

VICTORIAN CURRICULUM VERSION 2.0

POWERED BY oxforddigital

OXFORD

Third Edition

OXFORD

SCIENCE

Victorian Curriculum

8



Helen Silvester



VICTORIAN CURRICULUM VERSION 2.0

POWERED BY oxforddigital

Third Edition

OXFORD

SCIENCE

Victorian Curriculum

8



Helen Silvester

OXFORD UNIVERSITY PRESS

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.

© Helen Silvester 2025

The moral rights of the author/s have been asserted.

First published 2016
Third edition

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, transmitted, used for text and data mining, or used for training artificial intelligence, in any form or by any means, without the prior permission in writing of Oxford University Press, or as expressly permitted by law, by licence or under terms agreed with the appropriate reprographics rights organization. Enquiries concerning reproduction outside the scope of the above should be sent to the Rights Department, Oxford University Press, at the address above.

You must not circulate this work in any other form and you must impose this same condition on any acquirer.

ISBN: 978 0 1903 5042 0

Reproduction and communication for educational purposes

The Australian *Copyright Act 1968* (the Act) allows educational institutions that are covered by remuneration arrangements with Copyright Agency to reproduce and communicate certain material for educational purposes. For more information, see copyright.com.au.



Edited by Hannah Mae Cartmel
Typeset by Q2A Media Services Pvt. Ltd., Noida, India
Proofread by Jess Ni Chuinn
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.

Disclaimer

Links to third party websites are provided by Oxford in good faith and for information only. Oxford disclaims any responsibility for the materials contained in any third party website referenced in this work.

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 8 Victorian Curriculum* (Third edition) vi

Module 1 Science toolkit..... 2

1.1 Science is the study of the natural and physical world.....	4
1.2 Scientists value the knowledge and skills of Aboriginal and Torres Strait Islander Peoples.....	7
1.3 Scientists follow the scientific method.....	13
1.4 Scientists make observations and ask questions.....	17
1.5 Scientists plan and conduct experiments.....	21
1.6 Scientists use specialised equipment.....	26
1.7 Skills lab: Dissecting a chicken wing.....	29
1.8 Scientists measure and record data accurately.....	32
1.9 Skills lab: Making a balloon rocket.....	36
1.10 Scientists use tables, graphs, and models to record and analyse data.....	37
1.11 Scientists present accurate data.....	46
1.12 Scientists evaluate claims and results.....	50
1.13 Scientists keep a logbook.....	55
1.14 Skills lab: Marshmallow slingshots.....	57
1.15 Scientists use reports to communicate findings.....	59
1.16 Command terms identify tasks and communicate responses.....	63
1.17 Review: Science toolkit.....	66

Module 2 The rock cycle..... 72

2.1 Rocks have different properties.....	74
2.2 Challenge: Identifying rocks.....	77
2.3 Igneous rocks develop from magma and lava.....	78
2.4 Experiment: What affects crystal size?.....	81
2.5 Sedimentary rocks are compacted sediments.....	82
2.6 Experiment: Making sedimentary rocks.....	85
2.7 Metamorphic rocks require heat and pressure.....	87
2.8 Experiment: Making a metamorphic rock.....	90
2.9 The rock cycle causes rocks to be re-formed.....	91
2.10 Challenge: Modelling the rock cycle.....	94
2.11 Weathering and erosion can be prevented.....	96
2.12 Challenge: Preventing soil erosion.....	98
2.13 The age of a rock can be calculated.....	100
2.14 Experiment: Making a fossil.....	103
2.15 Science as a human endeavour: The locating and extraction of minerals relies on scientists.....	105
2.16 Experiment: Copper treasure hunt.....	109
2.17 Experiment: What if a muffin were mined in different ways?.....	111
2.18 Review: The rock cycle.....	112

Module 3 Plate tectonics..... 116

3.1 Earth is made of layers.....	118
3.2 Experiment: Cooling and layers.....	120
3.3 Forces cause tectonic plates to move.....	122
3.4 Boundaries between tectonic plates can be converging, diverging or transforming.....	125
3.5 Tectonic plates can be constructive or destructive.....	130

3.6	Challenge: Modelling a tectonic boundary	136
3.7	Science as a human endeavour: Engineering solutions in earthquake zones	138
3.8	Challenge: Design an earthquake-proof house	142
3.9	Review: Plate tectonics	143
Module 4 Energy		148
4.1	Energy can be transferred	150
4.2	Challenge: Draw flow diagrams of energy transfer	154
4.3	Potential energy is stored energy	157
4.4	Experiment: What if the amount of elastic potential energy was increased?	160
4.5	Moving objects have kinetic energy	161
4.6	Energy can be transformed	164
4.7	Heat is a by-product of energy transformation	168
4.8	Energy efficiency reduces energy consumption	170
4.9	Challenge: An energy audit records energy consumption	174
4.10	Challenge: Designing a passive design house	175
4.11	Science as a human endeavour: Solar cells transform the Sun's light energy into electrical energy	177
4.12	Review: Energy	181
Module 5 Electric circuits		186
5.1	Electricity is the movement of electric charges	188
5.2	Challenge: Making a simple torch circuit	191
5.3	Current can flow through series and parallel circuits	192
5.4	Challenge: Making series and parallel circuits	195
5.5	Voltage is the difference in energy per charge between two parts of a circuit	196
5.6	Current and resistance in a circuit can be altered	198
5.7	Challenge: Wiring a house	202
5.8	Review: Electric circuits	203
Module 6 Physical and chemical change		206
6.1	All matter is made up of atoms	208
6.2	Elements are made up of one type of atom	211
6.3	Experiment: Properties of the elements	214
6.4	Atoms bond together to make molecules and compounds	216
6.5	Experiment: Decomposing copper carbonate	218
6.6	Matter can be modelled	220
6.7	Physical change is a change in shape or appearance	222
6.8	Challenge: Melting chocolate	226
6.9	Chemical change produces new substances	227
6.10	Challenge: Making caramel	230
6.11	Experiment: Observing chemical reactions	231
6.12	Experiment: Detecting a mystery powder	233
6.13	Chemical reactions can break bonds and re-form new bonds	235
6.14	Experiment: Comparing reactants and products	239
6.15	Chemical reactions can be sped up and slowed down	240
6.16	Experiment: Effect of particle size on reaction rates	242
6.17	Experiment: Speeding up reactions with enzymes	244
6.18	Science as a human endeavour: Many substances exist because of the work of scientists	245
6.19	Experiment: Making casein glue	248

6.20 Science as a human endeavour: Physical and chemical changes are used to recycle household waste	250
6.21 Review: Physical and chemical change	253
Module 7 Cells.....	258
7.1 All living things are made up of cells	260
7.2 Challenge: Drawing cells.....	263
7.3 Microscopes are used to study cells.....	264
7.4 Challenge: Getting to know your microscope	267
7.5 Plant and animal cells have organelles.....	269
7.6 Experiment: Looking at organelles	273
7.7 Experiment: Measuring cells	274
7.8 Cells have different roles.....	276
7.9 Experiment: Plant and animal cells.....	280
7.10 Unicellular and multicellular organisms can cause disease	282
7.11 Experiment: Microbes all around.....	284
7.12 Science as a human endeavour: Fungal cells can save lives	287
7.13 Review: Cells	290
Module 8 Surviving	294
8.1 Systems are made up of cells, tissues and organs.....	296
8.2 The digestive system breaks down food	299
8.3 Experiment: Digesting protein	302
8.4 Experiment: What if an enzyme was boiled?.....	304
8.5 The digestive system varies between animals	306
8.6 Sometimes things go wrong with the digestive system.....	309
8.7 The respiratory system exchanges gases	311
8.8 Challenge: Measure your lung capacity	314
8.9 Challenge: Fish dissection	315
8.10 Sometimes things go wrong with the respiratory system.....	316
8.11 The circulatory system carries substances around the body	319
8.12 Experiment: Heart dissection.....	322
8.13 Sometimes things go wrong with the circulatory system.....	324
8.14 The excretory system removes waste.....	327
8.15 Experiment: Kidney dissection.....	328
8.16 Science as a human endeavour: Organs can be transplanted.....	330
8.17 Plants have tissues and organs	332
8.18 Challenge: Locating the xylem and phloem in a stem	334
8.19 Challenge: Modelling root cells.....	336
8.20 Experiment: Factors that affect transpiration	337
8.21 Review: Surviving	338
STEAM	344
Glossary.....	352
Index	359
Acknowledgments.....	364

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.



Physics



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 8 Victorian Curriculum* (Third edition)” in the “About this course” menu.

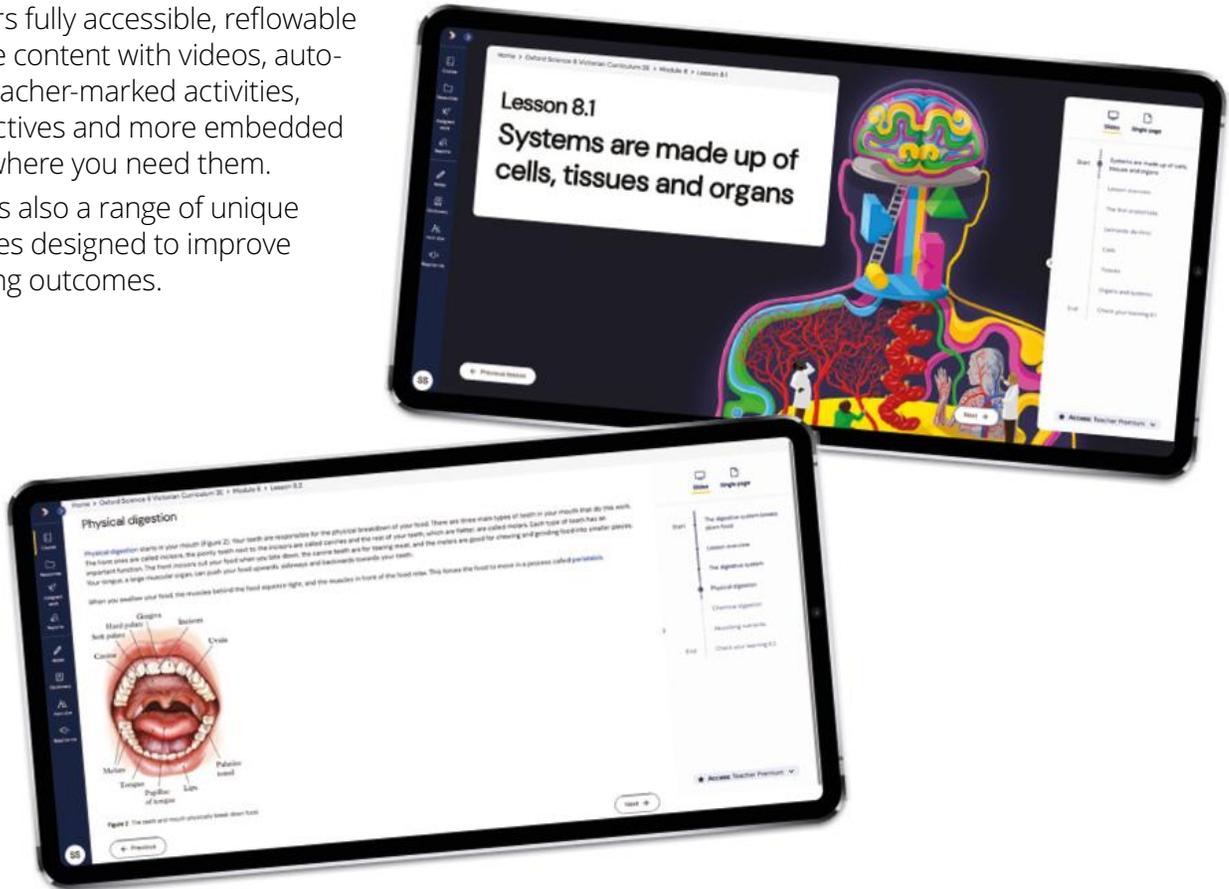


Key features of

oxforddigital

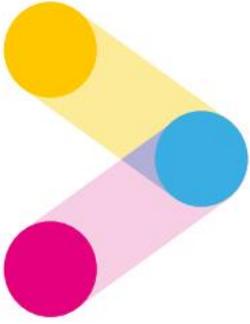
Oxford Digital has been designed in consultation with Australian teachers for Australian classrooms. The new platform delivers fully accessible, reflowable course content with videos, auto- and teacher-marked activities, interactives and more embedded right where you need them.

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



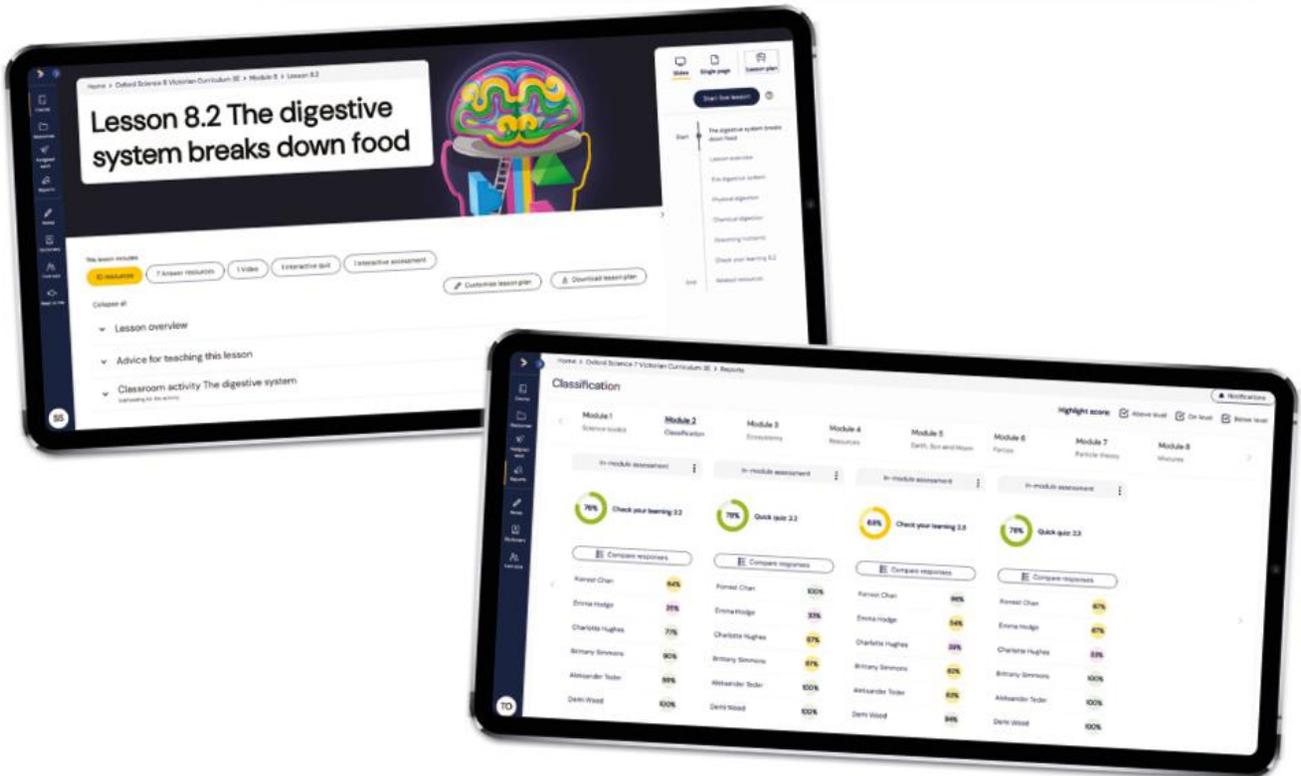
As a student, you can:

- > **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



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 8 Victorian Curriculum* (Third edition)" in the "About this course" menu.

Module

1

Science toolkit

Overview

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

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'll be learning and developing these skills across Years 7 and 8 and some lessons from the Year 7 course also appear in this module so you can revise them.





Lessons in this module

Lesson 1.1 Science is the study of the natural and physical world (page 4)

Lesson 1.2 Scientists value the knowledge and skills of Aboriginal and Torres Strait Islander Peoples (page 7)

Lesson 1.3 Scientists follow the scientific method (page 13)

Lesson 1.4 Scientists make observations and ask questions (page 17)

Lesson 1.5 Scientists plan and conduct experiments (page 21)

Lesson 1.6 Scientists use specialised equipment (page 26)

Lesson 1.7 Skills lab: Dissecting a chicken wing (page 29)

Lesson 1.8 Scientists measure and record data accurately (page 32)

Lesson 1.9 Skills lab: Making a balloon rocket (page 36)

Lesson 1.10 Scientists use tables, graphs, and models to record and analyse data (page 37)

Lesson 1.11 Scientists present accurate data (page 46)

Lesson 1.12 Scientists evaluate claims and results (page 50)

Lesson 1.13 Scientists keep a logbook (page 55)

Lesson 1.14 Skills lab: Marshmallow slingshots (page 57)

Lesson 1.15 Scientists use reports to communicate findings (page 59)

Lesson 1.16 Command terms identify tasks and communicate responses (page 63)

Lesson 1.17 Review: Science toolkit (page 66)

Lesson 1.1

Science is the study of the natural and physical world

Science is a quest for knowledge

science the study of the natural and physical world

natural world all living things in the world around us, including ecosystems and natural phenomena (e.g. plants, animals, oceans, ecosystems, weather patterns)

physical world all non-living things in the world around us, including the forces acting upon them (e.g. rocks, planets, energy, matter, and forces such as gravity and magnetism)

scientist a person who studies the natural and physical world

philosopher a “lover of knowledge”; someone who studies ideas, theories and questions

Science is the study of the **natural world** and the **physical world**. In other words, all of the living and non-living things in the world around us. The word “science” actually comes from the Latin word *scientia* – meaning “knowledge” – so science is really just the quest for knowledge.

Scientists are curious people! Many scientific discoveries in the past started with one person who was curious about something. The world today would be a very different place if scientists of the past hadn’t asked questions like “How does this work?” and “Why is this so?”

Curiosity about the world can be motivated by many different things.

Tens of thousands of years ago, the first humans were curious out of necessity. They had to discover, through trial and error, which foods were edible and which were poisonous. They also had to experiment with making fire, building shelter and treating injuries. This curiosity was driven by a need to survive, and could have life-or-death results!

Curiosity can also come from the desire to know more. In Ancient Greece, people were curious to know more about the Sun, the Moon, the stars and our own planet. Early scientists were not called scientists at all – they were called “natural philosophers” because of their interest in studying nature (Figure 1).

Philosopher means “lover of knowledge”. Natural philosophers used their observations to develop calendars, to locate Earth in the universe and to show that Earth is round, not flat.

Curiosity can also be driven by a desire to solve problems that affect individuals, communities, countries, or the entire planet. Many of the great advances in medicine, such as the discovery of penicillin, or the creation of vaccinations to prevent serious diseases, are the result of years of scientific research. Scientific discoveries have changed our lives, mostly for the better.



Figure 1 Early scientists were called “natural philosophers”. Natural philosophers used their observations to develop calendars and to show that Earth is round, not flat.

Science is in the news every day (Figure 2). Some important issues that scientists are curious about right now include:

- discovering new energy sources that are cleaner and greener for the planet
- improving access to clean drinking water and food sources to support the world's growing population
- developing treatments and cures for a range of viruses and deadly diseases (such as the Influenza virus, Ebola virus or corona viruses).
- exploring space travel and investigating the possibility of life on other planets
- investigating whether the human brain could one day be replaced by artificial intelligence.

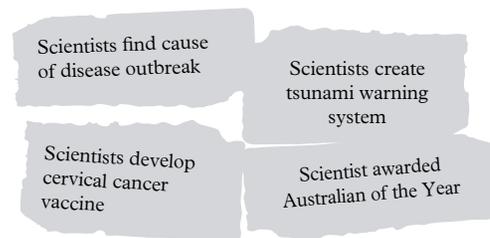


Figure 2 Curiosity about the world around us has resulted in many scientific discoveries

There are many branches of science

Science measures what we observe around us – see, hear, smell and feel – and tries to explain what is happening.

You will learn about the four main branches of science this year. These are listed in Table 1 with information about each one and a list of topics you will study in this course.

Table 1 There are four main branches of science. This year you will be learning about each of them.

	Earth and space	Physics	Chemistry	Biology
What is it?	The study of Earth's systems and its place in the universe	The study of matter, motion, force and energy, including how they interact with each other	The study of what things are made of and how they change when they interact with each other	The study of living things, including their life processes, growth and characteristics
What careers are there in this branch of science?	<ul style="list-style-type: none"> • Geologist • Volcanologist • Astronomer • Palaeontologist (Figure 3) 	<ul style="list-style-type: none"> • Physicist • Mechanical engineer • Electrical engineer (Figure 4) 	<ul style="list-style-type: none"> • Chemist • Biochemist • Forensic scientist • Pharmacologist (Figure 5) 	<ul style="list-style-type: none"> • Biologist • Entomologist • Marine biologist (Figure 6)
What questions do these scientists ask?	<ul style="list-style-type: none"> • What can dinosaur fossils tell us about modern life on Earth? • What do geological records tell us about climate change? 	<ul style="list-style-type: none"> • How can we keep our homes warm or cool? • Why does gravity exist? 	<ul style="list-style-type: none"> • What type of material would be best for making solar panels? • How can we make better batteries? 	<ul style="list-style-type: none"> • What plants could we grow in space? • How will rising sea levels affect the Great Barrier Reef?
What topics will I be studying in this course?	<ul style="list-style-type: none"> • Module 2 The rock cycle (page 72) • Module 3 Plate tectonics (page 116) 	<ul style="list-style-type: none"> • Module 4 Energy (page 148) • Module 5 Electric circuits (page 186) 	<ul style="list-style-type: none"> • Module 6 Physical and chemical change (page 206) 	<ul style="list-style-type: none"> • Module 7 Cells (page 258) • Module 8 Surviving (page 294)

Within each branch of science, there are many different types of careers and roles for different scientists. Scientists often dedicate many years of study to specialise in one particular area, but many roles require scientists to use and apply knowledge from many branches of science at the same time.

Science is an ever-expanding search for knowledge and, as you will learn this year, there is a lot more for us to learn. Welcome to the amazing world of science!



Figure 3 Palaeontologists usually have a background in the branch of science called Earth and space science.



Figure 4 Electrical engineers usually have a background in the branch of science called Physics.



Figure 5 Pharmacologists usually have a background in the branch of science called Chemistry.



Figure 6 Marine biologists usually have a background in the branch of science called Biology.

Check your learning 1.1



Check your learning 1.1

Retrieve

- 1 **Identify** the name given to the early scientists.
- 2 **Define** the term “science” in your own words.

Comprehend

- 3 **Describe** one reason why being curious and asking questions is important in science.
- 4 **Describe** an idea or invention that has been developed in your lifetime due to science.

Analyse

- 5 Scientists claim that “that there are more than four branches of science”. **Evaluate** this statement (by using the examples and

definitions in Table 1 to show how one type of scientific research might fit into more than one branch of science) and **justify** whether you think this statement is true or false.

Apply

- 6 Look carefully at Figure 6.
 - a **Propose** a possible question about coral reefs that the scientist may be investigating.
 - b **Describe** the risks that this type of research may have on:
 - i the scientist
 - ii the coral reef.

Lesson 1.2

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 60,000 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**.

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 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 in 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, broke up families, and prevented culture, knowledge, skills and language from being passed down from generation to generation. This includes the passing down scientific knowledge and skills.

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

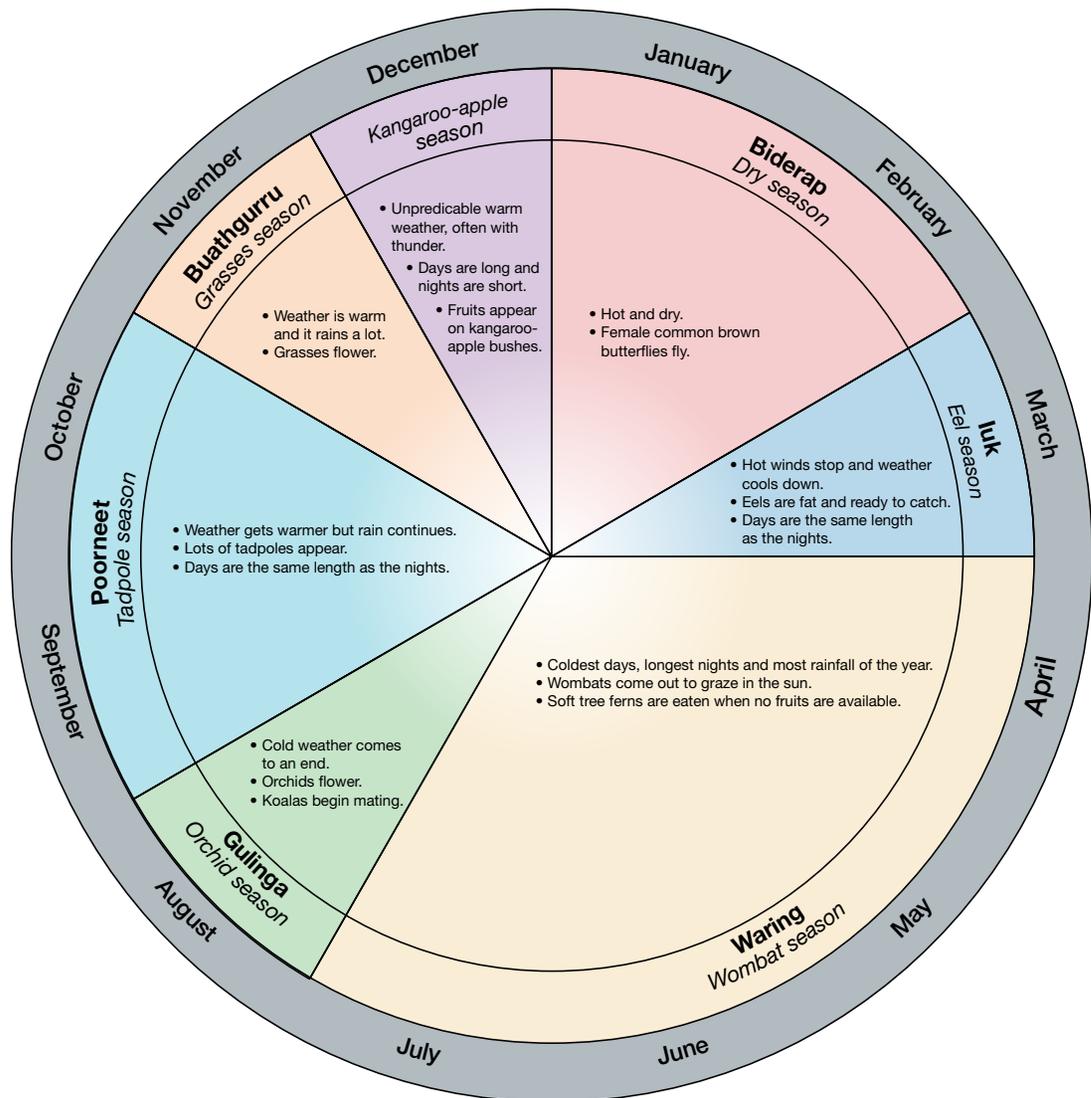


Figure 1 The Wurundjeri people of the Kulin Nation in Victoria identify seven seasons in their calendar. These seasons are marked by changes in the weather, the life cycles of plants and animals, and the position of the stars in the sky at night.

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.

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 the 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.

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.

- **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.

- **Cultural burning:** Aboriginal and Torres Strait Islander Peoples use controlled burning to manage landscapes, promote new growth and encourage biodiversity (Figure 2). 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.



Figure 2 Cultural burning in Kakadu National Park

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

- **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.

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. 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 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 4)



Figure 4 Boomerangs, spears and spear-throwers – like those of the Luritja and Pertame Peoples in Central Australia – were designed using principles of aerodynamics and physics.

- **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 5).
- **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.

Agriculture

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

- **Cultivation:** Evidence suggests that some Aboriginal and Torres Strait Islander Peoples in Victoria and New South Wales, cultivated yams, grains and other plants. Grinding stones dating 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 6).
- **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 5 The Gunditjmara people of Victoria dug channels (shown here) to catch and farm eels at Budj Bim Cultural Landscape (near Warrnambool in western Victoria). These channels are at least 6,600 years old.



Figure 6 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
<ul style="list-style-type: none"> • Passed down orally through stories, songs, and direct teaching • Knowledge is integrated with cultural and spiritual systems • Views everything 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 • Focuses on understanding specific places and ecosystems in detail 	<ul style="list-style-type: none"> • Written down in formal documents, papers and textbooks • Knowledge is considered separate from cultural and spiritual systems • Focuses on breaking things down into separate parts to study them (e.g. fields such as biology, chemistry and physics) • Uses standardised methods that can be repeated anywhere • Knowledge is often developed by specialist experts in laboratories • Usually aims to find universal laws (rules that apply everywhere)

Check your learning 1.2



Check your learning 1.2

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 group(s) 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 1.3

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**.

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.

validity a measure of how accurately a method measures what it is intended to measure

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.	<ul style="list-style-type: none"> • Lesson 1.4 Scientists make observations and ask questions (page 17)
Stage 2: Planning and conducting	There are many different ways to test a hypothesis. Scientists might make observations over time to describe an event or object. They might compare objects or events to identify similarities or differences. They could use information or data that already exists or design a controlled experiment to generate their own data. This approach allows them to collect and organise reliable information that can be trusted by everyone in the community.	<ul style="list-style-type: none"> • Lesson 1.5 Scientists plan and conduct experiments (page 21) • Lesson 1.6 Scientists use specialised equipment (page 26) • Lesson 1.7 Skills lab: Dissecting a chicken wing (page 29) • Lesson 1.8 Scientists measure and record data accurately (page 32) • Lesson 1.9 Skills lab: Making a balloon rocket (page 36)

Stages of the scientific method	What happens at each stage	Lessons in this module
Stage 3: Processing, modelling and analysing	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. 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.	<ul style="list-style-type: none"> Lesson 1.10 Scientists use tables, graphs, and models to record and analyse data (page 37) Lesson 1.11 Scientists present accurate data (page 46)
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.	<ul style="list-style-type: none"> Lesson 1.12 Scientists evaluate claims and results (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.	<ul style="list-style-type: none"> Lesson 1.15 Scientists use reports to communicate findings (page 59) Lesson 1.16 Command terms identify tasks and communicate responses (page 63)

inference a conclusion based on evidence and reasoning

hypothesis a proposed explanation for a prediction that can be tested

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.

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.

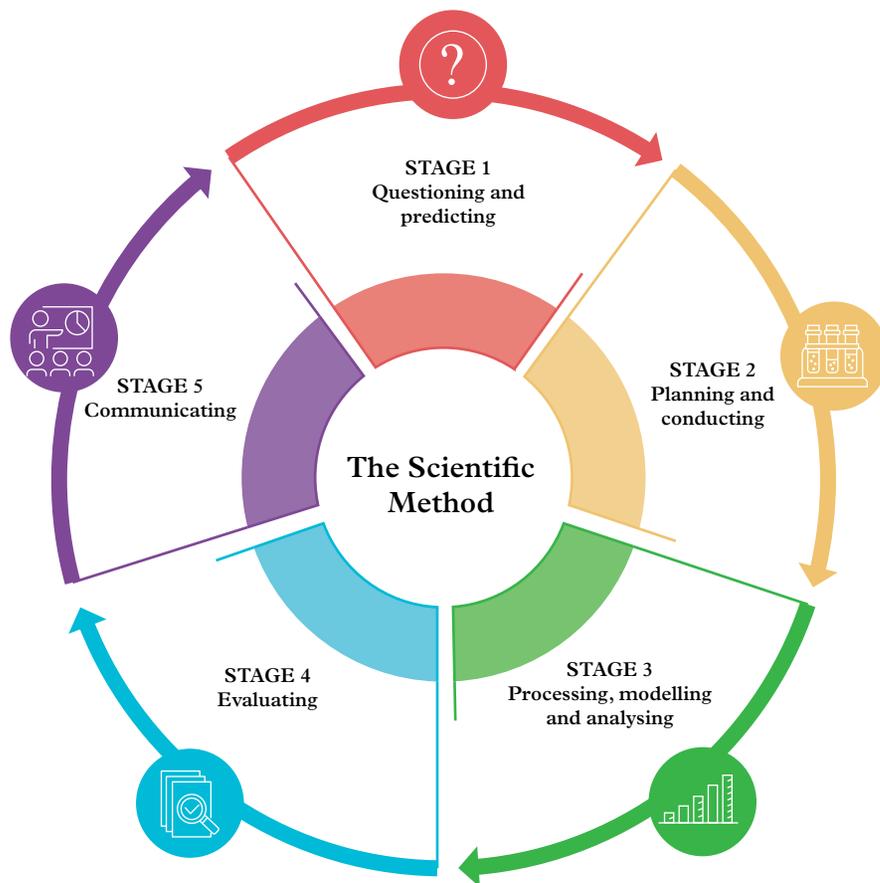


Figure 1 The scientific method

Pseudoscience

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). The word “pseudo” (pronounced *SYOO-doh*) comes from an Ancient Greek word that means “false”.

pseudoscience claims that are supposedly scientific but are made with no evidence to support them

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 the 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.

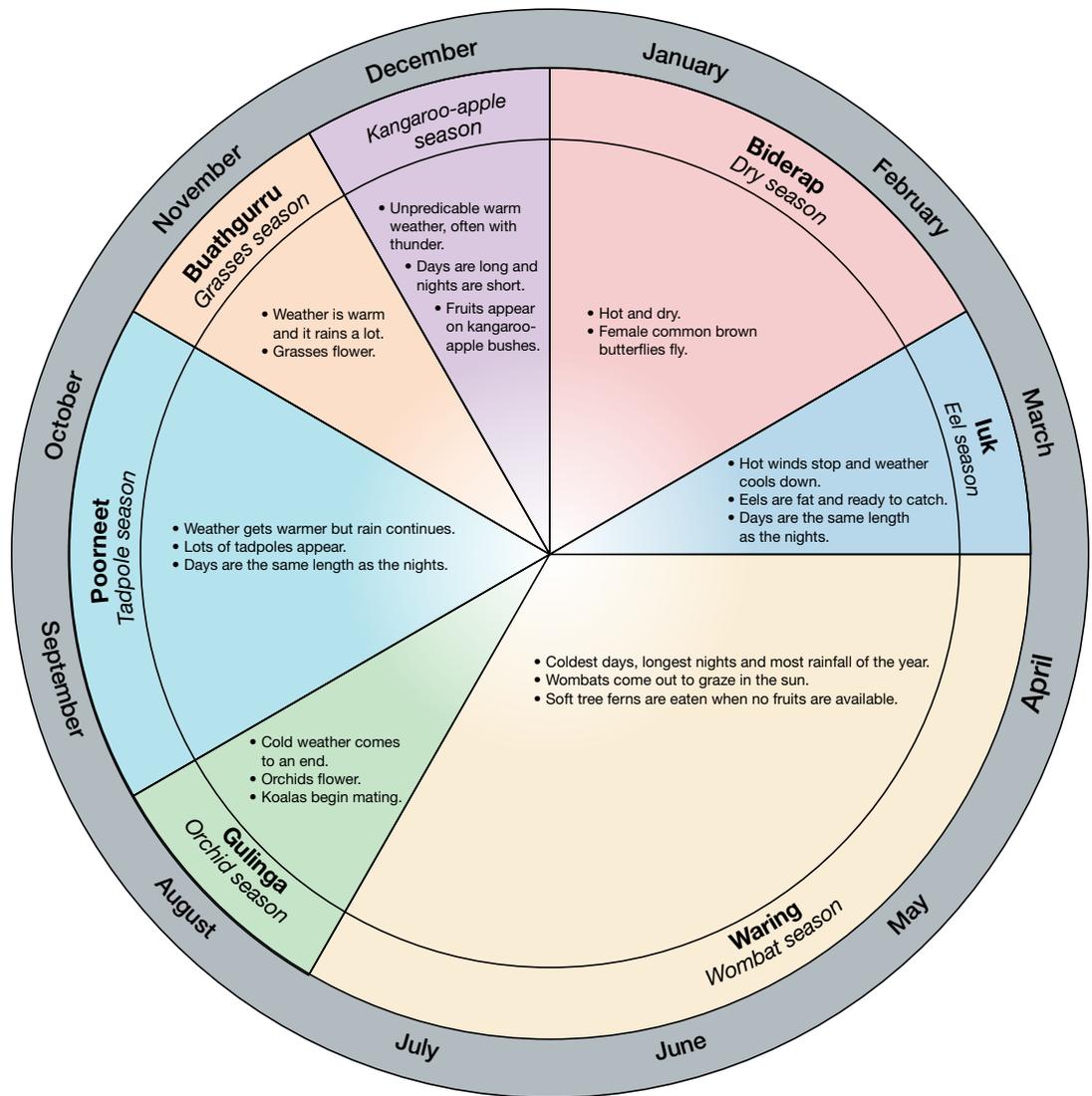


Figure 3 Repeated observations and analysis of patterns by the Wurundjeri people in Victoria identified the different seasons in their environments.

Check your learning 1.3



Check your learning 1.3

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.
- 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 1.4

Scientists make observations and ask questions

Key ideas

- Scientists make observations using their senses (i.e. what they see, hear, smell, taste and touch).
- Science involves making observations over time, identifying and comparing things to identify trends and patterns.
- Scientists use their observations to ask questions that can be investigated and infer (i.e. make an educated guess about) what is happening around them.



Learning intentions
and success criteria

The best way to learn is by observing

Following the scientific method means that all scientists following 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).

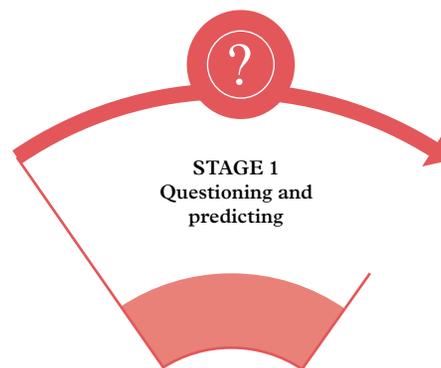


Figure 1 Stage 1 of the scientific method is **Questioning and predicting**.

All good science begins with observation

observation use of the senses to notice and gather information

The skill of **observation** requires you to take notice of the world around you.

Observation is how all good science starts. Before scientists can ask questions or try to solve problems, they need to first notice what is actually happening in the world. This includes making note of things that are the same, different or changing over time.

All scientists are curious about the world they live in. They use all of their senses to observe small changes taking place around them, then try to explain these changes by asking questions that they can investigate to find answers.

Observations can be quantitative or qualitative

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

Quantitative observations use **numbers** to describe the characteristics of something. As the name suggests, quantitative observations describe “quantities” (i.e. amounts). These quantities are usually accompanied by units that describe what is being measured (e.g. 2.7 m (metres) or 23°C (degrees Celsius)). Metres is a measure of length, and degrees Celsius is a measure of temperature.

Qualitative observations use **words** to describe the characteristics of something. As the name suggests, qualitative observations describe “qualities” (i.e. characteristics). The five main sense organs of the human body are essential for qualitative observations. What you can see, hear, smell, taste and feel are important factors to include when making qualitative observations. “Rough”, “sour”, “sweet”, “clear” and “yellow” are examples of words you might use to describe the qualities of something being observed.

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

Asking “What if?”

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

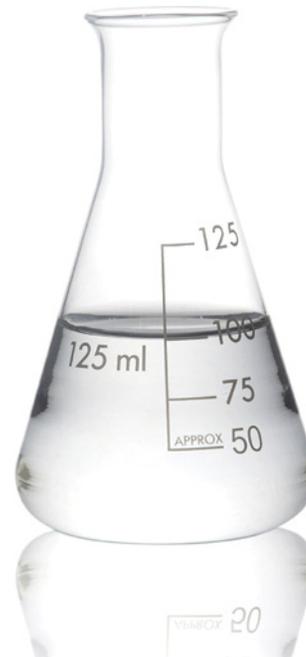


Figure 2 A **quantitative observation** of this conical flask is that it contains 100 mL (millilitres) of liquid at a temperature of 23°C (degrees Celsius). A **qualitative observation** is that it contains a clear liquid that has a sweet smell.

when conducting a scientific experiment on plant growth, some “what if” questions might include:

- What if the temperature was hotter?
- What if the temperature was colder?
- What if a different type of soil was used (e.g. sand, clay, potting mix)?
- What if the amount of sunlight the plants receive each day was increased?
- What if the amount of sunlight the plants receive each day was increased?

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: <ul style="list-style-type: none"> • 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.

Forming hypotheses

A **hypothesis** is a proposed scientific explanation for your 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. The

“If... then...” part describes **what** you are testing, and the “because...” part describes **why** it should have happened. For example:

- **Prediction:** If a tomato plant receives 12 hours of sunlight each day, then it will grow taller than a plant that receives 6 hours of sunlight each day
- **Hypothesis:** If a tomato plant receives 12 hours of sunlight each day, then it will grow taller than a plant that receives 6 hours of sunlight each day because the more sunlight a plant receives, the more food it can produce via photosynthesis (Figure 3).

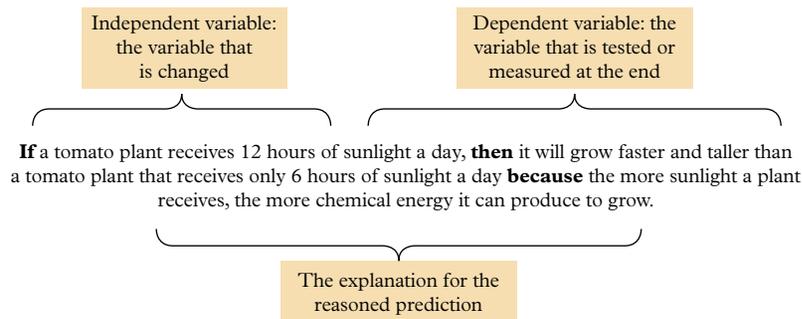


Figure 3 Elements of a hypothesis

Check your learning 1.4



Check your learning 1.4

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 prediction.
- 4 **Identify** one variable that you could not control in your balloon rocket experiment.

Comprehend

- 5 **Explain** why most variables need to be controlled.
- 6 **Explain** why it is important for an experiment to be reproducible.
- 7 **Describe** how to change a “what if” question into a hypothesis. Use one of the “what if” questions above that you did not test as an example.

Apply

- 8 Many experimental reports written by scientists are peer reviewed. **Investigate** what is meant by “peer reviewed” and write a definition in your own words.
- 9 A student wanted to convert their science question about the type of fishing line used on the reel of the fishing rod into a hypothesis (a possible explanation that can be tested in a reproducible test). Complete the below prediction and hypothesis to help the student.

Science question: What if a black fishing line was used to catch a fish instead of a clear fishing line?

Science prediction: If black fishing line was used to catch a fish then.....

Science hypothesis: If a black fishing line was used to catch a fish then because ...

Analyse

10 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.

Lesson 1.5**Scientists plan and conduct experiments****Key ideas**

- An experiment must be a reproducible test to ensure accurate and reliable results.
- Reliable results are those that are consistent and can be trusted because they are repeatable under the same conditions.
- When planning and conducting scientific experiments, managing risks is crucial for everyone's safety.
- Ethical issues are important questions or problems that scientists must consider before conducting an experiment (e.g. whether the research might harm living things, the environment, or go against important values like honesty, respect, and fairness).



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 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).

Experiments must be reproducible

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

reproducible test the ability to replicate the results of an experiment under similar conditions as the original test

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.

For example, if you're testing how sunlight affects plant growth, you should keep the type of plant, amount of water, and soil the same for all the plants, and only change the amount of sunlight each plant receives (Figure 2). 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.

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.)

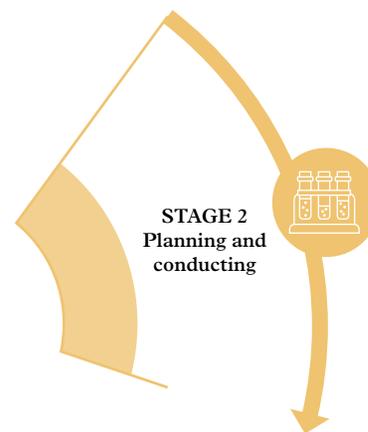


Figure 1 Stage 2 of the scientific method is **Planning and conducting**.



Figure 2 If you are testing how sunlight affects plant growth, you should control all other variables like water, soil, temperature and pot size.



Figure 3 Reliable results are those that are consistent and can be trusted because they are reproducible under the same conditions.

Repeating the experiment until you get the same results at 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.

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.

Science laboratories contain hazards

Science is a practical subject that includes hands-on laboratory investigations. You will be using many pieces of equipment, chemicals and other materials that are hazardous. A **hazard** is something that has the potential to put your health and safety at risk.

Chemical safety

A chemical may be listed as hazardous if it is considered dangerous for a person to touch, or **inhale**. Most of the chemicals you will use in your school science laboratory are safe to use provided appropriate precautions are taken. When working with chemicals, you should always wear a buttoned-up lab coat to protect your skin and clothes. Safety glasses should cover your eyes, long hair should be tied back and closed-toe shoes should always be worn. Occasionally you will need to wear gloves. Never taste, smell or mix chemicals unless specifically directed by your teacher, as this may cause a harmful reaction.



Figure 4 Safe disposal of materials

hazard something that has the potential to put a person's health and safety at risk

inhale breathe in

When observing chemical reactions ensure that you do not lean over any open containers and never breathe in any gases that may be produced. If your teacher instructs you to smell anything in the laboratory, use your hand to gently waft the gas towards your nose. If you have any concerns tell your teacher immediately.

Table 1 Read and follow all safety instructions and warnings carefully when planning and conducting experiments.

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.

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 1 lists the safe disposal techniques for various materials.

corrosive

destructive to living tissues such as skin and eyes, or to some types of metals

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.

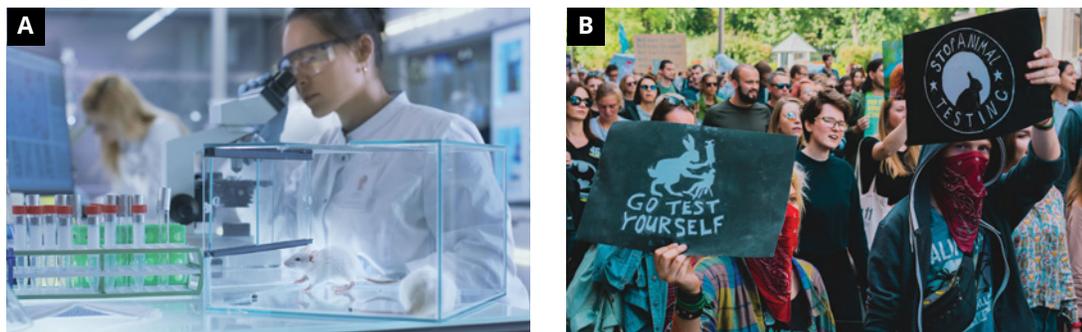


Figure 5 There are many ethical issues related to animal testing, including whether animals should have the more legal rights and how to balance the wellbeing of animals against the benefits of developing safe medicines for humans and other animals.

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.

Hammersely Gorge (Figure 6) 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 6 When conducting scientific research on sites in Australia that are culturally significant, it is essential that scientists seek permission and follow all protocols carefully.

Check your learning 1.5



Check your learning 1.5

Retrieve

- 1 **Define** the term “reproducible test”.
- 2 **Identify** three ways in which risks can be managed when planning an experiment.

Comprehend

- 3 **Describe** the difference between asking “Should we?” versus “Can we?” when planning scientific research. **Use** a specific example to illustrate your answer.
- 4 **Explain** why repeating an experiment several times and obtaining the same results increases the reliability of those results.
- 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.

Apply

- 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.
- 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 1.6

Scientists use specialised equipment



Learning intentions and success criteria



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

Key ideas

- Scientists use specialised equipment to conduct experiments in the laboratory and in the field.
- All instructions and safety protocols need to be followed when using specialised equipment.
- Scientific diagrams are used to show how specialised equipment needs to be set up to conduct an experiment.

Scientific equipment

equipment items used in the laboratory to conduct experiments

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

In Year 7, you learned to recognise and use some common scientific equipment is shown in Figure 1. Some of the names may sound unfamiliar, but you will soon learn what each piece of equipment is called and how it is used. The equipment in your school **laboratory** may look slightly different because each laboratory has its own types of equipment.

Scientists often select different pieces of equipment use them together to conduct an experiment. This selection of equipment is known as the **apparatus** for that experiment.



Figure 1 Types of equipment used in the laboratory

Dissection is an important skill requiring specialised equipment

Dissection is the process of cutting apart and observing something in order to learn more about it. The word dissection originates from the Latin word *dissecare*, meaning “to cut apart”.

Although it sounds gory, dissection is an essential learning tool for scientists. Dissecting organs and organisms does not just mean “chopping them up”. It requires careful techniques to make sure that the tissues are not destroyed so that their structures (i.e. anatomy) can be examined accurately. Dissection also relies on care being taken with very sharp instruments, such as scalpels and probes.

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; they are often presented in a table or graph

laboratory a specially designed space for conducting research and experiments

apparatus equipment placed together for an experiment

dissection the process of cutting apart and observing something in order to learn more about it

Surgical instruments of the past

Early scientists who performed dissections were known as anatomists. In the past, anatomists did not always have access to sterile (i.e. clean) and sharp cutting instruments, such as scalpels and precision saws for dissections. Dissections were performed with the same tools that surgeons used in early operations (Figure 2).



Figure 2 Early surgical equipment

Hands-on dissection

Some science skills are best learnt by doing! Follow the steps in Lesson 1.7 Skills lab: Dissecting a chicken wing (page 29) to learn and practise the skill of dissection.

Safety first

Dissection instruments and workspaces should be cleaned while you are still wearing your safety gear. Your lab coat and gloves should be on before you start your dissection, and they should not come off until the dissection is completely finished – this includes disposal and cleaning!

The last things you should do are:

- remove your gloves and throw them in the bin
- wash your hands thoroughly
- take off your lab coat and hang it up.

Dissection equipment

The most common equipment used for dissections in the laboratory include:

- forceps
- dissection scissors
- probes
- scalpels
- tweezers.



Figure 3 Forceps – a tool for grasping, holding, and manipulating organs and tissue samples during dissections. They can act as an extension of the hands and help scientists to make precise cuts.



Figure 4 Dissection scissors – a cutting tool with two blades used for cutting skin and other tissue. Dissection scissors often have rounded tips, which are less destructive to the tissue being cut.

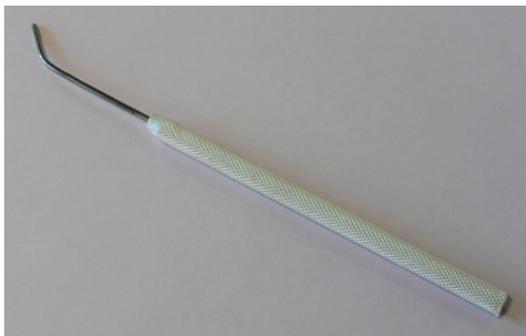


Figure 5 Probe – a pointed object used to look at and explore a specimen, and to probe openings.



Figure 6 Scalpel – a small and extremely sharp steel blade used to make clean, precise cuts.



Figure 7 Tweezers – a hinged instrument used for grasping and holding objects or organic tissue.

Check your learning 1.6



Check your learning 1.6

Retrieve

- 1 Contrast** (i.e. describe the differences between) “dissecting something” and “cutting something up”.
- 2 Describe** why dissection is a useful tool for scientists.
- 3 List** three important safety rules that you must follow during a dissection.
- 4 Name** three tools that are used as part of a dissection. Include a sketch of each tool.

Comprehend

- 5 Explain** why lab coats and gloves should be left on until after you have cleaned up.

Analyse

- 6 Explain** why our knowledge of human anatomy would be less advanced without dissection.
- 7 Explain** why it might be important for a surgeon to be skilled at dissection.

Lesson 1.7

Skills lab: Dissecting a chicken wing

Caution

- Always wear safety goggles, a lab coat and gloves when handling animal products.
- Scalpels and probes are extremely sharp. Use with great care.
- Always cut away from hands.
- If cut, inform your teacher immediately, then remove gloves and wash the cut under clean water. Apply antiseptic to the cut and cover with an adhesive bandage or dressing.

Aim

To explore the structure and function of a chicken wing.

What you need:

- Newspaper
- Dissection board
- Forceps or tweezers
- Probe
- Scalpel
- Dissection scissors
- Plastic bag for disposal



Figure 1 A scalpel

What to do:

- 1 Make sure you are wearing appropriate safety gear: gloves, lab coat and safety glasses.



- 2 Set up your workspace, covering surfaces with newspaper that can be disposed of easily and collecting any dissection tools you may need.



- 3 Collect your specimen for dissection. Identify all external structures.



- 4 You may want to pin the specimen to the dissection board to keep it from moving.



- 5 Use probes to look inside any folds.



- 6 Use forceps or tweezers to hold and pull the tissue.



- 7 Use scalpels to cut carefully away from your hands. Run the scalpel gently over the tissue several times to cut through. Do not dig the scalpel into the specimen or expect to cut through it in one movement.



- 8 When you can see what's under the structure, use scissors with rounded ends are less likely to cause unnecessary damage to the sample than those with pointed ends.



- 9 Fingers are always the least damaging way to 'look around' your specimen.



- 10 When finished, your specimen should be wrapped in newspaper for disposal and rinse your instruments in cleaning solution.



- 11 Remove your gloves then clean and disinfect your instruments thoroughly. Finish by washing your hands thoroughly with soap.

Questions

- 1 Recall why scissors with rounded tips are used for cutting the skin of the chicken wing.
- 2 Explain why a scientist should wear gloves when completing a dissection.
- 3 Explain why all equipment should be disinfected when the dissection is completed.
- 4 Identify two professions that need to be skilled in dissection.
- 5 Explain why some people might not want to practice this skill on a chicken wing.

Lesson 1.8

Scientists measure and record data accurately



Learning intentions and success criteria



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

Key ideas

- To achieve maximum accuracy, all measurements must be taken carefully, using the most suitable measuring device.
- Each scientific device must have a scale appropriate to the accuracy that you require.

Measure with the right equipment

When you're baking a cake in the kitchen, it's important to measure your ingredients accurately if you want it to be a success. You wouldn't use a bucket to measure a cup of flour because there's a high chance that your measurement won't be accurate.

When conducting experiments in the science laboratory, measuring accurately just as important if not more so! The first step in making sure measurements are **accurate** (i.e. close to the expected **true value**) is using the right equipment.

For example, if you need to accurately measure the volume of a liquid, then you would use a burette (Figure 1) or a measuring cylinder, but not a beaker. A burette has a more accurate scale than a measuring cylinder. Both are carefully checked during the manufacturing process; however, a burette has smaller units that can be controlled by the scientist. A beaker often has no scale.



Figure 1 A burette is piece of specialised equipment used to accurately measure liquids.

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

true value the actual value to be measured

precision how close measurements of the same item are to each other

reading error an error that occurs when markings on a scale are not read correctly

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

zero error an error that occurs when an instrument has not been adjusted to zero before the measurement is taken

Be precise

Choosing the right instrument is only part of a scientist's job. It is very important to take care with your measurements. A precise scientist is someone who checks their measurements several times to make sure that the measured numbers are almost the same. For example, if you measured 10 grams of lollies on three different sets of scales, they may produce the measurements 10.00 g, 9.98 g and 10.01 g. Although they are not exactly the same numbers, they are very close together. The measurements are precise. **Precision** is a special scientific term that means all of the measures are close together in value.

Identify errors

The most common errors that occur when scientists are recording measurements include:

- **reading errors**
- **parallax errors**
- **zero errors.**

Reading errors

A reading error can result when guesswork is involved when taking a reading. For example, when reading lines between the divisions on a scale, an estimate of the actual reading can result in a reading error.

The possibility of a reading error can be recorded in the data by noting the possible range. For example, if you were reading the marks on a ruler (Figure 2), you might estimate that the reading was somewhere between 1.6 and 1.8. This can be recorded as 1.7.

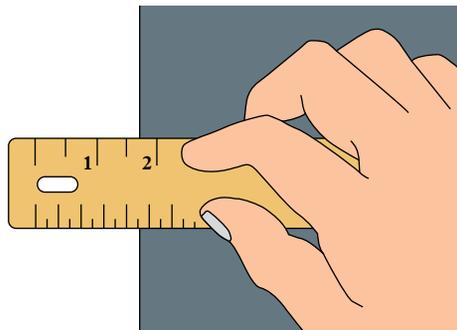


Figure 2 Estimating the measurement between units of measurement (e.g. between 1.5 and 2.0 centimetres) can produce a reading error.

Parallax errors

A parallax error occurs when the eye is not directly opposite the scale when the reading is being taken. You can avoid parallax errors by making sure that your eye is in the correct position when taking the reading. For example, when reading the level of a liquid in a measuring cylinder, place the cylinder on the bench and line up your eye with the bottom of the meniscus (Figure 3).

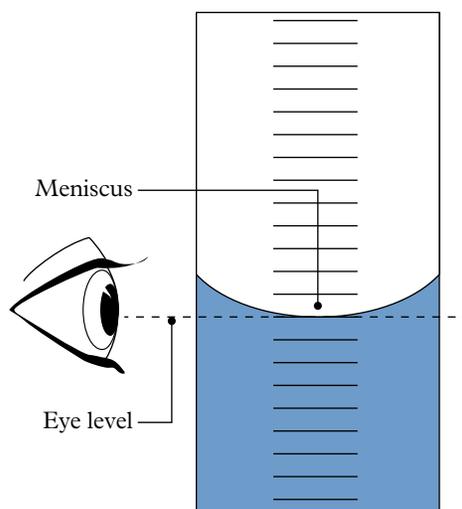


Figure 3 To avoid parallax error, make sure your eye is correctly lined up with the bottom of the meniscus.

Zero errors

A zero error happens when an instrument (e.g. a scale) has not been correctly adjusted to zero before taking a new measurement (or the reading has not taken into account the weight of empty containers). For example, the scales shown must have the watch glass placed on them first and then be set to zero before weighing the substance shown (Figure 4).

Ensure accuracy

When conducting a scientific investigation, accuracy is key. There are two main areas where it's important to be accurate: accuracy of equipment and accuracy of calculations.



Figure 4 Scales must be zeroed correctly before weighing any substance. When measuring liquids or powders, the measuring dish or container (e.g. watch glass) must be added to the scales before it is zeroed.

Accuracy of equipment

To check the accuracy of digital scales, scientists use a special mass that is known to be exact (Figure 5). When this is placed on the scale, the weight shown by the scale is compared to the known true mass. If they are the same, then the scale is accurate.



Figure 5 Scientists use a special mass with an exact weight to check and calibrate (i.e. adjust) lab equipment like digital scales. This helps to ensure all measurements are accurate.

Accuracy of calculations

When conducting a scientific investigation, mathematical accuracy is just as important as the accuracy of your equipment. Not only must your equipment be appropriate and precise to avoid errors, but your calculations must also be correct.

When taking a reading, you should quote the maximum allowed number of **significant figures** (i.e. the number of digits). This can represent the accuracy of a measurement or reading. When recording results, it is important to know the number of significant figures the instrument allows. When adding or subtracting numbers, the final answer will be based on the least number of decimal places. When multiplying or dividing numbers, the final answer can only be quoted correct to the number of significant figures in the least accurate result. For example, if one measuring device measures 10.22 (four significant figures and two decimal places) and a second device measures 20.345 (five significant figures and three decimal places), averaging these results means adding the values. This means the final answer should only have two figures after the decimal point. This might require a **rounding off** procedure.

Note that when a number ends in a zero (6.0), the final zero does not contribute to the actual value of the number. This means there is no difference between 9.0 and 9. When this occurs, the number is described as having one significant figure.

Accuracy of standard units

Scientists measure fundamental quantities, such as mass, time and length, in a standard unit that has been agreed upon by scientists around the world. The international system of units, known as the **SI system** of units, is based on the metric system. Table 1 shows some SI units. Other measurements, such as volume, are calculated from those basic units and are called **derived units**.

Table 1 SI units

Physical quantity	SI unit	Abbreviation or symbol
Length	Metre	m
Volume	Litre	L
Mass	Kilogram	kg
Time	Second	s
Thermodynamic temperature	Kelvin	K
Amount of substance	Mole	mol
Electric current	Ampere	A

significant figures the number of digits that contribute to the overall value of a number

rounding off reducing the number of significant figures by increasing or decreasing to the nearest significant figure; for example, 7.6 cm is rounded up to 8 cm, 7.2 cm is rounded down to 7 cm

SI system an international system of measurement based on the metric system, with units such as kilogram, metre, kilometre

derived units units of measurement that are calculated using a combination of SI (international system) base units, e.g. cm^3 for volume (base unit is cm), m^2 for area (base unit is m)

Although the SI unit for mass is the kilogram, this is not always the most suitable unit to use. Some objects are too heavy or too light for this to be the most convenient unit. The measurement would have too many zeroes in it. For example, a mass of 0.00000000743 kg or 850,000,000 kg is very inconvenient to write. Scientists and mathematicians choose a unit that requires as few zeroes as possible. They use a system of prefixes before the basic measurement unit, shown in Table 2.

