2 neutrons. Americium-241, which is commonly used in smoke detectors, is an example of an alpha particle emitter (Figure 2). Its nucleus decays to neptunium-237, which is a more stable atom.

The decay of americium-241 to neptunium-237 can be shown in a nuclear equation:

$$^{241}_{95}\text{Am} \rightarrow {}^{237}_{93}\text{Np} + 42\alpha$$

In a nuclear equation, the mass numbers on each side of the arrow add to the same value. In this case, they both add to 241. This demonstrates that the total mass of the particles before and after the decay is the same.

Beta particles are produced when a neutron in the nucleus decays into a proton and an electron. The electron is the beta particle that leaves the atom. An example of beta decay is the decay of iodine-131 to xenon-131:

$$^{131}_{53}\text{I} \rightarrow {}^{131}_{54}\text{Xe} + \beta$$

The beta particle has very little mass, so the mass of the new nucleus formed is very similar to the original iodine-131 nucleus. As the beta particle is released, a neutron in effect becomes a proton, so the atomic number of the resulting nucleus increases by one.

Gamma rays are high-energy electromagnetic rays, similar to X-rays, which are emitted after alpha particle or beta particle emission when the nucleus is still excited.

An example is when cobalt-60 decays to form nickel-60:

$$^{60}_{27}\text{Co} \rightarrow {}^{60}_{28}\text{N} + \beta + \gamma$$

Cobalt-60 is an artificially produced radioisotope that is used in medical radiotherapy, sterilisation of medical equipment and irradiation of food. Because gamma radiation is an electromagnetic wave (rather than particles, such as alpha and beta radiation), it is highly penetrating and can cause cell damage deep within the body if exposure levels are high (Figure 3).

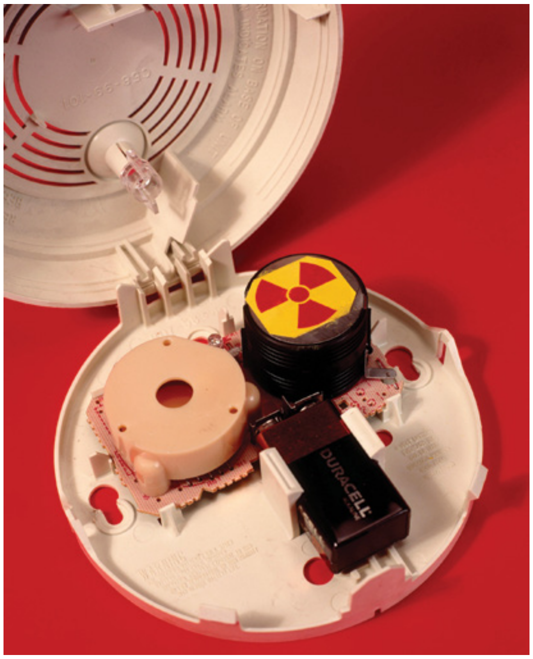


Figure 2 Smoke detectors contain a radioactive source, usually americium-241.

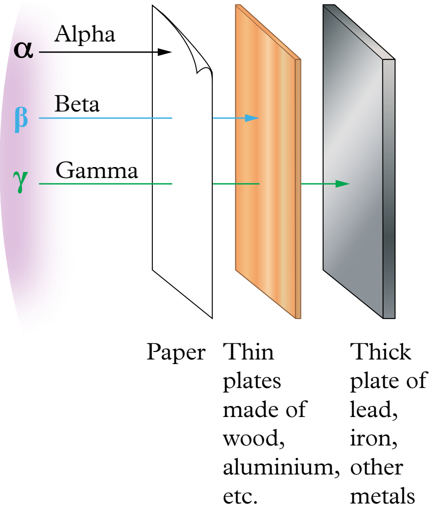


Figure 3 The relative penetrative power of alpha, beta and gamma radiation. Alpha particles are stopped by paper. Beta particles are stopped by aluminium foil. Gamma rays can only be stopped by lead.

beta particle a radioactive particle (high-speed electron or positron) with little mass; can be stopped by aluminium or tin foil

gamma rays high-energy electromagnetic rays released as a part of radioactive decay; can be stopped by lead

Radioactive half-life

Radioactive decay is a random process, so we cannot predict which radioactive nuclei in a sample will decay. However, the rate of radioactive decay follows a pattern. As a radioactive sample decays, less and less of the original radioactive atoms are left and more of the alternative stable atoms are formed. This means the radioactivity level drops. The **half-life** of a radioactive material is the time taken for half the radioactive nuclei in a sample to decay into the stable atoms (Table 1).

This is also equivalent to the time taken for the radioactivity to drop to half of its original value.

When the radioactivity reaches one-half of its original level, one half-life has passed. When it reaches one-quarter of its original level, two half-lives have passed, and the pattern continues. A graph of radioactive decay against time gives a characteristic shape called an exponential decay curve (Figure 4). Worked example 5.4A shows how to calculate the half-life of a radioactive element.

half-life the time it takes the radioactivity in a substance to decrease by half

Table 1 Half-lives of important medical radionuclides

Radionuclide	Half-life
Bismuth-213	46 minutes
Technetium-99m	6 hours
Lutetium-177	6.7 days
Iodine-131	8 days
Chromium-51	28 days
Strontium-89	50 days

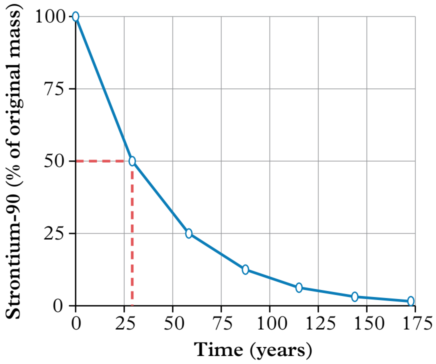


Figure 4 A radioactive decay curve for strontium-90, which has a half-life of 28.8 years

Worked example 5.4A Calculating half-life

Strontium-90 is a radioactive element that has a half-life of 28.8 years. For 1,000 g of strontium-90, calculate:

a the amount of strontium-90 left after one half-life

b the number of years it would take for the strontium-90 to decay to 125 g.

Solution

a After one half-life, half of the 1,000 g of strontium-90 would have decayed.

$$\text{remaining strontium-90} = \frac{1}{2} \times 1{,}000\text{ g}$$
$$= 500\text{ g}$$

b To calculate the number of years it would take 1,000 g of strontium-90 to decay to 125 g, the number of half-lives needs to be determined.

Starting strontium-90 mass (0 years) = 1,000 g
1 half-life (28.8 years) = 500 g
2 half-lives (57.6 years) = 250 g
3 half-lives (86.4 years) = 125 g
Therefore, the time for 1,000 g of strontium-90 to decay to 125 g = 86.4 years.

Check your learning 5.4

Check your learning 5.4

Retrieve

1 **Define** each of the following terms.
  - **a** Radioactive decay
  - **b** Radionuclide
  - **c** Half-life

Comprehend

2 **Represent** an isotope for each of the following in the form $^{A}_{Z}X$. You may need to use the periodic table to determine the atomic number of the elements.
  - **a** Iodine-131
  - **b** Cobalt-60
  - **c** Technetium-99m
  - **d** Fluorine-18

3 A number of the elements have radioactive isotopes. In each case, it is the nucleus of the atom that is unstable. **Describe** how you could protect yourself from each of the following types of radiation.
  - **a** Alpha
  - **b** Beta
  - **c** Gamma

Analyse

4 At 3:00 pm, 80,000 atoms of a radionuclide were sitting on the bench. At 3:10 pm, after 10 minutes of radioactive decay, there were only 5,000 of the original atoms left. (The others had decayed into a more stable isotope.)

- **a** **Calculate** the half-life.
- **b** **Explain** the relationship between the half-life of the radionuclide and the number of atoms it has.

Apply

5 **Investigate** one radioactive isotope that is used in medicine. **State** the symbol for the isotope and its uses.

Skills builder: Processing and analysing data and information

6 Look at Figure 4, which shows the radioactive decay curve for strontium-90.

- **a** **Identify** the level of strontium-90 at 25 years. (THINK: Which axis in the graph represents time?)
- **b** **Determine** how many years it took for the levels of strontium-90 to change from 75 to less than 10. (THINK: What scale does the graph use?)

Lesson 5.5

Challenge: Modelling radioactive decay

Background

This activity illustrates the idea of exponential decay and half-life. Counters represent the nuclei.

Aim

To model the half-life of a radioactive compound

What you need:

- Counters (at least 30)
- Permanent marker
- Disposable plastic cup
- A4 paper

What to do:

1 Copy Table 1 into your notebook and record your results.

Table 1 Results for modelling radioactive decay.

Number of shakes	Number of undecayed "atoms"		
	Trial 1	Trial 2	Trial 3
0 (start)			
1			
2			
…			

2 Draw an "M" on one side of each counter.

3 Count the total number of counters that you have, record this number and place them in the plastic cup.

4 Shake the cup and tip all the counters onto the paper.

5 Those that have the "M" facing upwards represent atoms that have decayed. Move these to a "discard" pile.

6 Count the remaining "nuclei" and record this number.
7 Place the remaining nuclei back into the cup, shake them and tip them out again.
8 Move the decayed nuclei to the discard pile and count those remaining. Record the number.
9 Continue until you have three or fewer nuclei.
10 Repeat steps 3 to 9 two more times, so you complete a total of three trials.
11 Draw a set of axes with the number of atoms remaining (vertical y-axis) and the number of shakes (horizontal x-axis). Plot points and draw a line of best fit through the points for each of the three trials.

Questions

1 The atomic nuclei were represented by counters. **Describe** how the half-life of the decay process was represented.
2 **Contrast** the shapes of the curves drawn for each trial.
3 **Explain** how the overall shape of the curves would or would not change if you started with more atomic nuclei.
4 **Identify** any outliers in your data. **Describe** a possible cause for the outliers, and if they affected the overall shape of the graph.
5 In this experiment, you would eventually end up with no "undecayed" counters. **Evaluate** whether this would be the case with a real radionuclide (by describing how atoms randomly decay in real life, comparing this to the counter demonstration and deciding whether every atom of a real radionuclide would become stable).

Lesson 5.6

The half-life of isotopes can be used to tell the time

Learning intentions and success criteria

Key ideas

→ Background radiation exists all around us from radioactive material and in the form of cosmic rays from the Sun and space.

→ The rate at which a radioactive material decays can be used to determine how long the material has been outside a living organism.

Carbon dating

Whether a nucleus is stable depends on the number of neutrons and protons in the nucleus. There is no easy formula that can be used to predict the stability of individual atomic nuclei, but some nuclei, such as carbon-12 nuclei, with 6 protons and 6 neutrons, are very stable. However, carbon-14, with 8 neutrons in its nucleus, is less stable and will decay over time, giving out radiation to form a different atom. It is very slightly radioactive, but safe.

Carbon-14 is being formed all the time as cosmic rays enter Earth's upper atmosphere. Plants absorb this carbon-14 when they photosynthesise and the carbon-14 then enters the food chain.

Therefore, all living organisms, including humans, contain a certain amount of radioactive carbon-14 while they are alive. However, when an organism dies and stops eating new carbon-14, the carbon-14 in its body begins to decrease at a reliable rate, with a half-life of 5,730 years.

We can measure the amount of carbon-14 to determine the age of artefacts that are up to 50,000 years old, including cave paintings and ancient scrolls. This method is called **carbon dating**.

Carbon dating is the most common way of dating ancient artefacts, and plant and animal material. It was used to measure the age of the Shroud of Turin (Figure 1), a linen cloth believed by many to have been used to wrap the body of Jesus Christ after his crucifixion. Carbon dating indicated that the Shroud of Turin was not as old as claimed.

carbon dating a method of estimating the age of organic material, by comparing the amount of carbon-14 in the material with the amount in the atmosphere, knowing the rate at which carbon-14 decays over time

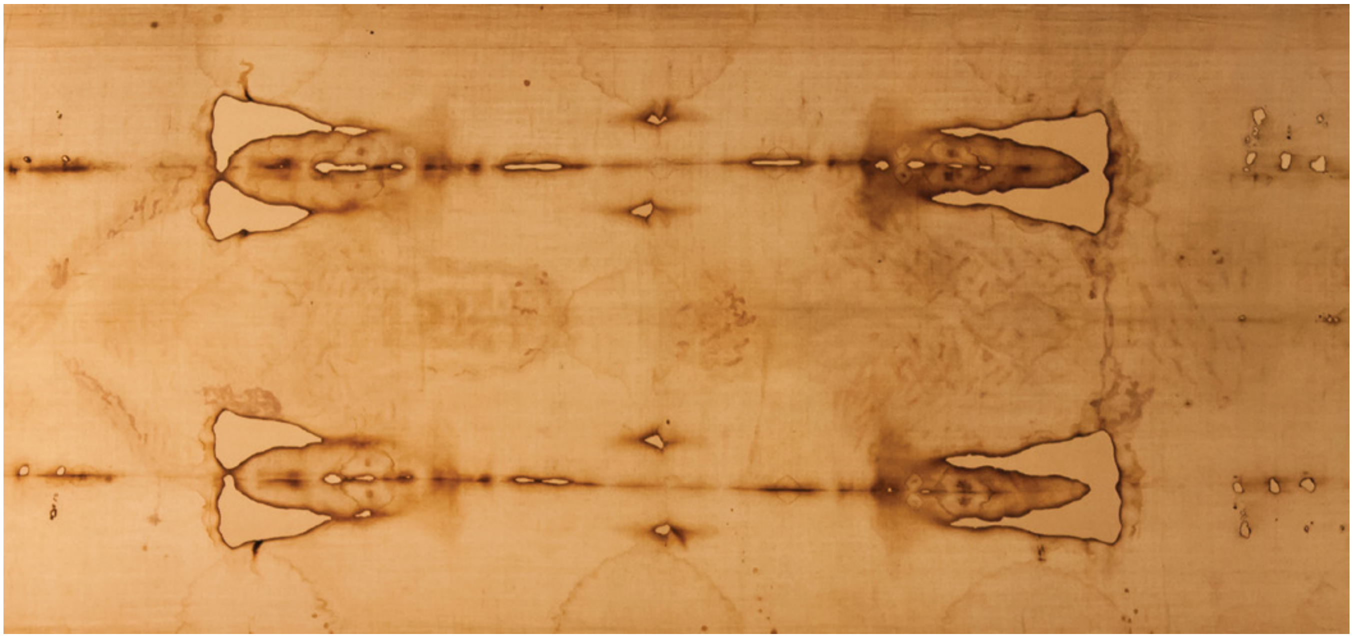


Figure 1 Carbon dating of the Shroud of Turin conducted in 1988 indicated that it was only 700 to 800 years old.

Rock art is often difficult to date using carbon dating because the pigment does not usually contain carbon. The Australian Nuclear Science and Technology Organisation was able to solve this problem by dating a series of wasp nests built over the unique Gwion Gwion style art in the remote Kimberley (Figure 2). With the permission of the Traditional Owners, scientists were able to collect carbon formed in ancient bushfires from the fossilised wasp nests. The amount of carbon-14 remaining indicated that the paintings were at least 10,000 to 12,000 years old.

Figure 2 The amount of carbon-14 in a wasp nest can date rock paintings underneath.

The decay of radioactive isotopes is often very slow. For example, it would take 5,730 years for half of a 10 g sample of carbon-14 to decay. The remaining 5 g would take another 5,730 years to reduce to 2.5 g, and another 5,730 to reduce to 1.25 g. Unless the amount of carbon is measured over an extremely long period, it might seem that no change is occurring. Only sensitive equipment can detect the radiation being released during the decay process.

Some other radioactive atoms decay incredibly quickly. For example, half of a sample of the isotope lithium-8 decays in less than 1 second. Uranium-235 takes a very long time to decay: it would take 700 million years to reduce to half of the original amount.

Figure 3 Carbon dating can be used to work out the age of animal remains.

In science, there are many situations where change takes place over a range of timescales. What makes radioactive decay special is that it is a random process. It is impossible to predict how long a particular atom will take to decay, giving out radiation as it does so. But with billions of atoms in any one sample, the overall rate of decay can be predicted. Think about a glass of water evaporating. It is impossible to predict when one particular water molecule will escape from the liquid, but overall it can be predicted how long the water will take to evaporate.

Figure 4 How can we determine the age of objects that might be older than 50,000 years?

Check your learning 5.6

Check your learning 5.6

Comprehend

1 **Explain** why carbon-12 atoms are more stable than carbon-14 atoms.

2 **Explain** why an isotope that decays very quickly would be considered more dangerous than an isotope that decays slowly.

3 **Describe** one way you might absorb new carbon-14 atoms into your body.

4 In 1988, carbon dating indicated that the Shroud of Turin was in fact created in the Middle Ages (between 1260 and 1390).
  - a **Explain** how carbon dating is used to determine the age of an object.
  - b **Explain** why this method dated the shroud to a range of years rather than a single year.

5 **Describe** how wasp nests can be used to date rock paintings.

Analyse

6 Carbon dating can be used to determine the age of objects less than 50,000 years old.
  - a **Consider** why carbon dating cannot be used to determine the age of older objects (by calculating the number of half-lives that will have passed, and describing whether the remaining carbon-14 could be detected).
  - b **Identify** another radioactive isotope with a longer half-life that could be used to date objects that are older than 50,000 years.

Lesson 5.7

Science as a human endeavour: Radiation is used in medicine

Key ideas

→ Radioactive materials can be used in cancer therapy.

→ Radiotechnicians need an understanding of the properties of radioactive materials and how to handle them.

Learning intentions and success criteria

Introduction

The radiation produced by isotopes can damage the cells in our body, or it can be used to identify and cure diseases. Nuclear medicine is a diagnostic imaging method often used in X-ray departments in hospitals and medical clinics.

Effects of radiation

The main reason that radiation can be harmful is that it can cause atoms in other substances to become **ions**. The emitted alpha and beta particles have enough mass and/or energy to remove electrons from the outside of atoms, which changes the properties of the atoms. This process also causes the release of reactive particles, called free radicals. If this occurs in our bodies, these free radicals can go on to damage other important molecules in the body.

If DNA is damaged, this can have serious effects, because DNA is the molecule that contains instructions for the cell's biochemical processes (Figure 1). It is also a molecule that can reproduce itself, so the effect of one damaged DNA molecule can be multiplied thousands or even millions of times as copies of the affected DNA are created. Many cancers linked to radiation start in this way.

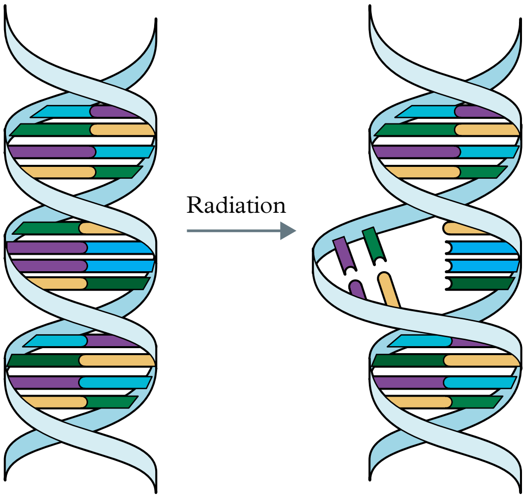


Figure 1 Radiation can damage the structure of DNA molecules.

ion an atom with a positive or negative electrical charge due to the loss or gain of electrons

Radiation and medicine

Despite the damage that can be caused by radiation, it has many uses in medicine. The most common medical application is the use of X-rays to identify damaged or broken bones (Figure 2). Less common is the injection of a radioactive isotope into a patient. The radiation accumulates at the site of a cancer or other damaged tissue and is detected by special monitors.

Figure 2 X-rays use radiation to make images of the bones in the body.

Radiation therapy uses the ability of radioactive isotopes to kill cancer cells. A gamma knife is a version of this where thin beams of radiation are targeted directly at the site of the cancer growth. Cancer cells are normal cells that have had their DNA slightly changed. This change is not enough to kill the cancer cell. Instead, it allows the cancer cell to grow very quickly. Radiotherapy uses radioactive isotopes to cause more damage to the cancer cells. Most commonly, the radioactive particles released by the isotope are directed at the site of the cancer. Eventually, when the cancer cells are damaged enough, they die (a process called apoptosis).

Careers in radiation

A nuclear medicine technologist uses medical imaging to help radiologists diagnose illnesses. Before the first patient arrives, the technologist must measure the amount of radioactivity delivered to the department. The isotope, in liquid form, is drawn up into the required amounts and added to “cold” kits so that the day’s scans can be performed.

A cold kit is a vial containing a particular chemical agent that, once introduced into the human body, will travel to a particular organ. Each test uses a particular compound, which travels to a known organ of the body based on its chemical composition and the way it is introduced into the body.

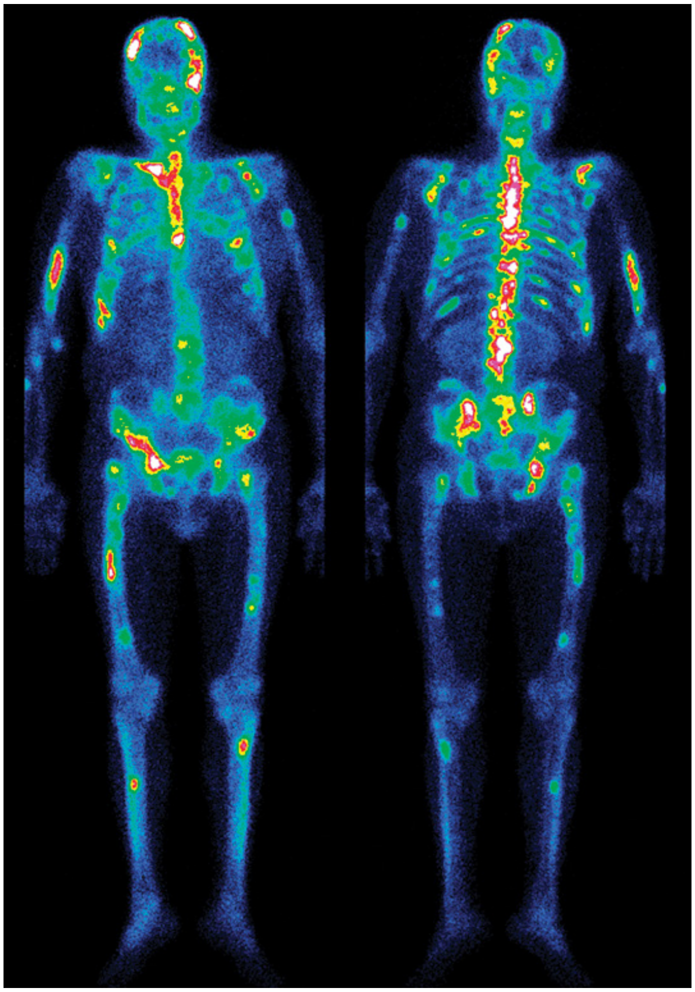


Figure 3 A technetium-99m bisphosphonate bone scan shows up abnormalities within bones.

Most people referred to nuclear medicine departments require bone scans. These may be performed to diagnose cancer, investigate the extent of arthritis, screen for fractures that do not show on a plain X-ray, or look at infection of bone (Figure 3).

In other cases, the blood is of interest. The blood of a patient can be "labelled" – mixed with a small amount of radionuclide. This is used to locate the site of an internal bleed (Figure 4). Once the bleed has been located, surgeons can operate, knowing exactly where to begin finding the haemorrhaging vessel so that it can be sealed to prevent further blood loss.

The nuclear medicine technologist typically performs a number of these tests each day, looking at a variety of conditions. Nuclear medicine technologists must be familiar with many organs in the body, in order to know whether the images obtained appear normal or abnormal. There is also the opportunity to learn about the various treatments for different conditions patients can have. Although a nuclear medicine technologist may learn to interpret

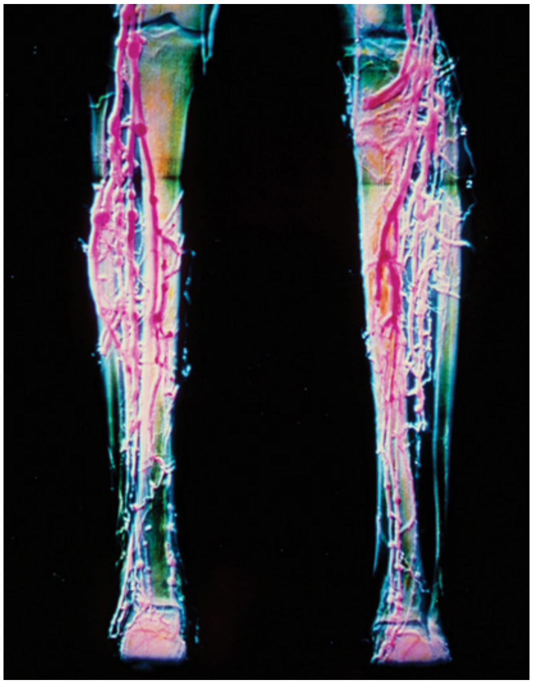


Figure 4 Radioactive dye injected into the blood shows blood flow in the blood vessels.

images and determine what condition a person has, they are are not qualified to make a formal diagnosis. They must present the images to the radiologist, who makes the diagnosis. Nuclear medicine technologists have a close working relationship with radiologists, surgeons and nurses.

Test your skills and capabilities

Asking questions

In critical thinking, you are encouraged to ask many questions. However, it can sometimes be difficult to think of the right questions to ask. The best questions will have the following characteristics.

- Asking yourself specific questions is useful and can help identify assumptions that you or someone else may be making. For example: “How do I know this?”, “What is the evidence that supports this?”, “Who wrote this?” and “Why did they write this?”.
- Open questions are best when they are directed at someone else. An open question does not have a yes or no answer. Instead, it encourages the person to explain their response. For example: “How do you feel about …?”, “Where do you think this idea came from?” and “What makes you say that?”.

1 **Develop** three questions that you could ask yourself or someone else about the radiation discussed in this lesson. They could be questions that identify any assumptions or biases that are held about radiation or cancer treatment.

2 **Develop** three open questions that you could ask a nuclear medicine technologist about radiation or cancer treatment.

If you have access to a nuclear medicine technologist, ask them the questions you wrote in question 2. Alternatively, ask someone in your class to answer the questions you wrote in question 1. A good question will make them think critically before they provide an answer.

Skills builder: Planning investigations

3 Stella has been told she has to receive an X-ray to see if her ribs are broken. Sometimes X-rays to the ribs need to be repeated to get a clear image. Stella is concerned about the amount of radiation this may involve, so she is conducting a risk assessment.

   a **Identify** the risk of high radiation to Stella. (THINK: Is the X-ray likely to deliver high levels of radiation?)

   b **Identify** measures that could be taken to prevent unnecessary radiation exposure. (THINK: Is there PPE Stella and the radiologist could wear?)

Lesson 5.8

Review: Subatomic particles

Summary

Lesson 5.1 Atoms are made up of subatomic particles

- The Rutherford model of atoms suggests that an atom has a central nucleus containing positively charged protons and neutrons with no charge.
- Negatively charged electrons travel around the space outside the atom's nucleus.
- Atoms have no overall charge.

Lesson 5.2 Atoms have mass

- The mass of an atom is made up of the protons and neutrons in the nucleus of the atom.
- Because atoms are so small, their mass is measured using a relative mass scale.
- Atoms are given their names according to the number of protons in their nucleus.

Lesson 5.3 Isotopes have gained or lost neutrons

- An isotope is a different form of the same element with a different number of neutrons in the nucleus of the atom.
- The periodic table lists the relative atomic mass of an atom, which represents the weighted relative mass of all the isotopes of that atom.

Lesson 5.4 Isotopes can release alpha, beta or gamma radiation

- Some isotopes are unstable and may decay.
- Radioactive decay produces alpha, beta and/or gamma radiation.
- The half-life of an isotope is the time it takes for half the remaining unstable isotopes to decay.

Lesson 5.6 The half-life of isotopes can be used to tell the time

- Background radiation exists all around us from radioactive material and in the form of cosmic rays from the Sun and space.
- The rate at which a radioactive material decays can be used to determine how long the material has been outside a living organism.

Lesson 5.7 Science as a human endeavour: Radiation is used in medicine

- Radioactive materials can be used in cancer therapy.
- Radiotechnicians need an understanding of the properties of radioactive materials and how to handle them.

Review questions 5.8

Review questions: Module 5

Retrieve

1 **Identify** the composition of the nucleus of an atom.
   A Made of protons and neutrons
   B Made of electrons and neutrons
   C Made of protons and electrons
   D Always negatively charged

2 **Recall** the term used for rows of the periodic table.
   A Groups
   B Periods
   C Valences
   D Electron configurations

3 John Thomson suggested that an atom is like a plum pudding (Figure 1). **Recall** what the "cake" and the "fruit" represent.

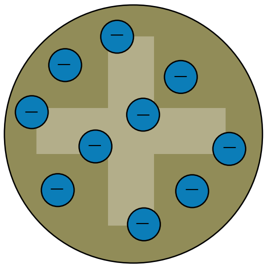
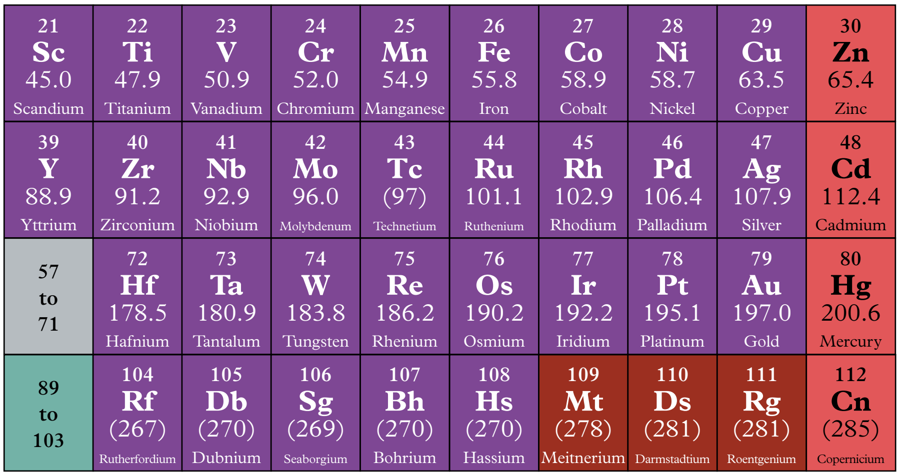


Figure 1 The Thomson plum pudding model

4 **Identify** the atomic numbers of the following elements using Figure 2.
   - **a** Mercury
   - **b** Tungsten
   - **c** Nickel
   - **d** Zirconium



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
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
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
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

Figure 2 A section of the periodic table

5 **Identify** what each arrow represents in Figure 3.

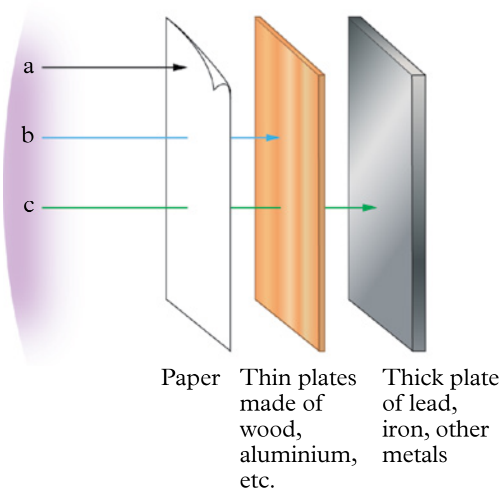


Figure 3 What does each arrow represent?

Comprehend

6 **Identify** the correct term to complete the following sentence.

“When an atom is uncharged, the number of protons and the number of electrons present are ________.”

7 **Describe** where each of the following particles is found in an atom, and **identify** its charge as positive, negative or neutral.
   - **a** Proton
   - **b** Neutron
   - **c** Electron

8 **Explain** why the mass numbers of isotopes are whole numbers but the relative masses of most atoms are not whole numbers.

9 **Explain** how radiation can both cause cancer and be used to treat cancer.

10 **Describe** an alpha particle. **Identify** its symbol, including the atomic and mass numbers in the correct positions.

11 **Explain** what carbon dating is. Provide an example to support your explanation.

12 **Explain** why molecules of water are impossible to see, even with a powerful microscope.

Analyse

13 **Use** the periodic table in Figure 5 (page 189) to **identify** the correct statement about calcium.
   - **a** It is in period 2.
   - **b** It has an atomic number of 20 and a mass of 40.08.
   - **c** It has 20 protons.
   - **d** It has 6 electrons.

14 Only 0.7 per cent of the uranium atoms in naturally occurring uranium exist as uranium-235. The other isotopes present are uranium-234 (0.01 per cent) and uranium-238 (99.3 per cent) (Figure 5). **Identify** the atomic masses of the other two uranium isotopes.

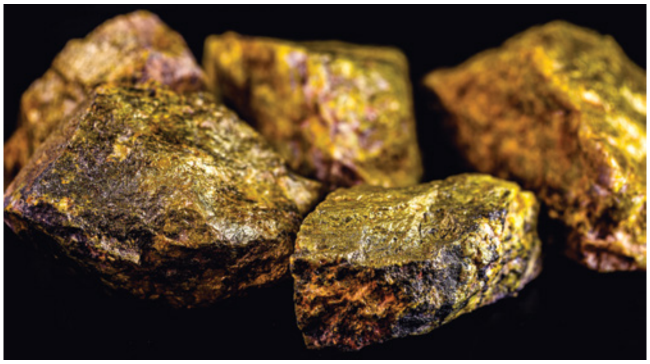


Figure 4 What is the relative atomic mass of uranium-238?

15 **Compare** the different types of radiation (alpha, beta and gamma).

16 Titanium is element 22 in the periodic table. It has five naturally occurring isotopes. **Compare** (the similarities and differences between) the isotopes of titanium.

17 Tellurium is element number 52. It has a relative atomic mass of 127.6. The next element, iodine, has a relative atomic mass of 126.9.

- **a** **Identify** the symbols for the isotopes of tellurium-127 and iodine-127.
- **b** **Explain** why the atoms of these two elements can have the same mass number.

18 **Compare** Dalton's model of an atom to the model proposed by Rutherford.

19 If a radioactive substance decays from 400 counts per minute to 50 counts per minute in 9 hours, **calculate** its half-life.

20 $^{235}_{92}U$ is an isotope of uranium that is used in nuclear reactors. In an uncharged atom, **calculate** how many:

- **a** protons are present
- **b** neutrons are present
- **c** electrons are present.

Apply

21 **Create** a radioactive decay curve for a substance that starts with an activity of 1,600 radioactive particles released per minute and has a half-life of 2 hours.

22 Scientists have had to infer what the inside of an atom is like from indirect evidence, in the same way that astronomers have worked out the temperature and composition of stars. **Discuss** the advantages and disadvantages of using indirect evidence to develop theories in science.

Social and ethical thinking

23 Radiation can be used as a form of treatment to kill cancerous cells. These processes need to be tested on cultured cells grown in a laboratory.

- **a** **Describe** how the radioactive materials are stored in a laboratory and the precautions the scientists must take.
- **b** The radiation treatment can also damage cells in non-cancerous parts of the body, causing side effects such as nausea, hair loss and fatigue. **Discuss** what is meant by the expression "The end justifies the means".

Critical and creative thinking

24 A primary school student who was learning about solids, liquids and gases was told by her teacher that everything around her is made of particles that she cannot see. Her response was that this is silly, because if you cannot see it, it cannot be there. **Develop** three critical thinking questions that the student may want to ask her teacher.

25 **Create** a poster that shows the different models of the atom, from the original theory that it was a solid particle, as proposed by English chemist John Dalton, to Rutherford's model. Use the internet to find images of the scientists involved and their models. Place copies of these onto your poster. **Investigate** the year in which each model was proposed and include a timeline.

26 Use your understanding of atoms and elements to **propose** reasons for the following.

- **a** Carbon dioxide is a heavier gas than oxygen.
- **b** Hydrogen and oxygen can be produced from water.
- **c** The relative atomic mass of argon (atomic number 18) is higher than the relative atomic mass of potassium (atomic number 19).
- **d** Beta particles can be stopped by a few millimetres of aluminium foil, but gamma rays will pass through aluminium foil.

Research

27 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.

Targeted alpha therapy

A cancer cell is a normal cell in the body that is growing in an uncontrolled way. This growth often means that cancer cells have different markers on their surface which makes them easier to identify. Targeted alpha therapy (TAT) uses special molecules that carry alpha radioactive particles to stick to the markers on a cancer cell.

- **Describe** how this form of therapy works.
- **Describe** the types of cancer that are treated by this method.
- **Describe** how widespread its use is.
- **Identify** the risks associated with this form of radiotherapy and how are they reduced.

CERN

The European Organization for Nuclear Research (CERN) is based on the border of France and Switzerland. It has been responsible for developing scientists' understanding of atoms.

- **Identify** the countries that collaborate in this project.
- **Describe** the types of scientists who work at CERN.
- **Describe** the work that is occurring at CERN.
- **Describe** the Large Hadron Collider (Figure 6).

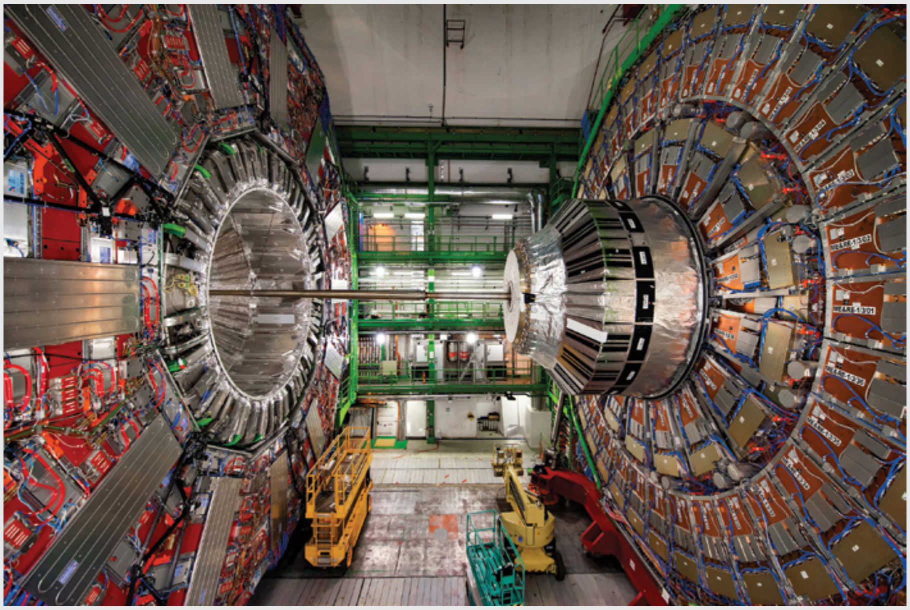


Figure 5 Part of the Large Hadron Collider

Earliest evidence of Aboriginal and Torres Strait Islander Peoples

In 2012 and 2015, the Mirarr Traditional Owners gave permission for scientists to excavate the Madjedbebe rock shelter near Kakadu. Carbon dating and optically stimulated luminescence (OSL) were used to date artefacts found at the site, which also allowed scientists to estimate how long Aboriginal and Torres Strait Islander Peoples have been present in Australia.

- **Explain** why the permission of the Mirarr Traditional Owners was needed before any testing could occur.
- **Identify** the artefacts that were found at the site.
- **Describe** how the age of the samples was determined.
- **Identify** the age of the samples.
- **Describe** the significance of this date to the theory that Aboriginal and Torres Strait Islander Peoples arrived in Australia 40,000 years ago.
- **Explain** why Aboriginal and Torres Strait Islander Peoples would need to be acknowledged when this research was published.

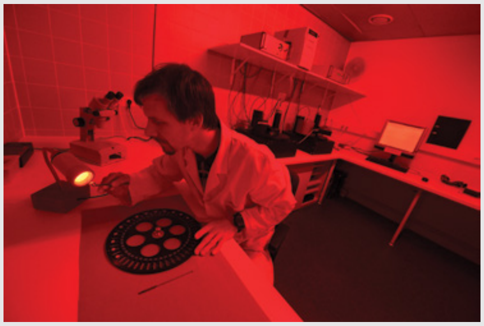
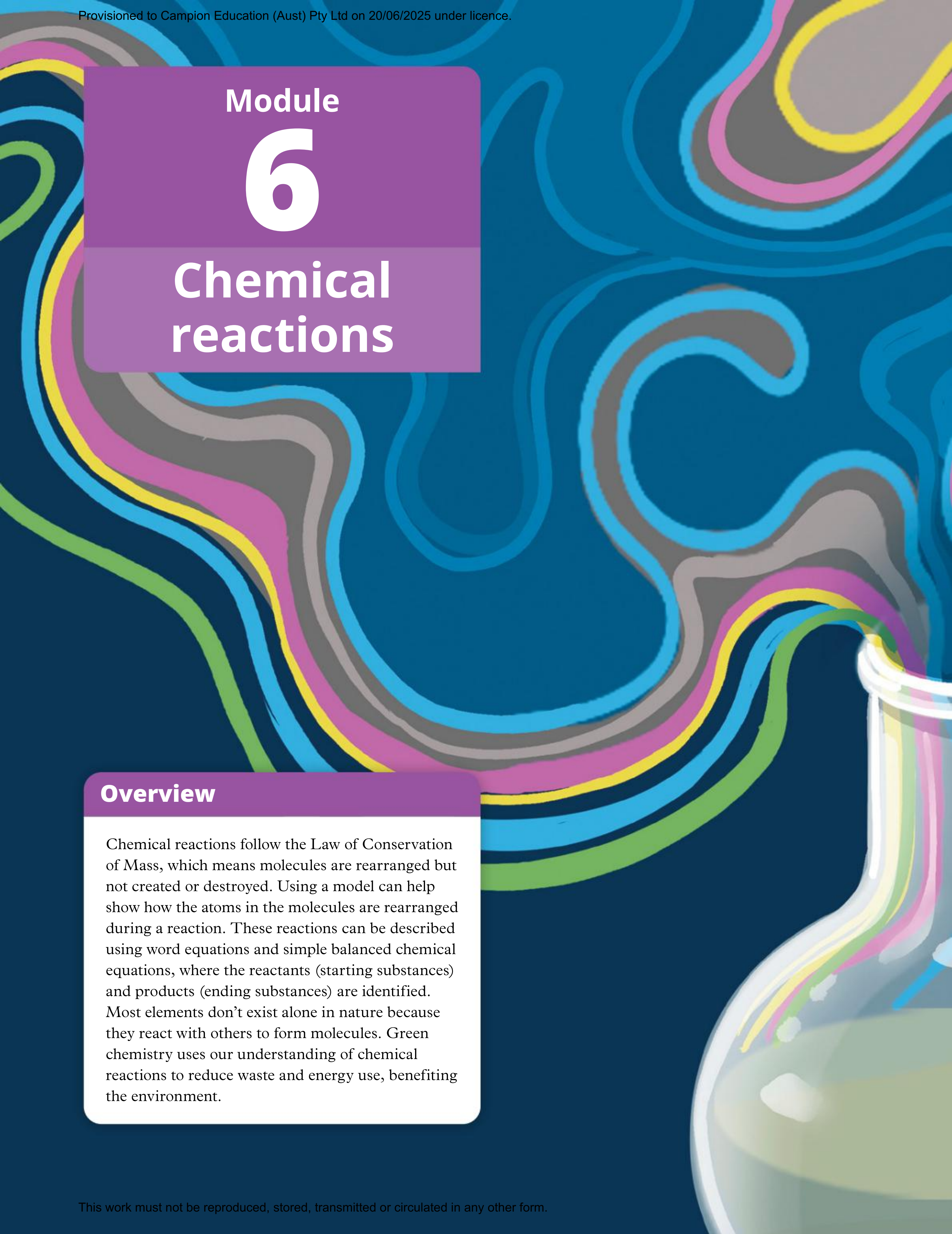


Figure 6 OSL dating determines when minerals were last exposed to sunlight.



Module

6

Chemical reactions

Overview

Chemical reactions follow the Law of Conservation of Mass, which means molecules are rearranged but not created or destroyed. Using a model can help show how the atoms in the molecules are rearranged during a reaction. These reactions can be described using word equations and simple balanced chemical equations, where the reactants (starting substances) and products (ending substances) are identified. Most elements don’t exist alone in nature because they react with others to form molecules. Green chemistry uses our understanding of chemical reactions to reduce waste and energy use, benefiting the environment.

Lessons in this module

Lesson 6.1

Mass is conserved in a chemical reaction

Learning intentions and success criteria

Check the next lesson for a linked practical activity or experiment.

Key ideas

→ In chemical reactions, the starting chemical reactants are on the left-hand side of the arrow.

→ In chemical reactions, the final chemical products are on the right-hand side of the arrow.

→ The Law of Conservation of Mass states that the total mass of the reactants is equal to the total mass of the products.

Representing chemicals

When examining **chemical reactions**, we can represent the substances in different ways. The substances that are present at the start of a chemical reaction are called the **reactants**. The substances formed by the chemical reaction are called the **products**. We can write this using a simple **word equation**. Consider the reaction between the acid in vinegar and sodium bicarbonate. This reaction produces water, carbon dioxide gas and a substance called sodium acetate, and it can be represented as:

acetic acid (in vinegar) + sodium bicarbonate → sodium acetate + carbon dioxide + water

The acetic acid and sodium bicarbonate are the starting chemicals (reactants) for this reaction. The products are the chemicals formed by the reaction. In this reaction they are sodium acetate, carbon dioxide and water.

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

word equation a representation of a chemical reaction using words

mass the amount of matter in a substance, usually measured in kilograms (kg) or grams (g)

The Law of Conservation of Mass

Sometimes a reaction only has one reactant. For example, when mercury oxide is heated (one reactant) it can produce two products, mercury metal and oxygen gas.

Like all gases, oxygen has a **mass**. This means it can be weighed in grams on Earth. In an open system, where there is no closed container or room, the oxygen gas from the mercury oxide reaction could escape. This means the reactant (mercury oxide) would weigh more before it was heated than the weight of the product (mercury metal) after heating because the oxygen would have escaped. This is different to a closed system, where the oxygen is not allowed to escape. In a closed system, the reactant (mercury oxide) would weigh the same as the products (mercury metal and oxygen gas). This is an important observation. It shows that the total mass of the chemicals is not changed in a chemical reaction.

When a chemical reaction takes place, the chemicals interact, causing the bonds between the atoms to break apart and make new different molecules. However, no atoms are produced in the process and no atoms are destroyed (Figure 1). This is one of the most important laws in science - the **Law of Conservation of Mass**.

Law of Conservation of Mass chemical law that states that matter cannot be created or destroyed

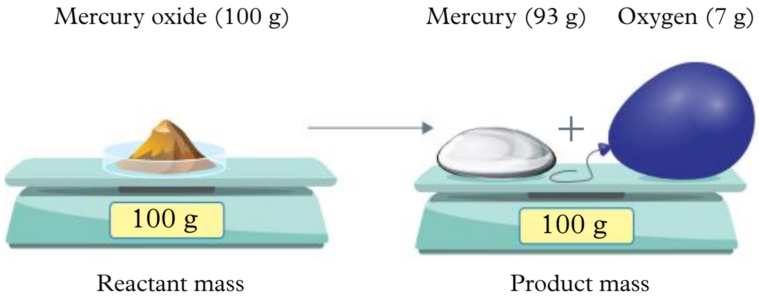


Figure 1 When mercury oxide (HgO) is heated, its atoms rearrange to form mercury liquid (Hg) and oxygen gas (O_2). The overall mass of reactants and products is the same – no atoms are destroyed, and no new atoms are created.

Example of a chemical reaction

Methane gas (CH_4) is the main gas present in natural gas, which is used in the home for cooking and heating. It has one carbon atom and four hydrogen atoms. When it burns, it combines with oxygen (O_2) in the air to form carbon dioxide (CO_2) and water (H_2O).

Figure 2 shows how the atoms in the molecules are rearranged during this reaction. Different atoms are represented by different colours and the first letter of their names (e.g. C for carbon). Table 1 shows the different representations of the reactants and products. To understand how the atoms are rearranged and write a chemical equation for this reaction, follow these steps:

1. Count the number of each type of atom in the reactants (left-hand side of the arrow) and count the number of each type of atom in the products (right-hand side of the arrow). What do you notice?
2. Describe what has happened to the hydrogen atoms during the chemical reaction.
3. Describe what has happened to the oxygen atoms. Make sure you use the correct names of the chemicals in your description.
4. Write the chemical reaction as a word equation where the reactants are on the left-hand side and the products are on the right-hand side (Figure 2).

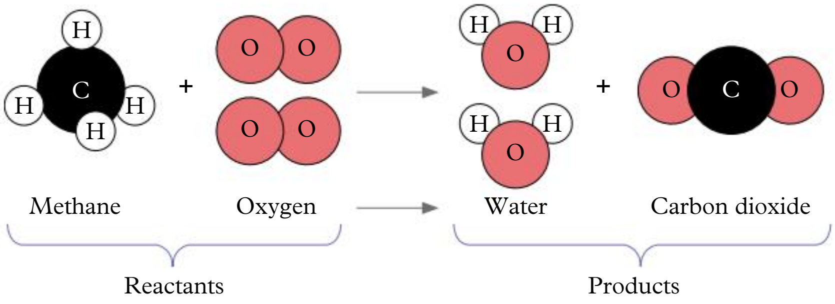
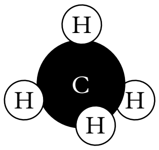
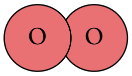
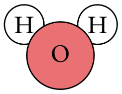
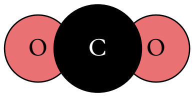


Figure 2 Atoms are rearranged during a chemical reaction.

Table 1 Representations of four chemicals

Chemical name	Formula/symbol	Diagram
Methane	CH_4	
Oxygen	O_2	
Water	H_2O	
Carbon dioxide	CO_2	

Check your learning 6.1

Check your learning 6.1

Retrieve

1 **Define** the term “mass”.

Comprehend

2 If no mass is lost or gained in a chemical reaction, **explain** what this tells you about the individual atoms involved in the reaction.

3 **Explain** why the products have properties very different from those of the reactants, even though the total mass remains the same.

4 **Represent** the following reaction as a word equation (by identifying the reactants and products):

Magnesium ribbon was burnt in the presence of oxygen to produce magnesium oxide.

Analyse

5 Use Table 1 to **identify** a reactant in Figure 2 with:

- **a** only one type of atom
- **b** two different types of atoms.

Apply

6 Early alchemists repeatedly tried to turn lead into gold. **Infer**, using the Law of Conservation of Mass, why this would be impossible.

7 **Evaluate** each of the following equations to **determine** if they obey the Law of Conservation of Mass (by comparing the number and types of atoms in the reactants to the number and type of atoms in the products and deciding if the atoms are conserved).

- **a** $C + O_2 \rightarrow CO_2$
- **b** $H_2 + O_2 \rightarrow H_2O$

Skills builder: Processing and analysing data and information

8 Presenting information and data in the most appropriate way will help you interpret and analyse the data. **Consider** the following reactions and write them as word equations. This can help you understand the reaction.

- **a** A piece of magnesium reacts with oxygen in the air to form magnesium oxide. (THINK: What is the product? What are the reactants?)
- **b** A piece of copper is added to a solution of silver nitrate to generate a solution of copper nitrate and solid silver. (THINK: What are the products? What are the reactants?)

Lesson 6.2

Experiment: Comparing mass before and after a chemical reaction

Aim

To determine if mass is conserved in a chemical reaction

Materials

- Electronic balance
- Watch glass
- Spatula
- Sodium bicarbonate
- Measuring cylinder
- Vinegar
- 2 conical flasks
- Balloon

Part A

Method

1 Copy the results table for Part A (Table 1) to record your results.
2 Weigh 2.0 g of sodium bicarbonate onto a watch glass.
3 Add 20 mL of vinegar to a conical flask.
4 Ensure the balance is reading zero. Weigh the vinegar and flask. Record this mass (M_1).
5 Predict whether the mass of the flask and vinegar after the reaction with the sodium bicarbonate will be more, the same or less than the initial mass.
6 Add the 2.0 g of sodium bicarbonate (M_2) to the flask containing the vinegar and swirl until the bubbling stops.
7 Weigh the flask after the reaction has stopped. Record the final mass (M_3).

Figure 1 Sodium bicarbonate

Results

Table 1 Results table

Mass of flask and vinegar (M_1)	Mass of sodium bicarbonate (M_2)
Total mass before reaction ($M_1 + M_2$)	**Mass after reaction (M_3)**

Part B

Method

1 Copy the results table for Part B (Table 1) to record your results.
2 Weigh 2.0 g of sodium bicarbonate onto a watch glass.
3 Add 20 mL of vinegar to a flask.
4 Ensure the balance is reading zero. Weigh the vinegar, flask and a balloon. Record this mass (M_1).
5 Predict whether the mass of the flask, vinegar and balloon after the reaction with the sodium bicarbonate will be more, the same or less than the initial mass.
6 Add the 2.0 g of sodium bicarbonate (M_2) to the balloon.
7 Carefully stretch the opening of the balloon over the neck of the flask, making sure that the sodium bicarbonate does not spill out of the balloon.
8 Hold the end of the balloon directly over the top of the flask so that the sodium bicarbonate spills into the vinegar (keeping the contents sealed).
9 Weigh the flask, with the balloon still attached, after the reaction has stopped. Record the final mass (M_3).

Figure 2 Hold the end of the balloon directly over the top of the flask.

Results

Table 2 Results table

Mass of flask, vinegar and balloon (M_1)	Mass of sodium bicarbonate (M_2)
Total mass before reaction ($M_1 + M_2$)	**Mass after reaction (M_3)**

Discussion

1 **Explain** why the balance needed to read zero before the chemical reaction was started.
2 **Identify** the number of decimal points that the balance measures. Use this to **explain** the limit of accuracy of the balance (i.e. what would happen if the mass being measured was above or below the reading?).
3 **Compare** the initial and final masses for each part of the experiment.
4 **Compare** the results with your prediction.
5 **Identify** the gas that was produced during the chemical reaction.
6 **Describe** the purpose of sealing the flask with the balloon.
7 **Describe** the purpose of the control for this experiment.
8 **Identify** a possible random error and systematic error for this experiment. **Describe** how this error could be minimised.

Conclusion

Evaluate the results of this experiment against the Law of Conservation of Mass (by describing the results of this experiment, describing the Law of Conservation of Mass, comparing the two descriptions and justifying if your experiment supported the law).

Lesson 6.3

Balanced chemical equations show the rearrangement of atoms

Key ideas

→ Chemical reactions can be described through observations, word equations or symbols.

→ The Law of Conservation of Mass is used to write a balanced chemical equation.

→ A balanced chemical equation has equal numbers of each type of atom on both sides of the equation.

Learning intentions and success criteria

Describing chemical reactions

Figure 1 Sodium metal reacts violently with water, undergoing a chemical change.

Perhaps you have seen sodium metal reacting with water at school or on the internet (Figure 1). This is a chemical reaction between the sodium metal and the water.

There are different ways to describe this reaction.

- **Describing observed changes:** The sodium metal dissolves in the water; heat is produced; fizzing is caused by the production of hydrogen gas. If there is enough heat, the hydrogen gas catches fire above the sodium metal.
- **Using a word equation:** The reactants are sodium and water and they interact to form the products, which are sodium hydroxide and hydrogen gas. A word equation summarises the changes:

$$\text{sodium} + \text{water} \rightarrow \text{sodium hydroxide} + \text{hydrogen}$$

- **Using a chemical equation:** This includes the formulas of all the substances involved and the ratio in which they react:

$$2Na(s) + 2H_2O(I) \rightarrow 2NaOH(aq) + H_2(g)$$

chemical equation a representation of a chemical reaction using chemical formulas

In this example, two sodium atoms react with two water molecules to form the following products – two molecules of sodium hydroxide and one hydrogen molecule. Each representation tells us something different about the changes occurring in the chemical reaction. The chemical equation also tells us the state (solid, liquid or gas) of each molecule (Table 1).

Table 1 States and their symbols

State	Symbol
Gas	(g)
Liquid	(l)
Solid	(s)
Aqueous (dissolved in water)	(aq)

Reacting hydrogen and oxygen

When hydrogen gas burns in oxygen, large amounts of heat energy are produced. If this reaction happens in uncontrolled conditions, it is very dangerous (Figure 2). However, when used safely in a carefully controlled way, hydrogen can be an excellent renewable fuel that does not emit carbon dioxide. Car manufacturers are already developing hydrogen-fuelled cars. An advantage of using hydrogen as a fuel is that the only substance emitted in the exhaust is water vapour – there are no carbon dioxide emissions. Also, unlike fully electric cars, hydrogen cars do not need large, heavy batteries.

Figure 2 The reaction of hydrogen with oxygen caused the *Hindenburg* explosion.

When hydrogen combusts with oxygen in the air, the oxygen atoms and hydrogen atoms split up from one another and join together to form water (H_2O). The atoms have not been created or destroyed. You can show what is happening in this reaction by using a diagram or a chemical equation (Figure 3). You will write and balance a chemical equation for this reaction in Worked example 6.3A.

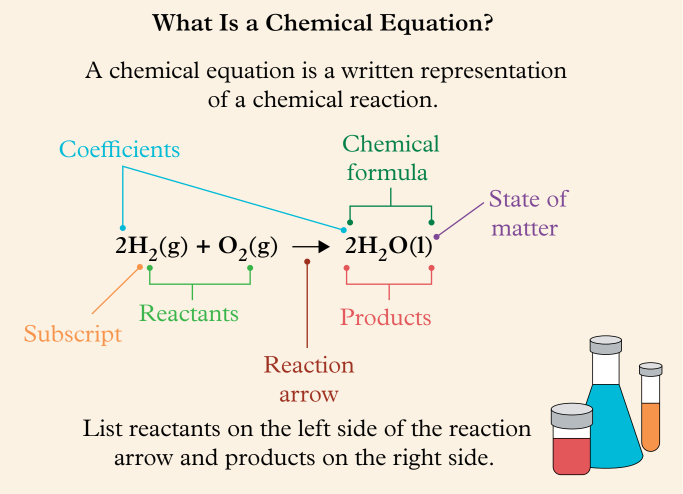


Figure 3 Parts of a chemical equation

Balancing chemical equations

Balancing chemical equations requires a systematic approach where each atom is counted on both sides of the equation. Changing the number of one group of molecules (by changing the larger **coefficients** and not the **subscripts**) may affect a number of other atoms. It is important to continue to check and change the coefficients until all atoms are conserved. Worked example 6.3A illustrates how to write balanced chemical equations.

coefficient in chemistry, a whole number in front of a chemical symbol or formula; indicates the number of molecules or elements

subscript in chemistry, a small-sized number after an element symbol; indicates the number of atoms of the element

Worked example 6.3A Balancing equations

Write the chemical equation for the following reaction:

Hydrogen combines with oxygen to produce water.

Solution

The equation can be written by using the following steps.

1 Write out the word equation for the reaction.

$$\text{hydrogen} + \text{oxygen} \rightarrow \text{water}$$

2 Write a simplified chemical equation using the formulas of each molecule involved. Identify the number of atoms in each molecule. For example, water is H_2O (two hydrogen atoms with a single oxygen atom) and hydrogen and oxygen exist as pairs of atoms. This is represented as subscripts (small numbers at the lower half of the symbol).

$$H_2 + O_2 \rightarrow H_2O$$

3 Work out the numbers of each type of atom in the reactants (left-hand side) and in the products (right-hand side), as shown in Table 2.

Table 2 Number of each type of atom in the reactants and products

	Reactants		→	Products	
Type of atom:	H	O	→	H	O
Number of atoms:	2	2		2	1

4 Compare the number of each type of atom in the reactants with the number in the product. In this case, there are four atoms in the reactants and three atoms in the products. This does not fit the Law of Conservation of Mass. We cannot have "lost" an oxygen atom. We cannot change the subscripts (from H_2O to H_2O_2) because this would change water into hydrogen peroxide.

Instead, we need to add a whole water molecule by including numbers (called coefficients) before the formula of the substances. This balances the number of oxygen atoms, but also doubles the number of hydrogen atoms (Table 3).

$$H_2 + O_2 \rightarrow 2H_2O$$

Table 3 The number of oxygen atoms is balanced

	Reactants		→	Products	
Type of atom:	H	O	→	H	O
Number of atoms:	2	2		4	2

The unbalanced hydrogen atoms can be balanced by doubling the number of hydrogen molecules (Table 4).

$$2H_2 + O_2 \rightarrow 2H_2O$$

Table 4 Check the equation is balanced

	Reactants		→	Products	
Type of atom:	H	O	→	H	O
Number of atoms:	4	2		4	2

This allows the number of atoms in the reactants to equal the number of atoms in the product – the equation is said to be balanced.

5 Add the state (solid, liquid or gas) of each molecule (Table 1).

$$2H_2(g)+O_2(g) \rightarrow 2H_2O(l)$$

Check your learning 6.3

Check your learning 6.3

Retrieve

1 **Recall** what the (s), (l), (g) and (aq) symbols represent in the chemical equation for the reaction of sodium metal with water.

Comprehend

2 **Explain** why chemical equations that are not "balanced" are always incorrect.

Analyse

3 Balance the following equations by adding numbers as required:

a $\_\_\_\mathrm{Na} + \_\_\_\mathrm{H_2O} \rightarrow \_\_\_\mathrm{NaOH} + \_\_\_\mathrm{H_2}$

b $\_\_\_\mathrm{H_2} + \_\_\_\mathrm{O_2} \rightarrow \_\_\_\mathrm{H_2O}$

c $\_\_\_\mathrm{CH_4} + \mathrm{O_2} \rightarrow \_\_\_\mathrm{CO_2} + \_\_\_\mathrm{H_2O}$

d $\_\_\_\mathrm{Mg} + \_\_\_\mathrm{HCl} \rightarrow \_\_\_\mathrm{H_2} + \_\_\_\mathrm{MgCl_2}$

Apply

4 **Identify** which representation of a chemical reaction tells us most about the chemicals. **Justify** your answer.

5 Imagine one of your classmates missed this class and asked for your help to understand how to balance chemical equations. **Consider** how you would explain it to them. **Create** a set of instructions using the medium you think would be most useful (e.g. a written list, an illustrated poster, a presentation).

Skills builder: Communicating

6 Balancing equations is a clear way of communicating to other scientists the chemical change in an experiment. Answer the following questions about when sodium metal reacts with chlorine gas to form solid sodium chloride.

a Write the word equation for this reaction. (THINK: What was present at the start? What is present at the end?)

b Write the word equation as a chemical equation using the formulas of the substances involved. (THINK: What is the original formula for each substance?)

Lesson 6.4

Chemical reactions are used to purify elements from ore

Learning intentions and success criteria

Check the next lesson for a linked practical activity or experiment.

Key ideas

→ Most elements are found as ore.

→ The reactivity of an element determines how easy it is to extract.

→ Extracting metals requires the concentration of the mineral and isolation of the metal.

Elements we need

We use a wide range of different elements and compounds in our everyday lives. The mobile phones, computers and cars we use rely on silicon, copper, gold, lithium and many other elements. Australia is one of the leading producers of bauxite (aluminium ore) and rutile (titanium dioxide), the second-largest producer of lithium, and the third-largest producer of iron ore and zinc.