Table 2 Standard prefixes and meanings

Prefix	Symbol	Value	Meaning
peta	P	10^{15}	one quadrillion (one thousand million million)
tera	T	10^{12}	one trillion
giga	G	10^9	one billion
mega	M	10^6	one million
kilo	k	10^3	one thousand
centi	c	10^{-2}	one-hundredth
milli	m	10^{-3}	one-thousandth
micro	μ	10^{-6}	one-millionth
nano	n	10^{-9}	one-billionth
pico	p	10^{-12}	one-millionth of one million

Notice that when the number is larger than the basic measurement, the symbol for the prefix is a capital letter. When it is only a fraction of the basic measurement, the symbol for the prefix is a small letter (i.e. lower case). For example, a megalitre, which is a million litres, is written as ML, while a millilitre, which is one-thousandth of a litre, is written as mL. “Kilo” is an exception to this general rule. A kilogram is 1,000 grams and its symbol is kg.



Figure 6 It is important to take care with your measurements to avoid errors.

Worked example 1.8A Significant figures

A student used two sets of scales to measure 0.44 g of sand and 0.696 g of water. Calculate the final mass when the sand was mixed with the water. Give your answer to an appropriate number of significant figures.

Solution

Add the mass of the sand and water together.

$$0.44 + 0.696 = 1.136 \text{ g}$$

As one number has only two decimal places, the final answer must have two decimal places. The number (1.136) is closer to 1.14 than to 1.13, so 1.14 is more accurate.

Final mass of sand and water = 1.14 g

Check your learning 1.8



Check your learning 1.8

Retrieve

- 1 Recall** and **define** three kinds of errors that can occur during an experiment.

Comprehend

- 2 Describe** how these errors can be reduced to improve accuracy.

Analyse

- 3 Compare** (the similarities and differences between) a reading error and a parallax error.
- 4 Identify** the symbol for:
 - millionths of a gram
 - billions of litres
 - thousandths of an ampere
 - thousands of metres.

- 5 Identify** the number of significant figures in each of the following measurements.

- 45.22 mL
- 8,000 L
- 9.0 s
- 3.005 m

Apply

- 6** A student took the following measurements during an experiment:

5.6 volts, 2.97 amperes, 3,000 seconds.

If these three numbers were used in a calculation, **identify** how many significant figures should be stated in the final answer.

Justify your answer (by explaining how you made your decision).

Lesson 1.9

Skills lab: Making a balloon rocket

Aim

To make a balloon rocket

What you need:

- 1 long piece of string
- 1 plastic straw
- 1 balloon
- Sticky tape
- 1 tape measure

What to do:

- 1** Tie one end of the string to a chair or other sturdy support.
- 2** Thread the other end of the string through the straw.
- 3** Tie the loose end of the string to a second chair or support so that the string is pulled tight.
- 4** Blow up the balloon and hold the end closed (don't tie it).

- 5 Use sticky tape to attach the balloon to the straw, as shown in Figure 1. Make sure the opening of the balloon is not taped and is easy to release.
- 6 Measure the circumference of the balloon with the measuring tape. Record the circumference in your notebook.
- 7 Release the open end of the balloon so that the straw slides along the string.
- 8 Measure how far the balloon rocket moves along the string. Record the distance the balloon moved in your notebook.
- 9 Repeat this experiment two more times with the balloon blown up to the same circumference. This ensures your test is reproducible.

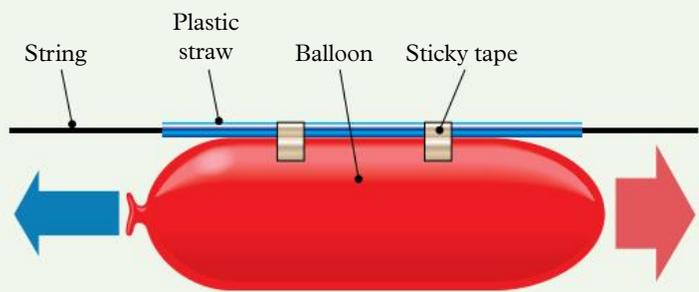


Figure 1 A balloon rocket

Questions

- 1 Identify one independent variable that you could change in this experiment.
- 2 Identify one dependent variable that you could measure in this experiment.
- 3 Identify three variables that you would need to control in this experiment.
- 4 Describe the method you would use to complete this experiment.
- 5 Write a hypothesis for this experiment.

Lesson 1.10

Scientists use tables, graphs, and models to record and analyse 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 helps a scientist to 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.



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
- mathematical relationships.

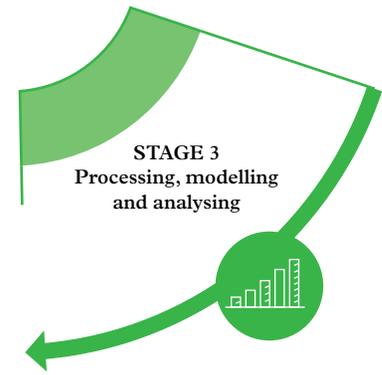


Figure 1 Stage 3 of the scientific method is **Processing, modelling and analysing**.

Data tables

One of the easiest and more efficient ways to record data is in a data table or spreadsheet (if you're working digitally).

Using a data table to show large amounts of data can make it easier to see patterns and relationships between the variables (Figure 1). When recording the results of experiments, the data collected should be presented neatly and accurately.

As shown in Figure 2, a data table should have the following features:

- A **title** which describes the information that is present.
- **Columns** for all relevant data being recorded
 - The first column usually contains the values of the **independent variable**.
 - The second column usually contains the values of the **dependent variable**.
- **Headings** for each column that include the values and the units of measurement (e.g. weeks, kg, etc.).
 - If **quantitative data** (i.e. numbers) is being recorded in the table, it should usually be ordered from the smallest value to the largest value.
 - If **qualitative data** (i.e. words) is being recorded in the table, the most important details should be recorded in brief, accurate descriptions.

quantitative data

data that can be measured numerically

qualitative data

data that can be measured using categories

Table 1 Average weight of juvenile koalas by age	
Age (weeks)	Weight (kg)
24	0.5
36	1.5
52	2.0

Figure 2 A table should have the following features:

- a** **Title:** The title should contain both the independent variable and the dependent variable.
- b** **Column headings:** The variable should be identified and the unit of measurement included.
- c** **Ordering of values:** the independent variable should be in the first column
- d** **Ordering of data:** The data for the independent variable should be organised from the lowest value to the highest.

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 butterflies in a specific location
- the number of votes in an election.

- **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.

categorical data information that can be divided into groups or categories

numerical data data in the form of numbers

discrete data data where the numbers can be separated into different groups

continuous data data that is measured and can be any value

Types of graphs

Scientists use many different types of graphs to record and analyse data. Three of the most common and useful graphs include:

- column graphs
- line graphs
- scatter graphs.

Column graphs

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 (i.e. the variable that is changed) is the location. The dependent variable (i.e. the variable that is measured) is the number of insects.

How to create a column graph

The following steps outline how to construct a column graph.

- **Step 1:** Use a pencil and a ruler to draw the horizontal and vertical lines of a graph. These lines are the axes. Add small lines along each of the axes at regular intervals (e.g. every 2 cm) (Figure 3).

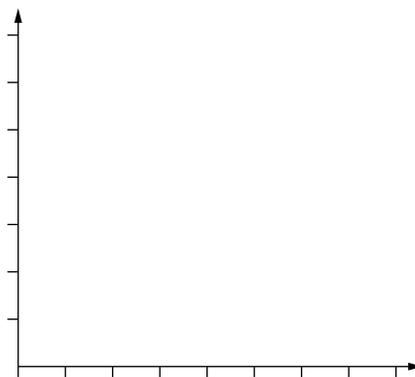


Figure 3 Drawing a set of axes

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

- **Step 2:** Label each axis (Figure 4). The independent variable is always on the x -axis (the horizontal line) of a graph. The dependent variable is always on the y -axis (the vertical line) of a graph.
- **Step 3:** Add numbers or categories at regular intervals to the lines along the axes. Mark each interval with a small line (Figure 5). It is important to make sure that all your data can be represented on the axis. For example, if the smallest number is 7 and the largest number is 62, then the axis should go from 0 to 70.

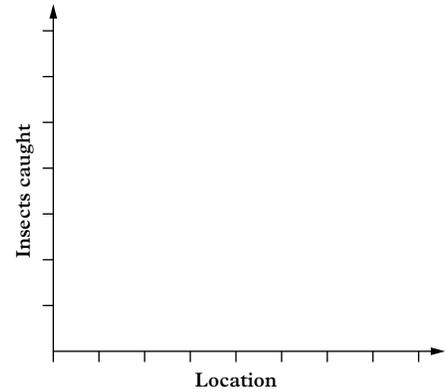


Figure 4 Labelling each axis

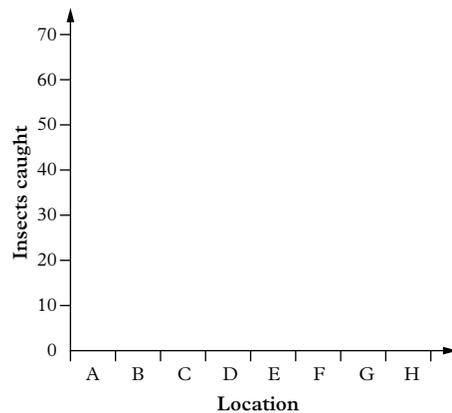


Figure 5 Adding numbers to each axis

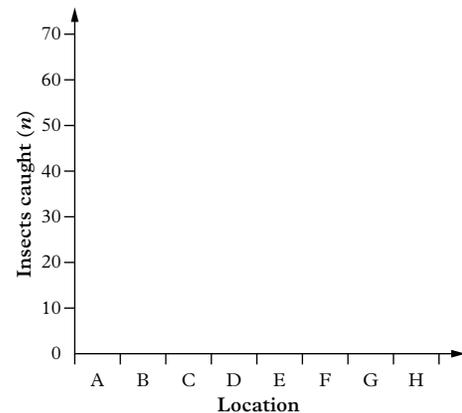


Figure 6 Adding units to the axes

- **Step 4:** Add units to the labels on the axes to explain what the numbers mean (Figure 6). For example, the units could be metres (m), seconds (s), minutes (min) or the number (n) of things. If an axis has categories instead of numbers, it does not need units.
- **Step 5:** Plot the data on the graph as columns (Figure 7). Rule the lines carefully, making sure there is a gap between the columns.
- **Step 6:** Write a descriptive title at the top of the graph (Figure 8).

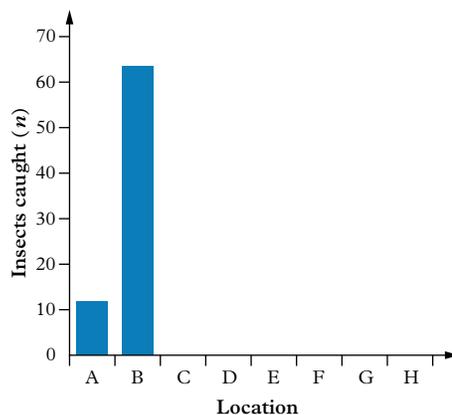


Figure 7 Plotting the data as columns

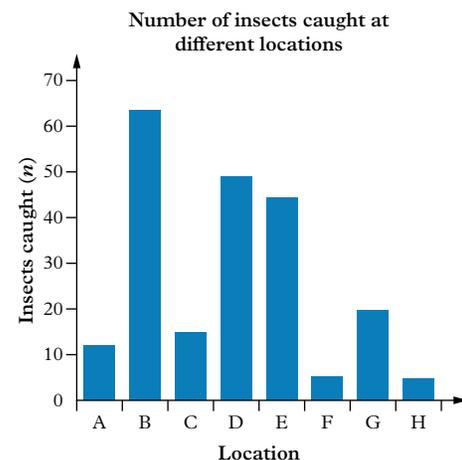


Figure 8 Writing a descriptive title for the column graph

Line graphs

Line graphs are the most common graphs that appear in scientific reports. These graphs are used to show the relationship between the independent variable and the dependent variable.

line graph a graph that uses lines to connect individual data points

How to create a line graph

The following steps outline how to construct a line graph.

- **Step 1:** Follow Steps 1 to 4 for creating a column graph.
- **Step 2:** Place a dot or small cross on the graph for each of the data points you have collected. Do this by transferring the data from your data table and plotting a coordinate on the graph at the point x and y coordinate meet. Make sure points are positioned accurately according to your scale.
- **Step 3:** Draw straight lines to connect each of the coordinated plotted on the graph. If your line graph is showing more than one series of data, use different colours for each line. If showing multiple data series (Figure 9), include a legend explaining what each coloured line represents.

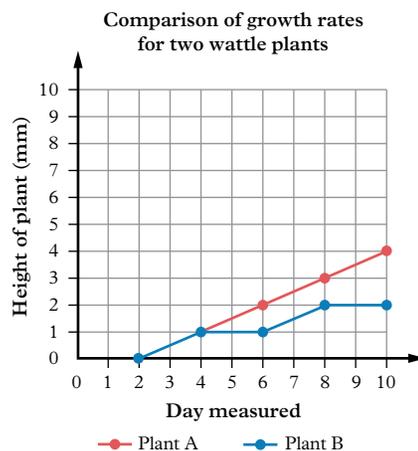


Figure 9 A line graph showing two data series - one representing the rate of growth for a Dirt plant

How to interpret a line graph

The shape of a line graph gives a hint of how the two variables are related.

When the line slopes upwards, this means the dependent variable increases in the same way as the independent variable increases. This is called a **directly proportional relationship** (Figure 10).

When the line is horizontal (i.e. flat), it means the dependent variable is not affected by the independent variable (Figure 11).

If the line slopes downwards, then the dependent variable decreases as the independent variable increases. This is called an **inversely proportional relationship** (Figure 12).

directly proportional relationship a relationship between two variables in which the dependent variable increases as the independent variable increases

inversely proportional relationship a relationship between two variables in which the dependent variable decreases as the independent variable increases

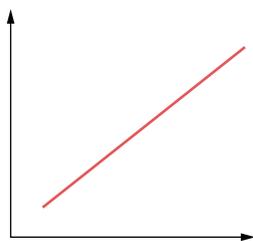


Figure 10 A line graph showing a directly proportional relationship

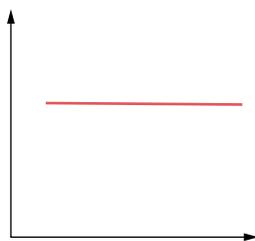


Figure 11 A line graph showing a dependent variable that is not affected by an independent variable

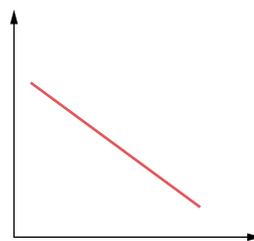


Figure 12 A line graph showing an inversely proportional relationship

Occasionally a line graph is curved (Figure 13). These graphs can be interpreted in sections. In section A (i.e. between 0 and 4), the dependent variable increases as the independent variable increases. In section B (i.e. between 4 and 8) the dependent variable decreases as the independent variable increases.

Sometimes you can use the results recorded in a line graph to make accurate assumptions.

For example, if you completed Lesson 1.14 Skills lab: Marshmallow slingshots (page 57) you may have recorded your results as a set of whole numbers (Table 1).

Figure 14 represents the results provided in this data table.

Table 1 Sample results from the Marshmallow slingshot experiment

Distance elastic is stretched (cm)	Distance marshmallow travels (cm)
1	13
2	28
3	55
4	94

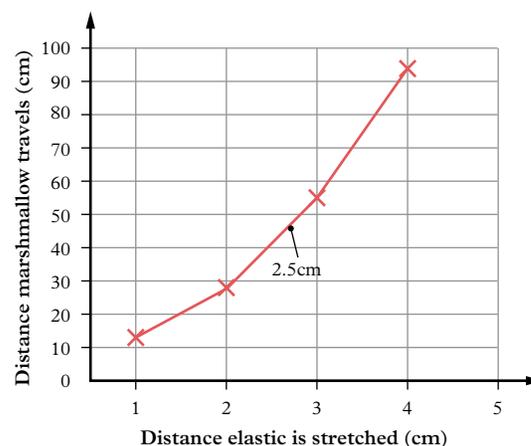


Figure 14 A line graph of the sample Marshmallow slingshot results

Using this line graph, you will now be able to make an accurate assumption about the distance a marshmallow would have travelled if the elastic had been pulled back by a different amount – for example 2.5 cm.

Scatter graphs

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

In a **scatter graph**, the relationship between two sets of data is compared. The steps for drawing a scatter graph are listed below.

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

How to create a scatter graph

The following steps outline how to construct a scatter graph to display the data they collect.

- **Step 1:** Use a pencil and a ruler to draw the x -axis (horizontal) and y -axis (vertical) of a graph. Label each axis. The independent variable is on the x -axis and the dependent variable is on the y -axis (Figure 15).

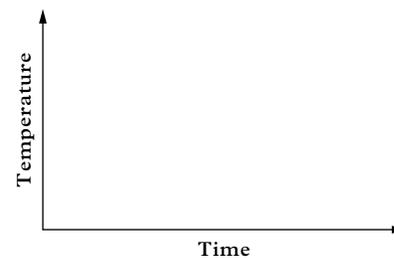


Figure 15 Drawing a set of axes

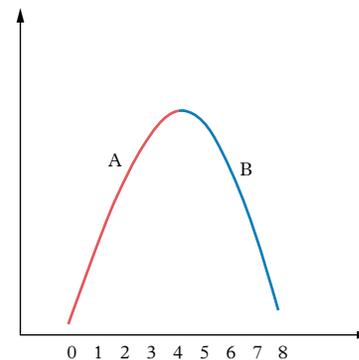


Figure 13 A line graph showing a curved line. Curved line graphs should be analysed in sections.

- **Step 2:** Add numbers at regular intervals to the lines along the axes. Mark each interval with a small line (Figure 16). It is important to make sure that all your data can be represented on the axis. For example, if the smallest number is 14 and the largest number is 178, then the axis should go from 0 to 200. Add units to the labels on the axes to give the numbers meaning.
- **Step 3:** Plot the data on the graph. Use small crosses rather than dots (Figure 17). It is easier to find the centre of a cross than the centre of a dot.
- **Step 4:** Draw a **line of best fit** or a smooth curve that passes through, or near to, as many data points as possible (Figure 18).
- **Step 5:** If you are plotting more than one set of data on the same graph, use different symbols (e.g. circles or triangles) for the other sets of data. Add a legend to identify each set of data (Figure 19).
- **Step 6:** Write a descriptive title at the top of the graph (Figure 20).

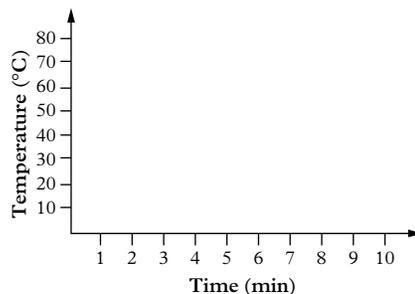


Figure 16 Adding numbers to axes at regular intervals

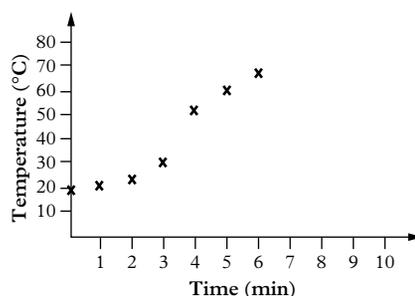


Figure 17 Plotting data on the graph using small crosses

line of best fit
the line on a scatter graph that passes through, or nearly through, as many data points as possible to show any overall trends in the data

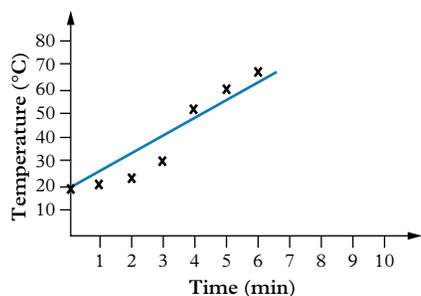


Figure 18 Drawing a line of best fit

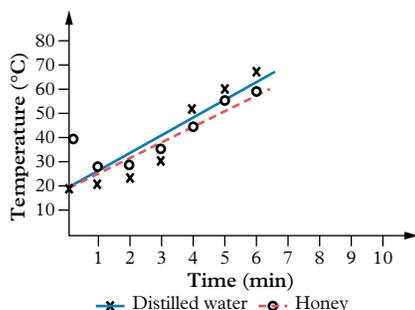


Figure 19 Using small crosses and circles when plotting more than one set of data

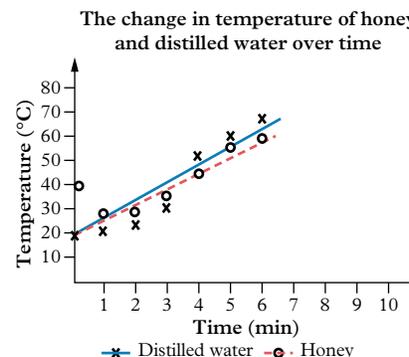


Figure 20 Writing a descriptive title for the scatter graph

Common features of graphs

There are a number of features that all good scientific graphs must have. These include:

- 1 **Title** – A descriptive title explaining what the graph shows.
- 2 **Axes** – Every graph should have two axes (i.e. a horizontal axis called the x -axis, and a vertical axis called the y -axis). Each axis should have:
 - **Labels:** Each axis should be clearly labelled with the variable it is showing and its units (e.g. “Temperature (°C)” and “Germination (days)”).
 - **Scale:** The scale of each axis should be appropriate for the data and allow for easy interpretation. Start at a value that works for your data (usually zero) and use sensible intervals (increasing by 1, 5, 10, etc.) that suit your data.

- **An independent variable:** This should be marked on the horizontal axis (i.e. x -axis)
 - **A dependent variable:** This should be marked on the vertical axis (i.e. y -axis).
- 3 **Data points** – Ensure each data point is placed correctly, clearly visible, and distinguishable.
 - 4 **Legend** – If necessary, use a legend to explain any symbols or colours shown in the graph.

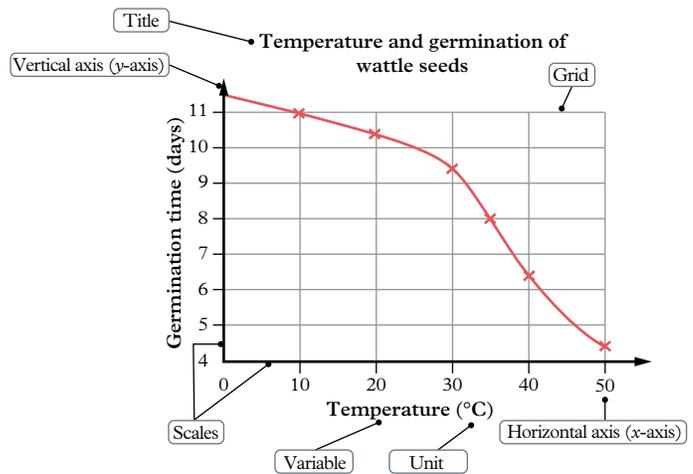


Figure 21 The independent variable (i.e. Temperature) should be on the horizontal axis (i.e. x -axis) and the dependent variable (i.e. Germination time) should be on the vertical axis (i.e. y -axis).

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 22).

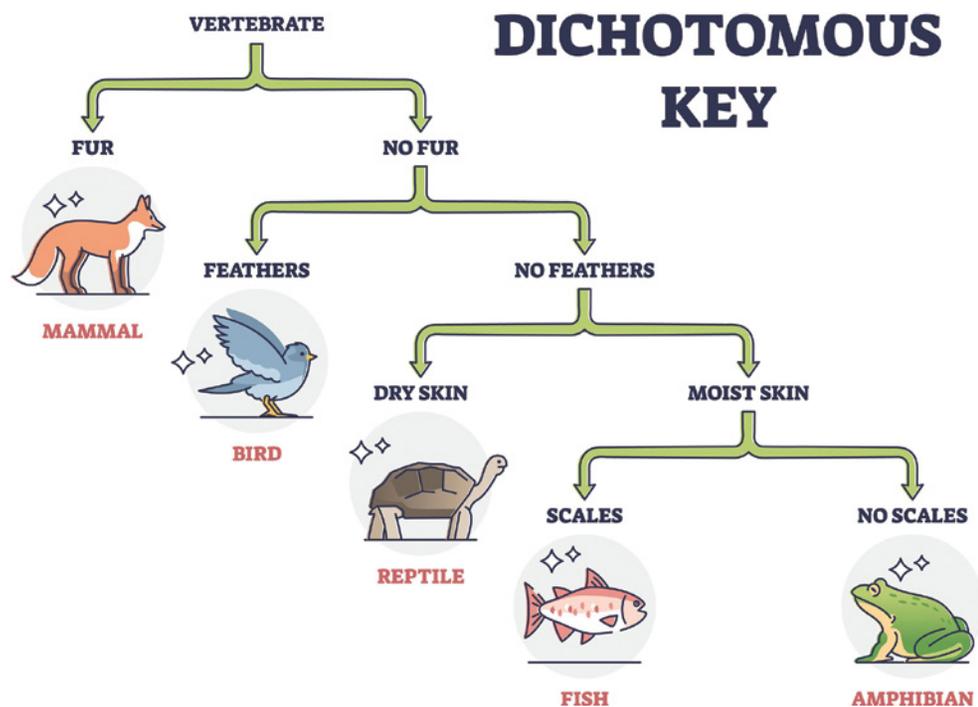


Figure 22 A dichotomous key can be used to identify animals based on their characteristics.

Models

Models are representations that help explain scientific concepts or systems. They include:

- a physical model of the solar system (Figure 23)
- a diagram showing how the water cycle works
- a computer simulation of weather patterns
- 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.

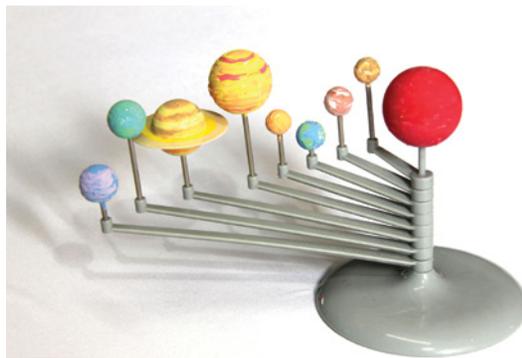


Figure 23 A physical model of the solar system

Mathematical relationships

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

- distance travelled = walking speed \times 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.

Check your learning 1.10



Check your learning 1.10

Retrieve

- 1 **Identify** the features that all graphs have in common.
- 2 **Recall** what it means when a graph of the independent and dependent variables is horizontal (i.e. flat).
- 3 **Identify** which variable (independent or dependent) is located on the x -axis of a graph.

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

Comprehend

- 5 **Describe** the relationship between the independent variable and dependent variable shown in Figure 24.



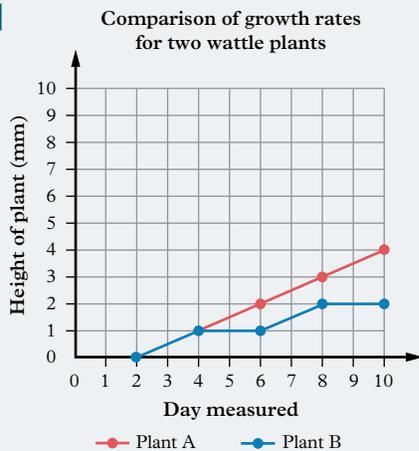


Figure 24 A graph showing plant growth

Analyse

- 6 A scientist was collecting data on the change in height of a plant over seven days.
Construct a table that could be used to record this data.

- 7 **Explain** why graphs are often used in scientific reports.

- a **Represent** the data in Table 2 as a graph.
 b **Identify** the relationship between the variables and **explain** your reasoning.

Table 2 Energy in chocolate bars

Number of chocolate bars	Energy (kilojoules)
3	606
4	808
6	1,212
8	1,616
10	2,020

Lesson 1.11

Scientists present accurate data

Key ideas

- Repeating an experiment helps to identify errors.
- Outliers are values that are very different from the main group of data.
- Outliers can affect the mean (average) of the overall results.
- The median (middle number of data when placed in increasing order) or the mode (most common result) is less affected by outliers.



Learning intentions and success criteria

Comparing results

It can sometimes be difficult for a scientist to know if their results are accurate, especially if they have only tried an experiment one or two times. For example, a botanist (a scientist who studies plants) plans an experiment to see if the amount of water given to a plant affects its growth. If only one plant is watered every day and dies, the botanist may claim that water killed the plant. They may not be able to see that the plant was infected with a fungus, and this was the reason that it died.

If the botanist tried watering 50 different plants every day and half of them died, they may still claim that some plants do not like water. While there are some plants that do not grow well with too much water, it would be difficult to claim this in an experiment if all the plants were different. A well-designed plant experiment should use many identical plants.

Sometimes this is difficult to do, so scientists will compare their methods and results to that of other scientists. If the methods are the same (consistent), all of the variables controlled and the measurements are accurate, then the data can be combined and analysed.

Identifying outliers and anomalies in the data

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

Outliers

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.

outlier a data value that is outside the range of all the other results

Consider the data in Table 1, which records the height of seedlings after three weeks of growth.

Table 1 Seedling growth after three weeks

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



Figure 1 How should you calculate the average growth of seedlings?

All seedlings (except for Seedling 5) grew between 3.5 and 4.3 cm. The height of Seedling 5 after three weeks is an outlier. The average (or mean) growth of the seedlings (including seedling 5) is 3.4 cm, which is below the growth of any of the seedlings other than Seedling 5. This shows how one outlier can present a distorted result of the seedling growth.

If the average is determined without using the height of Seedling 5, the average becomes 3.9 cm. This is a closer representation of the actual growth. However, is it fair to discard any results that we don't like?

An outlier is only excluded if an explanation is given as to how the results have been modified and the reason for doing so. For example, the discussion might include the statement that "Seedling 5 was excluded from the analysis because a fungal infection affected its growth".

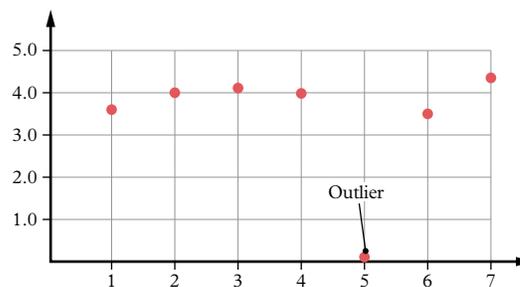


Figure 2 A data outlier can be identified by a graphed data point that is away from the other data.

anomaly a result that does not fit in with the pattern of data or what is normally observed

Anomalies

An **anomaly** is an unexpected pattern in a data set that differs from what is normally observed.

While an outlier can be due to an error in the data, anomalies can indicate something is wrong with the way the experiment is designed. It is important not to remove or ignore unexpected values or trends in data. If you can, try to explain what might have caused unexpected results.

Understanding trends in data

Before scientist can present the results of their experiments, they need to be able to describe whole set of data with a few single values that represent the “middle” or “centre” of the data set. This can help an audience to get an understanding of what’s “typical” in the data, or the “average” result. The most common ways of doing this is by calculating:

- mean
- median
- mode.

Mean

mean the average of a set of data

In science, the **mean** refers to the average value in a set of data. The mean is calculated by adding up all the values in a data set and then dividing that total by the number of values in the data set (Worked example 1.11A).

Worked example 1.11A Calculating the mean

Determine the mean (i.e. average) of the seedling heights shown in this data table.

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

Solution

average seedling height

$$\begin{aligned}
 &= \frac{\text{sum of all seedling heights}}{\text{number of seedlings}} \\
 &= \frac{3.6 + 4.0 + 4.1 + 4.0 + 0.1 + 3.5 + 4.3}{7} \\
 &= \frac{23.6}{7} \\
 &= 3.371
 \end{aligned}$$

As the seedling heights had two significant figures and one decimal place, the final answer must have two significant figures and one decimal place. The average seedling height is 3.4 cm (3.371 is closer to 3.4 than to 3.3).

Median

The **median** is the middle value of the data after all the numbers have been placed in ascending order (i.e. where values are arranged from smallest to largest).

median the middle value in a set of data

To find the median, you need to:

- 1 Arrange the data points in order from smallest to largest.
- 2 If the number of data points is odd, the median is the middle value.
- 3 If the number of data points is even, the median is the average of the two middle values.

For the previous data, this means:

0.1, 3.5, 3.6, 4.0, 4.0, 4.1, 4.3
 ↑
 median

The median amount the seedlings grew was 4.0 cm. If the outlier is removed, the median growth is still 4.0 cm. The median value of the data is not affected as much by outliers as the mean/average is.

Mode

The **mode** is the most common number in the set of data. In our set of data, the number 4.0 occurs twice (i.e. Seedlings 2 and 4).

mode the most common value in a set of data

This means the mode, or most common amount the seedlings grew, was 4.0 cm. If the outlier was removed, the mode of the seedling growth would still be 4.0 cm. An outlier does not affect the mode value.

Check your learning 1.11



Check your learning 1.11

Retrieve

- 1 **Define** the following terms.
 - a Outlier
 - b Anomaly
 - c Median
 - d Mean
 - e Mode

Comprehend

- 2 **Explain** why scientists often repeat experiments and then take an average.
- 3 **Describe** when an outlier should be included in the results.

Table 2 Number of ice creams sold in comparison to the daily temperature

Temperature (°C)	Ice creams sold
14.2	215
16.4	325
11.9	185
15.2	332
18.5	406
22.1	522
19.4	112
25.1	614
23.4	544
18.1	421
22.6	445
17.2	408

◀ Analyse

4 Draw an appropriate graph for the data in Table 2.

a Identify the outlier in the data.

b Calculate the mean number of ice creams sold each day.

c Calculate the median temperature over the 12 days.

Lesson 1.12

Scientists evaluate claims and results



Learning intentions and success criteria

Key ideas

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

Take a step back and evaluate

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

- evaluating the methods to identify assumptions, errors and improvements
- evaluating the results to identify outliers and anomalies.

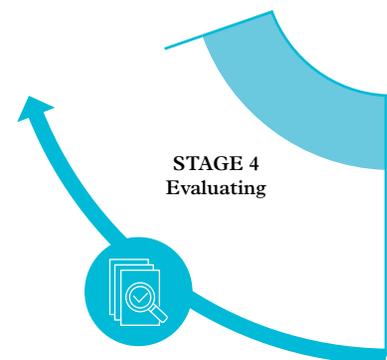


Figure 1 Stage 4 of the scientific method is **Evaluating**.

Reliable science

In Lesson 1.3 Scientists follow the scientific method (page 13) you learned about how pseudoscience claims are commonly made on the internet or in the media. These claims often use scientific words and describe poorly designed experiments that did not have all variables controlled. A reliable, valid science experiment needs to be carefully planned, the variables must be controlled, and the results should be carefully analysed to make sure that all errors have been minimised.

When you are planning your method or analysing the results of your experiment, there are approaches you can take to help you avoid making pseudoscientific claims. Some of these approaches are outlined below.

The difference between correlation and causation

While observation might seem a simple process, if a scientist does not plan and conduct a **valid experiment**, they may end up with misleading results.

For example:

- A scientist may notice that there are more shark attacks in summer than in winter.
- The same scientist may also notice that more ice-creams are sold at a kiosk on the beach in summer than in winter.
- Therefore, during winter, both ice-cream sales and shark attacks go down.

If this data is graphed (Figure 2), it could look like the ice-cream sales were causing shark attacks, because they both go up at the same time.

This data is misleading as there is another factor that has not been considered: hot weather. During hot weather, more people go swimming at the beach than in winter, Therefore, shark attacks are more likely because there are more people swimming.

Likewise, people are also more likely to buy ice-creams when they are at the beach in summer, rather than in winter.

The hot weather is, therefore, the cause of the increased shark attacks and ice-cream sales. A scientist would describe the relationship between the shark attacks and ice-cream sales as a **correlation** (i.e. when two or more things are related).

In our example, both shark attacks and ice-cream sales increase during hot summer days when more people go to the beach. As we have established, the real cause of both increases is the hot weather and beach attendance – not the fact that eating ice-cream causes shark attacks!

In other words, just because two things happen together doesn't mean one causes the other. That's why scientists conduct controlled experiments – to figure out what actually causes what.

Scientists need to be very careful about making assumption based on data. One way they do this is by recognising the differences between correlation and causation in the data they collect.

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

correlation a relationship between two or more things

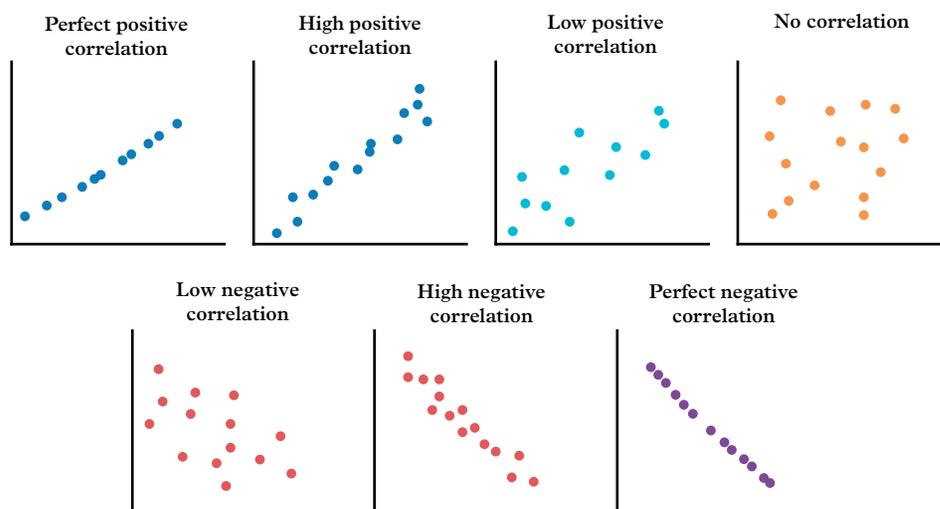


Figure 2 This graph shows that there is a relationship between the number of ice-creams sold and the number of shark attacks during the summer months. This is known as a positive correlation.

Correlation

Correlation means two things happen together or are related in some way. As shown in Figure 2, when two sets of data are strongly linked (i.e. when one changes, the other changes by a similar amount), the data is said to have a strong **correlation**.

- If both values increase at the same rate, this is called a **positive correlation**.
- If one value increases as the other decreases, then it has a **negative correlation**.

A number of different types of positive and negative correlations are shown in the graphs.

Causation

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

Unlike correlation, **causation** means one thing directly causes another thing to happen. There's a clear cause-and-effect relationship. For example:

- If you knock over a glass of water (cause), the table will get wet (effect).
- If you kick a ball (cause), it will fly through the air (effect).

Reliable science

In Lesson 1.3 Scientists follow the scientific method (page 13) you learned about how pseudoscience claims are commonly made on the internet or in the media. These claims often use scientific words and describe poorly designed experiments that did not have all variables controlled. A reliable, valid science experiment needs to be carefully planned, the variables must be controlled, and the results should be carefully analysed to make sure that all errors have been minimised.

When you are planning your method or analysing the results of your experiment, there are approaches you can take to help you avoid making pseudoscientific claims. Some of these approaches are outlined below.

Evaluating the method

One of the most difficult things to do in an experiment is to control all the variables. Sometimes random things, like someone opening a door or window, can cause an error in an experiment (Figure 3).



Figure 3 Something as small as room temperature (i.e. having a window open or closed) in the laboratory can impact the results of an experiment.

For example, if a scientist is testing whether salty water takes longer to boil than fresh water, opening a window might change the temperature of the air in the room. This is why it is important to check if an experiment was repeated at least three times with the same results. Repeated experiments are more reliable than single experiments.

Identifying assumptions

When a scientist decides that the temperature of the room does not change without measuring it, they have made an assumption. **Assumptions** are beliefs that are accepted as true without any evidence or testing. Some assumptions are reasonable. An example of this is the assumption that your science teacher has given you the correct materials for the experiment. Other assumptions should be questioned, such as are the scales you used to measure a material accurate?

When you are planning your own experiment, or reading about someone else's experiment, it is important to check if any assumptions have been made.

assumption statements or beliefs that are accepted as true without supporting evidence

Identifying errors

Scientists can make mistakes when conducting experiments. Mistakes should be fixed immediately, or the experiment should be started again.

An **error** is different from a mistake – it can happen for many reasons, no matter how careful you are. Errors can occur if the object you are measuring falls between two markings on a scale and you have to estimate the exact measurement. When this occurs, it is important to use a more accurate scale or a digital device.

Sometimes scales can be **calibrated** (set up) incorrectly, which means that, no matter what you measure, you will get a slightly inaccurate result. You can minimise the effect of this kind of error by always using the same measuring device.



Figure 4 Scales should always be calibrated to avoid an error.

error an inaccuracy or inconsistency in measurement

calibrate check the accuracy of a measuring device against known measurements

Identifying possible improvements

An effective scientist will always look for ways to improve their experiments. It is important to be open and honest about how the method could be changed to improve the reliability of your results.

Making a claim

If the data is reliable, has few outliers and no anomalies, and agrees with the original hypothesis, then the scientist can claim their hypothesis is supported. When making a claim, the scientist will:

- rewrite their hypothesis
- describe the experiment and the data that supports their hypothesis
- explain why the dependent variable was changed by the independent variable
- describe any relevant variables that have not yet been tested (the limitations).

If the data does not support the hypothesis, or there are several outliers, the hypothesis is refuted (not supported by the evidence). It is exciting when a hypothesis is not supported as this can lead to unexpected discoveries. As stated by famous scientist, Isaac Asimov, “The most exciting phrase to hear in science, the one that heralds new discoveries, is not ‘Eureka!’ but ‘That’s funny ...’”.

Check your learning 1.12



Check your learning 1.12

Retrieve

- 1 **Define** the terms “anomaly” and “outlier”.
- 2 **Identify** an assumption that a scientist may make when completing an experiment that tests how fast water boils.

Comprehend

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

Analyse

- 4 **Contrast** the terms “mistake” and “error”.

Apply

- 5 Associate Professor Elizabeth Tibbetts had difficulty putting marks on the wasps she was studying. When looking closely at the wasps, she realised that they all had different markings (Figure 5). This encouraged her to test if the wasps could tell one another apart.
Propose a hypothesis that the associate professor could test based off this idea.
- 6 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.



Figure 5 Associate Professor Elizabeth Tibbetts discovered that the wasps she was studying had individual markings.

Lesson 1.13

Scientists keep a logbook



Learning intentions and success criteria



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

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.

A logbook is used to record essential data and observations

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

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

All experiments 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).



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

logbook a day-to-day record of all activities you did on your research project

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. Each page should be numbered to help you find the relevant experiments.

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

Unit/subject	Experiment title	Page number

- 4 Always date every entry.
- 5 Each page should contain the title of the experiment.

Figure 2 shows a sample logbook entry.

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 elastic pulled back	Distance marshmallow has moved			
	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				

20.3
23.4
+19.9 **63.6 ÷ 3 = 21.2 cm**
63.6

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

Check your learning 1.13



Check your learning 1.13

Retrieve

- 1 **State** the purpose of an experimental logbook.
- 2 A student made a mistake and 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.

Lesson 1.14

Skills lab: Marshmallow slingshots

Aim

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

What you need:

- Rubber bands
- Plastic ring or pipe cleaners
- Chair
- Marshmallows
- Long tape measure

Caution

Always stand behind the apparatus when firing the marshmallow. Check that no one is in the firing line.

What to do:

- 1 Make a chain of rubber bands by threading the end of one band through and over the end of the second band, then pulling tight.
- 2 Place a plastic ring in the centre of the rubber band chain.
- 3 Secure the rubber bands to the legs of an upside-down chair as shown in Figure 1.
- 4 Insert a marshmallow into the plastic ring.
- 5 Pull back the marshmallow ensuring the rubber bands are horizontal to the ground. Measure the distance from the chair legs to the point where you have pulled the marshmallow back to (Figure 2).
- 6 Wait until everyone is out of the flight path, and then release the rubber bands.
- 7 Measure the distance the marshmallow travelled.

Inquiry: Choose one of the questions to investigate.

Choose one of the inquiry questions.

- What if the rubber bands were not horizontal?
- What if the rubber bands were tied tighter?
- What if a smaller marshmallow was used?

You will now design your own experiment to answer your inquiry question.

- **Develop** a prediction or hypothesis for your inquiry.
- **Identify** the (independent) variable that you will change from the first method.
- **Identify** the (dependent) variable that you will measure and/or observe.
- **Identify** two variables that you will need to control to ensure a fair test. **Describe** how you will control these variables.
- **Develop** a method for your experiment. Write this method in your logbook.
- **Construct** a table to record your results.
- Show your teacher your planning for approval before starting your experiment.

Results

- 1 **Record** your results and observations in your table.
- 2 **Construct** a graph that shows the distance travelled by the marshmallow at each attempt. Your graph should include:
 - the independent variable labelled on the x -axis
 - the dependent variable labelled on the y -axis
 - a title for your graph.
- 3 **Describe** your results by comparing how you changed the independent variable and how your dependent variable changed.

Discussion

- 1 **Identify** two variables that were difficult to control. Explain the measures you took to control them.

- 2 Use evidence from your results to **evaluate** the accuracy of your hypothesis by describing how the dependent variable changed and comparing it to the prediction you made. If they are similar, then the hypothesis is considered supported.
- 3 A student claimed that their rubber bands became stretched and less flexible by the end of the experiment. **Describe** how this could affect the results of the experiment. **Describe** how you could test if this had happened with your experiment.

Conclusion

Describe the relationship between the distance the rubber bands are pulled back and the distance a marshmallow travels.

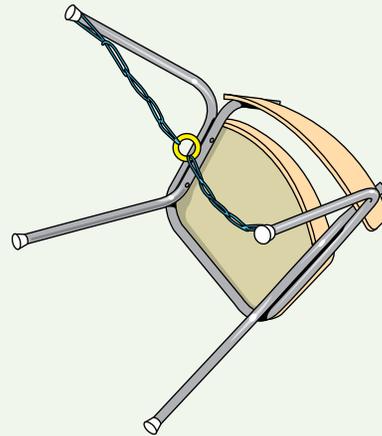


Figure 1 Secure the chain to the legs of a chair.

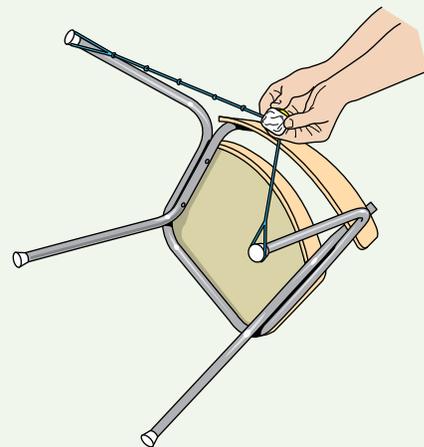


Figure 2 Pull back the marshmallow and measure the distance.

Lesson 1.15

Scientists use reports to communicate findings

Key ideas

- A scientific report is structured document that presents research findings and data in a formal, structured way.
- Scientists use a similar style and language in their reports so that they can be understood by scientists worldwide.
- Scientists communicate with other scientists so that they can learn from each other and expand on each other's work.



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.

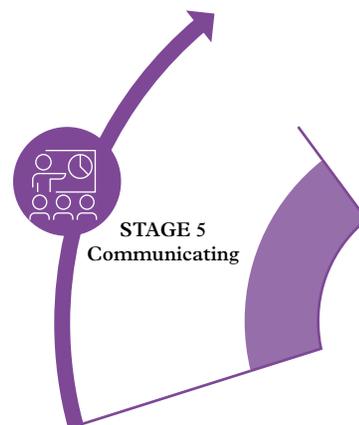


Figure 1 Stage 5 of the scientific method is **Communicating**.

peer review the evaluation of work by one or more people with similar skills and backgrounds (peers)

What is a scientific report?

A scientific report is a written account of an experiment or investigation. It usually has the following parts (i.e. headings and features):

- 1 **Title** – This should clearly state what you're investigating. It can be written as a statement or a question. Be descriptive but keep your title brief.
- 2 **Date** – This is the date (or dates) on which the experiment was conducted.
- 3 **Partners** – This is a list of people who conducted the experiment (if you are working in a group). Do not forget to include your own name here too.
- 4 **Aim (or question)** – This is what you were trying to find out or why you were doing the experiment.
- 5 **Hypothesis** – This describes the independent variable and dependent variable of the experiment or investigation and the scientific explanation that will be supported or refuted as a result of testing.
- 6 **Materials (or equipment)** – This contains a detailed list of the equipment and materials used.

aim the purpose of an experiment

method a series of steps explaining how to do an experiment

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

conclusion a statement that “answers” the aim of an experiment

- 7 **Method** – This lists the steps or procedure that you use to carry out the experiment or investigation, including diagrams of the experimental setup. There are two ways to write a method. The first is to plan what you are going to do. This method should be in the present tense. The second method is for a formal report. Past tense should be used for this method.
- 8 **Results** – These are measurements and observations recorded during an experiment or investigation, usually presented in a table, graph and/or diagram. A few sentences can be used to provide a description of the data in the tables, graphs and diagrams.
- 9 **Discussion** – This is your opportunity to discuss the patterns you see in the findings and any anomalies identified. You should describe any assumptions or errors and any suggestions for improvement or further investigation. The discussion should be written in the third person.
- 10 **Conclusion** – This describes the answer to the aim or question. It should be clear and reasoned, closely related to the aim or question, and if the investigation has a hypothesis, state whether it is supported or refuted by the results. The conclusion should be written in the third person.

How should a scientific report be written?

Scientific reports should present data objectively, letting the evidence speak for itself. This is why they’re typically written in the “third person” rather than the “first person”, removing the scientist from the spotlight and focusing on the work itself.

First person and third person are different perspectives or “points of view” used in writing and communication.

First person

- Writing in the first person uses the pronouns “I”, “me”, “my”, “we”, “us”, and “our”.
- Example: **I measured the temperature of each solution and recorded the results in my logbook.**

Third person

- Writing in the third person often avoids using pronouns altogether.
 - Example: **The temperature of each solution was measured and recorded.**
- When you write in third person:
- The experiment becomes the focus, not the person conducting it.
 - Results appear more universal and reproducible.
 - The science stands independent of who performed it.

A well-controlled experiment should yield similar results regardless of who conducts it – whether a renowned scientist or a complete novice. The methodology and results, not the experimenter, are what matter.

Case study Scientific report**Title**

This should clearly state what you're investigating. It can be written as a statement or a question. Be descriptive but keep the title brief.

What if concentrated vinegar was added to bicarbonate soda?**Date**

14 April 2026

This is the date (or dates) on which the experiment was conducted.

Partner(s)

Vanessa Xi
Lauren Watson
Nicholas Balik

This is a list of people who conducted the experiment (if you are working in a group). Do not forget to write your own name here.

Aim

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

To determine how the chemical reaction changes when concentrated vinegar is added to bicarbonate soda.

Hypothesis

If double strength vinegar is added to bicarbonate soda, then twice as many gas bubbles will be produced compared with regular white vinegar. This is because double strength vinegar has twice as much acid in it, so it will cause twice as much of the chemical reaction and produce double the gas bubbles.

This describes the independent variable and dependent variable of the experiment or investigation and the scientific explanation that will be supported or refuted as a result of testing.

Materials

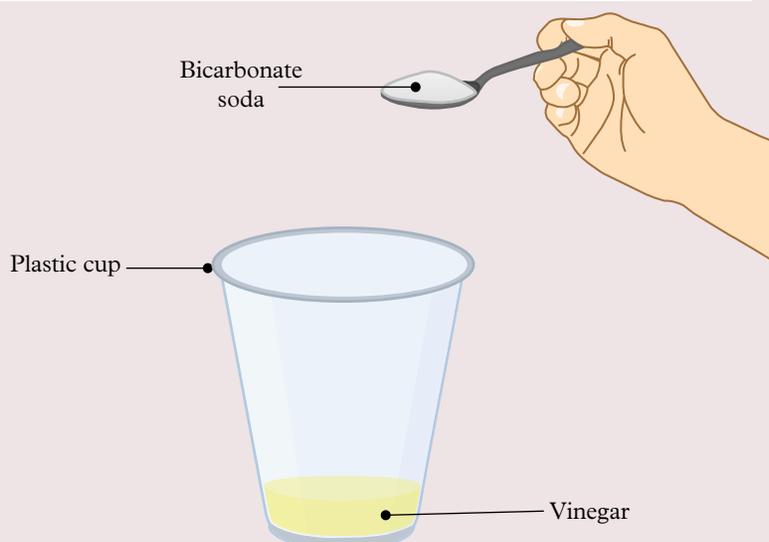
- Large plastic cup
- Teaspoon
- Permanent marker
- Bicarbonate soda (McKenzies brand recommended)
- White vinegar – 4% acidity (Coles brand recommended)
- Double-strength white vinegar - 8% acidity (Coles brand recommended)
- Ruler

This is a list of what you need.

Method

This gives step-by-step instructions and often a diagram of the equipment set-up.

- 1 1 cm of regular vinegar was placed in the plastic cup.
- 2 One level teaspoon of bicarbonate soda was added to the vinegar.
- 3 The permanent marker was used to place a mark on the outside of the cup identifying the height of the reaction. A ruler was used to measure the distance between the base of the cup and the mark.
- 4 The cup was rinsed with water.



- 5 Steps 1 to 4 were repeated three times to check that the reaction rose to the same mark.
- 6 Step 1 was repeated with 1 cm of double-strength vinegar.
- 7 Steps 2 to 3 were repeated.

Results

This often includes a table of results and a graph of the data collected.

Mixture	Height of the gas bubbles (cm)	Average height of gas bubbles (cm)
White vinegar (4% acidity) and bicarbonate soda	5.1	5.1
White vinegar (4% acidity) and bicarbonate soda	5.1	
White vinegar (4% acidity) and bicarbonate soda	5.2	
Double-strength white vinegar (8% acidity) and bicarbonate soda	7.7	5.1
Double-strength white vinegar (8% acidity) and bicarbonate soda	7.8	
Double-strength white vinegar (8% acidity) and bicarbonate soda	7.0	

Discussion

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

When vinegar and bicarbonate soda are mixed it produces carbon dioxide gas. This causes the mixture to bubble up.

It was hypothesised that using the double-strength vinegar would make the mixture make twice as many bubbles. This hypothesis was refuted because the height of bubbles in the double strength of vinegar was only 2.6 cm higher.

There was one measurement in the double-strength vinegar that was less than the other measurements (7.0 compared to 7.7 and 7.8). This could be a random error because the cup was not rinsed properly before the last measurement. This might have caused vinegar to be left in the cup.

To improve the experiment, the cup should be rinsed properly after each test.

Conclusion

This is the answer to the question you set out to investigate. Look back at the aim and see whether the results support the aim before writing the conclusion. Try to use one to two sentences and to write in the third person (e.g. instead of saying “I measured the length of the rubber bands”, say “the length of the rubber bands was measured”).

Double-strength vinegar caused more gas bubbles to be produced, but it did not double the reaction.

Check your learning 1.15**Check your learning 1.15****Retrieve**

- 1 **Define** the term “hypothesis”.
- 2 **List** the parts of a scientific report and provide a brief description of what should be included in each part.

Comprehend

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

- 4 **Explain** why personal pronouns are not used in scientific reports.
- 5 **Explain** why it is important that scientists prepare scientific reports.
- 6 **Explain** why using a common format for all scientific reports might make it easier for scientists to communicate with one another.

Lesson 1.16

Command terms identify tasks and communicate responses

Key ideas

- Command terms are “doing words” that ask you to perform a specific task.
- Command terms can be grouped into categories based on how much thinking and understanding is required to perform the task.



Learning intentions and success criteria

Understanding command terms

A **command term** is a verb or “doing word” that requires you to do a certain kind of thinking complete a set task.

Command terms are helpful for a number of reasons. They can help you to:

- understand exactly what the question is asking you to do
- identify how complex or difficult a question is
- think about your own thinking processes – a process called metacognition
- structure and communicate your responses more clearly.

Command terms are commonly used in questions – both in this course and in most of the assessment tasks you will be completing this year. In each lesson of this course, you’ll see that the command term in each question is bolded.

Some common command terms are listed in Table 1. Each one has an explanation that tells you what you whet the command term is telling you to do.

Some command terms involve simpler thinking processes that are easier to understand and master (e.g. define), whereas others are more complex and will take some time to practise and master (e.g. discuss). For this reason, command terms are organised into four categories based on the type of thinking processes required and how complex these are. These are also listed in Table 1. In order from least complex to most complex, these include:

- **retrieve**
- **comprehend**
- **analyse**
- **apply.**

As you work through this course, you’ll notice that the questions in the “Check your learning” activities in each lesson are organised into these categories. These categories will help you understand the types of thinking process you need to use when answering questions and the level of complexity required.

For example, if you are asked to “**Name** the two fruits in Figure 1, you will simply need to recall the terms “apple” and “orange” and provide them as your response.

“Name” falls in the “Retrieve” category of command terms so requires less complex thinking.

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

However, if you are asked to “**Compare** the two fruits in Figure 1, you would need to consider the two fruits carefully, identify at least one similarity and one difference between them, and make a comment on the importance of these similarities and differences.

“Compare” falls in the “Analyse” category of command terms so requires more complex thinking.

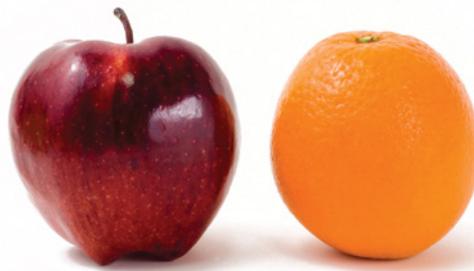


Figure 1 Being asked to “name” two fruits or “compare” two fruits are quite different things!

Table 1 Some common command terms. Familiarising yourself with different command terms can help you **identify** what a question is asking you to do and **communicate** your ideas.

Command term	Explanation	Category
Define	Give the meaning of a word, concept or phrase, and identify its qualities	Retrieve – Recall information from long-term memory.
Identify	Recognise, name and/or select a distinguishing factor or feature	
Name	Provide a word or term to identify a person, place or object	
Recall	Present remembered facts, experiences or ideas	
Use	Operate or put into effect	
Select	Pick out	
Describe	Provide a description of a situation, event, pattern, or process (including its features or characteristics)	Comprehend – Activate and transfer knowledge from your long-term memory to your working memory.
Explain	Provide a detailed account of how and/or why, referencing effects, causes, reasons and relationships between things	
Summarise	Give a brief statement of relevant and important details of text, events, processes, concepts or narratives; present ideas and information in fewer words and in sequence	
Classify	Arrange, distribute or order in classes or categories according to shared qualities or characteristics	
Compare	Recognise similarities and differences, and the importance of these	Analyse – Use your reasoning to go beyond what was directly taught.
Contrast	Give an account of the differences between two or more items or situations	
Distinguish	Recognise as distinct or different and note points of difference	
Interpret	Draw meaning from information, determine its significance and recognise patterns and trends	
Calculate	Determine or obtain a numerical answer using mathematical processes	

Command term	Explanation	Category
Create	Reorganise or put elements together into a new pattern or structure	Apply – Use your knowledge in specific situations.
Discuss	Present a clear argument that is balanced and considered, identifying strengths, weaknesses, issues and points for and against; talk or write about a topic	
Evaluate	Examine and determine the merit, value, amount or significance of something; make a judgement	
Justify	Give reasons or evidence to defend or support an answer, response, point of view or conclusion	
Predict	State an expected result or outcome of a future action or event; make an educated guess based on observations and prior knowledge	

Check your learning 1.16



Check your learning 1.16

Retrieve

- 1 Define** the term “command term”.
- 2 Identify** the command term that requires you to describe at least one similarity and one difference between two things.

Comprehend

- 3 Describe** what is required to correctly answer:
 - a “classify” question
 - a “distinguish” question
 - an “explain” question.

Analyse

- 4 Distinguish** the different categories of command terms.

Apply

- A student was asked to distinguish between the apple and orange in Figure 1.
 - a Identify** the command term in the question.
 - b** The student’s response was “Both the apple and orange are round in shape”. **Evaluate** whether the student has correctly answered the question.

Lesson 1.17

Review: Science toolkit

Summary

Lesson 1.1 Science is the study of the natural and physical world

- Science is the study of the natural and physical world.
- Science measures what we observe (e.g. see, hear, smell and feel) and organises it into testable explanations.
- Scientists have jobs that focus on asking questions and finding answers.
- Some scientists work in a laboratory; many scientists work in teams.
- Scientists answer questions by observing, recording and interpreting what they find.

Lesson 1.2 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 1.3 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 1.4 Scientists make observations and ask questions

- Scientists make observations using their senses (i.e. what they see, hear, smell, taste and touch).
- Science involves making observations over time, identifying and comparing things to identify trends and patterns.
- Scientists use their observations to ask questions that can be investigated and infer (i.e. make an educated guess about) what is happening around them.

Lesson 1.5 Scientists plan and conduct experiments

- An experiment must be a reproducible test to ensure accurate and reliable results.
- Reliable results are those that are consistent and can be trusted because they are repeatable under the same conditions.
- When planning and conducting scientific experiments, managing risks is crucial for everyone's safety.
- Ethical issues are important questions or problems that scientists must consider before conducting an experiment (e.g. whether the research might harm living things, the environment, or go against important values like honesty, respect, and fairness).