Elements are rarely found in their natural state because of their ability to react with other elements around them. This means most chemicals that are found in the world around us are compounds. A naturally occuring element or compound is known as a **mineral**. Most rocks contain a mixture of minerals. A rock that contains a high percentage of one type of mineral is called an **ore**.

mineral a naturally occurring element or compound

ore a rock that contains a high percentage of one type of mineral

It is not easy or cheap to extract the element or mineral from the ore. If the amount of an element in the ore is high enough, then the cost of extracting the mineral and eventually the element will be worth the time and expense. Consider a chocolate chip muffin. If you want just the chocolate chip “element” in the muffin, you will need to break away the muffin crumbs from the chocolate chips so that you can collect them. It takes time and effort to do this. If the number of chocolate chips per muffin is small, you might not think it worth the effort to extract them. You are more likely to look for a muffin that has a lot of chocolate chips present.

Reactive metals

Many of the minerals that we need to make modern products such as electronics are metals. Some metals are more reactive than others. This means that they are able to chemically react to produce a compound. When the reactivity of metals is arranged in order of most reactive to least reactive, it produces a **reactivity series** (Figure 1).

reactivity series a list of metals ordered from most reactive (at the top) to least reactive (at the bottom)

This reactivity series of metals is important when extracting a metal from its ore or mineral. A metal that is very reactive is more likely to bond with another atom in a chemical reaction. Metals found at the top of the table (potassium and sodium) are so reactive that they are never found in nature in their natural state. The less-reactive metals at the bottom of the table (gold and platinum) are more likely to be found as natural elements.

The types of minerals formed by reactive metals (given the letter X) can be broken into three categories: carbonates (XCO_4), oxides (XO) and sulphates (XSO_4). Oxide minerals such as hematite (iron oxide) (Figure 2), chromite (chromium oxide) (Figure 3), manganite (manganese oxide) and rutile (titanium oxide) (Figure 4) are usually found grouped together. Knowing the type of mineral can help determine the best extraction method for the metal.

Metals	Reactivity
Potassium	Reacts with water
Sodium	
Lithium	
Barium	
Strontium	
Calcium	
Magnesium	Reacts with acids
Aluminium	
Manganese	
Zinc	
Chromium	
Iron	
Cadmium	
Cobalt	
Nickel	
Tin	
Lead	
Antimony	Highly unreactive
Bismuth	
Copper	
Mercury	
Silver	
Gold	
Platinum	

Figure 1 The reactivity series of metals

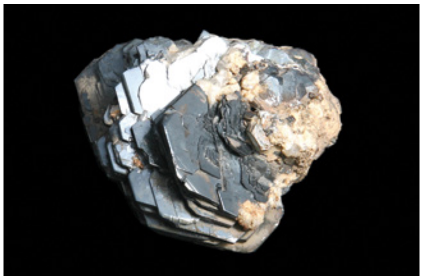


Figure 2 Hematite is the oxide form of iron. Iron is used in the construction industry.

Figure 3 Chromite is an oxide form of chromium metal that is used as an industrial catalyst or pigment.

Figure 4 Manganite and rutile contain manganese and titanium.

Concentration of the mineral in the ore

Once the ore rocks have been extracted from Earth's surface, the unwanted minerals need to be removed. There are several ways the important mineral can be concentrated.

Gravity separation

Some minerals are more dense than others. This difference in density can be used to separate the different metals containing minerals. Figure 5 shows the less dense materials being washed away, leaving the more dense material behind.

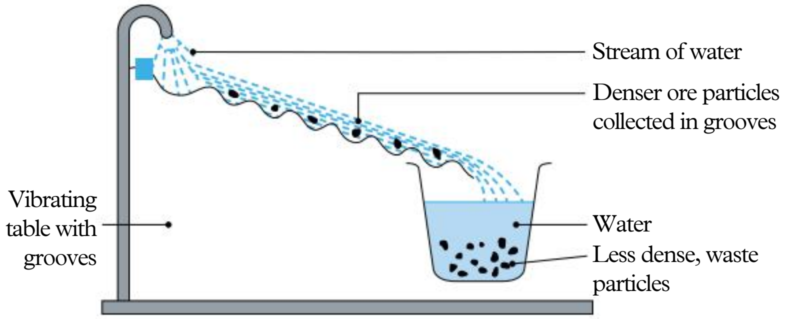


Figure 5 Gravity separation relies on heavy materials being left behind while the less dense materials are washed away.

Froth flotation

The crushed ore is added to water with a frother (similar to a detergent). When air is blown through the water, the important mineral (usually a sulfide or carbonate) will bubble to the surface with the froth (Figure 6).

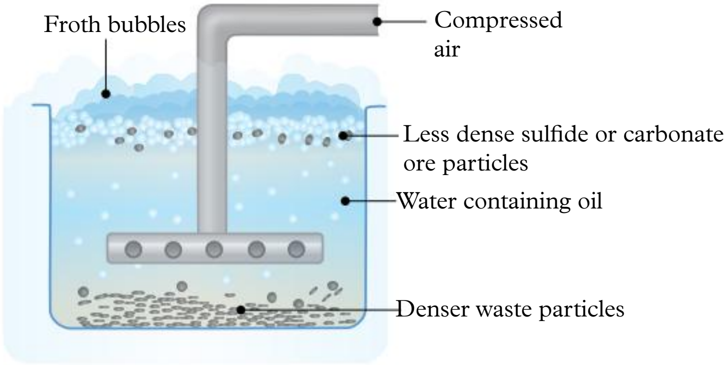


Figure 6 Less dense ore particles float to the surface.

Magnetic separation

If the crushed ore has magnetic properties, it is passed over conveyer belts with magnetic rollers (Figure 7). The rollers attract magnetic metal, separating it from unwanted minerals.

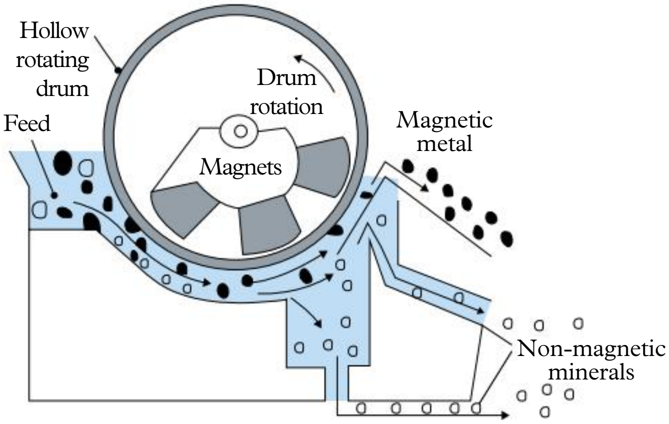


Figure 7 Magnets can be used to separate ore containing magnetic metals.

Leaching

Some ores of gold, silver and aluminium are heaped into a large pile and treated with a leaching solution such as sulfuric acid that dissolves the important mineral (Figure 8). The sulfuric acid containing the metal mineral (called a pregnant solution) is removed from the base of the heap. The metal ore is then isolated from the solution.

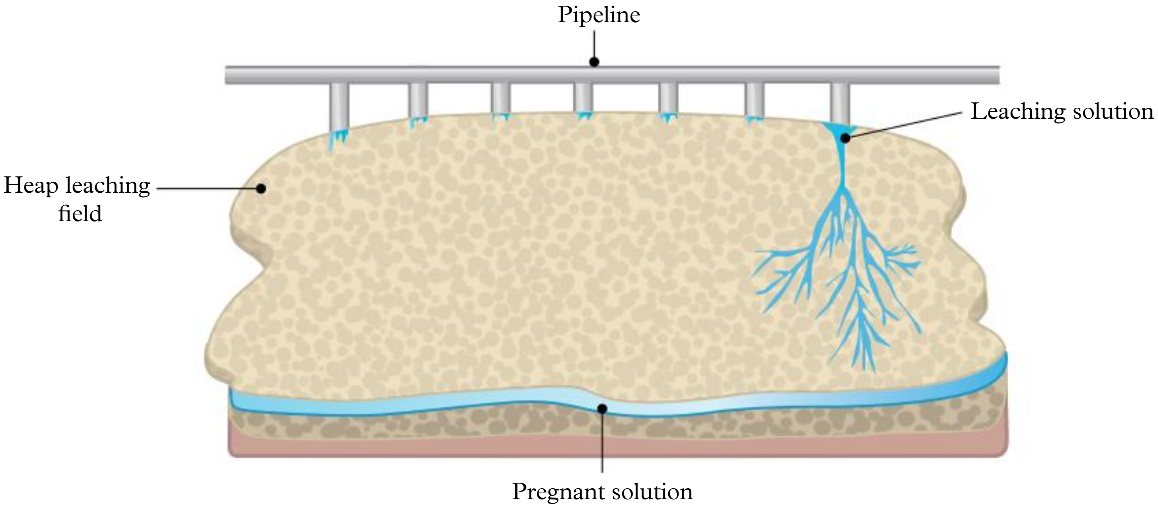


Figure 8 The metal mineral can be leached from the crushed ore using a leaching solution.

Isolation of metal from the ore

Just as there are different types of metal minerals (oxides, sulfides and carbonates), there are different chemical reactions that can be used to separate the metal elements from their compound. Which reaction is used is dependent on the reactivity of the metal. If the metal is more reactive (at the top of the reactivity series), it will be more easily separated than a less reactive metal. The isolation processes are summarised in Figure 9.

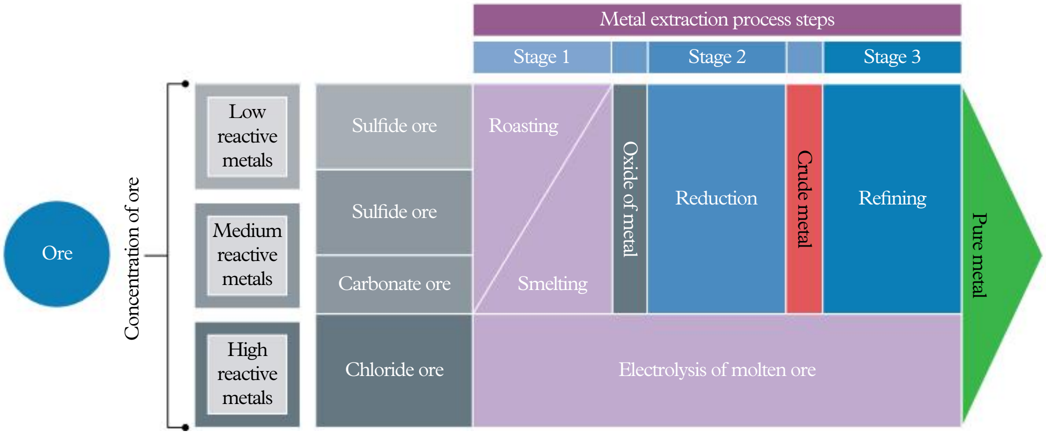


Figure 9 The different processes used to isolate a metal from its ore

Roasting

This process involves the heating of the metal ore, such as metal sulfide (XS) in the presence of oxygen (O_2). Because the oxygen is more reactive than sulfide, the metal will change from a metal sulfide to a metal oxide (XO), producing sulfur dioxide (SO_2) as well. The metal oxide can then undergo reduction.

$$2XS + 3O_2 \rightarrow 2XO + 2SO_2$$

Smelting

Smelting can be used to extract the metal from metal carbonates (XCO_3). It occurs when the ore is heated with carbon (C) in a limited air supply. It will produce a metal oxide (XO) and carbon dioxide (CO_2).

$$XCO_3 \rightarrow XO + CO_2$$

It can be more difficult to remove the last oxygen from some metal oxides. This is usually done through a reduction process.

Reduction

Reduction involves the removal of the oxygen from the metal oxide. If a metal is not very reactive, then the oxygen atom will be displaced to a more reactive metal. For example, copper is less reactive than aluminium. This means when the copper oxide is heated to a high temperature in the presence of aluminium, the oxygen will be displaced from the copper to the aluminium. Other metal oxides, such as hematite, can be purified using heat and carbon. When the metal oxide is combined with carbon at a high temperature, the oxygen binds with the carbon to form carbon dioxide.

$$2XO + C \rightarrow 2X + CO_2$$

Carbon cannot be used to remove the oxygen from the aluminium in bauxite, because the aluminium is more reactive than carbon. This means another method needs to be used.

Electrolysis

If a metal is highly reactive, like aluminium or lithium, it can be difficult to remove the metal oxide. This is because the metal is strongly attracted to the oxygen. When this occurs, extra energy is needed to remove the oxygen. Because the energy used is electricity, the process is called electrolysis.

The lithium or aluminium oxide is heated to a very high temperature (>1,000°C) so that the different charged atoms (called ions) are separated in a liquid form. To prevent them from rejoining, the electrical current forces them apart. The positively charged ions gain electrons at the negative electrode (cathode) and the negatively charged ions lose electrons at the positive electrode (anode).

Electrolysis can also be used to purify a metal by removing the impurities (Figure 10).

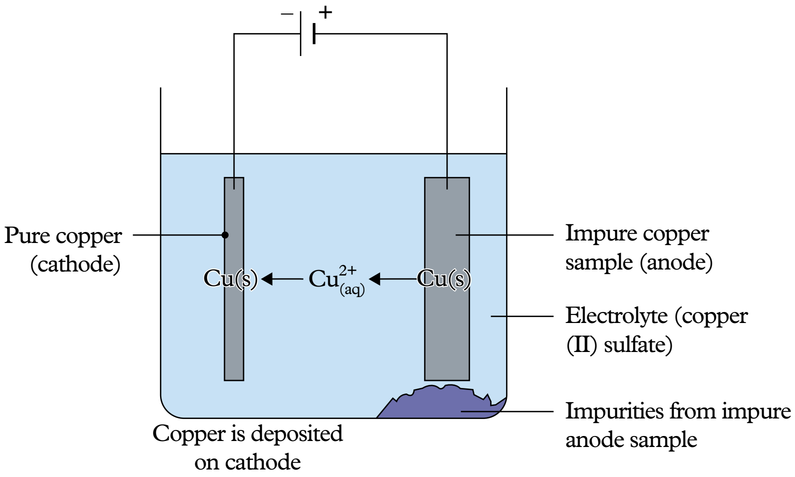


Figure 10 Electrolysis can be used to separate a metal from a mineral or to remove impurities.

Check your learning 6.4

Check your learning 6.4

Retrieve

1 **Define** the term "ore".

2 **Recall** the information contained in the reactivity series of metals to identify three metals and write them in the order of least reactive to most reactive.

3 **Identify** the elements that are found in the following ores.
   a Hematite
   b Rutile

Apply

4 **Describe** the processes that could be used to concentrate and isolate copper from malachite (a copper carbonate).

5 **Identify** which of gold or strontium are more likely to be found in their natural state in the environment. **Justify** your decision using the reactivity series of metals.

6 When left in the air too long, silver can tarnish (form a silver oxide). Tarnished silver can be cleaned by wrapping the silver in aluminium foil and placing it in a mixture of hot water and baking soda. Use the reactivity series of metals to **determine** why this process works.

Lesson 6.5

Experiment: Electrolysis of copper sulfate

Aim

To use electricity to produce copper metal from copper(II) sulfate through electrolysis

Materials

- Gloves and safety glasses
- Copper(II) sulfate
- Spatula
- 100 mL beaker
- Water
- Stirring rod
- Electronic balance
- 2 copper electrodes
- DC power supply
- 12 V globe and globe holder
- Wires with alligator clips

Method

1 Add one spatula of the copper(II) sulfate to the beaker and half-fill it with water.

2 Stir until the crystals are all dissolved.

3 Weigh each copper electrode individually. Record their mass.

4 Set the power supply to a maximum of 6 V and connect the circuit as shown in Figure 1.

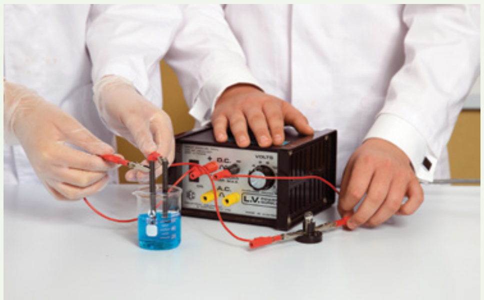


Figure 1 Connect the circuit.

5 Touch the copper electrodes together to check the circuit works and then place the copper electrodes in the beaker with a 1 cm gap between them.
6 Hold the electrodes in place for 30 seconds and observe any changes that occur.
7 Turn off the power supply.
8 Re-weigh each electrode. Calculate if they have gained or loss mass.

Results

Record your observations in an appropriate format.

Discussion

1 **Describe** the evidence that copper was formed in the reaction.
2 **Consider** the structure of the copper sulfate when describing the:
   - role of the electricity
   - reason that the copper was only found on one of the carbon electrodes.
3 **Evaluate** if a useable amount of copper could be produced this way (by describing the amount of energy used and the amount of copper produced in the time and deciding if it would make an effective business model). If not, **describe** the changes that would need to be made to the set-up to produce more copper.

Conclusion

Describe what you know about electrolysis.

Figure 2 Copper

Lesson 6.6

Science as a human endeavour: Green chemistry reduces the impact of chemicals on the environment

Key ideas

→ Green chemistry involves considering the environmental impact of the manufacture and end of life of new artificially produced chemicals.

→ The circular economy requires scientists to consider the whole life cycle (including the waste or recycling) of manufactured products.

Learning intentions and success criteria

Introduction

Being "green" means doing something positive for the environment. Scientists with special knowledge in ecology, biochemistry, zoology and botany study the environment and how it responds to changes. These scientists monitor the environment to detect changes caused by natural events and human actions.

Low-impact chemicals

Some chemicals have a negative impact on the environment and living things. When these substances are identified, scientists act to reduce their use and prevent them from entering the environment. Some substances are banned altogether.

New chemical products and processes are described as "green" if they have less impact on the environment than the product or process they replace. The study and development of new substances that have a low impact on the environment is called "**green chemistry**".

Some examples of the development of "green" alternatives are described below.

green chemistry a branch of chemistry that aims to develop chemical products and processes that are sustainable and do not damage the environment

Pesticides and herbicides

Pesticides and herbicides have been used to kill organisms that eat our food crops and other plants that compete with these crops for sunlight and nutrients. In the past, some of these products (such as DDT) killed all living things, not just the target species. Most were non-degradable (did not break down) and remained in the environment long after they were no longer needed. These substances are now banned and have been replaced with **biodegradable** poisons.

In many cases, chemical poisons have been replaced with new farming practices, such as crop rotation and planting pest-resistant crop varieties.

biodegradable describes an object or a substance that can be broken down by bacteria, fungi or other living organisms

Heavy metals

Heavy metals include lead, mercury and cadmium. Heavy metals had many uses, especially in dyes (cadmium), petrol (lead) and water pipes (lead). But these metals accumulated in the bodies of living things, including people. The most dramatic example of poisoning occurred in 1956 when people in Minamata, Japan, were poisoned by mercury after eating contaminated seafood.

The use of heavy metals in situations where they could enter the environment has been largely stopped. Heavy metals have been replaced with different catalysts and production processes have changed.

Solvent-based paints

Acrylic paints have slowly replaced solvent-based enamel paints and lacquers. The solvent used in the old paints was a hydrocarbon, such as turpentine, and it evaporated as the paint dried. The hydrocarbon solvents in enamel paint were toxic to aquatic life in waterways and the fumes from the paint caused "painter's disease" in workers who inhaled them.

Solvent-based paints have been replaced with acrylic paints, which are water based and set by polymerisation of the paint, not by evaporation of a solvent.

Circular economy

Understanding how particular chemicals can affect the environment means that chemical engineers can work with designers to maximise recyclability of products and to minimise the amount of landfill that is produced with new product.

This process of planning the life cycle of all components of a product, including planning to eliminate waste and pollution, circulating materials and regenerating nature, is part of the **circular economy**.

circular economy
an economic system where materials are reused and recycled rather than used and disposed of

The cosmetic company Lush joined the circular economy when it redesigned some of its personal care products so that they could be sold as solids. Their shampoos, conditioners and deodorants no longer need plastic bottles, reducing the amount of plastic in the environment.

Other companies, such as IKEA, are developing alternatives to plastic packaging for their products. Using recycled materials that have similar properties (such as shock absorbance) reduces landfill and promotes a circular economy.

How you can help

You can help protect the environment and the planet by adopting the slogans “reduce, reuse, recycle” and “act local, think global” to reduce your impact on the environment. You can:

- use your own reusable shopping bags instead of plastic bags
- compost grass clippings and food scraps and use the compost as fertiliser instead of using chemical fertilisers
- use trigger-action spray bottles, not aerosols
- avoid non-degradable products, such as some biocides
- leave the car at home for short journeys and take public transport or ride a bike instead
- use natural cleaning products and avoid chlorine-based cleaners.

Figure 1 There are many ways you can reduce your impact on the environment, such as (A) using trigger spray bottles instead of aerosols and (B) walking instead of driving.

Test your skills and capabilities

Personal and environmental safety

Before new agricultural or veterinary chemicals that contain a new active ingredient can be produced or imported into Australia, they must first be approved for use by the Australian Pesticides and Veterinary Medicines Authority (APVMA) to make sure they satisfy safety, trade, efficiency and labelling criteria. The information that needs to be provided may be the results of scientific experiments or a comparison to an existing chemical that is already in use.

1 A chemical manufacturer would like to import a herbicide (substance that kills plants) that has the active ingredient diquat dibromide monohydrate. As a scientist working for the APVMA, you are responsible for preparing recommendations for or against the importation of new products.

Write a recommendation with evidence to support your decision by:

- using the Safety Data Sheet (SDS) for this product (which can be found by searching the internet) to **describe** the chemical's toxicity to:
  - **a** humans
  - **b** animals
  - **c** the environment
- **describing** how this active ingredient is currently used in Australian agriculture
- **describing** how and why this chemical is used or not used in the European Union
- **outlining** your decision for or against the importation of the new product.

Skills builder: Planning investigations

2 Recently, a farm has started to use a new type of pesticide the farmers developed at home to protect their crops. They want to start producing this pesticide for commercial sale. Before they start this process, **describe** the environmental considerations that the farmers would need to examine. (THINK: Is there safe waste management? What is the effect of this pesticide on the crops and the local ecosystems?)

Lesson 6.7

Review: Chemical reactions

Summary

Lesson 6.1 Mass is conserved in a chemical reaction

- In chemical reactions, the starting chemical reactants are on the left-hand side of the arrow.
- In chemical reactions, the final chemical products are on the right-hand side of the arrow.
- The Law of Conservation of Mass states that the total mass of the reactants is equal to the total mass of the products.

Lesson 6.3 Balanced chemical equations show the rearrangement of atoms

- Chemical reactions can be described through observations, word equations or symbols.
- The Law of Conservation of Mass is used to write a balanced chemical equation.
- A balanced chemical equation has equal numbers of each type of atom on both sides of the equation.

Lesson 6.4 Chemical reactions are used to purify elements from ore

- Most elements are found as ore.
- The reactivity of an element determines how easy it is to extract.
- Extracting metals requires the concentration of the mineral and isolation of the metal.

Lesson 6.6 Science as a human endeavour: Green chemistry reduces the impact of chemicals on the environment

- Green chemistry involves considering the environmental impact of the manufacture and end of life of new artificially produced chemicals.
- The circular economy requires scientists to consider the whole life cycle (including the waste or recycling) of manufactured products.

Review questions 6.7

Review questions: Module 6

Retrieve

1 **Identify** each of the following statements as either true or false.
  a Reactants are the substances made in chemical reactions.
  b Atoms cannot be created or destroyed.
  c An ore is a concentrated mineral.
  d Metals at the top of the reactive series of metals are more reactive.

2 **Recall** the general equation for the following chemical processes used in isolating a metal.
  a Roasting
  b Smelting
  c Reduction

3 **Recall** the cause of Minamata disease.

4 **Name** the main element found in the mineral bauxite (Figure 1).

Figure 1 Bauxite

5 **Define** “circular economy”.

Comprehend

6 The reactants in the production of carbon dioxide and salt by mixing sodium bicarbonate and vinegar are:
   A carbon dioxide and vinegar
   B carbon dioxide and salt
   C sodium bicarbonate and salt
   D sodium bicarbonate and vinegar.

7 The products in the production of carbon dioxide and salt by mixing sodium bicarbonate and vinegar are:
   A carbon dioxide and vinegar
   B carbon dioxide and salt
   C sodium bicarbonate and salt
   D sodium bicarbonate and vinegar.

8 **Represent** the following reactions as word equations.
   a Most gas stoves burn methane with the oxygen in air to produce carbon dioxide and water.
   b The mixing of vinegar (acetic acid) and marble (calcium carbonate) produces bubbles of carbon dioxide, water and calcium acetate.
   c Carbon dioxide and water are produced when wood is burned with oxygen.

9 **Describe** the meaning of the “Law of Conservation of Mass” in your own words.

10 **Describe** the process of electrolysis.

Analyse

11 **Identify** which of the following is a balanced equation.
   A $CH_4 + O_2 \rightarrow CO_2 + 2H_2O$
   B $CH_4 + 2O_2 \rightarrow CO_2 + H_2O$
   C $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
   D $CH_4 + O_2 \rightarrow 2CO_2 + 2H_2O$

12 Write a balanced chemical equation for the following reaction.

Mercury oxide (HgO) is heated, its atoms rearrange to form mercury liquid (Hg) and oxygen gas (O_2).

Figure 2 Liquid mercury

13 **Identify** the number of atoms of carbon, hydrogen and oxygen in a molecule of ethanol (CH_3CH_2OH).

14 Balance the following equations.
   a $CO_2 + H_2O \rightarrow C_6H_{12}O_6 + O_2$
   b $SiCl_4 + H_2O \rightarrow H_4SiO_4 + HCl$
   c $Al + HCl \rightarrow AlCl_3 + H_2$
   d $Na_2CO_3 + HCl \rightarrow NaCl + H_2O + CO_2$
   e $C_7H_6O_2 + O_2 \rightarrow CO_2 + H_2O$
   f $KClO_3 \rightarrow KClO_4 + KCl$

15 **Consider** the reactions that occur as the following chemicals interact with each other:
   a iron filings (Fe) in in hydrochloric acid (HCl) to produce hydrogen gas (H_2) and iron chloride ($FeCl_2$)
   b carbon dioxide (CO_2) dissolves in water (H_2O) to form a solution of carbonic acid (H_2CO_3).

   For each situation, **describe** the reaction as:
   i the reactants and products
   ii a word equation
   iii a balanced chemical equation.

16 **Identify** the method that could be used to separate a very dense metal from its ore.

17 **Compare** a cathode and an anode in electrolysis.

18 **Identify** two examples of green chemistry that you could apply at home.

Apply

19 Smithsonite is an ore that contains high levels of zinc carbonate (Figure 3).
   a The mineral is concentrated using froth flotation and leaching. **Describe** these processes.
   b **Propose** how the zinc could be isolated from its mineral.
   c **Describe** some of the uses of zinc metal.

Figure 3 Smithsonite

Critical and creative thinking

20 **Create** a poster that outlines how to balance the chemical reaction below.

$$H_2SO_4 + HI \rightarrow H_2S + I_2 + H_2O$$

21 **Create** a poster that outlines the extraction and purification process of producing copper.

22 **Conduct** a PNI (positive, negative, interesting) analysis on the effect of plastics on our lives (Table 1).

Table 1 The effects of plastics on our lives

Positive	
Negative	
Interesting	

23 Some supermarkets have started producing biodegradable bioplastic bags from cornflour (Figure 4). **Evaluate** the impact of using corn to produce plastic (by defining the term "biodegradable", explaining the effect of growing extra corn on the environment and potential land clearing, explaining the effect of using non-biodegradable plastic bags on the environment and deciding which impact causes the least harm).

Figure 4 Biodegradable bioplastic bags

24 **Evaluate** the following statement.

"An important part of mining is the reclamation of the environment when the amount of metal ore is no longer worth the cost of extraction, concentration, isolation and purification."

Figure 5 The Mary Kathleen uranium mine in western Queensland closed in 1982.

Social and ethical thinking

25 The mining of metals can have a significant effect on the environment. Consider the effect of mining metals such as copper, silver, silicon and zinc that are needed to make solar panels. **Discuss** the views of each of the people below.

- **a** the miner extracting the ore
- **b** the farmer whose land is being mined
- **c** the person who wants to reduce greenhouse gases

Research

26 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.

Phosphoric acid

Phosphoric acid has a wide variety of uses, including as a fertiliser, rust remover and food additive. It is even an ingredient of cola drinks (Figure 6). **Describe** how it is produced and more about its uses.

Figure 6 Phosphoric acid is used to produce many products, such as fertiliser.

Rare metals

A range of rare metals is used in microelectronic devices. Many of these metals, such as tantalum and niobium, are sourced from Australia.

- **Identify** where these metals are found in Australia.
- **Identify** the chemical name of the mineral in which these metals are found.
- **Describe** the chemical processes that are used to extract the pure metal.

Figure 7 Niobium

Explosives

The history of the development of explosives is fascinating.

- **Identify** the person who discovered them.
- **Describe** when explosives were first used and how they work.
- **Identify** the main chemicals used and the different types of these chemicals.
- **Explain** the part Alfred Nobel played in the development of explosives.

Figure 8 Explosive device being tested in an isolated area

Carbon footprints

- **Describe** what is meant by the phrase "carbon footprint".
- **Identify** the chemical reactions that contribute to an increase in carbon dioxide in the atmosphere.
- **Identify** the other gases that contribute to the enhanced greenhouse effect.
- **Describe** how carbon footprints are measured.
- **Describe** what is meant by the phrase "carbon offset".

Figure 9 Our actions have an effect on the environment.

Module
7
The carbon cycle

Overview

Carbon is cycled through the Earth through the processes of photosynthesis, respiration, fire, weathering, volcanism, and burning fossil fuels. These processes change the Earth's systems – atmosphere, biosphere, hydrosphere and lithosphere – over time. The carbon cycle can be illustrated in diagrams or simulations and used to demonstrate how excess carbon dioxide is affecting the greenhouse effect that maintains temperatures that support life on Earth. Aboriginal and Torres Strait Islander Peoples use fire to manage energy and nutrients such as carbon in the ecosystem.

Lessons in this module

Lesson 7.1

Earth's spheres are balanced

Key ideas

→ Earth is made up of the lithosphere (solid crust), atmosphere (air), hydrosphere (water) and biosphere (living organisms).

→ Interaction between Earth's spheres maintains global temperatures and climate.

Learning intentions and success criteria

Introduction

The solid crust of Earth (lithosphere) interacts with the atmosphere (air) and hydrosphere (solid, liquid and gaseous water) to influence temperature and therefore the climate in mountains and deserts, as well as the ocean currents. In return, these three spheres affect all the living organisms in the biosphere. A balance must be maintained to ensure the survival of all life on this planet.

The lithosphere

lithosphere the outermost layer of Earth, consisting of the upper mantle and crust

The outermost rocky layer of Earth is the **lithosphere**. It is made up of the upper mantle and the crust (Figure 1). Although the crust and upper mantle are approximately 80 km thick, they actually form a very thin layer compared to the other layers of Earth.

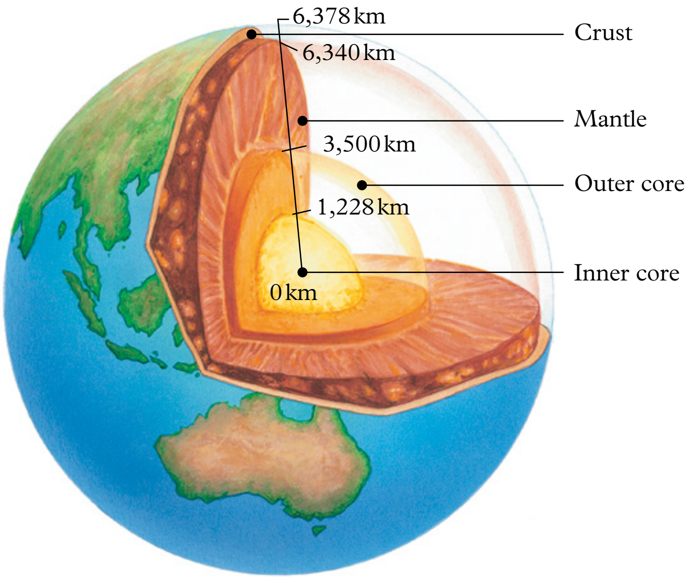


Figure 1 Earth is made up of layers.

The rocky crust of Earth is made from magma (molten rock), which cools very slowly and at different times all over the surface of Earth. The heat from the magma escapes into the air and water surrounding it. The cooled crust settles as uneven giant plates of rock that are mismatched and butt up against their neighbours, covering the entire surface of Earth. The giant pieces are called **tectonic plates**. These plates float on the semi-liquid magma at the top of the mantle. The heat in the mantle creates currents that slowly stir through the molten rock, moving the tectonic plates as well. The tectonic plates move about 2 to 10 cm per year – a similar rate to the growth of your fingernails.

tectonic plate a large layer of solid rock that covers part of the surface of the Earth; movement of tectonic plates can cause earthquakes

The outermost area of the lithosphere is the soil in which plants grow and many insects and animals live (Figure 2). The weathering of rocks produces small particles that can move into the waterways (hydrosphere) or provide essential nutrients for plants and animals (biosphere).

The lithosphere is the slowest of Earth's systems to change. Small changes can take thousands, even millions, of years.

Figure 2 Volcanoes are part of the lithosphere.

The atmosphere

The **atmosphere** is a layer of gases that we commonly call air. The atmosphere is relatively thin compared to the size of Earth. If Earth were the size of a party balloon, the atmosphere would only be as thick as the rubber skin of the balloon.

atmosphere the layer of gases surrounding the Earth

Earth is the only planet in our solar system that has an atmosphere that sustains life. The atmosphere helps keep us warm, controls our weather, protects us from the dangers from space and carries sounds.

The most important gas for humans and other animals is oxygen (O_2), which makes up 21 per cent of the atmosphere. Oxygen in Earth's atmosphere allows organisms to respire (use oxygen to produce energy), which is essential for almost all life on Earth. Other gases in the atmosphere include ozone (O_3), which offers protection from the Sun's ultra-violet radiation; carbon dioxide (CO_2); water (H_2O) and other greenhouse gases, which trap heat to keep us warm; and nitrogen (N_2), which makes up 78 per cent of the atmosphere.

Layers in the atmosphere

The atmosphere is more dense at ground level and thins out as you go higher above Earth's surface: 99 per cent of all the air in the atmosphere is found within 80 km of Earth's surface. There is not really a top to the atmosphere – the air just thins out, with decreasing pressure, until you reach the relative emptiness of space. These changing conditions are identified as several atmospheric layers (Figure 3).

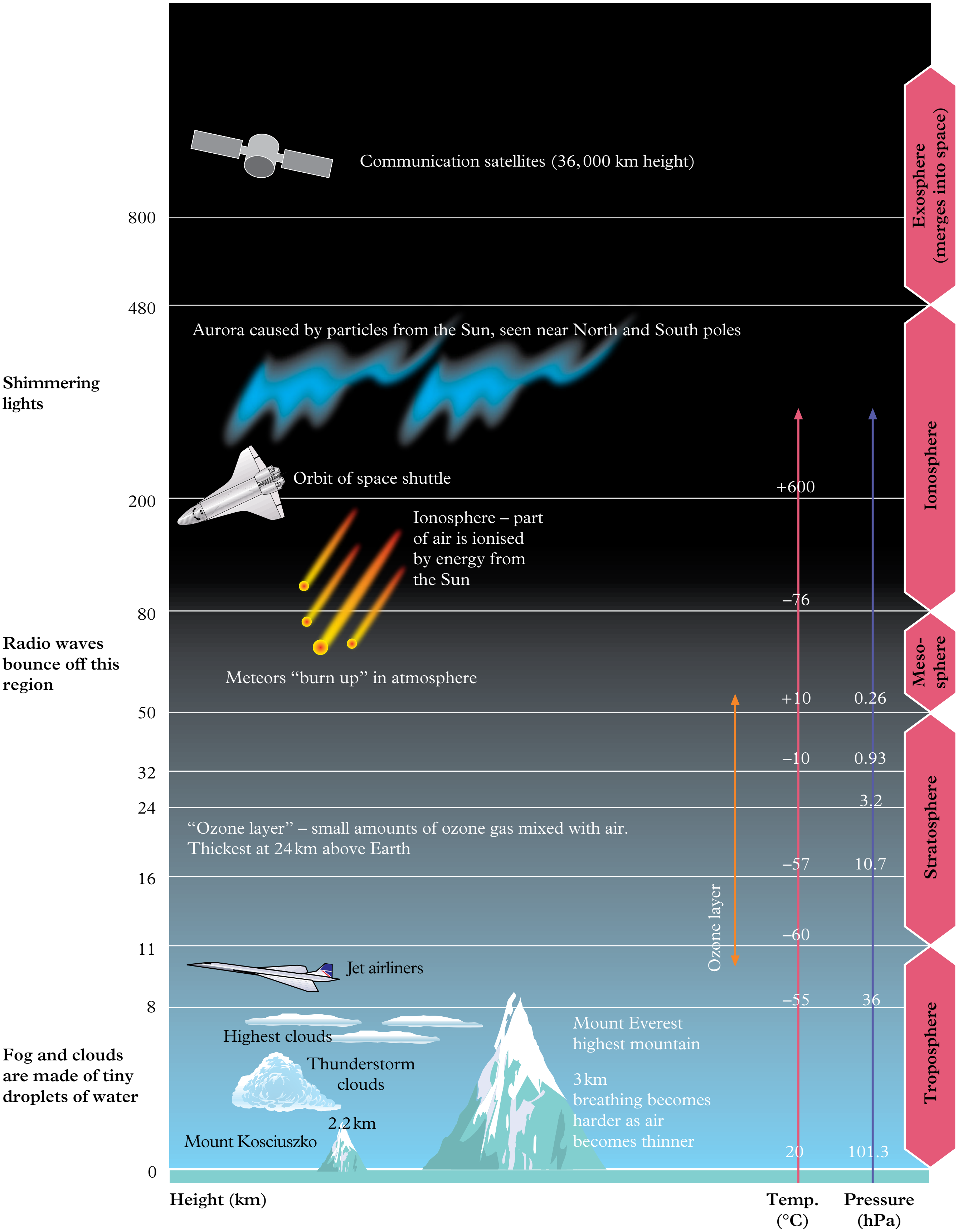


Figure 3 Each layer of Earth's atmosphere has different characteristics.

The hydrosphere

The **hydrosphere** is made up of all Earth's water – oceans and lakes, but also the water in glaciers, the soil and even in the air (Figure 4). The hydrosphere covers approximately 70 per cent of Earth's surface, making Earth the "blue planet" when viewed from space. The huge amount of water, in all its various forms, is also home to many types of plants and animals. The hydrosphere interacts with and is influenced by each of the other spheres. The heat from the lithosphere warms the atmosphere and hydrosphere, allowing water to exist in three different states: liquid, gas (vapour) and solid (glaciers and ice).

hydrosphere all the solid, liquid and gaseous waters on Earth that support life

Some chemicals, such as DDT (pesticide used in the 1960s) or PFAS (use in fire fighting foam), move between the lithosphere (soils) to the hydrosphere (waterways) and eventually into the living things in the biosphere. These chemicals are known as "forever chemicals" because natural processes do not break them down and they stay in the environment for a very long time.

Figure 4 All Earth's water makes up the hydrosphere.

The hydrosphere influences climate

The part of the hydrosphere that is made up of frozen water is called the **cryosphere**. The cryosphere is very important in regulating the climate of Earth and the amount of nutrients in the ocean. When the ice melts, it produces very dense cold water that sinks to the bottom of the ocean disturbing the nutrients on the ocean floor. As the icy water is carried away by the current, it slowly warms and lifts the nutrients to the surface, where

cryosphere the frozen water in the hydrosphere it starts the ocean's food chain. As the current travels north, the atmosphere heats the water, causing it to evaporate. The evaporation of water from the oceans increases the amount of water vapour in the atmosphere. This process affects Earth's climate as water vapour in the atmosphere influences temperature, humidity and precipitation (rain, sleet and snow).

biosphere a layer around the Earth's surface that supports life; consists of the atmosphere, hydrosphere and lithosphere

biodiversity the variety of life; the different plants, animals and mircroorganisms and the ecosystems they live in

The biosphere

The **biosphere** is made up of all the living things on Earth, including plants, animals and bacteria. Within this sphere, there is an enormous degree of organisation and an amazing variety of different types of organisms (**biodiversity**; *bio* = life, *diversity* = variety). Each organism is interdependent with others; the survival of each species is dependent on other species. The biosphere overlaps and interacts with all the other spheres on Earth and it needs to maintain a careful balance.

Earth is the only planet in our solar system that can support a biosphere. Although life exists in all spheres on Earth – from deep under the ocean to high in the mountains – most species can only survive in a fairly narrow range of conditions.

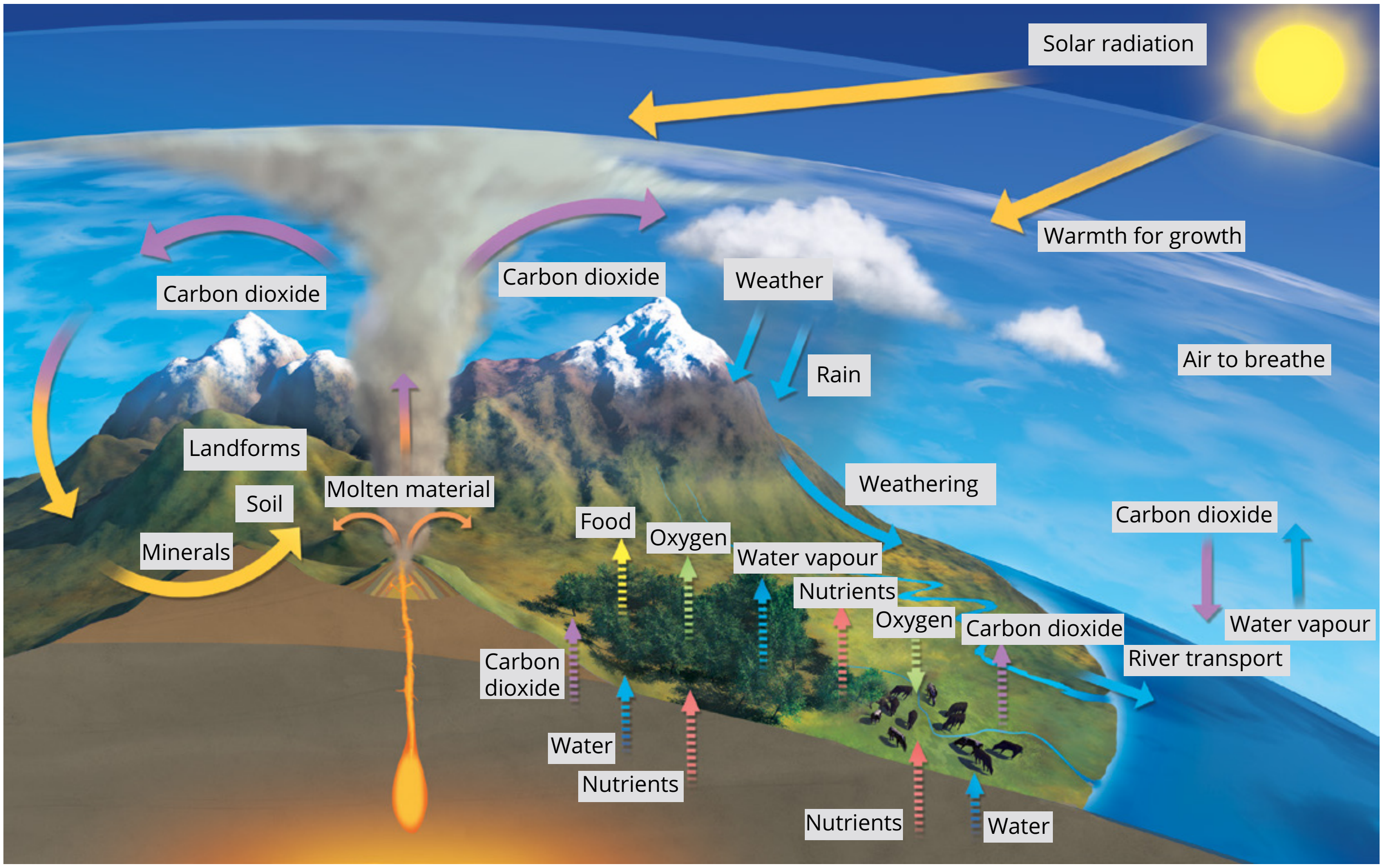


Figure 5 Many different elements and compounds move between the different spheres of Earth.

Check your learning 7.1

Check your learning 7.1

Retrieve

1 **Define** the term "biosphere".

2 **Identify** the layer of the atmosphere in which we live.

Comprehend

3 **Describe** the different parts that make up the lithosphere.

4 **Describe** what happens to the amount of air as you go higher into the atmosphere.

5 **Explain** how the hydrosphere interacts with the other spheres.

Analyse

6 **Compare** the hydrosphere and the cryosphere.

Apply

7 **Create** a Venn diagram with four interlocking circles, one for each of the spheres studied. Label each sphere and include all the features they share.

8 Some farmers spray pesticides on the soil (lithosphere) to reduce insects that may eat their crops. **Describe** how the pesticide can move into two other spheres.

Skills builder: Questioning and predicting

9 Making observations enables scientists to make predictions. In this task, you must make and record observations about one of Earth's spheres (atmosphere, biosphere, lithosphere and hydrosphere). Look outside for 10 minutes and make a list of observations about what is happening in nature.

  a **Select** a sphere to observe (atmosphere, biosphere, lithosphere or hydrosphere).

  b **Describe** your observations. (THINK: What sphere is it occurring in? What is it affecting?)

  c **Explain** why this may be occurring. (THINK: What existing theories are there for this? Can I explain what I am seeing using one of these theories? Is there interaction between the spheres?)

Lesson 7.2
Carbon cycles through Earth's spheres

Key ideas

→ The carbon cycle describes how carbon atoms cycle through an ecosystem.

→ Photosynthesis removes carbon dioxide from the atmosphere.

→ Carbon trapped in the lithosphere cycles very slowly, whereas carbon in the biosphere and atmosphere cycles much faster.

→ Carbon can be stored in carbon sinks such as fossil fuels and the ocean.

Learning intentions and success criteria

Cycles of matter

matter anything that has space and volume; matter is made up of atoms

Matter cannot be created or destroyed. This means matter must be recycled. The cycling of matter from the atmosphere or Earth's crust and back again is called a biogeochemical cycle (*bio* = living; *geo* = earth).

Carbon is the fourth most abundant element on Earth. All life on Earth is considered a "carbon-based life form" because many of the key chemical molecules that are essential to life (including DNA, carbohydrates, proteins and lipids) contain carbon atoms. Because carbon atoms cannot be created or destroyed, they must be continually cycled through the land, oceans and atmosphere of Earth's global systems (Figure 1).

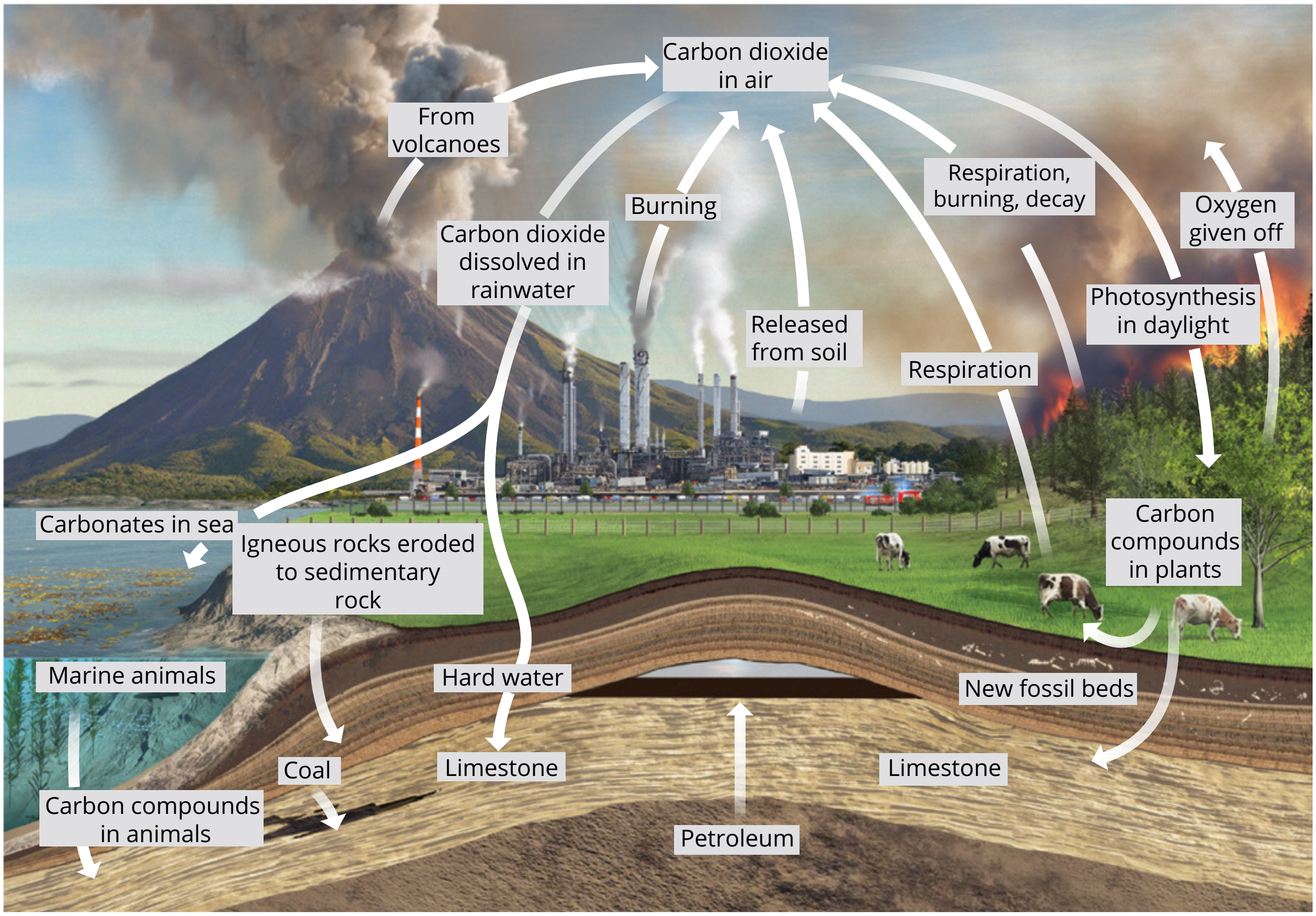


Figure 1 The carbon cycle

The carbon cycle

Carbon atoms circulate in and around all living things. These important atoms exist in all of Earth's spheres, from the carbonate molecules in limestone to the petroleum in fossil beds, and from carbohydrates in plants to proteins that help animals move. Carbon cycles can be divided into two categories depends on the length of time it takes the carbon to change its form.

- The geological carbon cycle is a long-term cycle that occurs from hundreds to millions of years and has resulted in the bulk of carbon being locked in rocks or in sediments as fossil fuels.

- The biological/physical carbon cycle is a short-term cycle that occurs over days, weeks, months and years, and it involves the cycling of carbon through photosynthesis and cellular respiration.

When describing the carbon cycle, one of the starting points used is the carbon dioxide in the air. Explaining how the carbon in the air enters and leaves the organic carbon molecules found in living things helps us to understand the complexity of the carbon cycle.

Photosynthesis

Living things need energy to grow, reproduce and repair, to defend themselves, and to move around (Figure 2). The energy in an ecosystem usually originates from the Sun. Plants, some algae and some bacteria are able to transform light energy from the Sun into chemical energy. Carbon is an important part of this process. The light energy of the Sun enables the plants to capture the carbon dioxide from the air. This carbon dioxide (CO_2) then chemically reacts with water (H_2O) to produce a carbon-based molecule called glucose ($C_6H_{12}O_6$), and oxygen (O_2) through a process called **photosynthesis**.

Figure 2 Plants use energy from the Sun to grow and repair.

photosynthesis a chemical process used by plants to make glucose and oxygen from carbon dioxide, sunlight and water

The overall equation for photosynthesis is:

Reactants		Products
carbon dioxide + water	$\xrightarrow{\text{light energy}}$	glucose + oxygen + water
$6CO_2 + 12H_2O$	$\rightarrow$	$C_6H_{12}O_6 + 6O_2 + 6H_2O$

Plants use the carbon, hydrogen and oxygen in glucose to make other structural molecules such as proteins, lipids and complex carbohydrates. These molecules are used to produce new leaves, roots and stems so that a plant can grow and repair itself.

One of the most common uses for the glucose is a chemical reaction that produces the energy needed to survive. When an animal eats a plant, it can use the carbon-based molecules in a chemical reaction called **cellular respiration**.

cellular respiration chemical reaction that transfers energy (ATP) to cells

Cellular respiration

Cellular respiration is similar to burning. Whenever we burn a fuel, such as wood or oil, we release the carbon that has been chemically stored in the molecules of the once living organism. The carbon in the fuel molecules is organised, or ordered, because it is bound in the molecule. Burning requires oxygen and is a rapid process, releasing the energy as heat energy. Carbon dioxide and water are also produced.

Cellular respiration is more organised and controlled than burning. Glucose is the molecule that our body uses for fuel. Each cell uses oxygen to "burn" glucose and convert the energy into **ATP (adenosine triphosphate)**. ATP is much easier for our bodies to use for energy. The carbon in 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 called **aerobic cellular respiration**.

ATP (adenosine triphosphate) molecule that stores and transfers energy in cells; produced during cellular respiration

aerobic cellular respiration a chemical reaction between glucose and oxygen to produce carbon dioxide, water and energy (ATP)

The general equation for aerobic cellular respiration is:

Reactants		Products
glucose + oxygen	→	carbon dioxide + water + energy
$C_6H_{12}O_6 + 6O_2$	→	$6CO_2 + 6H_2O + 36ATP$

The carbon stored in the glucose is released into the air as carbon dioxide.

Photosynthesis and cellular respiration

The reactants and products of photosynthesis and cellular respiration are almost mirror images of one another. The reactants of one are the products of the other. The main difference is that photosynthesis uses energy from the Sun (light energy), while cellular respiration produces chemical energy (ATP). Photosynthesis traps carbon dioxide in the air, converting it into carbon-rich glucose. Cellular respiration moves the carbon out of glucose and into carbon dioxide, which is then released back into the air. Many of the molecules in the two reactions are the same, but they are part of different pathways. Glucose is a product of photosynthesis, whereas it is a reactant in cellular respiration.

Globally, the return of carbon dioxide to the air by cellular respiration is balanced by its removal by photosynthesis. Other ways of returning carbon dioxide to the air include the burning of fossil fuels, bushfires and the decomposition of dead organic matter. The natural balance of this cycle is disturbed by excess burning, which contributes to the **enhanced greenhouse effect**.

enhanced greenhouse effect an increase in carbon dioxide and other heat-capturing gases in the atmosphere, resulting in increased warming of Earth

Storing carbon

Carbon is stored over the long term in the trunks and branches of trees. It is also temporarily stored in the bodies of other organisms, such as herbivores and carnivores. When these organisms die, carbon is returned to the atmosphere through cellular respiration by bacteria and fungi (decomposers).

A **carbon sink** is any feature of the environment that absorbs and/or stores carbon, keeping it from the atmosphere. Forests take in carbon dioxide for photosynthesis and use it to grow stems and leaves, so they are a very significant carbon sink (Figure 3). However, the ability of forests to absorb carbon has been reduced as a result of large-scale clearing of forests throughout the world.

carbon sink any feature of the environment that absorbs and/or stores carbon

Figure 3 Forests are an example of a carbon sink.

Termites recycle carbon

Plant cell walls are made of cellulose, a complex carbohydrate that is insoluble in water and does not break down easily. Fungi are able to break down cellulose and play a major role in the decomposition of wood, but they require a moist environment, like that in a rainforest. In drier areas of Australia, such as forests and woodlands in tropical and subtropical areas, as well as savannah grasslands, termites have a major role in the decomposition and recycling of carbon.

Figure 4 A termite mound in the savannah of northern Australia

Termites are social insects and live in nests. You may have seen termite mounds in drier parts of Australia (Figure 4). Microorganisms in the guts of termites break down the cellulose of plant material such as grasses, plants and wood. Scientists have estimated that termites recycle up to 20 per cent of the carbon in ecosystems such as savannah grasslands.

Ocean acidification

The ocean is another important carbon sink. Carbon dioxide is able to dissolve in the ocean water. An unfortunate consequence of this is the production of carbonic acid. This process is called **ocean acidification**.

ocean acidification the production of carbonic acid in the ocean due to the absorption of carbon dioxide

$$\text{water} + \text{carbon dioxide} \rightarrow \text{carbonic acid}$$

$$H_2O + CO_2 \rightarrow H_2CO_3$$

Although carbonic acid is a weak acid, it can affect the survival of reefs and ocean creatures that have shells made of calcium carbonate ($CaCO_4$). The carbonic acid reacts with the shells of many molluscs, causing them to become thin (Figure 5).

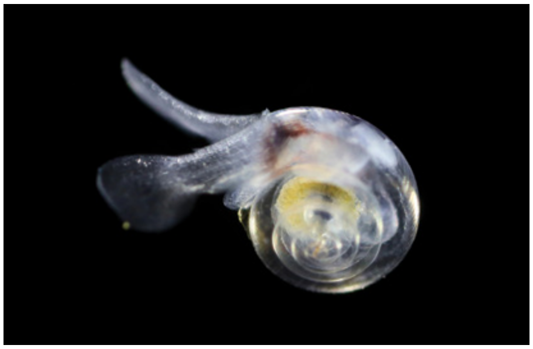


Figure 5 Mollusc shells become thin when exposed to carbonic acid.

Oceans are not the only sites that store carbon. It is also stored in:

- decomposed organic matter, such as coal, natural gas, petroleum and shale oil
- rocks, such as limestone, marble, dolomite, chalk and other carbonates
- organic matter in the soil
- dissolved carbon dioxide in other waters
- the shells of marine organisms and some terrestrial organisms.

All of these carbon sinks will release carbon if the environmental conditions change.

Figure 6 Increased carbon dioxide levels in the atmosphere cause the ocean to become acidic. As a result, the tiny animals (polyps) that live on the hard surface of coral die, causing coral bleaching.

Check your learning 7.2

Check your learning 7.2

Comprehend

1 **Describe** how matter moves through an ecosystem.
2 **Explain** what is meant by the term "carbon cycle".
3 **Describe** three ways carbon dioxide can be released into the atmosphere.
4 **Describe** two ways carbon dioxide can be removed from the atmosphere.

Analyse

5 **Contrast** the geological carbon cycle and the biological/physical carbon cycle.
6 **Compare** (the similarities and differences) the reactants and products of cellular respiration and photosynthesis.
7 **Infer** why cellular respiration is constantly occurring in cells (by identifying the key product of the reaction and what the organism uses this molecule for).

Apply

8 "You are eating the same atoms that were in dinosaur poo!"
Evaluate the accuracy of this statement (by describing how matter moves through an ecosystem, describing how the atoms in dinosaur poo will change over time and deciding whether the statement is correct).

Lesson 7.3

Human activity affects the carbon cycle

Learning intentions and success criteria

Key ideas

- → Combustion reactions use fuel and oxygen to produce heat and water.
- → The use of fossil fuels (petrol and oils) releases carbon into the atmosphere.
- → Increasing agriculture can disrupt the carbon cycle.

Releasing carbon dioxide

Humans tap into the geological carbon cycle by extracting oil, natural gas and coal (all of which are hydrocarbons) for use in cars and energy production. Large-scale extraction and the burning of these fossil fuels has resulted in increased levels of carbon dioxide in the atmosphere.

When you see something burn, you are witnessing a substance reacting with oxygen in a chemical reaction. The amount of energy released in this reaction can be huge. It is in the form of heat energy and light energy – which we see as a flame – and sometimes sound energy as well. The products of these reactions are always carbon dioxide and water (Figure 1).

What happens when fuels burn?

In science, a **fuel** is a substance that will undergo a chemical reaction in which a large amount of chemical energy is produced at a fast but controllable rate. We use fuels such as the methane in natural gas to produce heat and/or electricity, and fossil fuels to run engines and motors.

When a fuel reacts in the presence of oxygen, it is called a **combustion reaction**. These reactions produce heat and water.

Figure 1 Burning coal produces carbon dioxide.

fuel a substance that undergoes a chemical reaction producing large amounts of energy

combustion reaction a reaction between a fuel and oxygen that produces heat, carbon dioxide and water

hydrocarbon a molecule that contains only carbon and hydrogen atoms

Hydrocarbons are very common fuels that only contain the elements hydrogen and carbon. When hydrocarbons burn in unlimited air, carbon dioxide and water are produced. Petrol, diesel and liquefied petroleum gas (LPG) are all hydrocarbons.

hydrocarbon fuel + oxygen → carbon dioxide + water vapour + lots of energy

When the oxygen supply is more limited, for example when a candle burns in a poorly ventilated space, less heat energy is released and poisonous carbon monoxide gas is produced. Carbon monoxide can be deadly: it replaces the oxygen in our blood, which can kill us.

hydrocarbon fuel + limited oxygen → carbon monoxide (poisonous) + water vapour + some energy

Changing the carbon cycle

As the human population has increased, the balance between new growth plants and old growth plants has been disrupted. This has interrupted many parts of the carbon cycle. For example:

- freshwater ecosystems have been altered through the building of dams for irrigation and hydroelectric power production, resulting in whole landscapes decomposing under water.
- agriculture has converted more than half the world's many woodlands for human use, releasing the carbon stored in slow growth trees.
- farming livestock such as cattle and pigs has increased the number of animals releasing methane (CH_3) into the atmosphere.

Australian bushfires

The increased number and intensity of bushfires has also had an impact on the amount of carbon dioxide in the air (Figure 2).

Carbon stored in old slow growth bush becomes the fuel in a bushfire, producing carbon dioxide as well as methane, carbon monoxide and smoke (solid carbon particles). This was most obvious in the 2019–2020 Australian bushfires that burnt more than 143,000 square kilometres. During this time, scientists took daily pictures that measured the amount of carbon monoxide levels in the atmosphere. This was used to estimate that the amount of carbon dioxide released into the atmosphere during this period was 250 million tonnes (Figure 3).

Bushfire smoke and ash contain nutrients, such as carbon, phosphorous, nitrogen and other particles. When ash and smoke mix with ocean water, the nutrients in the mixture allow algae and microorganisms, called phytoplankton, to rapidly increase their populations. Algae and phytoplankton are the start of many marine food webs and a "bloom" in their populations provides a rich food source for the marine food web in that part of the ocean. A moderate increase in nutrients in a marine ecosystem can be beneficial but too much can cause excess growth of algae and phytoplankton, leading to an imbalance in oxygen levels of the water. This affects other organisms in the marine ecosystem.

Figure 2 Bushfires are an important part of the carbon cycle.

Figure 3 The 2019–2020 Australian bushfires released large amounts of carbon dioxide into the atmosphere.

Check your learning 7.3

Check your learning 7.3

Retrieve

1 **Identify** the two elements that are in hydrocarbons.

2 **Recall** the products of a hydrocarbon combustion reaction.

3 **Recall** the products of a hydrocarbon combustion reaction where oxygen is limited.

Comprehend

4 **Describe** two ways human activity affects the carbon cycle.

5 The fuels used in cars, trucks and buses are generally liquefied petroleum gas (LPG), petrol or diesel. These fuels are mainly hydrocarbons. **Explain** why scientists are warning that excessive use of these vehicles is contributing to the enhanced greenhouse effect.

Apply

6 **Consider** your response to question 5 and use the internet to **identify** one argument for and one argument against the use of petrol cars in Australia. **Evaluate** each argument (consider the reasoning and evidence behind them).

Lesson 7.4

Traditional knowledge reduces carbon emissions

Key ideas

→ Hazard reduction burning is the large-scale burning of all plants in an area.

→ Cultural burning uses cooler flames to burn small, selected parts of the landscape.

→ Cultural burning increases carbon storage and maintains key indigenous plants and animals.

Learning intentions and success criteria

Introduction

As the climate has changed over the last 50 to 100 years, the number and severity of bushfires has also increased. In the summer of 2019–2020, over 14.3 million hectares (143,000 square kilometres) of bushland and farming areas were burnt. Over 3,000 buildings were destroyed, and it is estimated that over three billion animals were killed. Satellite images were used by NASA to estimate that over 250 million tonnes of carbon dioxide were produced as a result. This was 50 per cent of Australia's total carbon dioxide emissions in 2018.

A number of factors contributed to the severity of the bushfires. CSIRO identified one of the key factors as climate change. Increases in the average global temperatures have led to an increased number and severity of droughts. This causes the bushland areas to become drier and make them burn hotter and faster.

Uncontrolled bushfires rapidly burn plant matter and the dead leaves that can form the top part of the soil. This form of rapid combustion can lead to:

- loss of food and shelter for native animals
- erosion of the topsoil
- loss of infrastructure such as fences and buildings
- production of large amounts of carbon dioxide.

Many Aboriginal and Torres Strait Islander Peoples have used fire as a gift to the environment. It is a tool that clears pathways in the land and encourages regrowth by restoring nutrients to the soil and making room for new plants to grow. This traditional form of selective burning is called **cultural burning**.

cultural burning
the practice of burning vegetation used by Traditional Custodians of Country to enhance the health of Country; informed by deep knowledge of and relationship to Country

Cultural burning

Cultural burning is different from a hazard reduction burn. A hazard reduction burn is the targeted burning of bushland to reduce the amount of plant matter and materials that could contribute to a bushfire. The goal of a hazard reduction burn is usually to remove as much of these materials as possible. When this occurs, the plants, like non-native bracken, quickly regrow and rapidly reproduce. These plants have a short life cycle and contribute to the build-up of bushfire fuel within the next one to two years.

Cultural burning usually occurs in the cooler seasons and involves slow burning of small areas in the larger landscape. This encourages the longer-term growth of plants that are less flammable and slower to grow, reducing the build-up of bushfire fuel in the long term. Cultural burning maintains the number of trees and some areas of plants and grasses so that native wildlife has food and shelter immediately after the burn. It also protects key areas of human habitation in some environments and prevents the loss of animals and people. The smaller fire areas are much cooler than a hazard reduction burn. Hazard burns burn hotter, damaging the soil and releasing larger amounts of carbon dioxide into the atmosphere. This increase in **carbon emissions** is one of the reasons why cultural burning is considered better for the environment.

Figure 1 Cultural burning involves selectively burning small areas of a landscape.

carbon emission
the release of greenhouse gases containing carbon, such as carbon dioxide, into the atmosphere

Cultural burning in northern Australia usually occurs at the end of the wet season when the amount of fuel is low and before native seeds and fruits are ripe for harvest. Each ecosystem will be different, and this is where local Aboriginal and Torres Strait Islander Peoples' traditional knowledge of the rhythm of the season and geography of the landscape is important.

Most cultural burning is carried out during the night or early morning, when the low wind and presence of plant dew can help control the fire. The flames are deliberately kept cool and below knee height so that the tree canopy and tree bark are protected (Figure 2). It also helps the soil maintain moisture.

The cool ground fire burns slowly with less oxygen compared to a fire in the canopy of a tree. Many Australian trees contain flammable oils that produce a hot flame. Cool ground fires can be more easily controlled, and do not affect the bacteria and insects that keep the soil healthy. It also prevents many soil nutrients from evaporating and being lost in the smoke.

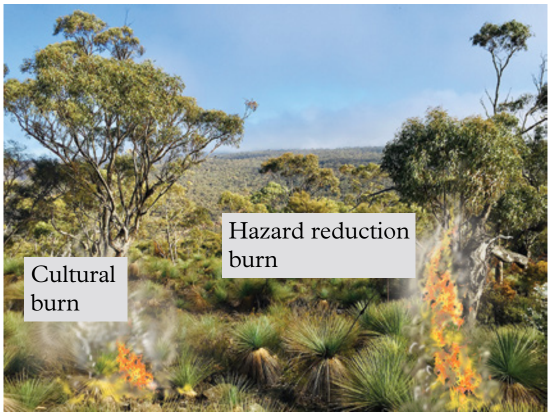


Figure 2 The difference between cooler cultural burning (left) and hot hazard reduction burning (right)

West Arnhem Land

For more than 40,000 years, Aboriginal Peoples have developed an understanding of the different landscapes in the Northern Territory and how they can be maintained. In 2004, scientists started working with the local people to develop a way to control the late season wild bushfires that were destroying up to one third of West Arnhem Land each year.

Over seven years (2005–2011), the Aboriginal Peoples of West Arnhem Land worked with scientists to re-establish cultural burning practices early in the dry season. The program has been extended across Arnhem Land. Figure 3 shows that as the number of early season cultural burns with lower carbon dioxide emissions increased, the number of hot wildfires releasing large amounts of carbon dioxide decreased. This means that the cooler cultural burning is able to keep the carbon in storage for longer, reducing the amount of carbon dioxide contributing to increased global warming.

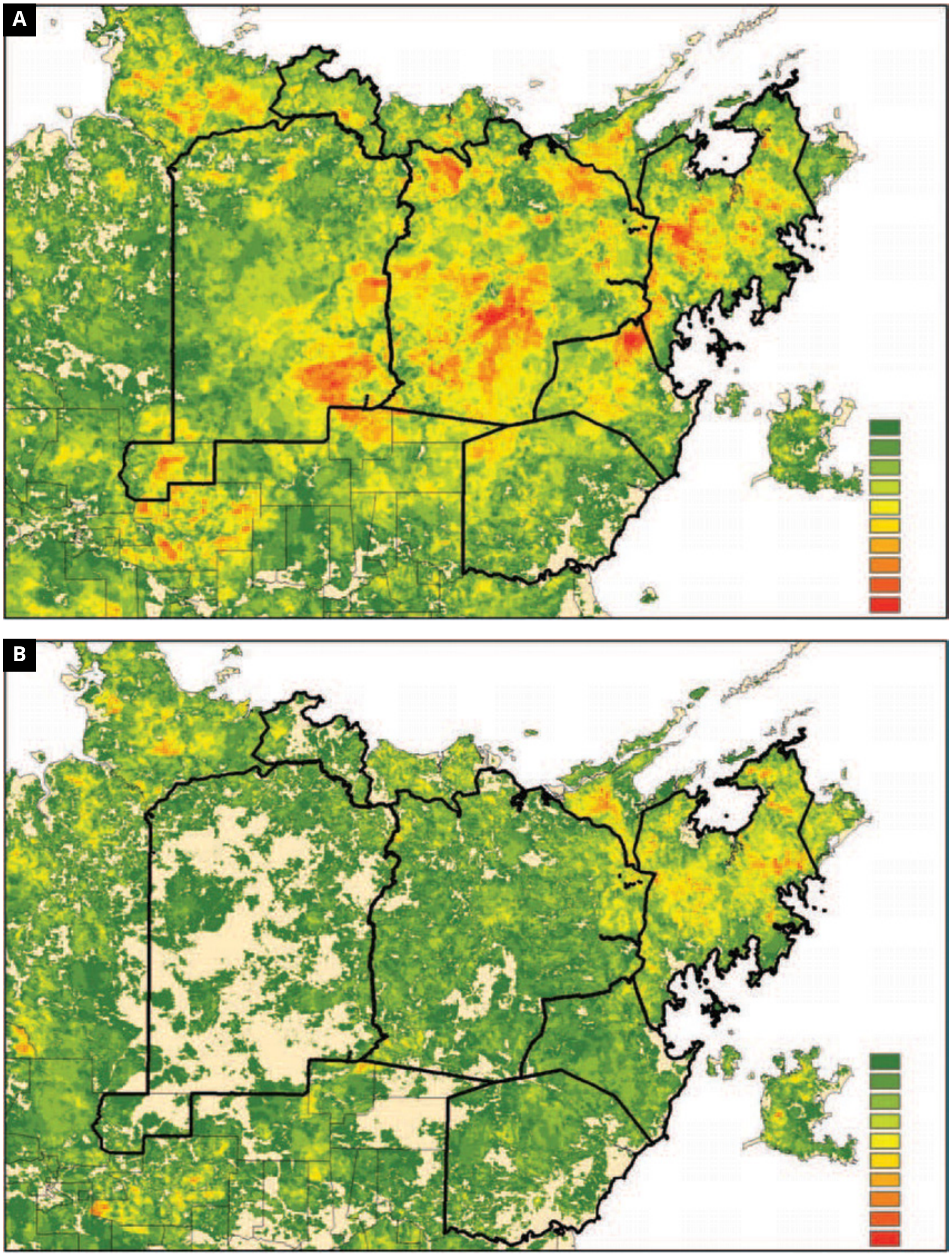


Figure 3 Early season cultural burning reduces the number of late season wild bushfires. (A) The number of late season wild bushfires across Arnhem Land, Northern Territory, 1995–2004 (B) The reduced number of late season wild bushfires, 2008–2017, following cultural burning

Check your learning 7.4

Check your learning 7.4

Retrieve

1 **Define** the term "cultural burning".

Comprehend

2 **Describe** how bushfires damage an ecosystem.

3 **Describe** how a hazard reduction burn can harm the plants and animals in an ecosystem.

4 **Describe** the evidence that supports the theory that cultural burning reduces bushfires.

5 **Explain** how cultural burning reduces carbon emissions.

Analyse

6 **Contrast** hazard reduction burning and cultural burning.

Lesson 7.5

Carbon dioxide levels affect the greenhouse effect

Learning intentions and success criteria

Check the next lesson for a linked practical activity or experiment.

Key ideas

→ Earth is surrounded by an atmosphere of natural greenhouse gases that reflect radiation from the Sun and retain the warmth from Earth.

→ Evidence for enhanced global warming can be found in the melting of sea ice and permafrost and increasing sea levels.

Introduction

Earth's climate has changed many times throughout history. These changes can take many thousands of years to slowly warm or cool the planet and change the climate. Climate change events are occurring now, from dusty farms experiencing drought in the outback to families fleeing their homes in the worst flooding we have ever seen. This climate change is due to the enhanced greenhouse effect and is different from previous changes. It started during the Industrial Age (1850) and has increased Earth's average temperature by 0.95°C since 1900. This short time period (100 years instead of 1,000 years) does not allow time for organisms (including humans) to adapt and evolve.

The greenhouse effect

The **natural greenhouse effect** is critical for maintaining life on Earth. Most of the Sun's energy is reflected back into space by the upper surface of the atmosphere. The reflective surface of clouds also prevents the energy from reaching Earth's surface. The solar energy that does pass through the atmosphere warms Earth's surface. Heat gradually leaves Earth's surface and is radiated back into space. Some heat is trapped by the gases in the atmosphere.

natural greenhouse effect the natural warming of Earth due to water vapour and other gases being present in small amounts in the atmosphere and affecting Earth's radiation balance

These gases act like a giant greenhouse of warm air, keeping Earth warm. If heat was not trapped, the temperature would drop to –100°C each night and rise to 80°C in the day. The gases that contribute to the greenhouse effect include carbon dioxide (CO_2), water vapour (H_2O), methane (CH_4), nitrous oxide (N_2O) and ozone (O_3).

Since the Industrial Revolution of the eighteenth and nineteenth centuries, the level of greenhouse gases in the atmosphere has been increasing, causing an enhanced greenhouse effect.

Increased levels of greenhouse gases

The concentration of carbon dioxide in the atmosphere has changed significantly, by approximately 34 per cent, since 1750 (Figure 1). The bulk of that increase has happened since 1959. The concentration of methane in the atmosphere has also risen dramatically over the past century, more than doubling.

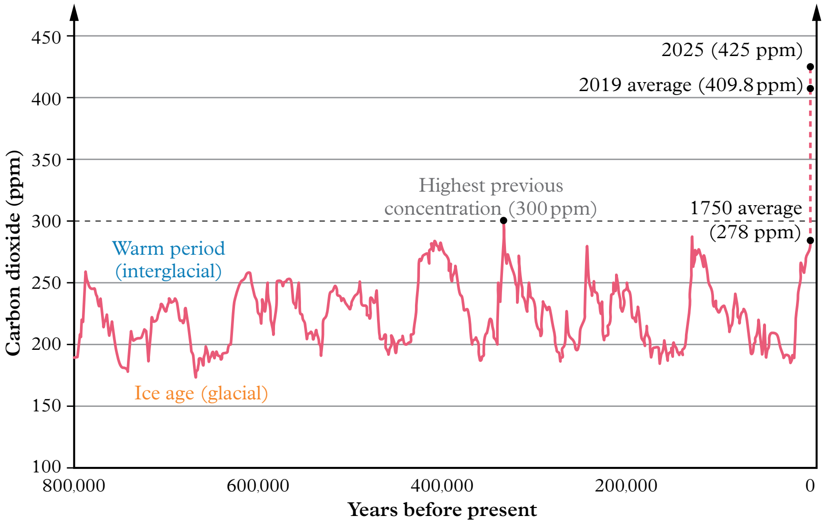


Figure 1 Carbon dioxide levels in the atmosphere have increased significantly since 1750. NOAA Climate.gov, Data: NCEI.

The main greenhouse gas is carbon dioxide. It is formed by the burning of fossil fuels, such as coal, petrol, oil and gas. We all use energy for heating, lighting, transport, industry and communications. Burning carbon-based fossil fuels releases energy (usually as heat) and produces carbon in the form of carbon dioxide and sometimes carbon monoxide or solid particulate carbon.

Forests use carbon dioxide in the process of photosynthesis. Massive deforestation for farming and urban land has reduced the amount of carbon dioxide being removed from the atmosphere by forests. This contributes to the increase in carbon dioxide levels in the atmosphere.

The increase in carbon dioxide production and decrease in carbon dioxide absorption has resulted in an overall increase in the amount of carbon dioxide present in the atmosphere. Figure 2 shows which parts of the world emit the highest amounts of carbon dioxide.

Natural sources of methane gas in Earth's atmosphere include the decay of organic materials in wetlands, emissions from the oceans and the melting of methane hydrates, which are frozen forms of methane found in the ocean floor. Human activity also produces methane through energy production, increased emissions from livestock (e.g. cattle), landfill, biomass burning and waste treatment. The increase in these greenhouse gases has resulted in more heat being trapped in the atmosphere (Figure 3). Figure 4 shows how average global temperatures have changed since 1900.

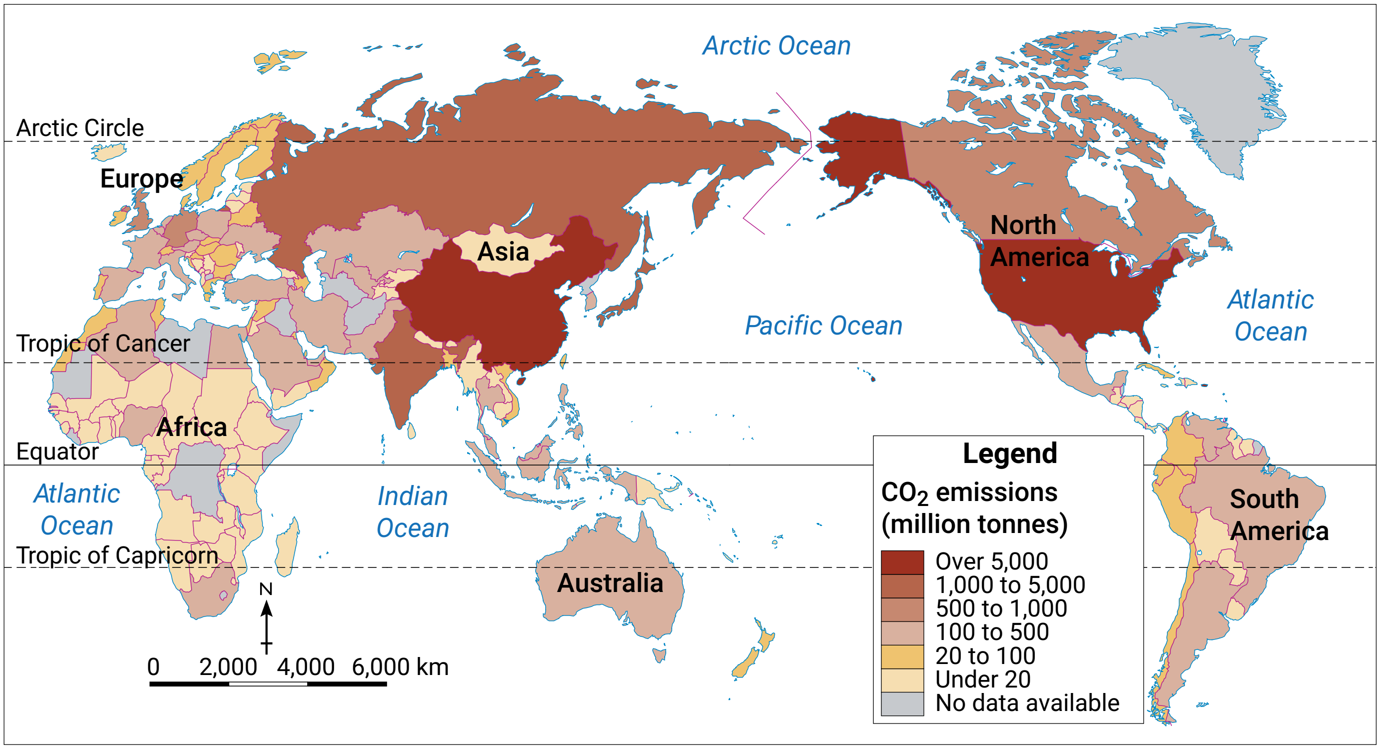


Figure 2 Global carbon dioxide (CO_2) emissions by area

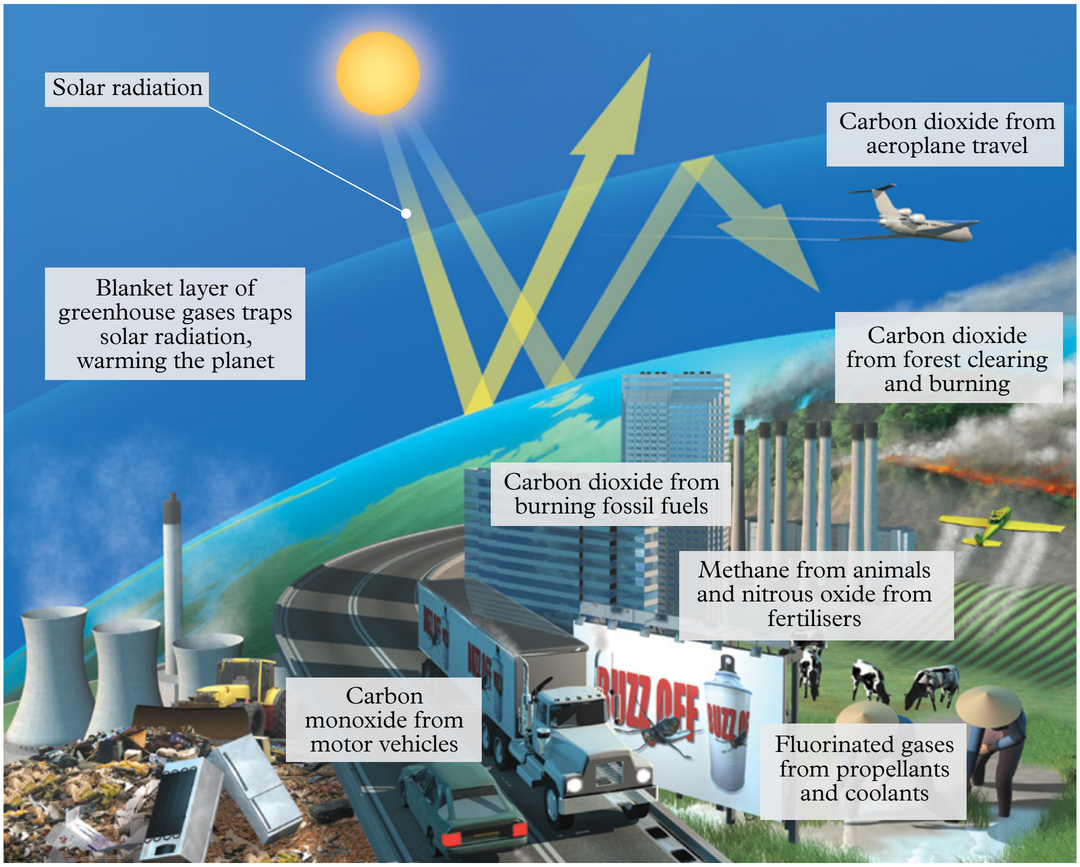


Figure 3 Factors contributing to human-induced climate change

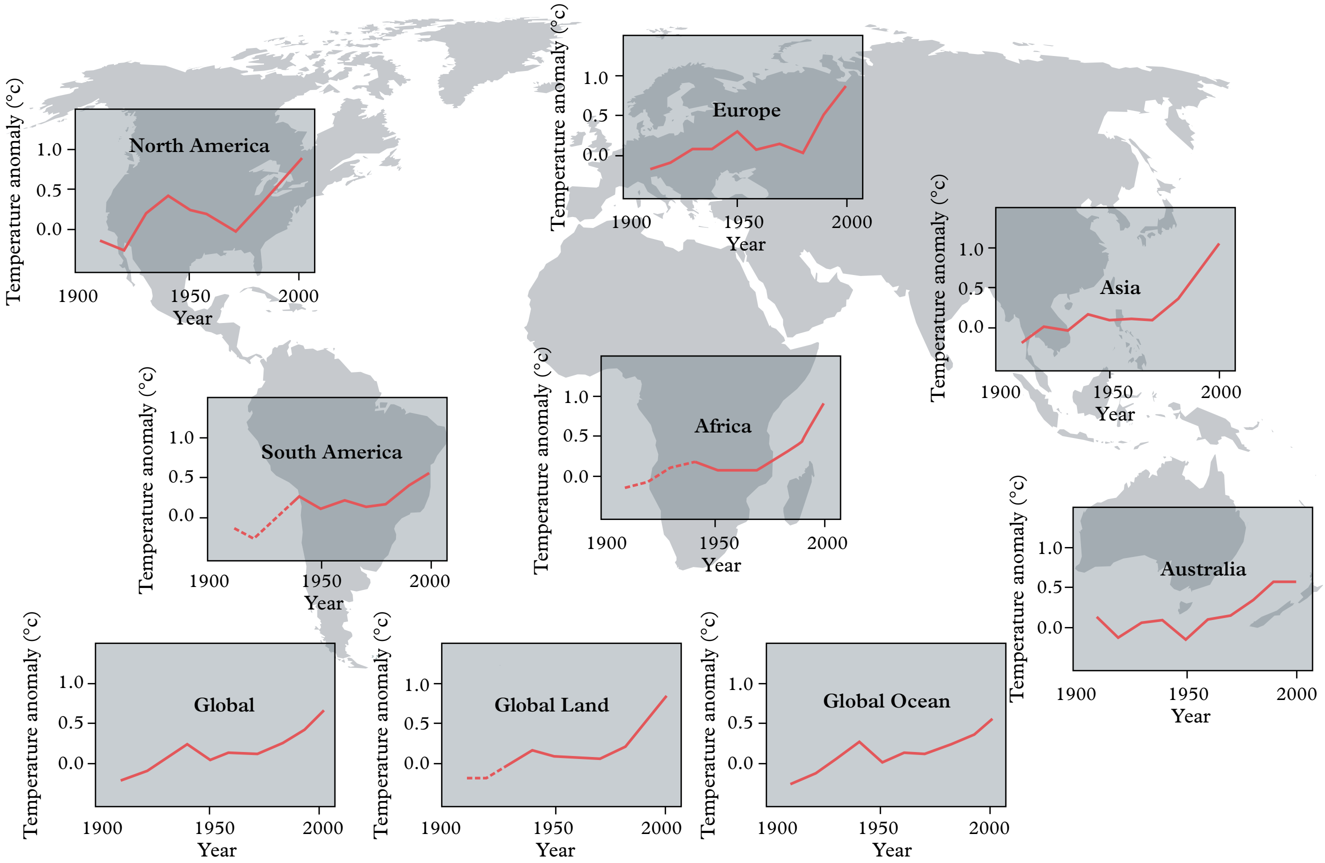


Figure 4 Global changes in long-term average temperature (temperature anomaly) since 1900

Melting sea ice

The ocean is very important in the regulation of global temperatures. It is a carbon sink, absorbing carbon, but it also absorbs up to 90 per cent of the solar radiation that hits the ocean.

As it warms, ocean water is less able to absorb solar radiation. The warmer water also causes sea ice to melt.

Figure 5 Arctic sea ice reflects heat from Earth.

Sea ice is vast, shiny and bright white; it acts as a big mirror that reflects the Sun's radiation back out to space, once again keeping Earth cooler (Figure 5). When this ice melts, more heat is absorbed by the water, increasing its temperature. The warmer water heats the atmosphere above it, driving a cycle that increases global temperature even further.

Melting permafrost

Permafrost is permanently frozen ground that stores carbon from plant material frozen during the last Ice Age. Scientists have been measuring the temperature of the permafrost in Siberia for over 150 years and they have noticed an upwards trend. This means the ice is getting close to melting temperature (0°C) (Figure 6). Scientists believe that as much as two-thirds of Earth's permafrost could disappear by 2200.

permafrost
permanently frozen ground

If Earth's permafrost does melt, it will release thousands of years' worth of carbon into the atmosphere. This would equate to roughly as much as half of all fossil fuel emissions to date from when the world became industrialised.

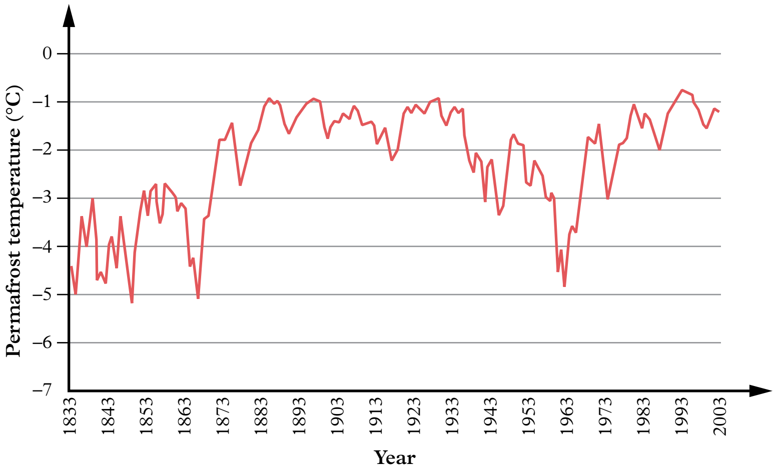


Figure 6 Historical measurements of Siberian permafrost temperatures at 5 m depth suggest that the permafrost is becoming warmer.

Rising sea levels

The gravitational pull of the Moon (and Sun), together with the rotation of Earth, mean there is a high tide approximately every 11 hours. Over many centuries, average water levels have varied. An Ice Age traps water in glaciers and sea ice, exposing land bridges for animals to migrate. These changes are very slow, taking thousands of years to affect sea levels. Over the last 100 years, there has been a dramatic change in sea levels as a result of enhanced greenhouse effect melting ice at the polar ice caps (Figure 7).

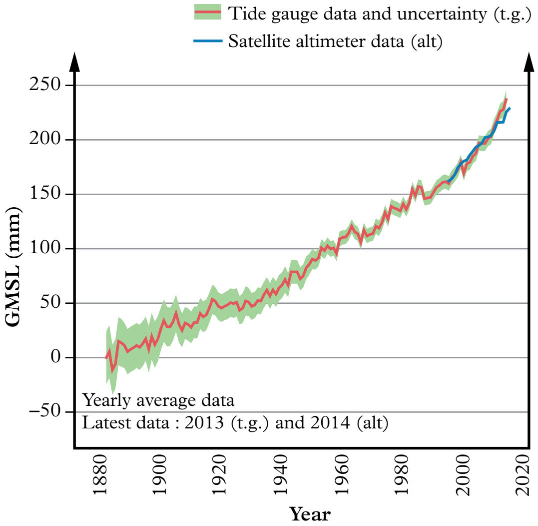


Figure 7 The CSIRO measured the global mean sea level (GMSL) from coastal tidal gauges and satellite data from 1880 to 2014. The overall trend indicates a consistent rise in sea levels.

Check your learning 7.5

Check your learning 7.5

Retrieve

1 **Identify** the two most significant carbon-containing greenhouse gases.

2 **Identify** how much the temperature on Earth has risen over the past century.

Comprehend

3 **Define** the term "permafrost", and **explain** why it will add to greenhouse gas emissions if it melts.

4 **Explain** why climate scientists compare trends over many decades rather than data for 1 or 2 years.

5 **Explain** why the natural greenhouse effect is actually good for life on Earth.

Analyse

6 **Examine** the data shown in this lesson. **Use** the data to support your opinion of the validity of global warming caused by the enhanced greenhouse effect.

7 Climate-change deniers suggest that the increase in sea levels is part of a normal cycle. **Investigate** and **compare** the timescale of previous global warming events to current climate change caused by the enhanced greenhouse effect.

Skills builder: Planning investigations

8 Information about climate change is shared in the scientific community and through media platforms.

- a **Select** two sets of data related to climate change: one from a blog and one that is from a scientific journal or government site. (THINK: Search for popular terminology in government websites.)
- b For each set of data, read the information surrounding it. **Assess** whether the language used increases or decreases the credibility of the data. (THINK: Is the data impacted by the information surrounding it? Does the data change based on where it was published if the original source is still used?)

Lesson 7.6

Experiment: What factors affect a greenhouse?

Aim

To determine which surfaces of Earth absorb energy and radiate it as heat and so are likely to contribute most to the warming of the atmosphere

Materials

- 6 identical clear, empty 600 mL soft-drink bottles with labels removed
- Marker pen
- White paint and brush
- Funnel
- 3 cups of dark soil
- 3 cups of white sand or perlite
- Water
- 6 thermometers inserted into one-hole rubber stoppers that fit securely into the tops of the bottles (or data-logging equipment using long steel temperature probes with Blu Tack to secure the probe in place)
- Sunlight or portable reflector lamp with 150 W floodlight bulb
- Stand to support the lamp set-up (retort stand and clamps)
- Stopwatch

Method

1 Work as a group and label the bottles A, B, C, D, E and F. Paint the upper one-third of bottles B, D and F white to represent cloud cover.

2 Use a funnel to fill the base of bottles A and B with dark soil, bottles C and D with white sand or perlite, and bottles E and F with room-temperature water. Ensure that you fill each bottle to the same depth (5 to 7 cm).

3 Put the six thermometers inserted into the rubber stoppers into the top of each bottle. Ensure that the thermometer bulbs are just above the top of the dark soil, sand/perlite and water, so you measure the temperature of the air (atmospheric). If the thermometer bulbs are touching the substances in the bottles, they will record the heat absorbed directly by the soil, sand or water, which will affect your data. If using a data-logger temperature probe, secure and seal it into the top of the bottle with Blu Tack.

4 Record the initial baseline atmospheric temperature of each bottle in a table. Predict which bottle will reach the highest temperature and justify your prediction.

5 If it is a sunny day, take your bottles outside. Alternatively, set up the 150 W light source on a stand facing down. Place the bottles underneath the light source approximately 15 cm away from the lamp. It is important that all bottles receive equal light. Depending on your light source, you may be only able to do two bottles at a time. If this is the case, ensure the two bottles contain the same substance (e.g. dark soil).

6 Record, in an appropriate table, the temperatures of each bottle every 2 minutes for at least 20 minutes. Calculate the mean, the median and the mode temperature of each bottle and record it in the table.

Results

Draw a graph of time (in minutes) against the mean bottle temperature.

Discussion

1 **Identify** any outliers that can be seen in your graph. **Describe** a possible cause for the outliers.

2 **Use** the graph to **compare** the rate of increasing temperature for the different bottles.

3 **Identify** which bottled environment:
  a produced the lowest temperature
  b would lead to the least heating of the atmosphere.

4 **Explain** the temperature difference between the dark soil and the white sand/perlite.

5 **Explain** the temperature difference between the water and the white sand/perlite.

6 **Explain** how this experiment demonstrates the effect of the oceans and dark and light surfaces on air temperature.

7 If deserts are expanding and ice is melting, exposing dark soil, **describe** the expected effects this will have on atmospheric temperature.

8 **Explain** why each bottle filling was duplicated in this experiment.

Conclusion

Summarise your key findings from this experiment. **Provide** evidence to support each finding.

Figure 1 Water absorbs heat.

Lesson 7.7

Science as a human endeavour: Humans can reduce the effects of climate change

Key ideas

→ Multiple countires have signed international treaties to reduce carbon emissions.

→ Geosequestation removes carbon dioxide from the atmosphere and stores it in the geosphere.

→ Carbon farming stores carbon in the biosphere.

Learning intentions and success criteria

Introduction

The idea of climate change (previously called global warming) was first raised by the scientific community in 1977. As a result, scientists around the world began to coordinate their research in the World Climate Research Program. By 1983, the enhanced greenhouse effect was becoming a political issue. Currently, climate change is seen as a worldwide problem and this has influenced the focus of scientific research.

Kyoto Protocol

In 1997, an international treaty called the Kyoto Protocol was signed by many of the countries that are part of the United Nations. This document stated that global warming exists and that it is a result of carbon dioxide emissions arising from human activity.

The countries that signed the protocol agreed to start working to reduce carbon emissions by 2005 (Figure 1). Australia ratified the agreement in 2007. This required the Australian Government to limit its average annual greenhouse gas emissions during 2008 to 2012 to 108 per cent of its emissions in 1990. In 2012, the protocol was amended to allow countries to extend the commitment to 2020, to allow time to create a new comprehensive climate treaty that would require all countries to reduce their emissions of greenhouse gases.

Figure 1 The use of renewable energy, such as wind power, is one way to reduce carbon emissions.

Paris Agreement

In 2015, a legally binding agreement was signed by all nations (rich, poor, developed and developing) to greatly reduce the amount of greenhouse gases that they produced. It has a system of monitoring and reporting the targets set by individual countries every 5 years. Australia has currently agreed to reduce its greenhouse gas emissions to 26 to 28 per cent below 2005 levels by 2030.

Reducing carbon emissions

Many governments are encouraging industries in their countries to reduce carbon emissions. Some governments are charging a fee for each tonne of carbon a business emits. This is often called a **carbon tax**. Other governments have instigated a **carbon trading scheme** where each business is allowed to release a predetermined amount of carbon emissions. If a company needs to release more carbon dioxide or methane as part of their production process, then they must buy an allocation from another company. This also allows other industries to actively extract carbon dioxide from the atmosphere in order to sell "carbon credits". One carbon credit is often equivalent to one tonne of carbon dioxide.

carbon tax a tax levied on the carbon content of fuels used by businesses or homes

carbon trading scheme the process of allocating a set limit of carbon credits to businesses, which can then trade the credits

Geosequestration

The capture and storage of carbon dioxide underground is called geosequestration. This process, often employed by oil companies, involves capturing carbon dioxide from power station chimneys, separating it and compressing it into a liquid. The liquid is then pumped into depleted oil or gas wells and sealed with a solid plug of thick clay.

Carbon farming

Plants remove carbon dioxide from the air as part of photosynthesis. This carbon dioxide is converted into sugars and proteins that are then used by the plant to grow. Therefore, the greenhouse gas becomes part of the plant's structure. The carbon is considered to be locked in the plant for as long as it lives. For some trees this can be hundreds of years. Carbon farming is the process of growing plants that are not harvested for firewood, building or any other purpose (Figure 2).

Figure 2 Carbon farming removes carbon from the atmosphere and locks it away for hundreds of years.

Reducing methane production

Methane, another greenhouse gas, is often produced as a result of grass fermenting in a cow's stomach. Our increasing global population has meant a need for more food (including meat). This has resulted in more cattle being farmed and, therefore, more methane being released into the atmosphere.

Microbiologists at the University of Queensland are studying ways to modify the bacteria in the stomachs of cows so that they do not produce as much methane. The model organism they use is the bacteria found in the foregut of kangaroos. This particular species of bacteria produces mainly acetic acid as a waste product. This acetic acid is then digested further by the kangaroo. It is hoped that the way these bacteria digest grasses can be mimicked by the bacteria in a cow, thereby reducing the emission of the greenhouse gas.

Small changes, big differences

There are many ways each person can reduce their impact on the climate. These include:

- using public transport or car pooling
- switching off electrical appliances
- using renewable energy such as solar panels
- buying local produce, which reduces fossil fuels being used to transport food long distances
- reducing, reusing and recycling items to prevent them going into landfill and generating methane.

Our ability to make these changes is affected by social factors. A country with a low socioeconomic population will consider increasing wealth to be more important than future environmental concerns. The challenge is to support these countries in considering larger global issues as well as local issues.

Test your skills and capabilities

Scientific communication

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. This can be through the use of graphs, pictures and important figures.

1 **Select** some of the key information you have learnt about climate change and **create** an infographic for your peers.
   a **Decide** on the one to two key ideas that you want to present in your infographic. This should be reflected in the pictures and data that you use in the infographic.
   b **Identify** data (graphs or tables) in this module that support the key ideas.
   c **Identify** how you can present this data in a simple and effective manner. Use pictures of different sizes to represent different values (Figure 3).
   d **Communicate** the key ideas in a short phrase or sentence so that they are clear to the viewer.

Figure 3 Data such as increasing storm strength or biodiversity can be represented in different ways.

Skills builder: Communicating

2 Imagine you are speaking with someone who thinks it is too hard to be environmentally sustainable and that climate change is inevitable.
  a **Explain** why it is important to be sustainable. (THINK: What are the key facts that need to be communicated?)
  b **Evaluate** the impacts of individuals living in a sustainable manner. (THINK: What will change? Will there be bigger impacts?)

Lesson 7.8

Challenge: Measuring carbon farming

Background

The key to measuring the amount of carbon stored in a tree is the size of the tree. Bigger trees are usually older and therefore have had more time to photosynthesise (capture carbon dioxide from the atmosphere). The size of the tree can be determined by the girth (circumference) of the tree at chest height (approximately 1.3 m above the ground)

Aim

To determine the amount of carbon stored in a tree

What you need:

- Tape measure
- Calculator

What to do:

1 Identify a tree in the grounds of your school.
2 Use a tape measure to measure the circumference (in cm) of the tree at 1.3 m above the ground. Repeat this measurement two more times.
3 Calculate the mean (or average) girth of the tree in centimetres.
4 Use Table 1 to determine the dry weight of the tree.

Table 1 The dry weight of trees according to their circumference

Circumference (cm)	Dry weight (kg)
50	106
100	668
150	1,964
200	4,221
225	5,771
250	7,641
275	9,842
300	12,410
325	15,350
350	18,700
400	26,674

5 Half the dry weight of a tree is carbon. Divide the mean dry weight of the tree by 2.
6 Record the amount of carbon stored in the tree you measured.

Questions

1 **Identify** the name of the process used by the plant to extract carbon dioxide from the atmosphere.
2 **Identify** reactants and products in the chemical reaction you named in the previous question.
3 **Calculate** the amount of carbon dioxide (in kg) that was absorbed by the tree to create its carbon store by multiplying the amount of carbon stored by 3.67.
4 **Describe** how the tree you measured does or does not represent all the other trees in the area. Use the term "sample size" to describe how the method you used could be improved.
5 **Describe** what would happen to the carbon stored in the tree if it was chopped up and burnt as firewood.
6 **Describe** what would happen to the carbon stored in the tree if it was turned into furniture or used to build a house.

Lesson 7.9

Review: The carbon cycle

Summary

Lesson 7.1 Earth's spheres are balanced

- Earth is made up of the lithosphere (solid crust), atmosphere (air), hydrosphere (water) and biosphere (living organisms).
- Interaction between Earth's spheres maintains global temperatures and climate.

Lesson 7.2 Carbon cycles through Earth's spheres

- The carbon cycle describes how carbon atoms cycle through an ecosystem.
- Photosynthesis removes carbon dioxide from the atmosphere.
- Carbon trapped in the lithosphere cycles very slowly, whereas carbon in the biosphere and atmosphere cycles much faster.
- Carbon can be stored in carbon sinks such as fossil fuels and the ocean.

Lesson 7.3 Human activity affects the carbon cycle

- Combustion reactions use fuel and oxygen to produce heat and water.
- The use of fossil fuels (petrol and oils) releases carbon into the atmosphere.
- Increasing agriculture can disrupt the carbon cycle.

Lesson 7.4 Traditional knowledge reduces carbon emissions

- Hazard reduction burning is the large-scale burning of all plants in an area.
- Cultural burning uses cooler flames to burn small, selected parts of the landscape.
- Cultural burning increases carbon storage and maintains key indigenous plants and animals.

Lesson 7.5 Carbon dioxide levels affect the greenhouse effect

- Earth is surrounded by an atmosphere of natural greenhouse gases that reflect radiation from the Sun and retain the warmth from Earth.
- Evidence for enhanced global warming can be found in the melting of sea ice and permafrost and increasing sea levels.

Lesson 7.7 Science as a human endeavour: Humans can reduce the effects of climate change

- Multiple countires have signed international treaties to reduce carbon emissions.
- Geosequestation removes carbon dioxide from the atmosphere and stores it in the geosphere.
- Carbon farming stores carbon in the biosphere.

Review questions 7.9

Review questions: Module 7

Retrieve

1 **Identify** the best definition for the lithosphere.
  - **A** The outermost rocky layer of Earth including the mantle and crust
  - **B** The layer of gases that surrounds Earth and other planets
  - **C** The intersection between the atmosphere, hydrosphere and biosphere
  - **D** The collection of all Earth's water

2 **Identify** which of the following would not reduce carbon emissions.
  - **A** Charging a carbon tax
  - **B** Using public transport
  - **C** Using solar energy
  - **D** Using fire instead of electricity

3 **Identify** the best definition for the cryosphere.
  - **A** The layer of gases we commonly call air
  - **B** All Earth's water
  - **C** Frozen water in the hydrosphere
  - **D** The rocky outermost layer of Earth

4 **Identify** which of the following statements are true and which are false.
  - **a** Carbon farming is the process of releasing carbon into the atmosphere.
  - **b** The Paris Agreement is a legally binding agreement through which European nations agreed to greatly reduce the amount of greenhouse gases they produced.
  - **c** Geosequestration is the capture and storage of carbon underground.
  - **d** Climate change is caused by melting permafrost.

5 **Identify** the layer of Earth where the tectonic plates are found.

6 The biosphere includes parts of the atmosphere, lithosphere and hydrosphere. **Identify** two parts or examples of the biosphere you may find in each of these three spheres.

Comprehend

7 **Identify** three gases that are found in our atmosphere and **explain** why they are important to life on Earth.

8 **Describe** one way carbon can move from the atmosphere to the biosphere.

9 **Explain** how the lithosphere contributes heat to the atmosphere.

10 **Describe** two ways carbon can move from the biosphere to the atmosphere.

11 **Describe** one way that increased industrialisation, particularly since the nineteenth century, has affected the carbon cycle.

12 **Describe** how agriculture has increased the amount of greenhouse gases in the atmosphere.

13 **Describe** two predicted outcomes of rapid climate change.

14 The hydrosphere is often considered a carbon sink.
  - **a** **Define** the phrase "carbon sink".
  - **b** **Identify** the chemical reaction that occurs as a result of the ocean acting as a carbon sink.
  - **c** **Describe** the impact on marine life that occurs as a result of the ocean acting as a carbon sink.

15 **Explain** the process of combustion and how it contributes to the enhanced greenhouse effect.

16 The glaciers on Mount Kilimanjaro in Tanzania are disappearing eight times faster than 20 years ago due to climate change (Figure 1). **Explain** how cloud cover can affect the atmospheric temperature and the melting of glaciers.

Figure 1 Notice the snow cap on Mount Kilimanjaro.

17 **Describe** two ways humans are trying to reduce rapid climate change due to the enhanced greenhouse effect.

18 **Describe** the impact of bushfires on the carbon cycling through Earth's spheres.

19 **Describe** how cultural burning could be used to reduce the transfer of carbon into the atmosphere.

20 The human population was fairly stable until about 1 CE. Then it started to grow, and its growth accelerated until it almost reached an exponential rate. In the past century, the human population has almost quadrupled. **Describe** two impacts of the population increase on world ecosystems.

Analyse

21 **Contrast** the natural greenhouse effect and the enhanced greenhouse effect.

22 **Contrast** the rate the climate changed millions of years ago to the way the enhanced greenhouse effect is causing climate change.

Apply

23 **Evaluate** the effects of melting permafrost on climate change (by defining "permafrost", describing the effects of melting permafrost on Earth's spheres, and deciding whether these effects will contribute to climate change) (Figure 2).

Figure 2 Melting permafrost can impact Earth's spheres.

24 The northern bettong is a very small, endangered nocturnal marsupial (Figure 3). It is an omnivore that eats small invertebrates, herbs, grasses and a species of fungus that makes up approximately 45 per cent of its diet. Northern bettongs were once widely distributed throughout Queensland. However, there are now only three populations left along the western edges of the wet tropics of north Queensland.

- a **Investigate** the northern bettong on the internet.
- b **Describe** the human activities that are contributing to the northern bettong being listed as endangered.
- c **Explain** how these same human activities affect the carbon cycle in the area.

Figure 3 The northern bettong is an endangered species.

Social and ethical thinking

25 Over 80 per cent of Earth's energy resources are non-renewable and declining. In the twentieth century, most energy use was concentrated in a few nations that make up only a small proportion of Earth's population. The seven largest economies at the beginning of the twenty-first century (with 10 per cent of the global population) used approximately 45 per cent of the total primary energy supply. Yet, approximately two billion people on Earth do not have access to electricity. In a group, **discuss** the ethical fairness of this distribution and the potential impact of this resource use on climate change and the global population.

Critical and creative thinking

26 **Create** a diagram that identifies the way carbon moves between Earth's spheres.

27 **Construct** a chart or table that describes environmental carbon sinks and carbon producers.

28 **Create** a mind map showing the potential connections and dependencies between the four spheres of Earth and their components. **Identify** as many links as possible.

29 Combustion for electrical energy is one of the most common ways humans contribute carbon to the atmosphere. Imagine you had to reduce your energy impact on the environment. Look at all the appliances and gadgets you use in your home.

- a **Identify** one appliance or gadget that you could absolutely not bear to give up.
- b **Outline** why this one item is "essential" to you.
- c **List** the appliances and gadgets that you could live without.

30 Manufacturers of solar panels claim that solar power is better for the environment.

- **a** **Investigate** solar panels and **evaluate** the manufacturers' claim (by describing the materials used in the manufacture of solar panels, the energy needed to produce them, how long a panel will last and what happens to a solar panel when it reaches the end of its life).
- **b** **Compare** these factors to the benefit of the solar energy generated and decide if the manufacturers' claim is valid.

31 Earth's climate and weather are the result of global interactions between systems and cycles. **Evaluate** how this supports the argument that logging in any country affects everyone else on the planet (by describing how trees contribute to the atmosphere, hydrosphere and biosphere, describing how the sphere in one country affects other countries, and describing how the spheres affect weather and climate).

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.

Responding to global warming

The Kyoto Protocol is an international treaty which states that global warming exists and is a result of carbon emissions arising from human activity (Figure 4). Australia did not ratify the agreement until 2007.

- **Identify** the measures that Australia agreed to commit to.
- **Describe** the strategies that Australia has used to meet its commitments.
- **Evaluate** how successfully Australia has met those commitments.
- Artificial intelligence can be used to identify any changes to the level of forest cover that is maintained in Australia. **Investigate** how satellite images can be used to estimate the level of deforestation that still occurs in Australia.

Figure 4 The Kyoto Protocol acknowledged the existence of global warming and the fact that it is a result of human activity.

Landcare Australia

Landcare Australia is an organisation involved in developing and providing a sustainable approach to integrated land management and building resilience in food and farming systems (Figure 5).

- **Investigate** the nearest Landcare group to your area.
- **Describe** the work that they do.
- **Explain** how this work could improve soil quality and increase carbon sequestration in soils.

Figure 5 Landcare Australia

Climate change: Global warming or ice age?

Like Earth, the Sun demonstrates cycles of behaviour. One such pattern that has been identified is a period during which sunspots are absent. The lack of sunspots could result in a global temperature decrease for Earth (Figure 6).

- **Investigate** sunspots and the solar cycle.
- **Describe** what a sunspot is.
- **Explain** what the solar cycle is.
- **Contrast** a solar maximum and a solar minimum.
- **Investigate** the potential impact of the solar cycle on Earth's climate.

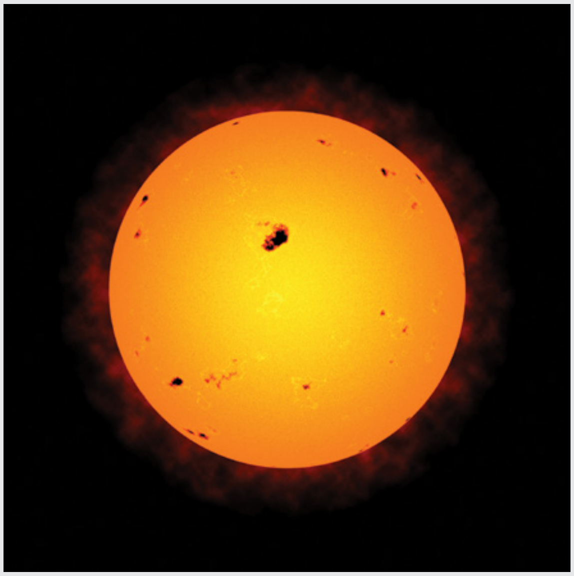


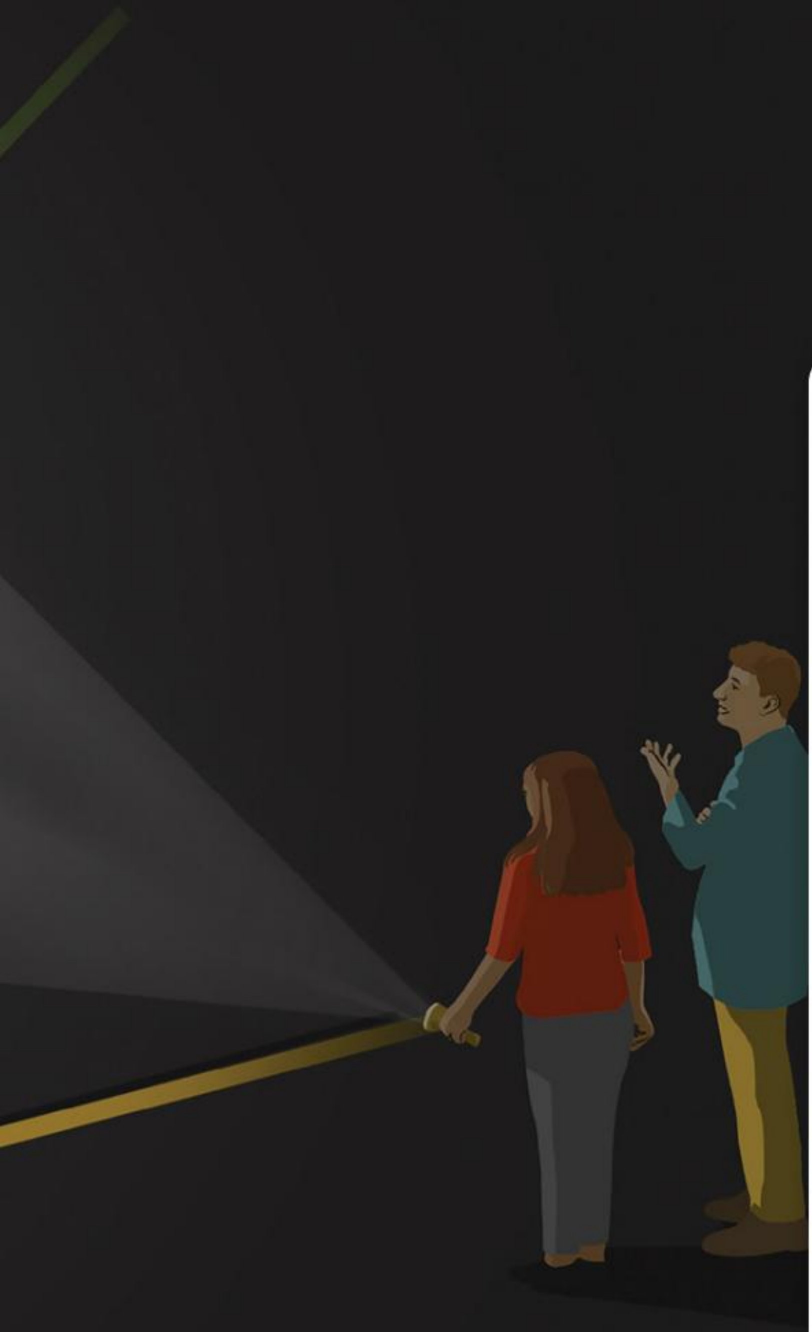
Figure 6 Scientists can use the presence of sunspots to track the solar cycle.

Module 8

Particles and waves

Overview

Energy transfer can be described using wave and particle models. Waves (electromagnetic and mechanical) have the properties of amplitude, wavelength, frequency and speed. Sound energy travels in waves, and its volume and pitch are linked to amplitude and frequency. Heat transfer is explained by the particle model in conduction and convection. The particle model can also be used to explain static electricity and electrical current, including voltage, conductors and insulators. Electromagnetic radiation, such as light, is understood through both wave and particle models and is used in radar, medicine and communication.



Lessons in this module

Lesson 8.1

Heat can be transferred by convection and conduction

Learning intentions and success criteria

Check the next lesson for a linked practical activity or experiment.

Key ideas

→ The energy from heat moves spontaneously from a hot material to a cool material.

→ Conduction occurs when the kinetic energy of particles is transferred.

→ Convection occurs when particles with high kinetic energy move to another space.

Modelling energy transfer

In Year 8 you discovered how energy can be transferred from one substance or medium to another. The way the energy is transferred can vary depending on the type of energy that is being transferred. This can be modelled using wave or particle models to explain the movement of the energy. Throughout this chapter we will look at the different ways to model thermal (heat) energy, sound energy, electrical energy and light energy.

Modelling thermal energy

The particle model suggests that all things are made up of particles of atoms or molecules that have kinetic (movement) energy. Solid objects have vibrating particles that are bonded closely together. If thermal energy is added to a solid object, the particles start vibrating faster until they can move around one another. This increase of energy and movement turns the solid into a liquid. If more energy is added to the liquid, particles will start moving faster until they are able to break free and move freely as a gas (Figure 1).

When modelling thermal energy, it is important to consider the movement of the heat. Cold objects have less thermal energy and hot objects have more thermal energy.

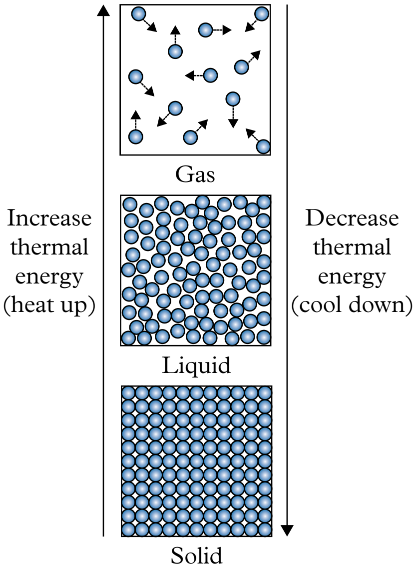


Figure 1 Increasing or decreasing thermal energy can change the movement of particles and the state of an object.

Heating by conduction

conduction the transfer of thermal energy from hot objects to cooler objects by direct contact with no movement of material

Heating an object by **conduction** involves the transfer of thermal energy between two objects that are in contact with each other. The energy is transferred from an object with high thermal energy to an object with low thermal energy (from hot objects to cooler objects) (Figure 2).

This continues until the two objects are the same temperature (equal amounts of thermal energy).

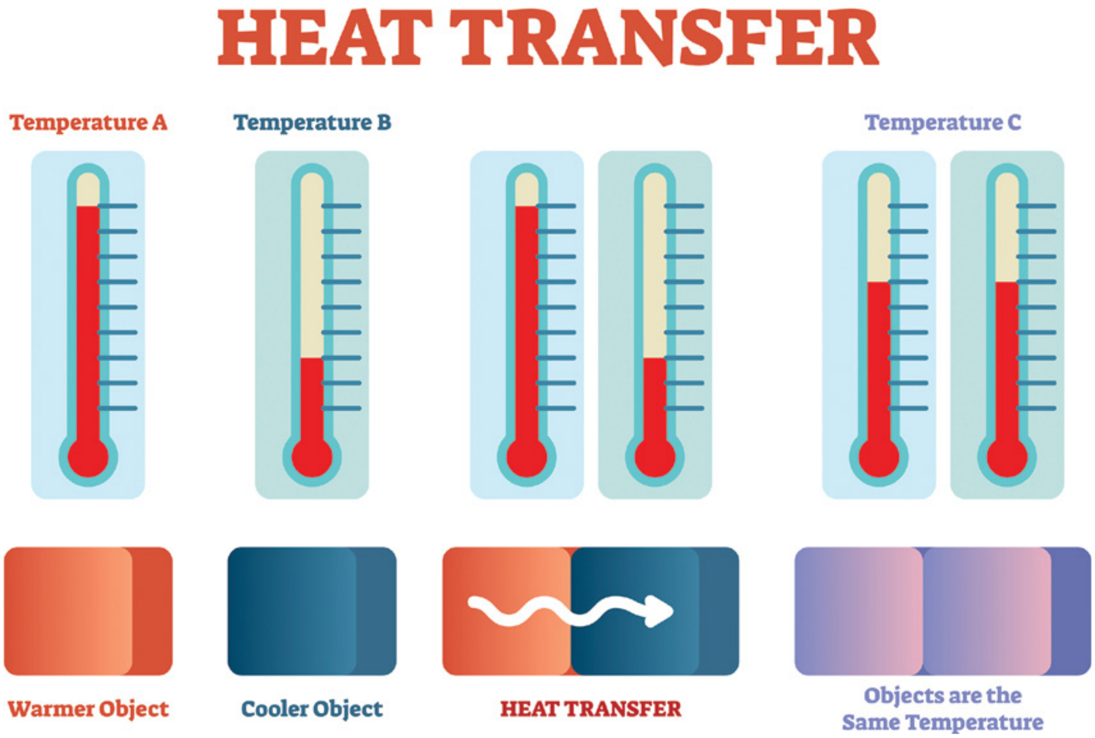


Figure 2 Thermal energy is transferred from an object of high thermal energy to an object with low thermal energy.

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 molecules in the gas flame move quickly and occasionally bump into atoms of the relatively cold metal of the saucepan.
3 Kinetic 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 thermal kinetic energy to them. This heats the saucepan.
5 When the saucepan heats up, the thermal kinetic energy is transferred to the water inside it.

Although the thermal 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.

Conductors and insulators

A **thermal conductor** is any material that allows thermal energy to flow easily through it. All metals are conductors of thermal energy, although some are better conductors than others. **Thermal insulators** are materials that slow down the transfer of thermal energy because the molecules don't allow the thermal kinetic energy to flow very easily (Figure 3). 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 loss during summer and winter. Insulation can hold thermal energy in or keep it out.

You can test the thermal conductivity of the different materials around you. If you put your hand on a metal object, it will feel cold to touch. This is because the metal conducts heat away from your hand, making it feel cold. If you touch a wood object, it will feel warmer than the metal object. In reality, both objects will be the same temperature, but the wood acts like a thermal insulator, preventing the thermal energy from being conducted away from your hand. Because your hand is not losing heat, it will feel warm.

thermal conductor a material that allows thermal energy to flow through

thermal insulator a material that prevents or slows down the transfer of thermal energy

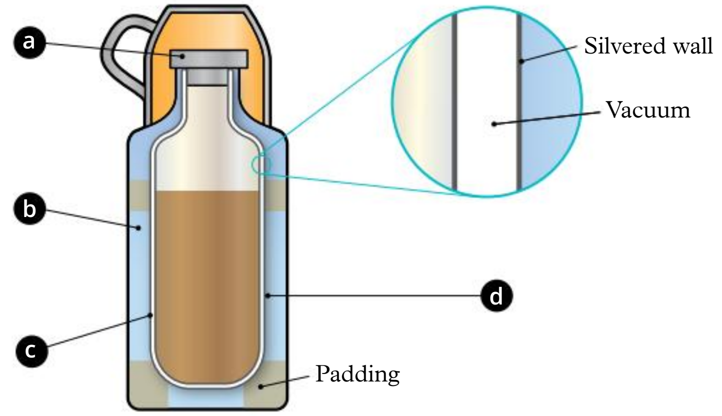


Figure 3 Vacuum flasks are designed to keep hot substances hot, and cold substances cold. To do this they must prevent the contents from losing or gaining heat – conduction and convection must be minimised. Careful choice of insulating materials and clever design make this possible.

- **a** The plastic stopper is an insulator – it prevents heat loss or gain through convection and conduction.
- **b** The glass walls are insulators – they prevent heat loss or gain through conduction.
- **c** The vacuum between the walls is an insulator – it prevents heat loss or gain through conduction and convection.
- **d** The silvered wall reflects heat – it prevents heat loss by radiation.

Heating by convection

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

The particles in liquid and gas materials are able to move more freely than in solid objects. In these materials, thermal energy moves by **convection**. As the particles gain thermal kinetic energy, they are able to move away from the heat source. Tiny currents, called **convection currents**, carry the particles and their thermal energy across the liquid or gas until the heat is evenly spread.

When we heat a saucepan of water on a gas flame, the following occur.

1 Thermal 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 gain kinetic energy and 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 (less dense) water molecules near the bottom of the saucepan begin to rise, leaving room for the cooler (more dense) water molecules to take their place (Figure 4).

4 The heated water molecules take thermal energy with them as they move.

We heat liquids from below because most of the energy transfer in liquids (and gases) takes place by convection. This process happens in the air. 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.

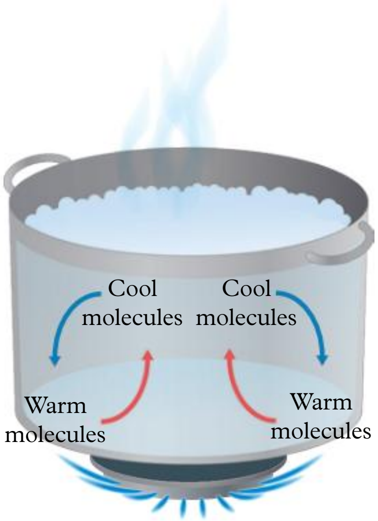


Figure 4 The pot conducts the heat from the flame to the water. Convection currents are created in a saucepan of water when it is heated. The heated water molecules (warm molecules) rise while the cooler ones (cool molecules) sink.

Check your learning 8.1

Check your learning 8.1

Retrieve

1 **Identify** two examples of situations where thermal energy is transferred by:
  a conduction
  b convection.

Comprehend

2 **Identify** one example of where good thermal insulators and conductors are needed in everyday life. **Describe** the materials that are used in each situation.