Lesson 1.6 Scientists use specialised equipment

- Scientists use specialised equipment to conduct experiments in the laboratory and in the field.
- All instructions and safety protocols need to be followed when using specialised equipment.
- Scientific diagrams are used to show how specialised equipment needs to be set up to conduct an experiment.

Lesson 1.8 Scientists measure and record data accurately

- To achieve maximum accuracy, all measurements must be taken carefully, using the most suitable measuring device.
- Each scientific device must have a scale appropriate to the accuracy that you require.

Lesson 1.10 Scientists use tables, graphs, and models to record and analyse 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 a scientist to 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.

Lesson 1.11 Scientists present accurate data

- Repeating an experiment helps to identify errors.
- Outliers are values that are very different from the main group of data.
- Outliers can affect the mean (average) of the overall results.
- The median (middle number of data when placed in increasing order) or the mode (most common result) is less affected by outliers.

Lesson 1.12 Scientists evaluate claims and results

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

Lesson 1.13 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 1.15 Scientists use reports to communicate findings

- A scientific report is a structured document that presents research findings and data in a formal, structured way.
- Scientists use a similar style and language in their reports so that they can be understood by scientists worldwide.
- Scientists communicate with other scientists so that they can learn from each other and expand on each other's work.

Lesson 1.16 Command terms identify tasks and communicate responses

- Command terms are “doing words” that ask you to perform a specific task.
- Command terms can be grouped into categories based on how much thinking and understanding is required to perform the task.

Review questions 1.17



Review questions: Module 1

Retrieve

- Identify** which of the following is a hypothesis.
 - Plants need water.
 - A plant needs to be watered every day.
 - If a plant was not watered, then it would die.
 - If a plant was not watered then it would die because plants need water to grow.
- Figure 1 shows the distance a marshmallow travelled when it was released from a slingshot stretched to various lengths. **Identify** the relationship between the variables shown on the graph.
 - Directly proportional
 - Inversely proportional
 - Having no direct relationship
 - A negative relationship

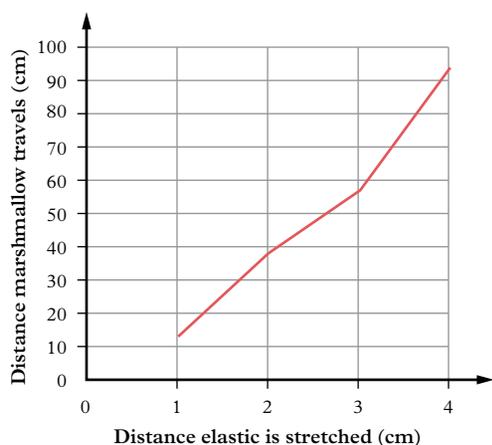


Figure 1 Distance a marshmallow travels according to distance elastic is stretched

- Recall** the variable that is placed on the horizontal axis of a graph.
 - Independent variable
 - Dependent variable
 - Controlled variable
 - Uncontrolled variable

- Define** the following terms.
 - Parallax error
 - Positive correlation
 - Dependent variable
 - Outlier
- State** the SI unit for the following measurements.
 - Time
 - Mass
 - Length
 - Volume
- State** the meaning of and write the symbol for the prefix for each of the following units of measurement.
 - Teralitre
 - Megalitre
 - Microlitre
 - Nanolitre
- Name** the four features that should be present on all graphs.
- Recall** the information that should be included in an experimental logbook.

Comprehend

- A student is planting out a new garden bed. They research how to care for their plants and learn that some people water their plants with orange juice as well as with water. The student wants to try this but doesn't know how often to use orange juice. The student starts an investigation. **Represent** the student's science question as a hypothesis.
- Explain** why it is best to present your data in table form.

11 Every year on her birthday, Enza has measured her height to see how much she's grown.

Represent the data in Table 1 as a graph, which shows how much Enza has grown in her first 8 years.

Table 1 Enza's growth from age 1 year to 8 years

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

12 Summarise why two scientists might compare their experimental results.

13 A scientist observed that as the temperature increased, the flowers on a rose bush started wilting and dropped off the bush. They drew a graph that showed a directly proportional relationship between the temperature and the three flowers on the rose bush. **Explain** why the scientist's observations of a single rose bush should not be extended to all rose bushes.

14 Describe the type of information that may be included in your logbook.

15 Explain why it is important to include in your logbook any changes you make to an experimental method.

16 A scientist conducted an experiment and did not keep a logbook. They were asked to prepare a formal report about their experiment as part of a request for further funding. **Explain** the problems the scientist will have when writing the report.

Analyse

17 Two students used two different balances to weigh some rock samples. Their results are in Table 2. **Calculate** the average weight of the rocks. Give your answer to the appropriate number of significant figures.

Table 2 Weight of rock samples

Rock sample number	Weight (g)
1	28.03
2	35.24
3	37.639
4	30.426

18 Calculate the mean, median and mode of the following set of data.

15, 13, 18, 16, 14, 17, 12, 13, 19

19 Contrast the independent variable and the dependent variable.

20 Differentiate between a directly proportional relationship and an inversely proportional relationship.

21 Contrast causation and correlation.

22 Compare parallax error and zero error.

23 Identify the number of significant figures in each of the following measurements.

a 65.301 g

b 0.006420 kg

c 40 L

24 A student recorded the results of an experiment in Table 3. **Identify** any errors in the table set up.

Table 3 The distance a marshmallow travelled when released from an elastic slingshot.

Distance marshmallow travels	Distance elastic stretched
93	4
55	3
38	2
12	1

25 Answer the following questions about the graph in Figure 2.

a Identify the label that should be on the x -axis.

b Identify the label that should be on the y -axis.

c Identify which year had the greatest number of road deaths.

d Identify the number of road deaths that occurred in 1965.

- e Describe** the trend between:
- 1945 and 1965
 - 1975 and 1985
 - 1990 and 2010.
- f Identify** one factor that could have caused the trend from 1985 to the current day.



Figure 2 A graph showing the number of road deaths from 1925 to 2010

Apply

Creative and critical thinking

26 Scientists often need to find new and creative ways to present the results of their experiments.

Propose two ways a scientist could publish information to the public. For each option, describe the audience they are trying to reach.

27 Scientists present formally written reports in scientific journals. Many of these reports must be examined (peer reviewed) by other scientists before they will be accepted for publishing.

Investigate and **discuss** one advantage of the peer review process.

28 Discuss why you think working in order from “retrieve” to “comprehend” to “analyse” and finally to “apply” type questions is beneficial for your learning.

Social and ethical thinking

29 When writing a report for a scientific journal, scientists will often mention the results of experiments from other scientists. If this work is a result of Aboriginal and Torres Strait Islander Peoples’ cultural practices, then the scientist is encouraged to use the CARE principles. Select one of the principles and **discuss** why it is important.

- **Collective benefit** – Using this data should provide benefit to Aboriginal and Torres Strait Islander Peoples.

- **Authority to control** – Aboriginal and Torres Strait Islander Peoples should have the right to control their data.
- **Responsibility** – Those using the data have the responsibility to engage respectfully with Aboriginal and Torres Strait Islander communities.
- **Ethics** – The ethics of Aboriginal and Torres Strait Islander Peoples should be used to minimise harm, maximise benefits and allow for future use.

Research

30 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.

Testing sticky tape

Design an experiment to test the strength of different types of sticky tape.

- **Identify** your independent variable.
- **Describe** how you will measure your dependent variable.
- **List** all the variables that could affect the results.
- **Describe** how you will control each of these variables.
- **List** the materials you will need.
- **Develop** a method in a step-by-step manner.



Figure 3 Rolls of sticky tape

Matilda effect

Historical science books are dominated by the discoveries of male scientists. The research of female scientists was often ignored or accredited to their male colleagues. This “Matilda effect” was first described by suffragist Matilda Joslyn Gage in 1870.

- **Investigate** the work of one of the following scientists: Jeanne Baret (1740–1807), Marian Diamond (1826–2017), Nettie Stevens (1861–1912) or Rosalind Franklin (1920–1958).
- **Describe** the work that they did, what they discovered and who received credit for their work.



Figure 4 Matilda Joslyn Gage

Aboriginal and Torres Strait Islander knowledge

Aboriginal and Torres Strait Islander Peoples of Australia have used their experiences to identify plants that can be used for food or medicines. This knowledge has been shared with other Australians, who are investigating producing these plants in commercial (large) quantities for sale.

- **Propose** who should be recognised for these scientific discoveries.
- **Justify** your decision by explaining how each group (Aboriginal and Torres Strait Islander Peoples or European owners of companies) contributed to the research, production and sale of a product such as Kakadu plum foods and beauty products.
- **Propose** how the contributors could be recognised.



Figure 5 Kakadu plum (*Terminandia ferdinandiana*)

Module

2

The rock cycle



Overview

The world around us is constantly changing. Some changes are so slow that they can be difficult to see. The rock cycle can be very slow and includes the processes of weathering, erosion and heat. Heat and forces shape the rocks, and fossils can help our understanding of when rocks were formed. Our understanding of rocks and their properties influences how we can use them effectively.



Learning intentions
and success criteria



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

Lesson 2.1

Rocks have different properties

Key ideas

- Geologists are scientists who study rocks.
- The characteristics of rock include the colour, presence of layers, hardness, density and crystal size.

Introduction

rock a naturally occurring solid substance that is made up of one or more minerals

properties in chemistry, the characteristics or things that make a substance unique

geologist a scientist who studies the physical structure and history of Earth

Rocks don't all look and feel the same. Each rock has characteristics that give clues to its identity, such as its colour or hardness. These characteristics are referred to as **properties**. By making careful observations of a rock's properties, **geologists** (scientists who study rocks) can tell where a rock came from and what has happened to it.

Identifying and selecting rocks

Rocks are used for particular purposes because of their properties. For example, granite is selected for kitchen benchtops because it is the hardest building stone, it is not porous (it does not let liquid through), it is not affected by temperature and it is resistant to damage from chemicals.

Aboriginal and Torres Strait Islander Peoples use their knowledge of the properties of rocks to make tools. For example, abrasive rock, such as sandstone, is used to grind seeds and other plant material.

You can identify rocks first by how they look. Coal is black or dark brown. Pumice and scoria are covered with holes. Each rock is made up of tiny grains or crystals called **minerals**. These minerals have unique properties that can determine the properties of the rock. Granite is made up of large crystals of the minerals quartz, mica and feldspar. This can make it very hard. Other rocks can break off in layers of minerals. Some, like conglomerates, are made up of individual stones cemented together.

Geologists also use a range of other properties to help identify rocks, such as layering, weight and the presence of crystals or grains (Figures 1 to 5). The properties of rocks can be used in a key, such as a **dichotomous key**, to identify and classify rocks.

Table 1 lists some different types of rocks and how they can be identified.

mineral naturally occurring elements or compounds

dichotomous key a diagram used in classification; each "arm" of the key contains two choices

Table 1 Rock identification

Rock	Grain size	Hardness	Usual colour	Density
Basalt	Fine or mixed	–	Dark	2.8–3
Coal	Fine	Soft	Dark	1.3
Conglomerate	Mixed	Hard or soft	–	–
Gneiss	Coarse	Hard	Alternating light and dark bands	2.3–2.6
Granite	Coarse	Hard	Light	2.6–2.7
Limestone	Fine	Soft	Light	2.3–2.7
Marble	Coarse	Soft	Light	2.4–2.7
Obsidian	Fine	Medium	Dark	2.6
Pumice	Fine	Soft	Light	0.6
Quartzite	Coarse	Hard	Light	2.6–2.8
Rhyolite	Fine	Hard	Light	2.4–2.6
Sandstone	Coarse	Hard	Light	2.2–2.8
Schist	Medium to coarse	Medium	Medium	2.5–2.9
Scoria	Fine	–	Dark	0.9
Shale	Fine	Soft	–	2.4–2.8
Slate	Fine	Soft	Dark	2.7–2.8



Figure 1 **Weight and density** are less if rocks contain large gas holes that were produced when the rock was formed. In pumice, the holes can be the size of a match tip or smaller. In scoria the holes are often the size of a pea.



Figure 2 **Layers** in rocks can look very different. Some rocks have different-coloured layers that line up like ribbons. Gneiss usually has alternating layers of colours, often black and white. Sandstone has layers of different-sized grains of sand. Wind or water distributes the sand so that the rock ends up being different shades of the same colour.



Figure 3 **Colour** is a property that depends on the chemicals in the rocks. For example, some red rocks contain a lot of iron, which has reacted with oxygen in the air (“rusted”) to form red iron oxide. Other red rocks don’t contain iron, so a rock cannot be identified solely by its colour.



Figure 4 Crystals are small pieces of organised particles that have smooth sides and sharp edges. They are usually just one colour and often reflect light off their flat surfaces. Crystals in a rock can be different sizes.



Figure 5 Grains are small pieces of material. The size of the grain can be used to identify the type of rock. Large grains (larger than a grain of rice) are said to be coarse. Smaller grains that can still be seen with the eye are medium grained. Fine grains cannot be seen without a microscope.

Check your learning 2.1



Check your learning 2.1

Retrieve

- 1 Recall** the branch of science that is the study of rocks.
- 2 Name** the properties that are used to identify different types of rocks.

Comprehend

- 3 Explain** why properties other than colour should be used to identify a rock.

Analyse

- 4 Use** Table 1 and Figure 6 to **identify** the rocks in the following descriptions.
 - a** I am light in colour with a fine grain. I am considered soft.
 - b** I am light in colour with holes in the surface.
 - c** I am soft, shiny and dark in colour. I am often used for flooring.
 - d** I have mixed grains and my colour can vary.

Apply

- 5 Investigate** different uses for three rock types of your choice.
- 6 Determine** whether pumice would be an appropriate material for a kitchen bench (by describing the properties needed for a kitchen bench and comparing these properties to the properties of pumice).



Figure 6 Some of the many different types of rocks

Skills builder: Planning investigations

7 A student was conducting an investigation about the properties of different rocks. They collected a piece of coal, pumice, sandstone and scoria. They then placed them in a large

bucket of water and observed which floated and which sunk. **Suggest** a question the student might be investigating. (THINK: What property were they trying to observe? Can you identify the independent and dependent variables in this investigation?)

Lesson 2.2**Challenge: Identifying rocks****Aim**

To use a key to identify different types of rocks

What you need:

- Rock samples (unnamed, perhaps labelled A, B, C, D etc.)
- Hand lens
- Dichotomous key (Table 1)

What to do:

- 1 Examine each rock sample with the hand lens and use the key in Table 1 to identify it. Be aware of the following.
 - Crystals in rocks have straight edges and flat, shiny surfaces.
 - Grains are not shiny, they are jagged or rounded and more like grains of sand.
 - Coarse grains are about the size of a grain of rice. Medium grains are smaller but still visible to the naked eye and small grains are only visible with a hand lens or magnifier.
- 2 Construct a table to record your results, identifying the rock sample (e.g. sample A), its main properties and its name.

Table 1 A dichotomous key for common types of rocks

1	Does the rock have layers? (Use a magnifying glass to check.)	Yes – Go to 3; No – Go to 2
2	Can you see cracks in the rock?	Yes – Go to 4; No – Go to 5
3	Can sand be rubbed off the rock?	Yes – Sandstone; No – Go to 8
4	Is the rock a light colour (i.e. mostly white)?	Yes – Marble; No – Go to 10
5	Does the rock look like glass?	Yes – Obsidian; No – Go to 6
6	Does the rock have a lot of holes that make it light to hold?	Yes – Pumice; No – Go to 7
7	Is the rock grey to black?	Yes – Basalt; No – Limestone
8	Can you see crystals in the rock?	Yes – Gneiss; No – Go to 9
9	Can you see layers of thin, flat pieces of rock? Could the rock be split easily?	Yes – Slate; No – Quartz
10	Does the rock have a lot of holes that make it light to hold?	Yes – Pumice; No – Granite

**Figure 1** Rocks can be identified using a dichotomous key.

Questions

- 1 **Describe** any difficulties you had when identifying your rock samples. Make a note of any samples that you could not identify.
- 2 **Compare** your results with those of another group. **Identify** any differences between your results and the other group's.
- 3 **Discuss** one error or assumption (something you thought was true but was not) that you might have made that could have changed the way you identified the type of rock.
- 4 Ask your teacher for the names of your rock samples and highlight the rocks that you correctly identified (hopefully all of them).

Lesson 2.3

Igneous rocks develop from magma and lava



Learning intentions and success criteria



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

Key ideas

- Magma (hot liquid rock) flows deep beneath Earth's surface.
- When the magma moves above Earth's surface it is called lava.
- Igneous rocks form when magma and lava become solid.

Introduction

Rocks are broadly classified according to how they are formed. The three main types of rocks – igneous, sedimentary and metamorphic – form in different ways. **Igneous rocks** form when the magma and lava from volcanic eruptions cool and solidify.

igneous rock rock formed by cooling magma and lava

Magma and lava

The term “igneous” comes from the Latin word *ignis*, which means “fire”. The hot, molten rock inside the Earth is called **magma** and its temperature can be more than 1200°C. The magma chamber under a volcano is the source of molten rock for the volcano (Figure 1).

magma semi-liquid rock beneath Earth's surface

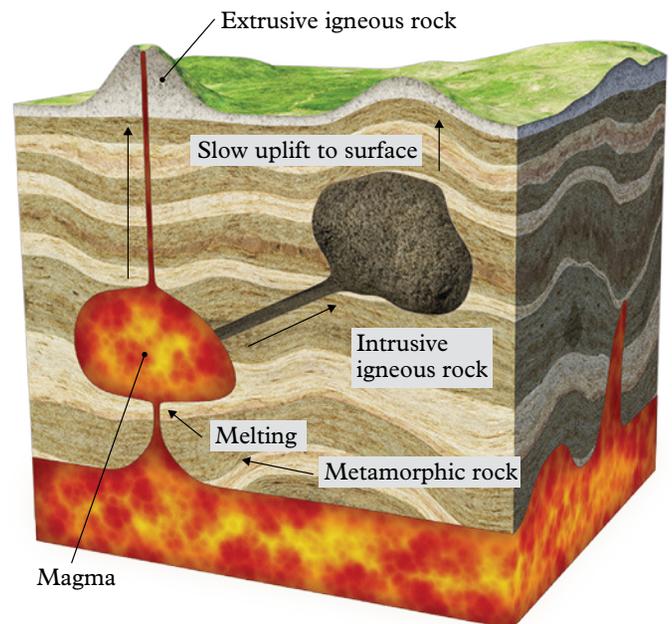


Figure 1 Igneous rocks are formed from volcanic magma.

In a volcanic eruption, the red-hot magma rushes out onto the surface of Earth as **lava**.

The cooler conditions at Earth's surface help to solidify the lava quickly. Igneous rocks also form from magma under the ground. These igneous rocks look quite different from those formed on Earth's surface because they cool much more slowly.

lava hot, molten rock that comes to the surface of Earth in a volcanic eruption

Intrusive igneous rocks

Intrusive igneous rocks form slowly beneath the surface of Earth when magma becomes trapped in small pockets. These pockets of magma cool slowly underground (sometimes for millions of years) to form igneous rocks. The longer it takes for lava to cool, the bigger the rock crystals that grow. Intrusive igneous rocks have large crystals locked together. Granite is an intrusive igneous rock in which the crystals can be seen with the naked eye (Figure 2). Although formed underground, intrusive igneous rocks reach Earth's surface when they are either pushed up by forces in Earth's crust or uncovered by erosion.



Figure 2 Granite is an intrusive igneous rock.

intrusive igneous rock rock formed underground by slowly cooling magma

Extrusive igneous rocks

Lava cools much more quickly on the surface of Earth. This causes it to form **extrusive igneous rock**. Because the lava is cooling more quickly than the magma underground, the crystals are smaller. Sometimes, the lava cools so quickly that no crystals are formed. For example, pumice has no crystal structure. Pumice forms when hot, gas-filled lava cools very quickly. The many tiny holes in pumice are formed by volcanic gases escaping from the cooling lava.

extrusive igneous rock rock formed at Earth's surface by quickly cooling lava

Pumice has so many holes that it is extremely light and can float on water (Figure 3). Pumice stones are used to scour hard skin from feet, and powdered pumice is found in some abrasive cleaning products.

Obsidian is a smooth, black rock that looks like glass (Figure 4C). It is formed almost instantly when lava cools and forms no crystals. Obsidian is used to make blades for surgery scalpels; the resulting blades are much sharper than those made from steel.



Figure 3 Pumice contains many holes that make it light enough to float on water.

The different forms of basalt

Magma can solidify into many different igneous rocks, which can vary in appearance. This is because of how igneous rocks form and the minerals they contain.

Basalt is the most common type of rock in Earth's crust. Most of the crystals in basalt are microscopic or non-existent because the lava cools so quickly that large crystals do not form.

We commonly think of basalt as the building product bluestone (Figure 4A). Aboriginal and Torres Strait Islander Peoples also use the hard basalt with strong tensile strength in the production of stone axes. Basalt can look different depending on the type of volcanic eruption that produced it and how quickly it cooled.

Scoria is a type of basalt that is full of bubble holes (Figure 4B). The lava was filled with gases when it began to cool and the holes in the scoria are where the gas bubbles once were. Scoria is a light rock that is often used for garden paths and as fill in drainage trenches.



Figure 4 Basalt comes in different forms: (A) bluestone and (B) scoria. Obsidian (C) has a higher level of silica than basalt.

Check your learning 2.3



Check your learning 2.3

Retrieve

- 1 **Define** the term “igneous”.
- 2 **Name** the type of rock that is produced by magma that cools deep below Earth's crust.
- 3 **Recall** an igneous rock that would float on water.

Comprehend

- 4 **Describe** how igneous rocks form.
- 5 The ancient civilisations that discovered obsidian had a competitive advantage over those who didn't. **Explain** a possible advantage of obsidian rock.

Analyse

- 6 **Contrast** (the differences between) the properties of intrusive and extrusive igneous rocks.

- 7 **Consider** the ways humans use these rocks and how their properties are important for their uses.

Skills builder: Processing and analysing information

- 8 In this topic you have learnt about different types of igneous rocks, including pumice, obsidian, scoria and basalt. **Construct** a table to clearly organise the information found in this topic about the properties of pumice, obsidian, scoria and basalt. (THINK: What information do you have and how can you group it?) Remember that a table should always have a heading and that columns should have labels.

Lesson 2.4

Experiment: What affects crystal size?

Aim

To grow crystals and determine what affects their size

Materials

- Alum
- Tablespoon
- Hot water
- 250 mL beaker
- Evaporating dish
- 2 Petri dishes
- Tripod
- Bunsen burner
- Heatproof mat
- Gauze mat
- Matches
- Safety glasses

Method

- 1 Prepare a solution of alum by mixing $2\frac{1}{2}$ tablespoons of alum with 120 mL of hot water in the beaker. Stir until the alum is dissolved.
- 2 Pour roughly equal amounts of alum solution into the evaporating dish and the two Petri dishes.
- 3 Put one of the Petri dishes in the refrigerator.
- 4 Put the other Petri dish on a window sill.
- 5 Place the tripod and the Bunsen burner on the heatproof mat. Place the gauze mat and then the evaporating dish on top of the tripod.
- 6 Safely light the Bunsen burner and move it under the tripod on the heatproof mat.

Close the collar on the Bunsen burner to produce a yellow (safety) flame.

- 7 While wearing safety glasses, gently heat the evaporating dish containing the alum solution over the yellow flame. The yellow flame is cooler and will allow for gentle boiling.
- 8 Continue heating the solution until nearly all the water has evaporated. Stand back from the evaporating dish and the solution while heating as the solution may spit and splatter.
- 9 Observe the size of the crystals formed in the evaporating dish. Turn off the gas when the water is almost gone and allow to cool. Store the crystals in a cool, dry place.
- 10 After 2 days, compare the size of the crystals formed by heating quickly to the crystals formed slowly on the window sill.
- 11 Observe the crystals formed in the refrigerator again after 4 or 5 days.

Results

Draw a labelled diagram of the crystals formed in the evaporating dish and in the two Petri dishes. Your diagram needs to show the different sizes of the crystals in the different dishes.

Discussion

- 1 **Identify** the independent variable for this experiment.
- 2 **Identify** the dependent variable.
- 3 **Name** three variables you needed to control. How were these controlled?
- 4 Each of these crystals grew over a different time span. **Describe** how allowing the

crystals to form slowly affected the size of the crystal.

- 5 **Compare** the results of your crystals to those grown by others in your class.
Describe the largest and smallest crystals formed.
- 6 **Identify** any factors that could explain any variation in the crystals formed.

Conclusion

Describe what you learnt about the factors affecting crystal size.



Figure 1 Different factors can affect the size of a crystal.



Learning intentions and success criteria



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

Lesson 2.5

Sedimentary rocks are compacted sediments

Key ideas

- Sedimentary rocks are formed from compacted particles or sediment.
- Stalactites and stalagmites are forms of sedimentary rock.

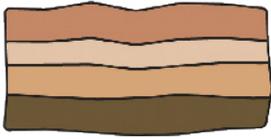
Sediments

Sediments are rock particles such as mud, sand or pebbles, which are usually washed into rivers and eventually deposited on the riverbed or in the sea. Sediment can be as small as a grain of sand or as large as a boulder. The particles can be moved by water, wind or moving ice (glaciers). This process is called **erosion** and is important in moving nutrients from one area to another.

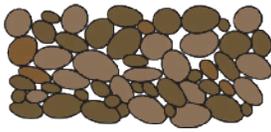
erosion water, wind, and other natural forces causing rocks and earth to wear away

Sedimentary rocks

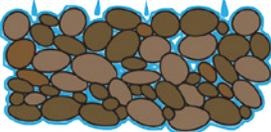
Over thousands or even millions of years, sediments form thick layers on the riverbed or sea floor. Pressure from the overlying sediments and water forces out air and any gaps in the bottom layer. Over time, the pressed-together (compacted) sediments become sedimentary rocks (Figure 1).



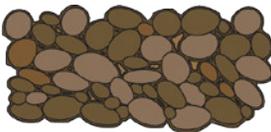
Sediments are deposited in layers called beds.



The grains of sediment in lower layers begin to squish together.



Chemicals that are dissolved in the water can soak into the sediments.



The chemicals help cement the grains together once the water has evaporated.

Figure 1 The formation of sedimentary rocks.

The names of some sedimentary rocks are clues to the sediments that formed them – sandstone, mudstone, siltstone and conglomerate are all types of sedimentary rock (Figure 2). Sandstone is made up of sand deposited in environments such as deserts and beaches (Figure 3). The word “conglomerate” means “gathered into a ball”. Conglomerate is a mixture of all sizes of rocks that have become cemented together (Figure 4).



Figure 2 Shale (or mudstone) is the most common sedimentary rock. Shale is a fine-grained sedimentary rock made up of clay minerals or mud.



Figure 3 Sandstone is a popular building material because it is strong and durable but also soft enough to easily carve. This ancient temple of Abu Simbel in Egypt was carved directly into the sandstone rock.

Biological rocks

Sedimentary rocks are not always formed from the sediments of minerals or other rocks. The remains of living things also break down and are deposited as sediments. Shells and hard parts of sea organisms break down and are deposited in layers on the ocean floor. Eventually, they become cemented together under pressure to form limestone.

The compaction of dead plant material can also help to form sedimentary rocks. For example, coal is formed from dead plants that were buried before they had completely decayed (Figure 5). Compression forces from the layers above can change the plant material into coal or oil.

Chemical rocks

Chemical sedimentary rocks form when water evaporates, leaving behind a solid

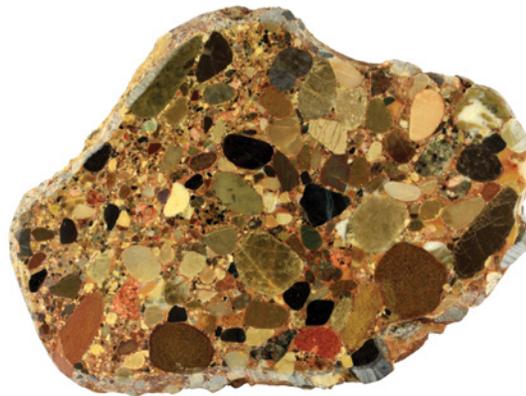


Figure 4 Conglomerate rocks have grains of different sizes.



Figure 5 When dead plant matter is buried before decomposing, it forms coals over millions of years.

substance. When seabeds or salt lakes, such as Lake Eyre in South Australia, dry up, they leave a solid layer of salt behind. If the layer of salt is compressed under the pressure of other sediments, it may eventually form rock salt.

Cave formations

When groundwater passes over limestone, it can dissolve calcium carbonate from the limestone. When the water evaporates, it leaves behind the calcium carbonate. Various rock formations in caves are formed by this method.

The amazing long strands of rock found on cave floors and ceilings are composed of calcium carbonate from the limestone ceiling of the cave. A stalagmite grows from the floor towards the ceiling (they “might” reach the ceiling one day) and a stalactite grows down from the ceiling (they hold on “tight”) (Figure 6). If these formations meet in the middle, they form a column.

Stalagmites and stalactites form when limestone rocks are dissolved by acids in water. The acid and dissolved limestone form a solution that drips through the ceiling of the cave and is deposited on the stalagmites and stalactites, gradually increasing their width and length.

It is important that visitors to limestone caves do not touch the stalactites and stalagmites because they are generally still forming. Oil from skin can interfere with stalagmite and stalactite formation.



Figure 6 Stalagmites and stalactites form in limestone caves.

Ochre

Ochre is one of the sedimentary rocks most valued by Aboriginal and Torres Strait Islander Peoples in Australia. It is valued for its high shine that generates a shimmering effect in the light of a fire. It is used in body paint, rock paint and on artwork. There are six colours of ochre, from yellow to deep orange or brown. Aboriginal and Torres Strait Islander Peoples have mined and traded sedimentary ochre for thousands of years. Wilgie Mia in Western Australia is 20 metres underground and is the world’s oldest continuous mining operation (Figure 7). This 27,000 to 40,000-year-old mine used pole scaffolding to prevent the mine from collapsing on the miners while thousands of rocks were removed to reach the ochre.



Figure 7 Wilgie Mia ochre mine.

Check your learning 2.5



Check your learning 2.5

Retrieve

- 1 **Recall** how sedimentary rocks form.
- 2 **Name** three different sedimentary rocks.
- 3 **Recall** how stalactites and stalagmites form.

Comprehend

- 4 **Explain** the link between plants and coal.

Analyse

- 5 **Compare** (the similarities and differences between) the formation of biological and chemical sedimentary rocks.
- 6 **Infer** why sandstone is often used for carving statues.

Apply

- 7 A student claims that sandstone is made up of sand. **Evaluate** their claim (by explaining

how sandstone is formed and using this to decide whether the claim is correct).

Skills builder: Communication

- 8 Imagine that you needed to explain how conglomerate rocks were formed to somebody who had never heard about rocks before. **Construct** a diagram to explain how conglomerate rocks are formed and include labels to **describe** the process. (THINK: What do they need to know about rocks to understand? How can you use the diagram to help?)

Lesson 2.6

Experiment: Making sedimentary rocks

Aim

To make small samples of sedimentary rocks and compare them against real samples

Materials

- Dry clay
- Mortar and pestle
- Teaspoon
- Samples of sedimentary rocks
- White tile

- Dry sand
- Plaster of Paris
- Small, smooth pebbles
- Water
- 4 empty matchboxes

Method

- 1 Grind a lump of dry clay with a mortar and pestle until it is fine and powdery.
- 2 Using the teaspoon, mix the dry ingredients for each rock sample on the white tile

according to the recipes in Table 1, but don't add the water just yet. You will need to prepare two shale samples to use in Lesson 2.8 Experiment: Making a metamorphic rock (page 90).

- 3 Pile up your ingredients into a little hill and make a small dip in the centre for the water.
- 4 Slowly add the water and stir until the ingredients are uniformly mixed. Be careful not to make the mixture too wet.
- 5 Press your mixture into an empty matchbox, label it with the rock type and your name and leave it to dry for 2 days.
- 6 When your "rock" is dry, peel off the matchbox and examine your sample. Take photos of your samples and photos of the "real" rocks for comparison. Keep your two shale samples for Lesson 2.8 Experiment: Making a metamorphic rock (page 90).

Table 1 Sedimentary rock experiment

Rock	Number of teaspoons				
	Dry Clay	Sand	Plaster of Paris	Pebbles	Water
Sandstone	½	4	½	0	2
Shale	5	½	0	0	2
Conglomerate	½	1	½	4	2



Figure 1 Sedimentary rock cliffs

Results

Include photos of your rocks in your results.

Describe what your rocks look like using the terms in Table 1 in Lesson 2.1 Rocks have different properties (page 75).

Discussion

- 1 **Describe** how sedimentary rocks are formed.
- 2 **Explain** how fossils are formed in sedimentary rocks.
- 3 **Compare** (the similarities and differences between) your rocks and other sedimentary rocks you have seen.

Conclusion

Describe the characteristics that are unique to sedimentary rocks.

Lesson 2.7

Metamorphic rocks require heat and pressure

Key ideas

- Rocks deep underground experience high pressure.
- High pressure generates high temperatures.
- High pressures and temperatures cause the rearrangement of minerals to form metamorphic rock.



Learning intentions and success criteria



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

Introduction

Metamorphic rocks are formed when other types of rock are changed by incredible heat and pressure inside Earth (Figure 1). When igneous, sedimentary or even metamorphic rocks are heated to extreme temperatures by magma, or when they are placed under extreme pressure from the layers of rocks above them, they can change into different types of rock. For example, limestone changes to marble (Figure 2).

metamorphic rock rock formed from other rock due to intense heat and pressure

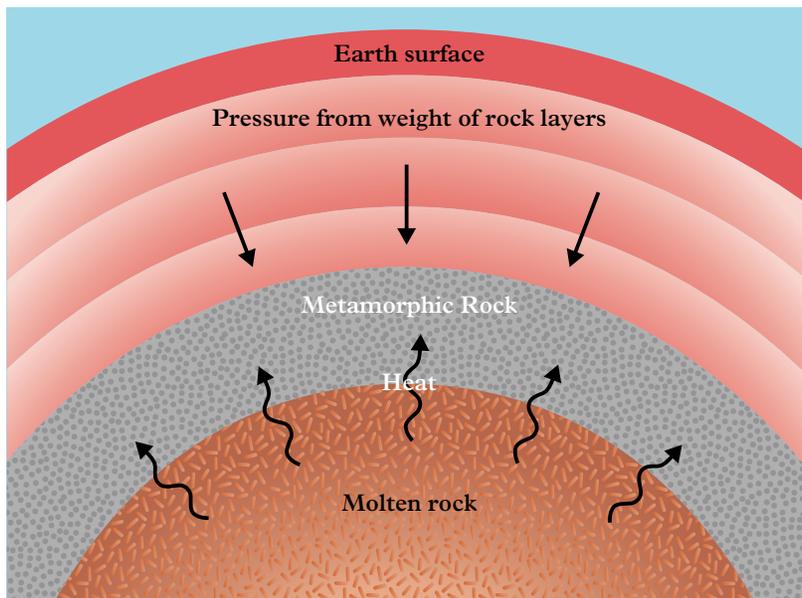


Figure 1 Metamorphic rocks are formed when other types of rock are exposed to extreme heat and pressure.



Figure 2 The Taj Mahal in India is made of marble, the metamorphosed form of limestone. With its dense composition and beautiful patterns, marble is a popular material for sculptures and kitchen benchtops.

Change in appearance

The combination of high temperatures and pressures causes differences in the appearance of metamorphic rocks. (Metamorphism means “change in form”.) As you go deep underground, the temperature gradually increases. Miners in South Africa’s West Wits minefield, who work up to 3.9 km below ground, report temperatures up to 60°C. Temperatures can get much higher anywhere magma intrudes.

foliation layering in a rock that occurs when the rock is subjected to uneven pressure

index mineral a mineral that only forms at a particular temperature and pressure; used to determine the history of the rock that contains the mineral

The pressure of the earth above the rock also contributes to the different appearance of metamorphic rocks. Bands can occasionally be seen in metamorphic rocks formed under high pressure. If the pressure is uneven, the rock crystals can twist. This is called **foliation** (Figure 3).

Change in minerals

Metamorphic rocks also change chemically. Some metamorphic minerals (sillimanite, kyanite and garnet) only form at high temperatures and pressures. They are called **index minerals** because they can tell us the history of what happened to the minerals in the rock – the temperature and pressure they were exposed to.

Other minerals, such as quartz, can withstand high temperatures and pressures and can sometimes be found in metamorphic rocks. The heat and temperature can cause some crystals to change their size and shape. Recrystallisation occurs when the crystals are squeezed together so tightly that they partially melt and form fewer, but larger, crystals. For example, when granite is squeezed under high pressure, the crystals change and the rock gneiss is formed (Figure 4). This can affect how metamorphic rocks are used.

Metamorphic rocks are stronger than the original material because the particles have been fused together under great pressure or heat. This strength made rocks such as quartzite useful to Aboriginal and Torres Strait Islander Peoples for producing grindstones and millstones (Figure 5). The rough surfaces of the stones made it easier to produce flour from different seeds. The Bama people of northern Queensland, however, cut ridges in smooth slate so that the rough surface could be used to grind toxic cycad kernels. Grinding the kernels with water releases the toxins and makes the kernels safer to eat.

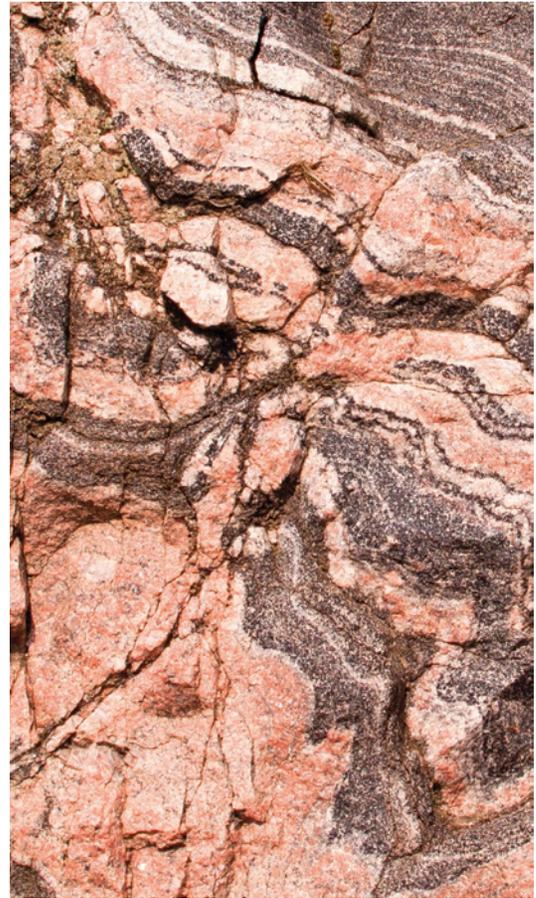


Figure 3 Foliation occurs when rock is subjected to uneven pressure.



Figure 4 (A) When granite, an igneous rock, is subjected to high heat or pressure, it can change into the metamorphic rock known as gneiss. (B) The bands on gneiss show that the crystals have been squeezed together under immense pressure.



Figure 5 A quartzite grindstone used by Aboriginal and Torres Strait Islander Peoples

The Bama people knew that slate, which absorbs little water, would not absorb the toxins from the ground kernels, making the tools safe to use again.

The Wurundjeri Woi Wurrung people also mined metamorphic rocks. They were responsible for a greenstone quarry in the Mount William area in the Grampians in the 1800s. Many other Aboriginal and Torres Strait Islander Peoples travelled to the area to barter for the prized greenstone that was used for stone hatchets.

Check your learning 2.7



Check your learning 2.7

Retrieve

- 1 **State** where metamorphic rocks are formed.

Comprehend

- 2 **Describe** how metamorphic rocks are formed.
- 3 **Describe** a foliated rock.
- 4 **Explain** why quartzite is useful for a grindstone.

Apply

- 5 A student claimed that a rock had to be igneous because it had quartz crystals. **Evaluate** their claim (by explaining how quartz crystals are formed and using this to decide whether the claim is correct).

- 6 **Identify** which type of rock is stronger: sandstone or marble. **Justify** your answer (by explaining how each rock is formed, linking this to its properties and deciding which is stronger).

Skills builder: Problem solving

- 7 A builder was asked to choose between slate or pumice as a building material for the floor of a house.
 - a **Identify** the advantages and disadvantages of using pumice and slate. (THINK: What are the properties of both materials? How would these properties impact on their function as a flooring material?)
 - b **Identify** which option you think is best.

Lesson 2.8

Experiment: Making a metamorphic rock

Aim

To make a sample of a metamorphic rock

Materials

- 2 shale rock samples from Lesson 2.6 Experiment: Making sedimentary rocks (page 85)
- Tripod
- Bunsen burner
- Heatproof mat
- Gauze mat
- Pipe clay triangle
- Matches
- Evaporating dish
- Heatproof gloves
- Tongs
- 2 × 250 mL beakers
- Water

Method

- 1 Allow your shale samples from Lesson 2.6 Experiment: Making sedimentary rocks (page 85) to dry for approximately 1 week.
- 2 Place the tripod and the Bunsen burner on the heatproof mat. Place the gauze mat and then the pipe clay triangle on top of the tripod. Place one of the shale samples on the pipe clay triangle. The second shale sample will not be heated.
- 3 Safely light the Bunsen burner and move it under the tripod on the heatproof mat. Open the collar on the Bunsen burner to produce a blue flame.
- 4 Strongly heat the shale sample for about half an hour. You could place an evaporating dish upside down over the shale to retain more heat.
- 5 After about 30 minutes of heating, turn off the Bunsen burner and allow the sample to cool for 10 minutes.
- 6 Put on the heatproof gloves and use the tongs to carefully pick up the shale sample and drop it into a beaker of water.
- 7 Drop the second, unheated shale sample into another beaker of water and observe what happens to the two rock samples.

Results

Construct a table to record your observations.

Discussion

- 1 **Contrast** (the differences between) the two rock samples when they are dropped into the water.
- 2 **Explain** how strong heat can change the properties of rocks over time.
- 3 **Compare** (the similarities and differences between) your new metamorphic rock sample with the original shale sample.

Conclusion

Describe what you know about the formation of metamorphic rocks.



Figure 1 Metamorphic rock

Lesson 2.9

The rock cycle causes rocks to be re-formed

Key ideas

- Weathering is the breaking down of rocks and minerals through the movement of water and animals, and extremes of temperature.
- Erosion is the movement of the sediment to another area.
- The rock cycle describes the formation of sediment and sedimentary rock, compression to metamorphic rock, melting and solidification to form metamorphic rock.



Learning intentions and success criteria



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

What is the rock cycle?

The **rock cycle** is an ongoing process that describes the formation and destruction of the different rock types (Figure 1). Each part of the rock cycle can take up to 20 million years.

rock cycle the process of formation and destruction of different rock types

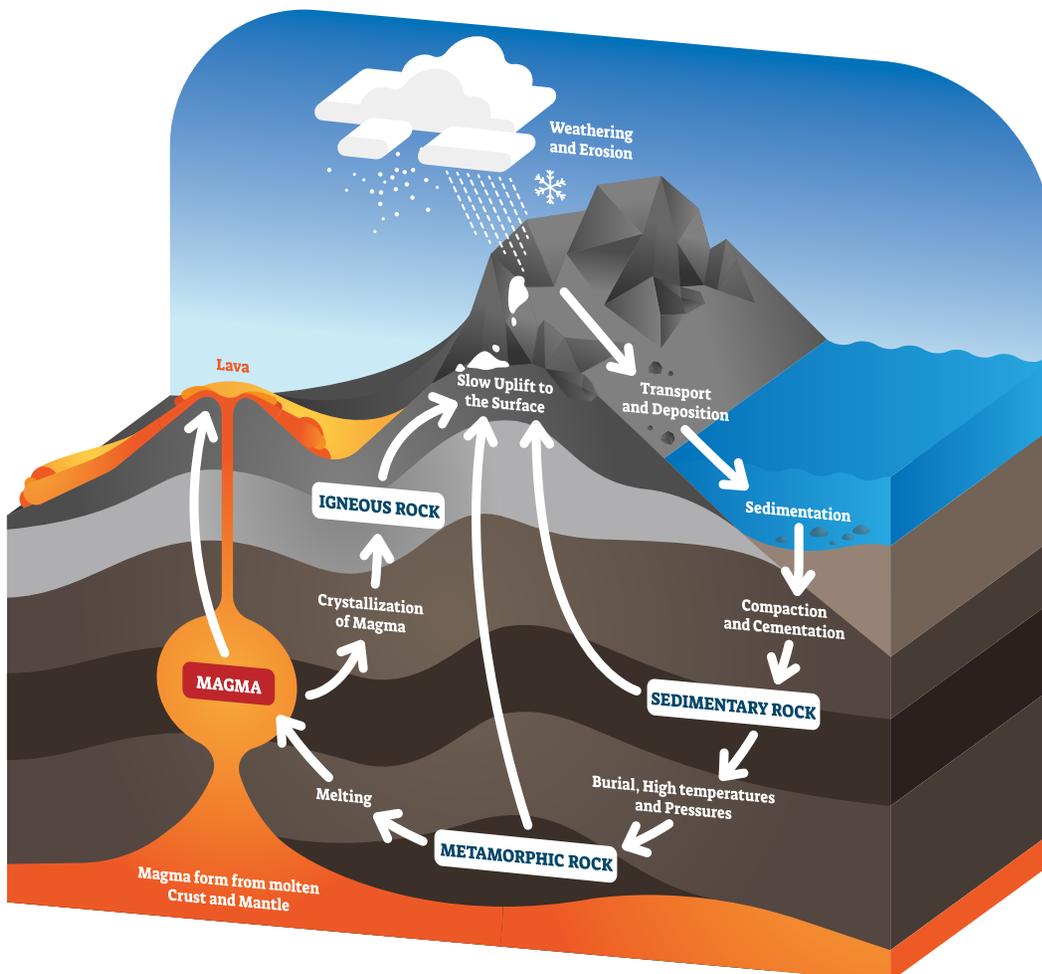


Figure 1 The rock cycle

Physical weathering

Mechanical, or physical, weathering occurs when a physical force is applied to a rock. It includes the breakdown of rocks by non-living things.

In a flowing river, the water is constantly moving over the rocks and stones on the river bed. Sometimes small particles of sand move with the water, rubbing against any rough surfaces on the rocks. This process of water and small particles wearing away rock is called **abrasion**. It can be similar to sandpaper on wood, rubbing away the rough edges of the rocks, making them smooth (Figure 2A).

In desert areas, the days are very hot and the nights are freezing cold. This daily heating and cooling affects only the outside of the rock. This is because rocks do not conduct heat very well. Sometimes the outside of the rock can peel off, just like an onion skin. This process is called **onion-skin weathering** and the round rocks produced in this way are called **tors** (Figure 2B).

When water freezes at night, it expands and takes up more space. When water freezes in the crack of a rock, it expands and pushes hard against the rock around it. This can make the crack larger. When the ice melts during the warmer day, water fills the crack again. The next night, ice forms again and makes the crack even larger. This process is repeated many times until part of the rock is split off. This process is called **frost shattering** (Figure 2C).

abrasion the process of wearing away a surface caused by friction between particles; a type of physical weathering of rock

onion-skin weathering weathering of rock where the outside of the rock peels off

tor a large, round rock produced by onion-skin weathering

frost shattering a process of weathering in which repeated freezing and melting of water expands cracks in rocks, so that eventually part of the rock splits off

Chemical weathering

Chemical weathering changes the minerals in rocks. Carbon dioxide in the air mixes with the water to form a weak acid rain (a much weaker acid than vinegar). When this acid rain falls on rocks such as limestone, a chemical reaction changes the minerals in the rock and the minerals are washed away (eroded). You can see evidence of this type of weathering in old statues (Figure 3).

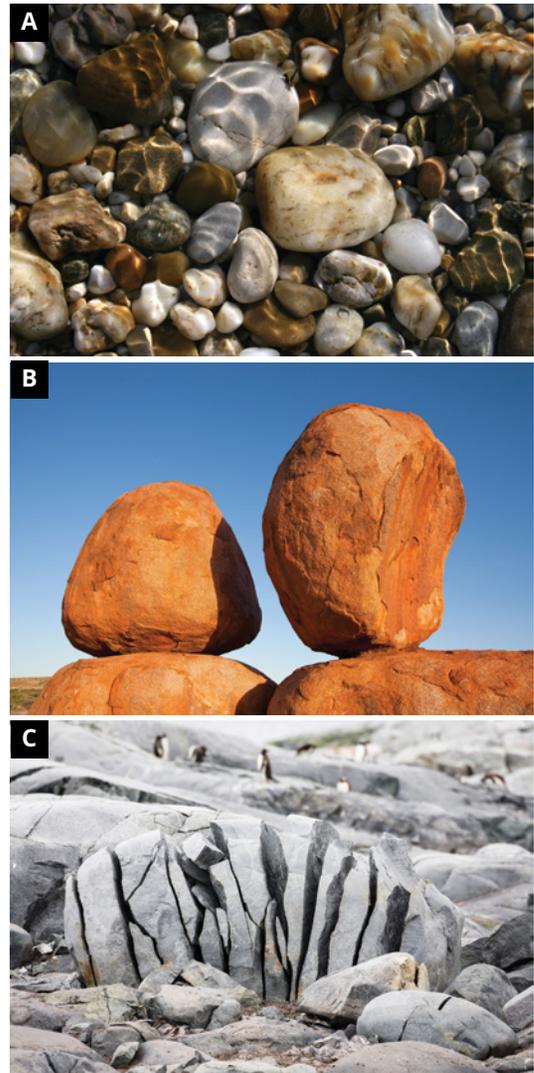


Figure 2 Physical weathering can include (A) wearing away by water (abrasion), (B) onion-skin weathering and (C) frost shattering.



Figure 3 Chemical weathering can be caused by acid rain.

Biological weathering

Biological weathering can start with a seed falling into a crack in the rock. Soil and water in the rock encourage the seed to grow. As the roots grow, they push on the cracks in the rock, eventually causing the rock to break (Figure 4).

Deposition

Over time and during the process of weathering, large rocks are broken down into smaller rocks, which are broken down into sediment. The sediment is eroded and carried by wind and water to an area where it accumulates in layers. Over time, many different layers of sediment from the different forms of weathering are built on top of each other. This process is called **deposition**. Gradually, the sediment becomes buried under many layers, re-forming as sedimentary rock.

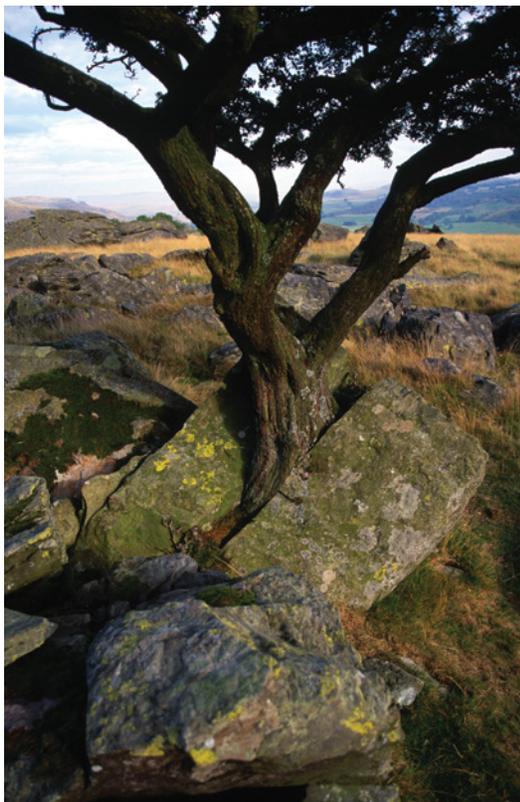


Figure 4 Biological weathering can be caused by plant roots.

deposition the process whereby sediment from different forms of weathering accumulates in layers

Heat and pressure

As more layers form on top of the sedimentary rock, it is put under pressure from the heavy top layers. Over time, the layers sink deeper, putting even more pressure on the deep layers. This can cause the rocks to heat up. Increased temperature and pressure cause physical and chemical changes in the rock, transforming it into metamorphic rock. If the temperature continues to rise, the rock will melt, turning it into its liquid form, magma.

Magma is also put under great pressure, causing it to seek any available space. Gradually it makes its way to the surface where it can cool as igneous rock. Over time, the rock is uplifted and exposed to wind and water. The cycle continues.



Figure 5 The rock cycle can lead to rocks being smoothed by wind and water.

Check your learning 2.9



Check your learning 2.9

Comprehend

- 1 **Describe** how tors are formed.
- 2 **Describe** the process of frost shattering.
- 3 **Describe** the different stages in the rock cycle. Use the rock cycle diagram in Figure 1 to assist you.

Analyse

- 4 Use a table to **compare** (the similarities and differences between) physical, biological and chemical weathering.
- 5 **Contrast** (the differences between) weathering and erosion.

Apply

- 6 **Create** a story about the “life of a rock”. Rocks change with time, as do humans. However, unlike humans, rocks are never truly “born”, nor do they “die” – they can

move through the rock cycle, covering the same stage many times in many different ways. **Describe** the life that your rock experiences. Remember to include the length of time that each step of the process takes.

Skills builder: Planning investigations

- 7 A student was asked to write a report during a double period about the effect of weathering on landforms in New South Wales.
 - a **Propose** the type of information the student should collect to complete the report on time. (THINK: Should the student design their own experiment to collect first-hand data? Or should they collect data using secondary sources online and in the library?)
 - b **Justify** your choice.

Lesson 2.10

Challenge: Modelling the rock cycle

Aim

To model the rock cycle

What you need:

- Crayons (3 different colours)
- Pencil sharpener
- 2 wooden blocks
- 2 sheets of aluminium foil
- Large clamp
- Beaker
- Tripod
- Bunsen burner or microwave
- Heatproof mat
- Gauze mat
- Matches
- Stirring rod

What to do:

- 1 Remove the paper from the crayons.
- 2 Shave the crayons into small piles using a pencil sharpener. Keep each colour in a separate pile.
- 3 Cover one wooden block with aluminium foil.
- 4 Sprinkle a layer of crayon shavings over the aluminium foil to form the first layer.
- 5 Repeat step 4 for each colour, sprinkling one colour at a time to create distinct layers.
- 6 Cover the layers of crayon shavings with another sheet of aluminium foil.
- 7 Place the second wooden block on top of the foil and press down with as much pressure as possible.
- 8 Remove the top wooden block and the aluminium foil. Examine the compacted crayon shavings, observing the form and texture.
- 9 Place the crayon shavings between the aluminium foil and wooden blocks again.
- 10 Use a large clamp to hold the wooden blocks together. Tighten the clamp as much as possible.
- 11 Remove the clamp, top wooden block and aluminium foil. Examine the compacted crayon shavings, observing the form and texture.
- 12 Place the compacted crayon shavings into the beaker. If you are using a microwave to heat the compacted crayon shavings, move ahead to step 15.
- 13 Place the tripod and the Bunsen burner on the heatproof mat. Place the gauze mat and then the beaker on top of the tripod.
- 14 Safely light the Bunsen burner and move it under the tripod on the heatproof mat. Close the collar on the Bunsen burner to produce a yellow (safety) flame.
- 15 Heat the compacted crayon shavings, stirring occasionally until all lumps are removed, and the mixture is smooth.

- 16 Allow the melted crayon mixture to cool in the beaker.
- 17 Examine the cooled crayon sample, observing its form and texture.

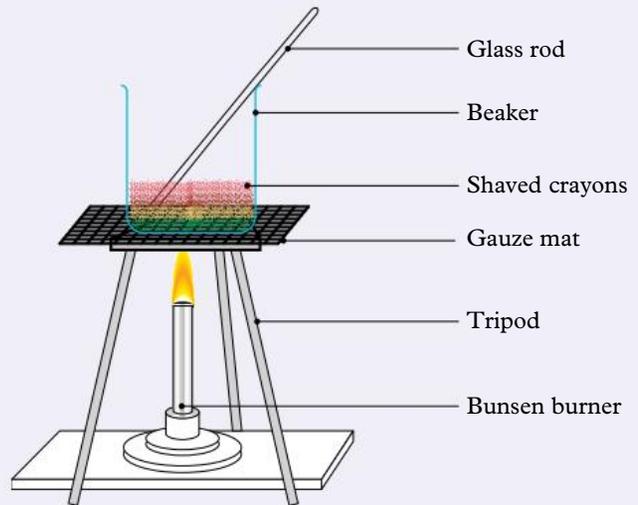


Figure 1 Experiment set-up

Questions

- 1 **Describe** the type of weathering (mechanical or chemical) that took place at step 2.
- 2 **Identify** the term used to describe the movement of the sediment pile of crayon shavings onto the aluminium foil at step 4.
- 3 **Identify** the type of rock formed in step 8.
- 4 **Identify** the type of rock formed in step 11.
- 5 **Identify** the type of rock formed in step 17.
- 6 **Compare** (the similarities and differences between) the three forms of rock you created.
- 7 **Describe** one way this rock model did not represent what occurs in the real world. This is referred to as the limitation of the model.



Figure 2 Colourful crayons

Lesson 2.11

Weathering and erosion can be prevented



Learning intentions and success criteria



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

Key ideas

- Humans can affect weathering and erosion.
- Understanding how weathering and erosion occurs allows us to prevent it.
- Engineers design solutions to prevent or reduce the impact of erosion.

Introduction

Humans are very good at changing their environment to suit their needs. However, this has changed the rate of rock weathering and erosion. This has resulted in flooding and poor food production. Soil erosion engineers are helping to solve this problem.



Figure 1 Footpaths, roads and roofs affect how water moves around the land.

Preventing erosion

The population of Australia has been steadily increasing for many years and as a result we have needed to build more houses and grow more food (Figure 2). Building houses means building roads and footpaths around the houses. Instead of trees and grasses lining a riverbank, footpaths and roads can be built right up to the edge of the water flow.

The roots of plants interlace with other roots and the soil, helping the soil resist the movement of wind and rain. If plants are removed, then the topsoil will erode.

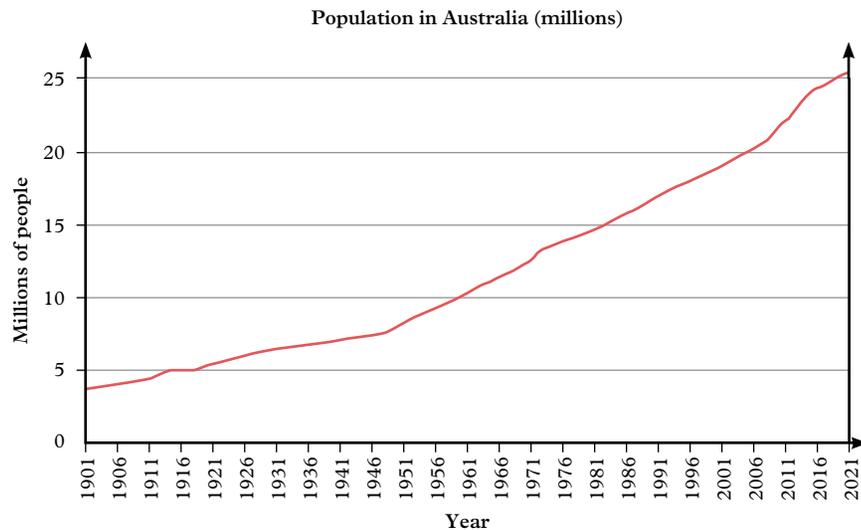


Figure 2 Australia's population has increased dramatically since the beginning of the twentieth century.

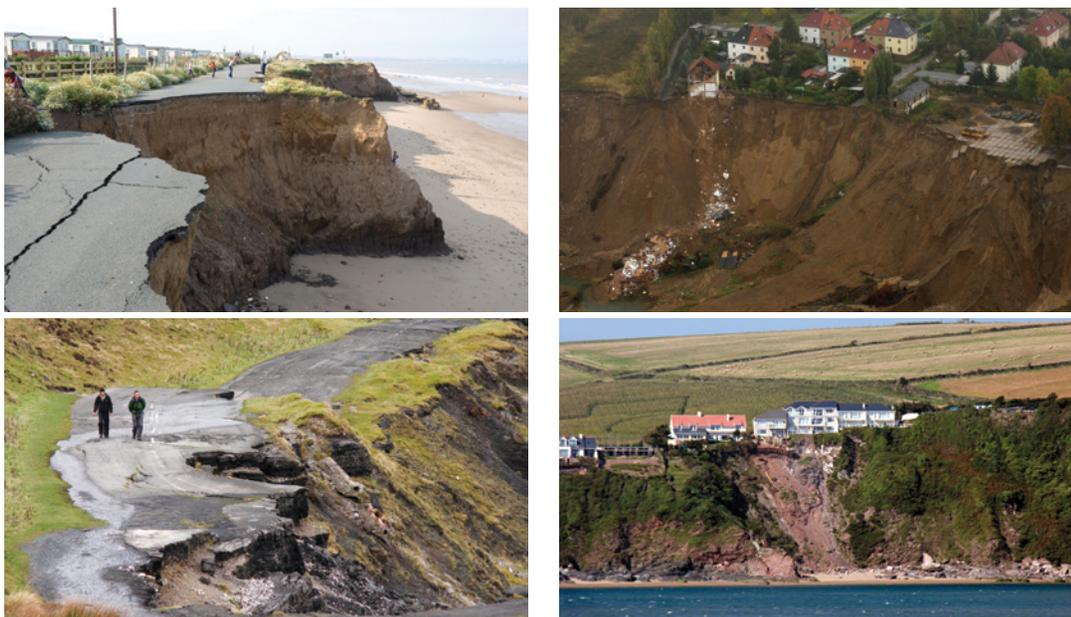


Figure 3 Soil erosion can lead to landslides that affect footpaths, houses and roads, endangering people's lives.