3 Some modern saucepans have a copper bottom, steel sides, a plastic handle and a glass lid. **Explain** why each of these materials is used for particular parts of a saucepan.

4 Think of a situation where you can see expansion due to heating of a solid, liquid or gas. **Explain** what the molecules or atoms are doing to cause the expansion.

Analyse

5 **Consider** why scientists are happy to refer to thermal energy transfer as heating, even though in every case something is being cooled. (HINT: Energy can sometimes be referred to as a property of an object. Can you have "cold energy"?)

Skills builder: Problem solving

6 The following materials are used to make the bottom, handle or lid of a saucepan. **List** the pros and cons of using each of the following materials. (THINK: What are the advantages? What would be the disadvantages? How would each material be affected by heat energy?)
  a Plastic for the handle
  b Copper as the lid
  c Glass as the bottom

7 Based on your pros and cons list in question 1, **identify** which material should be used for each part of a saucepan. (THINK: What do you need to touch? What holds the food being cooked?)

Lesson 8.2

Experiment: Investigating heating by convection

Aim

To investigate heating water by convection

Materials

- Bunsen burner
- Tripod
- Heatproof mat
- 600 mL beaker
- Water
- Potassium permanganate crystals (or a few drops of food colouring)
- Dropper or pipette

Method

1 Set up the experiment as shown in Figure 1.

2 Fill the beaker with water. Put individual crystals of potassium permanganate on the

bottom of the beaker, at the edge. Alternatively, 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 crystals. (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 coloured water takes from the burner to the top of the water and back down again.

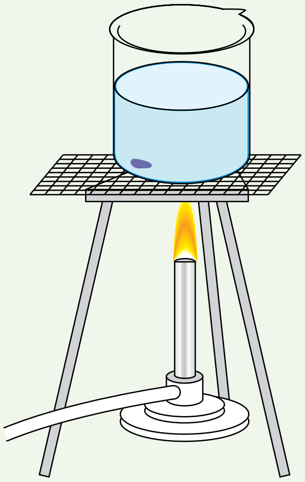


Figure 1 Experimental set-up

Results

Draw a labelled diagram showing the movement of the coloured water.

Discussion

1 **Define** the term "convection".

2 **Define** the term "conduction".

3 **Describe** the movement of the coloured water.

4 **Use** the terms conduction and convection to **explain** how the movement of water particles changes as they are heated.

5 **Use** the movement of the particles in the water to **explain** the movement of the coloured water.

6 **Develop** an experimental method to test the scientific question "What if a more dense solution was used?"

Conclusion

Describe what you know about heating water by convection.

Lesson 8.3

Experiment: Testing insulating materials

Background

Different materials have different thermal properties. The ability of a material to resist the transfer of thermal energy is called the R-value of the insulation. The higher the R-value, the more the insulator is able to resist the flow of thermal kinetic energy and the better it will insulate.

Aim

To test the insulating properties of different materials

Materials

- A variety of different materials with insulating properties (newspaper, tissues, cotton balls, Styrofoam, aluminium foil, petroleum jelly, Cheetos, etc.)
- 5 × 50 mL beakers
- Low temperature hot plate
- Scales
- 5 ice cubes (approximately the same size from ice trays)
- Stopwatch

Method

1 Write a hypothesis identifying which materials will have the highest R-value.
2 Select four materials to test.
3 Add 2 cm of each material to the bottom of an individual beaker. Leave the fifth beaker without any material in the base.
4 Turn the hot plate on a low temperature. Place each beaker on the hot plate so that they are exposed to the same amount of thermal energy.
5 Weigh and record the mass of each ice cube.
6 Place a single ice cube in the centre (on top of the materials) of each beaker.
7 Leave the ice cubes exposed to the thermal energy for 10 minutes.
8 Weigh the final mass of each melted ice cube.
9 Calculate the change in mass of each ice cube.

Results

Draw a table to record the initial mass, final mass and change in mass of each ice cube.

Discussion

1 **Define** the phrase "thermal insulator".
2 **Describe** how the thermal energy of the hot plate was transferred to the ice.
3 **Describe** how the thermal energy affected the water particles in the ice.
4 **Identify** the material that had the:
  a highest thermal insulating property
  b lowest thermal insulating property.
5 **Design** a valid experiment that would investigate the question "What if the amount of thermal insulator was doubled?" **Identify** any assumptions that you might make when selecting the materials to test.

Conclusion

Describe what you know about the insulating properties of the different materials used in this experiment.

Lesson 8.4

Vibrating particles pass on sound

Key ideas

→ Sound is caused by the vibration of particles moving in a longitudinal wave.
→ One wavelength is the distance between one compression of air particles and the next.
→ The distance the air particle moves from its normal position is called the amplitude.
→ The number of waves passing a point each second is the frequency of the wave.

Learning intentions and success criteria

Modelling sound waves

We know that sound energy travels because we can often hear it a long way from its source.

Consider the example of a drum being played. The drum skin vibrates (moves up and down) when it is hit. The kinetic energy of the vibrations is transferred to the surrounding air particles, pushing them closer together in one place and forcing them further apart in another. In this way, the air around the drum is made to vibrate too. This causes the particles further away to vibrate, and so on, until the air close to your ears eventually vibrates and causes your eardrum to vibrate too. And that's when you hear the sound.

compression part of a sound wave where air particles are forced close together

rarefaction a reduction in density; refers to part of a sound wave where air particles are forced apart

longitudinal wave a type of (sound) wave where the particles move in the direction of travel of the wave

amplitude the distance a particle in a wave moves, from its position of rest

The region with the particles forced close together is called a **compression**, and the less dense region where the air particles are further apart is called a **rarefaction**. Sound waves travel as a **longitudinal wave**. This means the air particles do not travel to your ear. Instead they move back and forth parallel to the wave as the vibration passes through the air. The distance a particle of air moves from its normal position is called the **amplitude** of the wave (Figure 1).

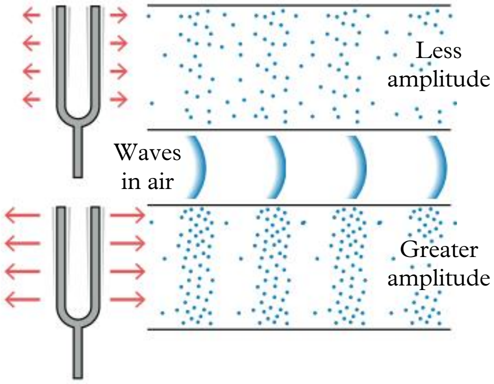


Figure 1 Arrows indicate how far a particle in a sound wave moves from its normal position.

Sound waves with a large amplitude mean the air particles move with greater kinetic energy. This makes the sound feel louder to our ears. An example of this is when musicians use amplifiers to increase the loudness of their music. Amplifiers increase the distance air particles move during compression and rarefaction.

A sound wave moves out in all directions from the place where the vibration began (Figure 2).

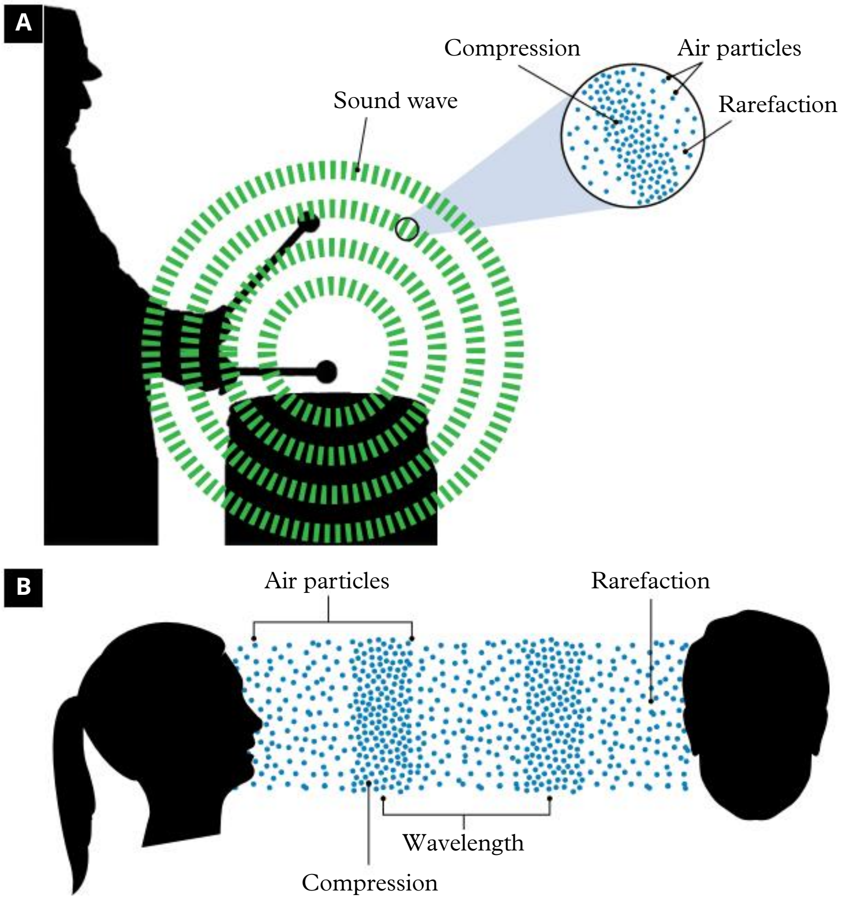


Figure 2 (A) When a drummer hits a drum skin and (B) when a person speaks, a sound wave is produced.

Describing sound

You can sing high. You can sing low. You can talk in a funny voice if you want to because you can alter the number of vibrations coming from your vocal cords every second.

The distance between compression waves can be close together or far apart. The distance between the start of one compression wave and the start of the next is called the **wavelength** (Figure 3). Short wavelengths mean more vibrations hit your eardrum each second.

When the compressions travel close together, they are considered more frequent. The number of waves that pass a point each second is called the **frequency** of the wave.

This is measured in the unit **hertz** (symbol Hz).

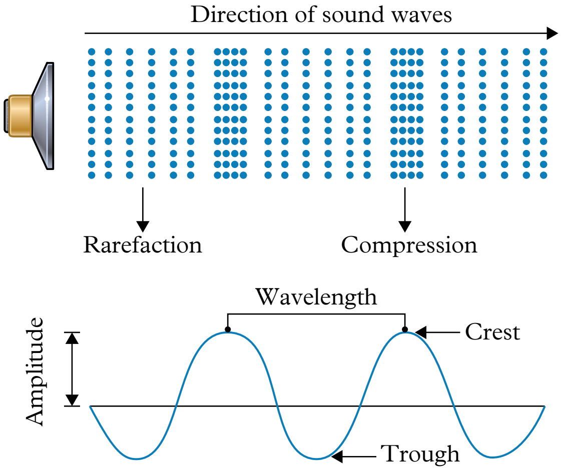


Figure 3 A wavelength is the distance between two crests or between two troughs.

wavelength the distance between two crests or troughs of a wave

frequency the number of waves that pass a point every second; measured in hertz

hertz the unit used to measure frequency

Pitch

We hear different frequencies as different pitches (Figure 4). For example, a soprano singer sings the high notes in an opera. These notes are high pitched. The sound waves for these notes have very short wavelengths and therefore high frequency. A deep bass singer is able to sing very low-pitched notes. These notes have long wavelengths and few of them can pass a point each second. Therefore, they have a low frequency.

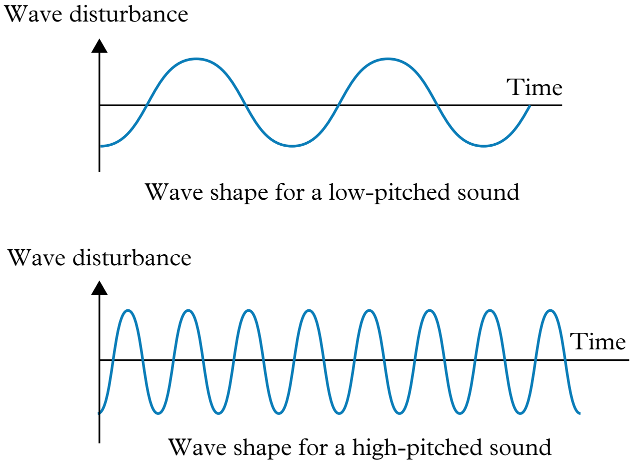


Figure 4 High-pitched sounds have shorter wavelengths than low-pitched sounds.

As the waves move further away from their source, they lose energy and eventually fade out (Figure 5). As neighbours will confirm, the closer you live to a drummer, the louder they seem!

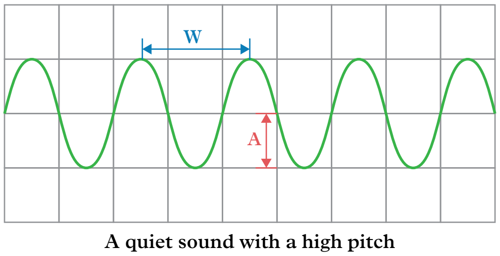


Figure 5 Quiet sounds have small amplitudes while high-pitched sounds have short wavelengths.

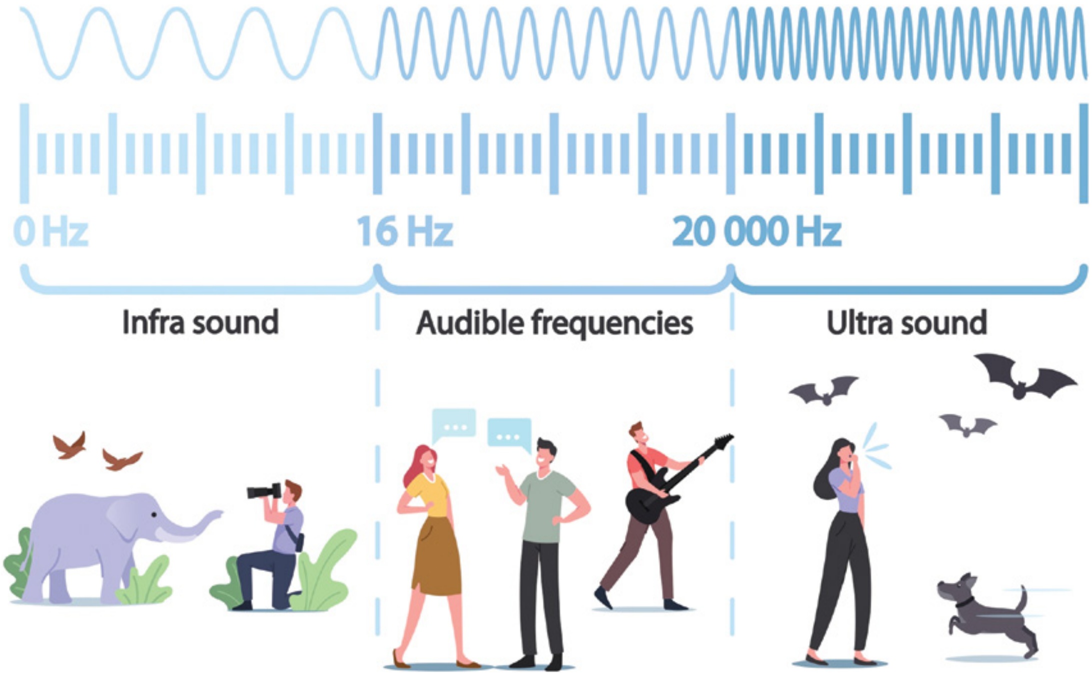


Figure 6 Human hearing is limited to frequencies between 16 Hz and 20,000 Hz.

Figure 7 Middle C (shown in red) played on a piano has a wavelength of 1.33 m and creates vibrations at a frequency of 256 vibrations every second, or 256 Hz.

Check your learning 8.4

Check your learning 8.4

Retrieve

1 **State** how the particles in air are arranged in a:
  - a compression
  - b rarefaction.

Comprehend

2 Work with a partner. **Explain** to your partner how the sound waves created by hitting a cymbal reach your ears. **Use** the following terms: compression, rarefaction, sound wave, spread out, air particles and ear. Write down your explanation.

3 **Explain** how the air moves when an opera singer sings a note.

Analyse

4 Of the two springs shown in Figure 8, **identify** which demonstrates a:
  a lower frequency
  b shorter wavelength.

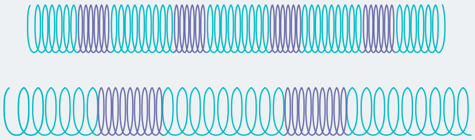


Figure 8 Springs

5 Imagine you have three tuning forks of frequencies 250, 500 and 1,000 Hz. **Identify** the frequency that would have the:
  a lowest pitch
  b highest pitch.

6 **Contrast** the frequency and the pitch of sound.

Apply

7 **Investigate** how the speed of sound in air changes in different temperatures (HINT: Hot air has faster moving particles).

Skills builder: Communicating

8 Sometimes, using a diagram is the best way to explain a scientific concept.
  a **Construct** a diagram of a longitudinal wave. (THINK: What does a longitudinal wave represent? What does a wave diagram look like? Is my diagram scientifically accurate?)
  b **Identify** a compression, rarefaction and wavelength on the diagram and add a label for each. (THINK: Have I put the correct labels on the right parts of the diagram?)

Lesson 8.5

Sound can travel at different speeds

Key ideas

→ Sound travels through air at approximately 340 m/s at sea level at 20°C.

→ The speed of sound varies according to the temperature and material through which it travels.

→ Particles have more kinetic energy at higher temperatures, so they can compress more easily.

→ The more closely packed the particles, the faster the sound wave travels.

Learning intentions and success criteria

Check the next lesson for a linked practical activity or experiment.

Sounds of silence

If you are a drummer, you have probably been told more than once to "Keep the noise down!" But is there somewhere you could play your drum kit as hard and as loud as possible with absolutely no sound being heard? The answer is "Yes", but it is not a place you can get to easily.

A famous sci-fi movie was advertised with the tagline: "In space, no one can hear you scream". The moviemakers were right. In outer space, you could play your drum kit without anyone hearing a sound – but you wouldn't hear it either. You could even see an explosion without hearing a thing. This is because sound needs something to travel through; it needs a substance (or medium) that contains particles that can be compressed to create the sound waves. The medium could be a solid, a liquid or a gas. In space, the particles are too far apart to push against each other (Figure 1).

Figure 1 In outer space, there are so few particles of gas, and they are so far apart, that they cannot be compressed. As a result, outer space is silent.

Speed of sound

The speed of sound is affected by the closeness of the particles in a material, and how far they can move. For example, the particles in water are much closer together than in air. This means the water particles can move and compress more easily than air particles. Sound such as the song of a whale will travel more easily through water than air (Figure 2). This is the reason that whales sing their tunes under the water rather than on the surface.

The particles in a solid are packed even closer together. Therefore, sound will travel even faster in most solids (Table 1).

The speed of sound also depends on the temperature of the material it is travelling through. Particles at higher temperatures have more kinetic energy. Since the particles are already vibrating fast, they can move more easily in a compression wave.

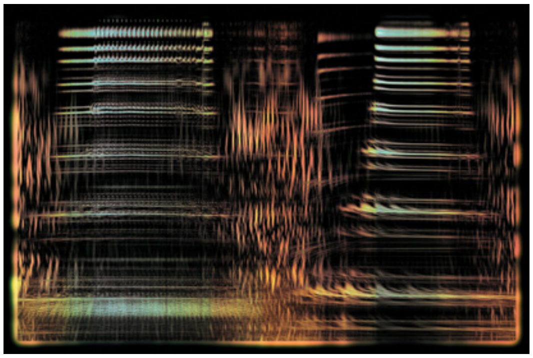


Figure 2 Sound travels five times faster in water than in air. Blue whales sing to each other in a series of moans and pulses (shown) that can travel thousands of kilometres under water.

Table 1 Speed of sound in different materials and at different temperatures

Material	Speed (m/s)
Air at 0°C	331
Air at 20°C	343
Water at 20°C	1,482
Lead	1,960
Glass	5,640
Steel	5,960

Echoes

Despite sound being able to travel faster through a solid, sometimes a sound in the air will bounce off the surface of a solid. This usually occurs when the solid is very dense and has a flat surface facing the direction of the sound. You may have noticed this when you shout from the top of one mountain into a valley. The sound of your shout will travel through the air and be reflected off the surface of the nearby mountain. You will hear the echo when the bouncing sound travels back to your ear (Figure 3).

Figure 3 Echos occur when a sound wave bounces off a flat surface.

If a surface is not flat and hard, and instead is soft or has many lumps and bumps, the sound wave is either absorbed or broken up. This means there is no reflection of the sound. Most music recording studios have walls with soft furnishings or walls with interrupted surfaces.

Sonar

Since the First World War, reflected waves have been used to detect enemy submarines under water.

In a similar way to radar (radio waves), **sonar** sends out sound waves and records how long the sound takes to reflect or echo back after striking an object (Figure 4). The longer the sound takes to return, the further away the object. An exact location can be calculated by knowing how fast sound travels in water. This information, along with the time taken for the sound to return, allows the exact location of a submarine to be determined.

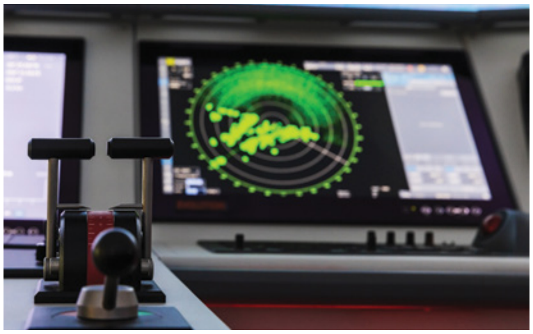


Figure 4 Sonar records the length of time it takes for a sound wave to return to the sensor.

sonar the detection of the location of objects through the use of soundwaves

Sonar is widely used today and can help to map the ocean floor, check the depth of water and locate schools of fish (Figure 5 and Figure 6).

Figure 5 Sonar is used to locate schools of fish in the ocean.

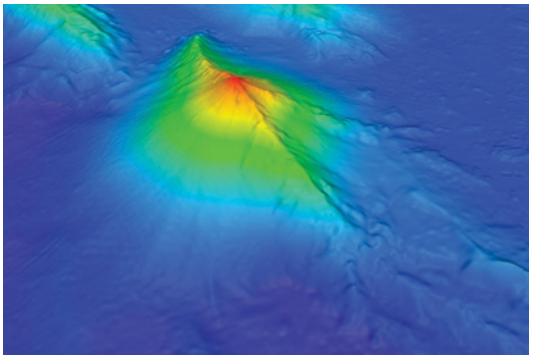


Figure 6 Sonar is used to map volcanoes on the ocean floor.

Check your learning 8.5

Check your learning 8.5

Retrieve

1 **Identify** which of the following materials will allow sound to travel the fastest.

- **A** Water
- **B** Lead
- **C** Air
- **D** Glass

Comprehend

2 **Describe** how sound moves through a liquid.

3 **Explain** why we would not hear the noise of an explosion on Earth if a nearby star were to explode.

Analyse

4 **Compare** sound moving through gases and solids.

Apply

5 Echoes occur when sound bounces off smooth surfaces. **Identify** which of the following is most likely to produce a loud echo. **Justify** your answer (by describing how sound moves in each case and deciding which will produce the loudest echo).

- **a** Talking in a furnished, carpeted room
- **b** Singing in a tiled shower
- **c** Yelling across an open field

Skills builder: Planning investigations

6 Music is a series of sound waves. Different musical instruments produce sounds of different frequencies and wavelengths to produce different notes.

- **a** **Research** two different types of musical instruments, and **explain** how each produces sounds at different frequencies and wavelengths. (THINK: What part of the instrument causes sound and how?)
- **b** **Select** one instrument and **identify** equipment you may need to investigate how it produces sound.

Lesson 8.6

Experiment: Testing the soundproof properties of a material

Background

There are many reasons why people may need to reduce the level of sound travelling from one area to another. An example of this is a recording studio or the wall between two apartments.

Aim

To test the effectiveness of a material in reducing the transmission of sound

Materials

- Noise device such as a small speaker, mobile phone or alarm clock
- Sound level meter (or the equivalent online sound meter) measuring in decibels
- Ruler
- A cardboard box large enough to hold the sound-making device

- A variety of materials large enough to cover the inside of the box (such as felt, paper, cardboard of different thicknesses)
- Scissors
- Sticky tape or masking tape

Method

1 Write a hypothesis that identifies the most and least sound-insulating material.
2 Select the sound that your noise device will make and the volume that it will be set at.
3 Place the noise device 30 cm away from the sound level meter.
4 Use the sound level meter to measure the number of decibels of the noise device.
5 Record your measurement.
6 Place the noise device inside the unlined cardboard box and close the lid.
7 Use the sound level meter to measure the number of decibels of the noise device.
8 Record your measurement.
9 Remove the noise device and select one of the materials to line the cardboard box. Use the scissors and sticky tape to carefully line the box (including the lid) with a single layer of the material.
10 Place the noise device inside the lined cardboard box and close the lid.
11 Use the sound level meter to measure the number of decibels of the noise device.
12 Record your measurement.
13 Repeat steps 9 to 12 with other selected materials.

Results

Draw a table and a graph to represent your results.

Discussion

1 **List** the materials from least sound insulating to most sound insulating.
2 **Describe** any similarities and differences between the thickness, flexibility or rigidity of the materials that were tested. **Describe** any patterns or trends that you observe.
3 **Describe** any systemic or random errors that might have occurred during your testing. **Describe** how these errors could have affected the sound levels measured.
4 **Compare** the sound level you obtained for one material to the value obtained by others in the class. **Explain** any differences that you observe.
5 **Describe** a commercial product that claims to reduce sound levels. **Identify** the material that is used in its construction. **Evaluate** their claim (by comparing their claim to your results and identify why the two values may vary).

Conclusion

Describe any trends you identified in the effectiveness of different materials in reducing the transmission of sound.

Lesson 8.7

Electricity is the presence and flow of charged particles

Learning intentions and success criteria

Check the next lesson for a linked practical activity or experiment.

Key ideas

→ Electrostatic charges occur when electrical charges are unable to move.

→ A closed circuit occurs when the positive and negative charges can be separated and reunited.

→ An electrical conductor allows the charges to flow easily.

→ An electrical insulator restricts the movement of the charges.

Introduction

"Electricity" is a general term related to the presence and flow of charged particles. An electric charge can be either positive or negative. It is produced by subatomic particles (parts of atoms) such as electrons, which carry a negative charge, or protons, which carry a positive charge.

Electrostatic charge

Objects are normally uncharged – their atoms usually have equal numbers of protons (positively charged) and electrons (negatively charged). But when two objects are rubbed together, some of the electrons on the surface may be transferred from one object to the other. This causes the object with fewer electrons to become positively charged and the one with extra electrons to become negatively charged. You can see examples of this with other examples of friction – for example, if you rub a balloon against a woollen jumper, take off synthetic clothing or walk across synthetic carpet. In all these cases, the positive or negative electric charge stays on the charged object without moving. This is called an **electrostatic charge**. When the charges on an object are the same (both positive or both negative), they are described as "like charges". If the charges are different (one positive and one negative), they are described as "unlike charges".

electrostatic charge an electric charge between two objects caused by a deficiency or excess of electrons (negative charges); also known as "static electricity"

Important rules to learn about electrostatics (Figure 1):

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

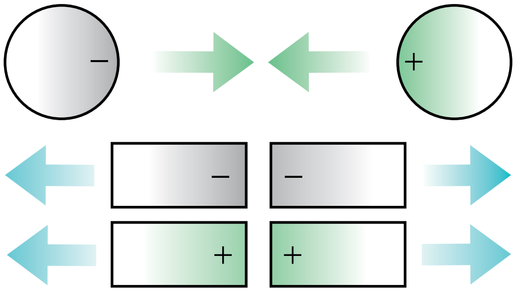


Figure 1 Like charges repel, unlike charges attract.

When charged objects are close to each other, the small negative electrons are attracted to the positively charged object (unlike objects attract). If these two objects are brought close enough, the electrons will try to jump across the gap as a spark. This is what happens when the air particles in a cloud rub against each other and become charged. If the charges build up enough, a large spark (lightning) will move between the charges in the clouds or toward the neutral ground (charged particles and neutral objects are attracted to each other).

The **van de Graaff generator** is a machine that produces an electrostatic charge by rubbing a belt (Figure 2). The surface of the dome can lose electrons and become positively charged. Anything that touches the top of the dome also becomes positively charged. If a person touches the surface of the dome, their hair can also become positively charged and stand away from each other (like charges repel).

Similar generators can be used to accelerate particles in X-ray machines, food sterilisers and process machines, and in nuclear physics demonstrations.

Figure 2 When the girl places her hands on the van de Graaff generator, electrons move from her hair to the dome. The positive charges left in her hair cause them to repel.

van de Graaff generator a machine that produces an electrostatic charge

Electrical energy and circuits

When electric charges become separated, they have **electrical energy**. This means they are in a state of excitement and the positive and negative charges try to get back together again. If a closed circuit is provided, the electrons will move along the wire to the positive charges and, as they do so, the electrical energy may transform into some other forms of energy, such as light or thermal energy.

However, it is difficult to continually rub things together to separate charges and give them electrical energy.

electrical energy the energy that results in the movement of electrons through a conductor towards a positive charge

A **dry cell** (for example, a torch battery) or a **wet cell** (for example, a car battery) uses a chemical reaction to continually separate charges and produce current electricity through wires.

A closed conducting pathway is called an **electric circuit**. As electrically charged particles move around an electric circuit, they carry energy from the energy source (such as a battery) to the device that transforms the energy (such as a light globe, motor or heater). An example of the movement of electrical energy in a simple circuit is shown in Figure 3.

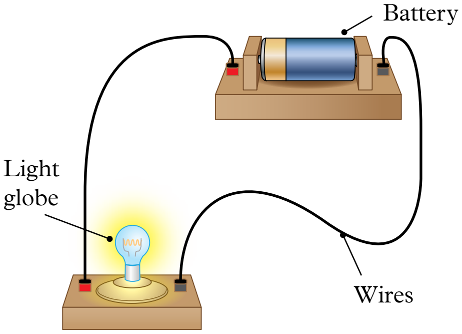


Figure 3 A simple circuit: electric charges move from the battery through the wires to the light globe.

dry cell an object, such as a torch battery, that uses a chemical reaction to produce electrical energy

wet cell an object, such as a car battery, that uses a chemical reaction to produce electrical energy

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

Measuring electric current

Electric **current**, or the flow of charge over time, is measured by counting the number of electrons that go past a point in the circuit in 1 second. The unit of measurement for current is amperes (symbol A). An ampere is a large unit of current, so smaller units, such as the milliampere (1,000 mA = 1 A), are often used. Traditionally an ammeter was used

current the rate at which electrons flow; measured in amperes (amps; symbol "A") to measure the current passing a particular point in an electric circuit. The ammeter must be connected into the circuit so that the current flows through it. More recently, a multimeter is used to measure many different aspects of a circuit, including the current (Figure 4).

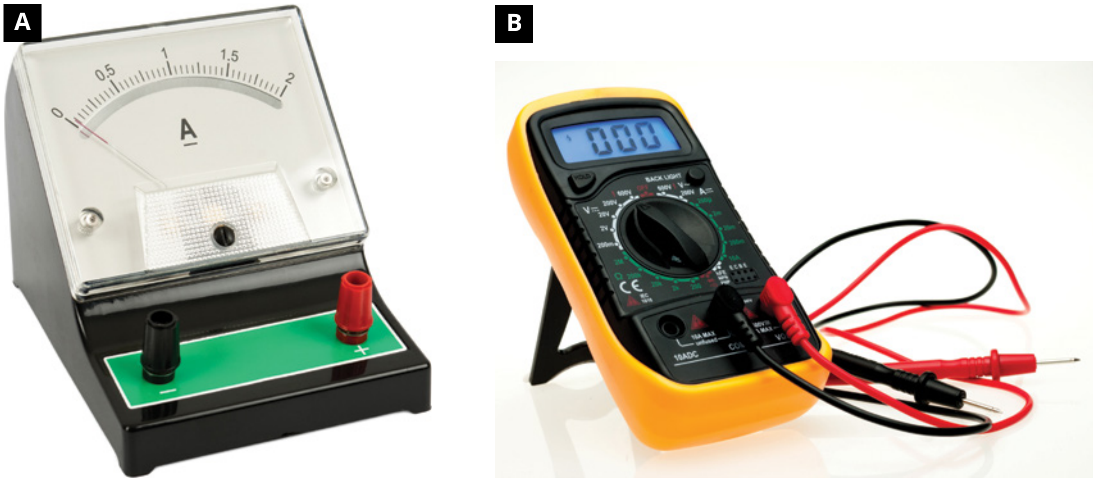


Figure 4 (A) An ammeter or (B) a multimeter is used to measure electric current or voltage.

potential difference	voltage; the difference in the electrical potential energy carried by charged particles between two different points in a circuit
voltage	potential difference; the difference in the electrical potential energy carried by charged particles between two different points in a circuit
electrical conductor	a material through which charged particles are able to move
electrical insulator	a material that does not allow the movement of charged particles
insulator	a substance that prevents the movement of thermal or electrical energy
semiconductor	a material that conducts electrical energy in one form and insulates against electrical energy in another form

Voltage

Each charged particle flowing through the circuit has potential energy. This energy (measured in volts) can be transformed into light and heat as it moves through a bulb, or into movement and sound if it moves through a speaker. This means the charged particle has different amounts of energy before and after the speaker or light bulb. This difference in energy for each charged particle is called **potential difference** or **voltage**.

Batteries provide energy to the charged particles. The amount of energy provided by the battery can be determined by connecting a voltmeter in parallel to the battery. In a 1.5 volt battery, each unit of charge receives 1.5 joules (symbol J) of energy as it passes through the battery.

Electrical conductors and insulators

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

Some substances are better **insulators** or better conductors than others. It depends on how easily they allow electrons to move through them – that is, they offer less or more resistance to the movement of charges. Air is a good resistor, because it is difficult for charged particles to move freely.

Some substances, such as germanium and silicon, are insulators in their pure form but become conductors if they are combined with a small amount of another substance. These materials are called **semiconductors**. Semiconductors are used in a wide range of technologies, including artificial intelligence, electric vehicles and advanced wireless networks.

Within a single silicon chip, very thin layers of silicon can be combined with other substances to make that layer a conductor. Complex microcircuits used in computing are made in this way.

Check your learning 8.7

Check your learning 8.7

Retrieve

1 **Identify** the charge on the following particles.
  a Protons
  b Electrons
2 **Define** the terms “current” and “voltage”.

Comprehend

3 **Describe** how objects can become electrostatically charged.
4 **Explain** the purpose of a battery in a circuit.
5 **Describe** an electric circuit.
6 **Describe** why silicon is called a semiconductor.

Analyse

7 **Compare** a conductor and an insulator.

Apply

8 If living organisms are good conductors and air is a good resistor, **discuss** why it would be dangerous to stand in open land during a lightning storm.

Lesson 8.8

Challenge: Demonstrating electrostatics

Aim

To model and explain electrostatic electricity

What you need:

- Rice Bubbles
- Large plastic bag with tie
- Woollen cloth
- Plastic comb
- Small pieces of paper
- Plastic rod or pen
- Balloon pump
- Balloons
- Felt-tipped pen
- String
- Tape

What to do:

Part A

1 Place some of the Rice Bubbles in the plastic bag. Blow air into the bag and seal it with the tie.
2 Rub the woollen cloth over both the plastic bag and the comb.
3 Bring the plastic bag and comb together.
4 Record what happens.
5 **Explain** your observations, using the idea of electrostatic charge.

Part B

1 Place eight small pieces of paper on the table.
2 Rub the woollen cloth over the plastic rod or pen.

▶

3. Show what happens to the pieces of paper when the positively charged woollen cloth is brought close to them.
4. Show what happens to the pieces of paper when the charged plastic rod is brought close to them.
5. **Explain** why the pieces of paper moved as a result of the plastic rod or cloth by discussing the movement of charges.

Part C

1. Using the balloon pump, blow up a balloon and carefully draw a face on it.
2. Tie the balloon onto a string and suspend it from a doorway or ceiling using tape, so that it is level with your head.
3. Rub the balloon face with the woollen cloth and walk towards it.
4. Record what happens.
   - **Identify** the distance you have to be from the "balloon face" before it is attracted to you.
   - **Describe** what happens if you put a piece of paper between you and the balloon.
5. Blow up another balloon and draw a face on it.
   - **Describe** what happens when you bring it close to your suspended balloon.

Questions

1. **Describe** your observations in Part A using the terms "like charges", "unlike charges" and "neutral or no charge".
2. **Describe** your observations in Part B using the terms "like charges", "unlike charges" and "neutral or no charge".
3. **Describe** your observations in Part C using the terms "like charges", "unlike charges" and "neutral or no charge".

Figure 1 Can you explain the attraction of the balloon?

Lesson 8.9

Visible light is a small part of the electromagnetic spectrum

Key ideas

→ Light moves in an electromagnetic transverse wavelike motion.

→ All electromagnetic waves travel at the same speed through a vacuum.

→ Light also behaves like a particle called a photon.

Learning intentions and success criteria

Introduction

Ancient civilisations believed that light was emitted from the eyes, allowing us to see. However, we now know that light comes from external sources, and we see objects when light reflects off them and enters our eyes.

Like sound, light is a form of energy that can behave like a wave. There are many different types of light, each with a wide range of wavelengths. Together, these forms of light are called the electromagnetic spectrum (Figure 1).

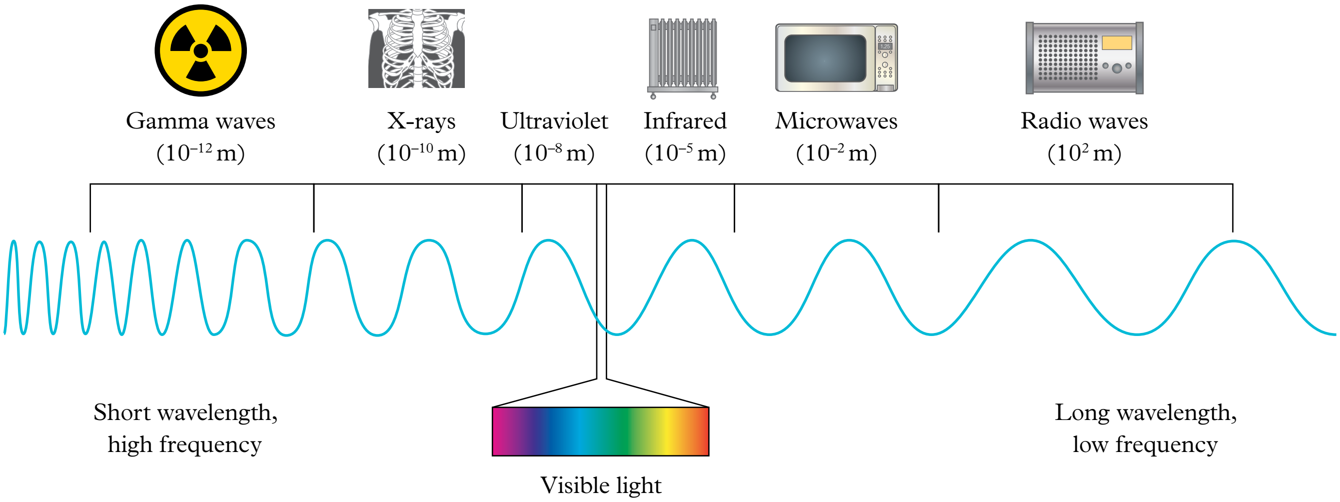


Figure 1 The electromagnetic spectrum

Electromagnetic spectrum

The electromagnetic spectrum includes the energy that provides music on your radio, the picture on your television and the heat to cook popcorn in your microwave.

We only see a small amount of this light energy. All of these different types of light have common features. They all travel at the same speed, the speed of light, but they have an obvious difference. They have different frequencies and therefore different wavelengths.

Transverse waves

Light waves are different from sound waves. Sound waves travel as longitudinal waves, where the vibrations of air particles are parallel to the wave's direction of travel. In contrast, light waves do not always move in the same direction as the light itself. These waves are called **transverse waves**.

transverse wave
a type of (light) wave where the vibrations are at right angles to the direction of the wave

The distance between two neighbouring peaks (rises) on a transverse wave is called the wavelength. It is the same as the distance between two consecutive troughs (dips) or between any two consecutive matching points on the wave (Figure 2). At a different wavelength, the nature of the light wave changes. In the region of visible light, this change of wavelength is seen as different colours.

Because light waves have different wavelengths, they also have different frequencies. As with sound waves, the frequency of a light wave is a measure of the number of waves that pass a point each second (unit Hz).

As the frequency becomes higher, more waves (with short wavelengths) pass a point each second. This means high frequencies have shorter wavelengths. Like sound, amplitude is a measure of how far a particle moves from its place of rest.

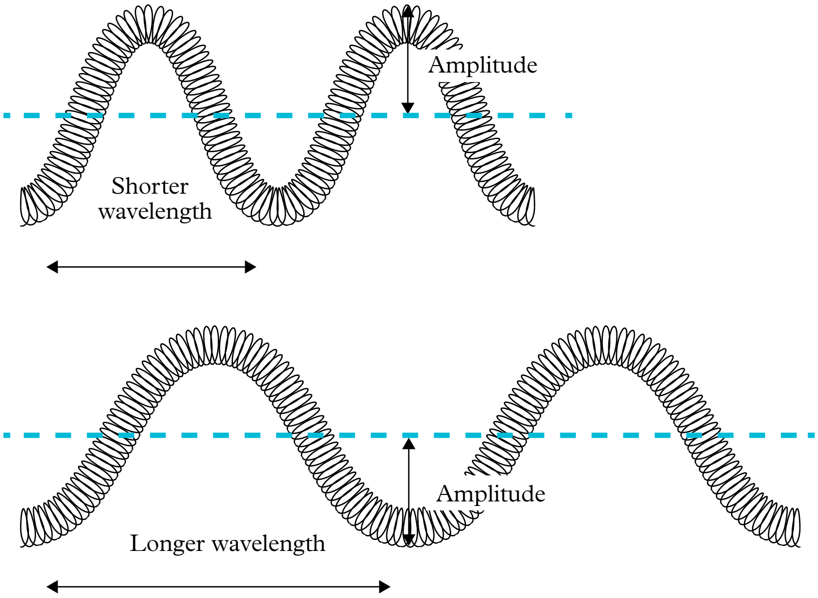


Figure 2 The wavelength of a wave is measured from any point on the wave (usually a peak or trough) to the next corresponding point.

Speed of light

Figure 3 A prism is a transparent object in the shape of a triangle that separates white light into the colour spectrum.

Light waves travel extremely fast – 300,000 km/s in a vacuum. This speed is known as the speed of light and is much faster than sound. This is why you always see lightning before you hear thunder. Light waves can also travel through other media, such as air, water and glass, where they slow down slightly. Unlike sound waves, light waves do not require a medium (solid, liquid or gas) to travel because they are electromagnetic in nature. They do not transfer energy from particle to particle causing compression waves as sound waves do. Light does not need other particles to move. This allows different forms of light to travel through space and reach us on Earth.

Particle or wave?

Experiments by early scientists provided two forms of evidence about how light behaves. In some experiments, light behaved as if it were a wave. Other experiments indicated that light was a particle.

Scientists now agree that light consists of a particle called a photon, which can move in a wavelike fashion. Just like a wave of water, it can bounce or reflect off surfaces and slow down if it travels through a thicker, denser material. Just like a separate particle, it can move by itself through space. This is how the light from the Sun can reach Earth.

Check your learning 8.9

Check your learning 8.9

Retrieve

1 **Recall** the unit used to measure wavelength.

Comprehend

2 The frequency of a wave is measured in units called hertz (Hz). **Describe** the relationship between a hertz and the unit of time, the second (s).

3 **Explain** why you see lightning before you hear thunder.

Analyse

4 Use a table to **compare** sound waves and light waves.

5 Sound is a wave, but sound cannot travel through a vacuum (empty space). Light can travel in a vacuum. **Contrast** sound and light to explain these two statements.

Apply

6 The relationship between wavelength and frequency is described as an inverse or reciprocal relationship. **Discuss** what is meant by "inverse or reciprocal" as used in this statement.

Skills builder: Questioning and predicting

7 The relationship between wavelength and frequency is described as an inverse or reciprocal relationship (as one increases, the other decreases). This can be confirmed by asking questions and making predictions.

   a **Develop** a scientific question that may help you test this. (THINK: What am I measuring? What am I changing?)

   b **Predict** what the outcome of your question might be. (THINK: Why do I think this would happen? What scientific theory is this?)

Lesson 8.10

Light reflects off a mirror

Key ideas

→ Light can travel through transparent objects and is blocked by opaque objects.

→ Translucent objects allow some light energy through.

→ When light is reflected off a mirror, the angle of incidence is equal to the angle of reflection (law of reflection).

→ The image in the mirror is called a virtual image.

Learning intentions and success criteria

Check the next lesson for a linked practical activity or experiment.

Introduction

Light can reflect off a glass window but most of the light is transmitted and passes through. This is because the glass in the window is **transparent**. Some types of frosted glass prevent us seeing through them clearly. They are **translucent** because they let some light through but objects cannot be seen clearly. If an **opaque** material is shiny enough or has a shiny coating, it will reflect the light and allow us to see the clear **image**. The best example of this is a mirror.

transparent
allowing all light to pass through, so objects can be seen clearly

translucent allowing light through, but diffusing the light so objects cannot be seen clearly

opaque not allowing light to pass through

image a likeness of an object that is produced as a result of light reflection or refraction

normal (in relation to light) an imaginary line drawn at right angles to the surface of a reflective or refractive material

angle of incidence the angle between an incident ray and the normal (a line drawn at right angles to a reflective surface)

angle of reflection the angle between a reflected ray and the normal (a line drawn at right angles to a reflective surface)

virtual image an image that appears in a mirror; it cannot be captured on a screen

Mirrors

The reflection of light from a mirror is shown in Figure 1. Light always follows particular rules when it reflects from a surface, no matter how rough or how smooth the surface is. The **normal** is an imaginary line that can be drawn at 90° (or perpendicular) to the mirror's surface. It is usually drawn as a dotted line.

The incident ray represents the incoming light and strikes the mirror at the base of the normal. The **angle of incidence** is the angle between the incident ray and the normal. The reflected ray leaves the mirror from the base of the normal at the same angle as the incidence ray. The **angle of reflection** is the angle between the reflected ray and the normal. An arrow is used to indicate which line is the incident ray and which is the reflected ray. The law of reflection states that the angle of incidence (symbol i) equals the angle of reflection (symbol r).

When we look in a plane mirror (a flat mirror), we see a picture, or image, of ourselves. In the case of a plane mirror, the image is always a **virtual image**. This means it cannot be captured on a piece of paper or on a screen as a movie projector does.

The image always forms where the light rays cross. The image we see in a plane mirror is also laterally inverted, or flipped sideways (Figure 2).

If we raise our left hand in front of a mirror, our image looks as if it is raising its right hand. The image is also the same distance behind the mirror as the object is in front of it.

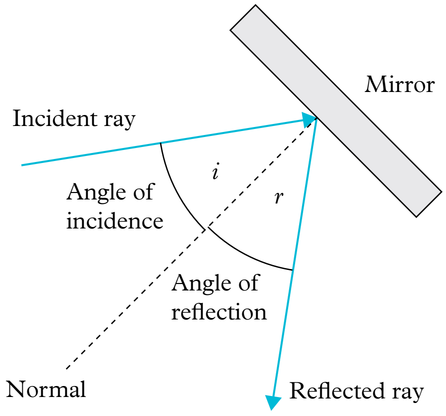


Figure 1 The angle of incidence (i) and the angle of reflection (r) are the same when light reflects off a mirror.

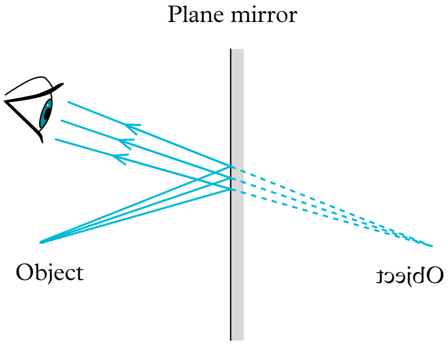


Figure 2 The image in a plane mirror is virtual, laterally inverted, the same size as the object and the same distance from the mirror.

Curved mirrors

Curved mirrors are not as predictable as plane mirrors. They can change the size and nature of the object's image (Figure 3).

convex refers to a lens or mirror that is thicker in the centre than at the ends

concave refers to a lens or mirror that is thinner in the centre than at the ends

Curved mirrors can be **convex**, where the centre sticks out, or **concave**, where the centre goes in, like a cave.

Concave mirrors cause the reflected light to bend towards a central point. They are used in reflecting telescopes. Convex mirrors scatter the light of an object. They are typically used in passenger side mirrors.

Figure 3 (A) A mirror shows the lateral inversion of what we look like. (B) Curved mirrors can distort the virtual image.

Check your learning 8.10

Check your learning 8.10

Retrieve

1 **Define** the terms "transparent", "translucent" and "opaque" and **identify** one example of each.

2 **Recall** one use each of convex and concave mirrors.

Comprehend

3 **Explain** why light fittings are often translucent.

4 **Define** the terms "normal", "incident ray", "angle of incidence", "reflected ray" and "angle of reflection". **Use** a diagram to illustrate your definitions.

5 **Describe** a virtual image and provide an example of where you would see one.

Analyse

6 **Compare** concave and convex mirrors.

7 **Compare** plane mirrors and convex mirrors.

Skills builder: Processing and analysing data and information

8 The way data is represented can help people understand your findings. **Construct** a table to summarise the information from this lesson. In your table, include:

- information about reflection
- the difference between concave and convex mirrors.

(THINK: What is the best structure for your table? What information is important? Can you structure it to compare information?)

Figure 4 Virtual or real?

Lesson 8.11

Experiment: Reflection from plane mirrors

Aim

To investigate the law of reflection: the angle of incidence equals the angle of reflection

Materials

- Ruler
- Pencil
- Sheet of white A4 paper
- Protractor
- Hodson light box kit
- Plane mirror from the light box kit
- Blu Tack
- Power supply

Method

1 Rule a straight line in pencil centrally across the width of the A4 paper. The mirror surface will be placed along this line.

2 Use the protractor to construct a normal line at 90° in the centre of the first line.

3 Position the back edge of the plane mirror along the first pencil line. Keep it in place with Blu Tack.

4 Set up the Hodson light box, darken the room and aim a single incident ray at the centre of the mirror where the normal begins. Mark the position of the incident and reflected rays with pencil dots.

5 Move the light box to a different angle and aim another incident ray so that it hits the mirror at the same place as it did the first time. Mark the incidence and reflection rays by drawing arrows. Label the lines A.

6 Repeat step 5 until five sets of lines are obtained. Label each set of lines B, C, D and E.

Results

1 Remove the light box and rule lines to show the straight path of the incident and reflected rays.

2 Carefully use the protractor to measure the five angles of incidence and the five angles of reflection for each set of lines A, B, C, D and E.

3 Move the protractor so that the 0° of the protractor is along the normal. Read the angle between the normal and each incident ray, and between the normal and reflected rays.

4 Record your results in a suitable table.

Discussion

1 **Explain** why the back edge and not the front edge of the plane mirror should be lined up on the pencil line.

2 **Compare** your angles of incidence to your angles of reflection. **Explain** how they support the law of reflection.

3 **List** two possible sources of error in this experiment.

4 **Describe** what happened when you directed the light at right angles to the mirror.

5 **Explain** whether the law of reflection is still obeyed if the angle of incidence is 0°.

6 **List** at least three examples where you have observed the law of reflection in action.

Conclusion

Describe what you know about the relationship between the angle of incidence and the angle of reflection.

Lesson 8.12

Light refracts when moving in and out of substances

Key ideas

→ Refraction is the bending of light as it enters or leaves different materials at an angle.

→ Light entering an optically dense medium bends towards the normal.

→ Light entering a less optically dense medium bends away from the normal.

Learning intentions and success criteria

Refraction

Refraction is the bending of light as it passes at an angle from one transparent **medium** (i.e. substance or material) into another. For example, light bends when it travels from air into water, or from water into air. Often when light is bent or refracted, it can make objects appear distorted. You might be familiar with this effect when light bounces off a spoon sitting in water (Figure 1).

Figure 1 Water refracts light and distorts images.

The amount that light bends depends on the distance between the particles of the medium. This optical density or **refractive index** of the material has the symbol *n*. Water has a higher optical density than air and therefore has a higher refractive index. When a light ray in the air enters water, it slows down and bends closer to the 90° normal. This bent ray is called the **refracted ray** (Figure 2) and its angle with the normal is the **angle of refraction**, *r*.

When the light ray leaves the optically denser medium (water) and moves into a less optically dense medium (air), it speeds up. When this happens, the light ray bends away from the normal.

refraction the bending of light as a result of speeding up or slowing down when moving into a medium of different density

medium a substance or material through which light can move

refractive index a measure of the bending of light as it passes from one medium to another

refracted ray a ray of light that has bent as a result of speeding up or slowing down when it moves into a more or less dense medium

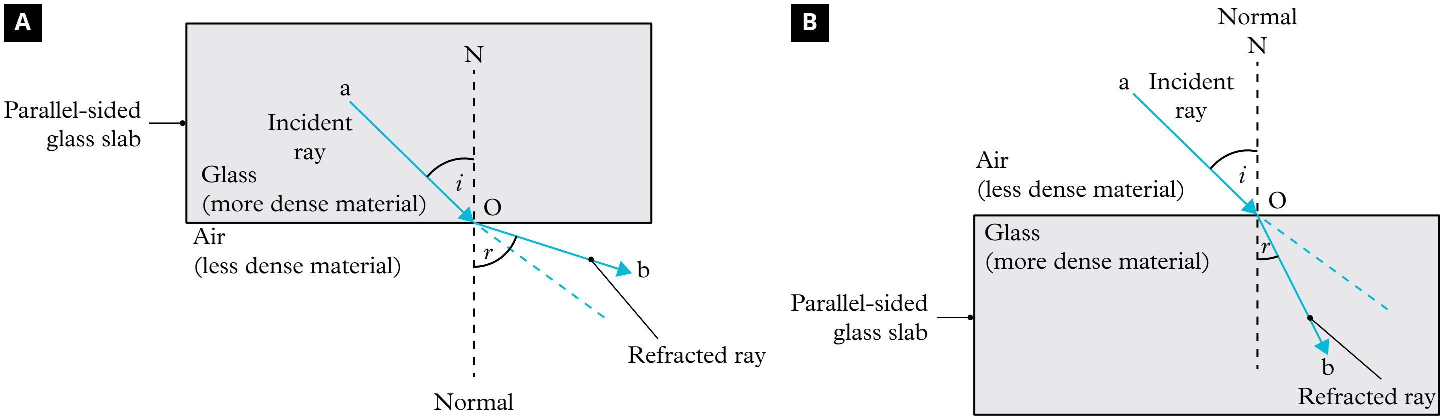


Figure 2 (A) Light entering a less optically dense medium bends away from the normal. (B) Light entering a more optically dense medium bends towards the normal.

angle of refraction the angle between a refracted ray and the normal (a line drawn at right angles to a refractive surface)

Generally, optically dense liquids have a higher refractive index than less optically dense gases. Optically dense solids have a higher refractive index than less optically dense liquids. Light bends because it changes speed. The lower the refractive index, the faster the light travels in the medium.

The only time that light does not refract is when it enters a new medium along the normal (90° to the surface). It still changes speed, but there is no bending of the light.

Figure 3 Swimming pools and the ocean look shallower than they really are. The depth we see is the apparent depth. This person looks shorter in the water because light bends as it leaves the water making the bottom of the pool appear closer.

Refraction in everyday life

Refraction explains a lot of everyday phenomena such as swimming pools and the ocean looking shallower than they really are (Figure 3 and Figure 4). This is because the light bends as it leaves the water making the bottom of a pool or objects under water appear closer to the surface than they really are.

Lenses

lens a curved piece of transparent material

converge (in relation to rays of light) to come together at a single point

focus the point where rays of light cross

focal length the distance between the centre of a lens and the focus

diverge (in relation to rays of light) to move away from each other

virtual focus the point at which a virtual image appears

A **lens** is usually a curved piece of transparent material, such as glass or plastic. Convex lenses are thicker in the centre than at the edges and concave lenses are thinner in the centre than at the edges. They work in a similar way to convex and concave mirrors.

Convex lenses cause light rays to **converge**, or focus. The **focus** (or focal point) is the point where the rays cross. The **focal length** is the distance from the focus to the middle of the lens (Figure 5).

Concave lenses cause light rays to **diverge** or spread out. The light rays appear to cross or focus on the other side of the lens. To find the focus, the diverging rays are followed back until they cross at the apparent light source (Figure 6). The focus can therefore be described as a **virtual focus** because the light rays do not really come from this point.

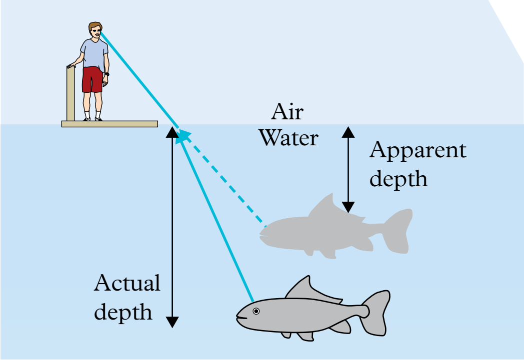


Figure 4 Refraction makes underwater objects appear closer to the surface than they really are. The fish looks closer to the surface than it really is because the light has left a denser medium.

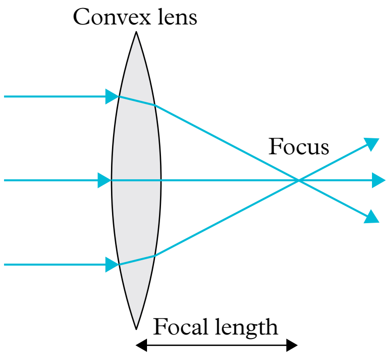


Figure 5 Parallel rays converge to a focal point with convex lenses.

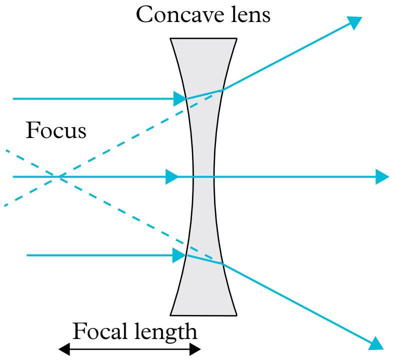


Figure 6 Parallel rays diverge from a focus through concave lenses.

Check your learning 8.12

Check your learning 8.12

Retrieve

1 **Select** "towards" or "away from" to complete the following sentences.
   - **a** Light travelling from a high refractive index to a low refractive index will bend (towards/away from) the normal.
   - **b** Light travelling from a low refractive index to a high refractive index will bend (towards/away from) the normal.

Comprehend

2 The refractive index of water is 1.33 and that of diamond is 2.42. **Create** a diagram to **explain** how a light ray bends when it travels from water into diamond. Remember to use arrows to show the direction the light is moving.

3 The refractive index of glass is 1.52 and that of air is 1.00. **Create** a diagram to **explain** how a light ray bends when it travels from glass into air.

4 **Describe** how convex and concave lenses are used.

Analyse

5 **Contrast** how light moves through convex and concave lenses.

6 **Compare** reflection and refraction.

Skills builder: Conducting investigations

7 It is important that any practical work is safe. To ensure safety, scientists perform risk assessments. An experiment designed to investigate convex lenses lists the following materials: light box kit, candle, matches, convex lenses.
   - **a** **Identify** risks associated with these materials. (THINK: Could these cause injury or harm? Do they have risks with electricity or reactions?)
   - **b** **Suggest** how these risks can be controlled. (THINK: Is there protective equipment you can wear? Can you substitute something?)

Lesson 8.13

Different wavelengths of light are different colours

Key ideas

→ Visible light can be separated (dispersed) into the colours of the visible spectrum – red, orange, yellow, green, blue and violet.

→ Each colour has a different wavelength and will refract different amounts to produce a rainbow.

→ An object appears coloured when some wavelengths are absorbed, and others are reflected into our eyes.

Learning intentions and success criteria

Check the next lesson for a linked practical activity or experiment.

Physics

Introduction

White light can be separated into an infinite range of different colours and shades, but it is generally considered to be six (or seven) basic colours – red, orange, yellow, green, blue and violet. Sir Isaac Newton discovered this concept, and it is popularly believed that he included a seventh colour for good luck, called indigo, between blue and violet. This makes the colour sequence easy to remember using the acronym "ROY-G-BIV". This range of colours is called the **visible spectrum**. The process used to produce these colours is called **dispersion**.

visible spectrum the variety of colours of wavelengths of light that can be seen by the human eye

dispersion the separation of white light into its different colours

Each colour of the visible spectrum has a different wavelength (the length of one complete cycle of a wave) and is refracted by a different amount when moving through mediums of different densities. This variation in refraction causes the separation of colours. A rainbow is an example of dispersion (and total internal reflection) where the white sunlight is separated (dispersed) into its component colours (Figure 1).

Figure 1 A rainbow shows all of the colours in the visible spectrum.

primary colours of light the three colours of light (red, blue and green), which can be mixed to create white light

secondary colours of light the colours of light (magenta, cyan and yellow) that result from the mixing of two primary colours of light

Three of the six basic colours are called the **primary colours of light**. These are red, green and blue. This is because these three colours can be added together to produce white light (Figure 2). When two of the primary colours are combined (additive mixing), they form **secondary colours of light**. Red light and blue light make a red-blue light called magenta. Blue light and green light make an aqua or turquoise light called cyan. Green light and red light make yellow light. These rules are different for paints, so if you are an art student, you will need to think differently when considering mixtures of light compared to mixtures of paint!

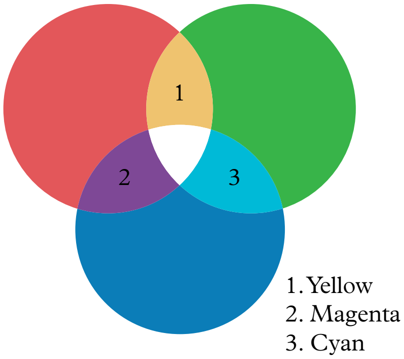


Figure 2 Where the red, green and blue lights overlap, white light is produced. The secondary colours are formed by the additive mixing of two of the primary colours.

If cyan light and red light are mixed, the result is white light. When only two colours are needed to make white light, they are called complementary colours of light. This is because the cyan light already contains blue and green, so if we add red light, we effectively have the three primary colours, which we already know make white light.

Colour of opaque objects

So, why do coloured objects appear coloured? When white light (or sunlight) falls on an opaque object, the energy of some colours may be reflected while others are absorbed (or soaked up or subtracted from the white light) (Figure 3). The colour the object appears to be depends on the mix of colours that reflects into our eyes. In most cases, it is easier to consider white light as made up of red, green and blue light energy.

If some energy colours are absorbed and some are reflected, the object will appear to be the colour of the mix it reflects. This rule is the same for objects illuminated by coloured light. So, a red top appears red because red light is reflected from the red surface to our eye. Grass is green because the red and blue wavelengths are absorbed and the green wavelength is reflected back to our eyes.

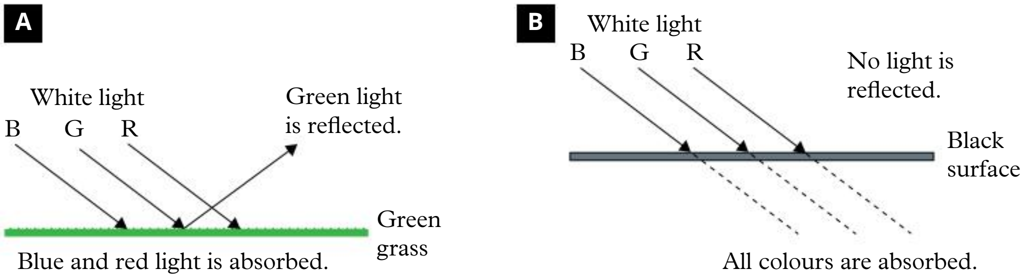


Figure 3 (A) A green surface reflects green light and so looks green. (B) A black surface absorbs all colours and so looks black. No colours are reflected.

Colour of transparent objects

Transparent objects, such as the coloured **filters** in the Hodson light box kits (Lesson 8.14 Experiment: What colour is it? (page 300)), or coloured cellophane, **transmit** (allow to pass) and absorb colours in the same general way that blue objects appear blue to us. If the blue colour is transmitted (passes through) while the red and green colours are absorbed, then the filter appears to be blue. Alternatively, a red filter appears red because the blue light and green light are absorbed and red passes through. Therefore, we see the red light from the filter. Secondary colour filters, such as yellow, block the blue light and allow the red and green light through (Figure 4).

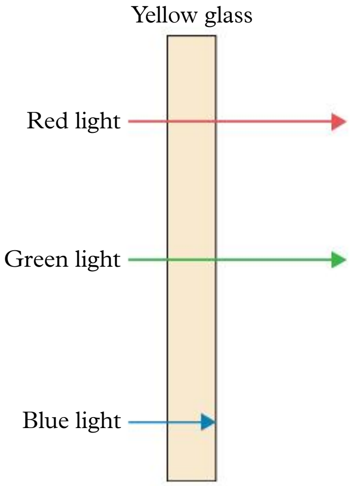


Figure 4 A filter that transmits red and green light and absorbs blue light will appear yellow (the secondary colour that comes from red and green).

filter a transparent material that allows only one colour of light to pass through

transmit to allow light to pass through

Check your learning 8.13

Check your learning 8.13

Retrieve

1 **Identify** the colour that is produced when magenta and green lights are mixed.

Comprehend

2 If white light is a mixture of all the primary colours of light, **explain** what black is.

Analyse

3 **Contrast** how light moves when hitting a filter and when hitting an opaque object.

4 **Contrast** the primary and secondary colours of light.

Apply

5 **Describe** what you would see if you looked at white light through a yellow filter. **Justify** your answer (by describing what happens to each of the primary colours of the white light when they hit the yellow filter).

6 **Describe** the colour that a green surface will appear in red light. **Justify** your answer by explaining what happens when the red light hits the green surface.

Figure 5 The colour of light

Skills builder: Communicating

7 When scientists conduct investigations, they need to present their findings to a range of audiences. This involves using clear and concise language.

- **a** **Investigate** the formation of rainbows. (THINK: What key words should I use? Is the source of information credible?)
- **b** Write a paragraph using scientific language to **explain** how rainbows are formed. (THINK: Is my language too descriptive? Am I explaining the scientific concept or describing a rainbow?)

Lesson 8.14

Experiment: What colour is it?

Aim

To investigate the addition of coloured light and explore the behaviour of coloured filters

Materials

- Hodson light box kit
- Power supply
- Sheet of white paper

Method

1 Connect the light box to a power supply and place it on the sheet of paper.

2 Place the three primary filters (red, green and blue) in each of the three separate slotted sections in the light box.

3 Adjust the mirror flaps so that the colours can overlap on the paper.

4 Change the combinations of filters by using two at a time or all three together. Observe the resulting colours and complete Table 1.

Table 1 Results for primary colour filters

Addition of primary colours	Colour produced
Red + green + blue	
Red + blue	
Green + blue	
Red + green	

5 Replace one of the primary filters with a secondary filter (yellow, cyan and magenta) and complete Table 2.

Table 2 Results for a combination of primary and secondary colour filters

Addition of colours	Colour produced
Yellow (side slot) + blue (front slot)	
Magenta (side slot) + green (front slot)	
Cyan (side slot) + red (front slot)	

6 Switch off the light box and remove the filters. Select a red, green, blue and yellow oblique surface from the light box kit. Hold each of the coloured surfaces against the back of each primary filter. Record in Table 3 the colour that each surface appears.

Table 3 Results when viewing the colour of surfaces through primary colour filters

Surface colour	Colour surface appears when viewed through a:		
	Red filter	Green filter	Blue filter
Red			
Green			
Blue			
Yellow			

Discussion

1 **Identify** the combinations of colours that produce white light.
2 **Describe** any patterns you observed in each of the tables. **Explain** the patterns you observed.
3 **Identify** one possible source of error in the experiment.
4 **Describe** the difficulties you had, and how you overcame them.

Conclusion

Describe what you know about what happens when coloured lights are added to each other.

Figure 1 Coloured filters

Lesson 8.15

The electromagnetic spectrum has many uses

Key ideas

→ Total internal reflection occurs when a light ray passes into a less dense medium at a particularly large angle.

→ Optic fibres use total internal reflection to pass data in the form of light pulses.

→ Other forms of the electromagnetic spectrum, such as microwaves, are used for communication and for cooking food.

Learning intentions and success criteria

Check the next lesson for a linked practical activity or experiment.

Total internal reflection

critical angle the angle of light that causes the reflected ray to move along the edge between two materials

total internal reflection the complete reflection of a light ray when it passes from a more dense to a less dense material at a large angle; the ray is reflected back into the dense medium

Many optical instruments, such as cameras, microscopes and some telescopes, use lenses, but several use prisms to reflect light. A prism is a block of glass that can change the direction of light through refraction and reflection. When light passes from a more dense medium (glass) to a less dense medium (air), it is refracted away from the normal. As the angle of the light (incidence) increases, the refracted ray may be refracted away from the normal so much that it travels at an angle of 90° to the normal. This means the refracted ray moves along the surface edge between the two media, known as the interface. The angle of incidence at which this occurs is called the **critical angle** (symbol i_c).

If the angle of incidence is increased more than the critical angle, the light has nowhere to go and is reflected back into the dense medium. This phenomenon is known as **total internal reflection**. This only occurs when light attempts to travel from a more dense medium (glass) into a less dense medium (air) and only for angles greater than the critical angle (Figure 1).

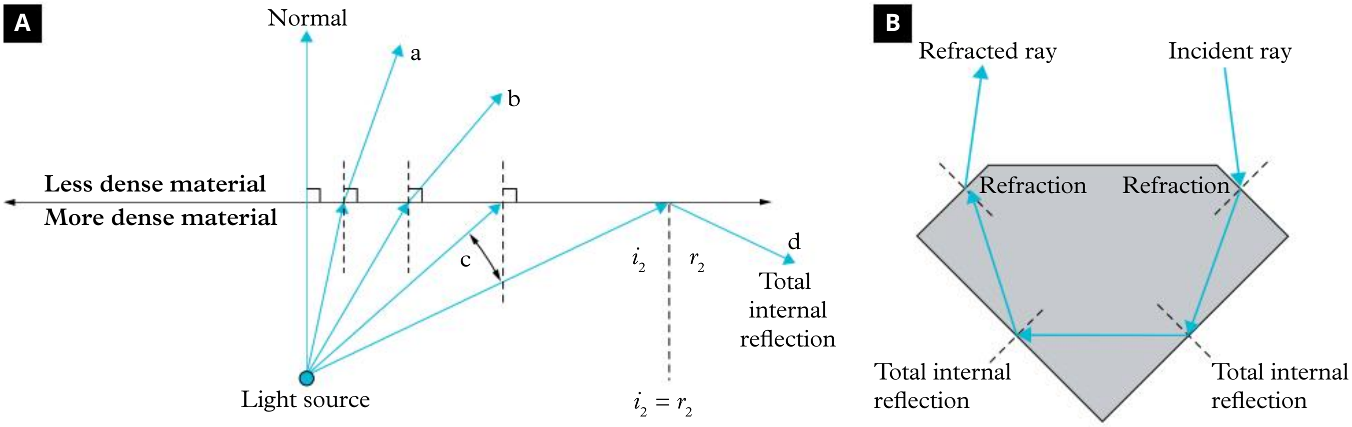


Figure 1 (A) Rays a and b are refracted because the angle of incidence is less than the critical angle. Ray c occurs when the critical angle is reached. Ray d is reflected when the angle of incidence is greater than the critical angle. (B) Total internal reflection

Using total internal reflection

optic fibre a thin fibre of glass or plastic that carries information/data in the form of light

Optic fibres have revolutionised communication systems (Figure 2). Instead of relying on copper wires to carry electrical signals, we now use bundles of optic fibres to carry light signals for landline telephone calls, the internet and the NBN (National Broadband Network). An **optic fibre** is a very thin fibre of glass or plastic that carries light that reflects (total internal reflection) off the internal surface continually. By sending the information as controlled pulses of light, a single fibre less than a millimetre wide can carry thousands of landline telephone calls and millions of bits of data.

In an optical fibre, the core (the innermost part where light travels) and cladding (surrounds the core) play a crucial

Figure 2 Optic fibres are used to carry digital light signals and have various applications.

role in guiding light efficiently through the fibre. The core has a higher refractive index compared to the cladding. This difference in refractive indices ensures that light rays hitting the core-cladding interface at a certain angle are reflected back into the core rather than escaping (Figure 3). This is an example of total internal reflection.

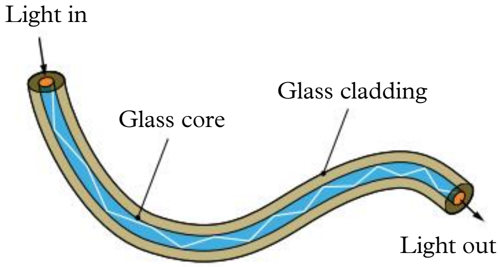


Figure 3 Light zigzags along inside an optic fibre at the boundary of the core and the cladding.

The advantages of optic fibres over copper wire are less signal loss, greater carrying capacity and immunity to electromagnetic interference. This means long distances can be covered with fewer repeater (or booster) stations. A repeater (or booster) station is placed at intervals to amplify the weakened optical signal and retransmit it, allowing the data to continue traveling over long distances without degradation. A single optic fibre carries much more data than a copper cable, so optic fibres save space, and crossed messages (a form of interference) cannot happen. Optic fibres do not generate heat like the current in a copper wire and are non-electrical, so they don't pose a fire risk and can be used around high voltages.

Microwaves

Microwaves are one small part of the electromagnetic spectrum. The wavelengths of microwaves are usually 1 mm to 1 m in length. Microwaves have many uses, from communication (mobile phones) to cooking, from global positioning systems (GPS) to radar. Microwaves can be focused into narrower beams than radio waves. This allows them to be used for person-to-person communication on Earth or even between Earth and the space station (Figure 4).

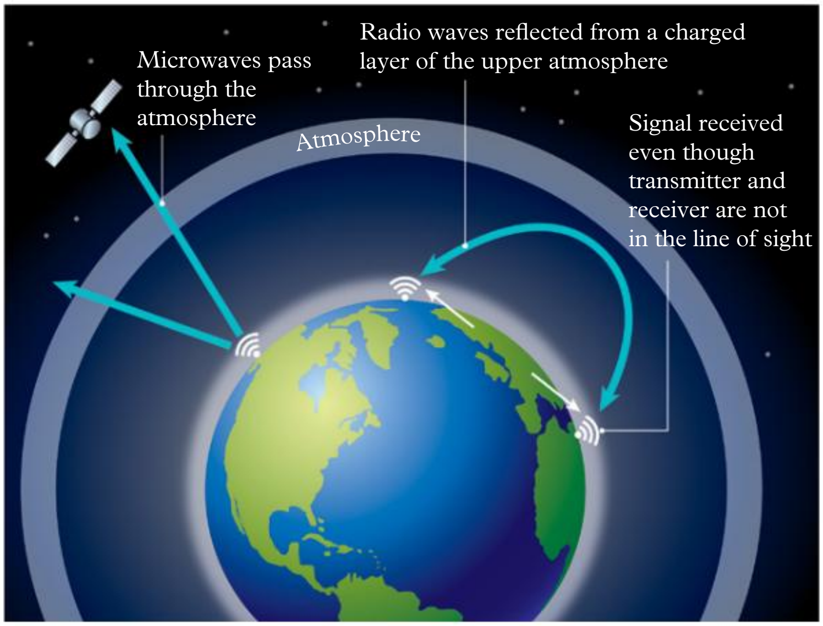


Figure 4 Electromagnetic waves with different wavelengths behave differently in Earth's atmosphere.

Microwave ovens

The electromagnetic waves in a microwave oven provide energy to make the water molecules in food move. The increased movement (kinetic energy) of the water molecules causes friction between the other molecules in the food. This friction between all the molecules causes the food to heat up.

Check your learning 8.15

Check your learning 8.15

Comprehend

1 **Describe** when and how total internal reflection occurs.

2 **Describe** why optic fibres are better for telecommunications than copper wire.

3 **Explain** why the amount of water in a food is important when cooking in a microwave.

Analyse

4 **Contrast** total internal reflection and the reflection from a plane mirror.

Apply

5 **Discuss** why total internal reflection cannot occur for light passing from a less dense material into a denser material.

6 **Investigate** one other use for other forms of electromagnetic waves.

Lesson 8.16

Experiment: What is the wavelength of a microwave?

Caution!

- Some students might have egg allergies.
- Take care when handling hot plates.

Background

A microwave oven uses electromagnetic waves to heat food. These waves move through the cooking area in a set fashion. All microwave ovens have turntables to rotate food so that it cooks evenly. This is necessary because of the wavelike motion of the energy. Without the turntable, the energy is focused in fixed parts of the oven.

You can use this understanding to determine the wavelength of the microwaves in your microwave oven.

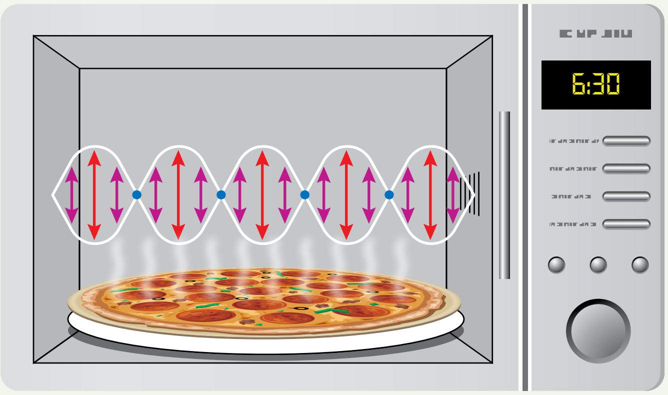


Figure 1 A microwave oven uses electromagnetic waves to heat food.

Figure 2 A microwave oven with the turntable and drive mechanism removed

Aim

To determine the wavelength of a microwave

Materials

- Egg
- Large flat plate at least 20 cm in diameter (safe for use in a microwave) or piece of black cardboard approximately the same size
- Microwave oven with the turntable removed
- Oven mitts
- Ruler

Method

1 Crack the egg and separate the egg white from the egg yolk.

2 Spread the egg white evenly over the plate or black cardboard.

3 Place the plate/cardboard in the oven and turn on for 15 to 30 seconds (depending on the power of the microwave). The egg should start cooking in stripes/patches.

4 Wearing oven mitts, remove the plate/cardboard from the microwave and identify the centre of the cooked stripes/patches. Measure the distance between two of the cooked patches.

5 Repeat this experiment several times and determine an average distance between the cooked egg white.

Figure 3 Use the cooked portions of the egg white to measure the distance between "hot spots" in the microwave oven.

Results

1 Record all your observations in a table.

2 Multiply the average distance between the cooked egg white by 2 to determine the length of a full wavelength.

Discussion

1 **Identify** the wavelength of the microwaves in your microwave oven.

2 **Describe** any difficulty you had when determining the centre of the cooked portion of egg. **Calculate** the error margin of your calculation (± the width of the cooked egg bands).

3 **Explain** why you needed to repeat your experiment several times.

Conclusion

Explain what you know about the wavelength of microwaves.

Lesson 8.17

Review: Particles and waves

Summary

Lesson 8.1 Heat can be transferred by convection and conduction

- The energy from heat moves spontaneously from a hot material to a cool material.
- Conduction occurs when the kinetic energy of particles is transferred.
- Convection occurs when particles with high kinetic energy move to another space.

Lesson 8.4 Vibrating particles pass on sound

- Sound is caused by the vibration of particles moving in a longitudinal wave.
- One wavelength is the distance between one compression of air particles and the next.
- The distance the air particle moves from its normal position is called the amplitude.
- The number of waves passing a point each second is the frequency of the wave.

Lesson 8.5 Sound can travel at different speeds

- Sound travels through air at approximately 340 m/s at sea level at 20°C.
- The speed of sound varies according to the temperature and material through which it travels.
- Particles have more kinetic energy at higher temperatures, so they can compress more easily.
- The more closely packed the particles, the faster the sound wave travels.

Lesson 8.7 Electricity is the presence and flow of charged particles

- Electrostatic charges occur when electrical charges are unable to move.
- A closed circuit occurs when the positive and negative charges can be separated and reunited.
- An electrical conductor allows the charges to flow easily.
- An electrical insulator restricts the movement of the charges.

Lesson 8.9 Visible light is a small part of the electromagnetic spectrum

- Light moves in an electromagnetic transverse wavelike motion.
- All electromagnetic waves travel at the same speed through a vacuum.
- Light also behaves like a particle called a photon.

Lesson 8.10 Light reflects off a mirror

- Light can travel through transparent objects and is blocked by opaque objects.
- Translucent objects allow some light energy through.
- When light is reflected off a mirror, the angle of incidence is equal to the angle of reflection (law of reflection).
- The image in the mirror is called a virtual image.

Lesson 8.12 Light refracts when moving in and out of substances

- Refraction is the bending of light as it enters or leaves different materials at an angle.
- Light entering an optically dense medium bends towards the normal.
- Light entering a less optically dense medium bends away from the normal.

Lesson 8.13 Different wavelengths of light are different colours

- Visible light can be separated (dispersed) into the colours of the visible spectrum – red, orange, yellow, green, blue and violet.
- Each colour has a different wavelength and will refract different amounts to produce a rainbow.
- An object appears coloured when some wavelengths are absorbed, and others are reflected into our eyes.

Lesson 8.15 The electromagnetic spectrum has many uses

- Total internal reflection occurs when a light ray passes into a less dense medium at a particularly large angle.
- Optic fibres use total internal reflection to pass data in the form of light pulses.
- Other forms of the electromagnetic spectrum, such as microwaves, are used for communication and for cooking food.

Review questions 8.17

Review questions: Module 8

Retrieve

1 **Identify** which of the following terms can be used to describe sound waves.
   - **A** Transverse waves
   - **B** Electromagnetic waves
   - **C** Microwaves
   - **D** Longitudinal waves

2 **Identify** which of the following is correct.
   - **A** Sound waves travel faster than light waves.
   - **B** Sound travels faster in air than in water.
   - **C** Light travels faster than sound.
   - **D** Sound can travel through space.

3 **Identify** the units of voltage and current, respectively.
   - **A** Amps, joules
   - **B** Joules, volts
   - **C** Volts, amps
   - **D** Volts, joules

4 **Define** the term “frequency” of sound. **Identify** its unit.

5 **Identify** materials that could act as a:
   - **a** heat insulator
   - **b** heat conductor.

6 Complete this paragraph by **identifying** the missing words. The first letter of each missing word is given.

Sound is created by v_______. The v_______ create c_______ and r_______ due to the movement of the particles as the sound w_______ passes through. The w_______ travels through the substance and is known as a l_______ wave. The greater the vibration, the higher the v_______ of the sound, which means it sounds l_______. Sound waves must have a m_______ to pass through.

Comprehend

7 **Explain** why astronauts could shout at each other with their helmets touching if the radio communication broke down on the Moon.

8 **Describe** what happens to light when it passes from the air into water.

9 Figure 1 shows a block of ice melting.
   - **a** **Describe** what is happening to the molecules as the ice melts. Draw a diagram to **illustrate** your answer.
   - **b** **Explain** where the energy to melt the ice comes from. **Explain** how the energy is transferred to the molecules of ice.

Figure 1 A block of ice melting

10 Butchers sometimes use red lights to illuminate their meat in the shop window. **Explain** why they might choose this colour.

11 **Explain** why sound travels faster in solids than in air.

12 **Describe** the difference between the primary colours of light and the primary colours of paint.

13 **Explain** how pitch and frequency of sound are related.

14 **Describe** the conditions that can slow the speed of light.

15 **Describe** how light moves in an optic fibre.

16 **Describe** the appearance of the Australian flag when viewed in:
   - **a** blue light
   - **b** red light
   - **c** green light.

Analyse

17 **Consider** why it is scientifically incorrect to say the fridge passed on its cold energy to you.

18 **Compare** current and voltage.

19 **Compare** transverse waves and longitudinal waves.

20 **Compare** the reflection of light and the refraction of light.

21 **Compare** conduction and convection.

22 **Describe** the movement of charged particles when a balloon is rubbed on a person’s hair.

23 **Describe** what will happen to the brightness of a bulb if an insulator is added in the connection between the wires and bulb.

Apply

24 A student claimed that black is not a colour. **Evaluate** their claim (by explaining how an object can appear black, defining what is a colour of light, and deciding if the student is correct).

25 Aboriginal and Torres Strait Islander Peoples use the didjeridu for many important ceremonies (Figure 2). Long didjeridu produce sounds that are lower in pitch and frequency than short didjeridus. **Describe** what this information tells you about the sound wave that is produced. (HINT: Consider the length of the sound waves produced by each didjeridu.)

Figure 2 Didjeridus of different lengths

26 **Discuss**, in terms of kinetic energy of particles, why:

- **a** convection can only occur in liquids and gases and not solids
- **b** when energy transfers by convection or conduction, the substance through which the energy transfers is also heated
- **c** a gas makes a better thermal insulator than a solid
- **d** neither convection nor conduction is a way of transferring energy through a vacuum.

27 Aboriginal and Torres Strait Islander Peoples have used possum, kangaroo and wallaby skin coats to keep themselves warm. Traditionally, the fur was worn with the fur facing towards the body to reduce heat loss. Use your understanding of the transfer of thermal energy to **discuss** the effectiveness of this strategy.

28 Rubber and wood have very high resistance to the flow of electricity. **Propose** how this will affect the current and voltage in a circuit.

Figure 3 Power lines carry electricity from this power station to towns and cities.

Critical and creative thinking

29 Table 1 shows the speed of sound at different temperatures.

- **a** Using graph paper, **create** a graph of the speed of sound (vertical axis) at various air temperatures (horizontal axis).
- **b** **Describe** what happens to the speed of sound as the temperature increases.
- **c** Use your graph to **identify** the speed of sound at 5°C.
- **d** Use your graph to **identify** the temperature of the air if the speed of sound is 351 m/s.

Table 1 The speed of sound at different temperatures

Air temperature (°C)	Speed of sound (m/s)
0	330
10	336
20	342
30	348
40	354

30 Astronauts in space can still see each other even if they cannot hear each other.

- **a** Use this information to **compare** how light and sound travel.
- **b** **Determine** what this tells us about the ability of light energy to travel through outer space.

31 **Investigate** the differences and similarities between audible sound, ultrasound and infrasound. Display your answer using a Venn diagram.

32 Use your understanding of current and voltage to **create** a model of the flow of electricity through a circuit. You might use people or even an animation as your model.

Research

33 Choose one of the following topics for a research project. A few guiding questions have been provided, but you should add more questions that you wish to investigate. Present your report in a format of your own choosing, but one component of your report must include a demonstration of sound (for example, if you make an instrument, it needs to be played). In a multimedia presentation, sound must be part of the presentation. If you interview someone as part of your research, you must present a taped recording of your interview along with your report.

Aboriginal and Torres Strait Islander Peoples didjeridu

The didjeridu is one of the most recognisable musical instruments of Aboriginal and Torres Strait Islander Peoples. Cultural laws and protocols dictate who is able to play it and at which ceremonies it can be played. The oldest record of a didjeridu is from a 1,500-year-old cave painting in Northern Australia.

- **Describe** the basic shape of a didjeridu.
- **Identify** if the didjeridu is an instrument of the Aboriginal and Torres Strait Islander Peoples in your area.
- **Describe** the materials that are used to make the instrument.
- **Explain** how the materials used, and/or the shape affects the type of sound that is produced.
- **Describe** how the didjeridu player can change the type of sounds that are produced.

Supersonic planes

- **Identify** what “supersonic sound” means.
- **Contrast** a supersonic jet and a normal jet aircraft.
- **Describe** one of the problems with supersonic planes.
- **Describe** why the Concorde was removed from air travel service (Figure 4).

Figure 4 The Concorde has been removed from air travel service.

Night vision goggles

Night vision goggles allow soldiers to see at night and spot the enemy before they are spotted themselves. They give an army a tactical advantage.

- **Describe** how the goggles work.
- **Identify** the limitations of these goggles (Will they work in a totally dark environment? Do they have any disadvantages to the soldiers operating them?)

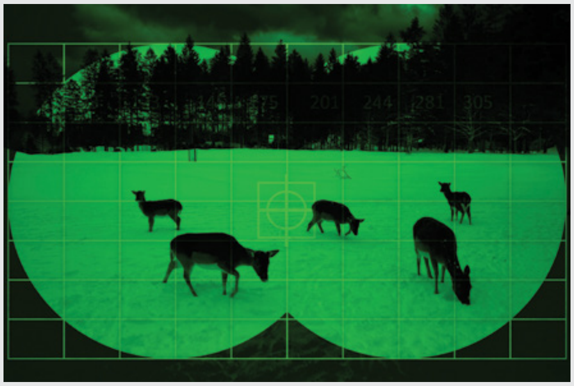


Figure 5 View of deer and forest through night vision goggles

Module
9
Energy efficiency

Overview

The Law of Conservation of Energy says that energy is always conserved during transfers and transformations, meaning the total energy stays the same. However, not all energy transfers are 100% efficient, and some energy is wasted as heat or sound. A Sankey diagram can show how energy transforms as it is transferred and transformed. We can use our understanding of energy efficiency to examine Aboriginal and Torres Strait Islander ground ovens or the sports of pole vaulting and archery. Comparing the energy sources of coal, solar and wind allows us to measure their efficiency in generating electricity.

Lessons in this module

Lesson 9.1

Energy cannot be created or destroyed

Learning intentions and success criteria

Key ideas

- → The Law of Conservation of Energy states that energy cannot be created or destroyed.
- → When energy is transformed, waste energy is produced.
- → Efficient energy transformations produce less waste energy.

Energy cannot be created or destroyed

People have been fascinated with **energy** for thousands of years, from the heat energy released in the earliest human-generated fires, to the energy that allows us to reach the Moon and beyond. In Module 8 Particles and waves (page 268), you examined the different models of heat, sound, electricity and light energy. When a saucepan is placed on a stove, the heat from the stove is transferred to the saucepan. **Energy transfer** is a way of describing energy being moved from one system or object to another. Sometimes the energy will change from one form to another. This process is called **energy transformation**. There is one law that is consistent across all forms of energy: energy cannot be created or destroyed.

Law of Conservation of Energy

When energy is transformed or transferred, the amount of energy that goes into a transformation must always be the same as the energy that comes out. The total energy remains constant, even if the type of energy changes – what goes in must come out!

This is considered the **Law of Conservation of Energy**. No energy can be created or destroyed. The energy at the end must be equal to the energy present at the beginning. When you lift an object up in the air, you add **gravitational potential energy**. This energy did not just appear. The **kinetic energy** provided by your hand was conserved and transformed into the gravitational potential energy of the object. When the object is dropped, the energy is not destroyed. The gravitational potential energy is once again transformed into kinetic energy as it falls.

Energy efficiency

If a device transforms most of its **input energy** into the most useful **output energy**, then it is considered to be a very energy-efficient device. Energy is said to be “wasted” if it is in a form that cannot be used such as heat or sound. The less **waste energy**, the more energy-efficient the device. **Energy efficiency** is a measure of the percentage of useful energy transformed.

$$\text{efficiency} = \frac{\text{useful energy output}}{\text{energy input}} \times 100$$

energy the capacity to do work

energy transfer the process of energy moving from one place to another

energy transformation the process of energy changing from one form to another (e.g. from electric energy into heat energy)

Law of Conservation of Energy a scientific rule that states that the total energy in a closed system is always constant and cannot be created or destroyed

gravitational potential energy the energy possessed by an object raised to a height in a gravitational field

kinetic energy the energy possessed by moving objects

input energy energy put into a device or system

output energy energy that comes out of a device or system; includes useful energy and waste energy

Take the trampoline example in Figure 1. The input energy was 500 units and the useful output energy was 400 units. This means that the trampoline is 400 ÷ 500 × 100 = 80% efficient.

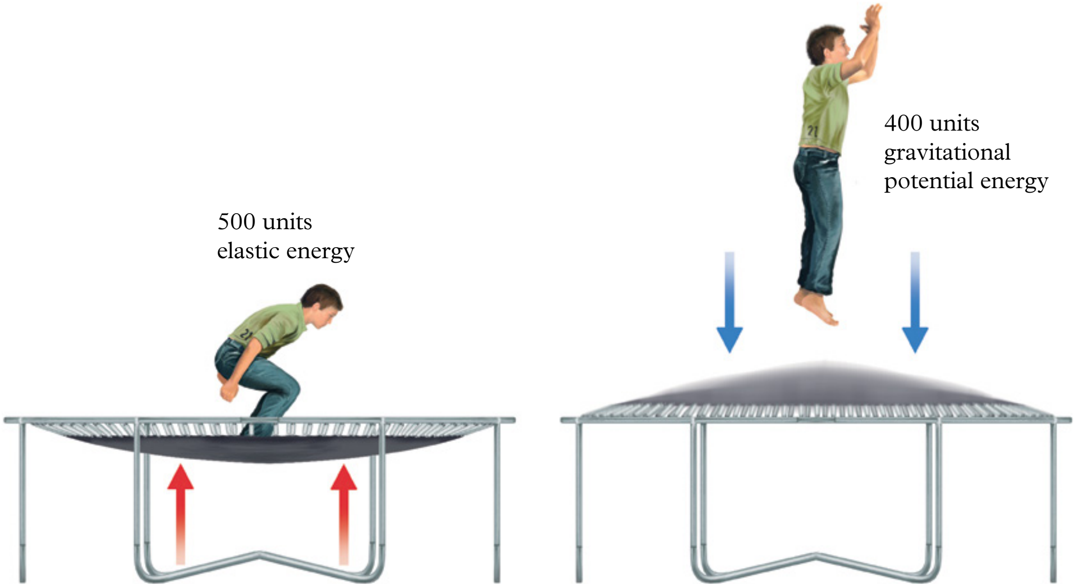


Figure 1 Five hundred units of energy are stored in the springs of the trampoline. At the highest point, the jumper has 400 units of gravitational potential energy. Where have the 100 "missing" units gone?

waste energy output energy that cannot be used for the intended purpose of the device or system; by-product of energy transfer and transformation

energy efficiency a measure of the amount of useful energy transformed in an energy transformation process; usually expressed as a percentage of the input energy (e.g. 90 per cent efficiency is very good)

Most energy transformations for everyday appliances are not efficient. Scientists are constantly trying to design the best appliances possible with the highest efficiency ratings. This would make them better for the environment and cost less to power. Do you and your family always buy the most efficient appliances? Are you familiar with the star ratings on appliances? More stars mean that the appliance is more energy efficient. Not only is it good to know that less energy is being wasted, but it also means that when you pay your electricity and gas bills you are paying for energy that is being used rather than for energy that is being wasted.

Worked example 9.1A shows how to calculate energy efficiency.

Worked example 9.1A Calculating energy efficiency

Todd held a tennis ball 1.5 m above the concrete before letting it fall. The ball hit the concrete before bouncing to 90 cm above the ground.

a Calculate the energy efficiency of the tennis ball.

b Calculate the waste energy as the tennis ball bounced.

Solution

1 Input gravitational energy comes from the ball at 1.5 m (150 cm) above the ground.
Useful output gravitational energy is shown by the ball being 90 cm above the ground.

$$\text{efficiency} = \frac{\text{useful energy output}}{\text{energy input}} \times 100$$

$$= \frac{90}{150} \times 100$$

$$= 60\%$$

The tennis ball had an energy efficiency of 60 per cent.

2 The ball is 60 per cent efficient.

waste energy = energy input – useful output energy

= 100% – 60%

= 40%

Therefore, 40 per cent of the energy is transformed into waste energy.

Heat and sound waste energy

If no system is 100 per cent efficient, but the energy cannot be destroyed, where does the energy go? In most cases, the energy is transformed into heat and sound energy. Think what happens when you drop a ball on the ground. The ball starts with gravitational potential energy, which is transformed into kinetic energy when you drop it (Figure 2). When the ball hits the ground, it makes a noise. The louder the noise, the more sound energy it has generated. If you bounce a ball many times in a row, you might feel the ball warm up. Heat energy has been generated. Both the heat and sound energy dissipate into the air. They are not lost or destroyed. We cannot reuse them. They are by-products of the main energy transformation.

Figure 2 When you drop a basketball on the ground, gravitational potential energy is transformed into kinetic energy.

Figure 3 Dropping a glass bottle onto the ground generates and releases sound energy, producing a large shattering noise.

Check your learning 9.1

Check your learning 9.1

Retrieve

1 **Recall** the Law of Conservation of Energy.

2 **Define** “energy efficiency”.

Comprehend

3 The Sun provides heat and light energy to our planet every day. Some of this energy becomes waste energy. **Describe** where most of the light energy that we make use of goes.

Analyse

4 When an elastic band is stretched, the kinetic energy is transformed into elastic potential energy.

a **Explain** why an elastic band that had 10 units of elastic energy cannot produce 12 units of kinetic energy.

b For the elastic band in part a, **calculate** its percentage efficiency if 7 units of kinetic energy were produced. **Describe** where the remaining 3 units of energy have gone.

5 **Identify** and **describe** the by-product energy transformations for a car.

Apply

6 A student claimed energy was lost when they bounced a ball. **Evaluate** the student's statement (by describing the Law of Conservation of Energy, describing how this law applies to the student's statement, and deciding if the statement is correct).

Skills builder: Questioning and predicting

7 Turning a scientific question into a hypothesis helps to structure an investigation. You are presented with the research question: "What happens to the amount of stored energy as a rubber band is stretched?"

- **a** **Use** the question above to **develop** a scientific question. (THINK: How can I make this measurable?)
- **b** **Identify** the dependent variable and the independent variable in your question. (THINK: What am I measuring? What am I changing?)
- **c** **Develop** a hypothesis for stretching a rubber band. (THINK: Have I included both variables? Have I included a potential result? What is the scientific explanation for this result?)

Lesson 9.2

Sankey diagrams can represent energy efficiency

Key ideas

→ The conservation of energy can be represented in a Sankey diagram.

Learning intentions and success criteria

Drawing energy efficiency

A hairdryer has two basic components: a fan and a heating element. When plugged in and switched on, the fan motor spins and the heating element heats up. The hairdryer converts electrical energy into thermal (heat) energy and kinetic energy. The air blown by the fan is directed over the heating element, passing the heat energy to the air, which flows out of the hairdryer. Some hairdryers have different speed and heat settings that control the amount of electrical energy flowing to each part of the device.

All energy transformations produce waste energy that cannot be directly used by the device. It can be difficult to compare the efficiency of the energy transformations in a particular device. One of the most effective ways to represent energy transformations is a **Sankey diagram**.

Sankey diagram a flow chart that represents movement or change in resources, such as the transfer or transformation of energy

Sankey diagrams

A Sankey diagram is a type of flow diagram. You learnt about flow diagrams in Year 8. Sankey diagrams are used to represent the efficiency of energy transfers and transformations. Each Sankey diagram has a series of arrows of different widths. The widths of the arrows represent the amount of energy that flows in and out of a system.

Let's look at the transfer and transformation of energy in toasters. Toasters use heating elements to convert electrical energy into thermal energy. Heating elements are made of wires that heat up without melting when electricity flows through them. These wires are not good **conductors** of electricity. If the wires resist the flow of charged particles and make it more difficult to move, then more electrical energy is transformed into thermal energy. The thermal energy is then passed to the air, which then passes the heat to the bread, toasting it. This transfer of energy can be represented in a Sankey diagram (Figure 1).

conductor material or substance that electrons can flow through; the flow of electrons through a conductor is electrical current

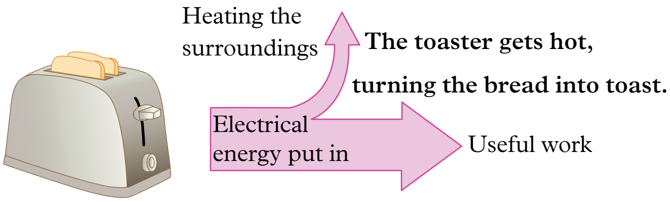


Figure 1 A Sankey diagram of energy transfer in a toaster

Drawing a Sankey diagram

Sankey diagrams have three main parts: the input energy, the waste energy and the output energy.

- The input energy is shown at the start of the arrow on the left-hand side of the diagram.
- The useful output energy is shown with an arrowhead travelling straight on to the right-hand side.
- The waste energy is usually shown by another arrowhead travelling either up or down on the diagram.
- Sankey diagrams are usually drawn on graph paper so that the width of the arrow can accurately represent the amount of energy (Figure 2).
- The length of the arrows is not important in Sankey diagrams.

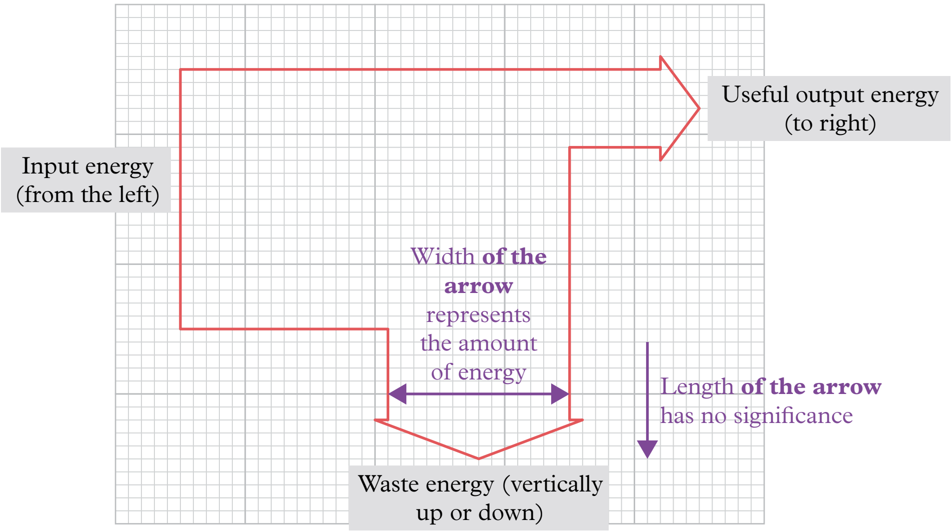


Figure 2 Key parts of a Sankey diagram

Sankey diagrams can also be used to represent more complex energy transitions. Worked example 9.2A shows the process of drawing a Sankey diagram.

Worked example 9.2A Drawing a Sankey diagram

A kettle has an input of 800 J of electrical energy. Three-quarters of the thermal energy is used to heat the water while one-quarter of the energy heats the surrounding air. Draw a Sankey diagram to represent this energy transfer.

Solution

One-quarter of 800 J can be determined by

$$800\text{ J} \div 4 = 200\text{ J}$$

Heating the water uses three-quarters of 800 J

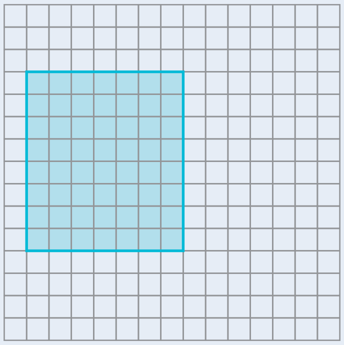
$$3 \times 200\text{ J} = 600\text{ J}$$

Heat into the surrounding air uses one-quarter of 800 J

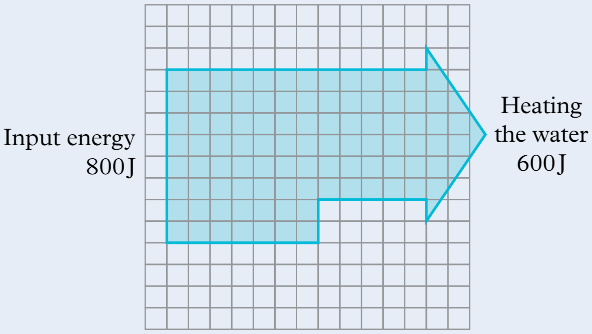
$$1 \times 200\text{ J} = 200\text{ J}$$

Before starting your diagram, you will need to decide the scale you will use on the graph paper. It is usually easiest to have 1 square being equal to a simple number. In this case, 1 square = 100 J.

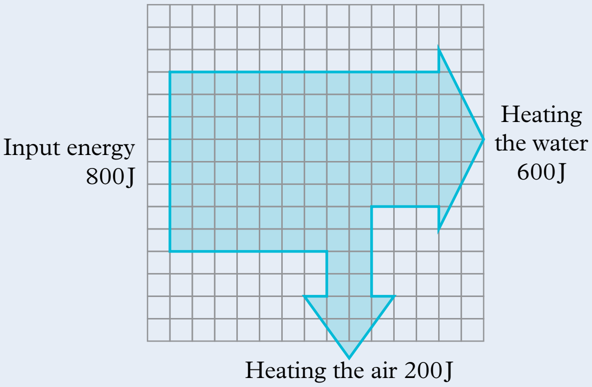
The input energy is 800 J (8 squares). To show this, colour 8 squares down the graph paper. You can colour across as many squares as you like but make sure to leave room for the useful output energy on the right side of the graph paper**.** Add a label to show the input energy.



The useful thermal energy that heats the water is 600 J. To show this, colour 6 squares down the graph paper from the top right of your input energy block. Colour across until you reach a few squares from the right edge of the graph paper. Add an arrow head to the right side and a label to show the output energy.



The waste energy (heating of the air surroundings) is 200 J. To show this, draw a block 2 squares wide, extending down from the right of the input energy block. Add an arrowhead and label to show the waste energy.



This is now a Sankey diagram of the energy input and output of the kettle.

Check your learning 9.2

Check your learning 9.2

Retrieve

1 **Identify** the three key parts of a Sankey diagram.

Comprehend

2 Use a Sankey diagram to **represent** the energy transfers and transformations of a rubber band that starts with 10 units of elastic energy and produces 6 units of kinetic energy and 4 units of waste heat.

Analyse

3 The Sun provides 400 J of light energy to a plant. The plant uses the light to store 100 J of chemical energy. **Calculate** the amount of waste energy from this process.

4 An electrical appliance company tested the energy efficiency of one of their appliances and drew a Sankey diagram to represent this (Figure 3).

   a **Describe** how this image could be misinterpreted by a potential buyer.

   b **Redraw** the image so that it is a true representation of the data.

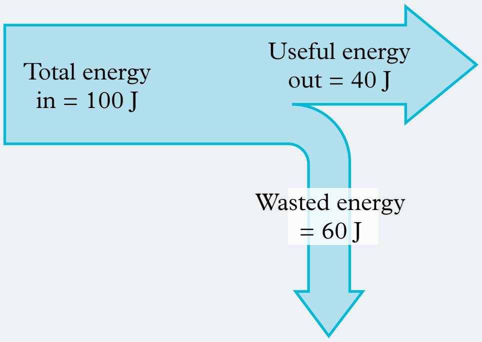


Figure 3 Sankey diagram for an electrical appliance

5 A student claimed a fan heater was inefficient due to energy lost as sound.

   a **Explain** why thermal energy and kinetic energy is considered “useful” in a fan heater.

   b Use the Law of Conservation of Energy to **explain** why sound energy is not “lost”.

   c Use Figure 4 to **calculate** the amount of sound energy generated by a fan heater.

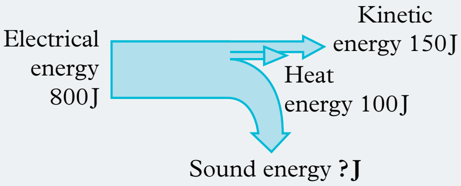


Figure 4 Sankey diagram for a fan heater

Lesson 9.3

Energy efficiency can reduce energy consumption

Learning intentions and success criteria

Check the next lesson for a linked practical activity or experiment.

Key ideas

→ Understanding how waste energy is formed allows it to be minimised.

→ Waste energy can be useful.

→ Insulation prevents the transfer of thermal (heat) energy.

→ Knowledge and understanding of energy transformations is not limited to scientists.

Useful waste energy

Most energy transformations can result in thermal waste energy. For thousands of years, Aboriginal and Torres Strait Islander Peoples have used their understanding of the way energy is transferred and transformed to develop energy efficient ways to generate heat and cook food using thermal waste energy.

Generating fire

The ability to generate fire is a skill used across many Aboriginal and Torres Strait Islander Peoples cultures. The fire drill method is an example of using what may be considered waste energy to cook or to stay warm. It involves pushing the blunt end of a long, thin drill stick into the flat surface of wood (Figure 1). As the drill stick is rubbed between the hands, the kinetic energy causes it to twist into the flat wood.

The friction between the two pieces of wood produces thermal energy in the flat wood. Eventually, the wood becomes so hot that a combustion reaction is started.

Figure 1 The fire drill method uses friction to generate thermal energy and start a combustion reaction.

Cooking food

One role of archaeologists is to develop an understanding of traditional methods used by Aboriginal and Torres Strait Islander Peoples to cook food. With the permission of the Barengi Gadjin Land Council Aboriginal Corporation, which represents the Traditional Owners of the Jadawadjali language group in western Victoria, archaeologists set out to re-create a traditional ground oven. They dug a large pit, 25 cm deep in the earth and lined the base of the pit with spheres made of clay and sand. On top of the spheres, a fire was slowly built up until it burnt strongly for 1 hour (Figure 2a–e). When the fire died down to glowing coal, half the coals and spheres were removed (Figure 2f). Wet reeds were placed on top of the remaining coals and clay spheres (Figure 2g) before the edible roots of *Microseris scapigera* (yam daisy) were placed on top of the reeds. The remaining hot coals and spheres (Figure 2h) were placed on top of the roots before being covered with large sheets of stringy bark (Figure 2i) and sand (Figure 2j). The food was cooked overnight. This process of using the reeds, stringy bark and sand to insulate the heat with the roots reduced the loss of heat and increased the efficiency of the ground oven.

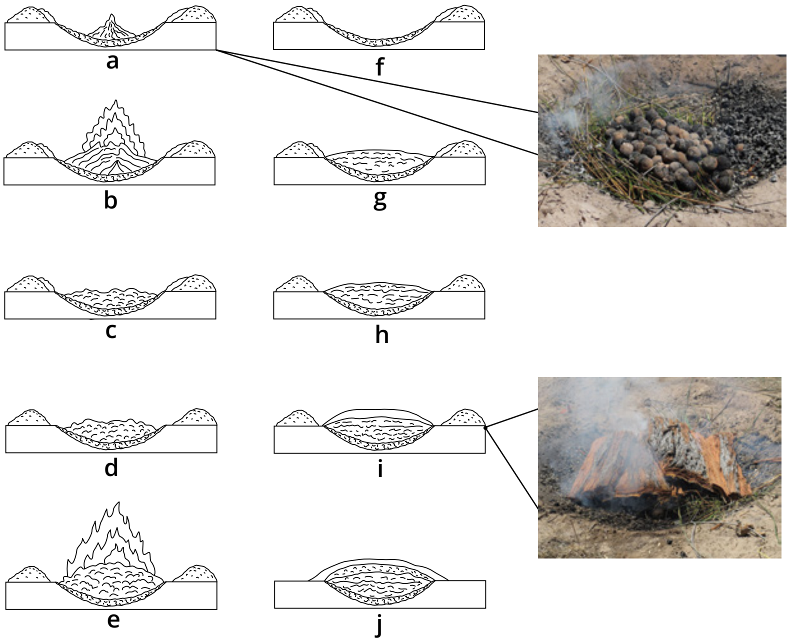


Figure 2 Re-creation of a traditional ground oven

Heating and cooling your house

You probably use electricity or gas to run heating or cooling systems at home. In a hot environment, energy is needed to remove the heat from inside your home, allowing it to cool down.

The warm air inside the house is moved over cool pipes in an air conditioner. The thermal energy of the house air is passed to the refrigerant inside the pipes and is then carried outside the house. If the house is well designed, thermal energy remains outside and the house stays cool.

Home design features

Architects design homes to help control the flow of thermal energy. They can add a variety of features that help limit the amount of heating or cooling your house needs.

Insulation

Lining the inside of the walls, floors and roof of your house can ensure that heat is not transferred between the outside air and the inside of the house (Figure 3). This keeps the heat inside on a cold day and outside on a hot day.

Figure 3 Insulation prevents heat energy being transferred between the inside and the outside of the house.

Reducing window heat

One of the main places that heat is transferred is through windows. On a hot day, light and heat from the Sun can easily penetrate a window. This transfers heat into the house. An awning on a window can limit this. Limiting the number of windows facing the Sun can also help to prevent the heat being transferred into the house.

Double-glazed windows have two panes of glass separated by an air gap (Figure 4). Air does not transfer heat very well (it is a good insulator). A home with double-glazed windows will not gain much heat during a hot day, or lose much heat on a cold night.

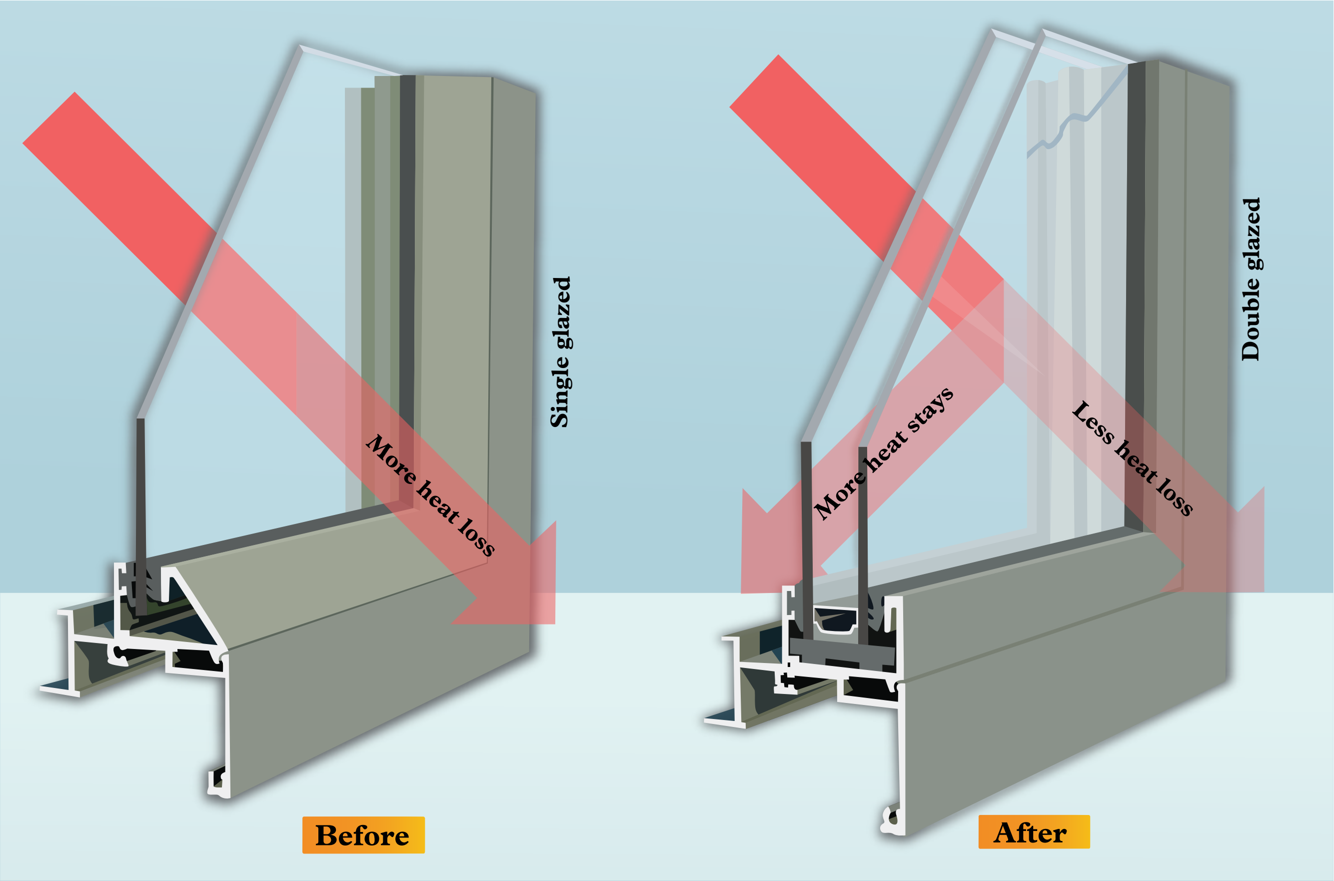


Figure 4 Double-glazed windows use two panes of glass to reduce the transfer of heat in and out of a house.

Verandas

Verandas work much like awnings, but also prevent heat and light from the Sun from shining on walls (Figure 5). This prevents heat from being transferred to the walls, and then to the air inside.

Figure 5 A veranda prevents heat from being transferred from the Sun to the walls of a house.

Energy ratings

Most modern appliances such as air conditioners, heaters and televisions have an energy star rating. These ratings are shown on a label and indicate the amount of energy consumed with average use (Figure 6). The star rating indicates the efficiency of the appliance and is determined by the amount of energy used and the size of the appliance. A large television will be less efficient than a small television.

Figure 6 Australia uses an energy rating system to allow consumers to identify the most efficient device.

Check your learning 9.3

Check your learning 9.3

Comprehend

1 **Represent** the fire drill method used by Aboriginal and Torres Strait Islander Peoples as a Sankey diagram with an input energy of 16 J, kinetic energy of 10 J and thermal energy of 6 J.

2 **Draw** flow diagrams for the following energy transformation processes that happen in your house. **Justify** the waste energy that you draw when:

  a heating during winter

  b cooling during summer.

3 **Describe** how window awnings and verandas keep a house cool in summer.

Apply

4 A hairdryer transforms electrical energy into thermal energy.

  a **Describe** how the hairdryer generates thermal energy.

  b **Predict** what would happen if the hairdryer used materials that were good conductors.

5 The temperature inside and outside a house was measured over 4 days and displayed in Figure 7. **Determine** from the graph whether the house was insulated. **Justify** your answer (by using numbers from the graph as evidence).

6 **Summarise** how architects use their knowledge of energy efficiency to minimise the energy used in heating or cooling a house.

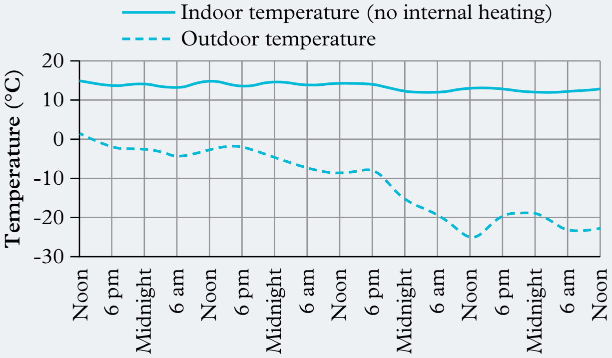


Figure 7 A graph showing the temperature inside and outside a house

Lesson 9.4

Challenge: Design an energy-efficient house

Design brief

Design and build two identical houses using cardboard or wood. Add a feature to one of the houses that will make it more efficient in staying cool. Test your design feature by exposing both houses to an energy source (a strong light) and determine the rate of temperature increase for each house.

Criteria restrictions

- Only one feature may be added to the second house.
- The feature must represent a design feature that is currently available to homeowners.
- The feature must be proportionate in size to the house.

Questioning and predicting

1 **Identify** the feature you will add.

2 **Identify** the materials you will use.

3 **Use** your knowledge of heat energy to **explain** why your added feature will keep the house cool.

Planning and conducting

1 **Explain** how you will measure the temperature of the two houses.

2 **Describe** how long you will expose the houses to the energy source.

Processing, analysing and evaluating

1 **Describe** the rate of temperature increase in both houses.

2 **Calculate** how efficient your feature was at preventing the transfer of thermal energy by comparing the difference in temperature of the two houses.

3 **Describe** the limitations of your design (when it will not prevent thermal transfer).
4 **Explain** how you could create a large-scale version of your design for a real house.
5 **Explain** how you would modify your device if you were doing this experiment again.

Communicating

Present the various stages of your investigation in a formal scientific report.

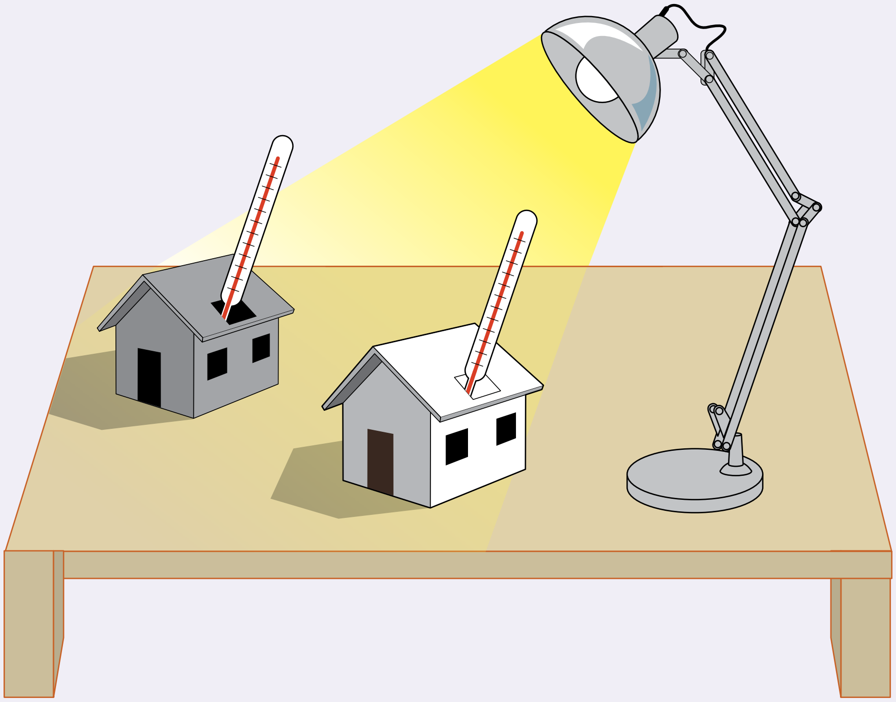


Figure 1 General set-up of experiment

Lesson 9.5

Athletes need to be energy efficient

Learning intentions and success criteria

Key ideas

→ Archery involves energy being transferred from the archer to the string and then to the kinetic energy of the arrow.

→ Pole vaulting involves energy being transferred into and out of an elastic pole.

Efficiency in sport

An understanding of energy efficiency can improve our understanding of the world around us. From reducing the amount of energy lost in archery to increasing the energy efficiency of the poles used in pole vaulting, understanding how to reduce waste energy can improve athletic performance.

Archery

Archery is a sport that involves using a bow to shoot an arrow at a target. There are three stages of energy transfer and transformation when an archer shoots an arrow.

1. The chemical energy in the archer's arm is transformed to kinetic energy as the fingers pull back the string on the bow.
2. The kinetic energy is transferred and transformed to elastic potential energy in the stretched string. For this to be efficient, the string must be evenly stretched. Some of the elastic potential energy is transformed into heat (thermal energy) in the arm and the string. This is waste energy because it cannot be reused.
3. When the fingers let go of the stretched string, the elastic potential energy is transferred and transformed into kinetic energy in the arrow. This process produces waste energy in the form of heat and sound from the string bouncing back to its original position and heat and sound from the friction of the arrow moving through the air (Figure 1).

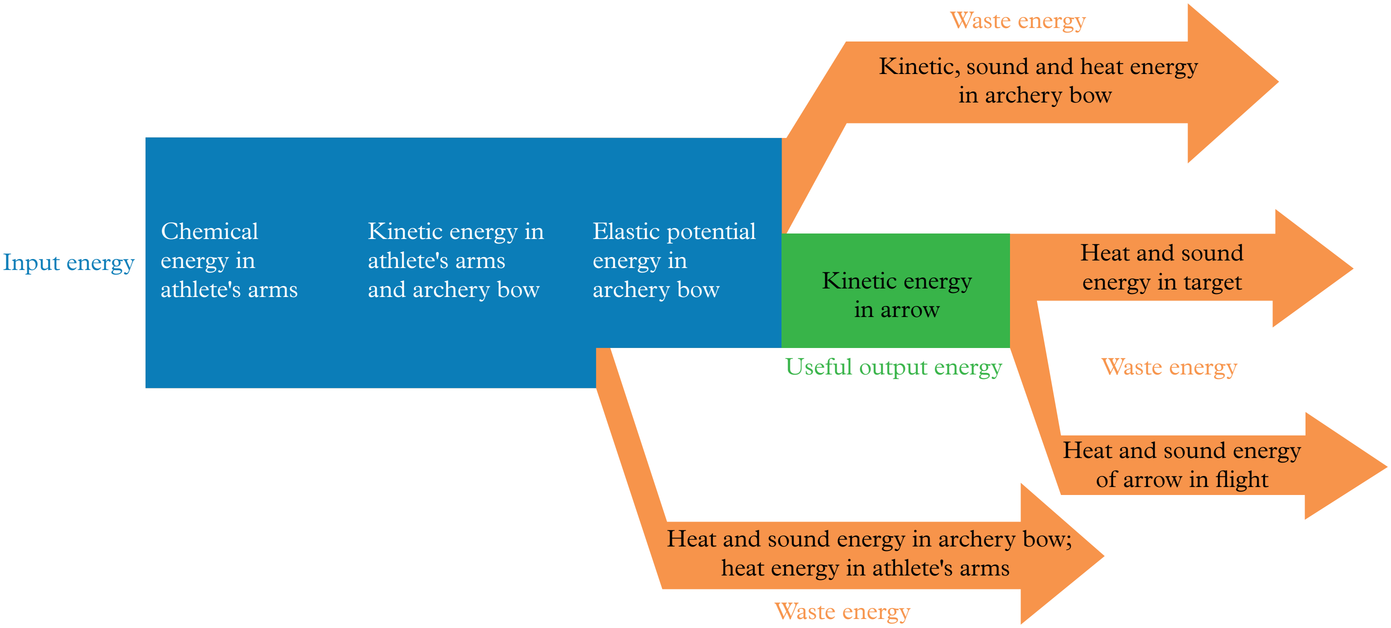


Figure 1 A Sankey diagram of energy transfer and transformation in archery

Studies of energy efficiency in archery have found that as the weight of the arrow increases, the bow becomes more efficient (Figure 2). This means less heat and sound is produced when the archer shoots a heavier arrow.