Rain falling on concrete paths and roads is not absorbed into the soil. Instead, it flows off the road and carries away further soil layers. This can slowly remove the support beneath the built structures, causing them to collapse. The loose soil and rocks can trigger damaging landslides (Figure 3). Engineers are developing ways to solve this problem.

Engineering solutions

Figures 4 to 9 show some solutions to weathering and erosion.



Figure 4 Engineers try to minimise erosion by controlling the flow of water with dams and levees.



Figure 5 Groynes are built on beaches to remove some of the energy of the waves. They protrude from the beach and trap the sand, preventing its erosion.



Figure 6 Terraces may be built to allow water to follow a set path that is protected from erosion by human-made structures such as drains, or by plants. This reduces the force of the water, making it less likely to cause damage.



Figure 7 New products have been developed that allow water to move through them instead of becoming run-off. This allows the water to be absorbed into the soil and join the groundwater.



Figure 8 Temperature erosion causes materials such as concrete to crack. Footpaths have grooves in them to allow for their expansion during hot weather.



Figure 9 Regular cleaning prevents the build-up of moss and pollution that might contribute to biological or chemical erosion.

Check your learning 2.11



Check your learning 2.11

Retrieve

- 1 **Recall** why a groyne might be used on a beach.
- 2 **State** what a soil engineer does.

Comprehend

- 3 **Explain** how an engineer could prevent water from eroding soil.

Analyse

- 4 **Identify** two ways erosion can affect food production.
- 5 **Contrast** (the differences between) weathering and erosion.

Apply

- 6 Find an area near your school that has been affected by erosion. **Propose** a way to prevent further erosion.

Lesson 2.12

Challenge: Preventing soil erosion

Design brief

Design a way to prevent a 5 cm layer of soil in a large foil lasagne dish from being eroded when water is poured from a watering can. The lasagne dish should be set at an angle to the bench.

Criteria restrictions

- Pebbles can be no larger than 1.5 cm in diameter.
- Sticks must be less than 5 cm long.
- Artificial materials must not be toxic to the environment.

- No more than 1 cup of material may be added.
- A maximum amount of soil must still be available for cultivation.

Questioning and predicting

Describe how you will prevent the soil from being washed away.

Planning and conducting

- 1 **Identify** the materials you will use.
- 2 Draw a diagram that shows where you will position the materials on the lasagne tray.
- 3 Place the 5 cm of soil in the base of the lasagne dish.
- 4 Arrange the remaining materials on the top of the soil to match your diagram.
- 5 Raise one end of the lasagne dish so that the dish is on an angle.
- 6 Fill a watering can with water and pour the water on the upper end of the dish.
- 7 Observe how the soil moves with the water.

Figure 1 shows the general set-up of the experiment.

Processing, analysing and evaluating

- 1 **Describe** how the soil moved with the moving water.
- 2 **Identify** the most successful feature of your design.
- 3 **Describe** the limitations (what did not work) of your design.
- 4 **Determine** whether it would be possible to create a large-scale version of your design (by calculating the amount of material that

would be needed to prevent a small hill from being eroded, and deciding if it would be possible to complete).

- 5 If you were doing this experiment again, **explain** how you would modify your design.

Communicating

Present the various stages of your investigation in a formal scientific report.

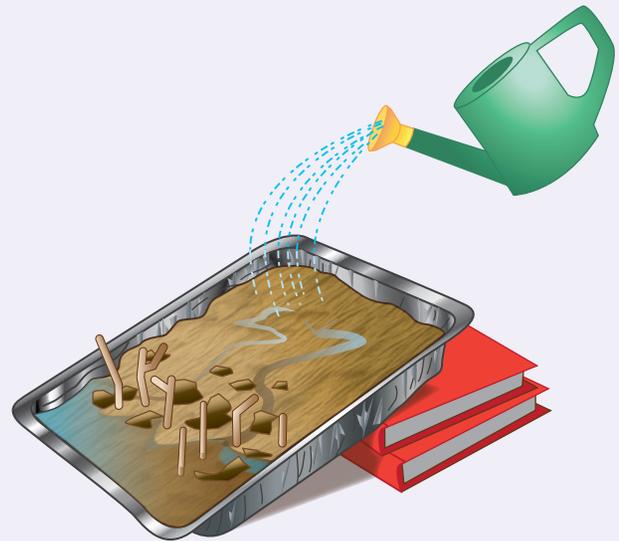


Figure 1 Experiment set-up



Figure 2 Soil erosion

Lesson 2.13

The age of a rock can be calculated



Learning intentions and success criteria



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

Key ideas

- Fossils can tell how and when a rock was made.
- Fossils can be the remains of an organism.
- Trace fossils are rock versions of prints of feet or leaves.
- Opalised fossils are opal replicas of a part of a once-living organism.

Introduction

megafauna large animal; many of Australia's megafauna became extinct during the Pleistocene

Over 95 million years ago Australia was populated by **megafauna**. These large animals included a wombat ancestor the size of a rhinoceros (*Diprotodon optatum*) (Figure 1) and a giant monitor lizard (*Varanus priscus*) that was up to 7 metres long (Figure 2).

We know that these animals existed because of the fossils found at Lightning Ridge in New South Wales and Coober Pedy in South Australia.



Figure 1 *Diprotodon optatum* is the largest marsupial that is known to have existed.



Figure 2 *Varanus priscus* is an extinct giant monitor lizard.

What are fossils?

fossil preserved remains or traces of an organism

trace fossil fossilised traces of an organism that existed in the past (e.g. footprints)

fossilisation the process of an organism becoming a fossil

Fossils are the remains or traces of organisms that are now extinct. A **trace fossil** can include footprints in the mud that become permanent when the sedimentary mud becomes hardened into sedimentary rock. This process can also occur when leaves fall to the ground and leave an imprint or mark in the dirt.

Fossilisation occurs when the footprint or imprint is covered by sediment (Figure 3). This prevents the weathering of the marks. Over time, more layers of sediment are deposited, pushing down on the dry imprinted mud. The pressure allows the sediment to form sedimentary rock.

Fossils are only found in sedimentary rock. If sedimentary rock is exposed to too much pressure or heat, then the rock will undergo physical and chemical changes

and become metamorphic rock. These changes will usually destroy the fossil. If the sedimentary rock is melted into magma and cooled into igneous rock, the fossils will also be destroyed.

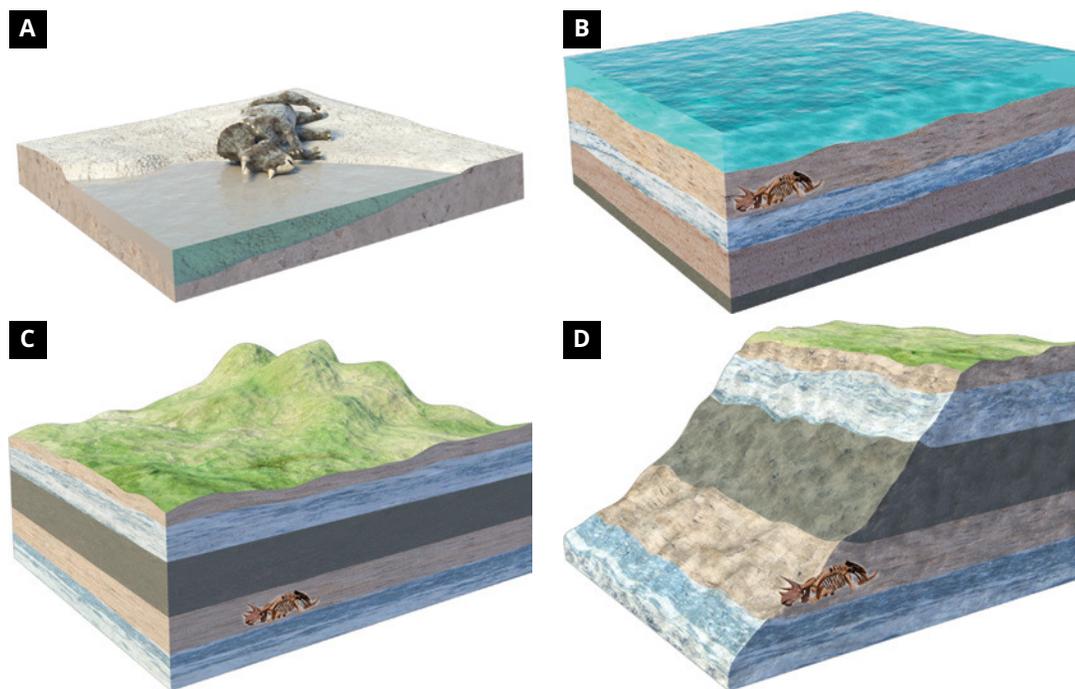


Figure 3 (A) and (B) Formation of a fossil happens over millions of years. If an organism dies near water, it has a greater chance of being buried in sedimentary sand. This protects the body from being eaten. (C) Over millions of years more sediment is deposited, replacing the remains so they are transformed into sedimentary rock. (D) Uplift, weathering and erosion may cause the fossil to be exposed.

Opalised fossils

When some Australian megafauna died, their bodies became covered in sediment such as sand or weathered rocks. This prevented other animals from eating them, or bacteria and fungi from decomposing the body. Sometimes the soft parts of the body would decompose, leaving just the bones to be covered. The bones take longer to break down. If the sediment hardened before the bones decomposed, then a cavity or hole in the shape of the bone would form. Over millions of years, this cavity would become filled with a type of silica, a mineraloid, that forms opal. This opalised fossil is a copy of the original bones that were buried. Eventually the sedimentary rock may be uplifted and the surrounding rock weathered and eroded, allowing the fossil to be seen. Shells of animals can also become opalised fossils, such as the ancient snail and clam shells shown in Figure 4.



Figure 4 The cavity left by a decomposed animal can be filled with the silica that forms opal.

Predicting the age of a rock

Knowing how long ago a megafauna such as *Zygomaturus trilobus* lived allows us to work out when a sedimentary rock was made. *Zygomaturus trilobus* was another large wombat-like marsupial the size of a large bull (Figure 5). Through a special form of dating that uses the amount of radioactive material in the fossil, it was worked out that the animal died about 33,000 years ago. This means that the sedimentary rock surrounding the fossil was 33,000 years old. The rock that is above the fossil is less than 33,000 years old, and the rock found deeper under the fossil is more than 33,000 years old (Figure 6).



Figure 5 *Zygomaturus trilobus* lived 33,000 years ago.

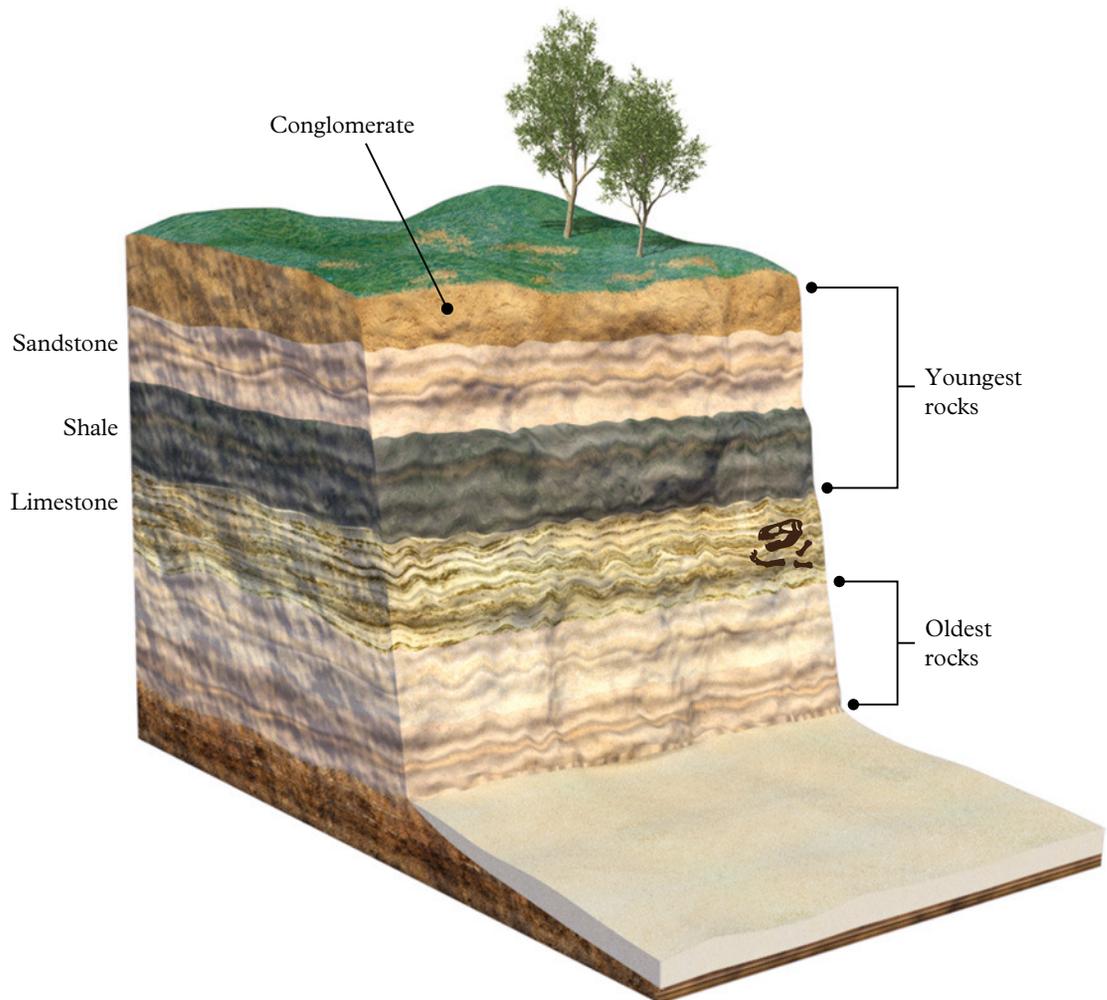


Figure 6 The rock above the fossil must be younger than the fossil. The rock below the fossil must be older.

Who killed the megafauna?

For many years it was thought that the Australian megafauna were killed over 50,000 years ago by Aboriginal and Torres Strait Islander Peoples who lived in what is now known as Australia. This is now being questioned as the discovery of the 33,000-year-old *Zygomaturus trilobus* at Willandra Lakes, New South Wales, suggests that the humans and megafauna lived in the same area for over 17,000 years. This coexistence suggests that the large wombat ancestors were not hunted out of existence during that time.

Check your learning 2.13



Check your learning 2.13

Retrieve

- 1 **Recall** two types of fossils.
- 2 **Identify** the mineral that is found in opal.
- 3 **Explain** why fossils are not found in igneous or metamorphic rocks.

Comprehend

- 4 **Describe** how fossilised opals are formed.
- 5 **Explain** why Aboriginal and Torres Strait Islander Peoples are no longer thought to have hunted megafauna to extinction in Australia.

Apply

- 6 **Determine** how old the rock above a 50,000-year-old fossil would be.

Skills builder: Questioning and predicting

- 7 A palaeontologist came across a little fossil of a shell while they were studying a bigger fossil of a dinosaur nearby.

They asked three questions:

- “Did this fossil come from a similar time as the dinosaur fossil?”
- “Is this fossil better than the dinosaur fossil?”
- “Did this fossil come from a big family?”

Identify which of these questions can be investigated. (THINK: Could you design an investigation to answer the question?)

Lesson 2.14

Experiment: Making a fossil

Aim

To make a trace fossil in sedimentary rock

Materials

- Dry clay
- Mortar and pestle

- Teaspoon
- White tile
- Dry sand
- Plaster of Paris
- Water
- 1 empty matchbox
- Dry leaves, plastic toy animals, etc.

Method

- 1 Grind a lump of dry clay with a mortar and pestle until it is fine and powdery.
- 2 Using the teaspoon, mix the following dry ingredients for the sedimentary rock on a white tile.
 - ½ teaspoon of dry clay
 - 4 teaspoons of sand
 - ½ teaspoon of plaster of Paris
- 3 Pile your ingredients into a little hill and make a small dip in the centre for the water.
- 4 Slowly add 2 teaspoons of water and stir until the ingredients are uniformly mixed. Be careful not to make the mixture too wet.
- 5 Press your mixture into the empty matchbox.
- 6 Gently place a dry leaf or toy animal into the surface of the mixture. Carefully remove the leaf or animal so that an imprint has been left in the surface.
- 7 Label the rock containing the trace fossil with your name and leave it to dry for 2 days.

- 8 When your “rock” is dry, peel off the matchbox and examine your sample.

Results

Record the results in your workbook. **Describe** what your fossil looks like.

Discussion

- 1 **Describe** how fossils are formed.
- 2 **Describe** what would happen if the rock containing your trace fossil was exposed to large amounts of pressure or a high temperature.

Conclusion

Explain how trace fossils are formed.



Figure 1 This dinosaur footprint is an example of a trace fossil.

Lesson 2.15

Science as a human endeavour: The locating and extraction of minerals relies on scientists

Introduction

Geologists are scientists who study the rocks and particles that make up Earth and the rocks that were formed. As part of this study they produce and use geological maps using geophysical methods such as seismic testing, magnetometer testing, electromagnetic testing and gravimetric testing. Geochemistry involves the use of chemistry principles to identify the location and type of minerals in the earth.

Geological mapping

Geological maps show all the rocks and minerals in an area. These maps are a representation of the types of rock found under the surface of Earth. Different colours or symbols are used to indicate the types of rock found at each location (Figure 1).

These maps can be used to locate groundwater, identify possible contamination risks, predict earthquakes or volcanic eruptions and identify energy and mineral resources and the costs of mining them.

They can be constructed in different ways. Most are a result of geophysical and geochemical testing.

Geophysical testing

Geophysical testing involves the testing of the physical properties of the earth and the atmosphere. This may include oceanography (the study of the ocean), seismology (the study of earthquakes), volcanology (the study of volcanoes) and geomagnetism (the study of Earth's magnetic field).

Seismic geophysical testing involves sending vibrations into the earth. The vibrations move differently in different types of rock. The vibrations often bounce off the different layers of rock and travel back to the surface. Special microphones called geophones are spread across the surface of Earth. These geophones record the returning vibrations and a computer uses the data to construct a 3D map.

seismic geophysical testing the collecting of geophysical data such as differences in magnetic fields and gravity fields between different geological locations

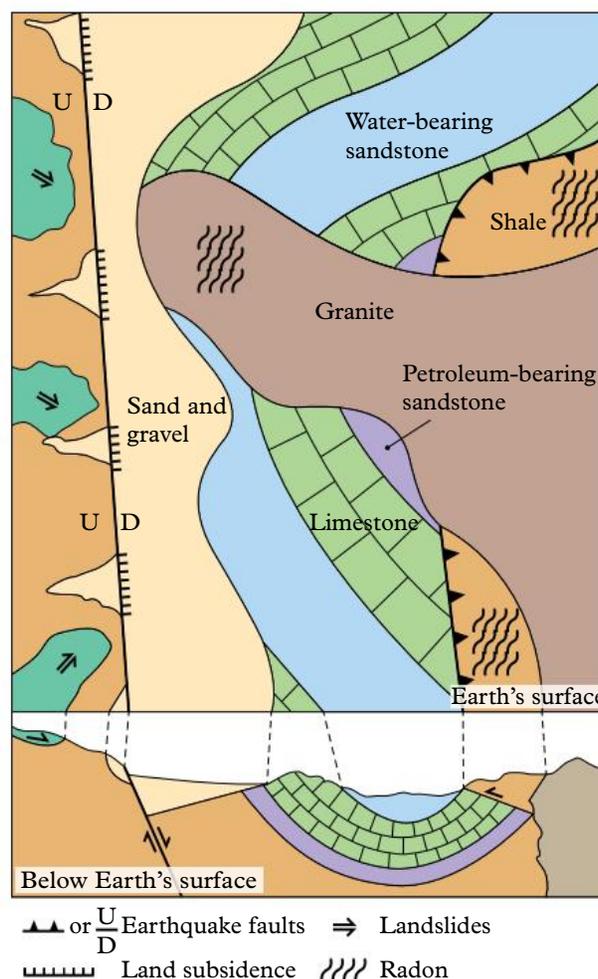


Figure 1 Geological maps allow geologists to determine the location of mineral resources that could be extracted.

Oceanography boats will often carry out geophysical surveys to locate geological structures on the ocean floor (Figure 2 and Figure 3).

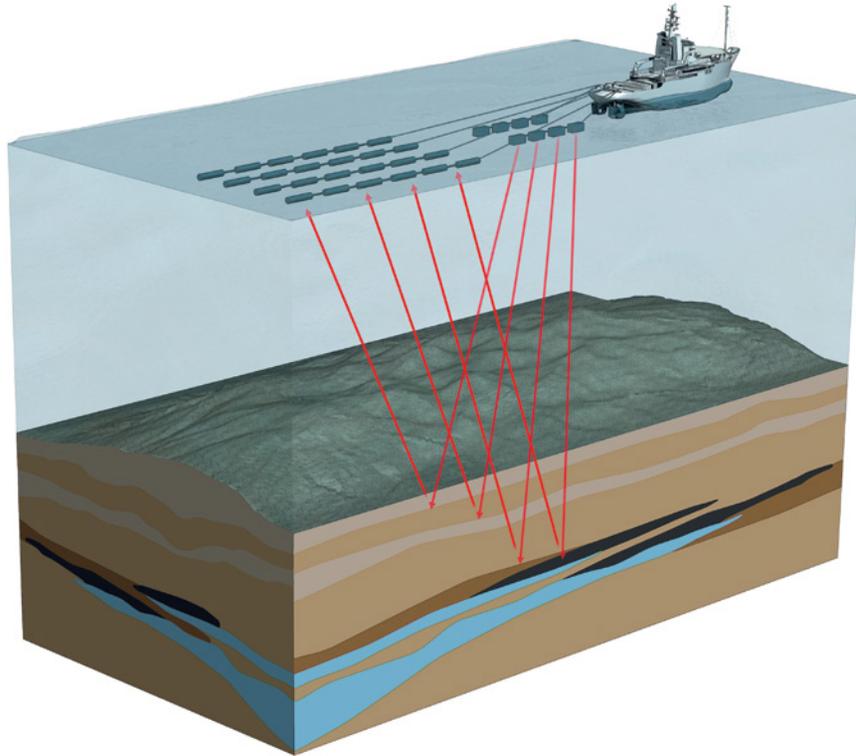


Figure 2 Seismic refraction method

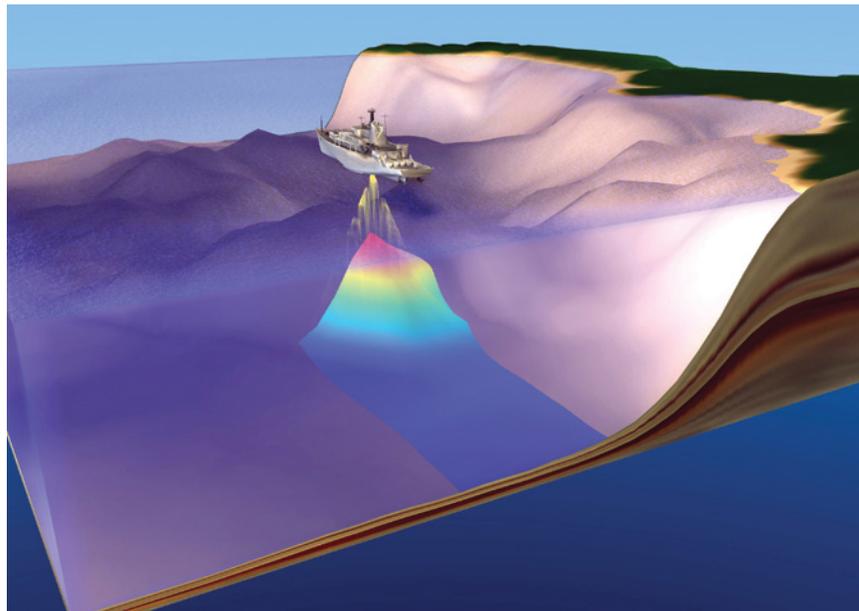


Figure 3 Oceanography boat

magnetometer

a device that detects the difference in a magnetic field between one location and the next

electromagnetic

relating to the physical interaction between moving charged particles and the magnetic field that is created as a result

The presence of some metals beneath Earth's surface can cause small changes in Earth's magnetic field. These small changes can be picked up by **magnetometers** (Figure 4).

Electromagnetic pulses can be sent into the soil to detect different types of minerals. Some rocks contain minerals that do not conduct electricity, whereas others are affected by the electromagnetic signal.

This change is detected by specialised meters carried by the geophysicist.

The gravity of Earth is not constant (Figure 5). Small changes are caused by the density of the rock under you. You would not be able to pick up these variations in gravity, but they can be detected by a **gravimeter**. For large-scale surveys, helicopters carrying gravimeters fly in grid patterns across the surface of Earth (Figure 6).

gravimeter a device that measures the difference in gravity between one location and the next

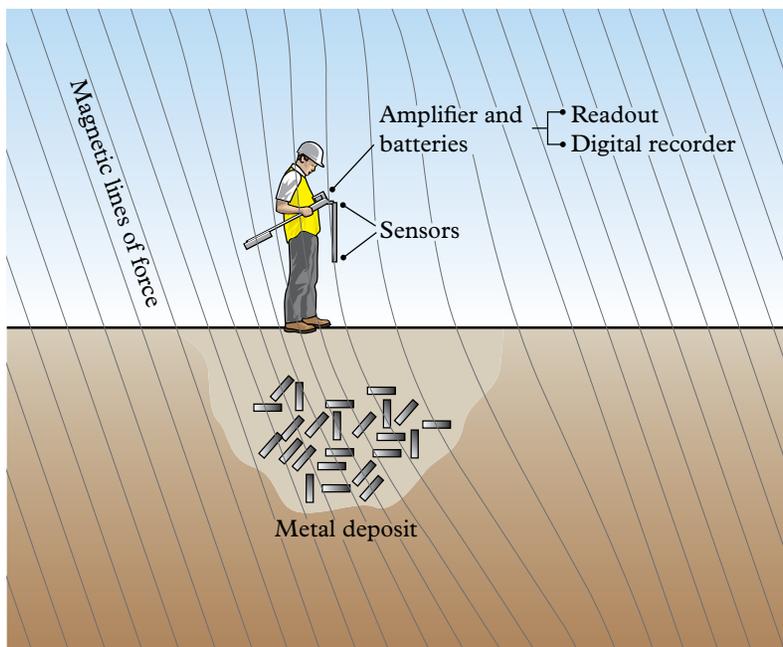


Figure 4 Person walking across Earth's surface with a magnetometer

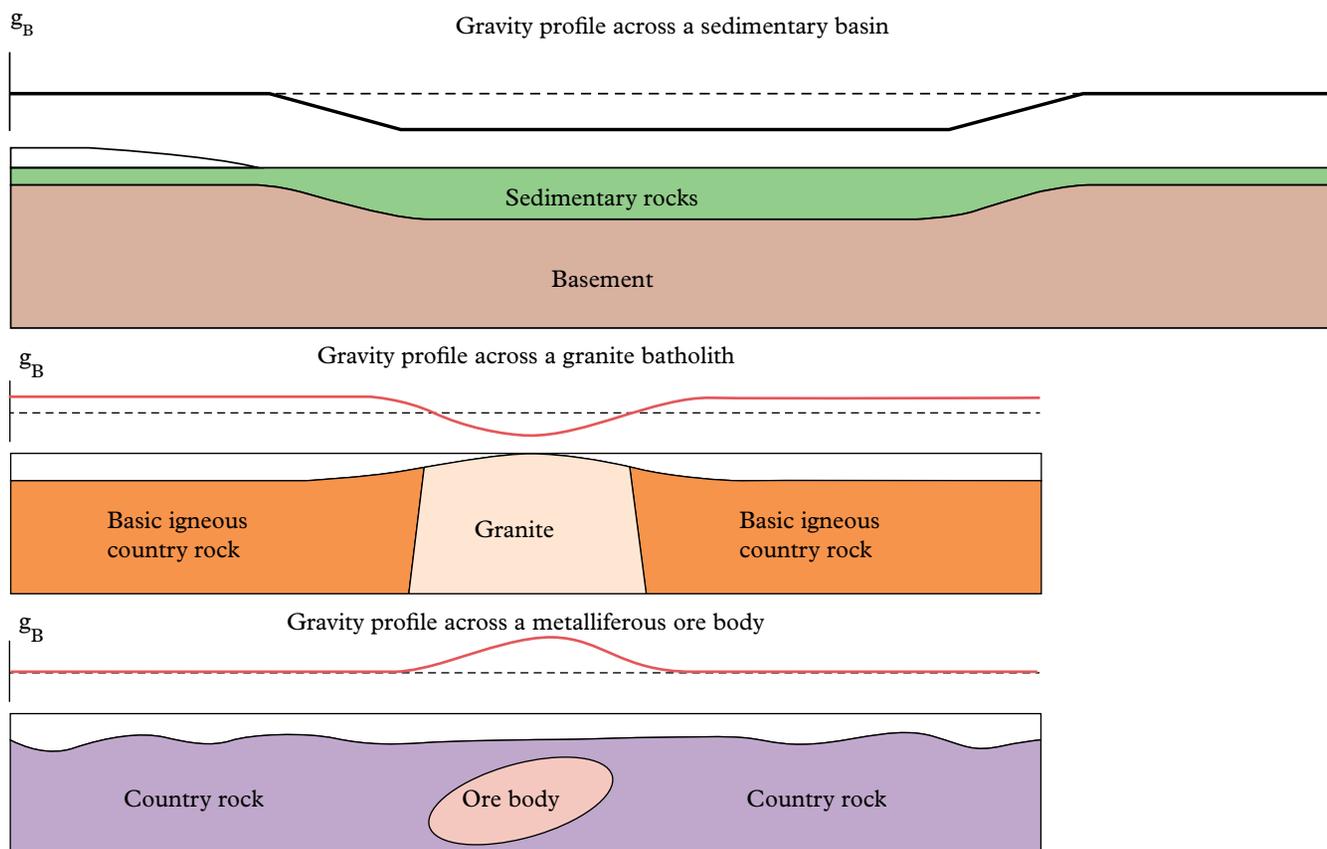


Figure 5 Granite and sedimentary rocks have lower gravitational fields than metal ores.

Geochemical testing

Geochemical analysis is used to determine what chemicals or minerals are in the rocks. It can be used to detect the presence of petroleum products, metals and commercially valuable minerals. It can be like a treasure hunt. Small samples of sediment or rocks are collected at a number of different sites and are taken back to a laboratory for chemical tests. Some samples might show a higher than normal level of a mineral such as copper. The geochemist will then go back to the site where those samples were located, and do further tests to locate the source of the copper.



Figure 6 Helicopter with a front-end gravimeter

Extracting the minerals

Extracting the minerals can be very expensive. If the mineral is close to the surface, open mining may be used. This involves removing the surface of the soil so that the mineral can be easily extracted and taken for processing. If the mineral is deep under Earth's surface, sub-surface mining – where tunnels or shafts are used to reach the mineral deposits – may be used. Geologists will often prepare reports on the costs of mining the mineral. This will then be compared to the amount of money expected to be made from selling the mineral. If the cost of mining is less than the expected value of the mineral, the extraction will begin.



Test your skills and capabilities

Evaluating the importance of land use

The amount of land available for use is limited. This can cause ethical conflict between the needs of different groups in the community, including:

- mining resources
- food production
- housing
- conservation of native plants and animals.

For each of the needs:

- 1 **describe** one reason why the need for an area of land in Figure 7 may be important.
- 2 **describe** how the use of land in this way could affect your life in a positive way and therefore be important to you.
- 3 **evaluate** which of the four uses of the land is most important by determining which of the reasons is most significant to you and explaining why you made this decision.
- 4 **consider:** if the land surrounding your house was needed for this use, **describe** how this would change the way you live. **Describe** whether this changes the decision you made in question 3. **Explain** your reasoning.

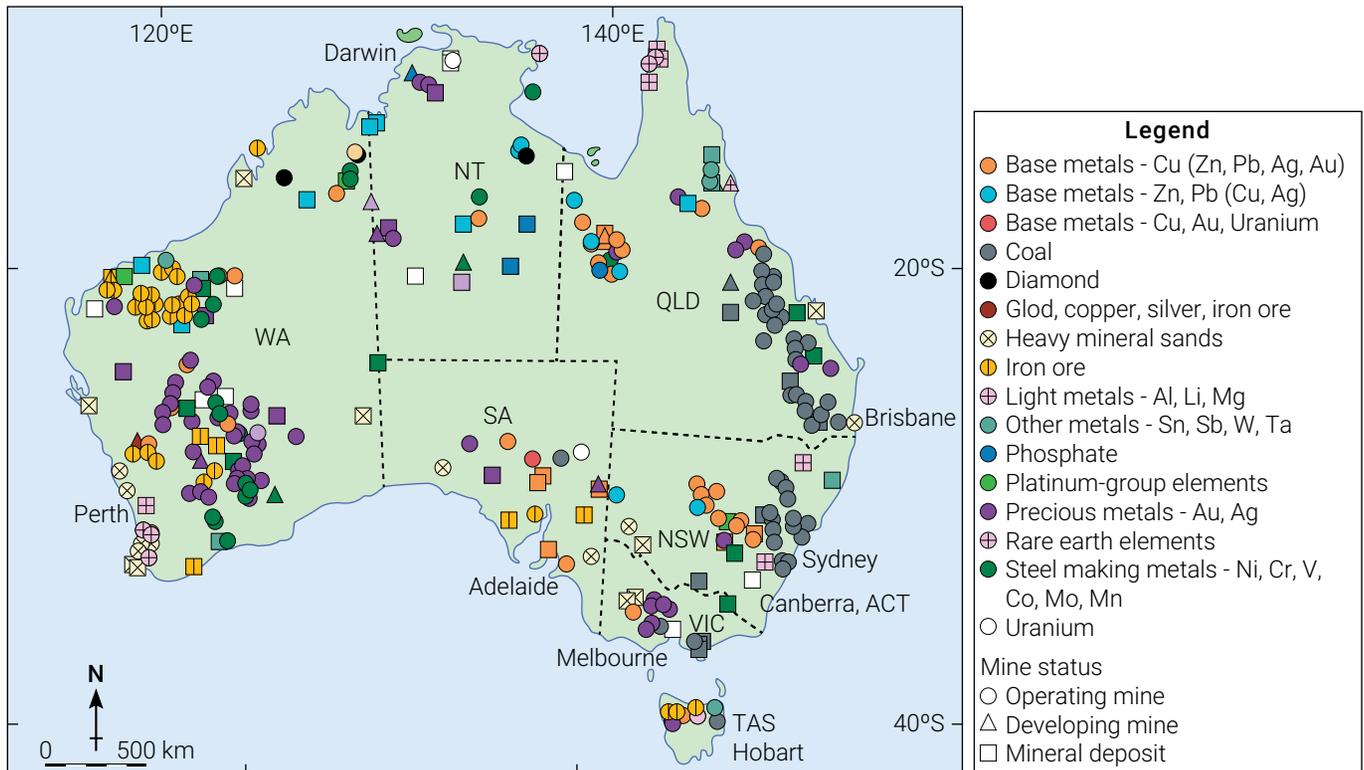


Figure 7 Geolocation has identified many different minerals across Australia.

Skills builder: Communication

- 5 Using digital technology of your choice, **create** an advertisement that encourages people to study one of the sciences outlined in this topic (such as geology, volcanology or oceanography). (THINK: Who is your audience? What is your key message? What is the most appropriate text type to deliver your message?)

Lesson 2.16

Experiment: Copper treasure hunt

Background

You are a geologist employed to identify the location of new copper sources. You have used geophysical testing to determine a region

around Mount Isa that has an intense electrical chargeability. You decide to complete a series of geochemical tests on the river silt to identify a possible source of the metal.

Aim

To determine the location of a source of copper mineral from samples collected along a river

Materials

- Bunsen burner
- Heatproof mat
- Matches
- Wire loops
- Beaker
- 0.1 M hydrochloric acid
- Soil samples 1 to 6

Method

- 1 Place the Bunsen burner on the heatproof mat and safely light it. Open the collar on the Bunsen burner to produce a blue flame.
- 2 Take a wire loop and dip it in a small beaker of 0.1 M hydrochloric acid. Flame the loop. This will clean the loop, ready for your soil sample. Avoid getting too close to the flame. Stand back a little.
- 3 Dip the clean wire loop into a small amount of the soil sample. Place the soil-covered loop into the blue flame and observe the colour of the flame.
 - A green flame suggests copper is in the soil sample.
 - If no green colour appears, this suggests the copper is further downstream.
- 4 Once you have finished observing the flame, clean the wire loop by dipping it in the 0.1 M hydrochloric acid again and flaming it. This prepares the loop for testing the next sample.

Results

Construct a table to record your results.

Discussion

- 1 **Describe** the possible location of the source of copper. **Describe** the evidence that supports your claim.
- 2 **Explain** why you cleaned the loop between each test.
- 3 **Evaluate** whether this geochemical method could be used if the copper ore was located deep under the ground (by describing how buried copper ore is different from surface ore and deciding if this would affect the results of the experiment).
- 4 **Describe** how you would test for copper ore that was located well below Earth's surface.

Conclusion

Describe what geochemical testing is and how it is used to test for minerals.



Figure 1 Copper

Lesson 2.17

Experiment: What if a muffin were mined in different ways?

Aim

To compare the effectiveness of different methods of mining and their impact on the environment

Materials

- 2 homemade chocolate chip muffins (each with the same number of chocolate chips – approximately 20)
- Plates
- Spoons

Method

- 1 Imagine each muffin is an area of land that contains a valuable ore: chocolate.
- 2 Place a muffin on a plate and use spoons to “mine” the chocolate from the first muffin using the “open mining” method, taking layers off the top and collecting the chocolate as it appears.

Inquiry: What if the muffin was mined using the sub-surface method?

Plan and conduct an experiment that answers the inquiry question.

- 1 **Describe** how this muffin can be mined so that the top environment remains intact.
- 2 **Identify** the (dependent) variable that you will measure and/or observe to determine which method was more effective.

- 3 **Identify** two variables that you will need to control to ensure that the test is reproducible.
- 4 **Develop** a method for your experiment. Write this method in your logbook.
- 5 **Construct** an appropriate table to record your results.
- 6 Show your teacher your planning to obtain approval before starting your experiment.

Results

Draw or take a photo of your two muffins.

Discussion

- 1 **Describe** which method recovered the most chocolate ore.
- 2 **Identify** which method recovered the chocolate ore in the shortest time.
- 3 **Identify** which was the easiest method to recover the chocolate ore.
- 4 **Explain** which method would allow the environment to be quickly rehabilitated.



Figure 1 Equipment for “muffin mining”

Lesson 2.18

Review: The rock cycle

Summary

Lesson 2.1 Rocks have different properties

- Geologists are scientists who study rocks.
- The characteristics of rock include the colour, presence of layers, hardness, density and crystal size.

Lesson 2.3 Igneous rocks develop from magma and lava

- Magma (hot liquid rock) flows deep beneath Earth's surface.
- When the magma moves above Earth's surface it is called lava.
- Igneous rocks form when magma and lava become solid.

Lesson 2.5 Sedimentary rocks are compacted sediments

- Sedimentary rocks are formed from compacted particles or sediment.
- Stalactites and stalagmites are forms of sedimentary rock.

Lesson 2.7 Metamorphic rocks require heat and pressure

- Rocks deep underground experience high pressure.
- High pressure generates high temperatures.
- High pressures and temperatures cause the rearrangement of minerals to form metamorphic rock.

Lesson 2.9 The rock cycle causes rocks to be re-formed

- Weathering is the breaking down of rocks and minerals through the movement of water and animals, and extremes of temperature.
- Erosion is the movement of the sediment to another area.
- The rock cycle describes the formation of sediment and sedimentary rock, compression to metamorphic rock, melting and solidification to form metamorphic rock.

Lesson 2.11 Weathering and erosion can be prevented

- Humans can affect weathering and erosion.
- Understanding how weathering and erosion occurs allows us to prevent it.
- Engineers design solutions to prevent or reduce the impact of erosion.

Lesson 2.13 The age of a rock can be calculated

- Fossils can tell how and when a rock was made.
- Fossils can be the remains of an organism.
- Trace fossils are rock versions of prints of feet or leaves.
- Opalised fossils are opal replicas of a part of a once-living organism.

Review questions 2.18



Review questions

Retrieve

- 1 **Recall** the visual properties of rocks that can help identify them.
- 2 **Recall** the basis of rock classification.

- 3 **Identify** the rock type that is formed from lava.

- A Sedimentary rock
- B Metamorphic rock
- C Igneous rock
- D Marble rock

- 4 **Define** the following terms.
- Extrusive igneous rocks
 - Intrusive igneous rocks
 - Sediment
- 5 **Recall** the term used to describe a rock breaking apart because of daily heating and cooling.
- Physical weathering
 - Chemical weathering
 - Biological weathering
 - Erosion
- 6 **Identify** the correct statement. Fossils usually form:
- in layers of sediment.
 - in layers of igneous rock.
 - as wind erodes layers of rock.
 - as water erodes layers of rock.

Comprehend

- 7 **Identify** the missing words in the following sentences.
- _____ are small pieces of organised particles that have smooth sides and sharp edges.
 - _____ rocks are formed when loose particles are pressed together by the weight of overlying sediments.
 - _____ rocks are formed when other types of rocks are changed by heat and pressure inside Earth.
 - _____ rocks form when magma and lava from volcanic eruptions cool and solidify.
- 8 **Describe** the properties used by geologists to identify different rocks.
- 9 **Explain** why colour alone is not a reliable guide for identifying rocks.
- 10 **Describe** the properties that would allow you to determine the difference between intrusive and extrusive igneous rocks.
- 11 **Explain** how sedimentary rocks form at Earth's surface.
- 12 **Describe** the properties of ochre that make it valuable to Aboriginal and Torres Strait Islander Peoples.
- 13 **Describe** how the different rock formations found in a cave (stalactites, stalagmites and columns) form.

- 14 **Describe** the relationship between weathering and erosion.
- 15 **Explain** why and how electromagnetic pulses detect metals.

Analyse

- 16 **Infer** why pumice has no crystal structure even though it is a rock.
- 17 Use Table 1 from Lesson 2.1 Rocks have different properties (page 75) to **identify** the following rocks based on their properties.
- a fine grain and no hardness, dark in colour
 - density of 2.2 to 2.8, light colour, coarse grain size, hard
 - fine grain size, soft, dark in colour
- 18 **Examine** the rock samples in Figure 1 and Figure 2.
- Use Table 1 in Lesson 2.1 Rocks have different properties (page 75) to **identify** the rocks.
 - Explain** your responses.
 - Recall** the type of rock each sample is.
 - Consider** how their appearance relates to the way in which each was formed.



Figure 1 Rock sample 1



Figure 2 Rock sample 2

- 19 **Compare** obsidian and scoria rocks.
- 20 **Contrast** magma and lava.

- 21 Some famous works of art are made of marble (Figure 3).
- Recall** the properties of marble.
 - Categorise** the properties of marble as being ideal for artworks and not ideal for artworks.



Figure 3 The famous marble statue of David, created by Michelangelo between 1501 and 1504

- 22 **Contrast** the different ways a rock can undergo weathering.
- 23 Cave systems in limestone rock follow the course of underground rivers. **Infer** why water is necessary to form caves.
- 24 **Reflect** on why only simple fossils are found in the oldest types of rocks, whereas younger rocks have fossils of larger mammals.

Apply

- 25 There are no active volcanoes on the mainland of Australia, but there are still examples of igneous rocks throughout the country. **Suggest** what this implies about the history of volcanic activity in Australia.
- 26 **Determine** what types of rocks you would look for if you were a palaeontologist searching for fossils.
- 27 **Propose** two ways to prevent water from eroding a memorial rock located in a town centre at the base of a hill.

Critical and creative thinking

- 28 Victoria, New South Wales and Queensland are susceptible to flood waters that can cause quick erosion. Based on the engineering solutions from Lesson 2.11 Weathering and erosion can be prevented (page 96), **propose** what towns in flood-prone areas could do to protect themselves.
- 29 Figure 4 shows the Twelve Apostles found along the Victorian coast.
- Use this image to **describe** how these rocks were formed.

- Create** a poster to show how the rocks were formed and how they would have changed over time.
- Describe** how they may change over the next 1,000 years.



Figure 4 The Twelve Apostles are located off the coast of Victoria.

- 30 **Create** a flowchart showing how fossils are formed.
- 31 Use the rock cycle (Figure 5) to **create** a mind map linking the concepts you have learnt about in this chapter. Include:
- the properties of rocks
 - the formation of different rock types
 - weathering and erosion and their prevention
 - dating of rocks
 - extraction of minerals.

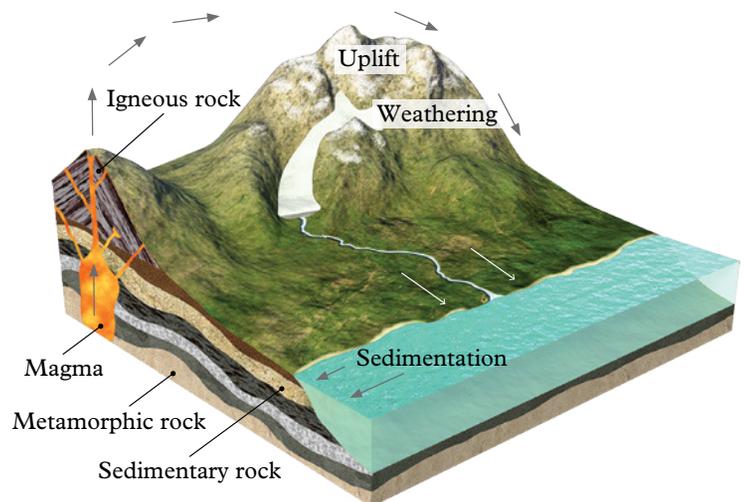


Figure 5 The rock cycle

Social and ethical thinking

- 32** Some people say that Australia is a huge quarry. This is because Australia mines so many minerals and sells them.
- Working on your own, **list** the advantages and disadvantages of mining and selling minerals.
 - Join with a classmate and combine your lists. **Organise** the items on your lists in terms of the strengths of the advantages and disadvantages (e.g. weakest to strongest advantage and disadvantage).
 - Join with another group and **compare** your lists. Prepare another list by considering the ethics involved in mining and **justify** your three best reasons for mining and the three best reasons against mining.

Research

- 33** 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.

Formation of oil

Oil is formed from the compression of dead marine-plant material in mud over millions of years. Oil is made up of hydrocarbons, which are lighter than rock and water, so it often migrates up through porous rock towards Earth's surface.

- **Describe** an oil reservoir.
- **Describe** the conditions that are needed for an oil reservoir to form.
- **Describe** how an oil field is formed.

Gemstones

A gemstone is a mineral crystal that has been cut and polished. They are often used in jewellery. Some rocks, such as opal and obsidian, are not crystals but can also be polished and used for decoration.

- **Describe** what gemstones look like.
- **Identify** which gemstones are found in Australia.
- **Select** one of these gemstones and identify where in Australia they have been mined.
- **Describe** how a miner might have extracted this gemstone from the earth.

Extraction of metals

Metals are extracted from ore using a variety of methods. Some are heated, some are purified using electrical energy and some are extracted using chemical processes.

- **Describe** why different metals are extracted using different chemical or electrical processes.
- **Investigate** how some metals are extracted, such as copper and aluminium, and **design** a poster that shows the process of extraction.

Module

3

Plate tectonics

Overview

Earthquakes, volcanoes and Aboriginal and Torres Strait Islander Peoples' oral histories provide evidence that the Earth is constantly changing. Theories explaining this movement have changed as new evidence is discovered and explored by scientists. The impact of these tectonic events on humans can be significant, but engineering solutions can help reduce damage.



Lessons in this module:

Lesson 3.1 Earth is made of layers (page 118)

Lesson 3.2 Experiment: Cooling and layers (page 120)

Lesson 3.3 Forces cause tectonic plates to move (page 122)

Lesson 3.4 Boundaries between tectonic plates can be converging, diverging or transforming (page 125)

Lesson 3.5 Tectonic plates can be constructive or destructive (page 130)

Lesson 3.6 Challenge: Modelling a tectonic boundary (page 136)

Lesson 3.7 Science as a human endeavour: Engineering solutions in earthquake zones (page 138)

Lesson 3.8 Challenge: Design an earthquake-proof house (page 142)

Lesson 3.9 Review: Plate tectonics (page 143)

Lesson 3.1

Earth is made of layers



Learning intentions
and success criteria



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

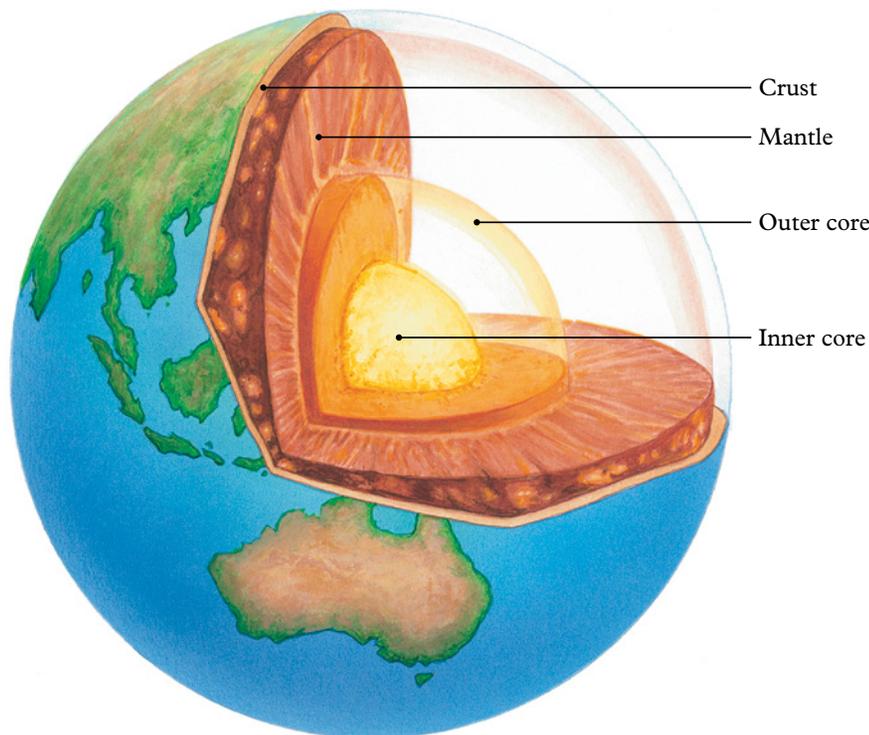
Key ideas

- Earth is made up of several layers.
- The centre of Earth, or core, has two layers: the outer core of liquid iron and nickel, and the inner solid core.
- The next layer, the mantle, is made up of molten rock.
- The outer layer of Earth (the one we live on) is the crust, or lithosphere.

What is Earth made of?

Although Earth is described as a solid planet, it began as a ball of molten materials. Scientists believe Earth and other planets are the result of an explosion billions of years ago. According to this theory, Earth began as a molten fragment from this explosion. Earth's surface has continued to slowly change and is still changing – many rocks have worn down to form soil and sand, mountains and valleys have formed, and the land and oceans have changed shape. Some of this change is caused by weathering and erosion at the surface. Other changes are due to the movement of the molten rocks from deeper down, which in places push their way up to the surface and also move sections of Earth's crust.

core the centre of
Earth



If you could journey deep inside Earth, you would find that it is made of several layers (Figure 1).

Core

The **core** is the centre of Earth. It consists of the outer core and the inner core. The outer core is made mainly of metals, not rock; the main metal is iron, possibly with some nickel. It is very hot and liquid, with temperatures ranging from 4,000°C to 6,000°C. The heat comes from nuclear reactions, and some of the heat is left over from when Earth was formed. The outer core gives Earth its north and south poles and magnetic field.

Figure 1 The volume of each layer of Earth is 1% crust, 84% mantle and 15% core.

The temperature of the inner core is almost 10,000°C, but it does not melt or boil because of the force of the rest of Earth pushing down on it. Of course, no geologist has ever seen the core. Even the deepest mines only penetrate a few kilometres of Earth's crust.

Mantle

The **mantle** is between the core and the crust. It is about 2,800 km thick. Temperatures at the top of the mantle (near the crust) are about 500°C and temperatures at the bottom of the mantle (near the core) reach 3,000°C. The bottom of the mantle is solid, but near the top the rock slowly moves. The top part of the mantle is more like modelling clay than solid rock. It is the source of volcanoes and earthquakes.

mantle the layer of molten rock beneath Earth's crust

Crust

The **crust** (or lithosphere) is the outer layer (7 to 50 km thick) of Earth. It is a thin, brittle outer coating, like the shell of an egg. It is made up of rocks and minerals, and approximately 70 per cent of it is covered by oceans. The crust is not smooth: it has hills, mountains, valleys, oceans and deserts. It is thickest under the **continents** and thinnest under the oceans (Figure 2). Compared to the rest of Earth's layers, the crust is very thin.

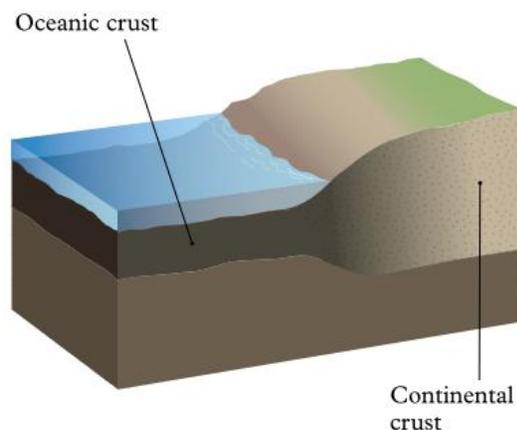


Figure 2 Earth's crust is thinner beneath the ocean than beneath the continents.

crust the lithosphere, or outer layer of Earth

continent a large, continuous landmass

The moving crust

The crust is broken into a number of pieces, called **tectonic plates**. These plates float on the semi-liquid **magma** at the top of the mantle. The speed of movement is similar to that of fingernail growth: between 1 cm and 10 cm per year. Sometimes the tectonic plates crash into one another, causing one plate to slide under the other. The plate on top buckles under pressure, pushing the land upwards (Figure 3). For example, the Indo-Australian Plate is sinking under the Eurasian Plate. This has caused the Eurasian Plate to buckle, pushing up the world's highest mountain range, the Himalayas (Figure 4).

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

magma semi-liquid rock beneath Earth's surface

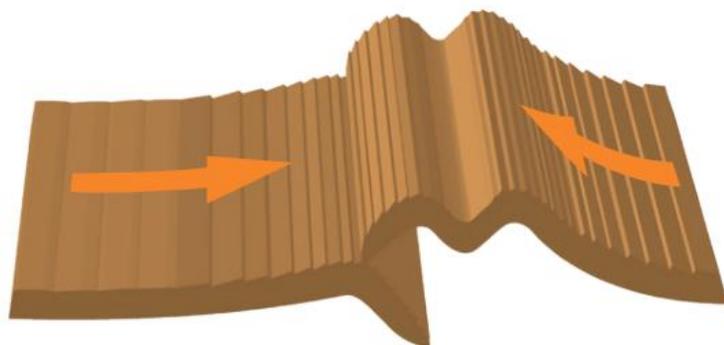


Figure 3 Colliding plates cause Earth's surface to buckle.



Figure 4 The Himalayan Mountains have been pushed up by pressure from beneath Earth's surface.

Check your learning 3.1



Check your learning 3.1

Retrieve

- 1 **Identify** the layer of Earth that contains tectonic plates.
- 2 **Identify** the layer that contains magma.

Analyse

- 3 If Earth's radius is about 6,370 km, use the information about the crust and the mantle to **calculate** the thickness of Earth's core in km.

Apply

- 4 "Earth's crust is the same thickness everywhere." **Evaluate** this statement (by comparing the approximate thickness of Earth's crust at two extremes – the Andes, South America, and Victoria, Australia – and deciding whether the statement is likely to be correct).

- 5 Examine Figure 3. **Evaluate** whether this diagram could be used to model the formation of the Andes Mountains (by describing how the Andes are formed, comparing this to the diagram and deciding whether it is an accurate representation).

Skills builder: Questioning and predicting

- 6 A team of scientists was trying to drill the deepest hole in the world. They planned to use a series of drills to dig 20 km down.
 - a **Predict** what the ground will be like to drill at about 15 km down. (THINK: What layer of the Earth will they reach?)
 - b **Explain** how you made this prediction. (THINK: What scientific knowledge did you use?)

Lesson 3.2

Experiment: Cooling and layers

Aim

To investigate whether cooling of a substance causes layers to form

- Gauze mat
- Copper sulfate
- Spatula
- Glass stirring rod

Materials

- 250 mL beaker
- Water
- Tripod
- Bunsen burner
- Heatproof mat

Method

- 1 Add 50 mL of water to the beaker.
- 2 Place the tripod and the Bunsen burner on the heatproof mat. Place the gauze mat and then the beaker on top of the tripod.

- 3 Safely light the Bunsen burner and move it under the tripod on the heatproof mat. Open the collar on the Bunsen burner to produce a blue flame and boil the water in the beaker (Figure 1).



Figure 1 Heat the water.

- 4 When the water is boiling, turn off the gas.
- 5 Use the spatula to add the copper sulfate to the boiled water a little at a time, stirring constantly to make it dissolve (Figure 2). Stop when no more copper sulfate will dissolve.



Figure 2 Add the copper sulfate.

- 6 Allow the beaker of saturated copper sulfate solution to cool undisturbed for about 20 minutes, then carefully place it in the fridge. Examine it after an hour if possible (or the next day).

- 7 When the beaker has cooled, without moving the beaker, examine its contents and observe where any solid copper sulfate might be located.



Figure 3 Examine the cooled contents.

Results

Describe what happened as the beaker cooled, and record where any solid copper sulfate is located.

Discussion

- 1 **Contrast** (the differences between) the density of solid copper sulfate and liquid water.
- 2 **Compare** (the similarities and differences between) the formation of solid copper sulfate from a solution, to the formation of solid tectonic plates formed from a molten mass.

Conclusion

Explain why layers are formed when a substance cools.

Lesson 3.3

Forces cause tectonic plates to move



Learning intentions and success criteria

Key ideas

- Continental drift describes the movement of the continents.
- Plate tectonics explains how and why the continents are moving.
- The forces involved in plate tectonics are convection current, ridge push and slab pull.

Introduction

theory an explanation of a part of the natural world that is supported by a large body of evidence

plate tectonics the theory that the surface of Earth consists of a series of plates that are continually moving due to convection, ridge push and slab pull

continental drift the continuous movement of the continents over time

supercontinent a landmass that is made up of most or all of Earth's land; Pangea is an example of a supercontinent

Many **theories** have tried to explain why there are earthquakes, mountains and deep-sea trenches over the surface of Earth. One of the first theories was that Earth was cooling down and therefore shrinking, causing “wrinkles” to form on the surface. Like all theories, this idea was testable and was eventually changed and refined as new evidence became available. In this lesson, you will see how the scientific hypothesis of continental drift was suggested, discounted, modified and then revived as **plate tectonics**.

Continental drift

One piece of evidence for continental drift is the similarities in shape between the coastlines of Africa and South America. They seem to fit together like a jigsaw puzzle. In the early twentieth century, German meteorologist Alfred Wegener (Figure 1) put this idea and other evidence into a book in which he outlined the theory of **continental drift**. He proposed that the continents once all fitted together in a giant continent known as Pangea.

Wegener proposed that Pangea was a **supercontinent** that existed 220 million years ago. When the supercontinent started to break up, the continents slowly drifted apart as they moved through the oceanic crust. He supported his claims with the evidence of coastline fit, similar fossils (Figure 2), rocks and landforms created by glaciers in now widely separated continents,



Figure 1 Alfred Wegener pioneered the theory of continental drift in his book *The Origin of Continents and Oceans*.

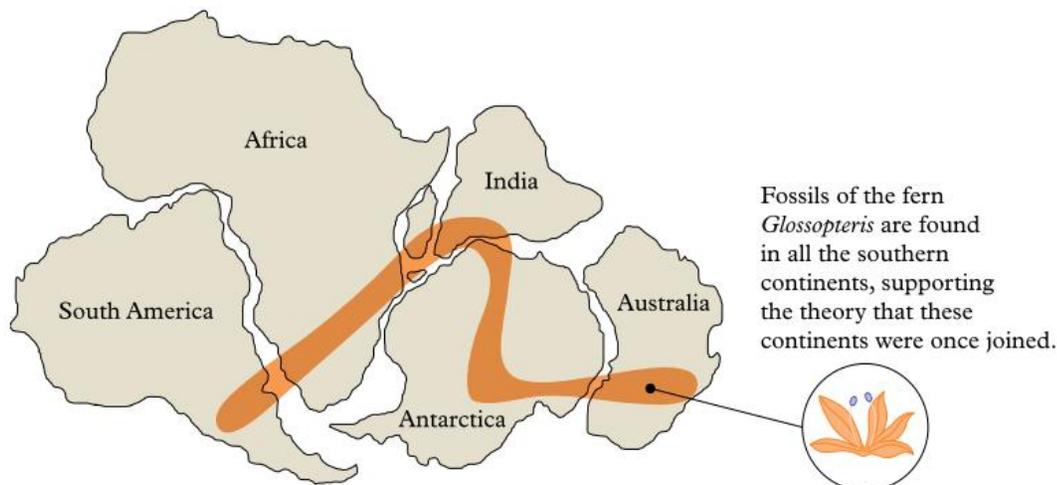


Figure 2 Given that the fossil fern *Glossopteris* cannot walk, swim or fly, its isolated occurrence in so many different parts of the world is evidence that the continents it is found on were once joined.

and the reconstruction of old climate zones.

For many years, other scientists did not support Wegener's theory of continental drift. It wasn't until after he died in 1950 that science developed the equipment to study smaller earth movements (**seismometers**) and landforms deep under the ocean (**magnetometers**). Marie Tharp and Bruce Heezen created the first map of the floor of the Atlantic Ocean. This map identified the Mid-Atlantic Ridge, the longest mountain range in the world. It just happens to be deep under the ocean (Figure 3).

Sea-floor spreading

The idea of **sea-floor spreading** was proposed by US geologist Harry Hess in 1962. Originally a commander of an attack transport boat during World War II, he kept the sonar operating all day and night to build a picture of the underwater surface. When the war ended, Hess re-examined the data and compared it with evidence of the Mid-Atlantic Ridge. Hess hypothesised that the melted rock (magma) under the tectonic plates was moving, creating currents of liquid rock. The magma rises in lines or ridges under the ocean, pushing on the tectonic plates, and causing them to spread and move apart.



Figure 3 The Mid-Atlantic Ridge provides evidence of sea-floor spreading.

seismometer a device used to measure the movement of the earth

magnetometer a device that detects the difference in a magnetic field between one location and the next

sea-floor spreading the theory that the middle of the ocean is spreading apart, forming new oceanic ridges

Convection currents

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

ridge push the force pushing the edges of tectonic plates away from each other when a ridge crest has formed

The movement of particles in liquids and gases transfers heat energy from one place to another. This process of moving heat is called **convection**. Convection is seen in Earth's mantle where the mantle closest to the core gains heat energy and the particles in the mantle's magma move faster. Because the particles move faster, they take up more space and become less dense. As a result, the heated magma near the core begins to rise to the surface, leaving room for cooler magma to take its place. The heated magma cools as it reaches Earth's crust. As it cools, it is pushed to one side as more heated magma arrives. This causes the tectonic plates that form the crust to move. Cool magma is more compact and dense, and so it sinks, following the convection cycle. These tiny currents of force are called **convection currents**.

Ridge push

If convection currents occur within Earth's mantle, then rising hot magma pushes up, creating a ridge crest. This usually occurs under the ocean. As the mantle rock moves away from the magma and ridge crest, gravity pulls the cooled ridges down and away from the hot magma still rising from the mantle. This pushes the ridges apart, forcing the new edges of the tectonic plate apart. This force is called **ridge push** (Figure 4).

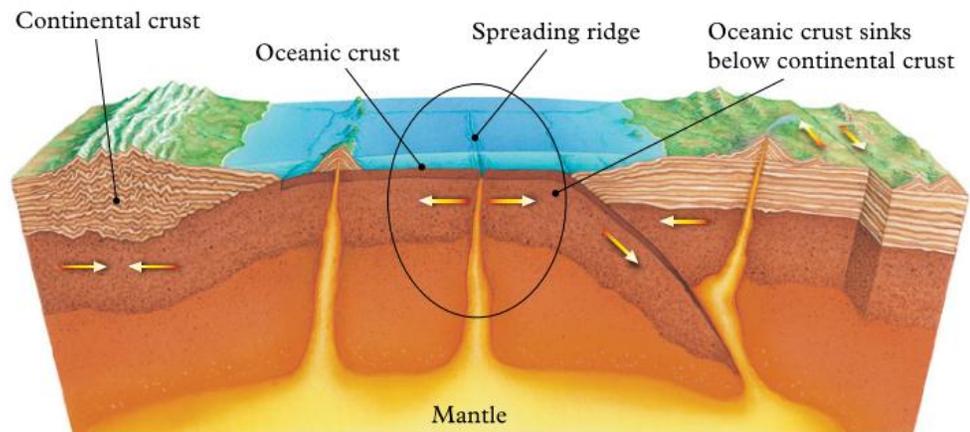


Figure 4 Tectonic plate movement

Slab pull

subduction the movement of one tectonic plate under another tectonic plate

slab pull the force pulling a tectonic plate beneath a less dense tectonic plate

continental shelf a flat area under shallow ocean water at the edge of a continent

Sometimes tectonic plates move towards each other. If one plate is denser (the particles are more tightly packed together), it will sink beneath the other plate. This is known as **subduction**. Sometimes the top, less dense plate will rise, forming a mountain range such as the Andes. Other times, the more dense plate will be pulled downwards, dragging down the rest of the tectonic slab. This force is called **slab pull**.

The movement of the plates explains the existence of landforms such as **continental shelves** and deep trenches in the ocean floor. It also explains how earthquakes and volcanoes are distributed, and the very young age of parts of the sea floor.

Check your learning 3.3



Check your learning 3.3

Retrieve

- 1 **Define** the term “slab pull”.

Comprehend

- 2 **Describe** how a ridge crest forms.
- 3 Use a labelled diagram to **describe** how convection currents move in the mantle.

Analyse

- 4 Examine a world map. Apart from Africa and South America, **identify** the other regions of the world that look as if they could fit closely together.
- 5 **Contrast** (the differences between) continental drift and plate tectonics theories.

Apply

- 6 **Describe** the evidence that Wegener presented in support of continental drift. **Discuss** why many scientists at the time may have rejected the idea.

Skills builder: Problem solving

- 7 As a scientist, you must think critically about theories that are presented. Both Wegener and Hess provided a solution to explain the Earth’s movement. Consider their theories.
 - a **Compare** their explanations. (THINK: What are the differences in their models?)
 - b **Evaluate** how they developed their theories using “working scientifically” principles. (THINK: Did they conduct tests? Observe data and make predictions? Use problem solving techniques?)

Lesson 3.4

Boundaries between tectonic plates can be converging, diverging or transforming

Key ideas

- At a transform boundary, tectonic plates slide past one another.
- At a convergent boundary, plates come together, forming mountains or subducting.
- At a divergent boundary, tectonic plates move apart.



Learning intentions and success criteria

plate tectonics the theory that the surface of Earth consists of a series of plates that are continually moving due to convection, ridge push and slab pull

Introduction

Plate tectonics explains a wide range of features of Earth. These features, once studied separately, can now be unified by a single concept: plate behaviour at plate

boundaries (Figure 1). There are three general types of plate boundaries, based on the direction of plate movement: transform boundaries, convergent boundaries and divergent boundaries.

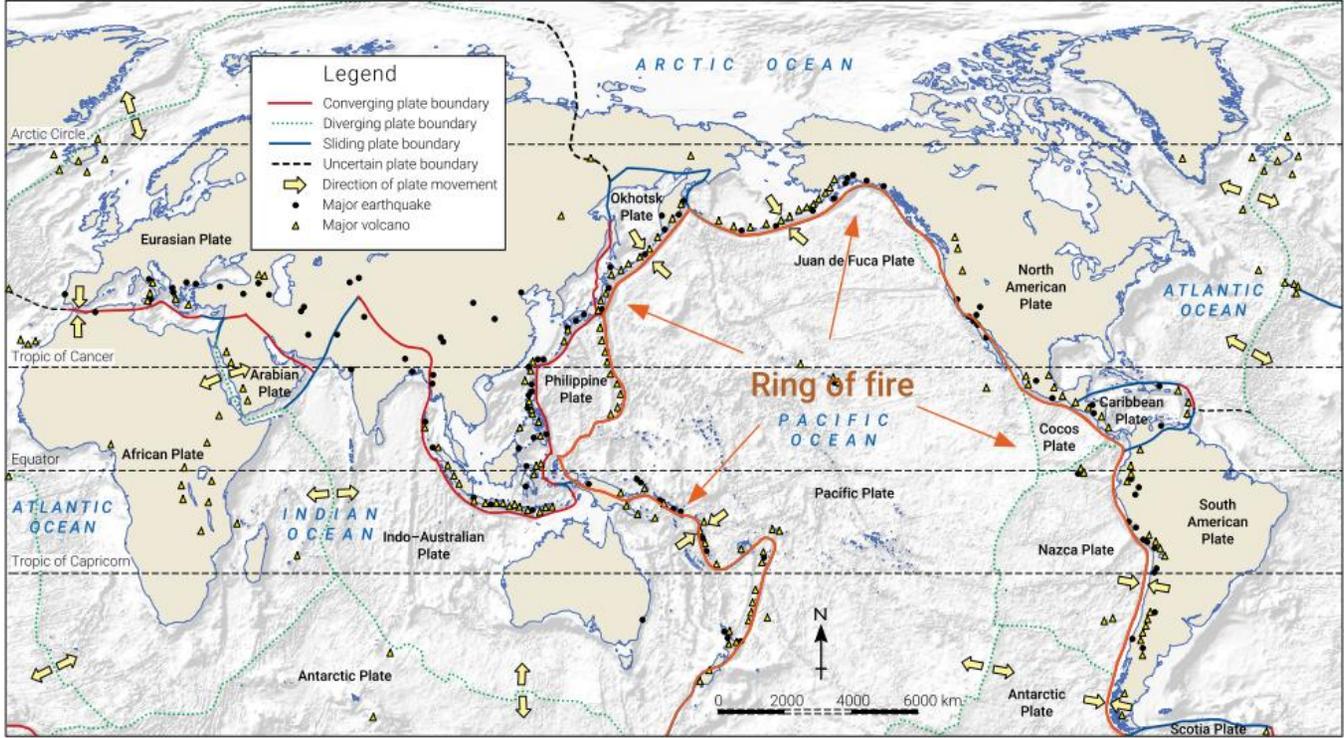


Figure 1 The ring of fire is an area around the Pacific Ocean where a large number of volcanoes are found. This provides hints of a plate boundary.

Transform boundaries

One plate can slide past another along a single fault line. This is called a **transform boundary** (Figure 2, Figure 3 and Figure 4).

A **fault** is a fracture in rock where movement has occurred.

transform boundary the boundary between two tectonic plates that are sliding past each other

fault a fracture in rock where the tectonic plates have moved

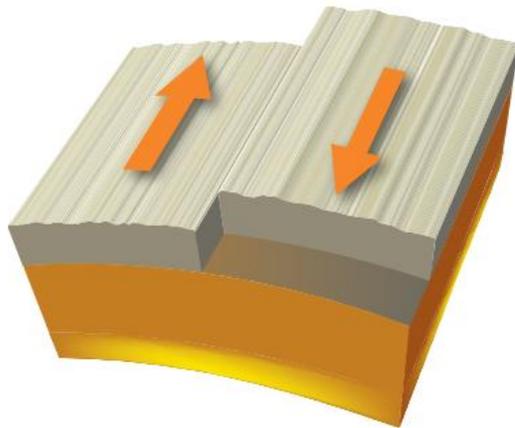


Figure 2 Transform boundary: one plate slides against another plate



Figure 3 Satellite image of the Southern Alps, New Zealand. The Alpine Fault, a transform boundary, runs along the western edge of the snowline on the South Island.

The two plates involved in a transform boundary can become jammed over a period of time until the pressure builds up and the plates slip. This slipping causes earthquakes, such as the large earthquake that destroyed San Francisco in 1906, when the rock of the transform fault slipped by up to 5 m.

Plate material is not created or destroyed; the plates just slide against each other.



Figure 4 The San Andreas Fault, which runs along the western coast of California, USA, is part of a transform boundary.

Convergent boundaries

At convergent plate boundaries, two plates move towards each other. There are generally three types of **convergent boundaries**, depending on the plates involved: ocean-to-continent, continent-to-continent and ocean-to-ocean. Many of the world's major landforms are formed by the collision of plates at converging boundaries. Mountain ranges, volcanoes and trenches can all be formed by convergent boundaries.

convergent boundary the boundary between two tectonic plates that are moving together

Ocean-to-continent collision

When **oceanic crust** collides with **continental crust**, the denser oceanic landform is pushed downwards into the mantle. The downward movement of one plate's edge under another plate is called subduction. The top crust is pushed upwards and creates a line of mountains along the crumpled edge (Figure 5). It can also create volcanoes as heat rises through cracks in the crust. An **ocean trench** may form at the line of plate contact.

oceanic crust part of Earth's crust that lies under the ocean

continental crust part of Earth's crust that makes up the continents (landmasses)

ocean trench a deep ditch under the ocean along a tectonic plate boundary

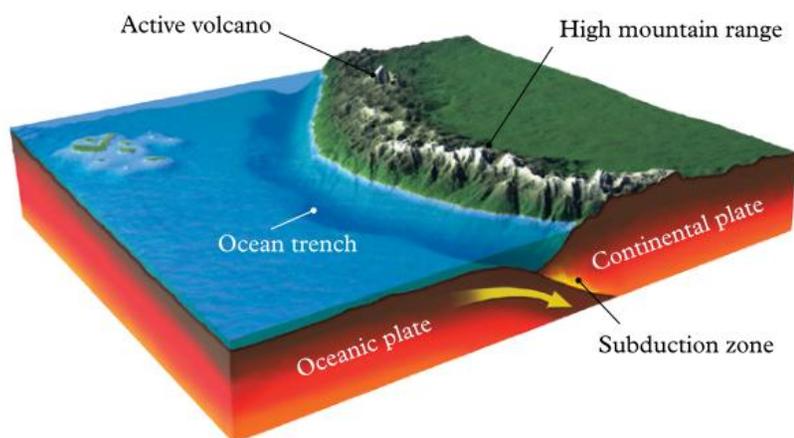


Figure 5 Ocean-to-continent collision causes subduction, and creates mountains, volcanoes and ocean trenches.

Continent-to-continent collision

When two continental plates collide, they have similar densities, so no subduction takes place. Instead, the edges of the two plates crumble and fold into high mountain ranges (Figure 6).

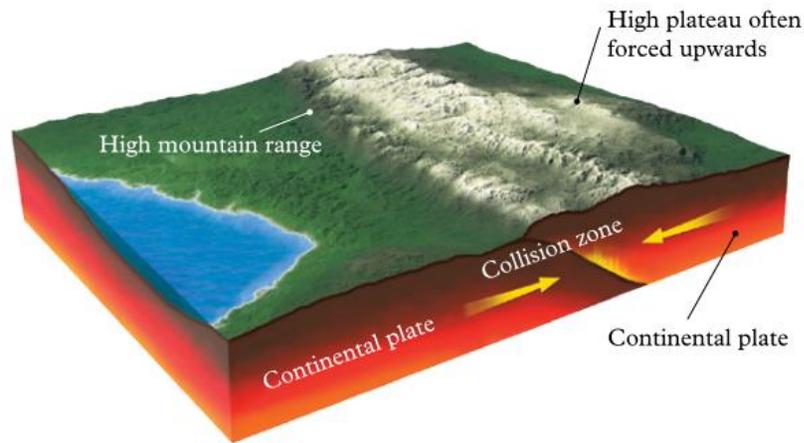


Figure 6 Continent-to-continent collision creates high mountain ranges.

Ocean-to-ocean collision

When two oceanic plates collide, the older, denser crust subducts below the newer crust, creating a deep ocean trench.

The subduction also creates a line of undersea volcanoes that may reach above the ocean surface as an island arc (Figure 7).

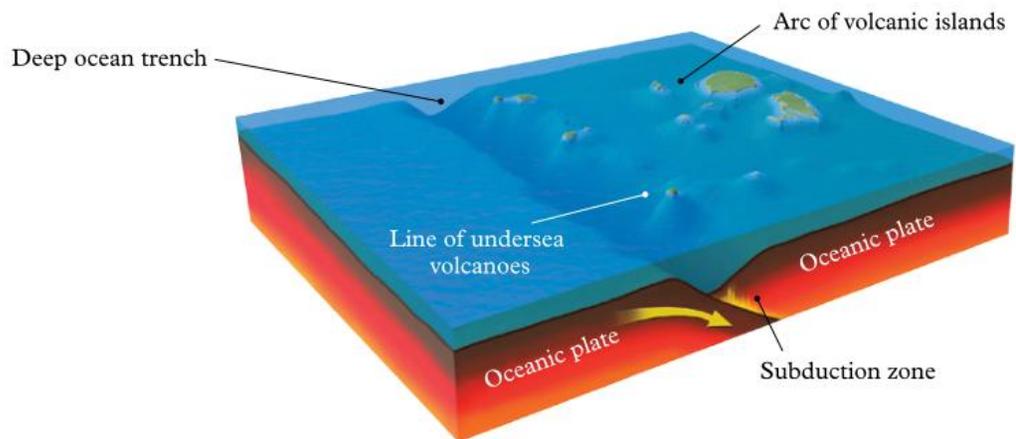


Figure 7 Ocean-to-ocean collision causes subduction and creates a trench and a line of undersea volcanoes.

Divergent boundaries

divergent boundary the boundary between two tectonic plates that are moving apart

Divergent boundaries are plate boundaries that are moving apart. They form different features than those of convergent and transform boundaries. These spreading boundaries can occur in the middle of the ocean or in the middle of land. The breaking up of the supercontinent Pangaea was probably due to divergent plate boundaries.

Hot rising mantle rock from deep within Earth might be the first step in a continent breaking apart. As the mantle rock rises, the continental crust is lifted and thins out.

Cracks form and large slabs of rock sink into the earth, forming a **rift valley** like those found in East Africa (Figure 8).



Figure 8 The East African rift valleys may represent the initial stages of the breaking up of a continent.

rift valley a deep valley that forms as a result of tectonic plates moving apart on land

Making oceans

As plates continue to diverge, the continental crust separates and a narrow sea or lake may form. The Red Sea between the Arabian and African Plates is thought to be a divergent boundary at this stage of development (Figure 9). As the plates separate further, the sea becomes an ocean with a **mid-ocean ridge** in its centre (Figure 10).

mid-ocean ridge a series of underwater mountains that form as a result of tectonic plates moving apart and allowing magma to rise to the surface

Mid-ocean ridges are very wide, up to 4,000 km. The rate of sea-floor spreading varies, averaging a rate of 2 to 5 cm per year. This helps to explain why the age of the ocean floor increases as you move away from the ridge, and that fossils found on the ocean floor are less than 180 million years old.

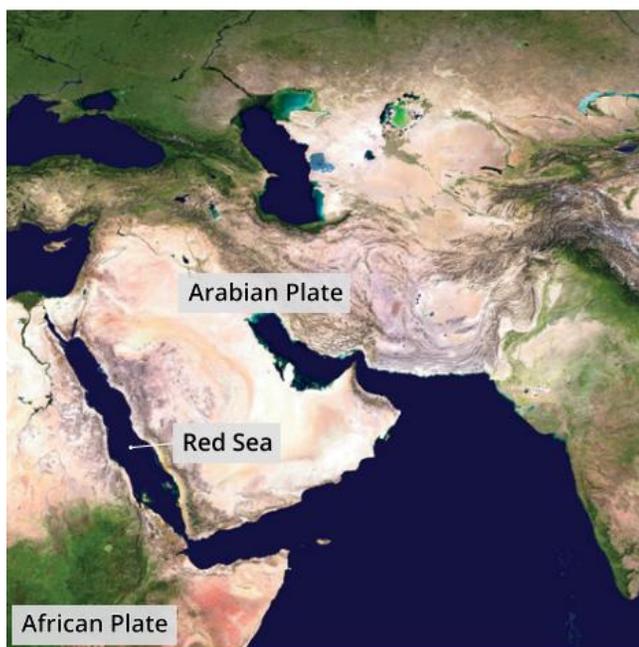


Figure 9 The Red Sea has formed as the African and Arabian Plates have diverged.

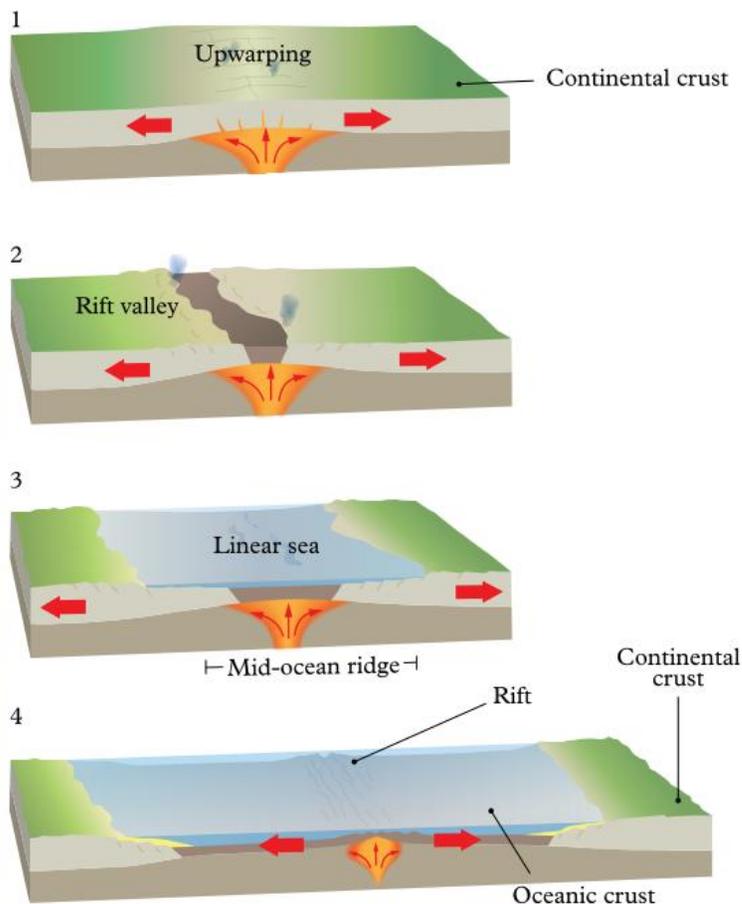


Figure 10 How divergent boundaries form oceans

Check your learning 3.4



Check your learning 3.4

Retrieve

- 1 **Identify** the factor that determines which plate subducts at a convergent boundary.

Comprehend

- 2 **Describe** the type of plate movement that happens at a transform boundary.
- 3 **Describe** what causes the continental crust to spread and break at a divergent boundary.
- 4 **Explain** how boundaries can produce earthquakes.
- 5 Transform boundaries are sometimes called strike-slip fault zones. **Explain** why both names are appropriate.

Analyse

- 6 Use Figure 1 to **describe** where the major mid-ocean ridges are located.
- 7 Use Figure 1 to **describe** where the divergent plate boundaries are located.
- 8 Use the location of the tectonic plates in Figure 1 to **describe** the location of

volcanoes. **Compare** (the similarities and differences between) these and the location of earthquakes.

Skills builder: Questioning and predicting

- 9 Using your knowledge of tectonic plate boundaries, write a scientific question and a prediction for the following scenarios.
 - a The “Ring of Fire” is located in the Asia–Pacific region. Because of its location across tectonic plates, it experiences heightened geological activity. (THINK: Look at Figure 1; what geological features are present? Can you write a measurable question for this area?)
 - b The Australian Alps run across the border of New South Wales and Victoria. The alps formed after geological activity. (THINK: Look at Figure 1; what geological features are near this location? Is future geological activity likely?)

Lesson 3.5

Tectonic plates can be constructive or destructive



Learning intentions and success criteria



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

Key ideas

- The movement of tectonic plates can cause destructive earthquakes or tsunamis.
- Molten mantle can escape from volcanoes and become lava.
- Lava can form new islands.

Introduction

The boundaries between the tectonic plates create a lot of pressure as they try to move against each other. This pressure can be released suddenly in the form of a destructive earthquake (Figure 1), which in turn can form a tsunami.



Figure 1 The San Francisco earthquake in 1906 destroyed much of the city.

Earthquakes can cause tsunamis

Undersea earthquakes can move the sea floor and push up the water to form a wave known as a **tsunami** (Figure 2). Tsunamis are large and powerful waves that are created when a large volume of water suddenly moves. An earthquake in northern Japan in 2011 was a **magnitude** 9.0 on the **Richter scale**. The earthquake was centred 140 km off the coast of Japan and sent a 10 m high wall of water towards coastal towns and cities.

The tsunami wave also travelled away from Japan, right across the Pacific Ocean, and was experienced as far away as North and South America, the Pacific Islands and even in northern Australia as a small wave.

Japan is the most seismically active country in the world because it lies near the boundaries of three tectonic plates: the Pacific, Eurasian and Philippine plates. The force of a tsunami can be enormous, enough to demolish buildings, cars and small ships.

tsunami a series of large waves that result from an underwater earthquake

magnitude a measure of size or quantity; a measure of the size of an earthquake

Richter scale a scale used to rate the magnitude of an earthquake

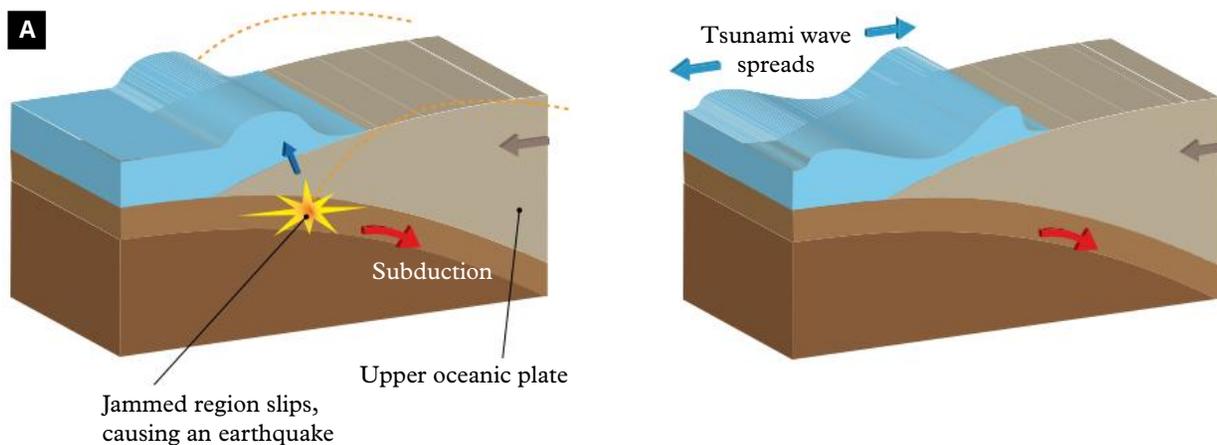


Figure 2 (A) How an earthquake causes a tsunami. (B) The aftermath of the earthquake and tsunami in northern Japan in 2011.

Volcanoes and tsunamis

Volcanoes pose great danger to those who live near them. Most tsunamis are caused by earthquakes but they can also be caused by volcanic eruptions, glaciers breaking and landslides. The 1883 volcanic eruption of Krakatoa, Indonesia, caused a tsunami that killed 36,000 people. The volcanic blast was heard 5,000 km away and ash rose 80 km into the atmosphere.

Volcanic eruptions spew lava and ash onto the surrounding land (Figure 3). When this material is broken down by the action of wind and water, and mixed with organic material from plants and animals, it forms some of the richest soil in the world. So, despite the dangers, the constructive nature of the volcano encourages people to continue to live near it because of the fertile soil it provides.



Figure 3 Volcanic eruptions spew lava and ash and can cause tsunamis.

Hawaiian Islands

The Hawaiian Islands are in the centre of the Pacific Plate. Hawai‘i is not near a mid-ocean ridge or plate boundary, yet it has frequent volcanic activity (Figure 4). Most geologists believe this volcanic activity is caused by the movement of the Pacific Plate over a “hot spot” beneath the plate. A **hot spot** is where a plume of hot magma from the mantle comes up through a thin area in Earth’s crust and creates a volcano.

The Hawaiian Islands are formed by just such an undersea volcano (Figure 5). Over time, a volcano like this grows until it pokes above the ocean surface and creates an island. As the plate moves over the hot spot, other islands are formed over millions of years and an island “chain” is created.

hot spot a region where Earth’s outer crust is thin and the magma is hotter than the surrounding area

The centre of a plate usually lacks earthquakes, volcanoes or folded mountain ranges because it is a long way from a plate boundary, although these landforms are still possible in areas of weakness or thinning in the crust. The theory of plate tectonics and what happens at the plate boundaries corresponds with the distribution of earthquakes and volcanoes around the world. Consider Australia's location and the limited number of earthquakes and extinct volcanoes on our continent.



Figure 4 Evidence of volcanic activity on the Hawaiian islands: (A) rocks that appear to flow into the sea formed from old lava flows, (B) mountains rising out of the sea, (C) and (D) volcanic rock formations, (E) steam rising from craters and (F) lava flowing from active vents.

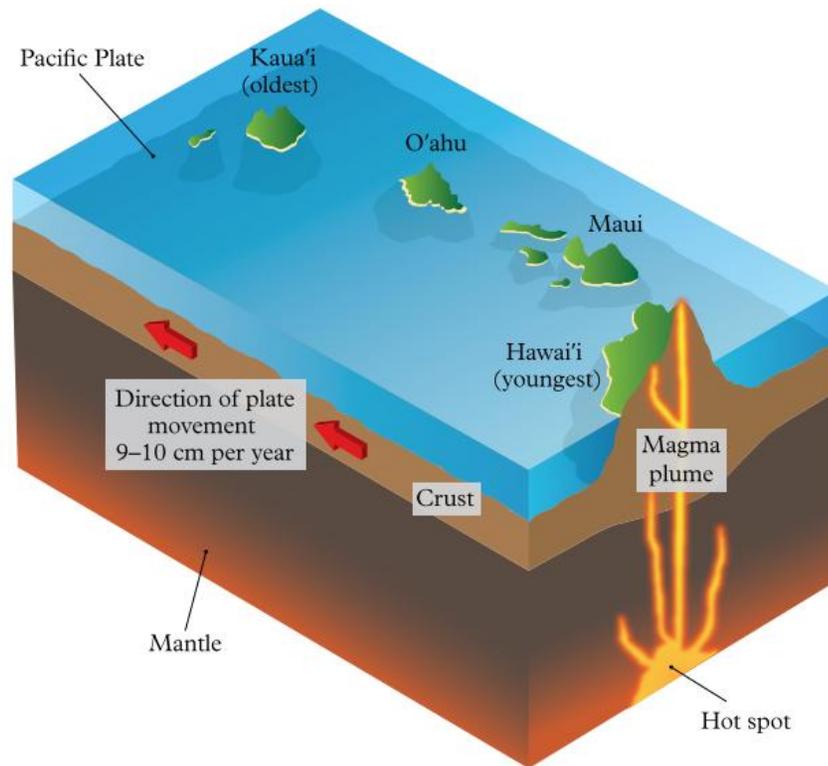


Figure 5 How the Hawaiian Islands were formed. (Only the largest islands are shown.) Hot spots result from magma pushing through thin areas of Earth's crust.

Earthquakes and volcanoes in Australia

Unlike New Zealand, Australia is located in the centre of the Indo-Australian Plate. It is thought that the plate formed when two smaller plates fused, 43 million years ago.

There are many forms of evidence of the volcanic history of Australia. While Western science is used to examine landforms and the layers of Earth, the oral history of Aboriginal and Torres Strait Islander Peoples also provides evidence of the disruptions of the past. A story told by the Boandik people describes a person called Craitbul and his family who tried to settle at what is now called Mount Muirhead, on the southern border between South Australia and Victoria. The story tells of them burying their food overnight to cook, suggesting that the soil was hot. When the bullin birds started calling loudly in the middle of the night (potentially warning of a possible eruption), the family fled to Mount Schank, where the pattern was repeated. The story tells of them escaping to Mount Gambier (Berrin), where this time the earth ovens flooded with water so they moved on again.

This story matches the geology of the area – Mount Muirhead and Mount Schank are areas of old volcanoes and Mount Gambier is an area where water mixed with superhot magma causing large explosions that threw rocks into the air, and eventually formed into lakes.

Although we think of Australia's tectonic plates as now being fixed, two large earthquakes (measuring 8.6 and 8.2 on the Richter scale) beneath the Indian Ocean in 2012 suggest that these two plates may be breaking apart again. The age of the tectonic plate on which Australia is located, and Australia's central position on the plate, have both resulted in minimal earthquake activity.

However, there are still more than 300 magnitude 3.0 or greater earthquakes in Australia every year. Our plate, the Indo-Australian Plate, is moving north towards the Eurasian, Philippine and Pacific Plates. This creates stress within our plate, and the release of this stress creates earthquakes.

One of Australia's worst earthquakes was of magnitude 5.6 and struck near the city of Newcastle in New South Wales on 28 December 1989. It killed 13 people and injured 160. Larger earthquakes have occurred in Australia, but the damage depends on how close they are to the surface and to large cities. A huge earthquake in the sparsely-populated outback is unlikely to cause a large loss of human life. Figure 6 shows Australia's earthquake and tsunami risk.

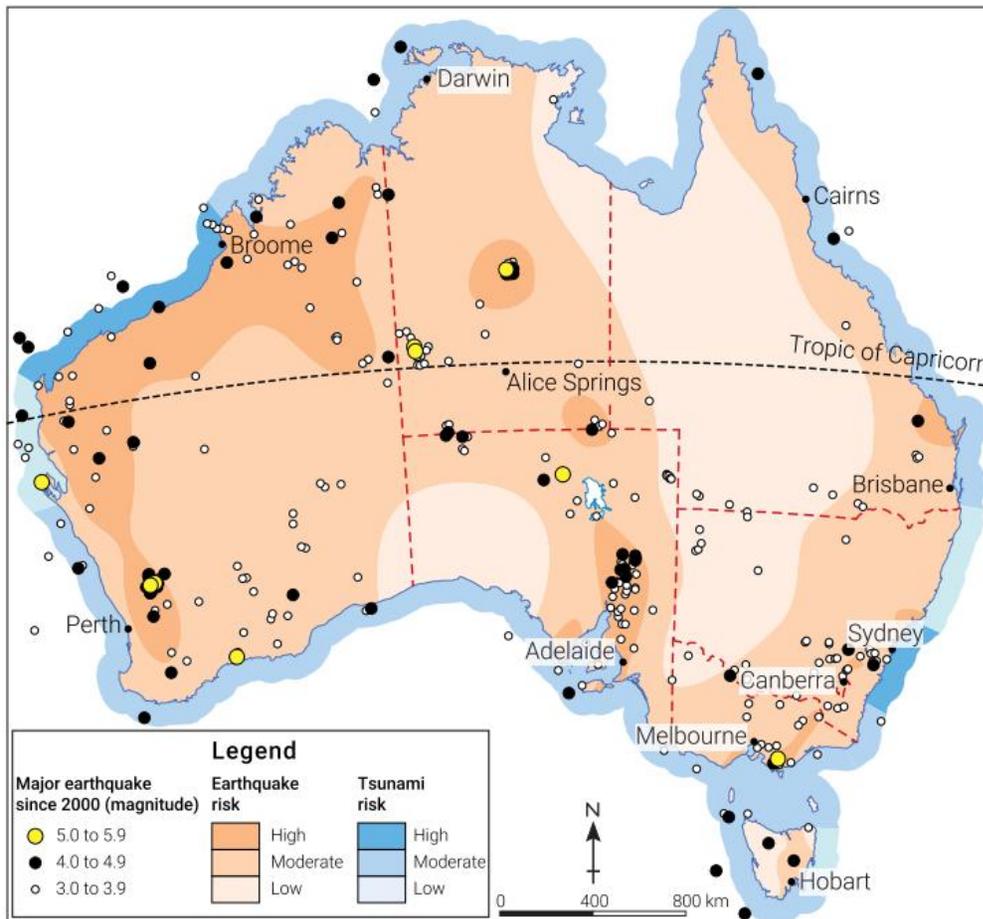


Figure 6 Australia: earthquake and tsunami risk

Check your learning 3.5



Check your learning 3.5

Retrieve

- 1 **Recall** two ways that the movement of tectonic plates can be destructive.

Comprehend

- 2 **Describe** a tsunami.
- 3 **Describe** where most earthquakes occur. **Explain** why earthquakes occur in these regions.
- 4 **Explain** how the movement of tectonic plates can be constructive.
- 5 **Explain** why there are few large earthquakes in Australia.

Apply

- 6 Like Australia, the Hawaiian Islands are in the centre of a tectonic plate. **Discuss** why the Hawaiian Islands have volcanoes and Australia does not.

Skills builder: Conducting investigations

- 7 Many geological sites around the world hold cultural significance. Before conducting scientific fieldwork in these areas, this significance must be acknowledged.
 - a Select and **describe** one geological area in New South Wales. (THINK: What are its features? How was it formed? What is its name?)
 - b **Identify** one ethical consideration you need to check before conducting fieldwork. (THINK: What are the cultural or societal impacts of the fieldwork? Can you conduct the fieldwork elsewhere?)
 - c **Identify** the next steps to take before proceeding. (THINK: Who do I need to contact? Does this need approval?)

Lesson 3.6

Challenge: Modelling a tectonic boundary

Background

Scientists can use a variety of equipment to measure the location (latitude and longitude) and strength of an earthquake. The amount of damage that can be done by an earthquake is dependent on the magnitude and the depth of the plate movement.

Aim

To recreate a 2D model of a tectonic boundary

What you need:

- Map of South America
- Computer
- Excel software

What to do:

Part A

- 1 Make a copy of the map of South America.
- 2 Map the location of each earthquake (the latitude and longitude) identified in Table 1. The latitude and longitude values are shown as degrees ($^{\circ}$).

Table 1 Earthquake data from South America

Station	Latitude ($^{\circ}$)	Longitude ($^{\circ}$)	Depth (km)	Magnitude
1	19.8	66.6	259	4.6
2	27.8	63.2	513	5.1
3	26.2	63.3	550	4.8
4	31.2	71.5	33	5
5	23.2	66.4	200	4.8
6	23.5	71	25	5
7	24.5	70.8	33	5
8	21.3	68.2	122	4.7
9	23.6	70	42	5
10	23.5	70.5	50	4.9
11	22.9	68.3	115	4.8
12	34.1	69.8	45	4.2
13	22.3	66.1	274	5
14	23.2	69.3	67	4.9
15	22.5	67.4	168	4.5
16	19.5	65.8	305	4.5
17	21.4	68.1	123	5.1
18	27	63	500	4.9
19	27.2	67.1	155	4.7
20	20.4	66	300	4.5
21	25.6	66	385	5
22	22.2	64.5	440	4.8

Part B

- 1 Open an Excel spreadsheet on your computer.
- 2 Enter the longitude ($^{\circ}$) and depth (km) into the spreadsheet.
- 3 Highlight the two columns on the table.
- 4 Select the “Insert” tab, and “Scatter graph”.

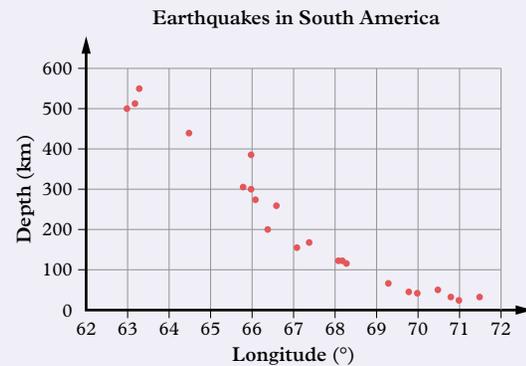


Figure 1 A scatter graph showing the longitude ($^{\circ}$) and depth (km) of earthquakes in South America.

Discussion

- 1 **Describe** the location of the earthquakes on the South American continent.
- 2 **Explain** the location of the earthquakes on the South American coast.
- 3 **Describe** the relationship between the longitude of the earthquakes and the depth of the earthquake.
- 4 **Describe** what is happening to the two tectonic plates at that boundary.

Lesson 3.7

Science as a human endeavour: Engineering solutions in earthquake zones

Introduction

The movement of tectonic plates can have devastating effects on human populations. When tectonic plates move against each other, pressure builds up and is released.

This release of pressure can cause two main types of earth movement: **body waves** and **surface waves**. Body waves are earth movements that can travel through the body of Earth and are not trapped near the surface. Surface waves can only travel along the surface of Earth.

body wave a seismic wave that travels through Earth (not at the surface)

surface wave a seismic wave that travels along the surface of Earth

Primary body waves

The primary body waves are pressure waves (P-waves) that can travel through solid rock, liquid ocean and the gases of the atmosphere. Each wave causes the particles to compress and move close together, before expanding out again (Figure 1). P-waves are the fastest moving of the earthquake waves (1,600 to 8,000 m/s) and move in the direction of the earth movement. Because they are so fast-moving, they are often the first waves noticed in an earthquake.

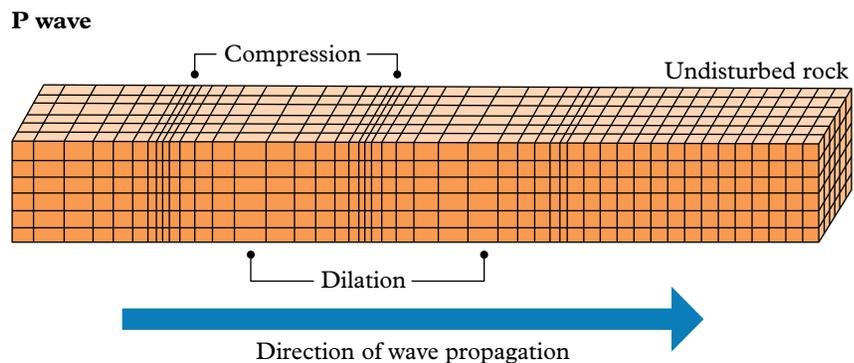


Figure 1 P-waves cause Earth's solids, liquids and gases to compress and expand.

Secondary body waves

Secondary body waves are also called shear or shaking waves (S-waves). S-waves can only move through solid earth. Some S-waves will move the earth from side to side, while others will move the earth up and down (Figure 2). S-waves move much slower than P-waves (900 to 4,500 m/s) but are more destructive as they can shake the whole landscape and cause buildings to collapse.

The speed of P- and S-waves will vary according to the density and elastic properties of the earth.

S wave

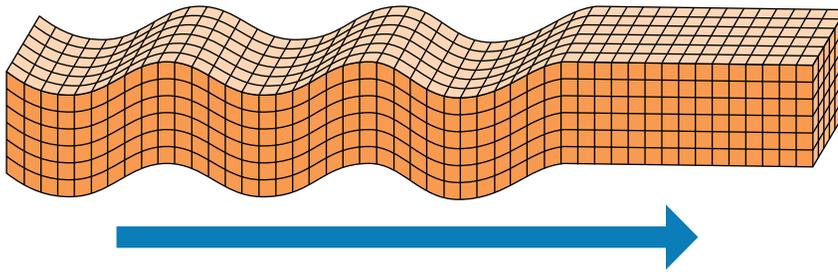


Figure 2 S-waves move from side to side or up and down. They are more destructive than P-waves.

Rayleigh surface waves

Like all surface waves, Rayleigh waves can only move along the surface of Earth. These waves cause the ground to move like waves or ripples (Figure 3). They can move up and down or side to side. People who have observed Rayleigh waves have described them causing parked cars to “bob up and down like corks floating on the ocean”. Rayleigh surface waves are slower than S-waves.

Rayleigh wave

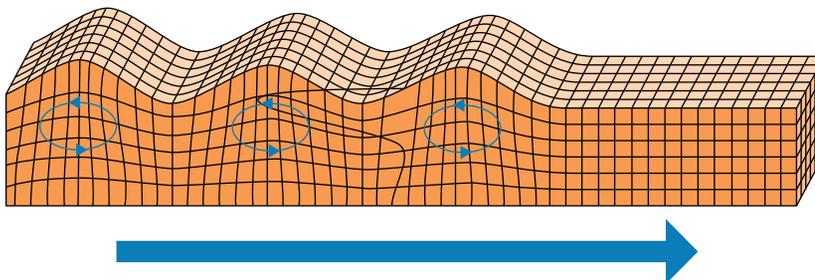


Figure 3 Rayleigh surface waves cause objects to bob up and down like corks.

Love surface waves

Love surface waves only move the earth from side to side (Figure 4). They travel faster than Rayleigh waves but slower than body waves. Their movement can cause a lot of damage to the foundations of buildings.

Love wave

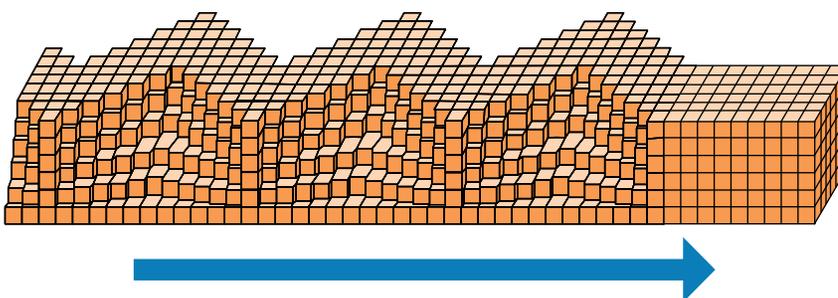


Figure 4 Love surface waves cause the earth to move from side to side, causing damage to building foundations.

Liquefaction

During earthquakes, the particles in the soil compress under the force of gravity, squeezing the space between particles. This causes the liquid caught in these spaces to be compressed, building up the pressure. When the pressure increases above a certain point, the soil particles start floating, and the ground starts acting like a liquid. This is called **liquefaction**. This is why some objects will sink during an earthquake (Figure 5), while other less dense particles will rise to the surface. You may have seen this when standing on a wet beach: if you wiggle your toes, your feet will sink.

liquefaction the transformation of solid soil into a liquid-like substance when under pressure during an earthquake



Figure 5 Liquefaction is when the soil acts like a liquid during an earthquake.

Designing for earthquakes

There are several factors that need to be considered when designing structures for earthquake zones. Love surface waves and liquefaction can damage the foundations of a building or bridge. This can be minimised by building flexible pads into the foundations. This allows the foundations to move during an earthquake, absorbing the energy of the earthquake while the building above stays relatively still.

Engineers use a variety of ways to stabilise tall buildings during an earthquake. Some suspend large heavy balls in the centre of the building. When a building begins to sway, the ball moves in the opposite direction (like a pendulum) to stabilise the building. Some engineers place dampers between the columns and beams on each floor of the building (Figure 6). Each damper can act like a shock absorber in a car, reducing the amount the building moves.

Many buildings in earthquake zones are also reinforced by adding cross braces (diagonal steel beams that help the building to keep its shape) and diaphragms (flat structures that transmit the horizontal movement away from the building frames).



Figure 6 Earthquake dampers reduce the movement of a building like a shock absorber reduces road bumps in a car.

Earthquake-resistant materials

The materials used in the building can also help the building control the movement energy in an earthquake. The materials used must be flexible enough to bend without

breaking. Concrete and brick are too brittle and will usually crack and fall. While steel and wood have been used in many buildings for the past 50 years, there are many old and new materials that may be more appropriate. Bamboo has much greater flexibility and is able to return to its original shape much better than steel and wood. It is very light as a building material, reducing the weight on the shaking foundations of the building. This also means that there is less risk to inhabitants if the building were to fall.

The multiple ties that are used in the construction of bamboo buildings can also help to maintain the flexibility of the structure.

Understanding of the properties of the traditional bamboo buildings constructed in earthquake zones has encouraged engineers to produce and use new materials with the same strength and flexibility. Strategies include:

- coating brickwork in acrylic-silicone paint resin and glass fibres to support flexibility
- combining cement with polymer-based fibres, fly ash or other additives to make it more flexible
- laminating wood by gluing layers of wood together with the grain running parallel.

These strategies work together to limit the damage caused by earthquakes and minimise the number of people killed each year.



Test your skills and capabilities

All scientists make predictions and hypotheses that can be evaluated to determine their truth or viability. This requires criteria to be developed and applied, to test the limitations of the model and determine whether modifications are needed.

Answer the following questions to critically **evaluate** the claim that all buildings in an earthquake zone should be made of bamboo.

- 1 **Identify** the types of earth movements that a building in an earthquake zone could experience.
- 2 **Identify** the ways a building in an earthquake zone could move.
- 3 **Describe** how this movement would affect the materials in the building.
- 4 **Compare** (the similarities and differences between) the flexibility and strength of different building materials including concrete, bricks, wood, steel and bamboo.
- 5 **Contrast** your descriptions of earth movement in question 2 with the material comparison in question 4.
- 6 **Identify** three questions you could ask an engineer about a building design in an earthquake zone.
- 7 **Investigate** one form of evidence or data that would cause you to disagree with the claim that all buildings in an earthquake zone should be made of bamboo.
- 8 **Determine** if you agree or disagree with the claim that all buildings in an earthquake zone should be made of bamboo.

Lesson 3.8

Challenge: Design an earthquake-proof house

Design brief

Design and build a house that will be stable in an earthquake zone. Test your design by placing the house in a large clear-sided tub of sand and water.

Criteria restrictions

- The house can be built from the materials provided (these might include pipe cleaners, icy-pole sticks, sticky tape, paper, aluminium foil, cardboard, play-dough and wire).
- The house must be closed in with walls and a roof.
- The house must have foundations that go into the soil.

Questioning and predicting

- 1 **Identify** the materials you will use.
- 2 **Identify** the properties of the materials you will use.
- 3 **Use** your knowledge of earth movement to **explain** why your house will survive an earthquake.
- 4 **Explain** how you will measure the effectiveness of your house design.
- 5 **Describe** the type of earth movement and the length of time of the earthquake.

Planning and conducting

- 1 Fill the tub $\frac{3}{4}$ full with fine sand.
- 2 Pour water into the container until it is just below the surface of the sand. Make sure that the water does not rise above the surface of the sand.
- 3 Place a small brick on the surface of the sand.
- 4 Slide the tub rapidly back and forth until water rises to the surface and the brick starts to sink. This is an example of liquefaction.
- 5 Use your hands to mix up the sand and water again.
- 6 Build your earthquake-proof house and place it on or embed it in the sand.
- 7 Slide the tube rapidly back and forth to test the effectiveness of your design.

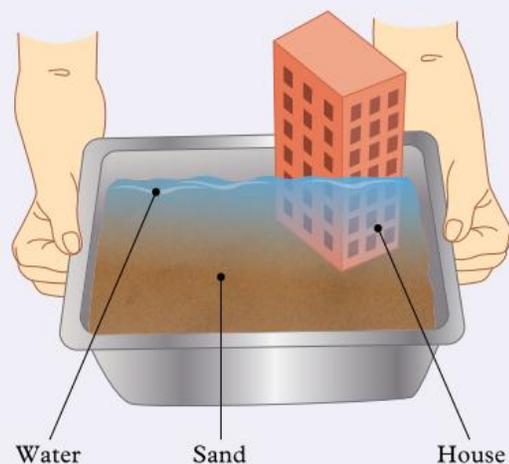


Figure 1 General set-up of experiment

Processing, analysing and evaluating

- 1 **Describe** the movement of your designed house during the model earthquake.
- 2 **Compare** the effectiveness of your design against other houses designed by your peers.
- 3 **Describe** the limitations of your design (the earth movements that will cause it to collapse).

- 4 **Describe** how you could create a large-scale version of your design for a real house.
- 5 **Describe** how you would modify your design if you were doing this experiment again.

Communicating

Present the various stages of your investigation in a scientific report.

Lesson 3.9

Review: Plate tectonics

Summary

Lesson 3.1 Earth is made of layers

- Earth is made up of several layers.
- The centre of Earth, or core, has two layers: the outer core of liquid iron and nickel, and the inner solid core.
- The next layer, the mantle, is made up of molten rock.
- The outer layer of Earth (the one we live on) is the crust, or lithosphere.

Lesson 3.3 Forces cause tectonic plates to move

- Continental drift describes the movement of the continents.
- Plate tectonics explains how and why the continents are moving.
- The forces involved in plate tectonics are convection current, ridge push and slab pull.

Lesson 3.4 Boundaries between tectonic plates can be converging, diverging or transforming

- At a transform boundary, tectonic plates slide past one another.
- At a convergent boundary, plates come together, forming mountains or subducting.
- At a divergent boundary, tectonic plates move apart.

Lesson 3.5 Tectonic plates can be constructive or destructive

- The movement of tectonic plates can cause destructive earthquakes or tsunamis.
- Molten mantle can escape from volcanoes and become lava.
- Lava can form new islands.

Review questions 3.9



Review questions

Retrieve

- Identify** which two of the following have led to our understanding of plate tectonics.
 - Continental drift
 - Subduction
 - Sea-floor spreading
 - Magnetometers
- Identify** the type of plate collision where subduction is most likely to occur.
 - Continent-to-mantle
 - Continent-to-continent
 - Ocean-to-ocean
 - Ocean-to-continent
- Identify** the type of natural disaster that can be caused by an undersea earthquake.
 - Hurricane
 - Volcanic eruption
 - Tsunami
 - Bushfire
- Recall** the evidence that Alfred Wegener used to support his theory of continental drift.
- Define** the following terms.
 - Subduction
 - Diverging boundary
 - Ridge push
 - Sea-floor spreading
 - Slab pull
 - Converging boundary
 - Convection

Comprehend

- Describe** Pangaea and what happened to it.
- Describe** the three forces that move the tectonic plates over the surface of Earth.
- Describe** the cause of major volcanic eruptions and earthquakes.
- Most earthquakes occur at plate boundaries. **Explain** how an earthquake can occur in the middle of a plate.
- Explain** why continental crusts cannot be subducted.
- Explain** how sea-floor spreading accounts for the young age of the sea floor.
- Modern Global Positioning Satellites (GPS) identify their location through instruments embedded in Earth's bedrock. **Explain** why GPS systems are useful for predicting future plate movements.

Analyse

- The Himalayas formed when India collided with the Eurasian Plate. Mount Everest, the highest mountain on Earth, is 8,848.86 m high and continues to be uplifted at a rate of about 1 cm per year. Assuming there is no erosion, **calculate** the height of Mount Everest in 1 million years if it maintains its current rate of increase.



Figure 1 The Himalayan mountain peaks

- Examine** Figure 2, which shows a topographic image of the Mid-Atlantic Ridge. **Consider** how this provides evidence of sea-floor spreading.

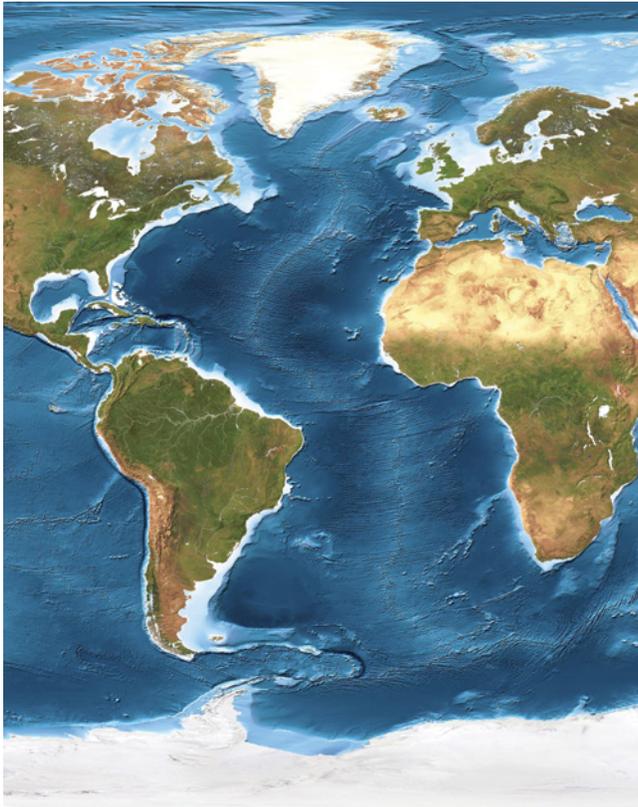


Figure 2 The Mid-Atlantic Ridge

15 If part of the Pacific Plate is moving at a rate of 10 cm per year, **calculate** how far it would move in:

- a 100 years
- b 10,000 years
- c 1 million years.

16 Contrast the different layers of Earth.

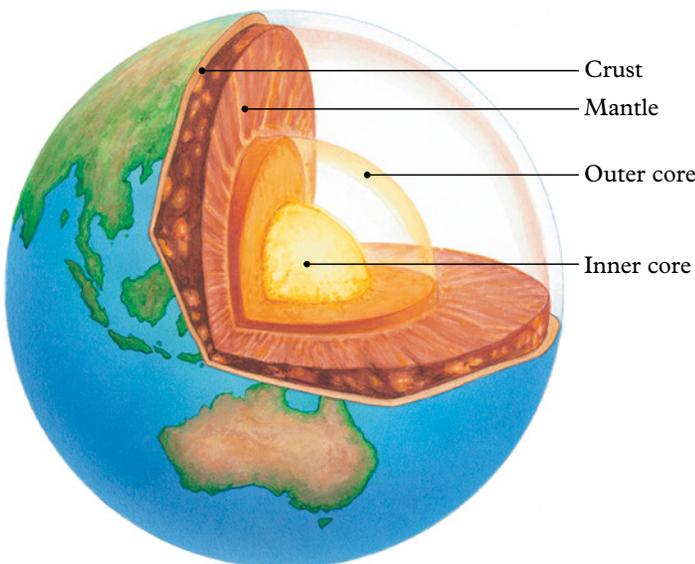


Figure 3 Layers of Earth

17 Connect the following terms with their definitions.

Term	Definition
Mantle	Central part of the Earth
Crust	Layer of hot, semi-molten rock below the crust
Oceanic crust	Theory that states that the continents move through oceanic crust
Continental crust	Theory that describes why large plates of Earth's crust gradually move
Plate tectonics	Less dense crust containing continents
Tectonic plate	Hot liquid rock that comes up from the mantle
Continental drift	Thin, semi-rigid outer layer of the Earth
Convection current	Large area that may include continent and sea floor
Magma	Dense crust under the sea floor
Core	Movement of liquids or gases caused by the rising of hot material

Apply

18 If Australia moves north to collide with Indonesia and Malaysia, **determine** the geographical features that will form and how our climate will change.

19 Once there was one supercontinent called Pangaea. Initially it split into two. One part, Laurasia, moved north while the other, Gondwana, moved south. Laurasia gave rise to Europe, Asia and North America. Gondwana gave rise to Africa, South America, Australia, India and Antarctica.

- a **Discuss** the climate changes each continent faced as it drifted to its current position.
- b **Explain** why, today, many plants and animals that originally inhabited the Gondwana subcontinents share physical similarities.

Social and ethical thinking

20 In 2009 there was a series of small earth tremors in the Italian city of L'Aquila. Six scientists (three seismologists, a volcanologist and two seismic engineers) provided advice to the city that an ongoing series of small- and medium-sized tremors did not necessarily mean a large earthquake was going to occur. As a result, the citizens did not take precautions, and many were indoors on the night the 5.9 magnitude earthquake hit. The scientists were charged with manslaughter for the deaths of 308 people, because they had failed to predict the earthquake. Their initial conviction was eventually overturned. **Evaluate** the fairness of this trial by:

- describing how the local townspeople would have reacted if the scientists had warned of the impending earthquake
- describing how the local townspeople would have reacted if the scientists had not offered any advice
- describing the accuracy of earthquake predictions
- deciding whether the scientists should have offered any advice to the townspeople.



Figure 4 The earthquake that struck L'Aquila in 2009 was one of the deadliest in Italy.

Critical and creative thinking

- 21 Create** a poster or multimedia presentation about a famous earthquake or volcanic eruption. **Describe** the facts of the earthquake or volcanic eruption and what plate movement caused it, along with the social, environmental and economic impacts and the subsequent recovery process.
- 22** The Mariana Trench is located in the Pacific Ocean. Its average depth is 11 km below the surface of the water.
- a Identify** the latitude and longitude of the Mariana Trench on a map.
 - b Explain** how the Mariana Trench formed.
 - c** Surprisingly, ocean explorers have found life at the bottom of the Mariana Trench. **Investigate** the organisms that live so deep and how they survive.
- 23** Imagine you could travel into the future, to a time when your local environment is drastically different from how it is today. Base your imagined scenario on the plate movements of the Australian continent. **Create** a travel brochure for a future tourist destination or journey on this new Earth.
- 24** Imagine you are an engineer designing a building for an area that often experiences earthquakes. **Discuss** the type of earth movements that could be caused by the earthquakes and **determine** what materials you will use to help limit the impact of the earthquakes on your building. **Justify** the use of materials and explain why the **ethical** use of materials is important.

Research

- 25** Choose one of the following topics to research. Some questions have been included to get you started. Present your findings in a format of your own choosing (such as filming a documentary), giving careful thought to the information you are communicating and your likely audience.

Subduction zones

The subduction of one plate under another is well understood by scientists today, but how this process begins is not.

- **Explain** what geologists mean by subduction.
- **Identify** which plates are involved in subduction.
- **Describe** what happens to the plates during subduction.
- **Describe** the geological features that are associated with subduction zones.