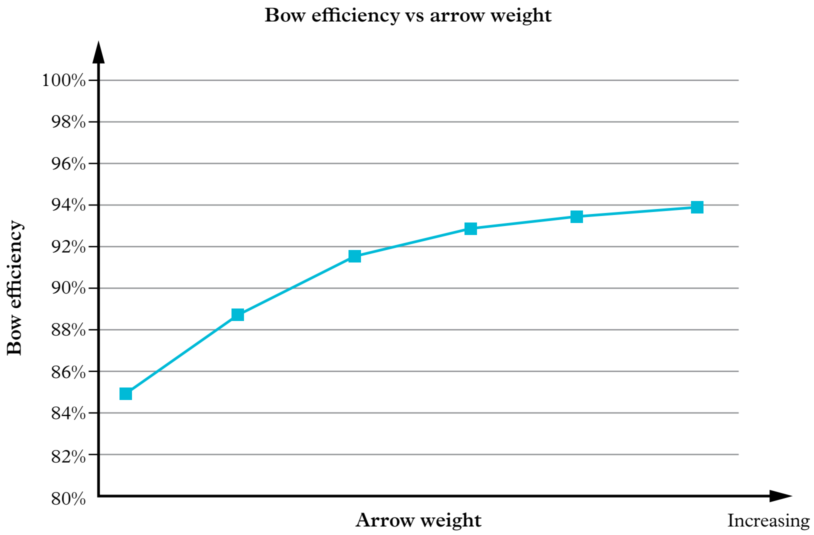


Figure 2 As the weight of the arrow increases, the bow becomes more efficient.

Pole vaulting

Pole vaulting is a unique sport that requires the athlete to have a solid understanding of energy efficiency (Figure 3). Many observers of the sport make the mistake of thinking that the vaulting athlete needs to have strong upper body strength to "pull" themselves over the bar. Although athletes in this sport do require arm strength to carry the pole and leg strength to increase kinetic energy in the run up, the key to being a good pole vaulter is understanding the importance of efficient energy transfer and transformation in the pole.

In the run-up, the athlete needs to rapidly increase their speed. This generates kinetic energy (from the chemical energy in their bodies). At the end of the run, the athlete plants their pole at the base of the bar. The kinetic energy of the run-up is transferred into the pole, causing it to bend and store energy as elastic potential energy. Like most energy transfers, waste heat energy is generated. The elastic energy is released as the pole straightens, transferring back to the athlete, and transforming into gravitational potential energy as the athlete rises into the air. As the athlete reaches full height (peak gravitational energy), the athlete lets go of the pole and moves over the bar and falls to the mat below (Figure 4). The athlete who is able to jump the highest bar without knocking it off will win the competition.

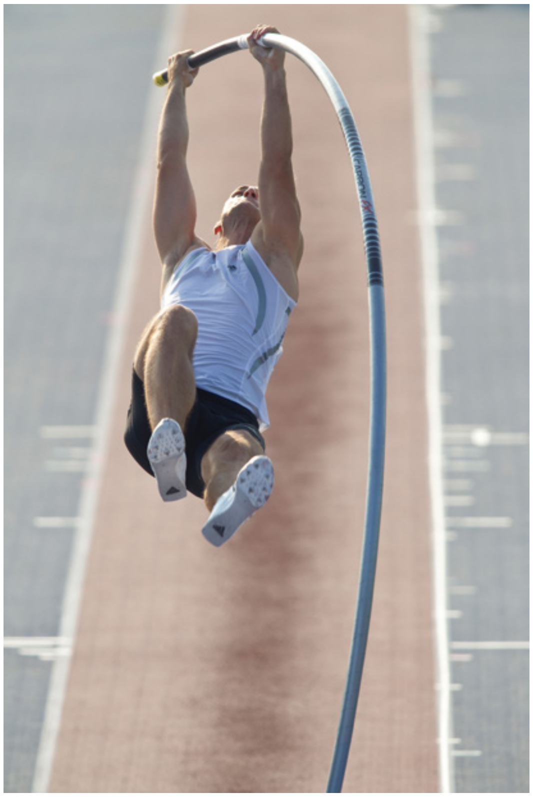


Figure 3 Pole vaulting involves an athlete using a pole to jump 5 to 6 metres over a bar.

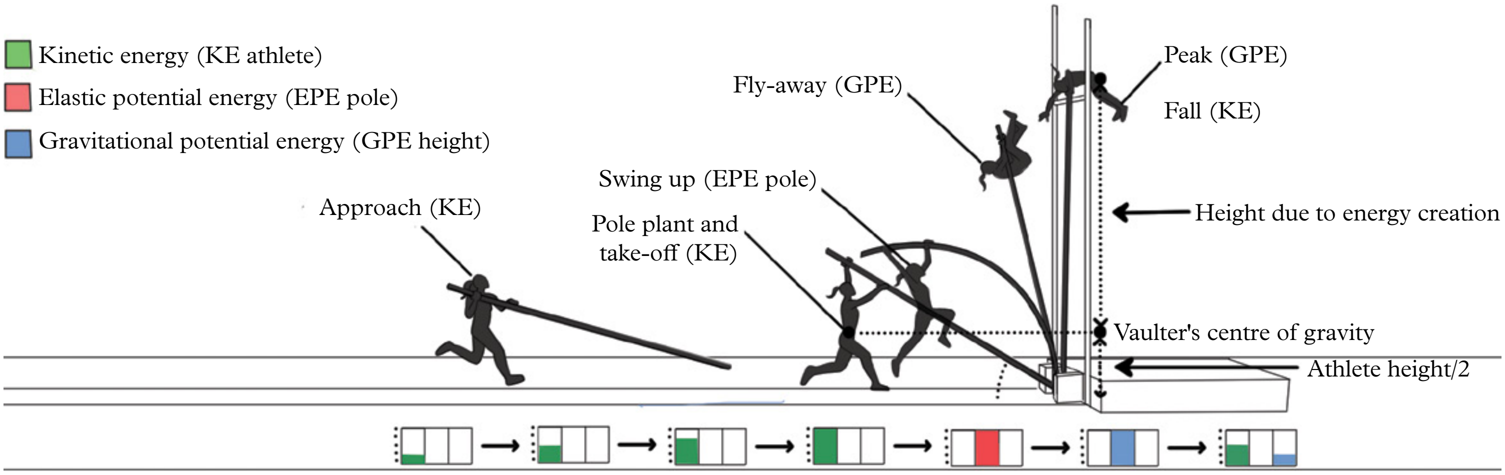


Figure 4 Pole vaulting involves the transfer of energy in and out of the pole.

The pole is the main point of energy transfer and transformation. The efficiency of energy transfer from the athlete to the pole, and from the pole back to the athlete, is the key to a successful jump. Early poles were made of wood with elastic properties. In the 1850s, wood from ash or hickory trees was used for the poles. Seven years later, athletes started using bamboo poles because they were able to store more elastic energy. In the 1940s, steel poles were trialled before flexible fibreglass was used. Most modern pole vaulters have added carbon fibre to the fibreglass to increase the flexibility and a fast recoil. This transfers more of the elastic energy stored in the pole to the vaulter.

Check your learning 9.5

Check your learning 9.5

Retrieve

1 **Identify** two types of energy involved in archery.

Comprehend

2 **Draw** flow diagrams for the energy transformation process that occurs in:
  - **a** archery
  - **b** pole vaulting.

3 **Represent** the energy transfer in pole vaulting with a Sankey diagram.

Apply

4 **Propose** why a moving arrow would generate thermal heat energy.

5 There are two types of bows that are used in competition archery in the Paralympic events. The recurve bow has limbs that curve away from the archer. The compound bow is less flexible and uses pulleys and cables to store the elastic potential energy. Both bows are effective in shooting arrows, but the recurve bow produces more sound when the arrow is released. Use this description to **identify** which bow is more efficient. **Justify** your decision.

Lesson 9.6

Review: Energy efficiency

Summary

Lesson 9.1 Energy cannot be created or destroyed

- The Law of Conservation of Energy states that energy cannot be created or destroyed.
- When energy is transformed, waste energy is produced.
- Efficient energy transformations produce less waste energy.

Lesson 9.2 Sankey diagrams can represent energy efficiency

- The conservation of energy can be represented in a Sankey diagram.

Lesson 9.3 Energy efficiency can reduce energy consumption

- Understanding how waste energy is formed allows it to be minimised.
- Waste energy can be useful.
- Insulation prevents the transfer of thermal (heat) energy.
- Knowledge and understanding of energy transformations is not limited to scientists.

Lesson 9.5 Athletes need to be energy efficient

- Archery involves energy being transferred from the archer to the string and then to the kinetic energy of the arrow.
- Pole vaulting involves energy being transferred into and out of an elastic pole.

Review questions 9.6

Review questions: Module 9

Retrieve

1 **Identify** the equation used to calculate energy efficiency.

A efficiency $= \frac{\text{useful energy input}}{\text{energy output}}$

B efficiency $= \frac{\text{useful energy output}}{\text{energy input}}$

C efficiency $= \frac{\text{useful energy input}}{\text{energy output}} \times 100$

D efficiency $= \frac{\text{useful energy output}}{\text{energy input}} \times 100$

2 **Identify** the amount of thermal energy produced by the electric motor in Figure 1.

A 14 J
B 36 J
C 50 J
D 86 J

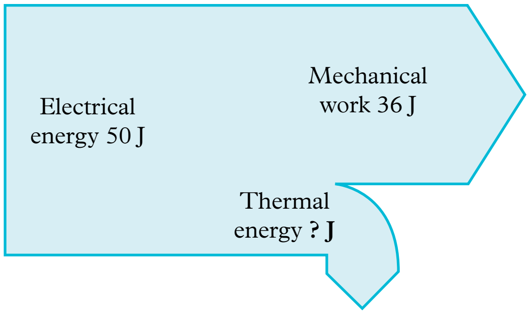


Figure 1 Sankey diagram showing energy produced by an electric motor

3 **Recall** how insulation can help to make a house more energy efficient in summer.

A It captures light energy to power the house.
B It stops heat getting in through the windows.
C It deflects light energy away from the house.
D It helps to keep heat out of the house during the day.

4 **Recall** what the stars on the energy rating of an appliance represent.

Comprehend

5 Use numbers in an example of your own to **explain** the Law of Conservation of Energy.

6 Use numbers in an example of your own to **explain** energy efficiency.

7 **Explain** why a ball that rebounds high is considered more efficient than a ball that does not rebound at all.

8 **Explain** what is meant by "waste energy".

9 **Describe** two different ways electrical energy can be generated.

Analyse

10 **Classify** the following as either true or false. Rewrite any false statements to make them true.

- **a** Archery bows only hold stored energy when they are stretched.
- **b** When an object is thrown up in the air, it gains gravitational potential energy.
- **c** Thermal energy is a type of potential energy.
- **d** Energy can be transferred with 100 per cent efficiency.

11 **Analyse** each of the following situations and **identify** the main form of energy in each.

- **a** A ground oven used for cooking
- **b** A stretched archery bow
- **c** The Sun heating the walls of a house
- **d** An arrow flying through the air

12 For each of the following, **consider** the energy transformation and **identify** a device that performs that transformation.

- **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

13 **Compare** the energy efficiency of a bamboo pole vault and a carbon fibre/fibreglass pole vault.

14 **Compare** the effectiveness of a veranda and window awnings in increasing the energy efficiency of an uninsulated house in summer.

15 **Calculate** the percentage efficiency of a device if it transforms:

- **a** 20 units of input energy into 12 units of useful output energy
- **b** 600 units of input energy into 500 units of useful output energy.

16 A large wind turbine is able to transform 2,500 J of mechanical energy into 2,000 J of electrical energy each second.

- **a** **Calculate** the amount of thermal waste energy produced each second.
- **b** **Calculate** the efficiency of the wind turbine.

17 Figure 2 illustrates the generation of electrical energy from coal. Use the Sankey diagram to **calculate** the energy efficiency of this process.

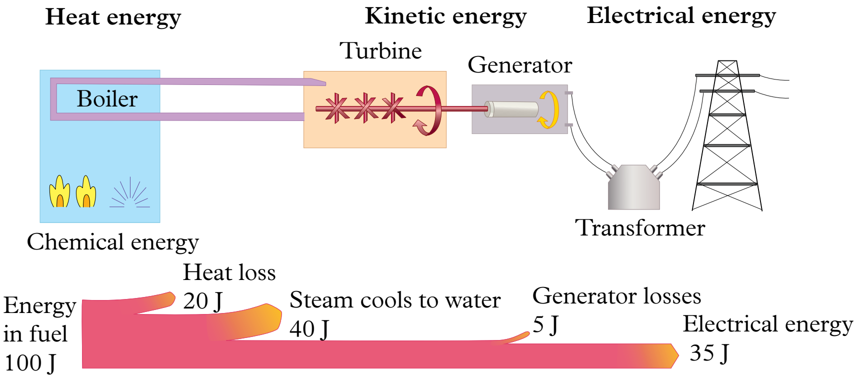


Figure 2 Generation of electrical energy

18 Identify which of the three lights in Figure 3 is most energy efficient. Use calculations.

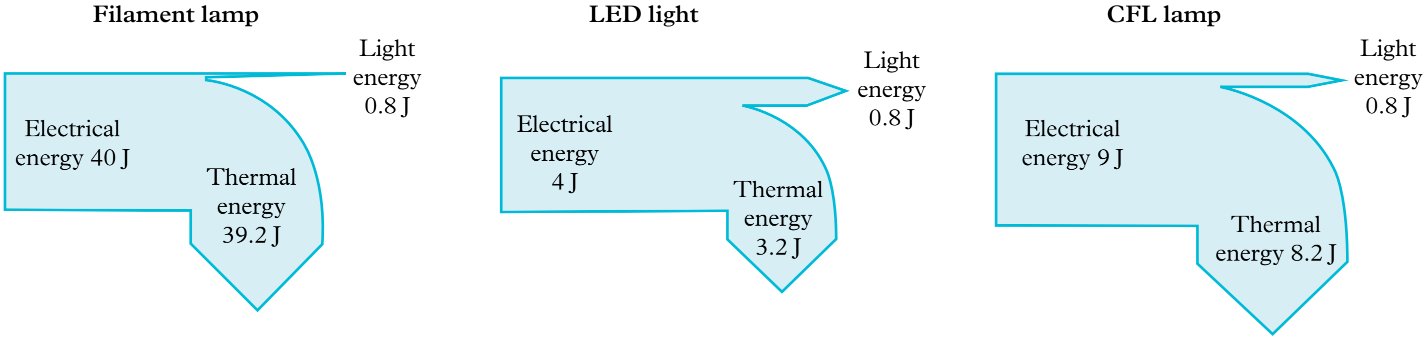


Figure 3 Sankey diagrams showing energy efficiency of three lights

Apply

Critical and creative thinking

19 Evaluate the energy efficiency of the light globes in Figure 4 (by calculating the efficiency of the light being produced, comparing the amount of waste energy produced and deciding which type of globe you would recommend in your house).

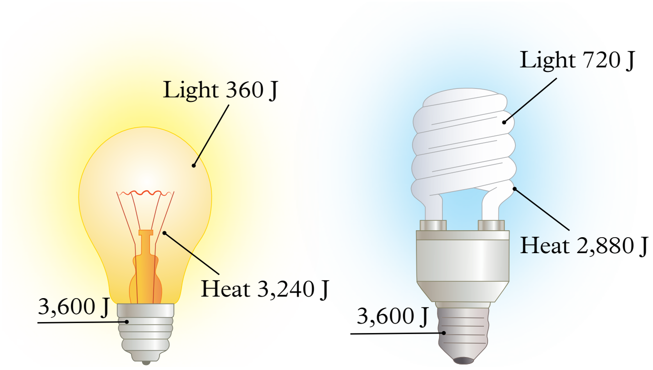


Figure 4 Energy efficiency of two light globes

20 Evaluate the efficiency of a ground oven (by describing how a ground oven cooks food, describing the advantages and disadvantages of a ground oven, comparing a ground oven to the oven in your kitchen, describing when using a ground oven would be more efficient than a kitchen oven).

21 Determine the main source of electrical energy generation in your area. Describe how that energy is generated.

22 The perpetual motion machine is a hypothetical machine that could keep working forever without any energy source. Use the Law of Conservation of Energy to **discuss** why this machine would be impossible.

Social and ethical thinking

23 A mobile phone charger that is switched on at the power point is constantly using energy, even when no phone is placed on it to be charged. **Evaluate** the ethics of maintaining this energy use when your phone is fully charged (by describing the advantages and disadvantages of leaving the phone charger on, deciding whether you are using an "ends justify the means" (consequentialism) approach or a "rules-based" (deontology) approach, and deciding whether the phone charger should be left on).

Research

24 Choose one of the following topics for a research project. A few guiding questions have been provided for you, but you should add more questions that you want to investigate. Present your research in a format of your own choosing, giving careful consideration to the information you are presenting.

Energy and matter

Our understanding of energy and matter has changed over time as a result of technology that can measure very small amounts of energy (subatomic particles such as protons, neutrons and electrons) and the energy of objects that are very far away (black holes). A particle accelerator such as the synchrotron at the Australian Nuclear Science and Technology Organisation uses and detects subatomic particles as part of its research (Figure 5).

- **Describe** in your own words how a synchrotron accelerates charged particles.
- **Identify** one of the research projects that uses the Australian Synchrotron.
- **Describe** the question the research project is trying to answer.
- **Describe** the results of their experiment so far.

Figure 5 The Australian Synchrotron examines the energy of subatomic particles

Electricity generation

Each time energy is transferred or transformed, waste energy is produced.

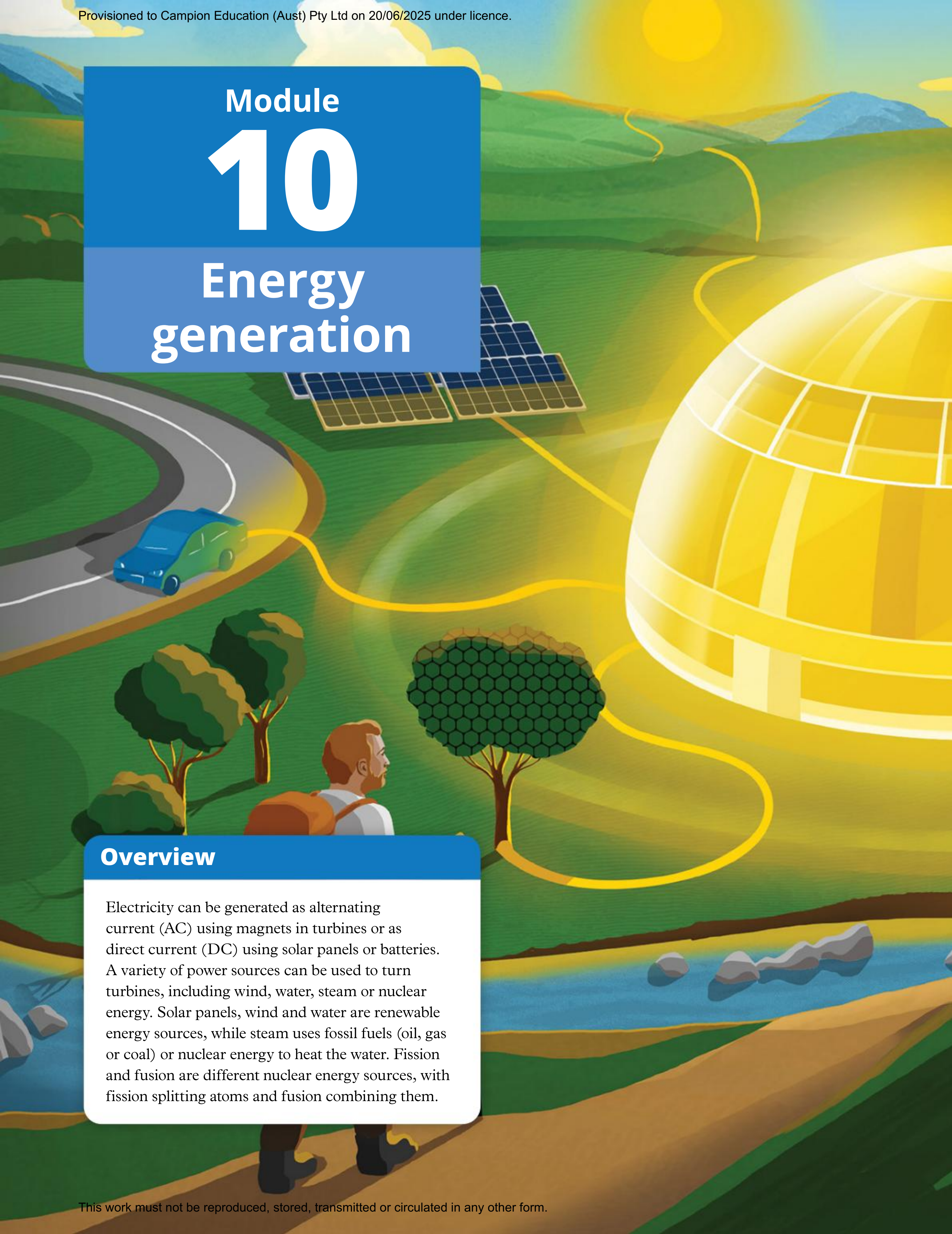
- **Describe** two ways electrical energy is generated (nuclear, hydroelectrical, gas, solar and wind).
- For each process, **compare** the waste energy that is generated each time the energy is transferred and transformed.
- Use the comparison to **identify** and **justify** which process of electricity generation is most efficient.

Energy-efficient housing

In previous societies, energy efficiency was important because people had limited access to different types of energy supply and their applications compared to today.

- **Investigate** 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.
- **Identify** what is meant by a “passive house”.

Figure 6 Solar panels on houses improve energy efficiency.



Module

10

Energy generation

Overview

Electricity can be generated as alternating current (AC) using magnets in turbines or as direct current (DC) using solar panels or batteries. A variety of power sources can be used to turn turbines, including wind, water, steam or nuclear energy. Solar panels, wind and water are renewable energy sources, while steam uses fossil fuels (oil, gas or coal) or nuclear energy to heat the water. Fission and fusion are different nuclear energy sources, with fission splitting atoms and fusion combining them.

Lessons in this module

Lesson 10.1

Wire carrying an electric current generates a magnetic field

Learning intentions and success criteria

Check the next lesson for a linked practical activity or experiment.

Key ideas

→ A magnetic field is generated when a current moves through a wire.

→ The direction of the magnetic field can be determined by the right-hand grip rule: the thumb points in the direction of the current (towards the negative terminal) and the fingers curl in the direction of the magnetic field.

→ Electromagnets use electricity to generate a strong magnet that attracts metal.

Magnetic fields

magnetic field the area around a magnet, a magnetic substance or an electric charge where there is a magnetic force

A **magnetic field** exists in the space surrounding a magnet. When iron or steel enters the magnetic field, it experiences a force. The shape of the magnetic field can be made visible by sprinkling iron filings around the magnet. The closer the iron filings are to the magnet, the stronger the magnetic force.

Using electricity to create magnetic fields

electric current the flow of electrical charge through a circuit

Magnets are not the only objects that generate magnetic fields. When Danish physicist Hans Christian Ørsted discovered that a wire carrying an **electric current** caused a compass to move when the current was switched on, he concluded that electricity could cause magnetism. A single current-carrying wire creates a circular magnetic field that gets weaker as the distance from the wire increases (Figure 1).

When a small compass is placed in the field, the needle shows the direction of the magnetic field.

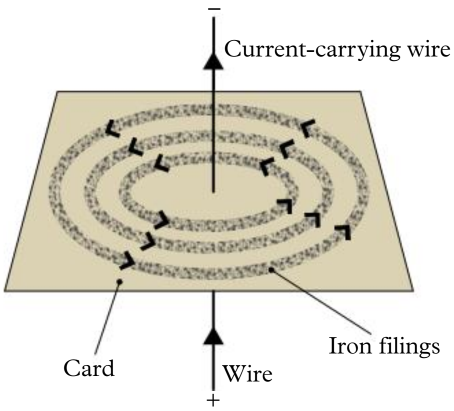


Figure 1 The magnetic field around a straight current-carrying wire is circular.

right-hand grip rule a rule used to predict the magnetic field direction around a current-carrying wire or the magnetic field of a solenoid; the right thumb indicates the current direction and the curled fingers give the magnetic field direction; also known as the right-hand curl rule

Just like the magnetic field around a magnet, the magnetic field around an electrical wire carrying a current has direction. The field around the outside of a magnet is always said to be moving from the north pole to the south pole of the magnet. To determine the direction of the magnetic field around an electrical wire, use the **right-hand grip rule** (also called the right-hand curl rule) (Figure 2).

Place your right hand so that your thumb is pointed along the wire in the direction of the conventional current, which traditionally is towards the negative terminal of the battery. Now curl your fingers. The way your fingers curl gives the circular direction of the magnetic field.

Electromagnets

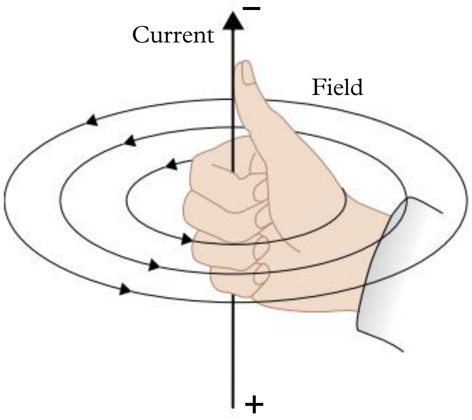


Figure 2 The right-hand grip rule. The way the fingers point around the wire gives the direction of the magnetic field. The direction in this diagram is anticlockwise.

Wires carrying an electrical current can be used to generate a magnetic field that can be turned on and off. This is called an **electromagnet**. To create a stronger, straighter magnetic field, you can loop a long, single, current-carrying wire into coils (Figure 3A). Such a coil of loops is known as a **solenoid**. The magnetic field produced by this arrangement is very similar to that of a bar magnet. To determine the direction of the magnetic field in this case, use the right-hand grip rule on any one of the loops of the solenoid. This will give the direction of the magnetic field inside and around the outside of the solenoid. The magnetic field inside the solenoid moves towards the north pole, and the magnetic field around the outside of the solenoid moves out from the north end and around the outside to the south end (just like a bar magnet).

electromagnet a type of magnet that uses an electrical current to produce a magnetic field

solenoid an electromagnet consisting of a coil of wire that can carry an electric current, with an iron core

To create an even stronger magnetic field, a soft iron core can be added inside the solenoid (Figure 3B). Pure iron is easily magnetised. If the current is switched on, the core becomes magnetised and strengthens the magnetic effect of the solenoid. If the current is switched off, the magnetic field is reduced. This is an example of an electromagnet, which is a type of magnet that can be turned on and off. The versatile nature of electromagnets has enabled many devices to be invented (Figure 4).

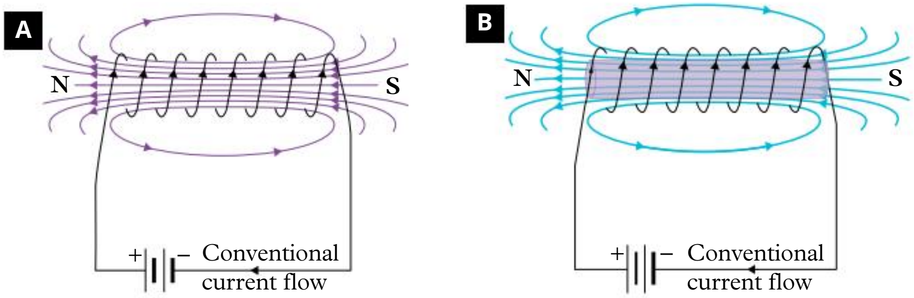


Figure 3 (A) A stronger magnetic field is created when a long, single, current-carrying wire is looped into coils. (B) An iron core increases the strength of the electromagnet.

Figure 4 The ability to switch the magnetic fields of electromagnets on and off has made them useful for many devices, such as this electromagnet that is used to sort scrap metal.

Check your learning 10.1

Check your learning 10.1

Retrieve

1 **Recall** how the strength of a magnetic field changes with the distance from a magnet.

Comprehend

2 **Describe** what happens to the strength of a magnetic field as you come closer to the current-carrying wire.

3 **Describe** how the right-hand grip rule can be used to show the direction of the magnetic field around a wire.

Apply

4 An electromagnet made by a student will pick up three paperclips, but it is not strong enough to pick up four paperclips. **Describe** two ways the student could modify the electromagnet so it can pick up four paperclips.

5 **Describe** how the strength of the magnetic field around a solenoid could be increased.

6 **Explain** why all electrical wiring on a ship should be kept away from the ship's compass.

Lesson 10.2

Experiment: Creating magnetic fields

Aim

To investigate the magnetic field around a single wire and a solenoid when connected to direct current (DC) and alternating current (AC)

Materials

- Different-shaped magnets
- Sheet of A4 paper
- Iron filings
- Long insulated wire
- Iron nail
- Retort stand
- AC/DC 12 V power supply
- Connecting wires
- 2 plotting compasses

Method

1 Arrange the magnets under the paper. Sprinkle the iron filings on the top of the paper. The iron filings will align with the magnetic field around the magnets. Draw the lines that are created. Include arrows showing the magnetic field moving from the north pole to the south pole of the magnets. Put the iron filings away before starting the next step.

2 Wrap the wire around the nail as many times as possible. Remove the nail to make a solenoid.

3 Sit the solenoid on the retort stand base.

4 Connect the solenoid to the power supply using the wires. Use the DC connections and turn the knob to 12 V. Before switching on the power, position the plotting compass under one of the connecting wires so that its needle is parallel to the wire.

5 Switch the power on and observe the compass needle. Move the compass above the connecting wire and observe. Test the other compass with the other connecting wire. Record your observations.

6 Insert the nail into the solenoid. What do you notice during this process? What happens to the temperature of the nail? Try to pull the nail out of the solenoid while the power is still on, and again after the power is off. Was there a difference? Move the solenoid off the stand base and again try to remove the nail while the power is on. Was there a difference?

7 Remove the nail and change the power to AC. Reinsert the nail. Is there any evidence that the magnetic field is vibrating? Does the nail get hot after a while?

Discussion

1 **Explain** why the magnetic field around the solenoid is stronger than around the wire.

2 **Explain** the difference in pulling the nail out of the solenoid with the power on and off.

3 **Explain** the effect of the stand on the ease or difficulty of removing the nail from the core.

4 **Describe** the effects of DC and AC on the nail.

5 **Explain** why the iron nail became hotter when the solenoid was switched on.

Conclusion

Describe the effects of an electric current on the magnetic field surrounding a wire and a solenoid.

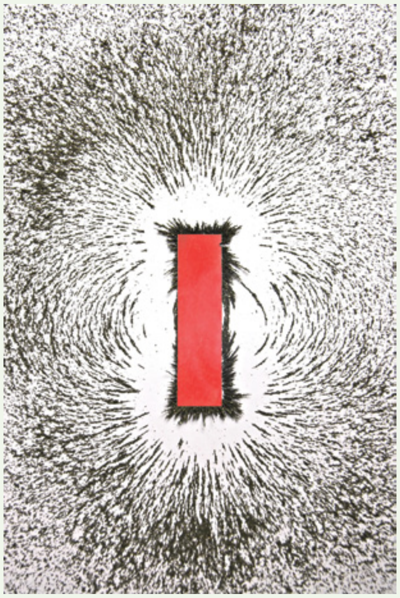


Figure 1 The pattern of iron filings shows the magnetic field.

Lesson 10.3

Magnetic fields and movement are used to generate electrical current

Key ideas

→ Moving magnetic fields can generate electrical current in coils of wire.

→ A dynamo generates direct current (DC) and an alternator generates alternating current (AC).

→ The generated current can be increased by increasing the number of coils or the speed of movement.

Learning intentions and success criteria

Electromagnetic induction

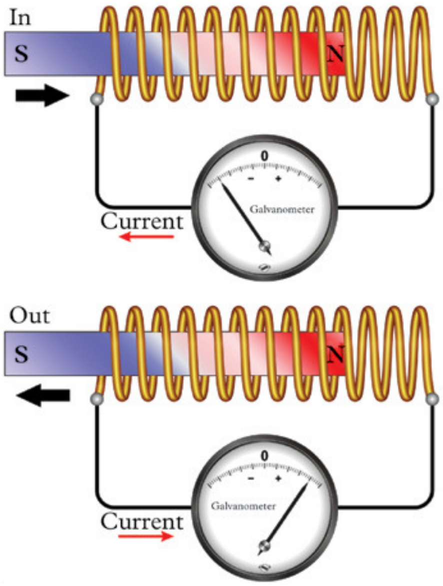


Figure 1 A magnet moving through a coil of wire will generate a current in the wire.

In Lesson 10.2 Experiment: Creating magnetic fields (page 336), you were able to use an electrical current (moving electrons) to generate a magnetic field that circles the wire. Michael Faraday, a nineteenth-century bookbinder and chemist, became interested in the idea of placing one end of a magnet in the coils of a wire that was electrified. He thought that this would generate a force on the magnet that would cause it to be pushed out of the coil. When he did the test, he found the magnetic field that surrounded the wire coils forced the magnet to move. While this was a good trick to show audiences, Faraday also experimented with moving a magnet (with its magnetic field) through a coil of wire. He found that this was able to make an electrical current (Figure 1).

This effect is due to the magnetic field around the magnet exerting a force on the moving electrons inside the wire, which pushes the electrons along the wire. The flow of electrons becomes an electrical current.

This process of using magnetic fields and movement to generate an electrical current is known as **electromagnetic induction** and is used to generate electricity in a dynamo. If the magnet only moves in one direction, so too does the current. This is called **direct current (DC)**.

When the magnet is pushed in the opposite direction, the electrons are pushed along the wire in the other direction and the current reverses. This constantly reversing current is known as **alternating current (AC)**. The same effect is achieved if the magnet is held still and the wire is moved up and down. The voltage driving the current can be increased by:

- increasing the speed of the movement
- using a bundle of wires rather than a single wire
- positioning the wires at a right angle to the magnetic field.

The generator

A more efficient way of generating electricity is to wrap one long wire into a coil and rotate it in a magnetic field. This process is the basis of all **generators** that produce electricity (Figure 2). The faster the coil is spun and the greater the number of turns in the coil, the greater the voltage that is generated. The type of electrical current that is generated will be determined by how the coils of wire are connected to the brush.

Most commonly, the electricity that is generated for household use is alternating current (AC). The advantage of a constantly changing alternating current rather than a one-directional flow of direct current is that an alternating current is more efficient in transferring the electricity along wires.

Electricity is often generated away from city centres. This means that it needs to be transported in high-voltage overhead powerlines to homes and businesses. A step-up **transformer** is needed to produce the high-voltage electricity (220,000 to 500,000 volts) that travels in the wires over long distances. The long span of wire resists the flow of electricity, causing energy to be lost as heat. Using high-voltage, low-current electricity reduces

electromagnetic induction the production of voltage (and hence a current) in a circuit, by the magnetic field through the circuit or by the relative movement of the magnetic field and the circuit; all dynamos and generators use this principle

alternating current (AC) an electric current in which the direction of the current (flow of electrons) changes at regular intervals

direct current (DC) an electrical current that flows in one direction only; electrical energy is produced in this form by a battery

generator a machine that uses the electromagnetic effect to separate charges and produce electricity

transformer a device that changes the voltage at which energy is transmitted by an alternating current; usually consists of two coils or wire (primary and secondary), an iron core and an AC power source

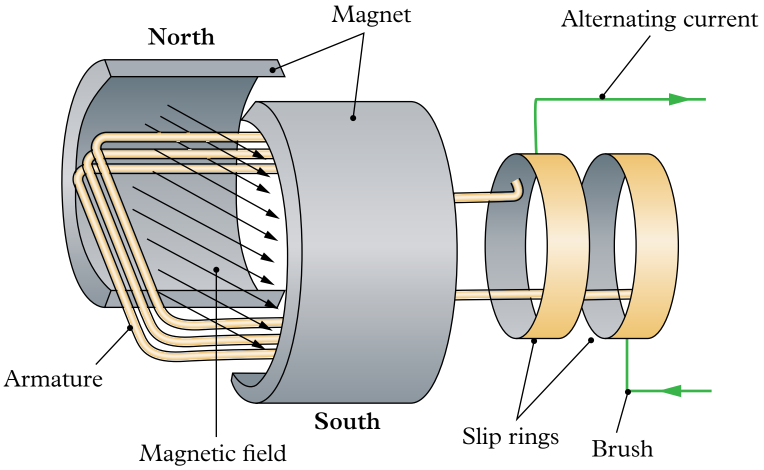


Figure 2 Parts of an AC generator. Most power plants use wind, water or heat from coal to turn the shaft of the generator. This causes the large loops of wire to turn between magnets, generating a current (usually AC).

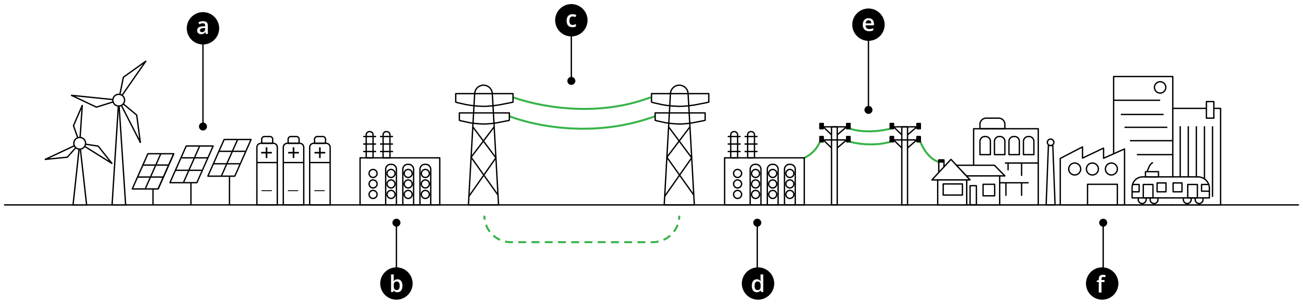


Figure 3 Electricity is usually generated away from the homes and businesses that use it.

- ⓐ **Generators** use energy sources to produce electricity.
- ⓑ **Step-up voltage transformers** at terminal stations increase the voltage ready for transmission. Higher voltages mean more electricity can be transmitted over long distances.
- ⓒ **Transmission** lines carry high voltages of electricity over long distances. These can be overhead lines or underground cables.
- ⓓ **Step-down voltage transformers** at terminal stations decrease the voltage ready for distribution lines.
- ⓔ **Distribution** lines carry lower voltages of electricity to homes and businesses.
- ⓕ **Homes and businesses** use the electricity.

the loss of energy. However, this low-current electricity is not useful for most appliances in our homes. Most towns will have step-down transformer stations that convert the flow of electricity to the 240 volts that we can use (Figure 3).

There are many ways electricity is generated in Australia. Most of them use movement, magnets and coils of wire. Their only variation is the method used to rotate the coils of wire in the magnets.

Fossil fuels

The traditional method of producing movement in a generator is through the use of steam. Fossil fuels such as coal, gas and oil are burnt in a combustion reaction to produce heat, carbon dioxide and water. The heat flows through a water boiler to produce steam and water vapour (the gas form of water). As the gas molecules increase movement and pressure, they turn a turbine, which causes the rotation of coils of wire in a generator. This movement of wires in a magnet generates the electrical current (Figure 4). In 2019, 70 per cent of the electricity generated in Victoria was produced through the use of coal.

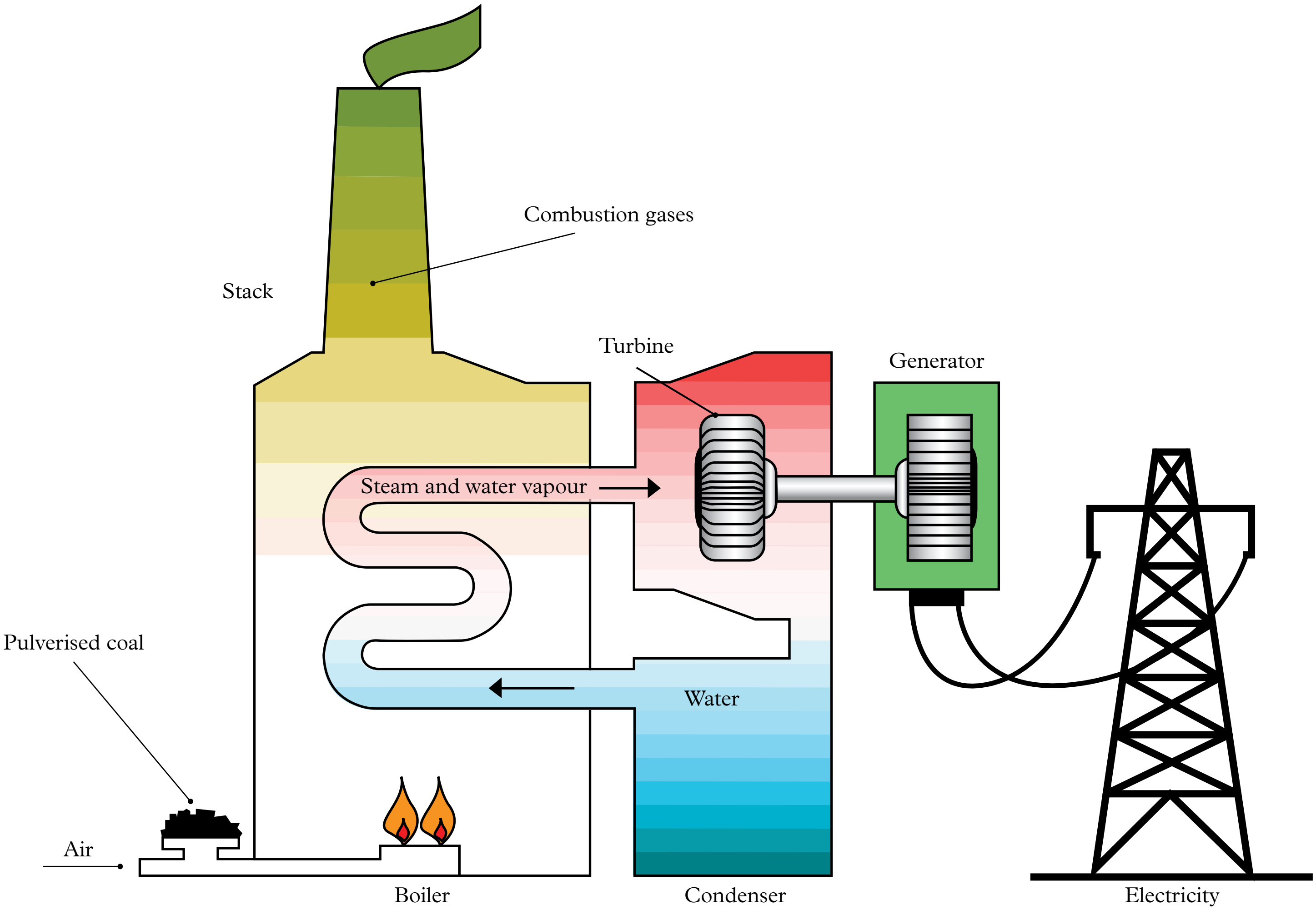


Figure 4 Fossil fuels are used to produce the steam that drives electricity generators.

Nuclear

Australia currently has one nuclear reactor that is used to generate materials for medical and scientific purposes. While Australia does not currently have laws that allow for a nuclear power plant, 32 countries use nuclear power to generate between 1 per cent (Iran) and 60 per cent (France) of their country's electricity.

The energy required to generate electricity in nuclear power plants comes from the unstable element uranium-235. This element is processed into small ceramic pellets that are sealed into metal tubes called fuel rods. When a neutron collides with the uranium atoms in the pellets, it causes the atom to split into smaller atoms, releasing more neutrons and large amounts of heat and radiation (Figure 5). This is called **nuclear fission**. The speed of the nuclear fission is controlled by placing the fuel rods in water. If the uranium is allowed

nuclear fission
a nuclear reaction in which a large atom splits into two or more particles

How fission splits the uranium atom

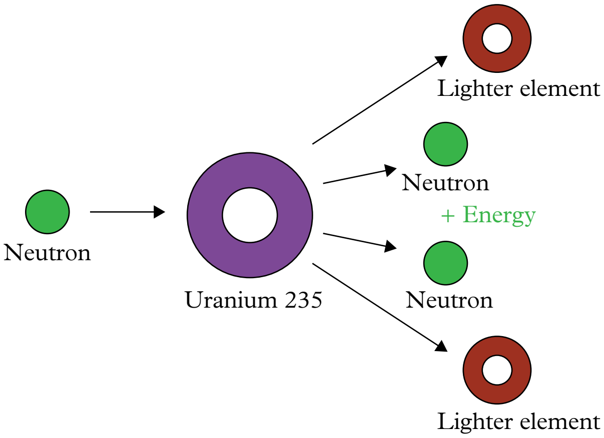


Figure 5 Nuclear fission involves the splitting of an atom into smaller particles and releasing energy.

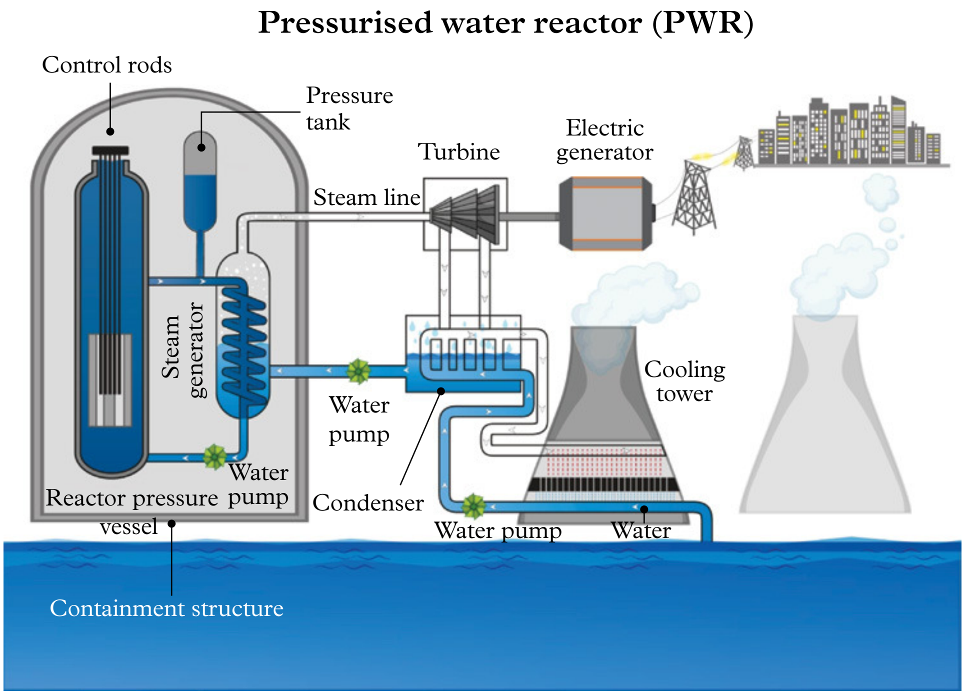


Figure 6 The heat from a nuclear reaction can generate steam and water vapour that drives electricity generators.

to undergo uncontrolled fission, it becomes a chain reaction in which one neutron hits one atom, releasing two more neutrons that hit two more atoms, and so on. Immersing the fuel rods in water allows some of the heat to be removed, cooling and slowing the movement of all the particles involved.

The heat generated by the nuclear fission reaction produces steam that is used to provide kinetic energy to an electrical generator (Figure 6).

In 2023, CSIRO and the Australian Energy Market Operator analysed the relative costs of producing electrical energy. They found that the cost of operating small modular reactors (SMRs) in Australia would be $509/MW hour in 2023 and would decrease to $282/MW hour in 2030. In comparison, the cost of using wind and solar to produce electricity would be $112/MW hour in 2023 and would decrease to $82/MW hour in 2030.

Check your learning 10.3

Check your learning 10.3

Retrieve

1 **Recall** two examples of a fossil fuel.

Comprehend

2 **Describe** how the voltage driving a current can be increased in a generator.

3 **Explain** how a generator works to a student in Year 7. Write down your explanation.

4 **Identify** which of the following will generate electricity.

- **a** A bar magnet moving in a coil
- **b** A bar magnet moving away from a coil
- **c** A coil being lowered over an upright bar magnet
- **d** A bar magnet being held still inside a coil
- **e** A direct current being turned on in a coil that is above another coil
- **f** An iron core being inserted into a coil ▶

Analyse

5 Use a Venn diagram to **compare** the production of alternating current (AC) and direct current (DC).

6 **Compare** how electricity is produced by fossil fuel and nuclear fission.

Apply

7 **Explain** the function of a transformer in improving energy efficiency when transporting electricity from the generator to homes.

Lesson 10.4

Renewable energy sources can generate electricity

Learning intentions and success criteria

Check the next lesson for a linked practical activity or experiment.

Key ideas

→ The speed of wind can affect the amount of power generated.

→ The potential energy of water stored upstream can be used to generate electricity.

→ The difference between the water levels at high and low tide can be used to generate electricity.

→ Excess renewable energy can be stored by pumping water into an upstream dam.

Introduction

renewable energy energy that comes from resources that are made naturally and available in an almost unlimited amount

Energy that is not depleted when it is used is called **renewable energy**. Sources of renewable energy include wind, water in streams or the ocean, thermal energy from deep in the ground and solar energy from the Sun. While Australia does not have easy access to the same thermal energy as Iceland's volcanic lands, it does have access to wind and water.

Wind

Some methods of turning a turbine are more direct. Wind turbines use wind to turn rotor blades that can be up to 80 m in length (Figure 1). Wind turbines are usually located in areas that have high levels of wind. Each turbine can start generating electricity when the wind reaches the "cut-in" speed (when the blades begin to rotate fast enough to generate power). Most wind turbines will also have a "cut-out" point, at which the turbine would become damaged if the wind speed were to increase any further (Figure 2). Each wind turbine is usually equipped with sensors that allow it to turn to face the wind to make sure the turbine is operating at maximum efficiency.

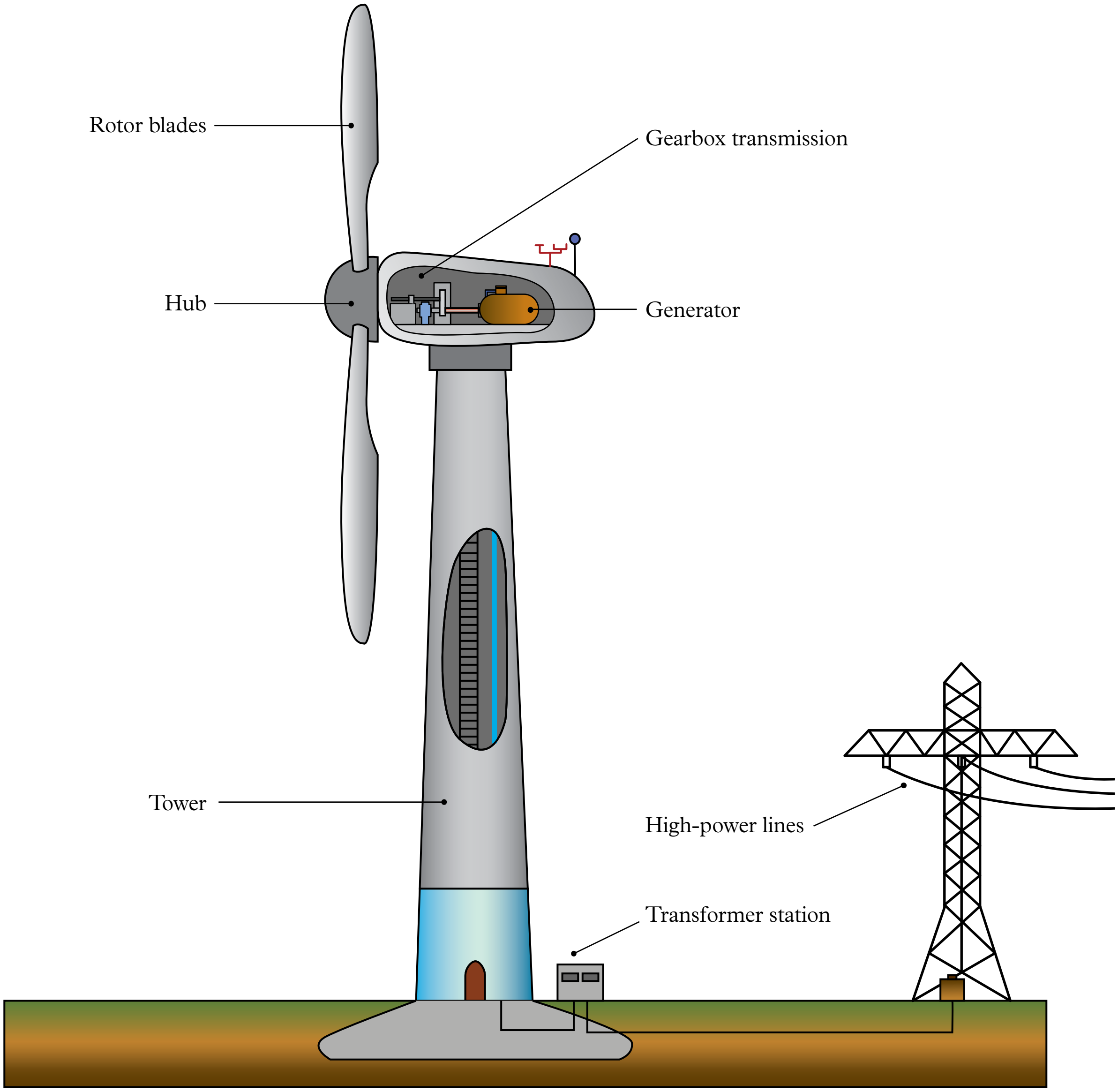


Figure 1 Wind is used to rotate the blades of a wind turbine, which in turn rotates coils of wire in the generator.

As the wind speed increases, the amount of power generated increases. High wind speeds cause the blades to rotate faster, which in turn cause the coils of wire to rotate faster. This generates more power (measured in watts). The electrical power generated can be calculated as the product of current and voltage (power = current × voltage).

Wind turbines are one of the most cost-effective sources of renewable energy. Once manufactured, there is no waste produced until the turbine needs to be replaced. The location of wind turbines needs to be considered carefully as they are most effective when placed on ridges or bluffs.

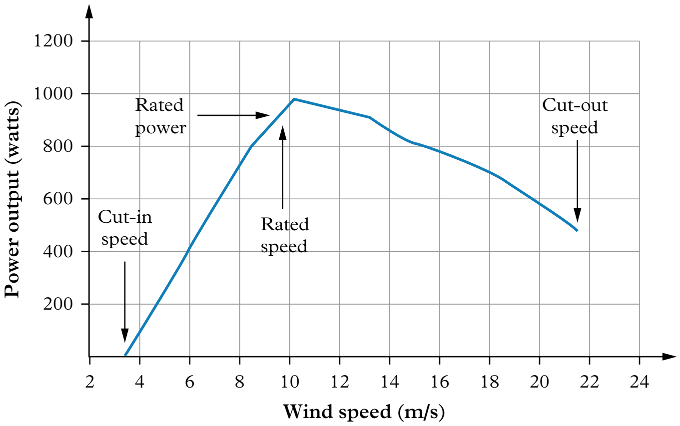


Figure 2 Power is only generated when the wind speed is between the cut-in speed and the cut-out speed.

Water

Hydroelectricity has used water to generate commercial electricity in Australia since 1895. When water is stored in a dam upstream, it contains gravitational potential energy. If the water is allowed to flow downstream through pipes, the gravitational energy is transformed into kinetic energy. This is then transferred to the rotating wire coils of the generator, usually located downhill from the dam.

Completed in 1895, the first hydroelectric power station in Australia was based near a river at Duck Reach, on the outskirts of Launceston, Tasmania (Figure 3). Water from the river was redirected via a series of pipes through a generator, providing the energy for the rotation of wire coils that generated the AC electricity that powered the first street lights in Launceston.

Australia currently has more than 100 hydroelectricity stations generating electricity. The largest of these is the Snowy Mountains Scheme, consisting of eight power stations that redirect water through 145 km of interconnected tunnels and pipes in southern New South Wales. As the water runs through the tunnels from the upper- to the lower-region dams, the moving water is used to turn the turbines and generate electricity (Figure 4). Using a series of 16 dams allows water to be stored and released through 33 turbines to control the generation of electricity as it is required.

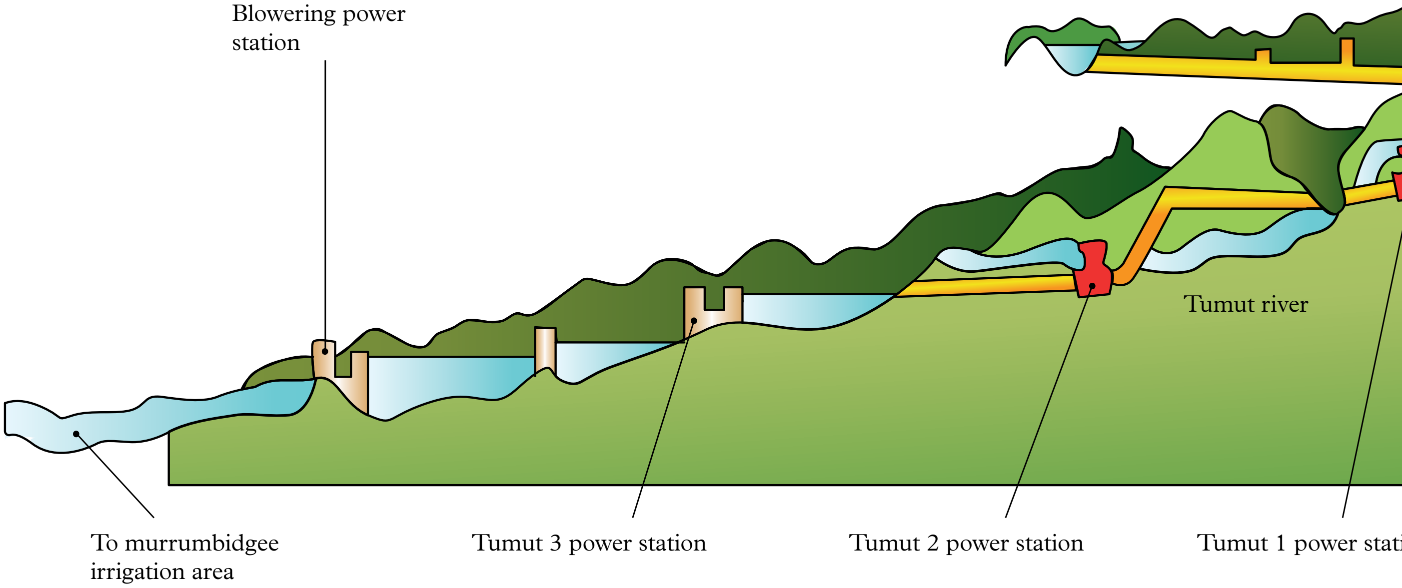


Figure 4 A series of dams controls the flow of water through multiple generators in the Snowy River Scheme.

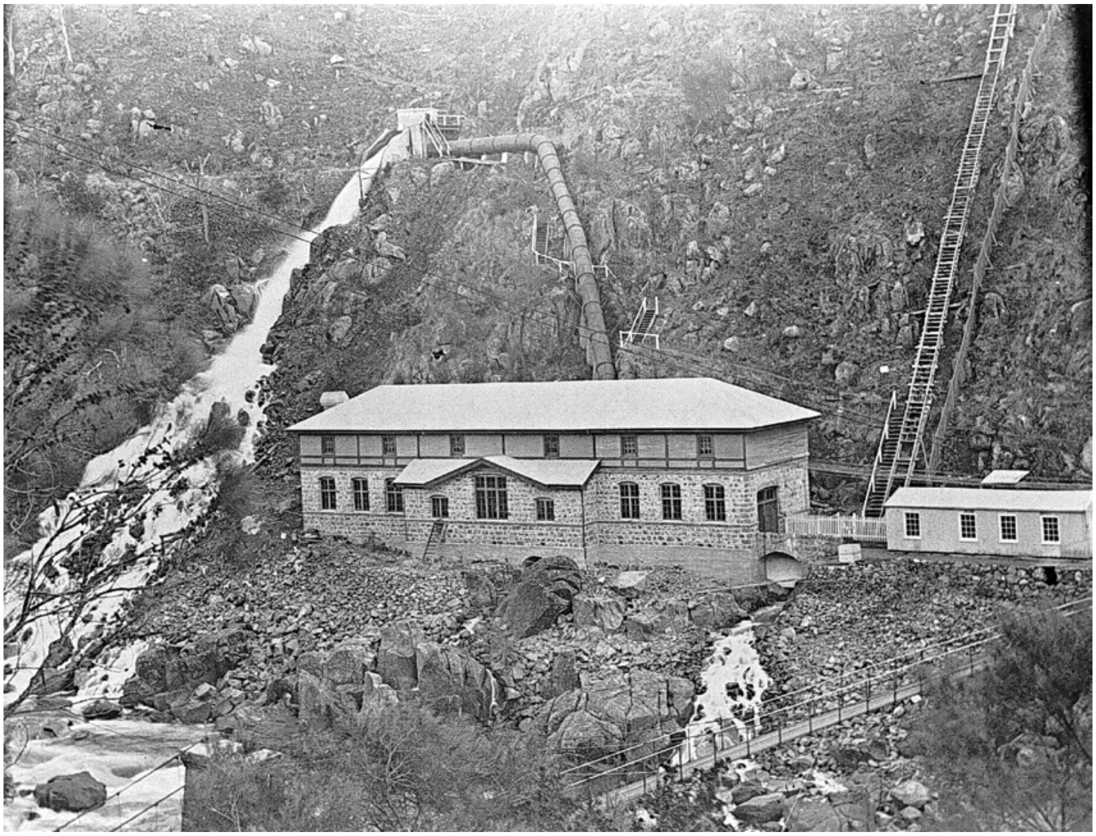
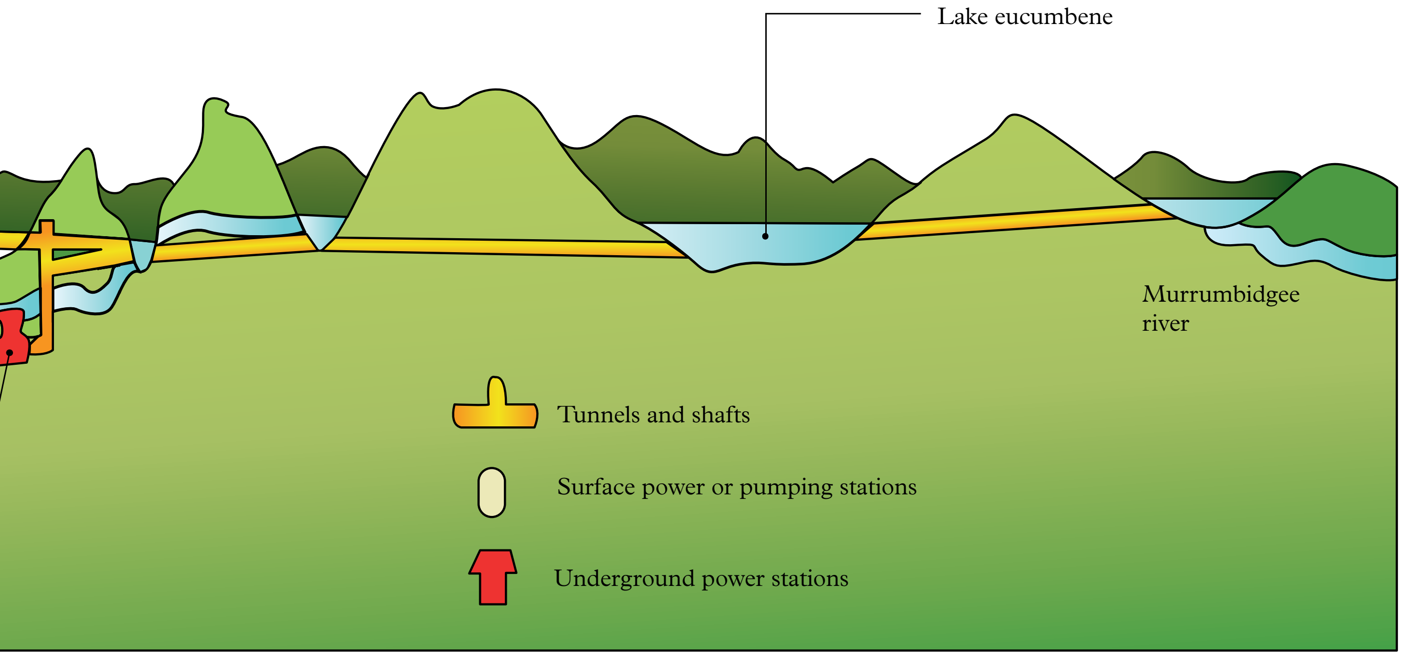


Figure 3 The first commercial hydroelectricity plant was located at Duck Reach, Tasmania.



ion

Tides

The gravitational pull of the Moon and the Sun causes low and high tides at different times of the day. The size of the tide can vary depending on the shape of the ocean floor. Some locations, such as the Gulf of Carpentaria between northern Australia and New Guinea (dark blue in Figure 5), experience very little difference between low and high tide.