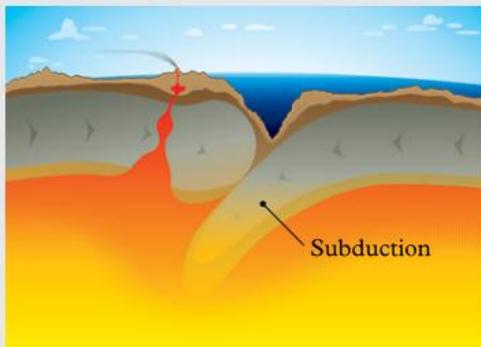


Figure 5 Subduction zone

The Budj Bim National Park

The Budj Bim National Park contains evidence of volcanic events from over 4,000 years ago. The Bungandij People have oral records that have preserved the cultural knowledge of the events that formed the crater lakes at this location.

- **Define** the term “oral records”.
- **Investigate** and **describe** the cultural accounts that provide evidence of earthquakes and volcanoes in this area.
- **Describe** why it is important to consider oral histories as a form of evidence of earthquakes and volcanoes.
- **Describe** the modern evidence that has confirmed the oral histories of Aboriginal and Torres Strait Islander Peoples.
- **Investigate** how partnerships between Western science and Aboriginal and Torres Strait Islander Peoples’ science have worked together to produce one science.

Tsunami warnings

Seismic data is collected and shared by a variety of governments across the Asia–Pacific region.

- **Describe** how sensors are used to collect earthquake information.
- **Describe** how information about potential tsunamis is shared between the different governments.
- **Describe** how the information is shared with the population and the actions that may be taken as a result.



Figure 6 Tsunami warning signs run along the Pacific coastline in California.

Magnetic striping

Magnetic striping was considered by some to be the final proof of plate tectonics.

- **Research** and **explain** magnetic striping.
- **Identify** where it exists.
- **Describe** how it is linked to sea-floor spreading.
- **Explain** what it tells us about the age of rocks and Earth’s history.

Module 4 Energy

Overview

Energy comes in different forms including thermal, chemical, gravitational and elastic, and can be either moving (kinetic) or stored (potential). Thermal energy moves around in different ways, through conduction, convection or radiation. Understanding how energy moves allows engineers to design more efficient materials that can be used in manufacturing cars or energy-efficient homes. Aboriginal and Torres Strait Islander Peoples' understanding of the energy in friction is evidenced in traditional fire-starting methods.



Lessons in this module:

Lesson 4.1 Energy can be transferred (page 150)

Lesson 4.2 Challenge: Draw flow diagrams of energy transfer (page 154)

Lesson 4.3 Potential energy is stored energy (page 157)

Lesson 4.4 Experiment: What if the amount of elastic potential energy was increased? (page 160)

Lesson 4.5 Moving objects have kinetic energy (page 161)

Lesson 4.6 Energy can be transformed (page 164)

Lesson 4.7 Heat is a by-product of energy transformation (page 168)

Lesson 4.8 Energy efficiency reduces energy consumption (page 170)

Lesson 4.9 Challenge: An energy audit records energy consumption (page 174)

Lesson 4.10 Challenge: Designing a passive design house (page 175)

Lesson 4.11 Science as a human endeavour: Solar cells transform the Sun's light energy into electrical energy (page 177)

Lesson 4.12 Review: Energy (page 181)



Learning intentions
and success criteria



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

Lesson 4.1

Energy can be transferred

Key ideas

- Energy is the ability to do work. It is how things change and move.
- Energy cannot be created or destroyed.
- When energy is passed from one object to another, it is said to be transferred.

Introduction

For hundreds of years, scientists (and some mystics) have been developing theories about energy. While scientists like Nikola Tesla were able to control different forms of energy in the development of radios, electrical devices and X-ray photographs, mystics such as Tesla's friend Swami Vivekananda collaborated to examine the links between the mass of an object and its energy.

All objects or groups of objects have energy (including moving objects, stretched objects and objects high off the ground). It is energy that gives objects the ability to change or move.

Energy cannot be created or destroyed. Instead, it is passed (**transferred**) from one object to another. It can sometimes be described as a property of an object or field.

Sometimes energy will also change its form from one type to another when it is transferred. We will look at the different forms of energy in Lesson 4.3 Potential energy is stored energy (page 157), Lesson 4.5 Moving objects have kinetic energy (page 161) and Lesson 4.7 Heat is a by-product of energy transformation (page 168).

transferred

describes energy that has moved from one object to another

The flow of energy

We have all felt the energy of the Sun on a hot day. It can warm anything that is left out in the Sun (Figure 1), including our skin.

Plants are very efficient at absorbing the energy of the Sun. The energy is transferred from the Sun to the plant. This can be

shown using a flow diagram where an arrow shows the direction of energy flow. The plant uses the energy to grow. Eventually, animals (including us) eat the plants and the energy is transferred to the animal (Figure 2).

We use the energy for moving, including walking (Figure 3). This also produces heat that then warms up the air around us (Figure 4).

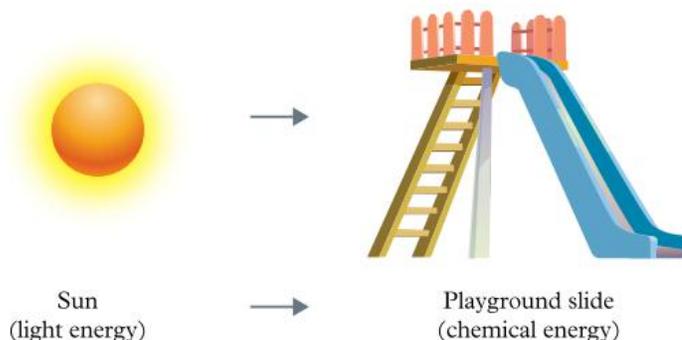


Figure 1 The heat energy from the Sun can be transferred to playground equipment.

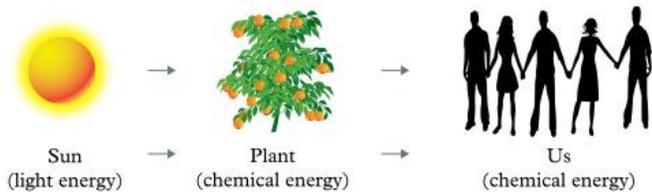


Figure 2 We need the energy from plants to move.



Figure 3 We need energy to walk and carry things.

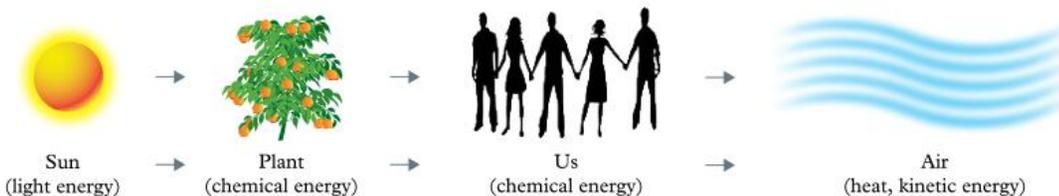


Figure 4 Heat energy can be transferred from us to the air.

Energy transfers for movement

Electric cars are designed to transfer the energy stored in batteries, rather than petrol, to power an electric motor that makes the wheels turn (Figure 5). This can be shown using a flow diagram (Figure 6).

Public transport transfers energy too (Figure 7). Trams and metropolitan trains transfer the energy from overhead wires into the motor that makes the wheels move (Figure 8).



Figure 5 Electric cars use an electric motor to send power to the wheels.

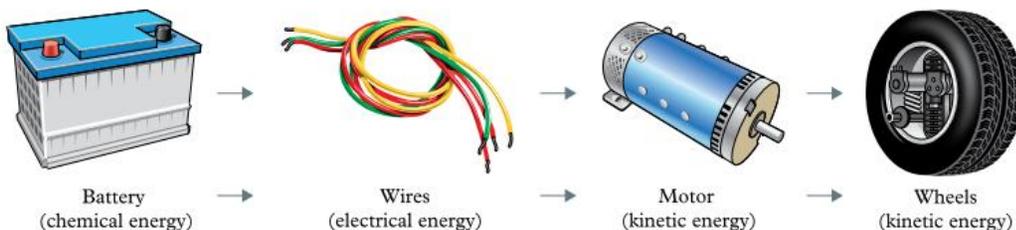


Figure 6 The energy stored in a car battery is transferred to the wires, then to a motor, and finally to the wheels of a car.

Trains that travel interstate or to country areas usually run on diesel fuel and don't need overhead electrical wires (Figure 9). The engines in these trains burn diesel fuel, transferring the energy into wheel movement via the motors (Figure 10). Ships and planes use a similar process in their engines.



Figure 7 Powerlines provide electrical energy for public transport.

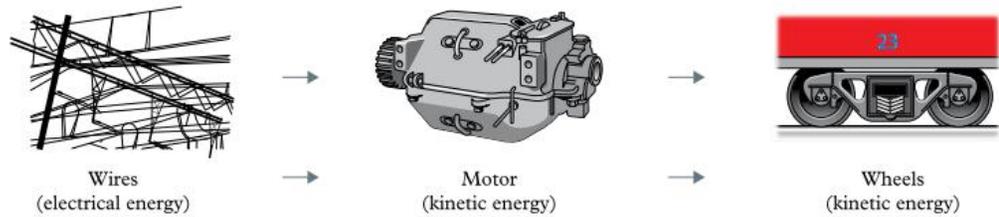


Figure 8 Energy in the wires transfers to the motor and then to the wheels of some trains.



Figure 9 Powerlines are not practical in rural areas, so diesel fuel is used.

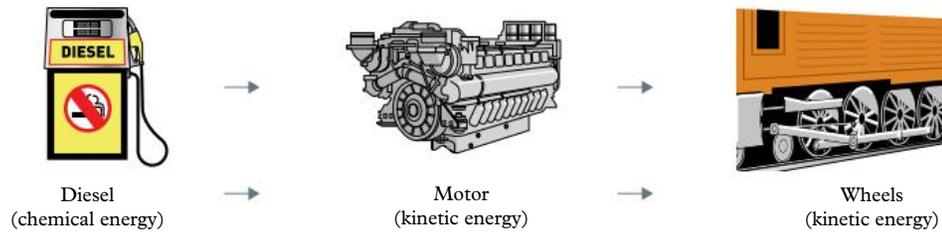


Figure 10 The energy of the diesel fuel is transferred to the motor and then to the wheels of some trains.

Energy transfers for entertainment

A mobile phone uses a speaker to produce the sound of a person's voice or the various ring tones and beeps that the phone makes. Home phones use a speaker too, as do sound systems, headphones, radios and many other devices. They all transfer energy from a battery to the wires inside the speaker, then the energy is transferred to the speaker to make sound (Figure 11).

remote control an electronic device used to operate a machine remotely (i.e. at a distance)

A television **remote control** transfers energy from the device through the air as light energy, which transfers into the television set (Figure 12). In fact, most remote controls use infrared light, which is



Figure 11 Headphones transfer energy in batteries to the wires and the speakers. The speakers transfer the energy to the air so we can hear the sound.

the invisible type of light usually associated with heat. The remote control sends a pulse of infrared light that represents a particular command, such as changing the channel or increasing the volume. An infrared light detector on the television receives the light signal and transfers it back into electrical energy, which then carries out the command (Figure 13).



Figure 12 A television remote control uses an infrared light-emitting diode (LED) to operate the television.

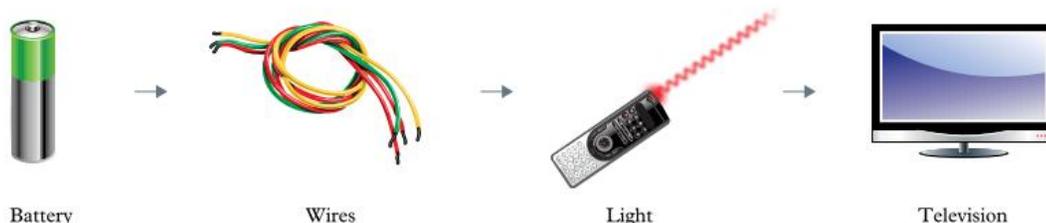


Figure 13 Television remote controls transfer small amounts of energy to the television to carry out commands.

Check your learning 4.1



Check your learning 4.1

Retrieve

- 1 Define** the term “energy”.

Comprehend

- 2 Describe** why the direction the arrows point in a flow diagram is important.
- 3 Explain** why country trains mostly use diesel fuel instead of electrical wires.

Analyse

- 4 Identify** the type of devices that the following energy flow diagrams could represent.
 - Wires → motor → air
 - Battery → wires → light globe
 - Food → muscles → bicycle
- Recreate Figure 14 and **draw** arrows to indicate the direction the energy flows between each object in an energy flow diagram.

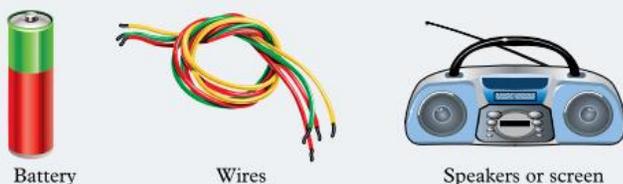


Figure 14 Flow diagram

Apply

- 6 Determine** the ultimate source of all energy.
- 7 Summarise** the entertainment devices mentioned in this lesson and **create** flow diagrams showing the direction the energy is transferred between the different objects.

Skills builder: Conducting investigations

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

Lesson 4.2

Challenge: Draw flow diagrams of energy transfer

Aim

To identify the transfer of energy between objects

What you need:

Station 1:

- Variety of wind-up toys

Station 2:

- Battery
- Small buzzer
- Wires

Station 3:

- Tuning fork

Station 4:

- Plastic cup
- Water
- Tablespoon
- Salt
- Aluminium strip
- Copper strip
- 2 wires
- Multimeter

Station 5:

- Plastic windmill
- Kettle

Station 6:

- Ramp
- Toy car
- Measuring tape

What to do:

Stations with different types of energy are spread around the room. Copy Table 1 into your notebook. Follow the steps below for each station and identify the object where you first see evidence of the energy (source), and the object where you last see the energy (output). Add the source and the output at each station to your table.

Station 1

- 1 Wind up the toys and watch them move.
- 2 **Identify** the source and output energy.



Figure 1 What path does the energy take as it is transferred through the wind-up toys?

Station 2

- 1 Connect the battery to a buzzer using wires.
- 2 **Identify** the source and output energy.

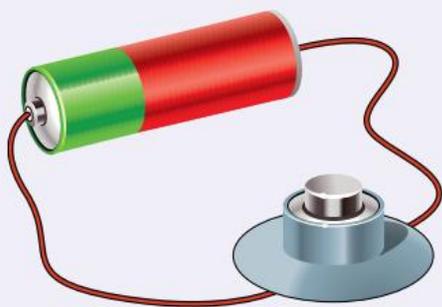


Figure 2 Use wires to connect the buzzer to the battery.

Station 3

- 1 Gently tap the forked end of the tuning fork on a table. Sound is generated by vibrations.
- 2 **Identify** the source and output energy.



Figure 3 Where does the sound energy come from or transfer from?

Station 4

- 1 Fill most of the cup with water.
- 2 Add 1 tablespoon of salt to the water.
- 3 Fold a strip of aluminium and a strip of copper over opposite sides of the cup so that one end is in the saltwater and the other end is on the outside of the cup.
- 4 Attach wires to the outside edges of the metal strips.
- 5 Connect the multimeter to the wires and adjust the multimeter so the voltage is measured.
- 6 Record the voltage generated by your chemical battery.

- 7 **Identify** the source and output energy.

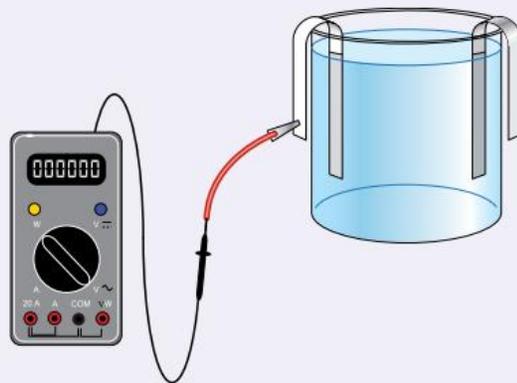


Figure 4 Connect the saltwater battery to a multimeter.

Station 5

- 1 Blow on the plastic windmill.
- 2 **Identify** the source and output energy.
- 3 Hold the plastic windmill over a boiling kettle while being careful not to burn yourself with the steam. Hold your hand as far away as possible from the steam. Ensure there is plenty of water in the kettle so it doesn't boil dry.
- 4 **Identify** the source and output energy.



Figure 5 A plastic windmill



Figure 6 A toy windmill acts like an electricity-generating turbine.

Station 6

- 1 Set up the ramp so that the top end is 10 cm above the ground.
- 2 Place the car at the top of the ramp.
- 3 Allow the car to roll down the ramp and along the floor.
- 4 Measure how far the car rolled.
- 5 **Identify** the source and output energy.
- 6 **Describe** how you could increase this output energy.



Figure 7 A toy car at a standstill



Figure 8 A tape measure

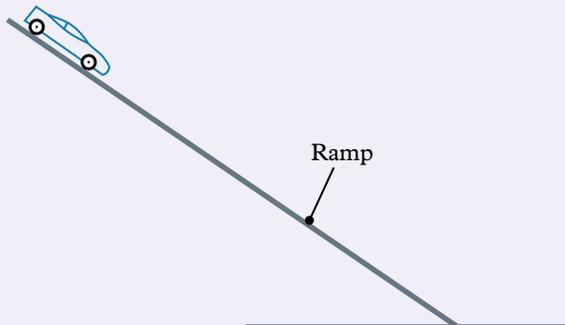


Figure 9 What path does the energy take as the toy car moves down the ramp?

Results

Copy Table 1 and use it to record your results.

Table 1 Energy transfer

Station	Where does the energy come from? (source)	Which object or part of the object has the energy last? (output)
1		
2		
3		
4		
5		
6		

Questions

- 1 **Describe** what is meant by “energy transfer”.
- 2 **Identify** which stations had energy transfer from one object to another.
- 3 **Draw** an energy flow diagram for each station.
- 4 **Describe** the original energy source for all of the stations and all objects on Earth.

Lesson 4.3

Potential energy is stored energy

Key ideas

- An object that has the potential (future ability) to do work has potential energy.
- Elastic potential energy is stored when an elastic object is deformed.
- Gravitational potential energy is stored when an object is lifted away from Earth's surface.
- Chemical potential energy is the energy stored when atoms are bonded to each other.
- Nuclear potential energy is the energy stored inside the centre of an atom.



Learning intentions and success criteria



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

Introduction

Some objects can store energy. This type of stored energy is called **potential energy**. There are many different ways energy can be stored. This allows it to be released or transferred at a later time.

Elastic potential energy

A trampoline has the ability to “store” energy, or hold it, for later use or if things change. The springs and the mat of the trampoline stretch under our weight and hold this stored energy. The more they stretch, the more energy they hold. The energy is returned to our bodies when the springs and mat return to normal and throw us into the air. Energy that is stored through stretching or squashing is called **elastic potential energy** (Figure 1).



Figure 1 Jumping stilts rely on elastic potential energy.

potential energy energy that is stored in an object due to its properties, position and the forces acting on it

elastic potential energy the energy possessed by stretched or compressed objects

Gravitational potential energy

If we lift an object to a height, it gains energy in a gravitational field (Figure 2). This type of energy is called **gravitational potential energy**.

The larger the mass and the larger the height, the more gravitational potential energy the object gains. Have you ever noticed that falling a greater distance produces a greater “thud” and can hurt more? This is because of the amount of gravitational potential energy. As an object falls, the object’s gravitational potential energy can be

gravitational potential energy the energy possessed by an object raised to a height in a gravitational field



Figure 2 This television has gravitational potential energy when raised above the ground.

transformed into other forms of energy. This happens when a person plays on a slide at the playground. The higher they climb, the more gravitational potential energy they get. When they slide down, the gravitational potential energy decreases. The person gains movement energy. They may also feel the friction of the slide as heat or even as a zap of static electrical energy (Figure 3).



Figure 3 Plastic slides are great at zapping us with static electricity, although it depends on the weather and the clothes we wear.

Chemical potential energy

After we have done a lot of exercise, we often crave foods that we believe will restore our energy levels. These foods, like everything on Earth, are made up of chemical molecules. Energy is often used to produce large chemical molecules like sugar. The energy is released when the large chemical molecules are broken down into smaller molecules. When we eat or drink high-energy foods, the breakdown of the usually sweet things, releases stored chemical energy quickly (Figure 4). The energy stored in chemical molecules is called **chemical potential energy**.



Figure 4 Energy drinks contain chemical potential energy.

chemical potential energy

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

Fuels, such as natural gas and petrol, provide us with energy too. A Bunsen burner uses the burning of natural gas to provide heat for laboratory experiments. Petrol has chemical energy stored in it, as do explosives and batteries.

These devices all contain chemical potential energy that can be released when we need it. Some batteries can be recharged – the chemical potential energy can be replaced.

Nuclear energy

Although nuclear energy is used throughout the world, it is not used in Australia. **Nuclear energy** involves the reaction in the nucleus, or centre, of atoms. When atoms react in chemical reactions, they usually release only small amounts of energy. However, if the centres (nuclei) of those atoms can be made to react, the amount of energy released is much, much larger. In fact, the amount of energy released is so huge that it can cause massive amounts of destruction (Figure 5).



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

nuclear energy energy stored in the nucleus of an atom and released in nuclear reactors or explosions of nuclear weapons; much greater than the chemical energy released in chemical reactions

Check your learning 4.3



Check your learning 4.3

Retrieve

- Define** the term “potential energy”.
- Identify** four examples of devices or situations that involve potential energy.
- Recall** the type of energy that is stored in a battery.
- We get our energy from the chemicals in food. **Identify** the type of energy found in food.

Analyse

- Biofuel is an alternative source of energy that comes from burning to release the energy stored in plants. **Identify** the type of potential energy released in biofuel.
- Identify** four devices, other than those mentioned already, that can be given elastic potential energy.
- Describe** how a person might use a bow to shoot an arrow. **Identify** the type of potential energy used in this process.

Skills builder: Problem solving

- Evaluate** the following claim: “Nuclear energy is good for the environment”.
 - Investigate** the advantages and disadvantages of using nuclear energy by using secondary resources to fill in a PMI table like the one below.
 - Copy and **use** this PMI table to **assess** the above claim. (THINK: Are some factors more important than others? Why or why not? Do you think this claim is correct, somewhat correct or incorrect? What evidence do you have to support this?)

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

Lesson 4.4

Experiment: What if the amount of elastic potential energy was increased?

Aim

To investigate how elastic potential energy can be used to power a boat

Materials

- Waxed cardboard (fruit boxes work well)
- Scissors
- Rubber band
- Butterfly pins
- Water bath or swimming pool
- Measuring tape

Method

- 1 Cut out the waxed cardboard to match the diagram in Figure 1.
- 2 Put the rubber band around the propeller.
- 3 Attach the propeller to the boat using butterfly pins.
- 4 Wind the propeller anticlockwise (when viewed from the right side of the boat), place the boat in the water and release it.
- 5 Measure how far the boat travels.

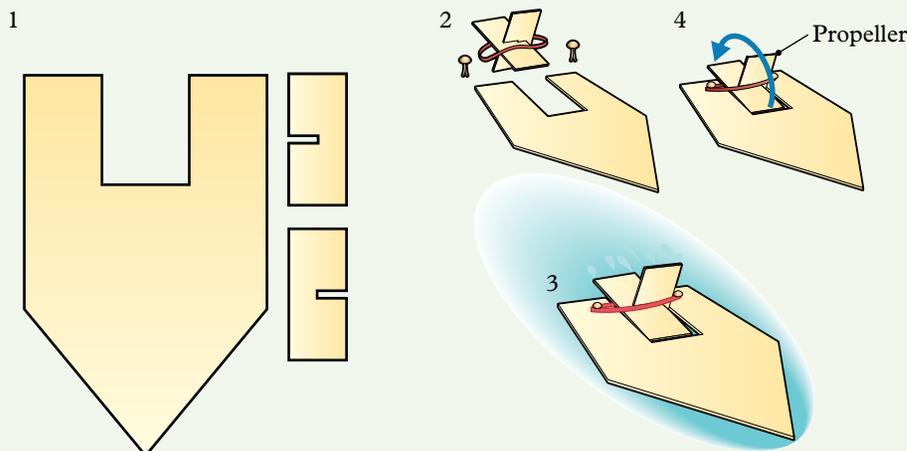


Figure 1 The parts and method of assembly for a rubber-band boat.

Inquiry: What if more elastic potential energy was stored in the rubber-band propeller?

Plan and conduct an experiment that answers the inquiry question.

- 1 **Develop** a prediction or hypothesis for your inquiry.
- 2 **Identify** the (independent) variable that you will change from the first method.
- 3 **Identify** the (dependent) variable that you will measure and/or observe.
- 4 **Identify** two variables that you will need to control to ensure a reproducible test. **Describe** how you will control these variables.
- 5 **Develop** a method for your experiment. Write this method in your logbook.
- 6 Copy Table 1 into your logbook to record your results.
- 7 Show your teacher your planning for approval before starting your experiment.

Table 1 Potential energy experiment

Number of rotations of the propeller	Distance the boat travelled Attempt 1	Distance the boat travelled Attempt 2	Distance the boat travelled Attempt 3	Average distance the boat travelled
1				
2				
3				
4				
5				

Results

- 1 Complete Table 1.
- 2 **Construct** a line graph showing the effect of increasing the elastic potential energy of the propeller on the distance the boat travelled.

- 2 **Explain** why you made three attempts at each propeller rotation to determine the average distance travelled.
- 3 **Identify** the type of energy that the elastic potential energy was transformed into.
- 4 Your hands provided the energy to wind the propeller. **Describe** where this energy came from.

Discussion

- 1 **Identify** the type of data as either qualitative or quantitative. **Justify** your answer (by defining each term and comparing it to your data).

Conclusion

Describe the relationship between the potential energy given to the propeller and the distance the boat moved.

Lesson 4.5

Moving objects have kinetic energy

Key ideas

- Kinetic energy is the energy found in a moving object.
- Moving heavy objects have more kinetic energy than moving light objects when they move at the same speed.
- The faster an object moves, the more kinetic energy it has.



Learning intentions and success criteria

kinetic energy the energy possessed by moving objects

Introduction

The energy of movement is more scientifically called **kinetic energy**. Whenever objects or people move, they have kinetic energy (Figure 1). It takes energy to force an object such as a car to start moving. Once it is moving, the energy has passed to the car. It is this energy that is called kinetic energy. The faster the object is moving, or the more mass the object has, the greater the kinetic energy. Even objects too small to be seen can have kinetic energy.



Figure 1 Kinetic energy is the energy of movement.

Light energy

Light energy is essential to our lives, and people have invented lots of devices to help us see in the dark, including oil, gas and kerosene lamps (Figure 2). The humble electric light bulb revolutionised the world and led to easily portable light sources such as torches. But the best source of light is, of course, the Sun.

Light energy is one type of energy that our eyes can usually detect. It moves in small packets of energy called photons. We see a range of colours (red, orange, yellow, green, blue and violet) in the visible spectrum, but the light we see is part of a larger group that is called electromagnetic radiation. This large group includes, but is not limited to, ultraviolet light, microwaves and X-rays.

The study of light energy is known as optics.

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

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

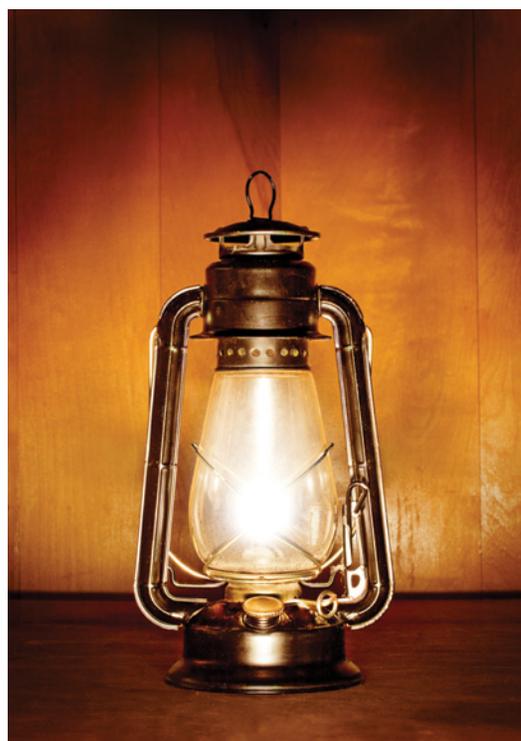


Figure 2 Kerosene lamps were used for many years before the invention of electricity.

solar cell a device that transforms sunlight directly into electrical energy; is usually in the form of a panel; also known as a solar panel

thermal energy the scientific term for heat energy

Heat energy

Heat energy is more scientifically known as **thermal energy**. Thermal energy can be generated by friction, such as by rubbing your hands together or by the movement of

a car's tyres on the road (Figure 3). It is also commonly generated by burning chemicals or by electrical devices. We experience heat energy being transferred from a high-temperature place to a lower-temperature place as we heat up or cool down. For example, an ice block feels cool because it takes the thermal energy away from our hands.



Figure 3 The heat of a “burn-out” creates great clouds of smoke.

Electrical energy

All substances are made up of positive and negative electric charges that, when separated, have **electrical energy**. This means that they are in a state of excitement and are trying to get back together again. If the positive and negative charges are locked together in one area, such as a wire, the separated charges can easily move back together. As they try to connect, the electrical energy they had when separated gets changed into light, heat or movement that we see in electrical lights, heaters or motors.

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

Sound energy

Have you been at a very loud concert and stood near the huge speakers? If so, you will remember that you not only heard the deep bass sound but also felt it in your body. You can feel the same vibrations in the car if you put your hand on the dashboard when the sound system is on full volume. Sound is made when things vibrate. Every time you make a sound – whether it be playing a musical instrument, speaking, singing or even whispering – you are making vibrations (Figure 4). Vibrations are simply tiny movements back and forth. Vibrations can occur in gases, liquids and solid things such as speakers. Energy is needed to make sound. For example, unless a drummer uses energy to hit the drums, the drum skin will not start to vibrate and will not make a sound (Figure 5). So, do you think **sound energy** is a type of kinetic energy?

sound energy a type of kinetic energy produced when things vibrate, causing waves of pressure in the air or some other medium



Figure 4 Sound energy is the kinetic energy produced when guitar strings vibrate.



Figure 5 Musical instruments use kinetic energy to produce sound.

Check your learning 4.5



Check your learning 4.5

Retrieve

- 1 **Recall** the scientific term for “movement energy”.
- 2 **Identify** what is moving in electrical energy.
- 3 **Identify** what is moving when a guitar produces sound energy.
- 4 **Recall** another name for heat energy.

Comprehend

- 5 **Describe** how solar cells are used in the transfer of energy.

Analyse

- 6 **Identify** the features of a car that would absorb the driver’s kinetic energy in a collision.
- 7 **Compare** (the similarities and differences between) kinetic energy and potential energy.

Lesson 4.6

Energy can be transformed

Key ideas

- Energy that changes from one form to another is transformed.
- Flow diagrams use arrows to show the direction that energy moves.
- Electricity can be generated when turbines are turned by water, wind or coal-generated steam.



Learning intentions and success criteria

Introduction

When energy is changed from one type of energy to another, we say it has been **transformed**. For example, in light bulbs, electrical energy is transformed into both light energy and thermal energy (Figure 1). When the energy in a battery is transferred to the wires in a circuit, the energy is transformed from chemical potential energy into electrical energy (Figure 2). Water at the top of a waterfall has gravitational potential energy. This is transformed into kinetic energy as the water moves down to the bottom of the waterfall.

The same thing happens when a pendulum or a swing in the playground is pulled back. When you pull back a swing, you also lift it higher into the air. This adds gravitation potential energy to the swing. When you let go of the swing, the potential energy is transformed into kinetic energy as the swing moves down.



Figure 1 In a light bulb, electrical energy is transformed into light and thermal energy.

transformed describes energy that has changed into a different form

The swing is moving at its fastest speed when it gets close to the ground before it starts swinging up again. During the upswing, the kinetic energy is transformed into gravitational potential energy once more.

Before investigating energy transformations, there are a few things you need to know.

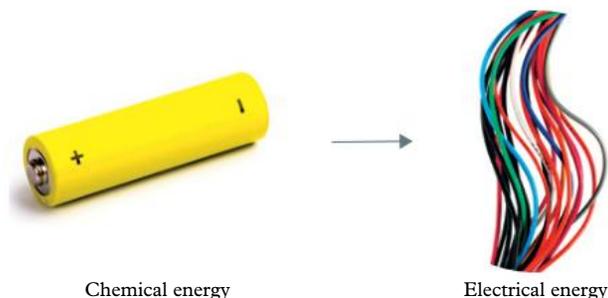


Figure 2 A flow diagram showing how a battery transforms chemical energy into electrical energy.

Flow diagrams

How do we represent an energy transformation scientifically? Flow diagrams that use an arrow to represent the transformation process help with this idea.

- 1 The arrow points in the direction of the transformation.
- 2 The starting energy input is written at the back of the arrow.
- 3 The useful energy output is written in front of the arrow.

Sometimes there is more than one energy output, so we try to concentrate on the main one. Think of how you would write the energy transformation in a light bulb. What is the energy input? What is the main energy output? Is there a by-product (wasted energy)?

In some devices several energy transformations make up an energy story, resulting in an energy chain. For example, the energy story in a mobile device would be described in the following way: “The chemical energy stored in the battery is transformed into electrical energy. The electrical energy flows through the wires to the headphones, where it is transformed into kinetic energy as the tiny speakers in the headphones vibrate. This is then transformed into sound energy, which our ears pick up.”

Figure 3 shows this energy story as a flow diagram.

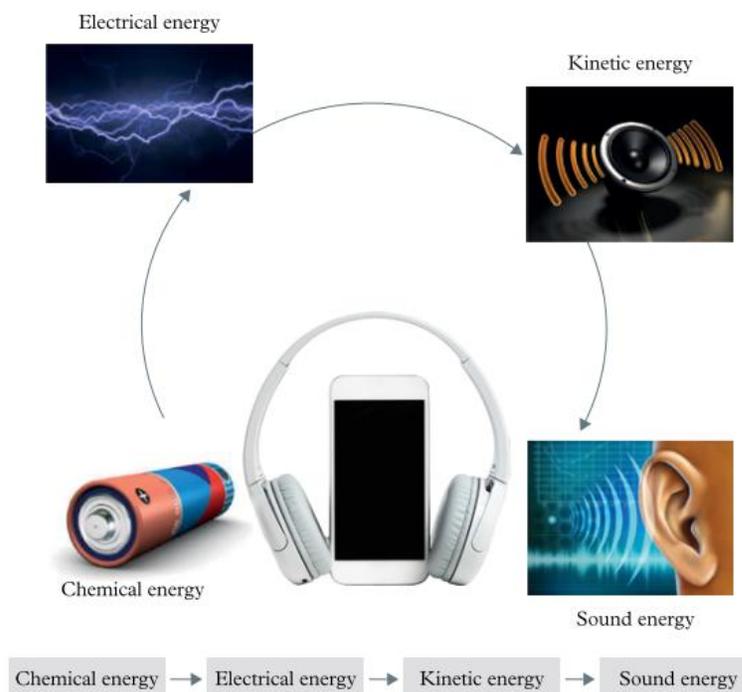


Figure 3 Chemical energy in the mobile device battery is transformed into the sound energy that we hear.

Energy cannot be created or destroyed

One of the special characteristics of energy is that it cannot be created or destroyed. All energy must be stored, transferred or transformed. We can see this when we get

on a roller coaster (Figure 4). First, electrical energy is transformed into kinetic energy in the carts as they are moved to the top of the first rise. The carts usually stop temporarily at the top of the first rise. The kinetic energy has been transformed into gravitational potential energy. As the carts start down the first slope, the gravitational potential energy is transformed into kinetic energy again. This process of transforming energy between kinetic energy and gravitational energy continues throughout the whole ride.

Not all energy transformations are 100% efficient. Some of the energy is always transformed into heat energy. The best roller coasters minimise the friction between the rails and the wheels so that more energy can be transferred between kinetic energy and gravitational potential energy, and the speed and heights of the carts can be maintained.



Figure 4 Roller coasters constantly transform kinetic energy into gravitational potential energy and back again.

Generating electricity

There are many ways to generate electricity. Different technologies use different methods to turn a turbine.

Wind generators use wind to turn the turbines. The kinetic energy of the wind is transferred to the kinetic energy of the turbines. The turbines then transform this energy into electrical energy (Figure 5).

Hydroelectric plants have large dams that store water. The large amount of water is usually part of the way up a hill. Therefore, the water has gravitational potential energy. Pipes control the flow of water down through the turbine, transforming the gravitational potential energy into the kinetic energy of the turbines (Figure 6).

Coal-based electricity generators use the chemical potential energy in coal when they burn the coal to heat water. The resulting steam rises, forcing the turbines to turn and transform the kinetic energy into electrical energy (Figure 7).

You use the electrical energy that comes from these generating plants for many different things: charging your mobile phone, cooking dinner, switching on a light. Energy may take many shapes or forms before you can use it.

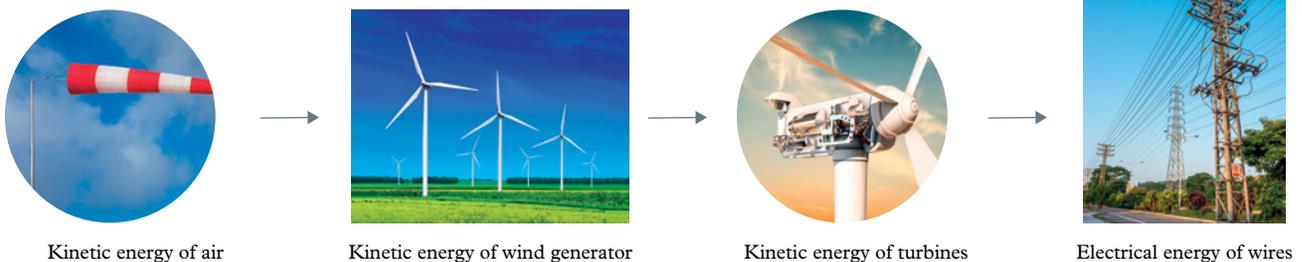


Figure 5 The transformation of kinetic energy

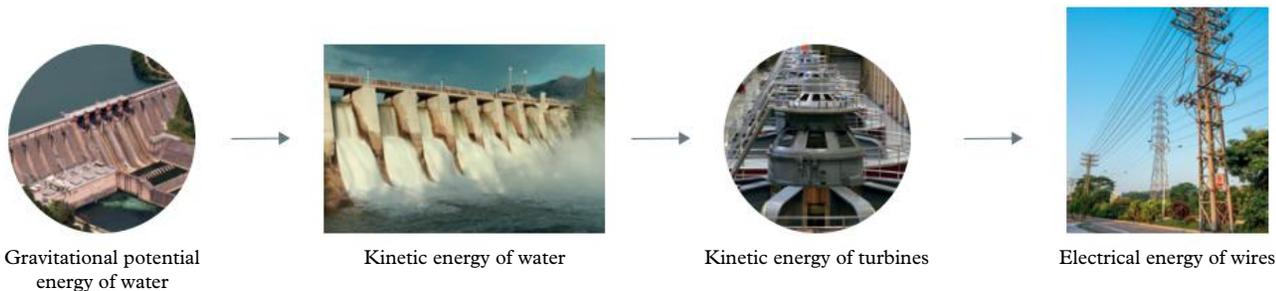


Figure 6 The transformation of gravitational potential energy

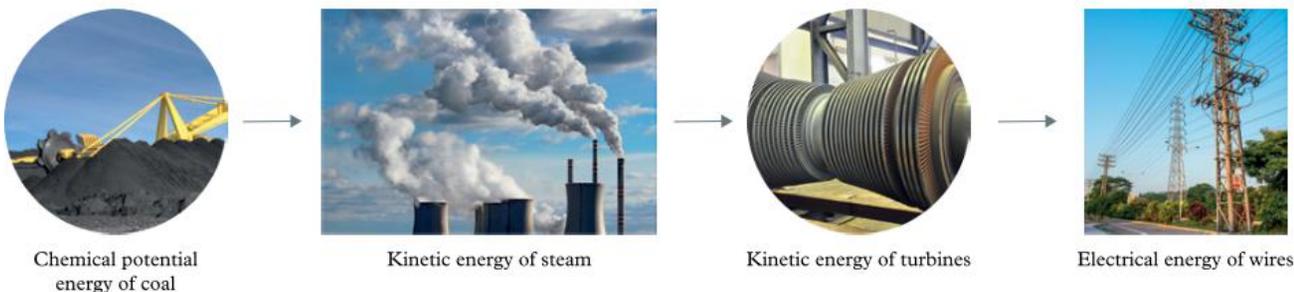


Figure 7 The transformation of chemical potential energy

Check your learning 4.6



Check your learning 4.6

Retrieve

- Identify** one way that energy can be transferred without being transformed.
- Identify** where the energy stored in coal comes from.

Analyse

- Contrast** (the differences between) energy transformation and energy transfers.

Apply

- Create** a flow diagram for the main energy transformations in a moving car.
- When a car crashes into a wall, it makes a lot of sound and heat. Create a flow diagram to show the transformation of energy that occurs.
- Create** an energy chain that shows how we get our energy from eating an apple. (HINT: Start with the Sun!)
- A Newton's cradle has a series of metal balls suspended on strings (Figure 8). When the

ball on one end is pulled back and released, the energy is transferred along the chain to the other end, causing that ball to swing up into the air. **Create** a flow diagram to show the energy transformation that occurs in a Newton's cradle.

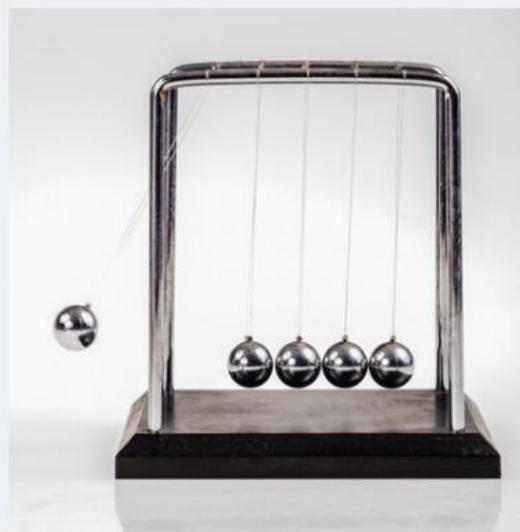


Figure 8 A Newton's cradle

Lesson 4.7

Heat is a by-product of energy transformation



Learning intentions and success criteria

Key ideas

- Heat is a by-product of energy transfer and energy transformation.
- Sankey diagrams can be used to describe energy inputs, energy outputs and by-products.

Introduction

Whenever energy is changed (either transferred or transformed) some energy is wasted. This means the energy is transformed into a form that cannot be used. This waste energy is often called the **by-product** of the energy transformation.

The by-product of energy transformation is most commonly heat energy or sound energy (or both). You may have noticed this when you stand next to an electrical light. In this case, the main energy transformation is from electrical energy to light energy, but most lights also produce a small amount of heat energy by-product.

You also produce a heat energy by-product when you exercise. The chemical energy in the food you eat is transformed into kinetic movement energy, but you also feel hot. This is the heat energy by-product that is produced by the transformation in your body.

by-product an extra or secondary product made in the manufacture or synthesis of something else

Representing energy transformation

In previous lessons, you used flow diagrams to represent the transfer and transformation of energy. However, these diagrams only showed where most of the energy went. A Sankey diagram is a way to show the pathway of all the energy when it is transferred or transformed. It can be used to show the energy that moves into a system and the energy that flows out, including any energy by-products.

For example, when a battery in your phone is being charged, electrical energy is being transformed into chemical energy. You may have noticed that when this happens, the phone battery also becomes hot. This is the heat energy by-product. This can be represented in a Sankey diagram (Figure 1).

The input energy (on the left-hand side) is the electrical energy. The main energy output, shown by the thicker arrow, is the chemical energy in the battery. The smaller arrow represents the heat energy

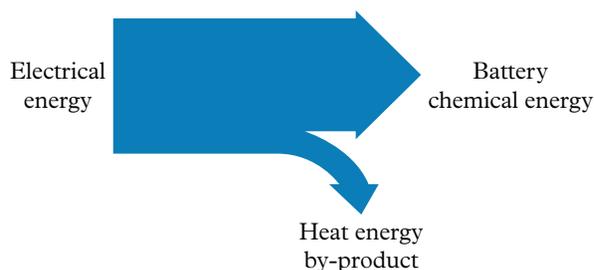


Figure 1 A Sankey diagram can be used to show the energy transformation in a recharging battery.

by-product. It is important that the thickness of all the arrows coming out is equal to the overall thickness of the arrows at the start. This demonstrates that energy is not created or destroyed in the process.

Aboriginal and Torres Strait Islander Peoples using the heat by-product

Fire is an important part of Aboriginal and Torres Strait Islander Peoples' lifestyles. Many of the methods used to start a fire are identical to those used elsewhere in the world. All of the methods use the heat energy by-product of another energy transformation.

The fire drill method uses a flat piece of softwood with an indent at the base. A long, thin stick (made out of hardwood) is then held between the palms of the hands (Figure 2). When the palms rub together, the stick is twirled and pushed into the indent. The kinetic movement energy of the hands is transferred to the twirling stick. The friction between the stick and base creates sawdust and transforms the kinetic energy into heat energy. This process heats the sawdust and can create an ember.

The fire saw method is similar to the fire drill method, except the base is usually split at one end and held open with a thin wedge. Fine, flammable material such as dry grass is placed under the split. When a hardwood stick (or knife or boomerang) is rubbed back and forth like a saw in the slit, the heat energy can cause the dry grass to catch alight.

Another approach is the fire plough method. Again, this uses a softwood base with a hardwood stick. The softwood base has a groove cut into it. The hardwood stick is rubbed back and forth (ploughed) in the groove until enough heat energy is transferred to the flammable material that is placed at the end of the groove.

The final approach used by Aboriginal and Torres Strait Islander Peoples is the percussion method. This process involves striking two flint stones to produce sparks that can be used to light the flammable material.



Figure 2 The fire drill method uses friction to transform kinetic energy into heat energy.

Check your learning 4.7



Check your learning 4.7

Retrieve

- 1 **Define** the term “by-product”.
- 2 **Identify** the two most common by-products of energy transformations.

Analyse

- 3 **Compare** the four methods of fire lighting used by Aboriginal and Torres Strait Islander Peoples.
- 4 **Explain** why rechargeable batteries can overheat if left on charge too long.



Apply

- 5 **Explain** why the fire drill method uses two different types of wood.
- 6 A student drew a Sankey diagram to represent an energy transformation (Figure 3). Use your understanding of energy to **describe** an example of an energy transformation that would match this diagram.

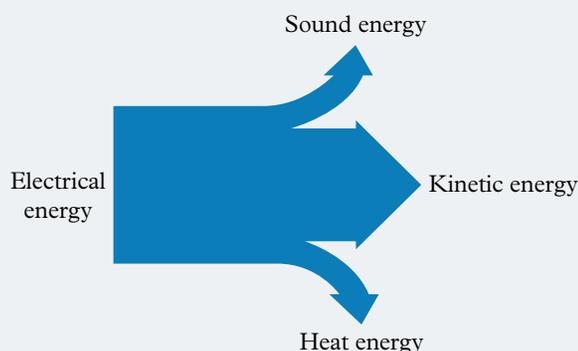


Figure 3 A Sankey diagram representing energy transformation.

Lesson 4.8

Energy efficiency reduces energy consumption



Learning intentions and success criteria



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

Key ideas

- Energy star ratings on appliances help people identify the energy that is required for a year of normal functioning.
- A passive house design reduces the amount of energy needed to heat or cool the house.
- Insulation, window coverings or double-glazed windows can reduce the transfer of heat in or out of a house.

Energy efficiency

Energy efficiency measures how much energy is transformed into the desired energy type, compared to the amount wasted as heat, sound or other by-products. We see this in many devices around the home. A washing machine requires kinetic energy to move the clothes around in the water. This transformation of electrical energy into kinetic movement energy is useful. Some of this energy is wasted as heat and sound energy. A quiet washing machine will be more efficient than a noisy washing machine.

It is impossible to get more energy output from a device than the energy input (as energy cannot be created or destroyed). Instead, scientists, engineers and

manufacturers work to design the best devices possible with the highest efficiency ratings. In Australia, this is done through a star system (Figure 1). The more energy-efficient a device is, the more stars it will have.



Figure 1 Energy-efficient devices are awarded more stars.

Kilowatt hours

Electrical energy used in the home is measured in kilowatt hours (kW h). The cost of each kW h for a household varies around Australia and between different companies. To find out how many kilowatt hours you use in your house, you will need to do an energy audit.

Heat energy

The efficient transfer of heat energy can be important in cold environments. Consider the different ways you can warm your hands on a cold day. You could hold a heat pack in your hands. This passes the heat directly from the heat pack to your fingers. This type of direct contact heat transfer is called **heat conduction**.

If the heat pack was too hot to hold, you might instead hold your hands above it. This allows the heat pack to heat the air around it. The hot air becomes less dense and rises to your hand. This movement of the air to transfer heat energy is called **convection**.

These two processes (heat conduction and convection) occur when water is heated in a pot on the stove. The heating element conducts heat to the pot (they are in contact), and the pot conducts heat to the water on the bottom of the pot. The hot water becomes less dense (sometimes forming a gas bubble), and rises to the top of the pot. The boiling water moving is an example of convection.

Another way heat energy can be transferred is through **radiation**. You have experienced this when you sit in the sun next to a window. There is no air movement so the heat is not transferred through convection, and you are not touching the window, so there is no conduction. Instead, the sun is releasing electromagnetic waves of energy that transfer heat to your skin.

Passive design

No doubt your house has some sort of heating or cooling system, depending on where you live. You probably use electricity or gas to power it. In a hot environment, energy is needed to remove heat from inside your home, allowing it to cool down. The warm air inside the house is moved over cool pipes in the air conditioner. The heat energy of the house air is transferred through conduction to the refrigerant inside the pipes and then carried outside the house. If the house is well designed, then the heat energy stays outside and the house stays cool.

heat conduction

the process of transferring heat energy from one region to another without the movement of material

convection

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

radiation

the transfer of energy through high energy particles such as electromagnetic waves

Architects design homes to help control the flow of heat energy. They can add a variety of features to a home that helps to limit the amount of heating and cooling it needs. A house that has a set number of special energy-efficient features that reduce heating and cooling requirements is called a passive house.

Insulation

During the summer months the heat from outside can be transferred through conduction or convection into a house, causing it to become hot. During winter months, the heaters inside the house might not work very well if the heat is conducted to the outside through the walls and windows. This transfer of heat energy can be stopped or slowed if the walls and roof of the house are filled with insulation (Figure 2). There are many different forms of insulation, including foam and wool. They all work the same way, by stopping or slowing the movement of thermal energy.



Figure 2 Insulation in the walls and roof prevents heat energy being transferred between the inside and outside of the house.

Window design

Have you ever stood near a window on a hot day? Windows can let a lot of radiant heat energy through. This is because the glass in a window can easily transfer heat between the inside and outside of a house. There are several ways that this radiation of heat can be reduced or prevented. Placing a barrier on the inside (curtains) or outside (awnings) of the window can reduce the amount of heat energy being transferred. Another alternative is to tint the windows to reflect the radiant heat away from the house. Some architects reduce the number of windows on a house's west side so that the amount of hot evening sunlight that enters the house is reduced.

Another way to reduce the transfer of heat energy through a window is to have double-glazed windows. These windows have two or three layers of glass, with a thin layer of air in between. This air layer acts as a barrier to the transfer of radiant energy without reducing the amount of light coming through.

"Queenslander" houses

A "Queenslander" is a style of house that was designed for the hot and sometimes wet climate of Queensland (Figure 3). It is usually built off the ground to allow any breeze to flow under the house. This provides natural ventilation, moving the heat away from the house. Tall ceilings also encourage hot air to flow up and out of the open windows (convection).

A "Queenslander" house is also surrounded by a verandah. This works like the awning on a window, preventing the radiant heat energy from the Sun shining on the outer wall and windows. This stops some of the heat energy from getting into the house.



Figure 3 A typical “Queenslander” house is built off the ground and is surrounded by a verandah.

Check your learning 4.8



Check your learning 4.8

Retrieve

- Identify** two ways you could prevent the transfer of heat energy through a window.
- Identify** a material that could be used to insulate a house.
- Identify** how many stars an energy-efficient washing machine might have.

Analyse

- Compare** conduction, convection and radiation.
- Describe** the features of a “Queenslander” house design that make it suited to the hot summers in Queensland.

Apply

- Draw** a house that is not suited to a cold winter.
- Draw** a house that is not suited to a hot summer.
- Compare** (the similarities and differences) between the two houses you have drawn.

Skills builder: Processing and analysing data

- The temperature inside and outside a house was measured over four days and displayed in Figure 4.
 - Describe** the temperature in the house compared with the temperature outside. (THINK: What do you notice happening to the line representing the temperature of the house?)
 - Use** the graph to **deduce** if the house was insulated. (THINK: Use the data as evidence to support your answer.)

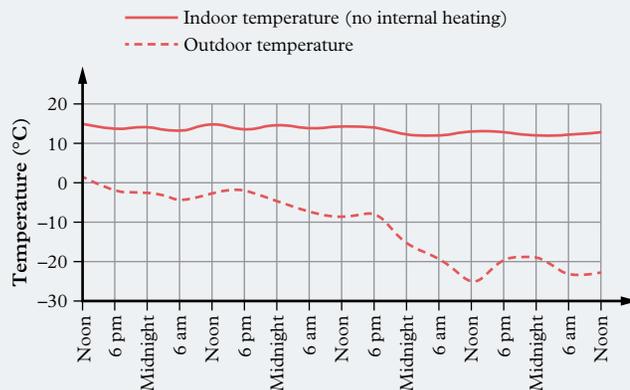


Figure 4 Temperature inside and outside house

Lesson 4.9

Challenge: An energy audit records energy consumption

Aim

To complete an energy audit of a home or building

What you need:

- Access to an electricity meter
- Calculator
- Appliances with electrical labels
- Your electricity bill

What to do:

- 1 Record** the reading on your electricity meter at a time you can repeat the reading the next day (for example, 7 pm).
- 2 Record** the reading on the electricity meter at exactly the same time the next day.
- 3 Calculate** the number of kilowatt hours (kW h) your family used in that 24-hour period (subtract the first reading from the second reading).
- Many houses have different electricity rates depending on the time of day the electricity is used. This may vary between 20 and 35 cents/kW h. For this audit, you can use the values on your electricity bill, or use an average of 27.5 cents/kW h. Use this value to **calculate** the cost of the electricity that your family used in the 24 hours (number of kilowatt hours measured \times 27.5 cents).
- Multiply this amount by 365 (the number of days in most years) to **calculate** the cost of electricity each year.

- 6 List** the electrical appliances used during this time (this might include electric hot water units, refrigerators, reverse cycle air-conditioning, computers, washers, dryers, ovens and stoves).
- 7 Select** four appliances in the house and read their electricity label (Figure 1). It might be on the back of the appliance or on the base. This should give details of the power an appliance uses.

For example, if a microwave oven has a 1,000 W rating, then it uses 1 kW (1 kW = 1,000 W). This means that if the microwave is used for 1 hour, it uses 1 kW h of energy.

Russell Hobbs	
Microwave Oven	
Model number: RHRETMM705C	
Rated voltage: AC220-240V	
Rated frequency: 50Hz	
Rated power input: 1150W	
Rated power output: 700W	
Capacity: 17L	
Microwave frequency: 2450MHz	
Batch No.: 19/01/09	
CE	

Figure 1 An electricity label found on a microwave

- 8 Estimate** how long each appliance is used for during an average day. Multiply the power rating of the appliance (in kW h) by your estimation of the number of hours it was used in the last 24 hours.

For example, the microwave may be used for 30 minutes (5 minutes \times 6 uses). The energy it used would therefore be:

$$\begin{aligned}
 &= 1 \text{ kW h} \times 0.5 \text{ h} \\
 \text{energy} &= \text{power} \times \text{time} \\
 &= 0.5 \text{ kW h}
 \end{aligned}$$

9 Calculate the total amount of energy each of the four appliances you chose uses each day and the total amount that all four of them use together each day.

10 Estimate the cost of using these four appliances each day (using 27.5 cents/kW h or the values on your electricity bill). You might like to copy and adapt the following table.

Appliance	Power (W)	Power (kW)	Time used (h)	Energy (kW × h)	Cost (cents)	Cost (\$)
Microwave	1000	1	0.5	0.5	13.75	0.14

11 Describe how you and your family could reduce the amount of electricity used at home in time for the next bill.

12 Record the reading on the electricity meter, then ask your family to do as many of these things as possible in the next 24 hours.

Record the changes that the family made. Check the reading on the meter again the next day.

13 Calculate any difference in the amount of electrical energy used by your family as a result of the changes.

14 Multiply this value by 365 days to determine the savings that your family could make each year.

15 Describe any other changes that your family could make to reduce the amount of electricity that is used even further.

16 Combine all of your data in an appropriate form and present it to your class.

Lesson 4.10

Challenge: Designing a passive design house

Design brief

Design and build two identical houses out of cardboard or wood. Add a feature to one of the houses that will make it more efficient in staying cool. You may decide to add insulation or a different material such as wood, wool or mud. 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 **Describe** how efficient your feature was at preventing the transfer of heat energy.
- 3 **Describe** the limitations of your design (when it will not prevent heat transfer).
- 4 **Describe** how you could create a large-scale version of your design for a real house.
- 5 **Describe** how you would modify your house if you were doing this experiment again.

Communicating

Present the various stages of your investigation in a formal scientific report.

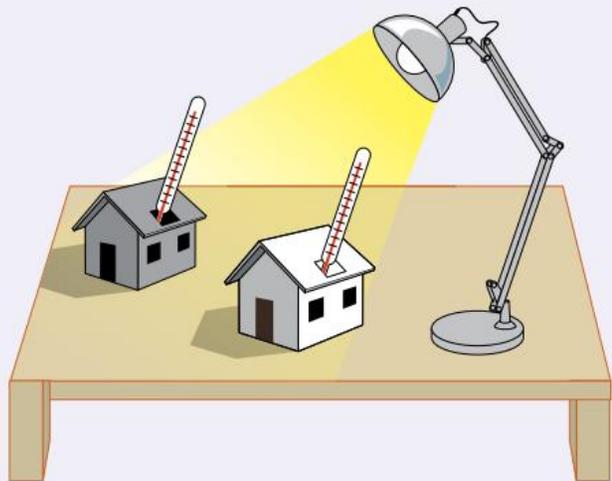


Figure 1 General set-up of experiment

Lesson 4.11

Science as a human endeavour: Solar cells transform the Sun's light energy into electrical energy

Introduction

A solar cell is any device that transforms the Sun's light energy into electrical energy. The number of households using light energy to heat water or to power heating and cooling devices is growing rapidly every year.

Using solar energy in Australia

Australia is often known as a “sunburnt country”. This is a reference to the large number of hours each day that the Sun shines. Australia is a big country and the number of hours the Sun shines varies greatly depending on the location and the time of year.

Solar energy is often measured in the number of peak sunlight hours every day (Figure 1). This is then averaged out over the whole year. For example, in the Hunter Valley in New South Wales, the number of peak hours can be as low as 4 hours/day in winter and as high as 6.5 hours/day in summer. Over a year, this averages out to 5.6 hours/day. In Tasmania, the average number of peak hours is 3 hours/day. In Queensland, the Northern Territory and Western Australia, the average is 6 hours/day.

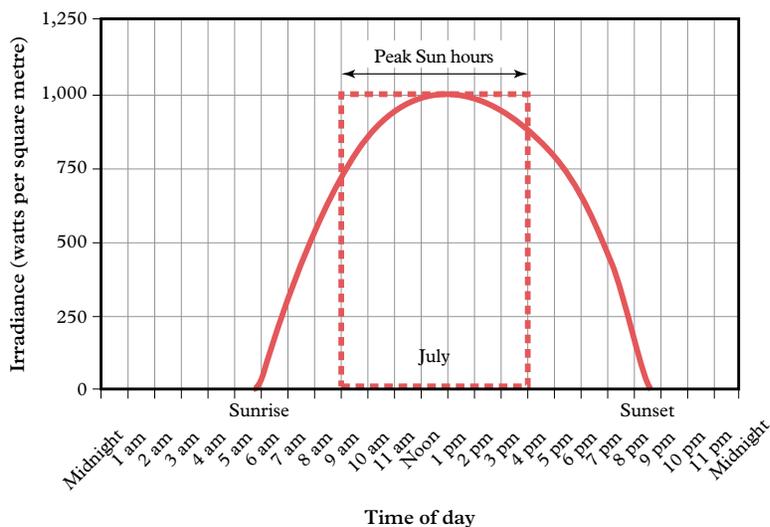


Figure 1 A graph showing the peak sunlight hours over a day

Converting light energy into chemical potential energy

Using light energy to power a house has its problems. The most common time people use electrical energy is not when light energy is available. This means that the light energy needs to be stored so that it can be used at night. The light energy is transformed into potential chemical energy in a battery (Figure 2) so that it can be used to heat water, provide light or supply energy for cooking.



Figure 2 The Tesla Powerwall is a rechargeable battery system that is used to store solar-generated electricity for use in homes and businesses.

photovoltaic cell an electrical device that converts light energy into electrical energy; see solar cell

Capturing the light energy

Solar panels are a collection of solar cells called **photovoltaic cells** (PV cells). When light shines on the surface of these PV cells, the light energy is transformed into electrical energy. The most efficient PV cells currently convert 30 per cent of the energy they receive from the Sun.