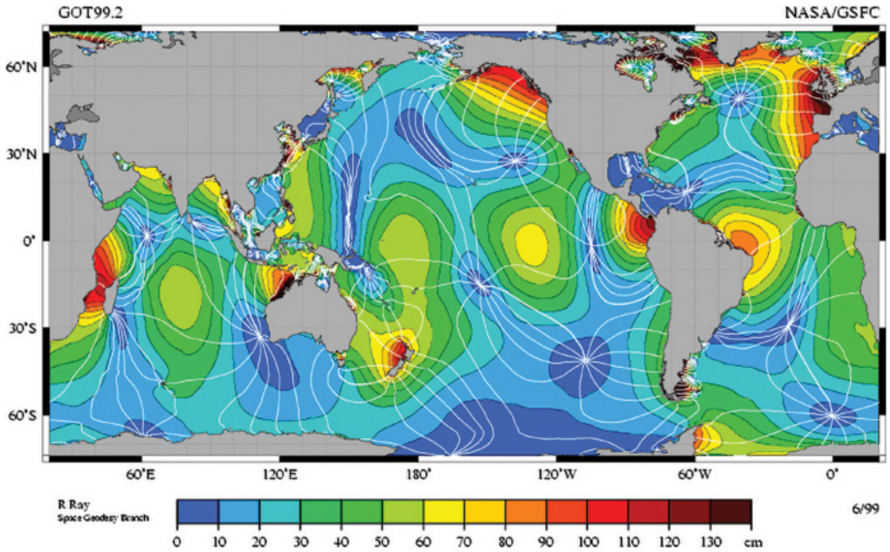


Figure 5 A map of the tidal ranges across the world (generated by NASA in 2015)

Other parts of Australia, such as Bass Strait (located between Victoria and Tasmania) and the northern parts of Western Australia, experience a significant difference between high tide and low tide. These locations would be ideal for the placement of tidal generators.

A tidal generator uses the changing water levels of low and high tides to produce the kinetic energy needed to rotate the generators. Some countries such as France have built tidal generators that harness the flow of the tide as it moves along a river (Figure 6). The Rance River experiences a tidal difference of 8.2 m between low and high tides. The water that moves with the tide is directed through 24 turbines to generate electricity for the local towns.

Water used as a battery

Different water levels can also be used as a way to store energy. Water stored further away from the centre of Earth contains potential (stored) energy. The original Snowy River Scheme involved building a series of dams that controlled the flow of water through a series of generators as it moved from the mountains down the river.

Snowy 2.0 is currently being built to store energy like a large battery. This stored energy is the excess energy from solar and wind farms that is not used immediately. Currently, there is nowhere for this energy to be stored so that it can be used when the Sun does not shine and the wind does not blow. When it is finished, Snowy 2.0 will use the excess energy to pump water through a tunnel from a dam at the bottom of the river to a dam at the top of the river. When electricity is needed to support other renewable energy sources, the water will be allowed to flow through turbines to generate the required electricity.

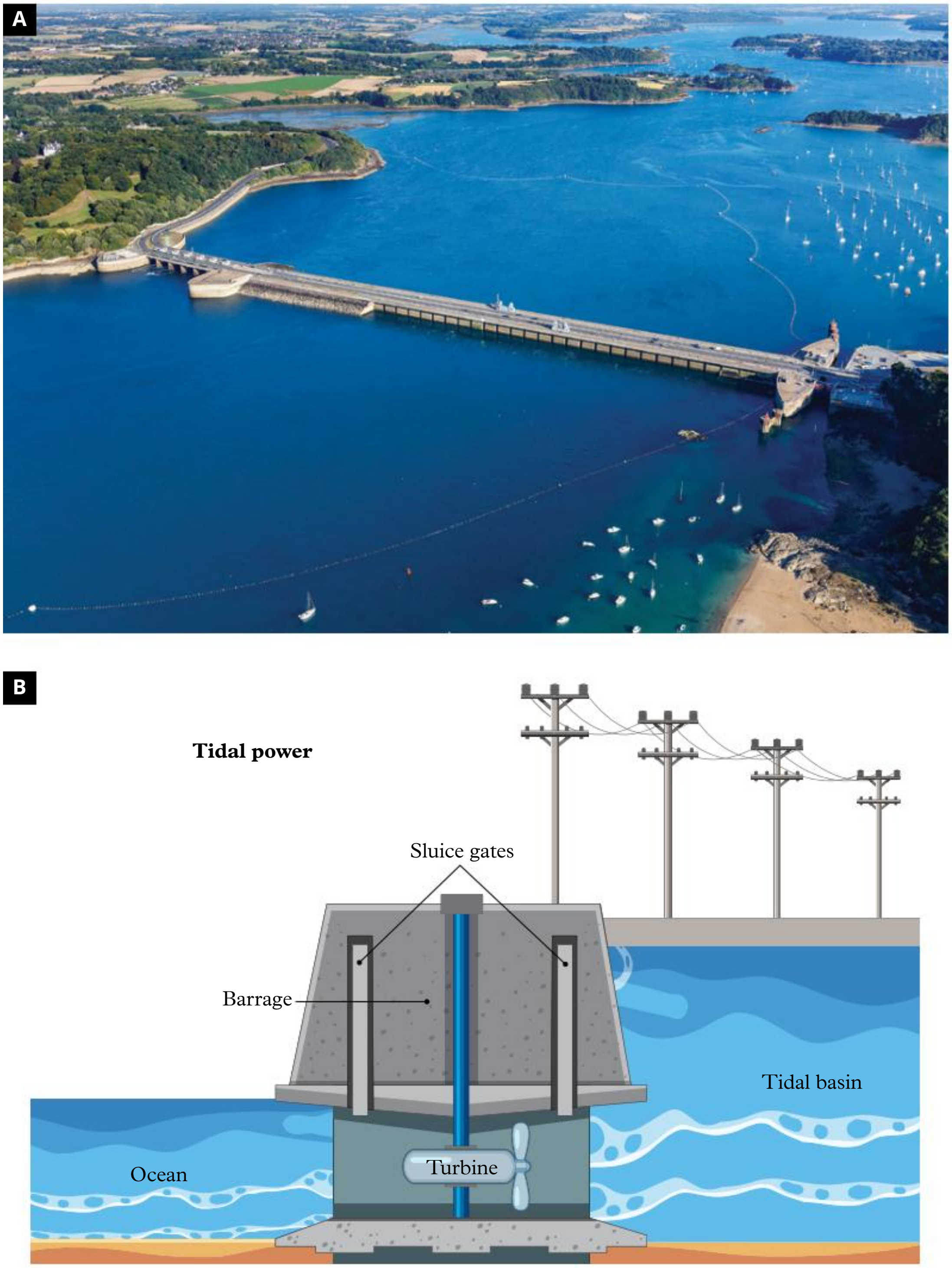


Figure 6 The Rance River in France (A) experiences 8.2 m difference between low and high tide. This allows water to be redirected through (B) a tidal generator, to produce electricity.

Check your learning 10.4

Check your learning 10.4

Retrieve

1 **Recall** two ways water can be used to generate electricity.

Comprehend

2 **Describe** the importance of the "cut-in" and "cut-out" speeds of a wind turbine.

3 **Explain** why a wind turbine should face into the wind to be effective.

Analyse

4 **Contrast** the movement of water in a hydroelectricity plant and a tidal generator.

5 **Explain** why a tidal generator could not be located in the Gulf of Carpentaria.

Apply and analyse

6 **Use** the terms "potential energy" and "kinetic energy" to **explain** how Snowy 2.0 acts like a giant battery.

7 **Use** Figure 5 to **identify** other potential locations for a tidal electricity generator. **Justify** your reasoning.

Lesson 10.5

Experiment: Wind-generated power

Aim

To examine the impact of blade size and shape on wind-generated power

Materials

- Thick cardboard (wind turbine blades)
- Scissors
- 4 paperclips
- Cork
- Retort stand, bosshead and clamp
- Small motor
- Multimeter or voltmeter
- Wires
- Fan (or access to wind)

Method

1 Use the scissors to cut four rectangular wind turbine blades from the cardboard. A good starting size is 2 cm × 5 cm.

2 Straighten one end of the paperclip so that it can be pushed into the cork.

3 Place one of the cardboard blades into the other end of the paperclip. Repeat for all four wind turbine blades.

4 Push the pointed end of the four wind turbine blades into the cork.

5 Use the bosshead and clamp to attach the small motor onto the retort stand.

6 Attach the end of the cork onto the motor.

7 Attach the multimeter to the wires of the motor.

8 Hold your wind turbine in front of the fan or in the wind. Record the amount of voltage it produces.

9 Modify the angle or shape of your wind turbine blades to maximise the voltage produced by your turbine. Draw and describe each modification and record your results.

Results

Complete the table.

Wind turbine blade design	Voltage produced	Use your knowledge of science to explain why this approach was or was not effective

Discussion

1 **Describe** the wind turbine blade arrangement that produced the greatest voltage.

2 **Describe** the wind turbine blade arrangement that produced the least voltage.

3 **Compare** the two arrangements to identify the potential factors that contributed to increasing the voltage output.

4 **Consider** your approach to this experiment.

  a **Identify** the number variables you changed in each attempt.

  b **Describe** how this experiment could be completed in a systematic manner.

Conclusion

Describe the factors that contribute to the effectiveness of wind-generated power.

Lesson 10.6

Photovoltaic cells harness the energy of the Sun

Learning intentions and success criteria

Check the next lesson for a linked practical activity or experiment.

Key ideas

→ A photovoltaic cell generates electricity from sunlight.

→ Solar panels are most effective in areas that have high numbers of sunshine hours.

→ Light provides energy that causes electrons to move from the n-type semiconductor to the p-type semiconductor.

→ Solar panels have a limited life span.

Australian research

Australian researchers have been instrumental in harnessing the energy of the Sun. The development of solar energy was slow until the 1950s due to the abundance of fossil fuels. In 1953, the CSIRO recognised that Australia had limited natural gas and oil resources, but had plenty of sunlight. Their subsequent work initially concentrated on developing solar water heaters, and by 1974 Australia was leading the world in the number of solar water heater installations in homes and commercial properties. By 1978, solar panels were used in remote communities, and in 1979 the world's first solar power plant was built in White Cliffs, New South Wales.

Photovoltaic cells

Australia is one of the top 10 countries in the world for the number of hours of sunshine experienced each year (Figure 1). The light energy from the Sun contains different wavelengths of electromagnetic radiation, including the visible spectrum of light that we can see, infrared (almost 50 per cent), ultraviolet (2 to 3 per cent), X-rays, and gamma rays that we cannot see. Most of the solar energy that enters the atmosphere is absorbed by Earth's surface. We can transfer and transform this light energy into electrical energy using **photovoltaic cells**.

photovoltaic cells technology that is used to transfer and transform solar light energy into electrical current

Photovoltaic cells are made up of two layers of semiconductors: p-type and n-type. The p-type contains silicon and boron or gallium. This combination of atoms generates a "hunger" or "hole" available for extra electrons. The n-type semiconductor is often a combination of silicon and phosphorus atoms that result in outer-shell electrons that are not involved in bonding. When light shines on the n-type conductor, these outer-shell electrons can absorb some of the energy and are "pulled" towards the p-type semiconductor. This flow of electrons from one semiconductor layer to another can continue if wires complete the circuit, and ultimately generates DC electricity (Figure 2).

An individual photovoltaic cell is small (1 to 9 cm across) and only produces enough electricity for a solar light or small calculator. Multiple photovoltaic cells can be arranged into panels that contain hundreds of cells to generate much larger amounts of electrical energy. As most of the electricity that we use requires AC, an inverter is needed to convert the DC electricity into AC electricity.

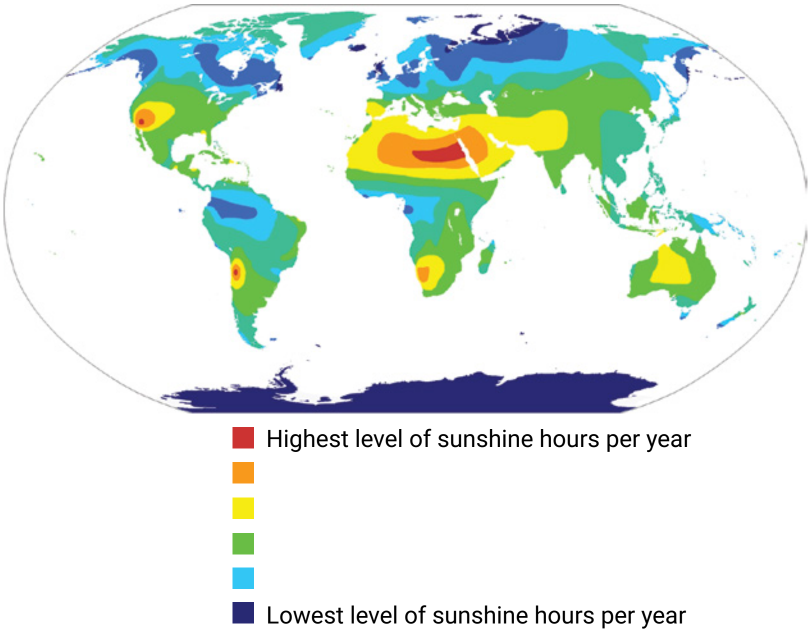


Figure 1 Annual number of sunshine hours across the world

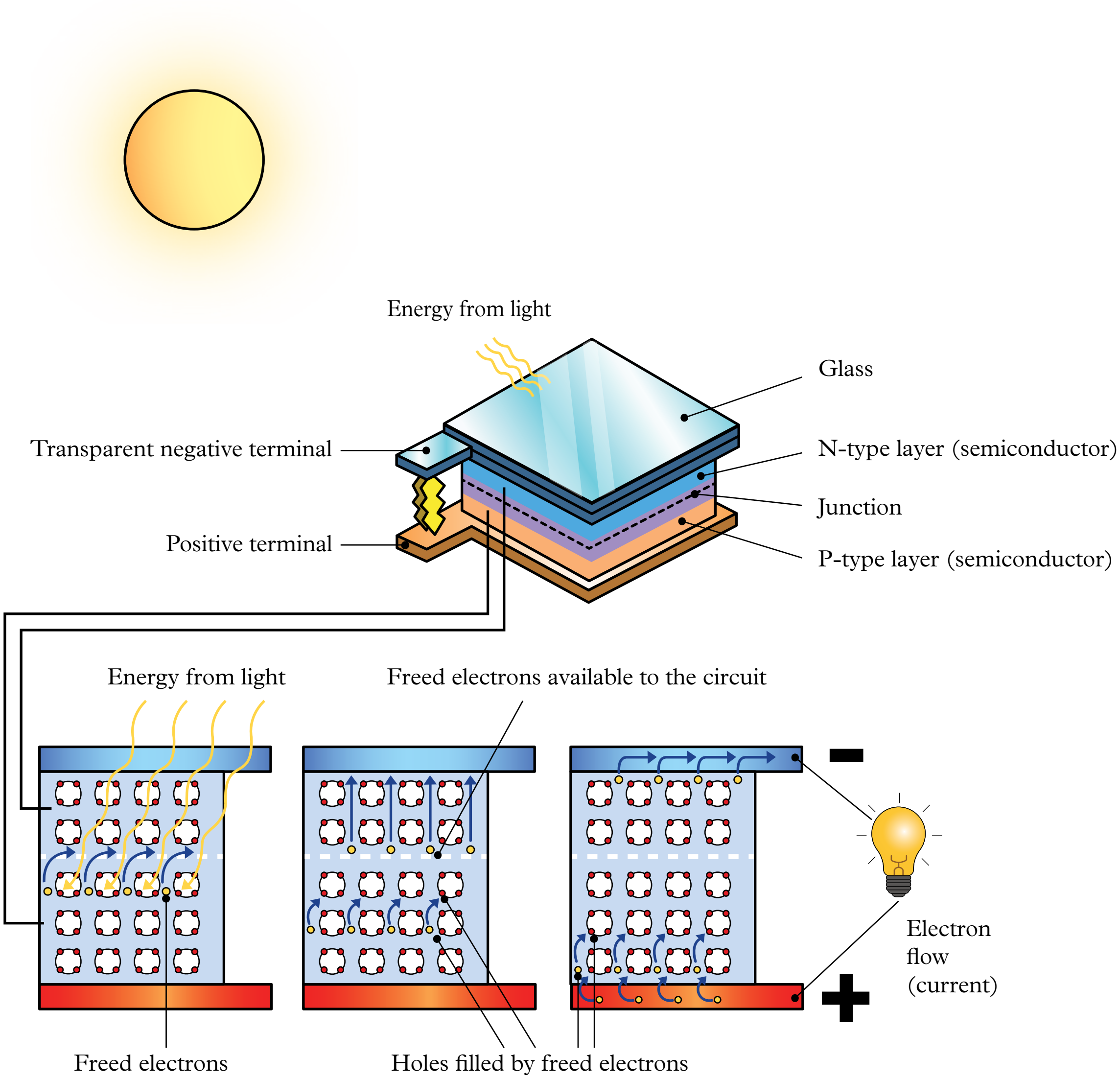


Figure 2 Sunlight provides the energy for electrons to move from the p-type semiconductor to the n-type semiconductor.

Locating solar panels

The amount of sunlight transferred and transformed by a solar panel can be affected by many factors, including the direction of the sunlight, the presence of building or tree shadows, and the number of panels.

In an ideal world, a solar panel should face directly towards the Sun. In practise, this would require the panel to track the Sun as it moves across the sky each day. This is not possible for the many solar panels attached to the roof of a household. The angle of the Sun in the sky also changes from summer (high in the sky) to winter (lower in the sky). Most houses try to face their solar panels to the north to capture as much sunlight as possible. The angle of the panels may vary according to the position of the Sun in winter. This will also vary depending on the location (latitude) of the house (Figure 3).

If a household requires more electricity at the start of the day, having a few solar panels facing east will support their needs. If most of the energy is required later in the day, some solar panels could face west to maximise the energy captured from the setting Sun. Most

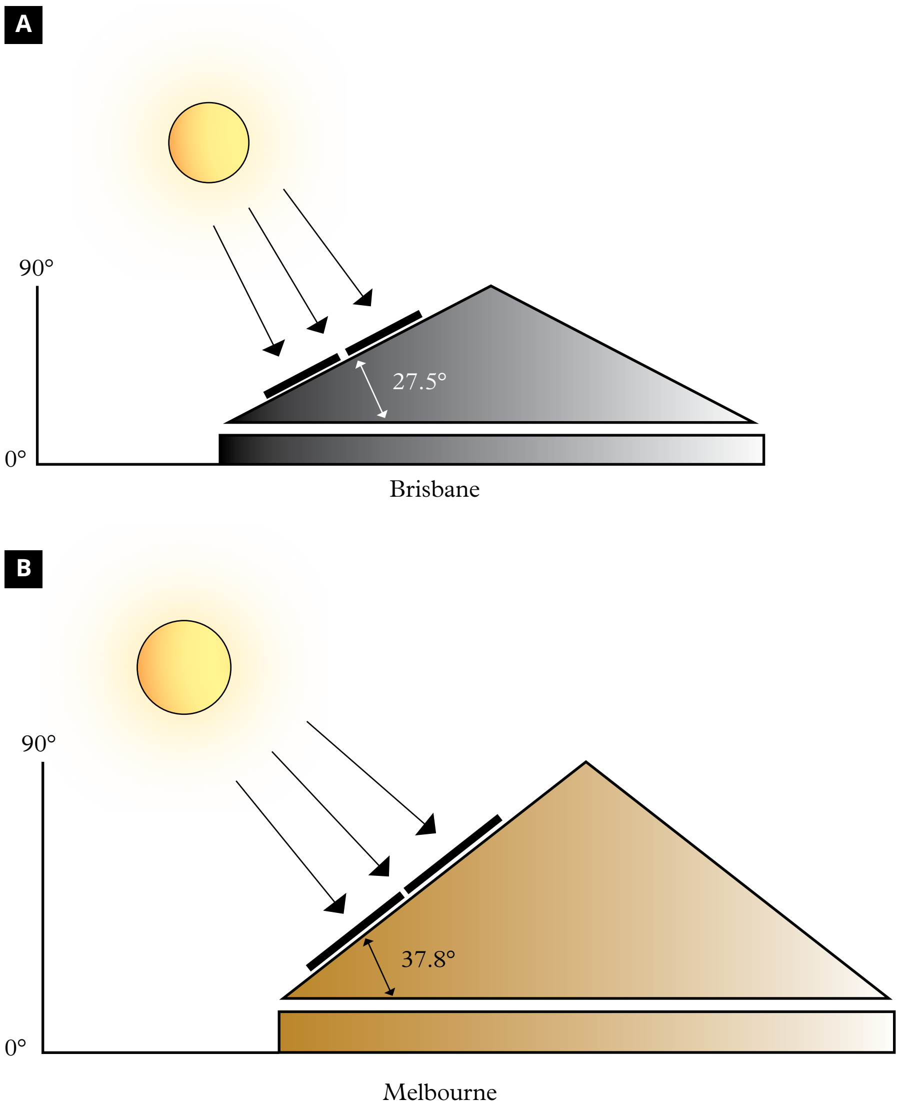


Figure 3 The placement of a solar panel will be determined by the latitude location of the house. (A) In Brisbane, Queensland, the Sun is higher in the sky in winter. This means a solar panel needs to sit at an angle of 27.5° to optimise the amount of light energy. (B) In Melbourne, a solar panel needs to sit at an angle of 37.8° to capture the winter sunlight.

solar panels are connected in series (connected to each other and then into the household electricity). If the shadow of a tree or neighbouring building falls on a single panel, no electricity will be able to flow from any of the panels. It may be useful to connect some solar panels in parallel (with a separate inverter) as well as in series.

Solar farms

Solar farms are areas of land that use hundreds of solar panels to generate electricity. These panels are sometimes connected to motors that allow them to follow the Sun as it moves across the sky during the day. The location of the panels requires a balance between available land, proximity to city centres (where the electricity will be used) and the average solar exposure. The availability of sunlight increases as the location moves north (Figure 4); however, this is where the most arable land is found, which is currently used to grow food. Many solar farms therefore also stock sheep, goats or cattle to keep the grasses down, and to maximise food production for Australia's growing population (Figure 5).

Once produced, solar panels can be used to generate electricity for 25 to 30 years. During this time the panels must be regularly cleaned to ensure that the photovoltaic cells can work at their maximum capacity.

Figure 4 The average daily solar exposure recorded annually

Figure 5 Solar farms can also be used to produce livestock such as sheep.

Solar waste

As the number of solar panels has rapidly increased over the last 40 years, so too has concern about what to do with solar panels at the end of their lifespan. Some parts of Australia, such as Victoria, have banned the disposal of solar panels in landfills as they contain small amounts of heavy metals (cadmium and lead). The sandwich design of the photovoltaic cells can make it difficult to extract the embedded silicon, silver and copper. Instead, some recyclers only remove the aluminium frame and metal wiring. More research is needed to develop the technology to extract and reuse resources from solar panels. This will help to ensure the sustainable development and continuation of future technologies.

Check your learning 10.6

Check your learning 10.6

Retrieve

1 **Recall** the direction that a solar panel should face to maximise the amount of sunlight.

Comprehend

2 **Describe** how light can be used to generate electron movement in a photovoltaic cell.

3 **Compare** the competing need for renewable energy sources and arable land.

4 **Explain** why some states have banned the disposal of solar panels in landfills.

Analyse

5 **Analyse** the energy needs of your household and the locations of surrounding buildings. Use this information to **justify** the ideal location of solar panels for your household.

Apply

6 CSIRO have developed a solar panel that can be printed onto flexible, plastic surfaces. **Describe** two unique ways that these panels could be used that are not currently possible with the rigid panels.

Lesson 10.7

Experiment: The effect of dust on solar panels

Background

Solar panels work most efficiently on cool, sunny days. Many factors can alter the effectiveness of the photovoltaic cells in the panels, including heat and dust. In this experiment, you will mimic the effect of a dust layer on a solar panel by using clear plastic sheets.

Aim

To determine the impact of dust on solar panels

Materials

- A solar bug toy (that vibrates in sunlight)
- Clear plastic sheets (e.g. acrylic sheet protectors)
- Ruler
- Timer

Method

1. Test that the solar bug toy functions by exposing it to sunlight.
2. Place a single clear plastic sheet 20 cm above the vibrating bug. Record how far the bug moves in 1 minute. Describe the motion of the bug.
3. Repeat step 2 with two clear plastic sheets held together over the bug.
4. Repeat step 2, adding a layer of plastic sheet each time, until the bug stops moving.

Results

Record the results of this experiment in a table. Use this information to draw a graph that compares the number of clear plastic sheets used to the distance moved by the bug.

Discussion

1. **Describe** the motion of the solar bug toy in direct sunlight.
2. **Describe** the purpose of the clear plastic sheets in this experiment.
3. Referring to the graph you have drawn, **describe** the impact of reducing the amount of sunlight being absorbed by the solar panel on the bug toy.
4. **Use** your results to **describe** the impact of dust on the efficiency of solar panels.

Conclusion

Explain why solar panels need to be cleaned regularly.

Lesson 10.8

Batteries store renewable energy

Key ideas

→ Big batteries can be used to stabilise the electrical grid in towns and cities.

→ A battery stores chemical energy that is transformed into electrical energy at the anode and cathode.

→ Lithium batteries can overheat when damaged and cause explosions and fires.

Learning intentions and success criteria

Why batteries?

Since 1888, when the first electrical grid was turned on in Tamworth, New South Wales, Australia has relied on generators to produce electricity. For most of this time, the energy for the generators came from fossil fuels. As Australia moves to replace this with renewable energy, it has been recognised that the wind does not always blow, and the Sun does not always shine.

In most capital cities, the majority of electricity is consumed at 9:00 am and at 8:00 pm in winter (Figure 1), while the least electricity is consumed at 4:00 am. When the demand for electricity is high, there needs to be enough available in the electrical grid so that it does not shut down. When the demand is low, the supply of electricity needs to be controlled to prevent a surge. Large batteries can be used to store electricity during times of high supply (a warm sunny day or if there are high winds), and to release energy when the wind stops or cloud cover prevents solar panels from transforming sunlight. This stabilises the electrical grid and balances fluctuations in supply, reducing the risk of blackouts.

The first “big battery” was built in South Australia in 2017 after Adelaide experienced instability in the electrical grid that resulted in load-shedding blackouts. Since the installation of the battery, load shedding has not occurred.

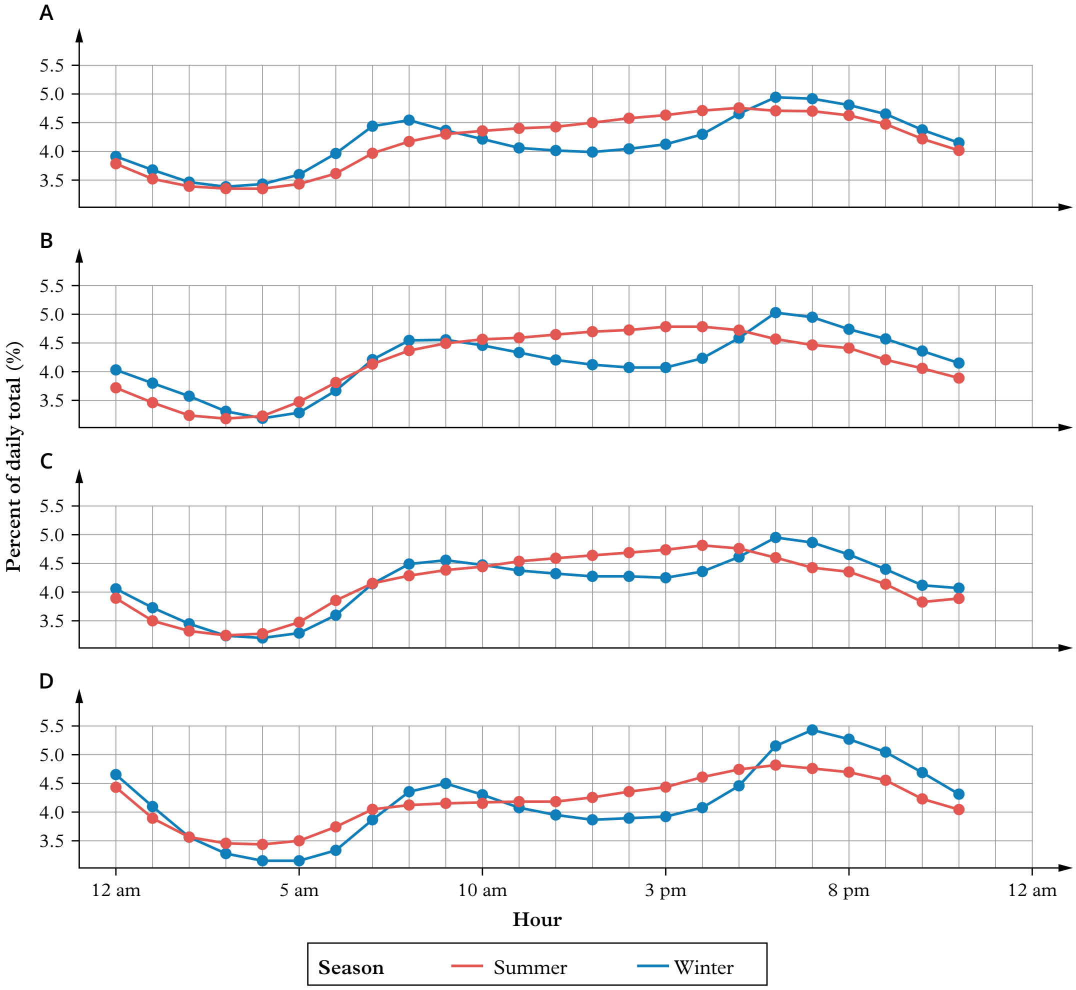


Figure 1 Average use of electricity in 24 hours in 2015 (midnight to midnight; 0000 hours to 2400 hours) in (A) Brisbane, (B) Sydney, (C) Melbourne and (D) Adelaide

How batteries store energy

Batteries are containers that store chemicals that react. During this process, they transfer electrons from one part of the reaction to another. Separating the two parts of the reaction allows the flow of electrons to be controlled.

When you are using (discharging) the battery, the first part of the reaction occurs at the anode electrode (the negative terminal of the battery). In a lithium-ion battery, the chemical reaction releases lithium ions:

$$C_6Li \rightarrow 6C \text{ (graphite)} + Li^+ + e^-$$

While the electrons travel through the wires, the lithium ions travel through the electrolyte (a liquid that allows charged particles to travel easily) to the cathode electrode (the positive terminal), where the other part of the chemical reaction occurs:

$$CoO_2^-(s) + Li^+ + e^- \rightarrow LiCoO_2(s)$$

Lithium-ion batteries are often used in rechargeable devices. During recharging, this chemical reaction reverses (Figure 2).

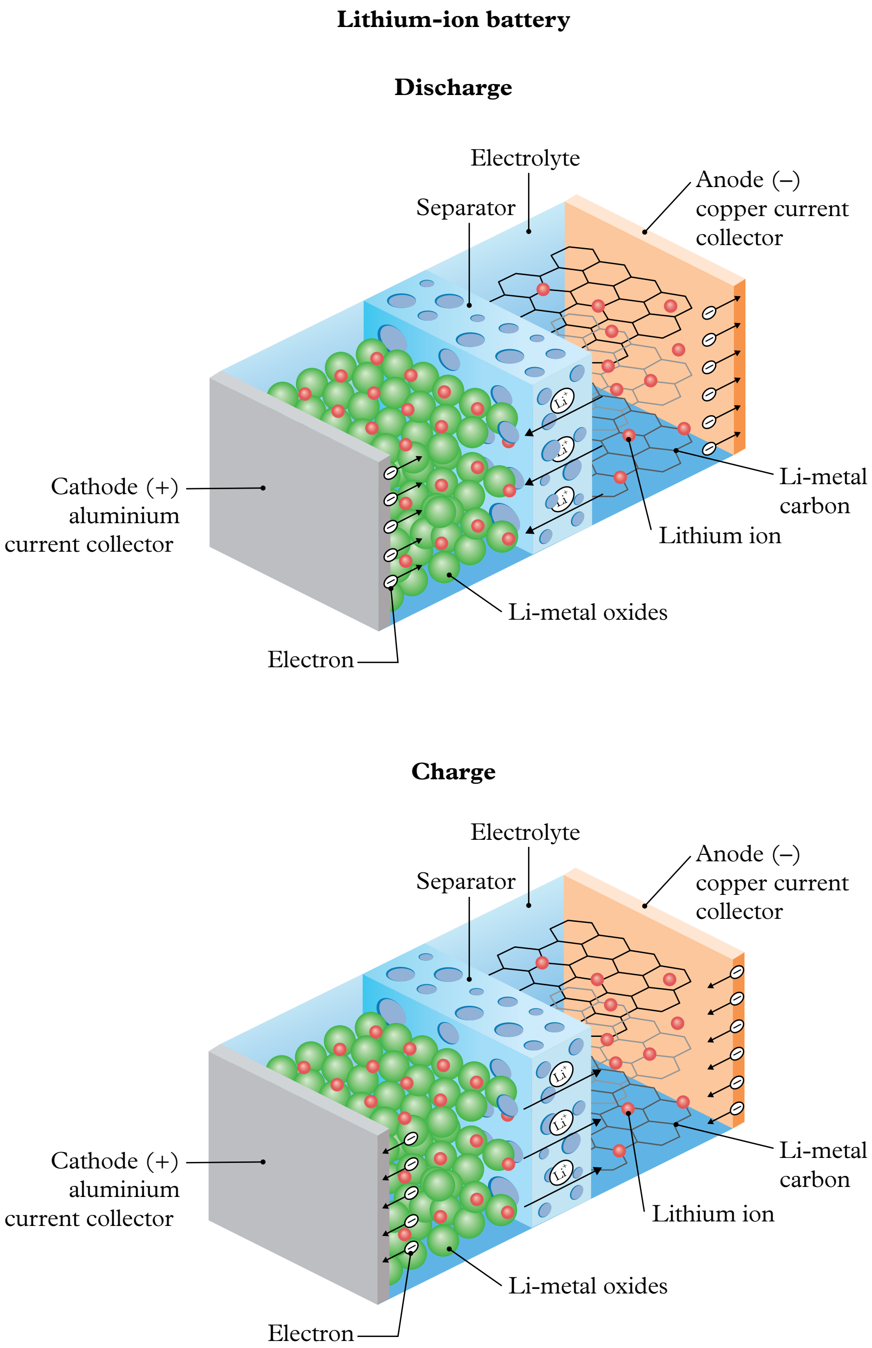


Figure 2 A lithium-ion battery produces an electrical current when it is discharging. Recharging the battery reverses this chemical reaction.

This type of battery is one of the most common found in phones, digital cameras and laptops today. One of the biggest challenges for lithium-ion batteries is the heat generated as part of the anode reaction (especially if the battery is overcharged). The high temperature that results can cause the cobalt oxide to decompose to produce oxygen, resulting in the battery becoming warped. This combination of oxygen and heat can cause the flammable chemicals in the electrolyte to rapidly overheat in a “runaway reaction”. If the battery casing breaks, the lithium (a group 1 element) can react with the moisture in the air, producing a fire that is difficult to put out.

The average lifespan of lithium-ion batteries is between 5 and 10 years. This provides a challenge for end-of-life waste management. Even small batteries cannot be put into landfill, as any rupture of the batteries can cause explosions and fire. Many also contain toxic chemicals such as hexafluorophosphate salt (LiPF6), which can cause respiratory failure, cardiac arrest and even death. The developing battery recycling industry has the potential to recycle 70 per cent to 90 per cent of the components.

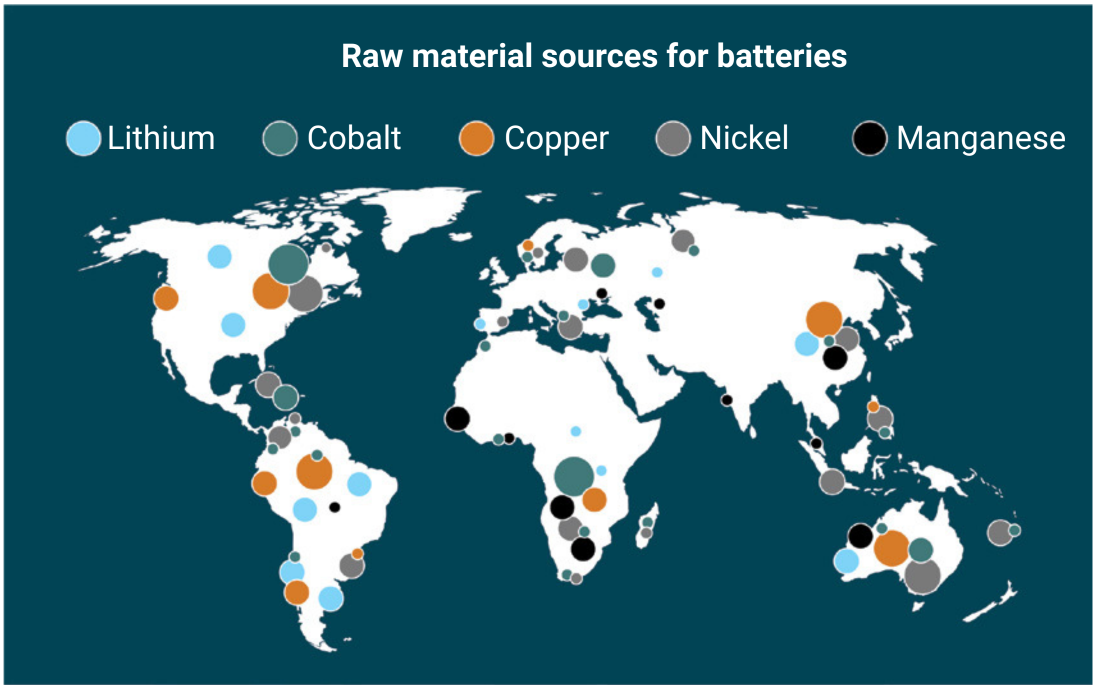


Figure 3 The raw supplies of battery resources are limited around the world.

Check your learning 10.8

Check your learning 10.8

Retrieve

1 **Recall** the chemical reactions that occur at the anode and the cathode when a lithium-ion battery is being recharged.

Comprehend

2 **Identify** the key components of a lithium-ion battery and **describe** their role in the discharge process.

Analyse

3 **Compare** the process of charging and discharging a lithium battery.

4 **Use** the two half-reactions that occur at the anode and the cathode to write the full chemical reaction that occurs in a lithium-ion battery.

Apply

5 **Explain** why water cannot be used to put out a lithium-ion battery fire.

6 Lithium is just one of the metals used in battery technology. **Identify** another metal that is used in battery technology and **investigate** the chemical reactions that occur to produce a flow of electrons.

Lesson 10.9

Science as a human endeavour: Electromagnetic fields are used in technology and medicine

Learning intentions and success criteria

Key ideas

→ A changing magnetic field generates a current in a wire that can recharge a battery.

→ Magnetic Resonance Imaging uses a changing magnetic field to generate internal images of the body.

Introduction

Current moving through a coiled wire generates a magnetic field. If the direction of the current continually changes (alternating current, AC), so too does the direction of the magnetic field. A constantly changing magnetic field can generate a current in a nearby wire coil. This process occurs in transformers and wireless chargers.

Transforming current

The movement of a wire or coil in a magnetic field or vice versa is not the only way to generate electricity. Michael Faraday was a poorly educated book binder who developed an interest in science by reading the books he was working on. In 1831, Faraday began a series of experiments on electromagnetic fields. He wrapped two insulated coils of wire around opposite ends of a large iron ring and found that when a current was passed through one coil of wire, a current appeared briefly in the other coil of wire. This current only lasted while the first wire's current was turned on or off. If the current in the first coil constantly changed direction, such as in an alternating current (AC), the current in the second wire also constantly changed direction. Therefore, electricity could be passed between wires without the wires touching each other. If the first coil of wire had more turns of wire than the second coil of wire, the voltage passed on would be less in the second coil.

This is what happens in a transformer (Figure 1) – the current and voltage are changed or transformed. Many electrical devices operate on less than the 240 volts that come from an electrical power point in Australia. For example, many computers have an electrical cord with a small black box attached, which transforms the 240 volts into a smaller voltage that the computer can use (Figure 2).

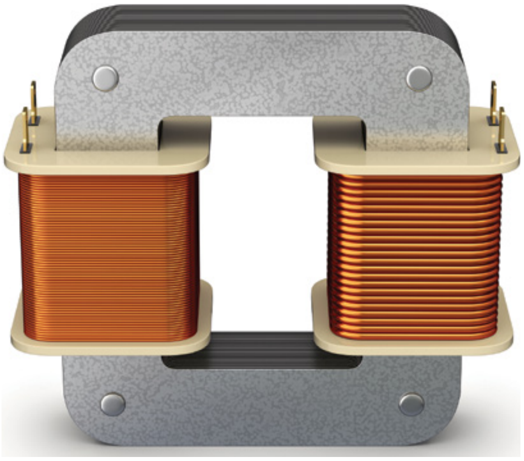


Figure 1 A transformer

Wireless charging

The process of transferring an electric current through coils of wire is used in wireless charging devices. Alternating current flows through coils of wire in the charging device. The resulting magnetic field generates a current in a coil in the receiving device, such as a mobile phone. When the current is converted into a direct current, it recharges the battery in the device. Although wireless chargers are convenient, the current generated is lower than when charging devices directly with a cord. If the coils of wire on the wireless charger are not directly aligned with the coils in the phone, most of the energy is lost as heat. Figure 3 shows the process of wireless charging for a mobile phone.

Figure 2 A laptop computer has a transformer in its power cord.

Magnetic resonance imaging (MRI)

Magnetic resonance imaging (MRI) involves placing a human body inside a strong, stable magnetic field. The magnetic field is usually generated by a large cylindrical coil of specially made wire in a bath of liquid helium, and the patient is positioned in the centre of the coil (Figure 4). The liquid helium is kept at –269°C. This very low temperature decreases the resistance of the wire to electric current so that it can conduct electricity indefinitely without any loss. Once current is flowing in the coil, it produces a strong magnetic field. The magnetic field causes the protons in the water (H_2O) in the person's body (we consist of 60 per cent water) to align with it.

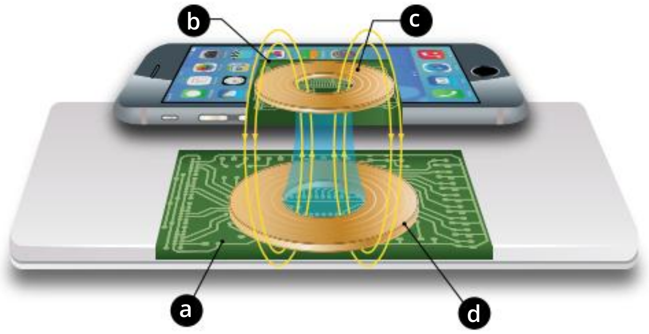


Figure 3 Wireless charging.

- ⓐ **Transmitter circuit**: Alternating current flows through coils of wire in the charging device.
- ⓑ **Receiver circuit**: A magnetic field is generated around the recharging device.
- ⓒ **Receiver coil**: When a mobile phone is within range of the magnetic field, a current is generated in coils within the phone.
- ⓓ **Transmitter coil**: The current is converted to direct current and the battery starts recharging.

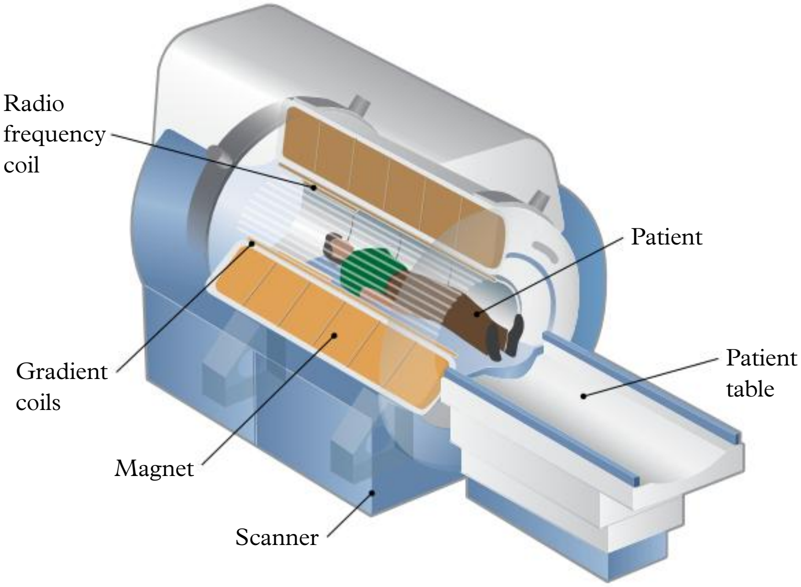


Figure 4 An MRI machine uses a magnetic field to generate images of the body's internal structure.

Extra small coils are also placed around the person and brief pulses of current are passed through them. These current pulses produce additional magnetic fields, which vary in strength and direction throughout the patient's body. This causes the protons in water to temporarily change their alignment with the main magnetic field. The amount the protons shift varies according to where they are in the body. The way the protons respond to these additional magnetic fields also depends on their chemical environment. These subtle changes in alignment can be detected and converted to an image of the internal structure of the body (Figure 5). In this way, medical specialists can identify any damaged or diseased tissues or organs and decide on appropriate treatment for the patient.

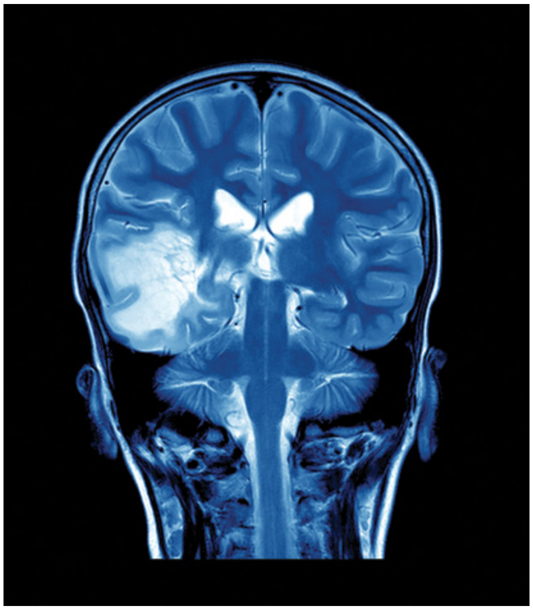


Figure 5 The brighter area of this MRI image indicates an abnormality in the brain.

Test your skills and capabilities

Some people consider that the magnetic fields generated by current moving through wires is a reason not to live near high-voltage wires or the generators in wind turbines or transforming stations. Use your critical thinking skills to answer the following questions.

1. **Identify** possible assumptions or biases that you might have about the dangers of high-voltage wires.
2. **Describe** how these assumptions could affect any decisions you might make about living near high-voltage wires.
3. **Evaluate** the accuracy of your assumptions, by:
   - **describing** the factors or arguments that could be made that would cause you to change your view
   - **identifying** whether these factors or arguments are correct
   - **deciding** whether your assumptions are accurate or you should change your mind.
4. **Describe** the importance of using critical thinking to avoid bias when making decisions.

Lesson 10.10

Review: Energy generation

Summary

Lesson 10.1 Wire carrying an electric current generates a magnetic field

- A magnetic field is generated when a current moves through a wire.
- The direction of the magnetic field can be determined by the right-hand grip rule: the thumb points in the direction of the current (towards the negative terminal) and the fingers curl in the direction of the magnetic field.
- Electromagnets use electricity to generate a strong magnet that attracts metal.

Lesson 10.3 Magnetic fields and movement are used to generate electrical current

- Moving magnetic fields can generate electrical current in coils of wire.
- A dynamo generates direct current (DC) and an alternator generates alternating current (AC).
- The generated current can be increased by increasing the number of coils or the speed of movement.

Lesson 10.4 Renewable energy sources can generate electricity

- The speed of wind can affect the amount of power generated.
- The potential energy of water stored upstream can be used to generate electricity.
- The difference between the water levels at high and low tide can be used to generate electricity.
- Excess renewable energy can be stored by pumping water into an upstream dam.

Lesson 10.6 Photovoltaic cells harness the energy of the Sun

- A photovoltaic cell generates electricity from sunlight.
- Solar panels are most effective in areas that have high numbers of sunshine hours.
- Light provides energy that causes electrons to move from the n-type semiconductor to the p-type semiconductor.
- Solar panels have a limited life span.

Lesson 10.8 Batteries store renewable energy

- Big batteries can be used to stabilise the electrical grid in towns and cities.
- A battery stores chemical energy that is transformed into electrical energy at the anode and cathode.
- Lithium batteries can overheat when damaged and cause explosions and fires.

Lesson 10.9 Science as a human endeavour: Electromagnetic fields are used in technology and medicine

- A changing magnetic field generates a current in a wire that can recharge a battery.
- Magnetic Resonance Imaging uses a changing magnetic field to generate internal images of the body.

Review questions 10.10

Review questions: Module 10

Retrieve

1 **Identify** the correct description of the right-hand grip rule.
   - **A** The right-hand grip rule is used to determine the direction of force on a wire.
   - **B** The right-hand grip rule has the thumb pointing in the direction of the electron movement.
   - **C** The right-hand grip rule is used to determine the direction of the magnetic field around a wire.
   - **D** The right-hand grip rule has the palm of the hand pointing in the direction of the current.

2 **Recall** how the current generated by electromagnetic induction can be increased.
   - **A** By increasing the number of coils in the solenoid or increasing the movement of the magnet
   - **B** By increasing the number of coils in the solenoid or decreasing the movement of the magnet
   - **C** By decreasing the number of coils in the solenoid or increasing the movement of the magnet
   - **D** By decreasing the number of coils in the solenoid or decreasing the movement of the magnet

3 Copy and complete the following paragraph with the most appropriate words or phrases.

A _______ is able to attract objects made of iron or _______. A magnet has two _______: north and _______. A current-carrying wire has a magnetic _______ around it. The direction of the field is given by the _______ rule. In most electromagnets, many _______ of wire are wrapped around an iron _______.

4 **Identify** each of the following statements as true or false. If a statement is false, rewrite it to make it true.
   - **a** A battery can be used to stabilise the electrical grid in a city.
   - **b** The fingers of the right-hand grip rule indicate the direction of the magnetic field of a solenoid.
   - **c** Lithium-ion batteries store electrical energy in lithium compounds.
   - **d** A changing magnetic field generates no current.
   - **e** Snowy 2.0 will generate hydroelectrical energy.

5 **Define**:
   - **a** electromagnet
   - **b** photovoltaic cell
   - **c** wind generator
   - **d** nuclear power generator.

6 **Define** the abbreviation “MRI”.

Comprehend

7 **Describe** how to use the right-hand grip rule.

8 **Describe** how a nuclear generator produces electricity.

9 **Describe** the advantages and disadvantages of hydroelectricity generators.

10 **Describe** how a phone can be charged wirelessly.

11 **Describe** how the chemical reactions that occur in a lithium-ion battery generate an electrical current.

Analyse

12 **Use** a table to **compare** the way electricity is produced by wind, water, tides, solar panels and nuclear energy.

13 Figure 1 shows an electric bell. **Explain** how the bell works when the switch is pressed.

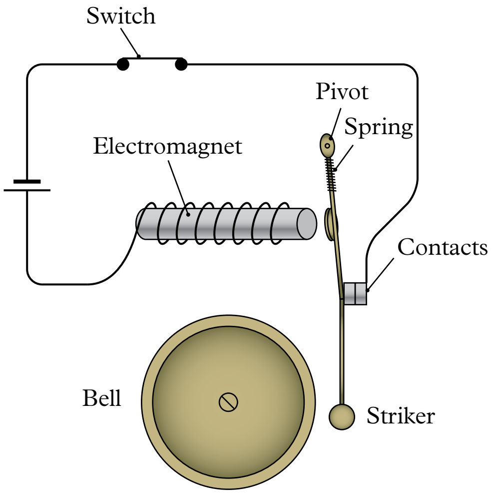


Figure 1 How does an electric bell work?

14 The wire in Figure 2 has a magnetic field travelling in a clockwise direction. Use the right-hand grip rule to determine whether the current is moving into or out of the page.

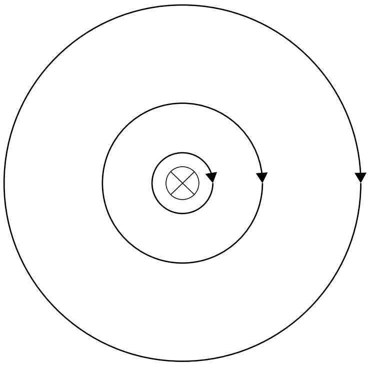


Figure 2 The right-hand grip rule can be used to determine the direction of the current.

15 **Draw** a diagram that illustrates the generation of electrical current in a photovoltaic cell.

Apply

16 Chargers can be used to recharge a mobile phone without using a cord.

a **Describe** how a mobile phone charger recharges a phone.

b Sketch a diagram to show two sets of coils and an iron core, like those inside a mobile phone charger. **Identify** which set would connect to the power point and which set would connect to the phone.

c **Identify** the other electronic components a mobile phone charger must contain.

17 A radio-controlled car works with a remote control.

a **Describe** how the remote-controlled car works.

b **Identify** the electronic components the remote control is likely to have.

c **Identify** the electronic components that are required for the toy car to move.

18 The amount of electricity generated from spinning a dynamo depends on the magnetic field strength, the size of the coil and the rotation speed.

a **Design** an experiment to investigate all three of these variables. **Develop** an aim, list of equipment, hypothesis and method. You don't need to carry out the experiment.

b Carefully **explain** in your method section how each variable is tested, one at a time, while the other variables remain constant.

Critical and creative thinking

19 Electricity can be generated by moving either a magnet or coils of wire. This can be achieved by moving water in a hydroelectric scheme, wind in wind turbines or coal-powered steam.

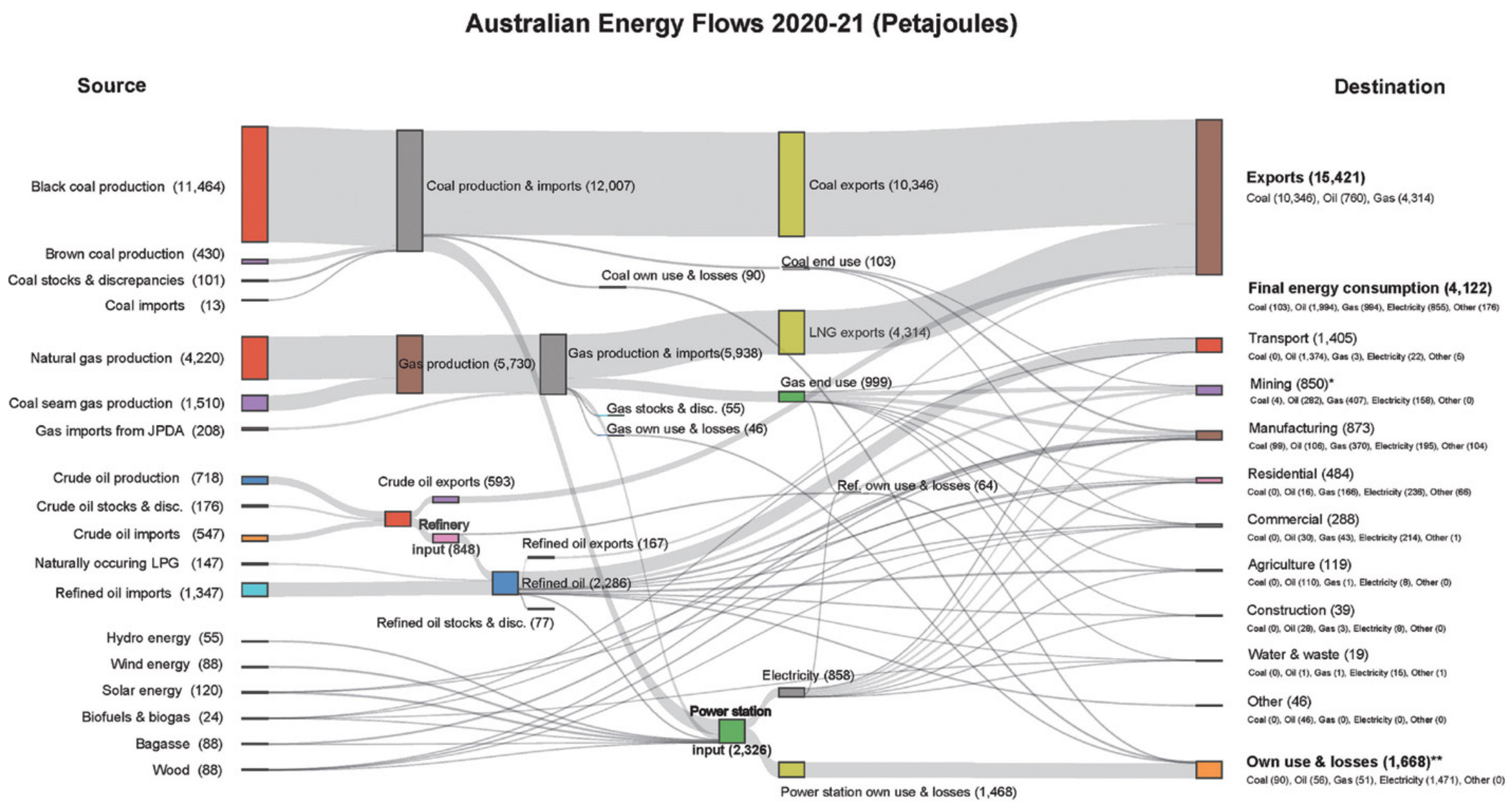
a Use Figure 3 to **evaluate** the effectiveness of each of these methods.

b **Describe** the effectiveness of each generating process in Australia during the shown period.

c **Describe** how you determined if an energy source was effective. For example, did you consider how the electricity was generated, the amount of energy generated or the environmental impacts of the process?

d **Compare** the evaluations you made with others in the class.

e **Justify** the decision you made.



Primary energy production 18,952 PJ + **Imports 2,114 PJ** – **Exports 15,421 PJ** – **Stocks change & discrepancies - 145 PJ** = **Primary energy supply 5,790 PJ** – **Own use & losses 1,668 PJ** = **Final energy consumption 4,122 PJ**

NOTES: Numbers may not add due to rounding. JPDA = Joint Petroleum Development Area. * includes LNG plant own use of gas. ** Conversion plants own fuel use & losses, and transmission losses.

SOURCE: Australian Energy Statistics 2022, Table A, Table F, and Table Q

Figure 3 The Australian Energy statistics record energy consumption, production, and trade statistics and balances.

Research

20 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, giving careful thought to the information you are communicating and your likely audience.

Nuclear fusion

- **Describe** the difference between the terms fusion and fission.
- Draw a series of diagrams to **describe** the process of nuclear fission.
- **Identify** where nuclear fission usually occurs.
- Draw a labelled diagram to **describe** the process of nuclear fusion.
- **Investigate** the challenges that limit the success of human-induced nuclear fusion as an energy source.

Synchrotron

A synchrotron is a huge scientific instrument that accelerates electrons to a very high speed. The electrons are forced to move in a circular path by large electromagnets. The direction of travel of an electron is the reverse of the direction of conventional current.

- **Identify** the arrangement of the north and south magnetic poles and the direction of the electron beam if the electrons are to be pushed to the right.
- **Investigate** this phenomenon to see if your arrangement is correct. If you were incorrect, **describe** the error(s) of judgement you made.

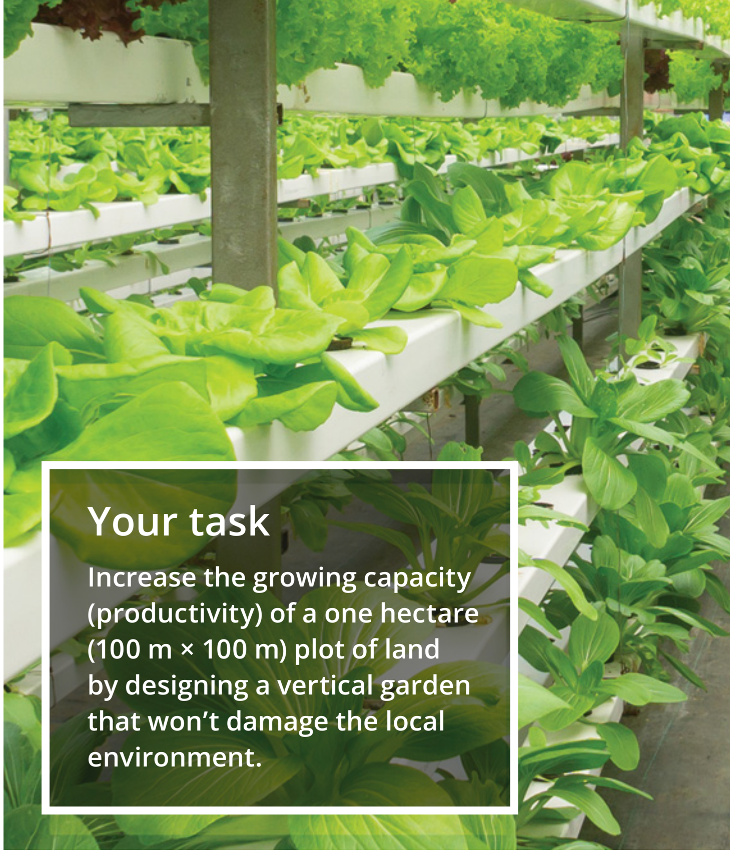
Hairdryers

A hairdryer generates heat and uses a fan to push the warm air over hair.

- Draw a diagram to **explain** how a hairdryer works.
- **Describe** how the heat is generated.
- **Explain** how electricity is used to move the fan.
- **Describe** how the amount of heat can be increased.
- **Describe** how the speed of the fan can be increased.