Alternatives to fossil fuel cars

Since the beginning of the 1900s, people have relied on cars to move from one place to the next. These cars rely on the chemical energy in fossil fuels (petrol and diesel) to generate the kinetic energy to move. This energy transformation from chemical energy to movement energy has contributed to the generation of carbon dioxide that is warming the atmosphere. As a result, modern scientists and engineers are working to develop alternative forms of energy transformation.

Hybrid cars combine combustion engines that use fossil fuels with electric engines that use energy stored when the car brakes, or any extra energy that is not used by the combustion engine. These cars cannot be plugged into the energy grid to charge the battery.

Electric cars use the chemical energy in batteries to generate kinetic energy. The batteries can be charged through the same electrical grid that powers your house.

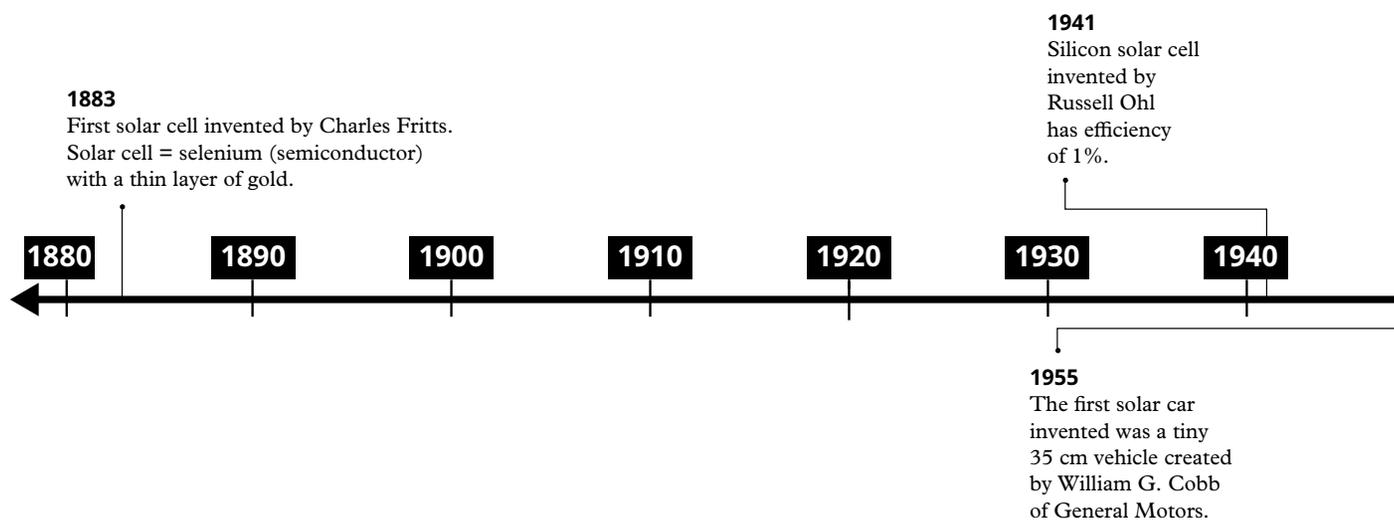


Figure 4 History of solar cars

They can also use solar panels to transform sunlight into electrical energy, which can be stored as chemical potential energy in the battery.

Solar cars use a variety of solar panels to transform light energy into kinetic energy. Most current solar-powered vehicles only carry one person (Figure 3). They are lightweight (approximately 600 kg) so that they are more energy efficient. Solar energy can be used to charge the batteries used in the electric cars found on our roads.



Test your skills and capabilities

Analysing graphs

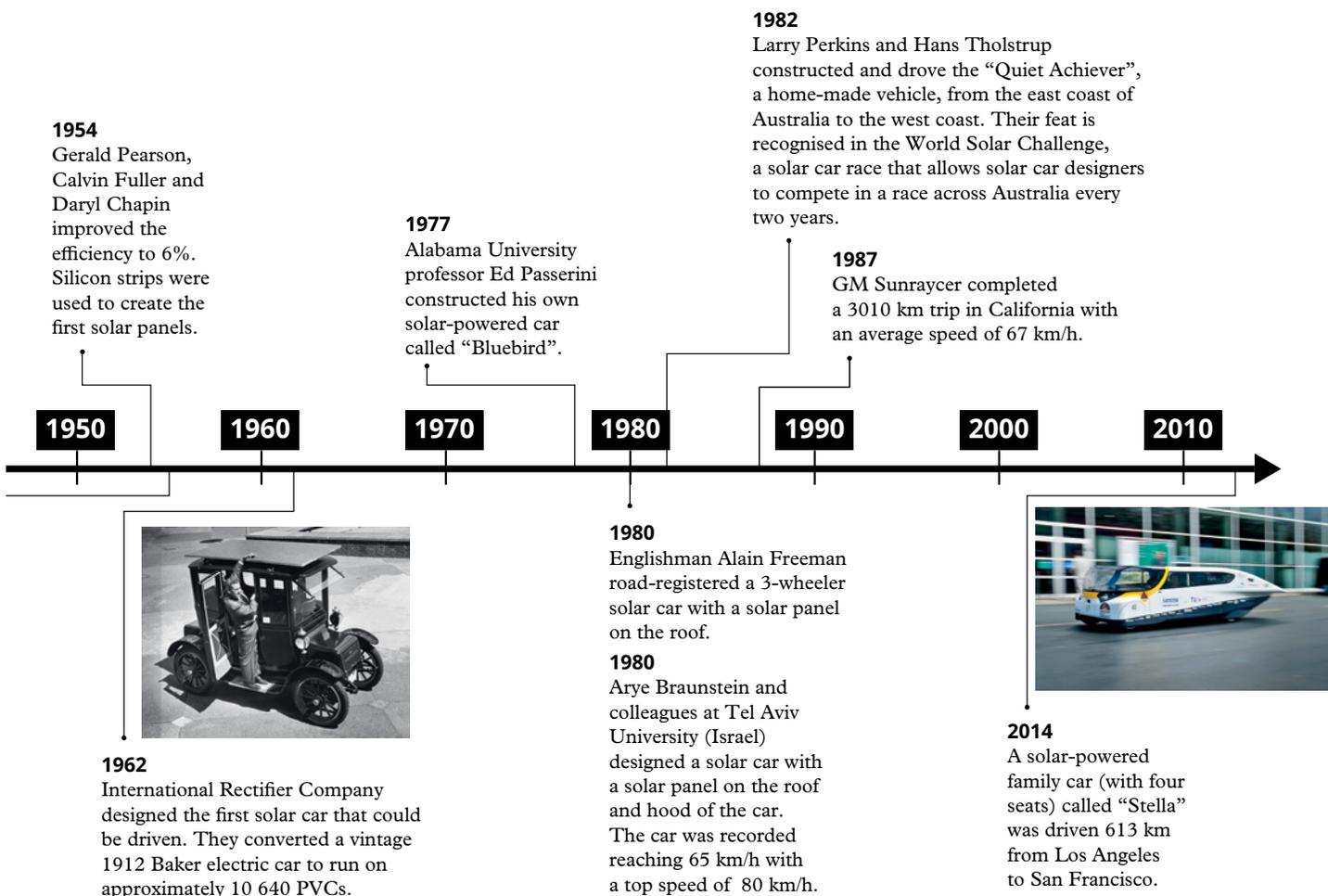
The amount of (photovoltaic) sunshine available across Australia changes according to the time of the year (Figure 6). Photovoltaic data is collected by a number of Australian research groups to track the effectiveness of energy transformation from light energy to electrical energy.



Figure 3 A three-wheeled solar car with a solar panel on the roof



Figure 5 A 1970s electric CitiCar



Analyse the graphs by answering the questions below.

- 1 **Identify** the variable on the horizontal x-axis.
- 2 **Identify** the variable on the vertical y-axis.
- 3 **Identify** Queensland's maximum percentage of photovoltaic capacity from the graphs.
- 4 The data was collected at different times of the year. **Evaluate** the energy efficiency of the different seasons by answering the following.
 - **Identify** which graph has the highest value.
 - **Explain** how the different seasons affect the level of sunshine available in Queensland.
 - **Decide** which season produces the highest percentage of photovoltaic capacity.
- 5 **Evaluate** which state is capable of transforming the most light energy into electrical energy through the use of PV cells by answering the following.
 - **Identify** which state has high percentages of photovoltaic capacity in both seasons.
 - **Explain** why transforming light energy across the whole year is more important than transforming the most light energy in just one season.
 - **Decide** which state is capable of transforming the most light energy into electrical energy.

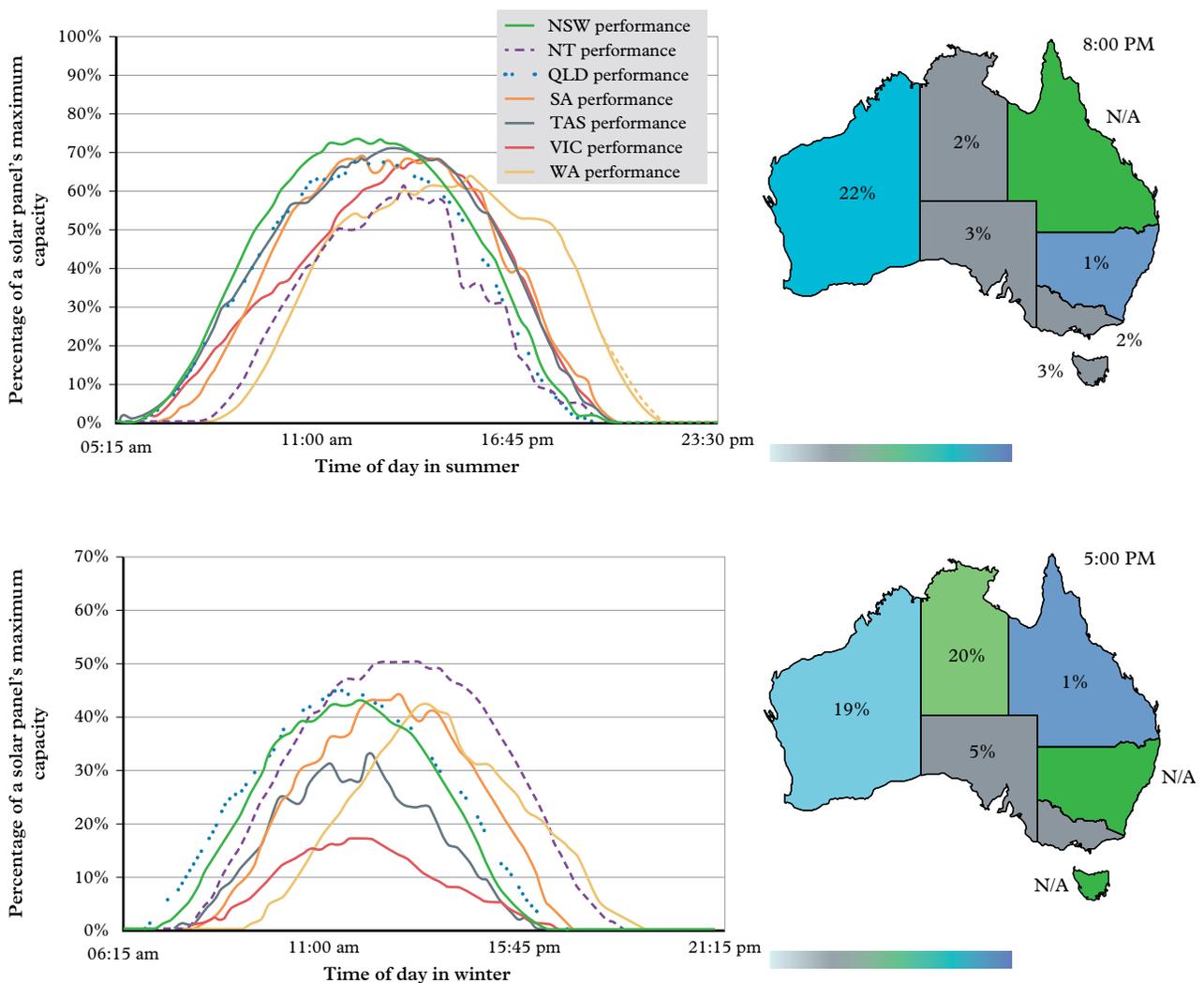


Figure 6 Estimated output of a solar panel as a percentage of its maximum photovoltaic capacity in each state at different times of the year.

Lesson 4.12

Review: Energy

Summary

Lesson 4.1 Energy can be transferred

- Energy is the ability to do work. It is how things change and move.
- Energy cannot be created or destroyed.
- When energy is passed from one object to another, it is said to be transferred.

Lesson 4.3 Potential energy is stored energy

- An object that has the potential (future ability) to do work has potential energy.
- Elastic potential energy is stored when an elastic object is deformed.
- Gravitational potential energy is stored when an object is lifted away from Earth's surface.
- Chemical potential energy is the energy stored when atoms are bonded to each other.
- Nuclear potential energy is the energy stored inside the centre of an atom.

Lesson 4.5 Moving objects have kinetic energy

- Kinetic energy is the energy found in a moving object.
- Moving heavy objects have more kinetic energy than moving light objects when they move at the same speed.
- The faster an object moves, the more kinetic energy it has.

Lesson 4.6 Energy can be transformed

- Energy that changes from one form to another is transformed.
- Flow diagrams use arrows to show the direction that energy moves.
- Electricity can be generated when turbines are turned by water, wind or coal-generated steam.

Lesson 4.7 Heat is a by-product of energy transformation

- Heat is a by-product of energy transfer and energy transformation.
- Sankey diagrams can be used to describe energy inputs, energy outputs and by-products.

Lesson 4.8 Energy efficiency reduces energy consumption

- Energy star ratings on appliances help people identify the energy that is required for a year of normal functioning.
- A passive house design reduces the amount of energy needed to heat or cool the house.
- Insulation, window coverings or double-glazed windows can reduce the transfer of heat in or out of a house.

Review questions 4.12



Review questions

Retrieve

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

- 2 **Identify** which of the following is true about energy.
 - A Energy cannot be created or destroyed.
 - B Energy is destroyed once it has been used.
 - C Energy is created constantly.
 - D Energy is precious because it is difficult to find.

- 3 Identify** which of the following correctly describes the energy transformation in a simple electrical circuit containing a battery and a light bulb.
- A** Battery → wires → light
 - B** Battery → light → wire
 - C** Electrical energy → light energy
 - D** Chemical energy → electrical energy → light energy
- 4 Identify** which of the following is true or false. Rewrite any false statements to make them correct.
- a** Springs only hold stored energy when they are stretched.
 - b** When an object is thrown up in the air, it gains gravitational potential energy.
 - c** Sound energy is a type of potential energy.
 - d** Petrol contains nuclear energy.
- 5 Identify** the main form of energy in each of the following situations.
- a** Water flowing slowly over a waterfall
 - b** A rollercoaster at the lowest point of the ride
 - c** The Sun coming in through a window on a sunny day
 - d** A boy riding his skateboard
 - e** A stretched rubber band
- 6 Identify** a device that transforms:
- a** electrical energy into light energy
 - b** elastic energy into kinetic energy
 - c** electrical energy into sound energy
 - d** gravitational energy into electrical energy
 - e** kinetic energy into electrical energy.
- 7 Recall** the type of energy musical instruments use to produce sound.



Figure 1 Musical instruments use energy to produce sound.

- 8 Select** an example of an energy transformation. Identify the input energy, the output energy and an energy by-product. Use your understanding of energy transformation to label the Sankey diagram shown.



Figure 2 A Sankey diagram

Comprehend

- 9 Explain** how the following housing design features can make a house more energy efficient.
- a** Insulation
 - b** A verandah
 - c** Double-glazed windows
- 10 Describe** two different ways that electrical energy can be generated.
- 11 Explain** why heat is generated in a light bulb.
- 12 Describe** the energy transformation and energy transfer in a torch.

Analyse

- 13 Contrast** the number of energy transfers in the generation of electricity in solar panels and hydroelectricity.
- 14 Compare** the energy transformation when electricity is generated by coal and water.
- 15 Connect** these words and phrases with their correct meanings.

Word/phrase	Meaning
Kinetic energy	The energy stored in a compressed spring
Nuclear energy	Another name for stored energy
Potential energy	The energy of an object when lifted up
Elastic energy	Used widely throughout the world to generate electricity from atoms
Gravitational energy	Possessed by all moving objects

16 Contrast the terms “transform” and “transfer”.

17 Compare potential energy and kinetic energy.

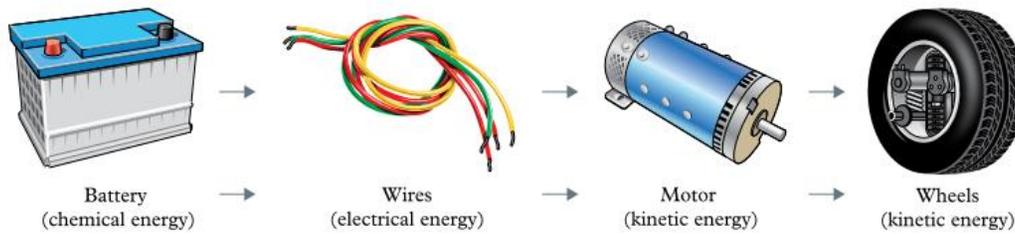


Figure 3 A car produces kinetic energy in its wheels.

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

Apply

20 Visit a local playground and **consider** the play equipment. Take a photo or draw a picture of a piece of equipment and **determine** what types of energy are demonstrated as a child plays on the equipment.

21 Create a flow diagram that demonstrates the flow of energy involved in riding a bike. (HINT: Start with the Sun!)



Figure 4 Pedal power

22 Describe the challenges of making a rented house energy efficient. **Describe** two things that people living in a rented property could do to make their house or appliances more energy efficient.

18 The main job of a car travelling on the road is to produce kinetic energy in its wheels.

Identify the other parts of a car that may demonstrate kinetic energy.

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

Social and ethical thinking

24 While clean energy projects like wind and solar farms are important in moving Australia towards a zero-carbon, renewable future, many of these projects are subject to Aboriginal and Torres Strait Islander Peoples’ rights and interests, though most Aboriginal and Torres Strait Islander Peoples have little to no legal input during the planning stages for these projects. **Evaluate** the importance of consulting the Traditional Custodians of the land you are working on or changing.

25 The transformation of chemical energy found in coal and gas into electrical energy has resulted in an increase in the level of carbon dioxide in the air. Despite the advantages of solar (photovoltaic) panels in producing electricity, their production can produce dangerous chemicals such as sodium hydroxide and hydrofluoric acid. **Evaluate** the effectiveness of using solar panels.

a Identify the advantages and disadvantages of photovoltaic cells.

b Identify the advantages and disadvantages of using another source of energy (i.e. coal or gas).

- c **Compare** (the similarities and differences between) the two methods of producing electricity.
- d **Identify** the different groups of people who will be affected by these two methods.
- e **Decide** which method would be most beneficial to one group.

Critical and creative thinking

26 Energy comes in many different forms. **Create** a poster that illustrates each type of energy using visual examples.

27 Draw a traditional “Queenslander” home. **Identify** and **describe** all the energy-efficient features that make it suitable for the Queensland environment.

28 The massive earthquake and tsunami in Japan in March 2011 caused extensive damage to the Fukushima nuclear power plant, north of Tokyo, and created an emergency situation.

Investigate this disaster and present a 2-minute news report to the class that highlights the issues surrounding the use of nuclear energy.

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.

Compact fluorescent lights

- **Explain** how compact fluorescent lights (CFLs) work.
- **Explain** how they differ from incandescent light globes.
- **Explain** why CFLs are initially more expensive to buy, but then more economical over time.
- **Identify** the benefit of using CFLs.



Figure 5 The CFL in this image is turned on.

Energy-efficient housing

In previous times, energy efficiency was important because people had limited access to energy supplies 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.
- **Describe** three ways modern humans can be energy efficient today.
- **Compare** the advantages and disadvantages of each energy-efficiency method used in the past and present.

Engineering energy

Engineers use their understanding of energy to solve problems. Select one of the fields of engineering, such as electrical, mechanical, chemical or nuclear engineering.

- **Describe** what an engineer in that field does.
- **Explain** what they need to know about energy in their work.
- **Identify** who they work with.
- **Describe** where they work.
- **Describe** the materials they work with.
- **Name** a significant project that an engineer in the field has worked on.



Figure 6 Aerospace engineers at work.

Rube Goldberg machine

Rube Goldberg was an American cartoonist who drew a series of complex machines that used a series of energy transfers and transformations to perform a simple task.

- **Design** your own Rube Goldberg machine by selecting a simple task that you do most days.
- **Draw** a picture that shows how this task could become more complex using a series of energy transformations and transfers.
- **Identify** each energy transfer and transformation that occurs in your machine.

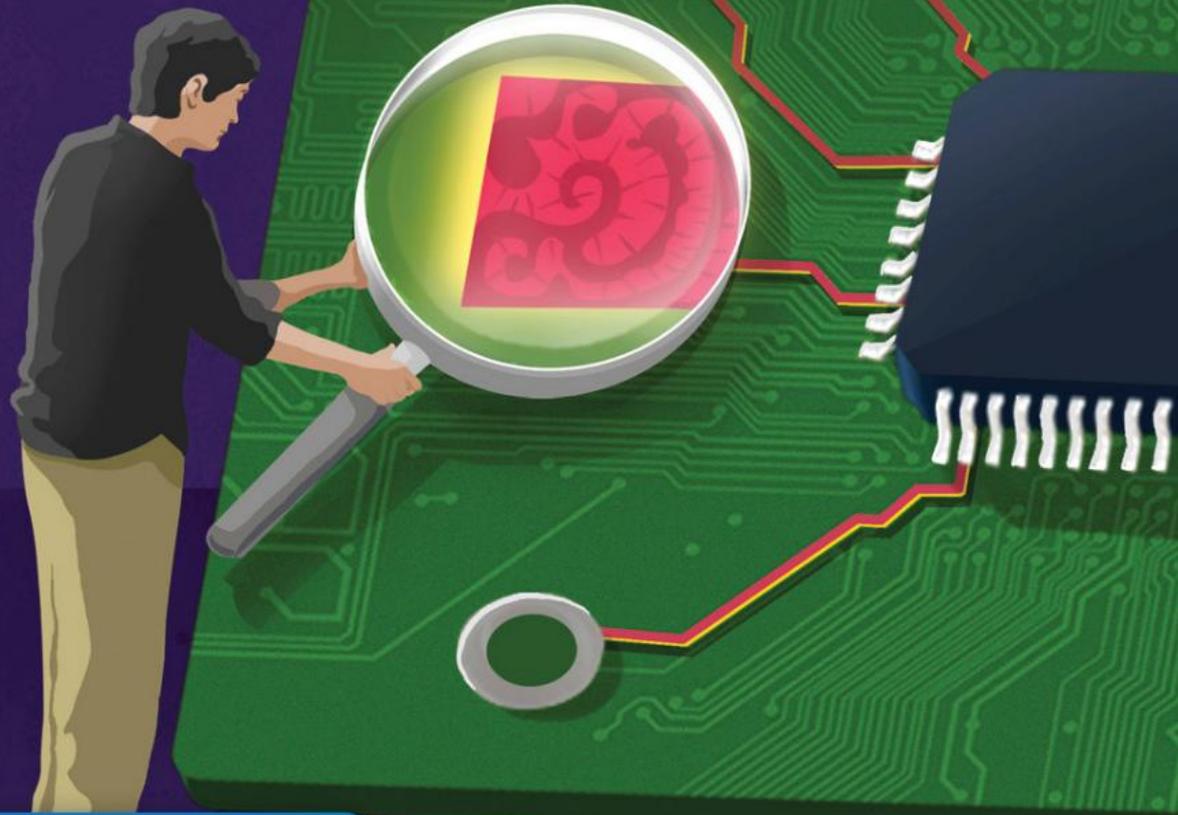


Figure 7 A Rube Goldberg cartoon

Module

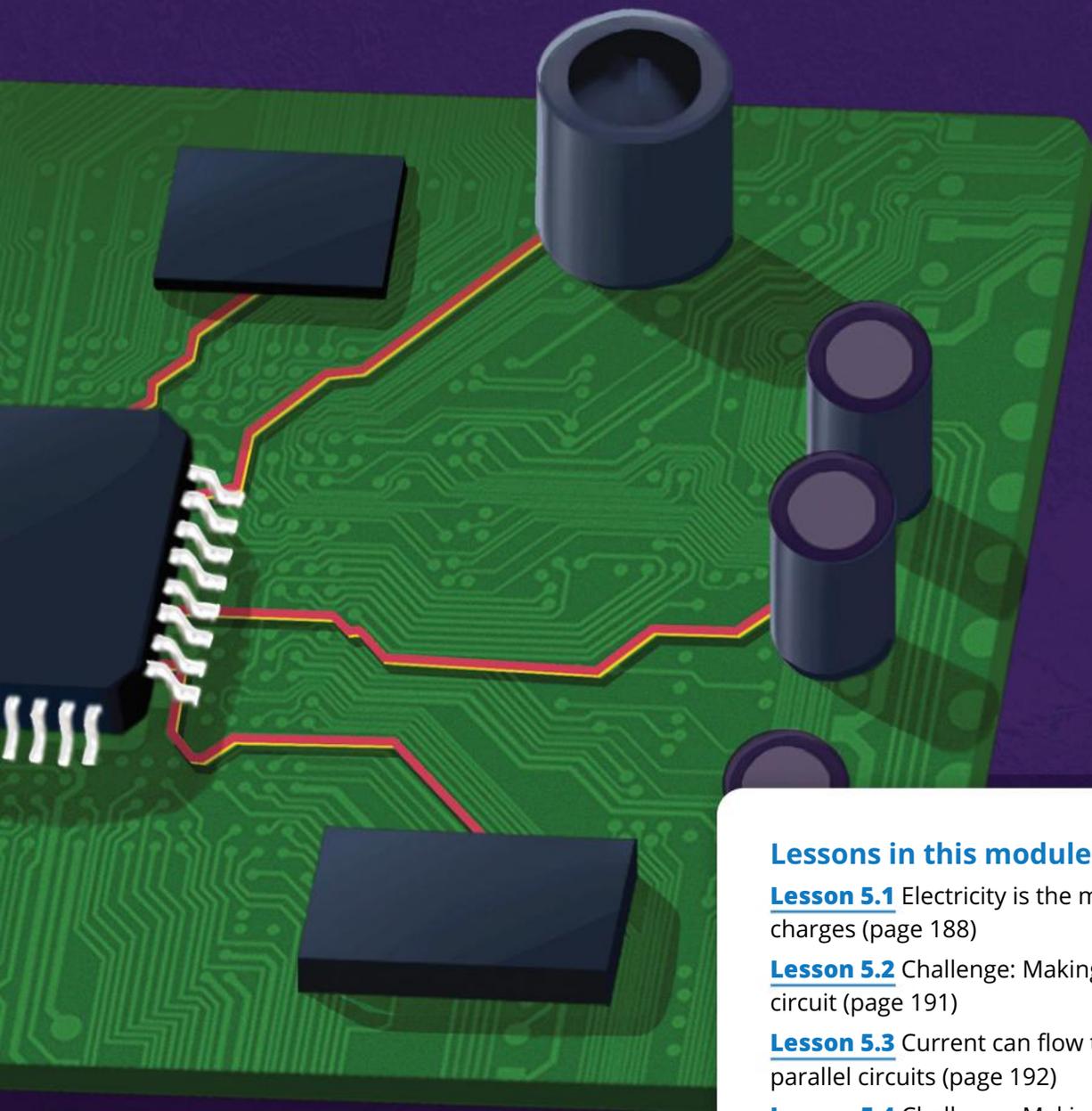
5

Electric circuits



Overview

Electrical circuits transfer energy when current flows, and they can be designed for different purposes using various components. Understanding how current and voltage behave in different types of circuits allows scientists to compare electrical circuits to household wiring, examine safety features including circuit protection devices, and how sensors are used in robotics and control devices.



Lessons in this module:

Lesson 5.1 Electricity is the movement of electric charges (page 188)

Lesson 5.2 Challenge: Making a simple torch circuit (page 191)

Lesson 5.3 Current can flow through series and parallel circuits (page 192)

Lesson 5.4 Challenge: Making series and parallel circuits (page 195)

Lesson 5.5 Voltage is the difference in energy per charge between two parts of a circuit (page 196)

Lesson 5.6 Current and resistance in a circuit can be altered (page 198)

Lesson 5.7 Challenge: Wiring a house (page 202)

Lesson 5.8 Review: Electric circuits (page 203)

Lesson 5.1

Electricity is the movement of electric charges



Learning intentions and success criteria



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

Key ideas

- A closed circuit occurs when the positive and negative charges can be separated and reunited.
- An electric circuit contains an energy source (a battery), a pathway (usually wires) and a load.
- The pathway of the charges can be represented by a circuit diagram.

Electrical energy and circuits

electricity the movement of charged particles

“**Electricity**” is a kinetic energy term for the presence and movement of charged particles. An electric charge can be either positively or negatively charged. When electric charges become separated, they have electrical potential energy. This means they are in a state of excitement and the positive and negative charges try to get back together again. They can do this along a metal wire in a circuit. If the wires are connected in a loop (closed circuit), the negative charges will move along the wire to the positive charges. As the charges move, the electrical kinetic energy may transform into some other forms of energy, such as light or thermal energy.

Electric circuits

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

The pathway travelled by the moving charged particles is called an **electric circuit**. Electric circuits must have an energy source, a pathway to carry the charged particles (usually wires), and a “load”, which is any device that converts the electrical energy into heat, light or kinetic energy. Many devices have “gaps” called switches to control the flow of electricity in a 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).

A battery stores chemical energy. When wires are connected to the terminals of a battery, the chemical energy is transformed into moving charged particles (electrical energy). An example of the movement of electrical energy in a simple circuit is shown in Figure 1.

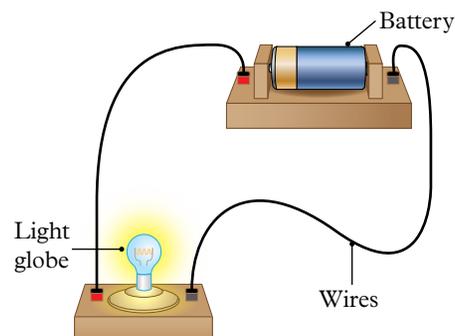


Figure 1 A simple circuit: electric charges move from the battery through the wires to the light globe.

Moving charges

An **electric current** occurs when negatively charged particles (**electrons**) move through an electric circuit. These particles move, or are conducted, from the **negative terminal** of the energy source to the **positive terminal**. This is different from the historical term “conventional current”, where the direction of the current is described as moving from the positive terminal to the negative terminal (Figure 2).

There are two types of current used in electrical circuits. In an **alternating current (AC)**, the flow of electrons reverses direction 50 times every second. This type of current is used in electrical power points. In **direct current (DC)**, the electrons flow in one direction only. This current is found in battery-powered circuits.

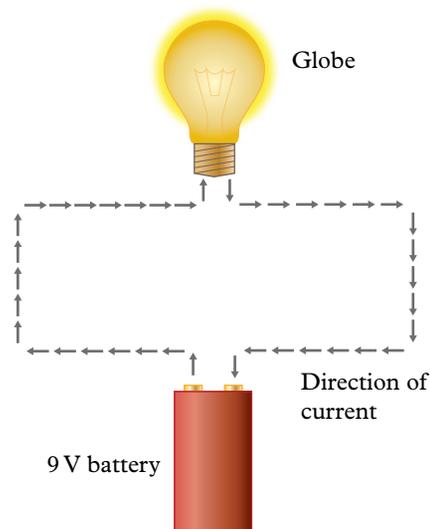


Figure 2 Current (electric charge/sec) flows around an electric circuit.

electric current the flow of electrical charge through a circuit

electron a negatively charged particle that moves around in the space outside the nucleus

negative terminal the point in the circuit where electrons flow out from

positive terminal the point in an electric circuit where electrons flow into

alternating current (AC) an electric current in which the direction of the current (flow of electrons) changes at regular intervals

direct current (DC) an electric current in which the direction of the current (flow of electrons) does not change

circuit diagram a diagrammatic way to represent an electric circuit

Circuit diagrams

Circuits are represented by **circuit diagrams**. Each component of a circuit is represented by a symbol (Figure 3). The circuit illustrated in Figure 4A includes a light globe, a battery, connecting wires, a switch and a meter, such as an ammeter, to measure the electric current. This circuit is represented by the circuit diagram in Figure 4B. Connecting wires are usually shown as straight lines, and when they meet at junctions they are joined at right angles. The longer line on the battery represents the positive terminal and the shorter line represents the negative terminal. These terminals are where the wires are connected.

When drawing a circuit diagram, you should use a ruler and a pencil. All lines should be connected to indicate that there are no breaks in the circuit. A break in the circuit means the current is not flowing.

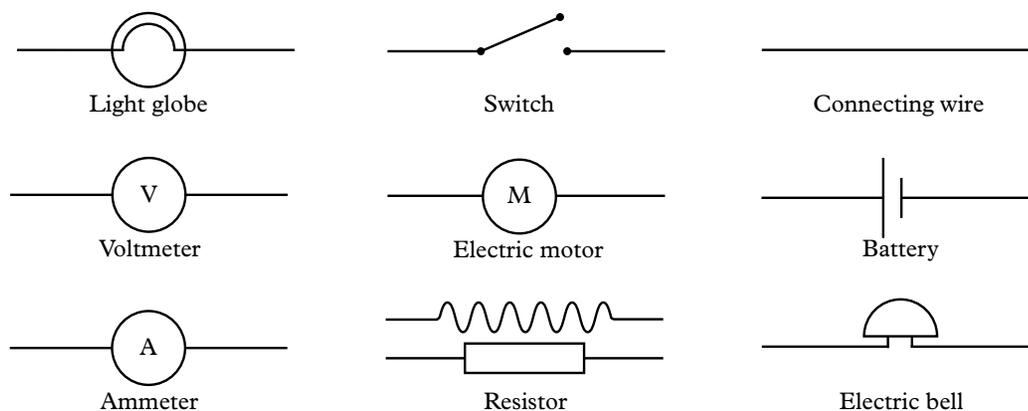


Figure 3 Some symbols used in circuit diagrams

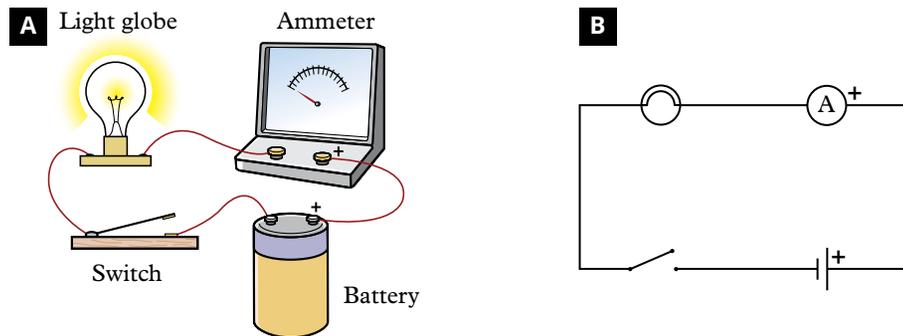


Figure 4 (A) A simple circuit (B) A circuit diagram of the simple circuit

Check your learning 5.1



Check your learning 5.1

Retrieve

- Identify** the direction of:
 - a conventional current
 - electrons in a circuit.
- Identify** the energy transformation that occurs in a battery in a circuit.

Comprehend

- Identify** and **describe** the role of each of the parts of the circuit in Figure 4.
- Describe** how you could stop the charged particles flowing in a circuit.

Analyse

- Contrast** (the differences between) AC and DC.
- Compare** (the similarities and differences between) the equipment and drawings used in Figure 1 and Figure 4B.
- Identify** which of the globes in Figure 5 will transform electrical energy into light energy.

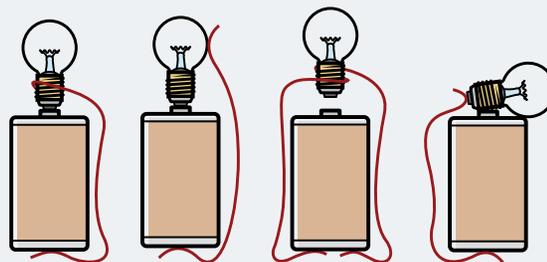


Figure 5 Light globes

Lesson 5.2

Challenge: Making a simple torch circuit

Aim

To use a simple circuit to transform electrical energy to light energy

What you need:

- Pieces of insulated electrical wire with the ends stripped bare
- 1.5 V battery
- 1.2 V torch globe
- Hand lens

What to do:

- 1 Try different arrangements of the wires, battery and torch globe to make the globe light up. Draw each arrangement that you tried.
- 2 Draw circuit diagrams to record some of the arrangements that work and some that do not.
- 3 Use the hand lens to look carefully at the filament in the globe. The filament is the tiny wire inside the glass of the globe – the part that glows brightly when the globe lights up. Draw what you see.
- 4 Use the hand lens to look at how a globe holder (the base of a globe) is constructed.

Discussion

- 1 **Select** one of the arrangements that did not allow the globe to light up. **Explain** why this arrangement did not allow electricity to pass through the circuit.
- 2 **Describe** how the filament in the light globe is able to transform electricity into light and heat.
- 3 **Describe** how the globe holder connects the light globe to the circuit.
- 4 Some battery manufacturers claim that their brands of batteries last longer than other batteries. **Design** an experiment to test this claim.



Figure 1 How does a torch work?

Lesson 5.3

Current can flow through series and parallel circuits



Learning intentions and success criteria



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

Key ideas

- In a series circuit, the loads are connected one after the other, and the current is the same throughout the circuit.
- In a parallel circuit, the loads are parallel to one another, and the current is shared between them.
- A short circuit occurs when the electrical energy can move through an easier path with less resistance.

Current

The energy in an electrical circuit that is transformed into light energy is moved by the current. **Current** is measured in amperes (amps for short; symbol “A”) and is the amount of electric charge moving past a point every second. It is measured using an **ammeter** connected next to a light bulb or battery. A power supply, such as a battery or generator, provides the energy needed to push charges through the circuit. A closed conducting loop (like a wire) allows charges to flow. If the circuit is open, no current flows.

current the rate at which electrons flow; measured in amperes (amps; symbol “A”)

ammeter an instrument that measures electric current at a point in a circuit

Types of circuit

When two or more light bulbs are connected in a circuit, two different types of connection are possible. In a **series circuit**, the light bulbs are connected one after the other so that the current goes through one bulb and then through the second (Figure 1A). In a **parallel circuit**, the circuit has two or more branches and the current splits between the branches (Figure 1B) and then comes back together.

series circuit an electric circuit that has one pathway

parallel circuit an electric circuit that has two or more pathways

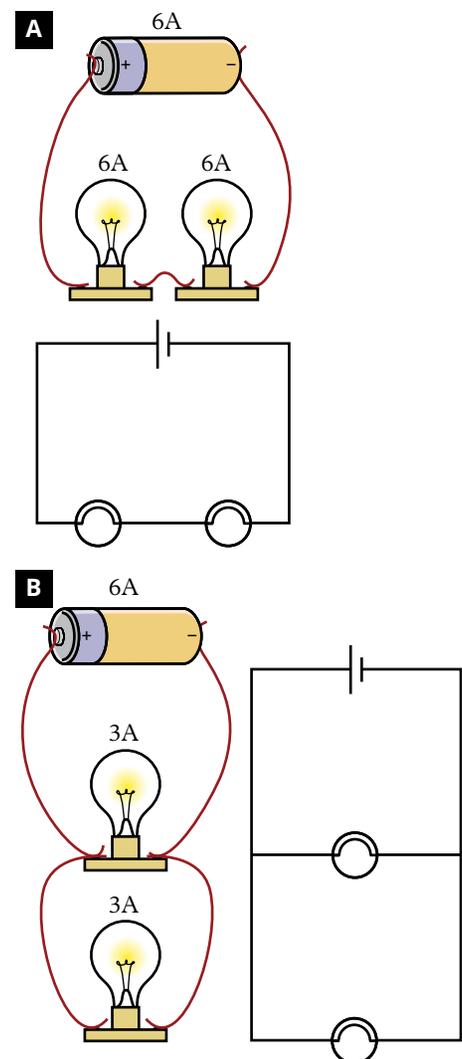


Figure 1 (A) In a series circuit, the same current flows through all components in the circuit. (B) In a parallel circuit, the sum of the current going through light bulb A and light bulb B is equal to the total current from the battery.

Comparing series and parallel circuits

If two light bulbs are connected in a series circuit, then all of the current (the electrons) passes through both light bulbs (Figure 1A). This means all the components are connected end-to-end in a single path. The current flows through each component one after another. Therefore, the current is always the same at all points in a series circuit.

However, if two light bulbs are connected in parallel, the current splits (Figure 1B). This means that when the charged particles reach the point where the wire splits, the particles will travel along one path or the other. Part of the current passes through each light bulb and then joins together again after passing through. This means the currents going through each light bulb must be added together to determine the total amount of current coming from the battery.

In a series circuit, a break at any point in the circuit (for example, from a switch) affects all the light bulbs in the circuit. Series circuits are simple, but not ideal for systems requiring independent operation of components. In a parallel circuit, a break in one of the branches of the circuit affects only the current (and light bulb) in that branch. Parallel circuits provide reliability and are used in most practical applications, such as home wiring.

In a household, lights and appliances are connected in parallel so that:

- some appliances can be on while others are off (achieved by inserting switches)
- if one appliance fails, the others will still work (Figure 2).



Figure 2 Traditionally, party lights were a series circuit. This meant that when one light broke, all the lights went out. Now, most modern party lights are arranged in a parallel circuit.

Worked example 5.3A Calculating currents

If the current leaving a battery is 6 amperes (A), calculate the current travelling through two identical light bulbs if they are connected:

- in series
- in parallel.

Solution

- If the light bulbs are connected in series, all the charged particles flow through each light bulb. Therefore, the current in each light bulb is 6 A.
- If the light bulbs are connected in parallel, the charged particles are divided between the wires. This means the current is divided equally between the light bulbs.

$$6 \text{ A} \div 2 \text{ light bulbs} = 3 \text{ A in each light bulb}$$

Batteries in series and in parallel

Batteries may be connected in series or in parallel, in a similar way to light bulbs. When batteries are connected in series, each charged particle picks up a certain amount of potential energy as it passes through the first battery and then an additional amount as it passes through the second battery. This arrangement allows particles to be given larger amounts of energy.

For instance, a simple torch normally has two 1.5 volt (V) batteries connected in series (Figure 3). As each charged particle passes through both batteries, it collects a total of 3.0 units of potential energy to light the torch bulb.

When batteries are connected in parallel, each charged particle passes through either one battery or the other. This means each particle collects the same amount of energy as it would from one battery on its own. The advantage of this arrangement is that the two batteries last longer than either one of them would in the same circuit on their own.

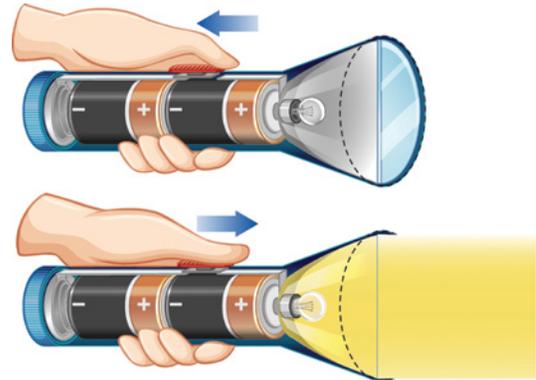


Figure 3 Batteries in torches are connected in series

Short circuit

short circuit an electrical circuit where the charged particles travel a shorter and faster path from the intended circuit

A **short circuit** occurs when a current (moving charged particles) flows along a different and faster path from the one intended. This can be caused by damaged insulation that usually surrounds the wires or by another shorter conductor, such as water, providing an easy path for the electrons. Electric charges will always take the path of least resistance. This means that large currents can flow through any short path or conductor that allows the charged particles to move most easily. Short circuits are dangerous because they can also lead to wires heating up from the fast flow of particles, causing damage or even fire.

Fuse

fuse a switch or wire that stops the flow of current if it starts moving too fast

An electrical **fuse** is a switch or thin piece of wire that burns up quickly when a large current flows too easily in a circuit. This causes a break in the circuit so the electrical energy stops flowing. This is to prevent damage to appliances from the high current. Most houses built today use safety switches (Figure 4) that react faster than the older style fuse.



Figure 4 A sudden increase in current will cause a fuse or safety switch to break the circuit. This stops the current from flowing and may prevent electrocution.

Check your learning 5.3



Check your learning 5.3

Retrieve

- 1 **Recall** the advantage of having a safety switch or fuse in the electric circuits of your house.

Comprehend

- 2 **Describe** how you could determine whether the light bulbs in the party lights in Figure 2 are connected in series or parallel.

Analyse

- 3 **Contrast** the movement of current in a series circuit and a parallel circuit.
- 4 Three identical light bulbs were connected in series to a battery that produced a 12 A current. **Calculate** the current flowing in each bulb.

Apply

- 5 **Infer** how the household appliances are connected in your house (in series or in parallel). **Justify** your answer (by explaining how series and parallel circuits behave and providing an example that matches your explanation).
- 6 Double adaptors and power boards enable you to connect additional appliances to a power point. **Explain** whether the double adaptors or power boards are more likely to be series or parallel connections. **Justify** your answer.
- 7 An electrician wanted to connect four light bulbs to a 6 A source so that two light bulbs had a current of 6 A and the other two light bulbs had a current of 3 A. **Create** a circuit diagram to show a possible arrangement of the light bulbs the electrician could use.

Lesson 5.4

Challenge: Making series and parallel circuits

Aim

To compare the current in series and parallel circuits

What you need:

- 2 × 1.2 V globes and holders
- 1.5 V battery and holder
- 8 connecting wires (with banana plugs or alligator clips)

- Switch
- Ammeter or multimeter

What to do:

- 1 Construct four circuits, placing the switch so that it controls:
 - a both globes, with both either on or off at the same time
 - b one globe only, with the other on all the time

- c the other globe only, with the first globe on all the time
- d both globes, with one globe on when the other is off and vice versa.

Complete step 2 before you disconnect each circuit.

- 2 Draw the circuit diagram to show where the switch was placed in each circuit.
- 3 Connect an ammeter at different places in each circuit and measure the current at each point.

Questions

- 1 **Describe** the effect of changing the location of the switch in a simple circuit.
- 2 **Define** the term “current”.
- 3 **Describe** how an ammeter should be connected to measure the current in a circuit.
- 4 **Describe** how the current did or did not change when the ammeter’s location was changed.

Lesson 5.5

Voltage is the difference in energy per charge between two parts of a circuit



Learning intentions and success criteria

potential difference voltage; the difference in the electrical potential energy carried by charged particles between two different points in a circuit

voltage difference in electric potential energy; a measure of the strength of a current; measured in volts (symbol “V”)

voltmeter an instrument that measures voltage at a point in a circuit

Key ideas

- Voltage is a measure of the difference in electrical potential energy carried by charged particles between different points in a circuit.
- Voltage can be measured using a voltmeter or multimeter in parallel to the circuit.
- Resistance is a measure of how difficult it is for current to flow through part of the circuit.

Voltage

Each charged particle has energy as it moves in an electric circuit. This potential energy can be transformed into sound as it moves through a speaker, or into light and heat if it moves through a globe. 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**.

Voltage is measured by a **voltmeter** or a multimeter in the unit volts (symbol “V”). To measure the potential difference of the charged particles, voltmeters are set in parallel across the two points in the circuit that you want to measure (Figure 1).

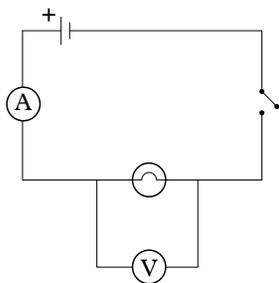


Figure 1 A voltmeter is used to measure voltage in a circuit.



Figure 2 Each unit of charge in this battery has 1.5 J of energy.

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 V battery, each unit of charge receives 1.5 joules (symbol J) of energy as it passes through the battery (Figure 2).

In a series circuit, the potential energy provided to each charged particle must be shared among the different loads. This means a 12 V battery connected to two light bulbs in series may supply 6 V across each bulb. If the two bulbs are connected in parallel, each charged particle moving through a bulb experiences the full 12 V and can convert it into light and heat.

Worked example 5.5A Calculating voltage

If a 6 V battery is connected to two identical light bulbs, calculate the voltage that can be transformed in each bulb if they are connected:

- in series
- in parallel.

Solution

- If the light bulbs are connected in series, the charged particles must divide the voltage (potential energy) between the bulbs.

Therefore, the voltage transformed in each bulb will be 3 V.

$$6 \text{ V} \div 2 \text{ lamps} = 3 \text{ V in each lamp}$$

- If the bulbs are connected in parallel, the charged particles will separate at the fork in the wires and carry all the energy to each bulb. This means the voltage (potential difference) transformed will be 6 V in each bulb.

Resistance

The amount of current flowing in a circuit is determined by the **resistance** of the circuit and the voltage applied. The electrical resistance of a material is a measure of how difficult it is for charged particles to move through it. As charged particles move through the circuit, they collide with atoms in the wires and other components, causing some of their electrical energy to be converted into heat. Most connecting wires are thick and made of good conductors to minimise resistance. Other components are made of different materials and have higher resistance (Figure 3).



Figure 3 Metal wires are low resistance while the plastic coating has high resistance.

resistance a measure of how difficult it is for the charged particles in an electric circuit to move

potentiometer a variable resistor that can adjust the output of voltage to a circuit and measure electric potential

ohm unit of electrical resistance; measure of resistance between two points of a conductor

Toasters and heaters often contain high-resistance materials. The wires in a toaster are designed to convert a large amount of electrical energy into heat – enough to make the wires glow red-hot and brown the toast.

Resistors can also be deliberately placed in circuits to control or limit the current. A **potentiometer** is a type of variable resistor that can be adjusted by rotating a dial. Light dimmers and oven temperature controls are examples of potentiometers. Resistance is measured using a multimeter in units called **ohms** (symbol Ω).

Check your learning 5.5



Check your learning 5.5

Retrieve

1 **Define** the term “voltage”.

Comprehend

2 **Describe** the voltage across two bulbs when they are connected:

- a in series
- b in parallel.

Analyse

3 **Explain** how a resistor prevents a current from moving through.

4 **Compare** (the similarities and differences between) the current and voltage of bulbs in a series circuit.

5 **Compare** (the similarities and differences between) the current and voltage of bulbs in a parallel circuit.

6 **Calculate** the voltage provided by a battery if two bulbs connected in parallel measure a voltage of 5 V each.

7 **Calculate** the voltage provided by a battery if two bulbs connected in series measure a voltage of 4 V each.

Lesson 5.6

Current and resistance in a circuit can be altered



Learning intentions and success criteria



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

Key ideas

- Diodes allow current to flow in one direction only.
- Rectifiers are a type of diode that convert alternating current to direct current.
- LEDs are diodes that emit light.
- Photoresistors alter their ability to conduct electricity according to the amount of light they are exposed to.
- Some thermistors reduce their resistance as they are heated.

Diodes

Many materials can alter their ability to conduct electricity. A **diode** (Figure 1) is a device that allows current to flow in one direction only. Most diodes are made of specially treated silicon. The symbol for a diode in a circuit diagram is shown in Figure 2.

When the diode is connected correctly, and the voltage is above the minimum threshold, current will flow through the circuit. If the diode is put in the wrong way, it blocks the charged particles that make up the current and stops them from moving (Figure 3).

Diodes can only carry small currents, of much less than 1 amp (A). Bigger currents produce too much heat, which would destroy the diode. Most diodes are connected in series with a normal resistor to stop the current from being too large.

Silicon diodes are useful for converting AC (alternating current) to DC (direct current). A lot of electrical equipment prefers the current to only move in one direction. This could be difficult if it is plugged into wall-based power. For example, a hair dryer plugs into an AC power point, but most hair dryers contain a rectifier circuit that converts the AC to DC before it flows to the heating elements and the fan motor. Such a device is called a **rectifier**.

Light-emitting diodes

A **light-emitting diode (LED)** is a special type of diode that not only keeps current flow in one direction but also produces light of a particular colour (Figure 4). The light from an LED is one of the visible colours (commonly red, yellow or green), infrared light or ultraviolet (UV) light. Many remote controls send their messages through infrared LEDs. Red LEDs are also used on electrical equipment to show that the power is on or to indicate a particular setting. They are also used in torches, and garden and vehicle lights. LEDs are replacing globes in traffic lights, where they appear as dots of coloured light.

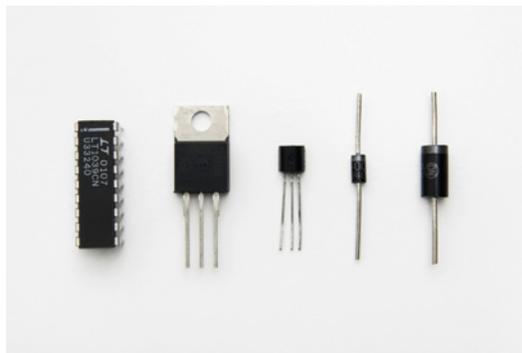


Figure 1 Diodes come in all shapes and sizes depending on their role in the circuit.

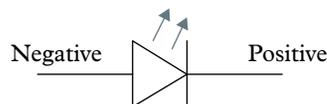


Figure 2 The symbol for a diode in a circuit diagram. Think of the triangle as an arrow that shows the direction that the diode allows the conventional current (from positive to negative) to flow.

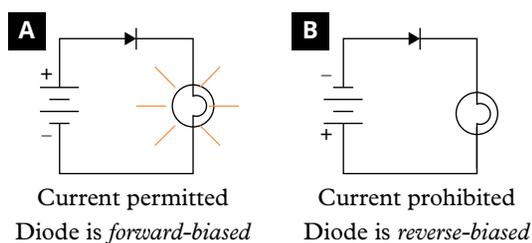


Figure 3 The diode allows current to flow in one direction only to light the bulb in (A), but not in (B) (reversed battery).



Figure 4 As LEDs are more efficient, longer lasting and use less power than light globes, their role is shifting from being used as indicator lamps to a wide range of applications.

diode an electronic component that allows current to flow in one direction only

rectifier an electronic component that converts alternating current (AC) to direct current (DC)

light-emitting diode (LED) an electronic component that converts electrical energy into light

LED televisions use the light from the LEDs behind a screen of liquid crystals. The LEDs produce a light that shines through the pixels to create an image. Because LEDs are more energy efficient, LED TVs are thinner than normal liquid crystal display (LCD) televisions.

Light-dependent resistors

light-dependent resistor an electronic component that decreases its resistance to electric current as light intensity increases (also known as a photoresistor)

photoconductivity the ability of a material to conduct electricity when it is exposed to light

Light-dependent resistors (or photoresistors) use light to change the amount of electric current that moves through the circuit. When light shines on the photoresistor, it lets the electric current flow. The more light that shines on a photoresistor, the less it resists the movement of the charged particles and the more the current is allowed to flow through the circuit (Figure 5). This property is called **photoconductivity**. In the dark, a photoresistor has a very high resistance (thousands of ohms), while light can reduce the resistance to a few hundred ohms. This means more light causes more current.

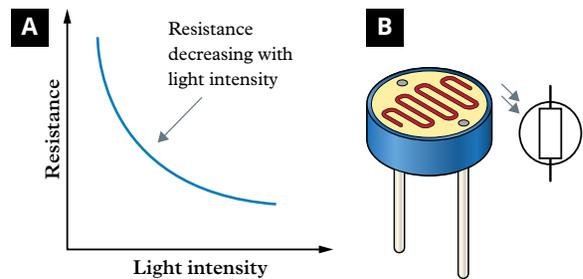


Figure 5 (A) The resistance of an light-dependent resistor (or photoresistor) decreases when more light shines on it. (B) A photoresistor and its circuit symbol

Photoresistors are used in camera light meters, night lights and solar street lamps. In solar street lamps, the photoresistor is connected between the solar panel and the energy source. When there is light available during the day, the photoresistor allows the sunlight transformed into an electrical current to charge the battery. When the light levels drop at night, the resistance in the photoresistor increases, blocking the connection between the solar panel and the battery. This allows current to flow into the lamp, allowing it to produce light. When the photoresistor detects light in the morning, the photoresistor lowers the resistance between the solar panel and the battery, switching the solar lamp off and recharging the battery.

Some automatic devices, such as robot vacuum cleaners, send infrared beams around a room (Figure 6). The amount of time it takes the light to bounce back tells the robot the size of the room. If the beam of light does not return, the robot knows there is a drop-off such as stairs, and reverses its motion.



Figure 6 Robot vacuum cleaners use photoreceptors.

Temperature-dependent resistors

Temperature-dependent resistors (or thermistors) are devices that change their resistance when the temperature varies (Figure 7). For example, if the temperature of a room becomes too high, a thermistor will let more charged particles through. If the temperature of a room drops, the resistance will increase, slowing the movement of charged particles. Other thermistors will increase their resistance if the temperature rises. Thermistors are often used in programmable circuits that measure the amount of current flowing and use it to display the temperature (as in thermometers). They are also used to turn on cooling fans in computers and heating elements in ovens.

temperature-dependent resistor an electronic component that changes its resistance to electric current with increasing or decreasing temperature

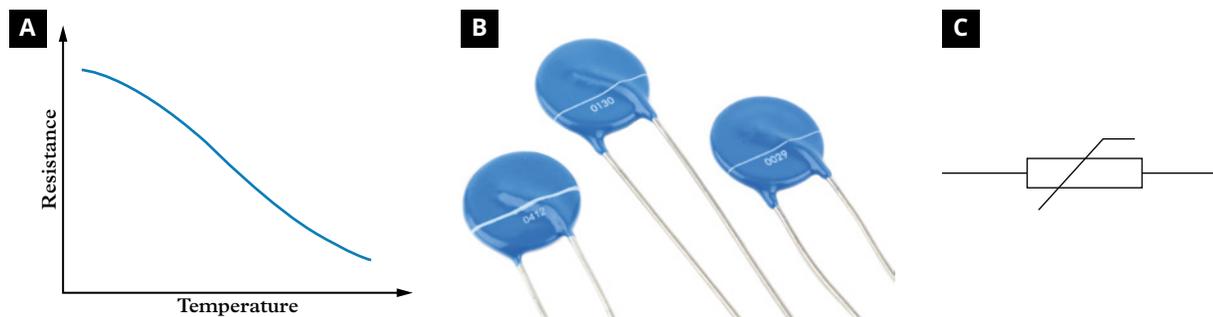


Figure 7 (A) The resistance of a thermistor changes with temperature. (B) Thermistors and (C) the circuit symbol for thermistors

Check your learning 5.6



Check your learning 5.6

Comprehend

- Describe** the role of the following devices in a circuit.
 - LED
 - Photoresistor
 - Thermistor
- Describe** the role of a resistor that is connected in series with a diode. Draw a circuit using circuit symbols showing the correct arrangement of these components.

Analyse

- Compare** a photoresistor and a thermistor.
- Explain** why an electrical device such as a toaster would need a rectifier.
- A television remote control usually has an infrared LED that converts electrical energy into infrared energy. **Identify** the device the television must have to communicate with the remote.

Apply

- LEDs are gradually replacing traditional street lights and traffic lights because they are more energy efficient. Unfortunately, this makes the lights much brighter, which can interrupt the sleep or migration patterns of local wildlife, including the bogong moth. The bogong moth is a major food source for the pygmy possum. When the moths are attracted to the LED lights in the city, this diverts them away from the pygmy possum's habitat, and so the possums fail to get the food they need to survive. **Discuss** the ethical dilemma caused by use of LED lights, by:
 - describing** the advantages of using LED lights
 - describing** the disadvantages of using LED lights
 - deciding** whether the advantages are more important than the disadvantages (consequentialism) or whether some rules should not be broken (deontology).

Lesson 5.7

Challenge: Wiring a house

Aim

To determine the wiring requirements for a house

What you need:

- Cardboard box
- 6 LEDs
- 4 resistors (330 Ω)
- 9 V battery
- Wires
- Paperclip
- Split pins
- Cardboard
- Optional: decorations for your house

What to do:

- 1 Design a room in a house that needs lighting for at least three parts of the room and a power switch that needs to be turned on and off. It may be a bedroom with an overhead light, a computer or television and a bedside lamp. It may be a study with an overhead light, a desk light and a computer terminal. It may be a kitchen with an overhead light, an oven light and a fridge where the light turns on when the door is opened. You may choose to use several LEDs to make more complicated overhead lights (such as a chandelier).
 - a Draw your room design.
 - b Draw a circuit diagram for your room. **Consider** whether you need the devices connected in series or in parallel. **Describe** the reasons for each of your decisions.

- 2 Use the LEDs, wires, resistors, switch and other items as needed to complete your room design in the cardboard box.

Questions

- 1 **Describe** the advantages and disadvantages of devices being connected:
 - a in series
 - b in parallel.
- 2 Party lights often have groups of five LEDs connected in series. These groups are then connected in parallel with other groups of LEDs. **Describe** what will happen if one of the LEDs is damaged.
- 3 **Explain** why it is important that resistors be used when wiring LEDs.
- 4 Government codes require circuit switches (with electrical fuses) to be included in the electrical wiring of a house. **Describe** where you would put a circuit switch in your house to prevent damage in the event of a short circuit.