[STEAM project 1]

How can we use sustainable farming practices so that no one goes hungry in the future?



Your task

Increase the growing capacity (productivity) of a one hectare (100 m × 100 m) plot of land by designing a vertical garden that won't damage the local environment.

Figure 1 Vertical farming allows people to grow more food in a smaller space.

The United Nations ranks food shortages and hunger among the most serious issues affecting humankind. It predicts that more than 840 million people will be hungry by 2030. Even in a high-income country such as Australia, 5 per cent of the population are unable to access enough nutritious food. The experience of having inadequate access to food or having an inadequate supply of food is known as food insecurity. Food insecurity is linked to poor general health, higher rates of some cancers and higher mortality.

Rapid climate change is increasing threats to Australia's and the world's food security. Changes in the amount of rainfall, longer droughts and an increase in the number of extreme weather events are expected to disrupt the amount and quality of food that Australia can produce. A hotter climate is expected to cause stress in livestock animals, such as chickens, sheep and cattle, and to increase the amount of water needed for crop irrigation.

Figure 2 Drought impacts Australia's production of important crops, such as wheat.

Sustainable farming

Sustainable farming practices use methods that balance the needs of all members of the community. This means that new and old technologies are used to make sure that food production is:

- economically viable – if farmers cannot make enough money to survive, then the farming practice is not sustainable
- socially supportive – if the lifestyle of the farming community is not supported, then people will not want to live in the area
- ecologically sound – if the local environment is not supported, then the land will be unable to support food production.

Sustainable farming also works to maintain the diversity of the local wildlife.

HUMANITIES

In Geography this year, you will learn about food security around the world and food production in Australia. You will investigate the factors that influence crop yield (such as temperature and rainfall) and how food production can alter a biome. In Economics and Business, you will look at exports, such as agricultural resources, that form a large part of Australia's trade economy.

To complete this task successfully, you will need to investigate the environmental constraints on agricultural production in Australia, such as climate and distribution of water resources. You will also need to understand the extent to which agricultural innovations have overcome these constraints.

MATHS

In Maths this year, you will build on your knowledge of measurement and geometry to determine areas and volumes of more complicated shapes. You will study right-angled triangles using Pythagoras' theorem and trigonometry. You will also extend your skills in collecting, representing and investigating data.

To complete this task successfully, you will need to perform calculations involving angles, lengths and areas of two-dimensional and three-dimensional shapes. You will need to apply your understanding of scale factors to build a prototype of your designed product. To consider the situation at local, national and international scales, you will need skills in dealing with ratios and proportions. You may also find it helpful to use scientific notation for very large or very small numbers.

You will find help for applying these maths skills in Module 5 "Measurement", Module 6 "Scale and trigonometry", and Lesson 1.5 "Scientific notation" of *Oxford Maths 9 Victorian Curriculum (Second edition).*

Sustainable farming uses technology to increase the production of fresh, nutritious food while minimising the impact on the local environment.

SCIENCE

In Science this year, you will learn about the carbon cycle and the ways human activity can disrupt it. You will also consider the consequences of disruption, including the enhanced greenhouse effect. You will also learn about asexual reproduction and investigate vegetative propagation.

To complete this task successfully, you will need to understand the factors required to keep a system, such as a vertical garden, alive. You may need to consider how these factors can be monitored and controlled automatically. You will also need to be familiar with the scientific method and understand how to conduct a fair test.

You will find more information on this in Module 4 "Reproduction" and Module 7 "The carbon cycle" of *Oxford Science 9 Victorian Curriculum*.

The design cycle

To successfully complete this task, you will need to complete each of the phases of the design cycle.

Discover

When designing solutions to a problem, you need to know who you are helping and what they need. The people you are helping, those who will use your design, are called your end-users.

Consider the following questions to help you empathise with your end-users:

- Who am I designing for?
- What problems are they facing? Why are they facing them?
- What do they need? What do they not need?
- What does it feel like to face these problems?

To answer these questions, you may need to investigate using different resources or conduct interviews or surveys.

Define

Before you start to design your vertical garden, you need to define the criteria that you will use to test the success of your vertical garden in achieving your goal.

Define your version of the problem

Rewrite the problem so that you describe the group you are helping, the problem they are experiencing and why it is important. Use the following phrase as a guide:

"How can we help (the group) to solve (the problem) so that (the reason)?"

Determine the criteria

1 What is the total area of the 100 m × 100 m plot of land? (Remember to use the correct units.)

2 If the plants are planted 25 cm apart in a 100 m row, and the rows are placed 1 m apart, how many plants could be planted in the plot of land?

Hint: Draw the plot of land to make sure you reach maximum capacity.

3 What criteria will you use to measure the success of your solution or design? How will you measure how much the end-users have been helped?

Ideate

Once you know who you're designing for, and you know what the criteria are, it's time to get creative!

As a group, brainstorm ways the problem can be solved. Remember that there are no bad ideas at this stage. One silly thought could lead to a genius innovation!

Once you have many possible solutions, it is time to sort them by possibility. Select three to five ideas that are possible. Research whether these ideas have already been produced by someone else. If they are already on the market, can you make a better version?

Build

Draw your top two vertical garden designs. Label each part of the designs. Include the materials that will be used for their construction.

Include in the designs:

a the total surface area available for plant growth

b a description of how food production will be increased

c a description of how the design (inputs and waste) will impact the local ecosystem

d a description of how the workers will access all areas of the design to tend the plants

e at least one advantage and disadvantage of each design.

Select one of the designs to take to the building and testing stage.

Build the prototype

You will need to build at least three versions of your vertical garden design prototype. The first prototype garden will be tested for effectiveness. The second prototype will be used to survey the group you are helping. The third prototype will be used for the presentation. The prototype may be full size, or it may be a scale model (10 cm represents 1 m). Use the following questions as a guideline for your prototype:

- What materials will you use?
- What material will you use to represent the plants?
- How will you represent the height, width and angle of the finished prototype?

Test

Prototype 1

Use the scientific method to design an experiment that will test the effectiveness and strength of your first vertical garden prototype. You will test the prototype more than once to compare results, so you will need to control your variables between tests. What criteria will you use to determine the success of your prototype? Conduct your tests and record your results.

Prototype 2

If your prototype will be used to help market gardeners, then you will need to generate a survey to test whether the prototype is appropriate for their use. (How would they use it? Would they consider buying it?)

If your prototype will be used to help another group, or native plants and animals, you will need to consider how you could test the impact it will have. (Will the prototype affect normal behaviours? How will the prototype affect the soil or waterways?)

Prototype 3

Use the information you have obtained from testing the first two versions to adapt your last prototype to be more effective and usable for the group you are helping. You may want to use the first two prototypes to demonstrate how the design has been improved.

Communicate

Present your vertical garden design to the class as though you are trying to get your peers to invest in it. Describe the criteria and testing used to measure the effectiveness of your vertical garden design.

In your presentation, you will need to:

- explain why we need to be more efficient with food production
- describe the key features of your design and how they improve or solve the problem of food shortages
- show a labelled, to-scale diagram of your prototype
- describe how the ecosystem will be affected by the installation of the prototype
- explain the relevant scientific principles that support your designed solution (e.g. water cycle, photosynthesis, nitrogen/carbon cycle)
- quantify the increase in food production that your design allows; present calculations to justify your claim
- present a calculation for the estimated cost of producing a full-size model of your design
- explain the implications of your design, at a state or national level, by comparing the benefits and costs.

Online resources:

Student booklet
This helpful booklet will guide you step-by-step through the project.

What is the design cycle?
This video will help you to better understand each phase of the design cycle.

How to manage a project
This “how-to” video will help you to manage your time throughout the design cycle.

How to pitch your idea
This “how-to” video will help you with the “Communicate” phase of your project.

[STEAM project 2]

How can we harness technology so that we can live healthier lives?

A disorder or disease is a condition that affects the normal functioning of the body. Different disorders and diseases can affect many parts of the body. They can be caused by infectious agents such as bacteria or viruses that spread from person to person. Some disorders or diseases are inherited. Environmental factors (such as pollution or diet) can also have an impact on the development of disorders or diseases.

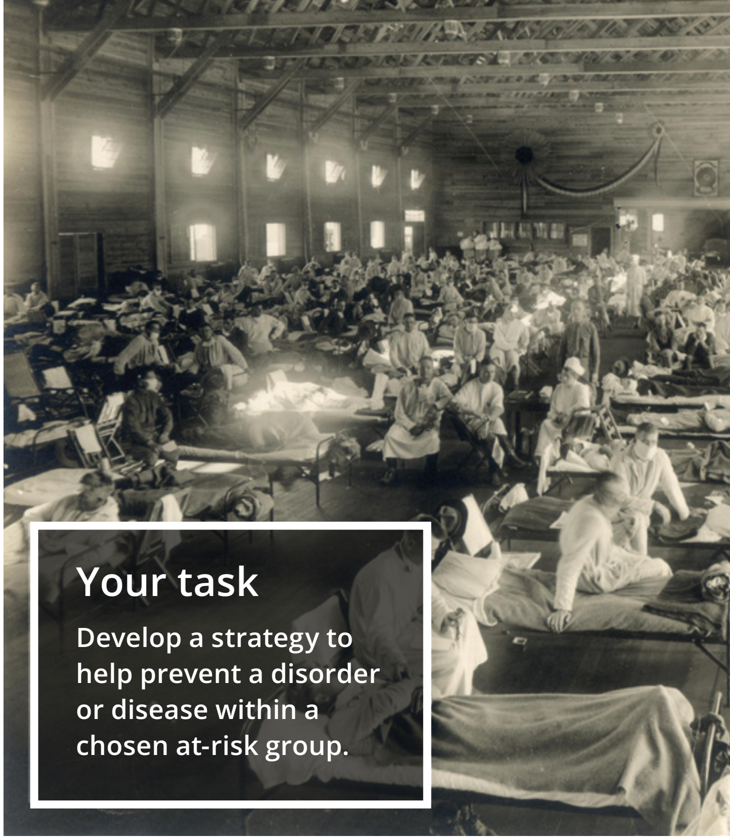
Heart disease, a non-infectious disease, is the leading cause of death globally. Mental health disorders, such as depression, bipolar disorder and dementia, also affect many people around the world.

Disorders and disease affect both high-income and low-income countries, but there are large differences in the ability of different healthcare systems to provide adequate care for people. The need for low-cost health care has led many researchers to investigate how technology can be used to help people live healthier lives.

Prevention of disorders and disease

There are many disorders and diseases that can be prevented through simple, low-cost interventions. Below are a few examples.

- Wearing a helmet or a seat belt has been shown to decrease the risk of brain injury from a road accident. In Vietnam, when wearing a helmet was made mandatory for motorcycle riders, it resulted in a 16 per cent decrease in head injuries.
- The use of mosquito nets can help to prevent malaria, a disease that can lead to life-long neurological impairment, such as epilepsy in children if they have a severe infection.
- Providing vaccinations for viruses such as polio and meningitis can also prevent neurological conditions.
- Promoting a healthy lifestyle and educating the population about the importance of diet can reduce the prevalence of stroke. In Japan,



Your task

Develop a strategy to help prevent a disorder or disease within a chosen at-risk group.

Figure 1 During the 1918 flu pandemic (sometimes called the Spanish flu), an estimated 500 million people, a third of the world's population, were infected with the virus.

Figure 2 Healthcare workers wear personal protective equipment (PPE) to prevent the spread of infectious disease.

campaigns and treatment for high blood pressure have reduced the rate of strokes by 70 per cent.

- Personal protective equipment (PPE) is used to protect people from catching infectious diseases, such as Covid-19.

HUMANITIES

In Geography, you will study how people are interconnected through travel, technology and trade. These connections affect where and how people access the services they need. In History, you will examine the experiences of different groups during the Industrial Revolution and the reforms made to improve living standards.

To complete this task successfully, you will need to research the demographics of your local area and the location and accessibility of health services. You should also consider the economic performance of your area to determine what type of preventative strategy would be most successful for your at-risk group.

MATHS

In Maths this year, you will extend your skills in representing and interpreting data. You will consider media reports that use statistics and collect secondary data to investigate social issues. You will relate real-world data to probabilities of events, and compare data sets using summary statistics and different graphical displays. You will evaluate and represent data, both with and without digital technology.

To complete this task successfully, you will need to find data to quantify the problem, work out how much your strategy will cost and calculate a quantitative, evidence-based estimate of the possible benefits of your strategy. You will need skills in dealing with ratios, proportions and percentages to consider the situation at local, national and international scales.

You will find help for applying these maths skills in Module 7 “Statistics” of *Oxford Maths 9 Victorian Curriculum (Second edition).*

SCIENCE

In Science this year, you will learn about how the body coordinates and regulates its internal systems so that it can respond to changes. When things change in the environment (such as the emergence of a disease-causing agent) or a part of the body fails, the normal functioning of the body is interrupted. The body needs to respond and attempt to return to a normal homeostatic state before permanent damage is caused.

To complete this task successfully, you will need to identify how the body’s systems work together to maintain a functioning body. You should consider the type of disorder or disease that you will be fighting and how it may cause changes in the body’s normal function and response mechanisms.

You will find more information on this in Module 2 “Control and regulation” of *Oxford Science 9 Victorian Curriculum*.

The design cycle

To successfully complete this task, you will need to complete each of the phases of the design cycle.

Discover

When designing solutions to a problem, you need to know who you are helping and what they need. The people you are helping, who will use your design, are called your end-users.

Consider the following questions to help you empathise with your end-users:

- Who am I designing for? Is it the people directly affected by the disorder or disease, or do their families and carers need support too?
- What problems are they facing? Why are they facing them?
- What do they need? What do they not need?
- What does it feel like to face these problems? What words would you use to describe these feelings?

To answer these questions, you may need to investigate using different resources or conduct interviews or surveys.

Define

Before you start to design your solution to the problem, you need to define the parameters you are working towards.

Define your version of the problem

Rewrite the problem so that you describe the group you are helping, the problem they are experiencing and why it is important. Use the following phrase as a guide.

"How can we help (the group) to solve (the problem) so that (the reason)?"

Determine the criteria

1. Describe the type of life that the people you are helping lived before their lives were affected by the disorder or disease.
2. Describe how the people affected by the disease have needed to change their lives to cope with the effects of the disorder or disease.
3. Describe how you will know that you have made their lives better as a result of your prototype strategy.

Ideate

Once you know who you're designing for, and you know what the criteria are, it's time to get creative!

Outline the criteria or requirements your design must fulfil (i.e. usability, accessibility, cost).

Brainstorm at least one idea per person that fulfils the criteria.

Remember that there are no bad ideas at this stage. One silly thought could lead to a genius innovation!

Build

Each group member should draw an individually designed solution. Label each part of the design. Include the materials that will be used for its construction.

Include in the individual designs:

a a detailed diagram of the design

b a description of why it is needed by the individual or group

c a description of any similar designs that are already available to buy

d an outline of why your idea or design is better than others that can be purchased.

Present your design to your group.

Build the prototype

Choose one design and build two or three prototypes.

Use the following questions as a guideline for your prototype.

- What materials or technology will you need to build or represent your prototype design?
- What skills will you need to construct your prototype design?
- How will you make sure your prototype design is able to be used by the people who need it?
- How will you describe the way the prototype design will work?

Test

Prototype 1

Use the scientific method to design an experiment that will test the effectiveness and strength of your first prototype. You will test the prototype more than once to compare results, so you will need to control your variables between tests.

What criteria will you use to determine the success of your prototype?

Conduct your tests and record your results in an appropriate table.

Prototype 2

If your prototype will be used to help individuals with the disorder or disease, then you will need to generate a survey to test whether the prototype is appropriate for their use. (How would they use it? Would it make their life easier or harder? Would they consider buying it? How much would they be willing to pay to access the design?)

Prototype 3

Your last prototype should be adapted using the information gathered from testing the first two versions to make it more effective and usable for the group you are helping. You may want to use the first two prototypes as a demonstration of how the design has been improved over time.

Communicate

Present your design to the class as though you are trying to get your peers to invest in your design.

In your presentation, you will need to:

- outline the relevant disorder or disease and how it affects individuals, as well as society as a whole
- create a working model or a detailed series of diagrams, with a description of how it will be used by an individual or group
- explain how you changed your design as a result of testing or feedback
- describe how the design will improve the life of an individual or group
- describe how many people need or will use the design
- describe how individuals will be able to access the design (will they need to purchase it or will it be publicly funded?)
- describe how the design will improve an individual's ability to contribute to society as a whole.

Online resources:

Student booklet
This helpful booklet will guide you step-by-step through the project.

What is the design cycle?
This video will help you to better understand each phase of the design cycle.

How to manage a project
This "how-to" video will help you to manage your time throughout the design cycle.

How to pitch your idea
This "how-to" video will help you with the "Communicate" phase of your project.

Glossary

A

accurate

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

aerobic cellular respiration

a chemical reaction between glucose and oxygen to produce carbon dioxide, water and energy (ATP)

allergy

an overreaction by the immune system in response to pollen, dust or other non-pathogens

alpha particle

a radioactive particle containing two protons and two neutrons; can be stopped by a piece of paper

alternating current (AC)

an electric current in which the direction of the current (flow of electrons) changes at regular intervals

amplitude

the distance a particle in a wave moves, from its position of rest

anaphylaxis

a life-threatening overreaction by the immune system to a normally harmless substance

angle of incidence

the angle between an incident ray and the normal (a line drawn at right angles to a reflective surface)

angle of reflection

the angle between a reflected ray and the normal (a line drawn at right angles to a reflective surface)

angle of refraction

the angle between a refracted ray and the normal (a line drawn at right angles to a refractive surface)

anther

the end part of a stamen (male part of a flower); produces pollen

antiseptic

a chemical that kills a pathogen on your skin

asexual reproduction

type of reproduction in which one parent produces offspring that are all genetically identical to the parent

atmosphere

the layer of gases surrounding the Earth

atom

the smallest particle that forms the building blocks of matter; the smallest particle that retains the properties of an element

atomic number

the number of protons in an atom's nucleus

atomic theory

the theory that all matter is made up of atoms

ATP (adenosine triphosphate)

molecule that stores and transfers energy in cells; produced during cellular respiration

autoimmune disease

a condition caused by the immune system targeting the body's own cells and tissues

autonomic nervous system

the part of the nervous system that controls involuntary actions such as heartbeat, breathing and digestion

axon

the part of a neuron (nerve cell) that carries an electrical message away from the cell body to the synapse

B

b cell

an immune system cell that produces antibodies in response to pathogens

beta particle

a radioactive particle (high-speed electron or positron) with little mass; can be stopped by aluminium or tin foil

bias

discrimination against ideas, people or in the collection and interpretation of information

binary fission

a form of asexual reproduction used by bacteria; the splitting of a parent cell into two equal daughter cells

biodegradable

describes an object or a substance that can be broken down by bacteria, fungi or other living organisms

biodiversity

the variety of life; the different plants, animals and microorganisms and the ecosystems they live in

biosphere

a layer around the Earth's surface that supports life; consists of the atmosphere, hydrosphere and lithosphere

blind study

when participants do not know who is receiving the real treatment or placebo

C

carbon dating

a method of estimating the age of organic material, by comparing the amount of carbon-14 in the material with the amount in the atmosphere, knowing the rate at which carbon-14 decays over time

carbon emission

the release of greenhouse gases containing carbon, such as carbon dioxide, into the atmosphere

carbon sink

any feature of the environment that absorbs and/or stores carbon

carbon tax

a tax levied on the carbon content of fuels used by businesses or homes

carbon trading scheme

the process of allocating a set limit of carbon credits to businesses, which can then trade the credits

carpel

the female reproductive organ of a flower; includes the stigma, style and ovary and ovule

categorical data

information that can be divided into groups or categories

cell body

the main part of a cell that contains the nucleus/genetic material

cellular respiration

chemical reaction that transfers energy (ATP) to cells

central nervous system

the brain and spinal cord

cerebrum

the largest part of the brain; divided into four lobes called the frontal lobe, the parietal lobe, the temporal lobe and the occipital lobe

cervix

the narrow neck connecting the uterus and the vagina

chemical equation

a representation of a chemical reaction using chemical formulas

chemical reaction

a procedure that produces new chemicals; same as chemical change

circular economy

an economic system where materials are reused and recycled rather than used and disposed of

coefficient

in chemistry, a whole number in front of a chemical symbol or formula; indicates the number of molecules or elements

cognition

mental processes that are involved in acquiring, storing, manipulating and retrieving information

colostrum

nutrient-rich, antibody-packed first milk produced by mammals after giving birth, providing essential immune protection and nutrients to newborns

column graph

vertical bars used to compare data

combustion reaction

a reaction between a fuel and oxygen that produces heat, carbon dioxide and water

command term

a “doing word” that requires you to perform a specific thinking task

compression

part of a sound wave where air particles are forced close together

concave

refers to a lens or mirror that is thinner in the centre than at the ends

conclusion

a statement that “answers” the aim of an experiment

conduction

the transfer of thermal energy from hot objects to cooler objects by direct contact with no movement of material

conductor

material or substance that electrons can flow through; the flow of electrons through a conductor is electrical current

confirmation bias

a preference for information or data that supports pre-existing beliefs or the hypothesis

continuous data

information that can be any value, including decimals and fractions that are measured

contraception

medical or chemical techniques used to prevent pregnancy

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

converge

(in relation to rays of light) to come together at a single point

convex

refers to a lens or mirror that is thicker in the centre than at the ends

corrosive

a substance that can damage or destroy other materials

Country

a term used by Aboriginal and Torres Strait Islander Peoples to describe the connections between land, water, sky, animals, plants, people, stories, songs, cultural practices and spiritual beliefs that make up a traditional area

critical angle

the angle of light that causes the reflected ray to move along the edge between two materials

cross-pollination

the exchange of pollen and ova between different plants of the same species

cryopreservation

the preservation of cells for extended periods of time at very low temperatures

cryosphere

the frozen water in the hydrosphere

cultural burning

the practice of burning vegetation used by Traditional Custodians of Country to enhance the health of Country; informed by deep knowledge of and relationship to Country

cultural norm

often unspoken expectations about one’s behaviours and beliefs

current

the rate at which electrons flow; measured in amperes (amps; symbol “A”)

D

dendrite

the part of a neuron (nerve cell) that receives a message and sends it to the cell body

direct current (DC)

an electrical current that flows in one direction only; electrical energy is produced in this form by a battery

discrete data

information that can only take on specific and distinct values like whole numbers

disease

a disruption or change in the normal structure or functioning of an animal or plant

disinfectant

a chemical that kills a pathogen on non-living surfaces

dispersion

the separation of white light into its different colours

diverge

(in relation to rays of light) to move away from each other

double-blind study

when researchers and participants do not know who is receiving the real treatment or placebo

dry cell

an object, such as a torch battery, that uses a chemical reaction to produce electrical energy

E

electric circuit

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

electric current

the flow of electrical charge through a circuit

electrical conductor

a material through which charged particles are able to move

electrical energy

the energy that results in the movement of electrons through a conductor towards a positive charge

electrical insulator

a material that does not allow the movement of charged particles

electromagnet

a type of magnet that uses an electrical current to produce a magnetic field

electromagnetic induction

the production of voltage (and hence a current) in a circuit, by the magnetic field through the circuit or by the relative movement of the magnetic field and the circuit; all dynamos and generators use this principle

electron

a negatively charged particle that moves around in the space outside the nucleus

electrostatic charge

an electric charge between two objects caused by a deficiency or excess of electrons (negative charges); also known as “static electricity”

element

a pure substance made up of only one type of atom

endemic

a disease that regularly occurs in a community

endocrine system

a collection of glands that make and release hormones

endometrium

the lining of the uterus

energy

the capacity to do work

energy efficiency

a measure of the amount of useful energy transformed in an energy transformation process; usually expressed as a percentage of the input energy (e.g. 90 per cent efficiency is very good)

energy transfer

the process of energy moving from one place to another

energy transformation

the process of energy changing from one form to another (e.g. from electric energy into heat energy)

enhanced greenhouse effect

an increase in carbon dioxide and other heat-capturing gases in the atmosphere, resulting in increased warming of Earth

epidemic

the rapid spread of a disease in a community in a short time

epidemiology

study of the distribution, causes and effects of health-related conditions in populations to inform public health practices and disease prevention

epididymis

a coiled tube behind the testes that carries sperm to the vas deferens

equipment

items used in the laboratory to conduct experiments

ethics

a system of moral principles about what is good, bad, right and wrong

experiments

an investigation used to test a hypothesis, solve a problem or find an answer to a question

external fertilisation

when the egg and sperm meet outside the bodies of the parents

extrapolation

estimating unknown values from trends in known data

F

fallopian tubes

tubes that connect the ovaries to the uterus

fertilisation

the process where two gametes (sex cells) fuse to produce a single cell

fetus

an unborn animal or human after the embryo stage; in humans this is after 8 weeks of development

filament

male structure in a flower that supports the anther

filter

a transparent material that allows only one colour of light to pass through

focal length

the distance between the centre of a lens and the focus

focus

the point where rays of light cross

fragmentation

asexual reproduction that occurs when a new organism grows from a fragment of the parent

frequency

the number of waves that pass a point every second; measured in hertz

fuel

a substance that undergoes a chemical reaction producing large amounts of energy

G

gamete

a sex cell; in humans, the sperm and egg cells

gamma rays

high-energy electromagnetic rays released as a part of radioactive decay; can be stopped by lead

generator

a machine that uses the electromagnetic effect to separate charges and produce electricity

genetic diversity

the variety of DNA and genes in a population or species

genetic material

information that is stored in DNA and passed onto the next generation by asexual or sexual reproduction

gestation

the length of time between fertilisation and birth

gravitational potential energy

the energy possessed by an object raised to a height in a gravitational field

green chemistry

a branch of chemistry that aims to develop chemical products and processes that are sustainable and do not damage the environment

group

a vertical list of elements in the periodic table that have characteristics in common

H

half-life

the time it takes the radioactivity in a substance to decrease by half

herd immunity

an indirect way of protecting an individual from infection by vaccinating a larger number of individuals in a population

hermaphrodite

an organism that has both male and female reproductive systems

hertz

the unit used to measure frequency

homeostasis

the process by which the body detects and responds to stimuli to ensure a stable internal state is maintained

hormone

a chemical messenger that travels through blood vessels to target cells

host

a living organism that provides energy and nutrients to another organism, including a pathogen

hydrocarbon

a molecule that contains only carbon and hydrogen atoms

hydrosphere

all the solid, liquid and gaseous waters on Earth that support life

hyperglycaemia

when there are high levels of glucose in the blood which can occur when the body has too little insulin

hypothesis
a proposed explanation for a prediction that can be tested

I

image
a likeness of an object that is produced as a result of light reflection or refraction

immune
able to fight an infection as a result of prior exposure

immune system
a system of organs and structures that protect an organism against disease

Indigenous science
a system of knowledge developed by Aboriginal and Torres Strait Islander Peoples over tens of thousands of years that combines careful observation and testing of the natural world with cultural understanding to explain how things work and are connected in nature

inference
a conclusion based on evidence and reasoning

input energy
energy put into a device or system

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

internal fertilisation
when the sperm fertilises the egg inside the body of an organism

interneuron
a nerve cell that links sensory and motor neurons; also known as a connector neuron

interpolation
determining a value from existing values

intracytoplasmic sperm injection
a single sperm is injected into the egg and then transferred to a woman’s uterus

intrauterine insemination
where sperm is placed directly into the uterus

inversely proportional relationship
when one quantity decreases the other quantity increases or vice-versa

in vitro fertilisation
when an egg is fertilised naturally by the sperm in a laboratory, then transferred to a woman’s uterus

ion
an atom with a positive or negative electrical charge due to the loss or gain of electrons

isotope
an atom of a particular element that has more or fewer neutrons in its nucleus than another atom of the same element

K

k-strategist
organisms living in stable environments who breed carefully

kinetic energy
the energy possessed by moving objects

L

Law of Conservation of Energy
a scientific rule that states that the total energy in a closed system is always constant and cannot be created or destroyed

Law of Conservation of Mass
chemical law that states that matter cannot be created or destroyed

lens
a curved piece of transparent material

lesion
raised bumps that develop on the skin during the infection

line graphs
individual data points that are connected and that change over time

line of best fit
a straight line that goes through the middle of all the scatter points to minimise the distance between the line and the scatter points

lithosphere
the outermost layer of Earth, consisting of the upper mantle and crust

logbook
a detailed recording of observations and data from your investigation

longitudinal wave
a type of (sound) wave where the particles move in the direction of travel of the wave

M

magnetic field
the area around a magnet, a magnetic substance or an electric charge where there is a magnetic force

malnutrition
a condition caused by too much or too little nutrient intake, or an imbalance of essential nutrients

marsupial
mammal that gives birth to immature offspring that complete their development in their mother’s pouch

mass
the amount of matter in a substance, usually measured in kilograms (kg) or grams (g)

mass number
a number that represents the total number of protons and neutrons in the nucleus of an atom

matter
anything that has space and volume; matter is made up of atoms

mean
the average of a data set

median
the middle value for data arranged from smallest to largest

medium
a substance or material through which light can move

memory cell
an immune system cell produced in response to an infection; retains the memory of how to fight the pathogen

menstruation
also know as a period; the process of the endometrial lining of the uterus breaking down and leaving the vagina

microorganism
a living thing that can only be seen with a microscope

mineral
a naturally occuring element or compound

mode
the value(s) that appears the most in a data set

monotreme
mammal that lays eggs

motor neuron
a nerve cell that carries a message from the central nervous system to a muscle cell

multicellular organism
a living thing that has many cells

myelin sheath
a fatty layer that covers the axon of a nerve cell

N

natural greenhouse effect
the natural warming of Earth due to water vapour and other gases being present in small amounts in the atmosphere and affecting Earth’s radiation balance

negative feedback mechanism

a regulatory loop in which the stimulus causes a response that acts in the opposite direction to whatever is being regulated

neuron

a nerve cell

neurotransmitter

a chemical messenger that crosses the synapse between the axon of one neuron and the dendrite of another neuron

neutron

a neutral (no charge) subatomic particle in the nucleus of an atom

non-infectious disease

a disease that cannot be passed between plants or between animals

normal

(in relation to light) an imaginary line drawn at right angles to the surface of a reflective or refractive material

nucleus

the centre of an atom, containing protons (positive charge) and neutrons (no charge)

numerical data

information in the form of numbers

O

objective

information free of prejudices that is based on evidence and is verifiable

ocean acidification

the production of carbonic acid in the ocean due to the absorption of carbon dioxide

oestrogen

a reproductive hormone in females

offspring

new organisms that are produced by asexual or sexual reproduction; an organism’s young, or child

opaque

not allowing light to pass through

opportunistic

the ability to make the most of favourable conditions to thrive and multiply

optic fibre

a thin fibre of glass or plastic that carries information/data in the form of light

ore

a rock that contains a high percentage of one type of mineral

outlier

a data point that differ significantly from the main group of data

output energy

energy that comes out of a device or system; includes useful energy and waste energy

ovaries

the female organ that produces eggs

oviduct

the tube through which eggs travel from the ovary

ovulation

the part of the menstrual cycle when an egg is released from the ovary

ovule

structure inside the ovary of seed plants that contains an egg cell; develops into a seed after fertilisation

ovum (egg)

the female gamete (sex cell); also called an egg

P

pandemic

an outbreak of a disease that crosses international borders

parthenogenesis

asexual reproduction where a female fertilises her own eggs

passive immunity

temporary protection against disease provided by antibodies transferred from another source, such as from mother to baby or through antibody injections

pathogen

a microbe that can cause disease

pattern

a repeated sequence or arrangement of numbers/data points

peer review

a process in which experts evaluate the findings of a report before it is published

period

(in chemistry) a horizontal list of elements in the periodic table

periodic table

a table in which elements are listed in order of their atomic number, and grouped according to similar properties

peripheral nervous system

all the neurons (nerve cells) that function outside the brain and spinal cord

permafrost

permanently frozen ground

phagocyte

an immune system cell that surrounds, absorbs and destroys pathogens

photosynthesis

a chemical process used by plants to make glucose and oxygen from carbon dioxide, sunlight and water

photovoltaic cells

technology that is used to transfer and transform solar light energy into electrical current

placebo

a substance or treatment that has no effect

placenta

the organ that connects the developing fetus to its mother

placental

mammal that has a placenta to nourish their offspring during gestation

pollen

a powdery substance for transporting the male gametes of flowering plants and cone-bearing plants; contains pollen grains that produce male gametes (sperm cells)

pollination

fertilisation of gametes in plants

potential difference

voltage; the difference in the electrical potential energy carried by charged particles between two different points in a circuit

prediction

an outcome that is expected based on prior knowledge or observation

preimplantation genetic testing

embryos that are created through IVF that are tested for genetic or chromosomal abnormalities before being transferred to a woman’s uterus

primary colours of light

the three colours of light (red, blue and green), which can be mixed to create white light

product

a substance obtained at the end of a chemical reaction; written on the right side of a chemical equation

prostate gland

a walnut-sized structure surrounding the neck of the male bladder that blocks the flow of urine so sperm can move along the urethra

proton

a positively charged subatomic particle in the nucleus of an atom

pseudoscience

a claim that has not been tested using the scientific method

Q

quarantine

the separation and restriction of movement or travel

R

r-strategist

organisms living in unstable environments who breed rapidly

radioactive decay

the conversion of a radioactive isotope into its stable form, releasing energy in the form of radiation

radionuclide

a radioactive isotope

random error

unpredictable variations in measurements that are not the same every time

randomised

when participants in a trial are assigned to separate groups by chance

rarefaction

a reduction in density; refers to part of a sound wave where air particles are forced apart

reactant

a substance used at the beginning of a chemical reaction; written on the left side of a chemical equation

reactivity series

a list of metals ordered from most reactive (at the top) to least reactive (at the bottom)

receptor

a structure that detects a stimulus or change in the normal functioning of the body

reflex

an involuntary movement in response to a stimulus

refracted ray

a ray of light that has bent as a result of speeding up or slowing down when it moves into a more or less dense medium

refraction

the bending of light as a result of speeding up or slowing down when moving into a medium of different density

refractive index

a measure of the bending of light as it passes from one medium to another

relative atomic mass

the average mass of an element, including the mass and prevalence of its different isotopes

reliable

consistency of a measurement, test or experiment

renewable energy

energy that comes from resources that are made naturally and available in an almost unlimited amount

repeatable

the same results and observations can be made under the same conditions and using the same method

reproducible

the ability to repeat and replicate a test exactly

response

a change in an organism's behaviour or function in reaction to a stimulus

results

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

rheumatoid arthritis

a chronic autoimmune disorder that causes inflammation, pain, and swelling in the joints

right-hand grip rule

a rule used to predict the magnetic field direction around a current-carrying wire or the magnetic field of a solenoid; the right thumb indicates the current direction and the curled fingers give the magnetic field direction; also known as the right-hand curl rule

risk

exposure to danger

risk assessment

the process of identifying and evaluating potential risks, including how they can be mitigated and what to do if there is exposure to the risk

S

safety data sheet (SDS)

a document that details health and safety information about a material including safe handling and its properties

sampling bias

the selection of participants is not random and does not represent the larger population

Sankey diagram

a flow chart that represents movement or change in resources, such as the transfer or transformation of energy

scatter plot

a type of graph that displays the relationship between two sets of numerical data

scrotum

a sac-like structure that contains the testes

secondary colours of light

the colours of light (magenta, cyan and yellow) that result from the mixing of two primary colours of light

self-pollination

when both gametes come from the same plant

semiconductor

a material that conducts electrical energy in one form and insulates against electrical energy in another form

seminal vesicles

a pair of small pouch-like structures that provide a sugary fluid that assists sperm to travel along the vas deferens

sensory neuron

a nerve cell that carries a message from a receptor to the central nervous system

sexual reproduction

type of reproduction in which two parents produce offspring that are genetically different to the parent; the fusion of gametes from two parents

sexually dimorphic

describes species in which the male and female organisms look structurally different

solenoid

an electromagnet consisting of a coil of wire that can carry an electric current, with an iron core

somatic nervous system

the part of the nervous system that controls the muscles attached to the skeletal system

sonar

the detection of the location of objects through the use of soundwaves

sperm

the male gamete (sex cell)

spore

a tiny reproductive structure that, unlike a gamete, does not need to fuse with another cell to form a new organism

stamen

the male part of a plant, consisting of a filament supporting an anther

stigma

the top of the carpel; where the pollen from the anther begins its journey to the ovary

stimulus

any information that the body receives that causes it to respond

style
female structure in a flower that connects the stigma to the ovary

subatomic particle
a particle that is smaller than an atom

subscript
in chemistry, a small-sized number after an element symbol; indicates the number of atoms of the element

synapse
a small gap between two neurons that must be crossed by neurotransmitters

systematic error
predictable variations in measurements due to faulty equipment or method

T

t cell
an immune system cell that recognises and kills pathogens

target cell
a cell that has a receptor that matches a specific hormone

tectonic plate
a large layer of solid rock that covers part of the surface of the Earth; movement of tectonic plates can cause earthquakes

testes
the male reproductive organ that produces sperm (plural: testes)

testosterone
a male hormone involved in the reproductive system

thermal conductor
a material that allows thermal energy to flow through

thermal insulator
a material that prevents or slows down the transfer of thermal energy

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

total internal reflection
the complete reflection of a light ray when it passes from a more dense to a less dense material at a large angle; the ray is reflected back into the dense medium

transformer
a device that changes the voltage at which energy is transmitted by an alternating current; usually consists of two coils or wire (primary and secondary), an iron core and an AC power source

translucent
allowing light through, but diffusing the light so objects cannot be seen clearly

transmission
the movement of a pathogen from one host to another

transmit
to allow light to pass through

transparent
allowing all light to pass through, so objects can be seen clearly

transverse wave
a type of (light) wave where the vibrations are at right angles to the direction of the wave

trend
represents the overall direction of the data points

type 1 diabetes
an autoimmune disease in which the immune system attacks the insulin-producing cells in the pancreas

U

unbiased
showing no prejudice for or against something

unicellular organism
a living thing that has one cell

uterus
an organ in the female reproductive system; where the fetus develops

V

vaccination
an injection of an inactive or artificial pathogen that results in the individual becoming immune to a particular disease

vagina
a female reproductive organ; a muscular tube connecting the outside of the female body to the cervix

valid
where a test investigates what it sets out to investigate

van de Graaff generator
a machine that produces an electrostatic charge

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

vas deferens
the tube through which sperm travel from the epididymis to the prostate

vegetative reproduction
a type of asexual reproduction where part of a plant breaks off, forming a new organism with no need for seeds or spores; similar to fragmentation

virtual focus
the point at which a virtual image appears

virtual image
an image that appears in a mirror; it cannot be captured on a screen

virulent
a pathogen's ability to cause damage in a host organism

visible spectrum
the variety of colours of wavelengths of light that can be seen by the human eye

voltage
potential difference; the difference in the electrical potential energy carried by charged particles between two different points in a circuit

W

waste energy
output energy that cannot be used for the intended purpose of the device or system; by-product of energy transfer and transformation

wavelength
the distance between two crests or troughs of a wave

Western science
a system of knowledge based on careful observation, measurement, testing and experimentation (known as the scientific method) to develop and test hypothesis to explain how things work

wet cell
an object, such as a car battery, that uses a chemical reaction to produce electrical energy

white blood cell
an immune system cell that destroys pathogens

word equation
a representation of a chemical reaction using words

Z

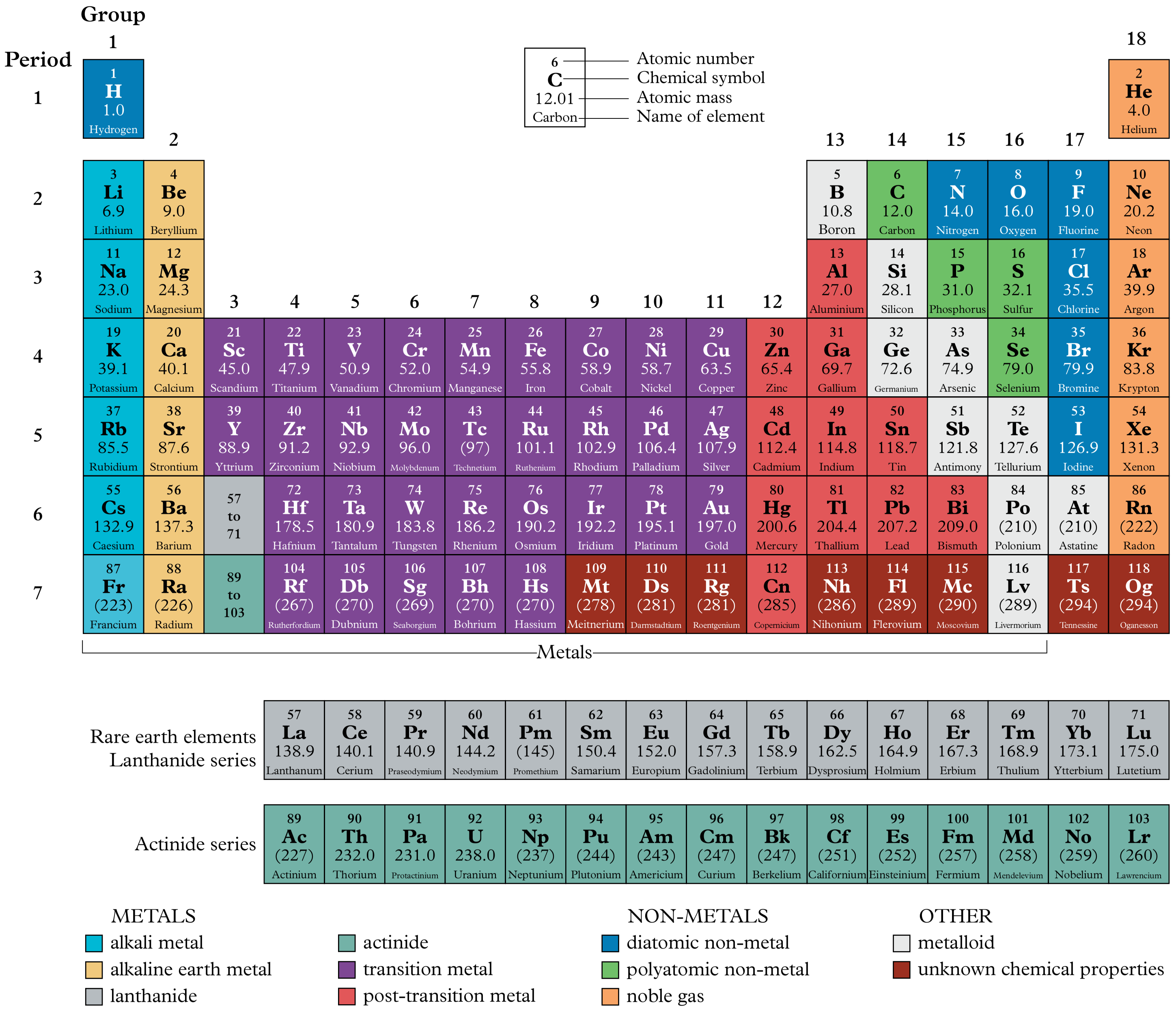
zygote
a fertilised egg

Index

Acknowledgements

Cover image: SAM FALCONER, DEBUT ART/SCIENCE PHOTO LIBRARY. **Glossary:** Irina and Denis/Shutterstock; **Prelims:** Mongkolchon Akesin/Shutterstock. **Module 1 Opener:** SAM FALCONER, DEBUT ART/SCIENCE PHOTO LIBRARY. Lesson 1.1: Fig. 3, Imago/Alamy Stock Photo; Fig. 2, Reproduced with permission of Firestick Alliance; Fig. 4, spline_x/Shutterstock; Fig. 5, Benny Marty/Shutterstock; Fig. 6, Andrew Bain/Alamy Stock Photo; Fig. 7 (a), Prachaya Roekdeethaweesab/Shutterstock; Fig. 7 (b), Australian official journal of patents, 1910, p. 910; Fig. 8, BlueSnap/Shutterstock; Lesson 1.2: Fig. 2, Sunnydream/Shutterstock; Lesson 1.4: Fig. 2, I. Noyan Yilmaz/Shutterstock; Fig. 3, Halfpoint/Shutterstock; Fig. 4, Katcha_Natsarin/Shutterstock; Fig. 5 (a), Gorodenkoff/Shutterstock; Fig. 5 (b), AndriiKoval/Shutterstock; Fig. 6, bmphotographer/Shutterstock; Lesson 1.5: Fig. 2, Science Photo Library/Alamy Stock Photo; Fig. 3, Science Photo Library/Alamy Stock Photo; Fig. 5, Science Photo Library/Alamy Stock Photo; Fig. 6, Boko Style/Shutterstock; Lesson 1.6: Fig. 1 (a), boyoz/Shutterstock; Fig. 1 (b), Bjoern Wylezich/Shutterstock; Fig. 2 (a), Shuttertum/Shutterstock; Fig. 2 (b), New Africa/Shutterstock; Fig. 2 (c), Anwarul Kabir Photo/Shutterstock; Fig. 2 (d), Shuttertum/Shutterstock; Fig. 2 (e), Mehmet Cetin/Shutterstock; Fig. 2 (f), Pixel-Shot/Shutterstock; Fig. 2 (g), Hora Studio/Shutterstock; Fig. 2 (h), PixelSquid3d/Shutterstock; Fig. 2 (i), Peter Sobolev/Shutterstock; Fig. 2 (j), Chadchai Krisadapong/Shutterstock; Fig. 2 (k), Nataliass/Shutterstock; Fig. 2 (l), Rabbitmindphoto/Shutterstock; Fig. 2 (m), creativesunday/Shutterstock; Fig. 2 (n), Picture-Syndicate/Shutterstock; Fig. 2 (o), eczserapyilmaz/Shutterstock; Fig. 2 (p), Jan Kaliciak/Shutterstock; Fig. 4, Vereshchagin Dmitry/Shutterstock; Fig. 3, desdemona72/Shutterstock; Lesson 1.7: Fig. 5, VectorMine/Shutterstock; Fig. 6, NASA/SCIENCE PHOTO LIBRARY; Lesson 1.8: Fig. 1, PATRICK LANDMANN/SCIENCE PHOTO LIBRARY; Lesson 1.10: Fig. 2, Dusit/Shutterstock; Fig. 5 (a), Pavel Zhelev/Alamy Stock Photo; Fig. 5 (b), Dragana Gordic/Shutterstock; Fig. 6 (a), MARTYN F. CHILLMAID/SCIENCE PHOTO LIBRARY; Fig. (b), Vera Aksionava/Shutterstock; Lesson 1.11: Fig. 2, GraphicsRF.com/Shutterstock; Lesson 1.12: Fig. 1, Creativa Images/Shutterstock; Fig. 2, Edcel Mayo/Shutterstock; Lesson 1.13: Fig. 2, Billion Photos/Shutterstock; Fig. 3, artcasta/Shutterstock; Fig. 4, gresei/Shutterstock; Fig. 5, RimDream/Shutterstock; Fig. 6, Parinya/Shutterstock. **Module 2 Opener:** SAM FALCONER, DEBUT ART/SCIENCE PHOTO LIBRARY. Lesson 2.1: Fig. 1, Denis Radovanovic/Shutterstock; Fig. 2, BSIP SA/Alamy Stock Photo; Fig. 3, Stana/Shutterstock; Fig. 5, Eric Isselee/Shutterstock; Fig. 7, dogboxstudio/Shutterstock; Fig. 9, Norma Cornes/Shutterstock; Fig. 11, maewshooter/Shutterstock; Lesson 2.3: Fig. 3, pixelheadphoto digitalskillet/Shutterstock; Fig. 4, Scott Camazine/Alamy Stock Photo; Fig. 5, KOTOIMAGES/Shutterstock; Fig. 6, Omfotovideocontent/Shutterstock; Fig. 7, iofoto/Shutterstock; Fig. 8, Ann Tyurina/Shutterstock; Lesson 2.5: Fig. 1, Brent Parker Jones Photographer; Fig. 2, Brent Parker Jones Photographer; Fig. 3, Brent Parker Jones Photographer; Fig. 4, Brent Parker Jones Photographer; Lesson 2.6: Fig. 1 (a), JOHN T. ALESI/SCIENCE PHOTO LIBRARY; Fig. 3, Adam Trafford/AFL Media/Getty Images; Lesson 2.7: Fig. 1, ttsz/Getty Images; Fig. 3, Johan Swanepoel/Shutterstock; Lesson 2.8: Fig. 1, PIKOVIT/SCIENCE PHOTO LIBRARY; Lesson 2.9: Fig. 1, Christian Bertrand/Shutterestock; Fig. 2, Connect Images/Alamy Stock Photo; Fig. 3, ttsz/Getty Images; Fig. 7, Evikka/Shutterstock; Fig. 8, Denis Kuvaev/Shutterstock; Fig. 9, EpicStockMedia/Shutterstock; Fig. 10, ArtVisionStudio/Shutterstock; Lesson 2.10: Fig. 1, Chesky/Shutterstock; Lesson 2.11: Fig. 1, Habrovich/Shutterstock; Fig. 2, Melinda Nagy/Shutterstock; Fig. 3, F01 PHOTOy/Shutterstock; Lesson 2.12: Fig. 1, Rapt.Tv/Alamy Stock Photo; Fig. 2, fusebulb/Shutterstock; Fig. 3, Mario Tama/Getty Images; Fig. 4, Nomad_Soul/Shutterstock; Lesson 2.13: Fig. 2, Ioannis Pantzi/ Shutterstock; Fig. 3, F01 PHOTOy/Shutterstock; Fig. 4, Mix and Match Studio/Shutterstock; Fig. 5, visual7/Getty Images; Fig. 6, sfotoz/Shutterstock. **Module 3 Opener:** SAM FALCONER, DEBUT ART/SCIENCE PHOTO LIBRARY. Lesson 3.1: Fig. 1, wutwhanfoto/Getty Images; Fig. 2, Daria Kulkova/Getty Images; Fig. 3, Kintarapong/Getty Images; Fig. 4, Volodymyr Horbovyy/Getty Images; Fig. 5, State of New South Wales, through the Parliament of New South Wales 2021; Lesson 3.4: Fig. 1 (a), Connect Images/Alamy Stock Photo; Fig. 1 (b), Connect Images/Alamy Stock Photo; Fig. 3, TONY ASHBY/AFP via Getty Images; Lesson 3.6: Fig. 1, Science Photo Library/Alamy Stock Photo; Fig. 2, S.Toey/Shutterstock; Fig. 3, CAVALLINI JAMES/BSIP/SCIENCE PHOTO LIBRARY; Fig. 4, sruilk/Shutterstock; Fig. 5, VISUAL CAPITALIST/SCIENCE PHOTO LIBRARY; Fig. 6, Juan Gaertner/Shutterstock; Lesson 3.7: Fig. 1, Hafiez Razali/Shutterstock; Fig. 2, Francesco Scatena/Shutterstock; Fig. 4, © State of Victoria 2021; Lesson 3.12: Fig. 2, Mark Kelly/Alamy Stock Photo; Fig. 3, Hriana/Shutterstock; Fig. 4, mikeforemniakowski/Shutterstock; Lesson 3.13: Fig. 1, icare NSW Annual Reports for 2016-17, 2017-18, 2018-19 and 2019-20;, Experton, B., Elena, A., Hein, C. S., Nordenberg, D., Walker, P., Schwendiman, B., & Burrow, C. R. (2022). Enhanced Vaccine Effectiveness during the Delta Phase of the COVID-19 Pandemic in the Medicare Population Supports a Multilayered Prevention Approach. Biology, 11(12), 1700. https://doi.org/10.3390/biology11121700. Released under CC BY 4.0 https://creativecommons.org/licenses/by/4.0/. **Module 4 Opener:** SAM FALCONER, DEBUT ART/SCIENCE PHOTO LIBRARY. Lesson 4.1: Fig. 1, StockMediaSeller/Shutterstock; Fig. 2, Shamils/Shutterstock; Fig. 3, Paolo Reda - REDA &CO/Alamy Stock Photo; Fig. 4, sunsetman/Shutterstock; Fig. 5, Gerald Robert Fischer/Shutterstock; Fig. 6, Kathy Hutchins/Shutterstock; Lesson 4.3: Fig. 1 (a), Karin Duthie/Alamy Stock Photo; Fig. 1 (b), Auscape International Pty Ltd/Alamy Stock Photo; Fig. 1 (c), agefotostock/Alamy Stock Photo; Fig. 2, Christopher Mansfield/Shutterstock; Fig. 3, NAOTO JACK FUKUSHIMA/Shutterstock; Fig. 4, Nature Picture Library/Alamy Stock Photo; Fig. 5, Alex Stemmer/Shutterstock; Fig. 6, Avalon.red/Alamy Stock Photo; Lesson 4.4: Fig. 2, Mikael Damkier/Shutterstock; Fig. 6, BlackJack3D/Getty Images; Lesson 4.5: Fig. 1, MAURO FERMARIELLO/SCIENCE PHOTO LIBRARY; Fig. 2, Gorodenkoff/Shutterstock; Lesson 4.6: Fig. 1, imageBROKER.com/Alamy Stock Photo; Lesson 4.7: Fig. 5, kkaplin/Shutterstock; Fig. 6, keith burdett/Alamy Stock Photo; Fig. 7, GraphicsRF.com/Shutterstock; Lesson 4.9: Fig. 1, Philip Brookes/Shutterstock; Fig. 3, Ivaylo Ivanov/Shutterstock; Fig. 4, Dave Watts/Alamy Stock Photo; Fig. 5, Viorel Sima/Shutterstock; Fig. 2, Triff/Shutterstock; Lesson 4.10: Fig. 1, janez volmajer/Shutterstock; Fig. 5 (a), Eric Isselee/Shutterstock; Fig. 5 (b), Scorpp/Shutterstock; Fig. 6, Avalon.red/Alamy Stock Photo; Fig. 7, luchschenF/Shutterstock; Fig. 8, Kichigin/Shutterstock. **Module 5 Opener:** SAM FALCONER, DEBUT ART/SCIENCE PHOTO LIBRARY. Lesson 5.2: Fig. 1, Designua/Shutterstock; Lesson 5.4: Fig. 1, Everett Historical/Shutterstock; Fig. 2, Science Photo Library/Alamy Stock Photo; Lesson 5.6: Fig. 1, Paolo Gallo/Shutterstock; Fig. 2, Used with permission of Dr. Damien Finch; Fig. 3, Creativemarc/Shutterstock; Fig. 4, urfin/Shutterstock; Lesson 5.7: Fig. 2, MarcelClemens/Shutterstock; Fig. 3, CENTRE JEAN-PERRIN/SCIENCE PHOTO LIBRARY; Fig. 4, Science Photo Library/Alamy Stock Photo; Lesson 5.8: Fig. 5, RHJPhtotoandilustration/Shutterstock; Fig. 6, Shutterstock; Fig. 7, ROBBIE SHONE/SCIENCE PHOTO LIBRARY. **Module 6 Opener:** SAM FALCONER, DEBUT ART/SCIENCE PHOTO LIBRARY. Lesson 6.2: Fig. 1, Photographer: Brent Parker Jones; Fig. 2, Photographer: Brent Parker Jones; Lesson 6.3: Fig. 1, Phil Degginger/Alamy Stock Photo; Fig. 2, Everett Collection/Shutterstock; Fig. 3, Anne Helmenstine – Sciencenotes.org; Lesson 6.4: Fig. 2, Mike Greenslade/Alamy Stock Photo; Fig. 3, Phil Degginger/Alamy Stock Photo; Fig. 4, MICHAEL SZOENYI/SCIENCE PHOTO LIBRARY; Lesson 6.5: Fig. 2, Mara Fribus/Shutterstock; Lesson 6.6: Fig. 1 (a), prapass/Shutterstock; Fig. 1 (b), ChameleonsEye/Shutterstock; Lesson 6.7: Fig. 1, KrimKate/Shutterstock; Fig. 2, MarcelClemens/Shutterstock; Fig. 3, MarcelClemens/Shutterstock; Fig. 4, MikeDotta/Shutterstock; Fig. 5, mark higgins/Shutterstock; Fig. 6, Singkham/Shutterstock; Fig. 7, Bjoern Wylezich/Shutterstock; Fig. 8, KREML/Shutterstock; Fig. 9, SoRad/Shutterstock. **Module 7 Opener:** SAM FALCONER, DEBUT ART/SCIENCE PHOTO LIBRARY. Lesson 7.1: Fig. 4, Danita Delimont/Alamy Stock Photo; Fig. 2, Shutterstock; Lesson 7.2: Fig. 2, nadiya_sergey/Shutterstock; Fig. 3, Vasiliy Koval/Shutterstock; Fig. 4, twildlife/Getty Images; Fig. 5, NOAA/SCIENCE PHOTO LIBRARY; Fig. 6, Norhayati/Shutterstock; Lesson 7.3: Fig. 1, Doctor Jools/Shutterstock; Fig. 2, Craig Abraham/Fairfax Photos; Fig. 3, Janelle Lugge/Shutterstock; Lesson 7.4: Fig. 1, Marco Taliani de Marchio/Alamy Stock Photo; Fog. 2, Samantha Terrell/Shutterstock; Fig. 3, Used with permission of Ansell, J., & Evans, J., from Contemporary Aboriginal savanna burning projects in Arnhem Land: a regional description and analysis of the fire management aspirations of Traditional Owners. International Journal of Wildland Fire, 29(5), 2019; permission conveyed through Copyright Clearance Center, Inc.; Lesson 7.5: Fig. 5, Steve Bloom Images/Alamy Stock Photo; Lesson 7.6: Fig. 1, Nikola Spasenoski/Shutterstock; Lesson 7.7: Fig. 1, Steve Meese/Shutterstock; Fig. 2, Michael Warwick/Shutterstock; Fig. 3 (a), d1sk/Shutterstock; Fig. 3 (b), Anastasia Lembrik/Shutterstock; Lesson 7.9: Fig. 1, Lubo Ivanko/Shutterstock; Fig. 2, Andrey Mihaylov/Shutterstock; Fig. 3, petpics/Alamy Stock Photo; Fig. 4, Nneirda/Shutterstock; Fig. 6, Olesia_Ru/ Shutterstock. **Module 8 Opener:** SAM FALCONER, DEBUT ART/ SCIENCE PHOTO LIBRARY; Lesson 8.1: Fig. 2, VectorMine/Shutterstock; Lesson 8.6: Fig. 6, ivector/Shutterstock; Lesson 8.5: Fig. 1, STS-41B, NASA; Fig. 2, Science Photo Library/Alamy Stock Photo; Fig. 3, Antonio Guillem/ Shutterstock; Fig. 4, Evannovostro/Shutterstock; Fig. 5, RMFerreira/ Shutterstock; Fig. 6, Science Photo Library/Alamy Stock Photo; Lesson 8.7: Fig. 2, David R. Frazier Photolibrary, Inc./Alamy Stock Photo; Fig. 4 (a), Andrei Nekrassov/Shutterstock; Fig. 4 (b), david john abrams/Shutterstock; Lesson 8.8: Fig. 1, Laurent Hamels/Getty Images; Lesson 8.9: Fig. 3, Webspark/ Shutterstock; Lesson 8.10: Fig. 3 (a), Ulrich Willmunder/ Shutterstock; Fig. 3 (b), Scott Camazine/Alamy Stock Photo; Fig. 4, Eric Isselee/Shutterstock; Lesson 8.12: Fig. 1, Anna Kuhmar/Shutterstock; Lesson 8.12: Fig. 3, amana images inc./Alamy Stock Photo; Lesson 8.13: Fig. 1 (a), Gail Johnson/ Shutterstock; Fig. 1 (b), petrroudny43/Shutterstock; Fig. 5, Arsgera/ Shutterstock; Lesson 8.14: Fig. 1, OlgaLis/Shutterstock; Lesson 8.15: Fig. 2, Photo Provider Network/Alamy Stock Photo; Lesson 8.17: Fig. 1, r.classen/ Shutterstock; Fig. 2, Reid Dalland/Shutterstock; Fig. 3, inavanhateren/ Shutterstock; Fig. 4, John Selway/Shutterstock; Fig. 5, Raimundo79/ Shutterstock. **Module 9 Opener:** SAM FALCONER, DEBUT ART/ SCIENCE PHOTO LIBRARY; Lesson 9.1: Fig. 2, Monkey Business Images/ Shutterstock; Fig. 3, pics five/Shutterstock; Lesson 9.3: Fig. 1, ChameleonsEye/ Shutterstock; Fig. 2 (a), Maurizio Campanelli & Alice Mora; Fig. 2 (b), © 2025 Wimmera CMA; Fig. 3, pryzmat/Shutterstock; Fig. 4, Richard Majlinder/ Shutterstock; , © Department of Climate Change, Energy, the Environment and Water 2023, https://www.energyrating.gov.au/industry-information/ understand-requirements/labelling/access-sample-energy-rating-labels; Lesson 9.3: Fig. 3, PCN Photography/Alamy Stock Photo; Lesson 9.6: Fig. 5, Australia's Nuclear Science and Technology Organisation, (ANSTO); Fig. 6, zstock/ Shutterstock. **Module 10 Opener:** SAM FALCONER, DEBUT ART/ SCIENCE PHOTO LIBRARY; Lesson 10.1: Fig. 4, TFoxFoto/Shutterstock; Lesson 10.2: Fig. 1, Awe Inspiring Images/Shutterstock; Lesson 10.3: Fig. 1, Fouad A. Saad/Shutterstock; Fig. 3, © The State of Victoria Department of Energy, Environment and Climate Action 2023. This work is licensed under a Creative Commons Attribution 4.0 International licence; Fig. 6, U.S. Department of Energy; Lesson 10.4: Fig. 3, Penta Springs Limited/Alamy Stock Photo; Fig. 5, Dr. Richard Ray, NASA Goddard Space Flight Center, Jet Propulsion Laboratory, Scientific Visualization Studio; Fig. 6 (a), Hemis/Alamy Stock Photo; Fig. 6 (b), BlueRingMedia/Shutterstock; Lesson 10.6: Fig. 4, © Copyright Commonwealth of Australia 2025, Bureau of Meteorology. Released under Creative Commons Attribution 4.0 International Licence; Fig. 5, Espen Beck/Getty Images; Lesson 10.8: Fig. 3, Dimitrios Karamitros/Shutterstock; Lesson 10.9: Fig. 1, mipan/Shutterstock; Fig. 2, Brent Parker Jones Photographer; Fig. 5, AkeSak/Shutterstock; Lesson 10.10: Fig. 3, © Commonwealth of Australia 2024. Department of Climate Change, Energy, the Environment and Water. Released under CC BY 4.0.

Periodic table



6
C
12.01
Carbon

Atomic number
Chemical symbol
Atomic mass
Name of element

Period	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

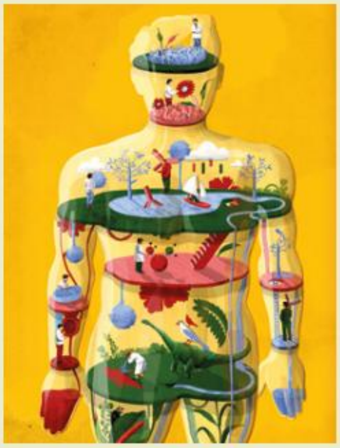
Metals

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



Human bodies have particular requirements in order to survive and function efficiently. The process of regulating the internal conditions of the body is called homeostasis. The body needs to detect and correct changes in its levels of nutrients, water and temperature to stay healthy.

Other titles in this series

OXFORD
UNIVERSITY PRESS

visit us at **oup.com.au** or
contact customer support at **oup.com.au/help**