Figure 1 What is the best way to organise wiring in a house?

Lesson 5.8

Review: Electric circuits

Summary

Lesson 5.1 Electricity is the movement of electric charges

- A closed circuit occurs when the positive and negative charges can be separated and reunited.
- An electric circuit contains an energy source (a battery), a pathway (usually wires) and a load.
- The pathway of the charges can be represented by a circuit diagram.

Lesson 5.3 Current can flow through series and parallel circuits

- In a series circuit, the loads are connected one after the other, and the current is the same throughout the circuit.
- In a parallel circuit, the loads are parallel to one another, and the current is shared between them.
- A short circuit occurs when the electrical energy can move through an easier path with less resistance.

Lesson 5.5 Voltage is the difference in energy per charge between two parts of a circuit

- Voltage is a measure of the difference in electrical potential energy carried by charged particles between different points in a circuit.
- Voltage can be measured using a voltmeter or multimeter in parallel to the circuit.
- Resistance is a measure of how difficult it is for current to flow through part of the circuit.

Lesson 5.6 Current and resistance in a circuit can be altered

- Diodes allow current to flow in one direction only.
- Rectifiers are a type of diode that convert alternating current to direct current.
- LEDs are diodes that emit light.
- Photoresistors alter their ability to conduct electricity according to the amount of light they are exposed to.
- Some thermistors reduce their resistance as they are heated.

Review questions 5.8



Review questions

Retrieve

- 1 **Identify** the units of voltage, current and resistance, respectively.
 - A Amps, ohms, volts
 - B Ohms, volts, amps
 - C Volts, amps, ohms
 - D Volts, ohms, amps

- 2 **Identify** the term used to describe the potential energy that can be transformed in a lamp.
 - A Current
 - B Voltage
 - C Resistance
 - D Load

- 3 Identify** the correct terms to complete the following sentences.
A bulb with a current of 5 amp (A) is connected in parallel to another identical bulb. The total current flowing through the battery is _____. If the voltage in one of the bulbs is 2 volts (V), then the voltage in the other bulb will be _____.
- A** 5 A, 2 A
B 10 A, 4 V
C 5 A, 4 V
D 10 A, 2 V

- 4 Define** each of the following.
- LED
 - Rectifier

Comprehend

- 5 Create** a circuit diagram for a circuit containing a battery, globe and switch.
Identify the direction of electron flow and the direction of conventional current.
- 6 Describe** the role of an ammeter.
- 7** If you don't connect the conducting wires to a globe correctly, the globe doesn't light up.
Explain why this will happen.
- 8 Compare** current and voltage.
- 9 Describe** how current moves in a parallel circuit.
- 10 Contrast** a voltmeter with a multimeter.
- 11 Describe** the relationship between current and resistance.
- 12 Describe** how voltage moves through a series circuit.
- 13 Identify** the circuit in Figure 1 as either a parallel circuit or a series circuit.

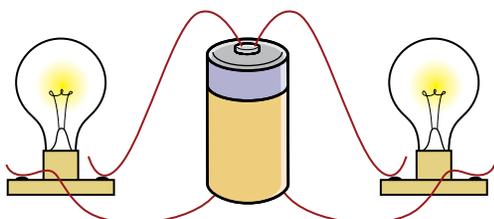


Figure 1 Identify the circuit.

- 14** The lights in Figure 2 are connected in series.
Describe what will happen if one globe fails.

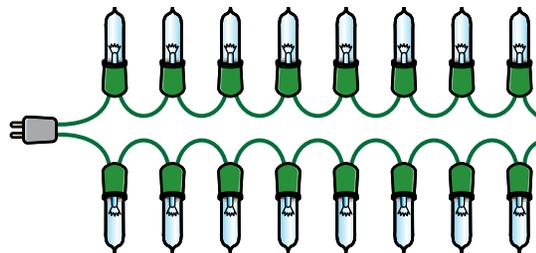


Figure 2 Lights connected in series

Analyse

- 15 Match** each circuit symbol shown in Figure 3 with its name.
- Ammeter
 - Battery
 - Globe
 - Switch

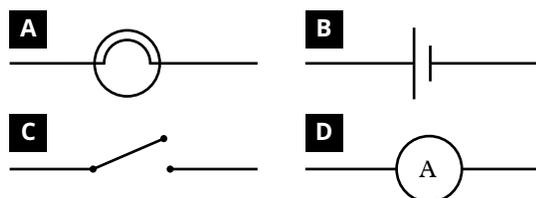


Figure 3 Circuit symbols

- 16 Create** a circuit diagram that shows a battery and a switch, with a globe on either side of the switch.
- Describe** if/how the circuit will be affected if the switch is placed before both globes.
 - Identify** the direction of electron flow and the direction of conventional current in the circuit.
- 17 Describe** how increasing the resistance affects the flow of electricity in a circuit.
- 18 Explain** how the flow of electricity changes in a streetlight (with a photoresistor) as the sun rises.
- 19 Calculate** the current flowing through a bulb if another bulb connected in series has a current of 18 A moving through it.
- 20 Calculate** the voltage of a bulb connected in parallel when it is connected in series with a 15 V bulb.
- 21 Calculate** the current and voltage of a bulb when it is connected in parallel with a bulb with 5 V and 2 A flowing through it.

Apply

22 Power lines carry electricity from power stations to cities and towns. The long lines mean that there is more resistance than shorter lines. **Explain** electrical resistance, and why a long power line will have more resistance than a shorter line.

23 **Use** the correct symbols to draw a circuit consisting of a 6 V DC supply, an LED, and a 100 Ω resistor connected in series. Add a voltmeter to measure the voltage drop across the LED.

24 In a storm, a tree has been blown over onto the main power line to your neighbourhood. The electricity supply is cut. **Describe** your day without electricity.

25 **Use** your understanding of current and voltage to **model** the flow of electricity through a circuit. You might use people or even an animation as your model.

Research

26 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.

Seeing the light

Investigate incandescent light globes.

- **Identify** what is meant by “incandescent”.
- **Describe** the materials that these globes are made of.
- **Explain** why the filament must contain an inert gas like argon.
- **Describe** the temperature the filament needs to be heated to so that it gives off light.
- **Describe** the efficiency of incandescent light globes.



Figure 4 Incandescent light globes

Light-emitting diodes

- **Describe** diodes and how they work.
- **Describe** light-emitting diodes (LEDs) and explain why they are used in traffic lights.
- **Evaluate** the benefits of using LEDs.
- **Identify** other applications of LEDs.
- **Compare** their longevity to that of compact fluorescent globes and incandescent globes.



Figure 5 LEDs are used in traffic lights

Thermal fuses

A thermal fuse is a thermal safety device that prevents an electrical device such as a clothes dryer from overheating.

- **Use** your understanding of thermal resistors to **describe** how an electrical circuit might be protected through the use of a thermal fuse.
- **Explain** why a clothes dryer might still rotate without heating if it overheats. (HINT: Consider how the circuits might be wired.)



Figure 6 The electrical system in a clothes dryer needs to be wired carefully to prevent overheating.

Module

6

Physical and chemical change

Overview

The atomic theory helps explain the difference between elements, compounds and mixtures. Elements use symbols, while compounds are shown with chemical formulas. Some chemicals change when they are mixed, producing a colour or temperature change, gas production or a new substance forming. This can be used to make new materials including some that are more eco-friendly and reduce waste in landfills. These ideas help us understand matter and how science can help the environment.

Lessons in this module:

Lesson 6.1 All matter is made up of atoms (page 208)

Lesson 6.2 Elements are made up of one type of atom (page 211)

Lesson 6.3 Experiment: Properties of the elements (page 214)

Lesson 6.4 Atoms bond together to make molecules and compounds (page 216)

Lesson 6.5 Experiment: Decomposing copper carbonate (page 218)

Lesson 6.6 Matter can be modelled (page 220)

Lesson 6.7 Physical change is a change in shape or appearance (page 222)

Lesson 6.8 Challenge: Melting chocolate (page 226)

Lesson 6.9 Chemical change produces new substances (page 227)

Lesson 6.10 Challenge: Making caramel (page 230)

Lesson 6.11 Experiment: Observing chemical reactions (page 231)

Lesson 6.12 Experiment: Detecting a mystery powder (page 233)

Lesson 6.13 Chemical reactions can break bonds and re-form new bonds (page 235)

Lesson 6.14 Experiment: Comparing reactants and products (page 239)

Lesson 6.15 Chemical reactions can be sped up and slowed down (page 240)

Lesson 6.16 Experiment: Effect of particle size on reaction rates (page 242)

Lesson 6.17 Experiment: Speeding up reactions with enzymes (page 244)

Lesson 6.18 Science as a human endeavour: Many substances exist because of the work of scientists (page 245)

Lesson 6.19 Experiment: Making casein glue (page 248)

Lesson 6.20 Science as a human endeavour: Physical and chemical changes are used to recycle household waste (page 250)

Lesson 6.21 Review: Physical and chemical change (page 253)

Lesson 6.1

All matter is made up of atoms



Learning intentions
and success criteria

Key ideas

- All matter is made up of atoms.
- Scientists refine models over time.

What are atoms?

In Year 7 you learnt about the ideas of Democritus and the Ancient Greeks. They used the word *atomos* to describe those particles that could not be divided up any further. The concept of the **atom** was also described in ancient Indian texts over 2,000 years ago. Although we cannot see atoms, there is much evidence that this basic form of matter exists.

atom the smallest particle of matter; cannot be created, destroyed or broken down (indivisible)

In around 450 BCE, the Greek philosopher Democritus said:

By convention there is colour, by convention sweetness, by convention bitterness, but in reality there are atoms and the void.

Democritus was a natural philosopher. He did not carry out experiments, but proposed hypotheses based on thought and reasoning. Over the next 1,500 years, scientists tried many experiments to detect these invisible particles that make up all life on Earth.

By the 1780s, French chemist Antoine Lavoisier and his wife Marie-Anne Lavoisier (Figure 1) were convinced that matter could not be created or destroyed. Like many scientists of the time, they were interested in the study of mixtures in “invisible” air. They used a series of tests to divide the different “atoms” into metals and non-metals.

English scientist John Dalton was fascinated by this research and in 1810 he stated:

Matter, though divisible in an extreme degree, is nevertheless not infinitely divisible. That is, there must be some point beyond which we cannot go in the division of matter ... I have chosen the word “atom” to signify these ultimate particles.

Dalton was one of the first scientists to consider the link between elements and atoms. He was the originator of what is now called the **atomic theory**.



Figure 1 Antoine Lavoisier and his wife, Marie-Anne, were convinced that matter could not be created or destroyed.

atomic theory the theory that all matter is made up of atoms

Dalton's atomic theory

One of the pieces of evidence that Dalton published was that all atoms had different weights. Although the weight of an atom is too small to measure, Dalton was able to compare the weight of the lightest atom (hydrogen) to all of the other atoms that were then known. He assigned comparison weights to atoms such as oxygen, carbon and nitrogen, using the results of chemical analysis carried out by other chemists.

Evidence supports atomic theory

A scientific theory aims to explain existing evidence and observations. A good theory supported by evidence can be used to make testable predictions. Ever since Dalton proposed his atomic theory, it has been used to make predictions, and evidence that was not available in Dalton's time supports his theory. Evidence supporting the presence of atoms include:

- Elements can join together to form new substances.
- Water always contains twice as much hydrogen as oxygen.
- When chemicals react with each other, the total mass of the chemicals does not change.
- Pure oxygen has the same properties wherever it is found on Earth or even in space.
- Gases, some of which are invisible, have mass, and different gases have different masses.
- Modern scanning tunnelling microscopes produce images of surfaces that look “bumpy”.
- Under a microscope, tiny particles of pollen in water move in strange ways as if bumping into invisible objects.

Mendeleev organises atoms

By 1869, up to 56 atoms had been discovered by chemists around the world. In 1865, British scientist John Newlands published a paper that described how these atoms could be arranged into groups of eight atoms with similar properties. He called this the Law of Octaves. While many scientists did not agree at the time, Russian scientist Dmitri Mendeleev was preparing a textbook for his university students when he dreamed of patterns of atomic properties. When he woke up, he drew the pattern of atoms in a table. This table was so accurate, he was able to predict the properties of atoms that had not yet been discovered. This table became known as the **periodic table** (Figure 2).

The periodic table we use today identifies the many different properties of every atom that has been discovered or created so far. Both Mendeleev's version and the modern periodic table have:

- elements arranged in groups and periods
- hydrogen in the first row
- the same second row of elements
- the metals arranged in a group
- the non-metals arranged in a group.

periodic table a table in which elements are listed in order of their atomic number, and grouped according to their similar properties

A

но въ ней, мнѣ кажется, уже ясно выражается примѣнимость въ ставляемаго мною начала ко всей совокупности элементовъ, най которыхъ извѣстны съ достовѣрностію. На этотъ разъ я и желалъ преимущественно найти общую систему элементовъ. Вотъ этотъ опытъ:

			Ti=50	Zr=90	?=180.
			V=51	Nb=94	Ta=182.
			Cr=52	Mo=96	W=186.
			Mn=55	Rh=104,4	Pt=197,4
			Fe=56	Ru=104,4	Ir=198.
			Ni=Co=59	Pt=106,8	Os=199.
			Cu=63,4	Ag=108	Hg=200.
H=1	Be=9,4	Mg=24	Zn=65,2	Cd=112	
	B=11	Al=27,4	?=68	Ur=116	Au=197?
	C=12	Si=28	?=70	Su=118	
	N=14	P=31	As=75	Sb=122	Bi=210
	O=16	S=32	Se=79,4	Te=128?	
	F=19	Cl=35,5	Br=80	I=127	
Li=7	Na=23	K=39	Rb=85,4	Cs=133	Tl=204
		Ca=40	Sr=87,6	Ba=137	Pb=207.
		?=45	Ce=92		
		?Er=56	La=94		
		?Yt=60	Di=95		
		?In=75,6	Th=118?		

а потому приходится въ разныхъ рядахъ имѣть различное измѣненіе разностей, чего нѣтъ въ главныхъ числахъ предлагаемой таблицы. Или же придется предлагать при составленіи системы очень много недостающихъ членовъ. То и другое мало выгодно. Мнѣ кажется притомъ, наиболѣе естественнымъ составить кубическую систему (предлагаемая есть плоскостная), но и попытки для ея образованія не повели къ надлежащимъ результатамъ. Слѣдующія двѣ попытки могутъ показать то разнообразіе сопоставленій, какое возможно при допущеніи основнаго начала, высказаннаго въ этой статьѣ.

Li	Na	K	Cu	Rb	Ag	Cs	—	Tl
7	23	39	63,4	85,4	108	133	—	204
Be	Mg	Ca	Zn	Sr	Cd	Ba	—	Pb
B	Al	—	—	—	Ur	—	—	Bi?
C	Si	Ti	—	Zr	Sn	—	—	—
N	P	V	As	Nb	Sb	—	Ta	—
O	S	—	Se	—	Te	—	W	—
F	Cl	—	Br	—	J	—	—	—
19	35,5	58	80	100	127	160	190	220.

B 1 Group

1	1 H 1.0 Hydrogen																	
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	
3	11 Na 23.0 Sodium	12 Mg 24.3 Magnesium	3	4	5	6	7	8	9	10	11	12	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	
4	19 K 39.1 Potassium	20 Ca 40.1 Calcium	? 45.0 Scandium	22 Ti 47.9 Titanium	24 Cr 52.0 Chromium	25 Mn 54.9 Manganese	26 Fe 55.8 Iron	? 58.7 Nickel	29 Cu 63.5 Copper	30 Zn 65.4 Zinc	? 69.7 Gallium		33 As 74.9 Arsenic	34 Se 79.0 Selenium	35 Br 79.9 Bromine			
5	37 Rb 85.5 Rubidium	38 Sr 87.6 Strontium		40 Zr 91.2 Zirconium	41 Nb 92.9 Niobium				47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	? 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine			
6	55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57 to 71	73 Ta 180.9 Tantalum	74 W 183.8 Tungsten				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					

Figure 2 There are some similarities between (A) Mendeleev’s periodic table and (B) the periodic table we currently use.

Check your learning 6.1



Check your learning 6.1

Comprehend

- Summarise** the discoveries made by the following scientists.
 - Antoine and Marie-Anne Lavoisier
 - John Dalton
 - John Newlands
 - Dmitri Mendeleev
- Describe** why the periodic table is useful for scientists and chemists today.

Analyse

- Compare** (the similarities and differences between) a philosopher such as Democritus and a scientist such as John Dalton.
- Compare** (the similarities and differences between) the arrangement of the known

elements in Mendeleev's periodic table and the arrangement of the same elements in the current version of the periodic table.

Apply

- Use** the dates and events in this lesson to **create** a timeline that shows the development of atomic theory from Democritus through to the formation of the modern periodic table.

Skills builder: Planning and conducting

- Develop** two of your own scientific questions about atoms. (THINK: What would you like to know more about?) **Describe** how you could identify a website that can be trusted to provide answers to your questions.

Lesson 6.2

Elements are made up of one type of atom



Learning intentions and success criteria



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

Key ideas

- An element is a pure substance with one type of atom.
- The periodic table organises elements according to their chemical and physical properties.

What are elements?

An element is a pure substance made of only one type of **atom**. All the atoms in the element are identical. For example, the element carbon is only made up of carbon atoms; oxygen is only made up of oxygen atoms.

There are 94 to 98 different elements that are found naturally on Earth. Each element is made up of its own type of atom. Another 20 or so atoms have been made artificially, but these are highly reactive and break down within a second.

atom the smallest particle of matter; cannot be created, destroyed or broken down (indivisible)

Elements cannot be broken down into other substances because they are already the simplest substances. They can be thought of as being “elementary”, which is the origin of the name element.

The element is the substance that can be observed and has properties that can be measured. Single atoms are far too small to be observed with most microscopes and are incredibly difficult to measure.

The elements are classified into two main groups: metals and non-metals. In the solid state, atoms of metals are held in a lattice (Figure 1). Most other elements, which are not metals, are called non-metals. Most non-metals are gases at normal temperatures. Some gases, such as neon and helium, are **monatomic**. This means that each gas particle is a single atom (mono = one) (Figure 2A). However, the atoms in other gases, such as oxygen, hydrogen and nitrogen, are **diatomic molecules**. The atoms of these elements join together in pairs (di = two) (Figure 2B).

monatomic

consisting of a single atom

diatomic molecule

a molecule that consists of two atoms

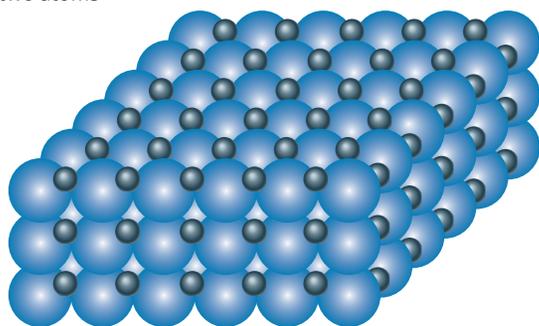


Figure 1 A metallic lattice

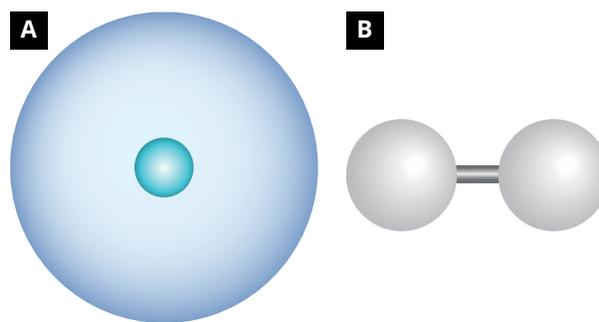


Figure 2 (A) Helium is monatomic, while (B) hydrogen is diatomic.

Elements and the periodic table

The periodic table arranges all the elements in order of the size of their atoms. It also groups together elements with similar properties. The horizontal rows in the table are called **periods**. The vertical columns are called **groups**. The elements in a vertical group often have similar properties, such as the way they look or how they behave.

Metals are found to the left of the grey zigzag line of elements in Figure 3 and the non-metals are found to the right of these elements.

On the periodic table, you will notice that elements are represented by their symbols, which consist of one or two letters: hydrogen has the symbol H; helium has the symbol He. Other symbols are oxygen (O), carbon (C), nitrogen (N), sulfur (S), gold (Au) and silver (Ag).

Elements can also be classified based on their chemical properties (Figure 4). These include how they react with other substances, such as acids and the oxygen in the air.

period (in chemistry) a horizontal list of elements in the periodic table

group (in chemistry) a vertical list of elements in the periodic table that have characteristics in common

1 Group												18						
Period 1	1 H 1.0 Hydrogen											13	14	15	16	17	2 He 4.0 Helium	
Period 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
Period 3	11 Na 23.0 Sodium	12 Mg 24.3 Magnesium	3	4	5	6	7	8	9	10	11	12	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
Period 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
Period 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
Period 6	55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57 to 71 Lanthanide series	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
Period 7	87 Fr (223) Francium	88 Ra (226) Radium	89 to 103 Actinide series	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

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
---------------------------------------	------------------------------------	--	---------------------------------------	--	--------------------------------------	--------------------------------------	--	-------------------------------------	--	-------------------------------------	------------------------------------	-------------------------------------	---------------------------------------	--------------------------------------

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	NON-METALS	OTHER
■ alkali metal	■ diatomic non-metal	 metalloid
■ alkaline earth metal	■ polyatomic non-metal	■ unknown chemical properties
■ lanthanide	■ noble gas	
■ actinide		
■ transition metal		
■ post-transition metal		

Figure 3 The periodic table



Figure 4 Not all metals are the same and they are classified based on their properties.

Check your learning 6.2



Check your learning 6.2

Retrieve

- 1 Identify** the two large groups in the periodic table.
- 2 Recall** the name given to the rows of the periodic table.
- 3 Identify** the names and symbols of the first five elements in the periodic table.

Analyse

- 4 Identify** the element found in period 3, group 2.

- 5 Identify** the two letters of the alphabet that are not represented in the elemental symbols of the periodic table.

- 6 Compare** (the similarities and differences between) atoms and elements.

Apply

- 7 Create** five words using the elemental symbols of the periodic table. (Example: Helium (He), lithium (L) and phosphorus (P) can spell HeLP.)

Lesson 6.3

Experiment: Properties of the elements

Aim

To observe the differences between different elements of the periodic table

Materials

- Steel wool
- Forceps
- Battery
- Lamp
- 3 wires
- 6 test tubes
- Test-tube holder
- 0.5 M hydrochloric acid

Samples for testing

- Aluminium metal strips
- Copper metal strips
- Magnesium metal strips
- Graphite/lead pencil
- Zinc metal strips
- Iron nail (non-galvanised)

Method

- 1** Use the steel wool to rub a small section of your first sample. Copy Table 1 and use it to record the colour and appearance (dull or shiny).

- Use the forceps to try to bend your sample. Identify whether it is malleable (able to bend) or brittle (breaks when bent). Record this in your table.
- Set up a circuit with the battery, lamp and wires as shown in Figure 1. Connect the two loose wires to your sample. Identify whether the light glows. Explain whether your material conducts electricity.
- Place your sample into a test tube and add 3 cm of 0.5 M (dilute) hydrochloric acid to the test tube. Describe any reactions that you observe. If possible, leave it overnight to see if there is any change.
- Repeat steps 1 to 4 for all of the samples and record your observations in your table.

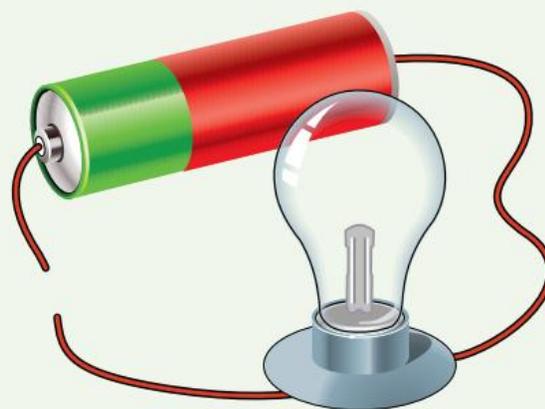


Figure 1 This incomplete circuit can measure the conductivity of objects.

Results

Copy Table 1 and use it to record your results.

Table 1 Materials and their properties

Element (sample)	Is it shiny/dull?	Is it malleable/ brittle?	Does it conduct electricity?	Does it react with acid?

Discussion

- Compare** your observations of the elements you tested.
- Use** your results to **categorise** the materials into two groups. **Describe** the properties you used to separate the materials.
- If you discovered a new material that was shiny and that was malleable when you bent it, **explain** which group you would put it in.

Conclusion

Describe what you know about the physical and chemical properties of the materials you observed.

Lesson 6.4

Atoms bond together to make molecules and compounds



Learning intentions and success criteria



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

Key ideas

- Molecules are groups of two or more atoms that are bonded together.
- When the atoms are different elements bonded together, they can also be called compounds.
- Elements and compounds can be represented by chemical formulas, while mixtures cannot.

What are molecules?

molecule group of two or more atoms bonded together (e.g. a water molecule, H_2O)

molecular element a molecule that contains two or more of the same atoms bonded together (e.g. oxygen, O_2)

compound a substance made up of two or more types of atoms bonded together (e.g. water, H_2O)

When two or more atoms are linked or bonded together, they are called **molecules**. Molecular substances can be broken into two groups: those with only one type of atom (**molecular elements**) and those with two or more types of atoms (**compounds**). This is summarised in Table 1.

Table 1 Summary of elements and molecules

	1 type of atom	>1 type of atom
1 atom	Monatomic element, e.g. He	Cannot exist
>1 atom	Molecular element, e.g. O_2	Compound, e.g. H_2O

Oxygen is an example of a molecular element. An oxygen molecule consists of two oxygen atoms joined together (Figure 1). Oxygen gas is a substance made of oxygen molecules. Pure oxygen gas consists of millions and millions of oxygen molecules, all exactly alike.

This means that the word “oxygen” can be used in two different ways: it can be used to describe the element or it can be used as the name of the molecule. When you see the names of chemicals, check the way in which the name is being used.

Molecules of a compound contain atoms of two or more different elements. Carbon dioxide is a **molecular compound**. Its molecules contain one carbon and two oxygen atoms (CO_2) (Figure 2). Pure carbon dioxide gas (the substance) consists of millions and millions of carbon dioxide molecules.

Water is another molecular compound. A water molecule is made up of two hydrogen (H) atoms and one oxygen (O) atom. This is why water is

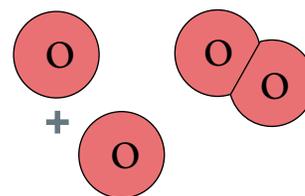


Figure 1 Oxygen (O_2) is a molecular element formed by two oxygen atoms.

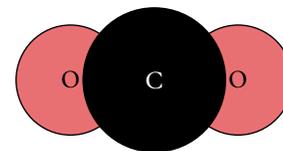


Figure 2 Carbon dioxide (CO_2) is a molecular compound made up of one carbon atom and two oxygen atoms.

molecular compound a molecule that contains two or more different atoms bonded together (e.g. carbon dioxide, CO_2)

referred to as H_2O (Figure 3). The small numbers (called subscript) after an element tell you how many atoms of that element there are.

A glass of water consists of many billions of water molecules.

When sugar ($\text{C}_6\text{H}_{12}\text{O}_6$) is mixed with water (H_2O), there are two different compounds in the **mixture**. Because the two compounds are not chemically bonded to each other, they can be easily separated. This means mixtures cannot be represented by chemical formulas. Figure 4 shows the difference between compounds and mixtures.

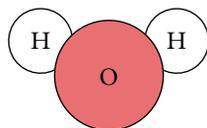


Figure 3 Water (H_2O) is a molecular compound made up of two hydrogen atoms and one oxygen atom.

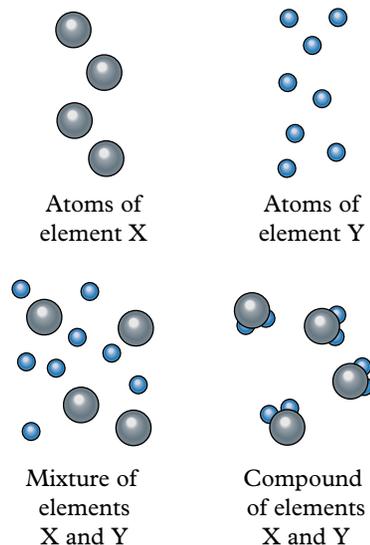


Figure 4 Mixtures are different from compounds.

mixture a substance made up of two or more pure substances mixed together

Compounds

You have seen that elements contain only one type of atom. However, there are far more substances than just the 94 to 98 naturally occurring elements.

Most of the substances we use are compounds. By altering the numbers and types of atoms in a substance, chemists can alter its properties. Many substances that are important to our society are used because of their important properties. These compounds are made in factories or obtained from natural products for example, pharmaceuticals and fertilisers.

Some compounds are individual molecules, such as water and carbon dioxide. Other compounds are long strings of atoms called **polymers**. The groups of atoms in these strings repeat over and over – like the beads on a necklace. Plastics are examples of polymers. Other polymers include chemicals found in plants and animals, such as starch and proteins.

Other compounds exist in a lattice arrangement, with atoms held together in three-dimensional networks. This can make them very strong as each atom is held in place by many bonds.

Elements and compounds can be **pure substances**. This means that all the particles in the substances are identical to each other. Water is an example of this. Pure water contains many molecules of H_2O (water molecules). The flow chart in Figure 5 shows the different types of substances.

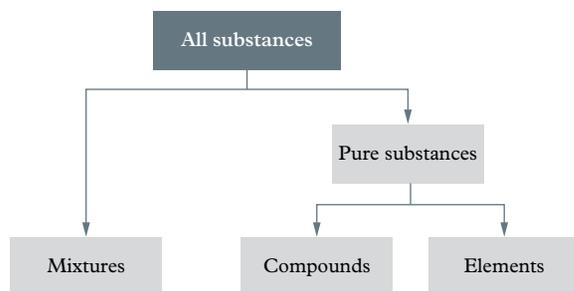


Figure 5 Mixtures contain different substances mixed together. Pure substances only contain one type of substance. That substance could be an element or a compound.

polymer a long-chain molecule formed by the joining of many smaller repeating molecules (monomers)

pure substance something that contains only one type of substance (e.g. a single element or a single compound)

Check your learning 6.4



Check your learning 6.4

Retrieve

- Identify** two elements that exist as elementary molecules rather than single atoms.

Analyse

- Ammonia is a gas that contains molecules with the formula NH_3 . **Identify** the elements that are present in ammonia and the number of each type of atom in each ammonia molecule.
- Compare** (the similarities and differences between) molecules and compounds.
- Contrast** (the differences between) the following terms.
 - Atom and molecule
 - Element and compound

- Compound and mixture
- Molecule, polymer and lattice.

Apply

- A student claimed that “all elements are molecules, but not all molecules are elements”. **Evaluate** this statement by:
 - defining the terms “molecules” and “elements”
 - deciding whether the first part of the claim is correct
 - deciding whether the second part of the claim is correct.

Lesson 6.5

Experiment: Decomposing copper carbonate

Aim

To decompose (break into smaller parts) copper carbonate

Materials

- Electronic balance
- Plastic beaker
- Test tube or crucible
- Spatula
- Copper carbonate
- Tripod
- Bunsen burner
- Heatproof mat
- Matches
- Wooden tongs
- Paper towel

Caution

- Wear safety glasses and lab coat, and tie long hair back when using a Bunsen burner.
- Use a yellow (cooler) safety flame for this experiment.
- Hold the test tube or crucible securely with the tongs and always point it away from yourself and others.
- Never place hot objects on the balance.

Method

- 1 Use the “tare” button to zero the balance. Place a plastic beaker containing the test tube on the balance. Record the mass in grams (this is M1).
- 2 Using a spatula, add approximately 3 g of copper carbonate to the test tube. Record the mass in grams (this is M2).
- 3 Place the tripod and the Bunsen burner on the heatproof mat. Safely light the Bunsen burner and move it under the tripod on the heatproof mat. Close the collar on the Bunsen burner to produce a yellow (safety) flame.
- 4 Using the wooden tongs to hold the top of the test tube, gently wave the base of the test tube over the flame twice. Record any changes. Continue to do this for 2 minutes, recording any changes. Be very careful to point the open end of the test tube away from others and yourself.
- 5 Allow the test tube and copper carbonate to cool. Wipe off any black powder from the outside of the tube with paper towel.
- 6 Use the “tare” button to zero the balance. Place the test tube in the original plastic beaker. Reweigh the test tube and beaker and record the mass in grams (this is M3).

Results

Copy Table 1 and use it to record your results.

Table 1 Copper carbonate before and after heating

Mass of beaker and test tube (M1) (g)	Mass of copper carbonate before heating (M2) (g)	Mass of copper oxide after heating (M3) (g)	Difference (M2 – M3) (g)

Discussion

- 1 **Describe** what happened to the copper carbonate. **Consider** the colour and any change in mass.
- 2 **Describe** the evidence that copper carbonate is a compound and not an element.
- 3 **Describe** one possible source of error in this experiment.

Conclusion

Describe what happens when copper carbonate decomposes.



Figure 1 Matches are used to light the Bunsen burner flame.

Lesson 6.6

Matter can be modelled



Learning intentions
and success criteria

Key ideas

- Elements are represented by symbols.
- Compounds and molecules are represented by formulas.
- Mixtures are represented by percentages.

particle theory
theory that explains
the properties of
matter (also called
the “particle model”)

Introduction

For hundreds of years, many scientists refused to believe that matter was made up of atoms. This was because the atoms were too small to be seen. It wasn't until scientists developed the **particle theory** that they asked what the smallest particles (atoms) looked like and how atoms joined together to form a compound.

The particle model does not show exactly what molecules look like, but, like most models used today, it is a useful tool to explain the structure and shapes of groups of atoms.

Representing elements

The development of the periodic table by Mendeleev and other chemists allows us to identify the different elements that make up the world around us. Each element has a unique chemical symbol that can be used to identify the type of atom. For example, the element oxygen is represented by the letter O, while hydrogen is represented by the letter H. Some elements are represented by two letters. When this occurs, the first letter is a capital letter, while the second letter is a lowercase letter. For example, helium is represented by He. When modelling atoms, all elements are usually represented by a single ball shape (Figure 1).

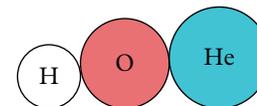


Figure 1 Element atoms are represented by a single ball shape.

Chemical formulas

When atoms join or bond together, they form molecules. An example of this is the water molecule (H_2O). The small number two after the H describes the number of hydrogen atoms that are in the water molecule. If there is no number after the letter, then it means there is only one of that atom present. For example, each water molecule (H_2O) will always have two atoms of hydrogen and one atom of oxygen (Figure 2). This formula for water remains the same if the water is a solid (ice), liquid or gas (water vapour).

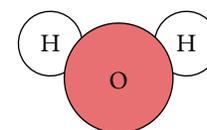


Figure 2 A water molecule is made up of one oxygen atom and two hydrogen atoms.

If the ratio of hydrogen and oxygen atoms changes (H_2O_2) then the compound becomes a new chemical (hydrogen peroxide).

Chemical formulas are also used to show when two atoms join together to form a molecular element. For example, oxygen rarely exists as a single atom. Instead, it joins with another oxygen atom to form O_2 (Figure 3). Other examples are carbon dioxide (CO_2), which has one carbon atom and two oxygen atoms (Figure 4), and methane (CH_4), which has one carbon atom and four hydrogen atoms (Figure 5).

When modelling atoms, it can sometimes be difficult to label individual atoms. For this reason, scientists usually have a colour code to identify the different atoms (Table 1).

Table 1 Different colours are used to represent different types of atoms in a model.

Element	Atom colour
Carbon	Black
Hydrogen	White
Oxygen	Red
Nitrogen	Blue
Fluorine	Yellowish green
Chlorine	Light green
Sulfur	Yellow
Phosphorus	Purple

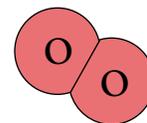


Figure 3 An oxygen molecule is made up of two oxygen atoms.

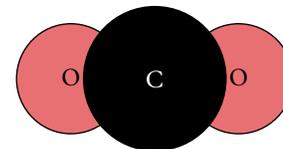


Figure 4 Carbon dioxide is made up of one carbon atom and two oxygen atoms.

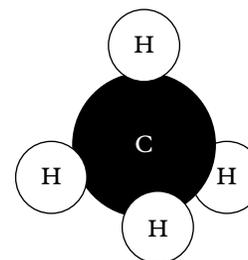


Figure 5 Methane is made up of one carbon atom and four hydrogen atoms.

Mixtures

When two different molecules are mixed together, it can become difficult to use symbols to tell the two types of molecules apart. For example, when water (H_2O) is mixed with sodium chloride (NaCl – table salt), we need to know how much water and table salt is present. For this reason, percentages can be used to represent the amount of each substance. An example of this is the amount of salt in the ocean, described as 35% NaCl ; 65% H_2O (350 grams of NaCl salt in every litre of seawater). As you learnt in Year 7, seawater is a **solution** because the NaCl (salt solute) is mixed evenly through the water (solvent). This can be modelled by the molecules being evenly mixed together without being bonded (stuck) together.

solution a mixture of a solute dissolved in a solvent

Suspensions

Suspension mixtures usually occur when the solute particles are too large to “hide” between the solvent particles. An example of this occurs when dirt is mixed with water (Figure 6). Over time, the solute can sink to the bottom of the container and become sediment. This is more difficult to model as the large solute particles need to be combined together like a solid before being mixed with the solvent. Suspensions can also be represented using percentages (25% dirt in water).



Figure 6 A good example of a suspension is dirt mixed with water.

suspension a cloudy liquid containing insoluble particles

colloid a type of mixture that always looks cloudy because clumps of insoluble particles remain suspended throughout it rather than settling as sediment

Colloids

Colloids such as milk occur when two substances with larger particles remain mixed evenly together. Like a suspension, this can be difficult to model using 3D model atoms. Colloids can also be represented using percentages.

Check your learning 6.6



Check your learning 6.6

Retrieve

- Identify** the symbol and colour used to represent each of the following atoms.
 - Hydrogen
 - Carbon
 - Oxygen
 - Nitrogen
- Identify** the chemical formula for each of the following molecules.
 - Water
 - Carbon dioxide
 - Methane
 - Oxygen

- Define** the term “solution”.

Comprehend

- Describe** how seawater can be modelled.
- Describe** how water vapour can be modelled.
- Explain** why a mixture cannot be represented by a formula.

Analyse

- Identify** the types and number of atoms present in the compound glucose ($C_6H_{12}O_6$).
- Contrast** (the differences between) a suspension and a colloid.

Lesson 6.7

Physical change is a change in shape or appearance



Learning intentions and success criteria



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

Key ideas

- A physical change occurs when the molecules remain the same but the substance has different properties.
- A change in state (solid, liquid or gas) is a physical change.
- Physical changes are easily reversed.

Physical changes are reversible

Physical changes are alterations in the properties of a substance, even though the particles of the substance have not changed. When you put water (H_2O) in the

freezer, it turns to solid ice (H_2O). When you take the ice out of the freezer, it melts back into liquid water (Figure 1). In this way, we observe that a physical change has taken place because the water molecules are unchanged and no new substances have been created.

Most physical changes are reversible, which means the change can be undone and the substance goes back to how it was. Liquid H_2O can go back into the freezer and once again turn to solid ice.

The particle model states that particles don't change when they change state. The molecule of water that contains two hydrogen atoms and one oxygen atom (H_2O) is exactly the same when it is a solid, a liquid or a gas. The only difference is how closely packed all the water molecules are and how much kinetic energy they have.

In ice, all the water molecules are in a regular arrangement (rows, columns and layers). A three-dimensional arrangement of particles in a regular pattern is called a **lattice** (Figure 2). The water molecules in ice are constantly vibrating. This ice lattice is unique when compared to most other solids. Most solids are denser and more compact than their liquid versions. The solid ice is different because it takes up more space than the liquid water. This is because the 3D bonds between the water molecules take up more space in the solid than the liquid.

When heat energy is added, the water molecules vibrate faster. However, the molecules are still held in place in the lattice by other water molecules around them. As the ice warms up more, the water molecules gain more energy and vibrate even faster. Eventually they have so much energy that they break free of the others around them and are free to move around. The solid ice has melted to become liquid water.



Figure 1 Ice melting to water is an example of a physical change.

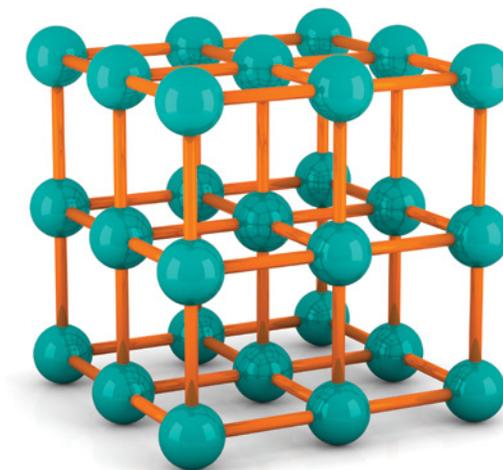


Figure 2 Particles in a solid may be arranged in a lattice.

lattice a three-dimensional arrangement of particles in a regular pattern

Changing state

Substances can change between the three states. You are familiar with seeing water change state (when ice blocks melt), but other substances may only ever be seen in one state. Theoretically, all substances can be changed into different states if the temperature is hot (or cold) enough. Even gases, such as nitrogen, can be turned into a liquid at very low temperatures. “Dry ice” is actually solidified carbon dioxide (CO_2).

Vaporisation and condensation

vaporise to change state from a liquid to a gas; evaporate

vapour gaseous form of a substance that is normally solid or liquid at room temperature (e.g. water vapour)

When a liquid evaporates to become a gas, we say it has evaporated or **vaporised**. A **vapour** is the gaseous form of a substance that is normally a solid or liquid at room temperature. For example, when water is turned into a gas, it is referred to as water vapour (Figure 3). Vapours that are smelly are often called fumes. Vapours and fumes are gases and will behave like gases.

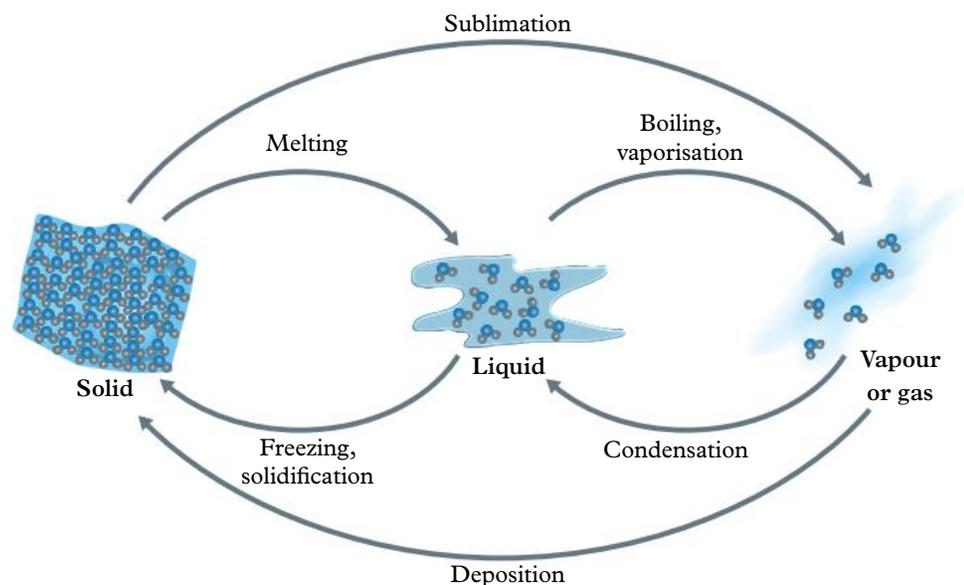


Figure 3 Changing states of water molecules. A solid contains lattice water molecules, a liquid contains a loose arrangement of water molecules and a vapour or gas contains separated water molecules.

volatile describes a substance that easily becomes a gas

Volatile substances, such as petrol, vaporise easily. Cooking oil does not vaporise if left at normal room temperatures. Cooking oil is not a volatile liquid.

When a liquid is heated and boils, it changes from liquid to gas. Water left in the open at normal room temperature will evaporate very slowly. If the water is heated to its **boiling point**, the water molecules will quickly gain kinetic energy and evaporate or vaporise faster.

boiling point the temperature at which a liquid boils and becomes a gas

condense to change state from gas to liquid

When a gas cools down, we say it **condenses** into a liquid. The most common condensation you can observe is when your breath condenses on a cold surface (Figure 4). The kinetic energy of the water molecule/particle passes to the surface as heat energy. The water molecules do not change, but they cool down, slow down and condense from a gas to a liquid.



Figure 4 Water vapour in the air has condensed on this cold window.

Melting and solidification

melting point the temperature at which a solid becomes a liquid

When a solid is heated and changes state to become a liquid, we say it has melted. The temperature at which a solid changes to a liquid is called its **melting point**.

When the liquid loses heat and becomes a solid, it is called **solidification**. When solidification happens to water, it is sometimes called freezing. In both these examples, the molecules do not change – only the amount of energy they have changes.

solidification the process of a liquid turning into a solid

Sublimation

Some substances don't ever exist as liquids. They just change state from a solid to a gas or from a gas to a solid. The process of a solid becoming a gas is called **sublimation**. Dry ice (CO_2) changes directly from a solid into a gas when it warms up (Figure 5). Dry ice is often used to produce smoke effects on stage at concerts. However, the “smoke” you see is not carbon dioxide, but clouds of water. When dry ice sublimates to form carbon dioxide gas, it cools the air quickly. This drop in temperature causes water vapour in the air to condense and form clouds of water.



Figure 5 Dry ice is solidified carbon dioxide gas.

sublimation a change of state from a solid directly to a gas

Diamond (a form of carbon) is the hardest known substance on Earth. It also sublimates, but only at extremely high temperatures (above $3,500^\circ\text{C}$).

Check your learning 6.7



Check your learning 6.7

Retrieve

- Define** the following terms.
 - Lattice
 - Condense
 - Sublimation
 - Volatile

Comprehend

- Explain** why physical changes are reversible.
- Explain** why shattering a block of ice is considered a physical change.
- Explain** why all perfumes are volatile liquids.
- Illustrate** the three major states of water. **Identify** the physical changes the water goes through to form ice and water vapour.

Apply

- A student claimed that the bubbles in boiling water were oxygen. **Evaluate** their claim (by describing the kinetic energy changes that occur in boiling water, describing the types of molecules found in the bubbles and deciding if the statement is correct).

Skills builder: Communicating

- Construct** a visual aid to demonstrate the three major states of water and the physical changes water goes through to form ice and water vapour. (THINK: How could you represent this information visually? Would you use a flow chart, a diagram or a table?)

Lesson 6.8

Challenge: Melting chocolate

Caution

Do not eat or drink in the laboratory.

Aim

To examine the physical change in melting chocolate

Materials

- Milk, dark and white cooking chocolate buttons (approximately 10 of each)
- 3 × 100 mL beakers
- Thermometer
- Water
- 250 mL beaker (as a water bath)
- Timer
- Stirring rod
- Heatproof mat
- Heatproof gloves
- Bunsen burner or hotplate
- Matches

Method

- 1 Place 4 to 6 buttons of milk cooking chocolate in a 100 mL beaker.
- 2 Place a thermometer in the beaker.
- 3 Place the beaker in a hot water bath (using the Bunsen burner to heat water in a 250 mL beaker) and heat it to 60°C. Do not stir the chocolate.
- 4 Use the stirring rod to gently poke the chocolate to determine if it has melted.
- 5 Time how long it takes to melt. Record your observations.

- 6 Use the heatproof gloves to remove the beaker from the hot water and place it on the heatproof mat.



Figure 1 Placing the small beaker of chocolate buttons in a beaker of hot water causes the chocolate to melt.

Inquiry: What if another type of chocolate was melted? Would it melt faster or slower than milk chocolate?

Plan and conduct an experiment that answers the inquiry question.

- 1 **Develop** a prediction or hypothesis for your inquiry.
- 2 **Identify** the (independent) variable that you will change from the first method.
- 3 **Identify** the (dependent) variable that you will measure and/or observe.
- 4 **Identify** two variables that you will need to control to ensure a fair test. **Describe** how you will control these variables.
- 5 **Develop** a method for your experiment and write it in your logbook.
- 6 **Construct** a table to record your results.
- 7 Show your teacher your planning (for approval) before starting your experiment.

Results

- 1 **Record** your observations, including any diagrams and photographs.
- 2 **Construct** a column graph of the time it took for each type of chocolate to melt.

Discussion

- 1 **Contrast** (the difference in) the time it took for each type of chocolate to melt.
- 2 **Compare** the pattern of melting for all three types of chocolate. (Inside first or outside edges first?)
- 3 **Describe** how a chef could apply your observations in the kitchen.

- 4 **Describe** any discolouration or burning of the chocolate that occurred.
- 5 **Identify** whether a new substance formed if the chocolate burnt.

Conclusion

Compare the properties of the milk, dark and white chocolate.



Figure 2 Chocolate buttons can be melted.

Lesson 6.9

Chemical change produces new substances

Key ideas

- Chemical changes can cause heat or light to be produced.
- Chemical changes can cause an object to change colour.
- Chemical changes can cause a new gas or solid to be formed.
- When a chemical change occurs, a new substance is formed.



Learning intentions and success criteria



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

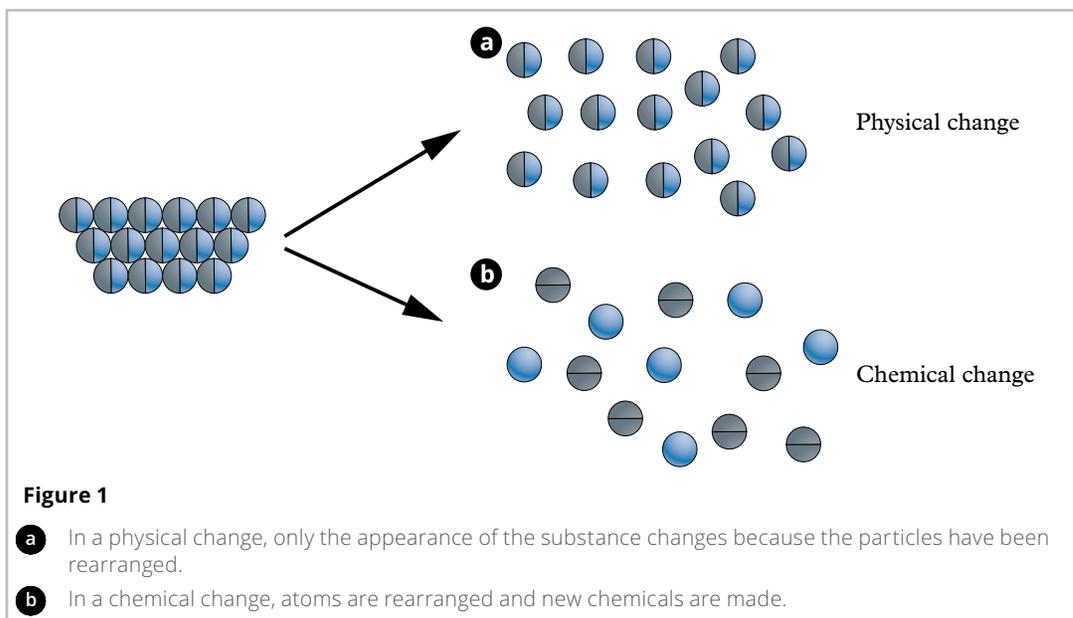
Chemical changes

In a chemical change, a new substance is formed. This means that the atoms have been moved around into new arrangements. In some chemical changes, the atoms in a molecule can be separated to make new chemicals. Sometimes atoms and molecules join together to make new chemical substances with larger molecules. New substances have new particles and new properties. Both the physical and chemical properties of

the new substance (the product) will be different from those of the original substance (the reactant).

In every chemical reaction, one or more substances are changed into new, different substances with different physical and chemical properties. Many chemical changes are not reversible – you cannot un-burn toast!

Whether a change is physical or chemical (Figure 1) depends on the substances, the temperature and how you mix them.



Physical change or chemical change?

When solid chocolate is heated gradually, it melts and changes shape; when cooled, it goes back to the solid state. It may have a different shape, but the molecules are the same. It is still chocolate. In this situation, a physical change has taken place because the chocolate is still the same substance: it is still made up of the same particles.

However, if you heat chocolate at too high a temperature, it burns (Figure 2). When it cools, it no longer tastes of chocolate, but of burnt chocolate. This is a chemical change, because a new substance is formed that is different from chocolate – you can tell by the taste and smell! This is why most chocolate recipes suggest heating chocolate over boiling water rather than over a hot plate, so that the chocolate does not get too hot and a chemical change does not take place.

When you bake a cake, mixing the ingredients together produces a physical change. Baking the cake involves a chemical change.



Figure 2 Heating chocolate slowly causes it to melt – a physical change. If it is heated quickly and at a higher temperature, the chocolate will burn – a chemical change.

Cooking often turns food brown. This is due to the sugar in the food caramelising – turning into brown caramel. This is an example of chemical change. It cannot be easily reversed.

Aboriginal and Torres Strait Islander Peoples use carefully controlled heat to cause a chemical change to produce a red pigment (iron oxide) from yellow ochre for their paintings. The change forms a new substance and is not reversible. It is a chemical change.

We can usually identify a chemical change if one of the things shown in Figures 3 to 6 occurs.



Figure 3 A gas is produced, which we either see as bubbles or fizz.



Figure 5 Light or heat is absorbed or produced. When the atoms in sodium metal and water rearrange themselves, the extra energy is released as light and heat.



Figure 4 A colour change occurs that is non-reversible. Heating an iron nail to red hot is a physical change because the red colour will disappear as the nail cools down; however, if the iron in the nail reacts with air and becomes rusty, it is a chemical change.

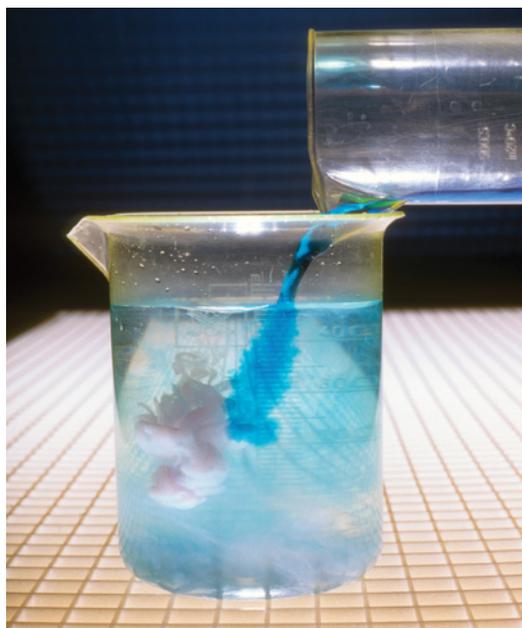


Figure 6 A precipitate forms. A precipitate is the name given when new solid particles form during a chemical change.

Check your learning 6.9



Check your learning 6.9

Comprehend

- 1 **Describe** the observations that would tell you that a chemical change had occurred.
- 2 Sugar turns brown when heated in a process called caramelisation. **Explain** why caramelisation is considered a chemical reaction.
- 3 **Describe** the evidence that baking a cake from egg, flour and butter is a chemical reaction.

Analyse

- 4 **Contrast** (the differences between) chemical and physical change.
- 5 When melted chocolate is put in the fridge, it cools quickly, producing small crystals that were not present before. This changes the taste of the chocolate. **Identify** this as a chemical or physical change.

6 **Identify** the following as either a physical or a chemical change.

- a Melting cooking chocolate into animal shapes
 - b Burning magnesium ribbon to form a white ash
 - c Boiling water and condensing the vapour
 - d Dissolving magnesium in acid to produce hydrogen gas
 - e Separating leaves from woodchips using a garden blower
- 7 **Identify** the key evidence that suggests that producing the reddish-brown pigment from yellow ochre is a chemical change.

Skills builder: Questioning and predicting

- 8 A student was asked to investigate the type of change that took place when an egg was heated in boiling water and cooled in cold water. **Develop** a scientific question for this investigation. (THINK: Is your question specific and can it be tested?)

Lesson 6.10

Challenge: Making caramel

Caution

Do not eat or drink in the laboratory.

Aim

To identify the chemical change when heating sugar

What you need:

- Sugar
- Test tube
- Bunsen burner
- Heatproof mat
- Matches
- Safety glasses
- Test-tube holder or wooden tongs

What to do:

- 1 Place a pea-sized amount of sugar into a dry test tube.
- 2 Place the Bunsen burner on the heatproof mat. Safely light the Bunsen burner and open the collar on the Bunsen burner to produce a blue flame.
- 3 Wearing safety glasses, hold the test tube with the test-tube holder or tongs. With the test tube facing away from you and everyone else, gently heat the sugar by passing it through the top part of the blue flame.
- 4 If you are careful, the sugar grains will crumble (they lose water in a chemical reaction) and turn into a brown syrup. This brown syrup is caramel. You may see condensation on the inside of the test tube as the water is driven out of the sugar. If you continue heating, or heat too strongly, you will burn the sugar.

Questions

- 1 **Describe** the evidence that a chemical reaction occurs at step 3.

- 2 **Describe** the chemical change that could occur if you continued heating the caramel in step 4.



Figure 1 Sugar undergoes a chemical change when heated.

Lesson 6.11

Experiment: Observing chemical reactions

Aim

To observe the reactants and products in different chemical reactions

Materials

- Spatula
- Copper carbonate (solid)

- 2 test tubes
- Safety glasses
- Bunsen burner
- Heatproof mat
- Matches
- Test-tube holder
- Beaker
- Baking soda (sodium bicarbonate)
- 6 mL of 1 M hydrochloric acid
- Wooden splint
- Thermometer
- Magnesium ribbon (1 cm length)
- Tealight candle
- Jar that fits over a tealight candle
- 30 mL of 0.5 M copper sulfate solution
- 100 mL beaker
- Tongs
- Piece of steel wool, about thumb size when rolled up

Method

Part A

- 1 Place a large spatula of copper carbonate in a test tube.
- 2 Wearing safety glasses, place the Bunsen burner on the heatproof mat. Safely light the Bunsen burner and open the collar on the Bunsen burner to produce a blue flame.
- 3 Using a test-tube holder, gently heat the test tube by passing it over the flame twice. Make sure the test tube is facing away from you and everyone else. Observe any changes and repeat until the powder changes colour.
- 4 Collect the waste powder in a beaker for disposal.

Part B

- 1 Place the baking soda in a test tube to a depth of 0.5 cm.

- 2 Add an equal amount of 1 M hydrochloric acid to the test tube and observe.
- 3 Conduct a carbon dioxide test by holding a burning wooden splint above the tube. If the flame goes out, carbon dioxide is present as one of the products of the chemical reaction.

Part C

- 1 Pour 5 mL of 1 M hydrochloric acid into the bottom of a test tube. Measure its temperature with the thermometer.
- 2 Add the magnesium ribbon to the test tube. Measure its temperature again.
- 3 Observe what happens using sight, touch (the outside of the tube only!) and sound.

Part D

- 1 Examine the tealight candle. Observe the temperature of the candle (hot, room temperature, cold).
- 2 Use a match to light the candle.
- 3 Draw a picture of the flame. Record any changes to the wax.
- 4 Place the jar over the top of the candle. Observe any changes to the flame and wax.
- 5 Remove the jar and relight the candle.
- 6 Place the jar over the candle until the flame is about to go out, then gently remove the jar.
- 7 Observe what happens to the flame.

Part E

- 1 Pour 30 mL of 0.5 M copper sulfate solution into a 100 mL beaker.
- 2 Use the tongs to place the steel wool into the copper sulfate solution.
- 3 Carefully observe the changes that occur to both the steel wool and the copper sulfate solution.
- 4 Collect the copper sulfate/steel wool solution in a beaker for safe disposal.



Figure 1 When heating a test tube, be sure to point it away from you or anyone else close by.

Results

Include your observations in your notebook.

Discussion

- 1 Describe** what happened to the copper carbonate when it was heated.
- 2 Describe** your observations of the copper carbonate when it was taken away from the heat.

- 3 Compare** the copper carbonate experiment with the melting chocolate experiment.
- 4 Identify** what is produced in the baking soda and acid experiment.
- 5 Explain** why the flame on the burning splint goes out if carbon dioxide is present.
- 6 Explain** what happened to the magnesium metal.
- 7 Explain** what happened to the candle flame when the jar was placed over it. **Suggest** a hypothesis for why this occurred.
- 8 Explain** why the flame did not go out when the jar was removed the second time it was placed over the candle.
- 9 Design** an experiment to test the science question, “What if twice as much magnesium was used in Part C of the experiment?”

Conclusion

Explain what you observed about the reactants and products of chemical reactions.

Lesson 6.12

Experiment: Detecting a mystery powder

Aim

To use knowledge of common chemical changes to identify a mystery powder

Materials

- 5 spatulas or icy-pole sticks
- 2 white spotting tiles
- Baking soda

- Cream of tartar
- Corn starch
- Baking powder
- 4 plastic pipettes
- Water
- 20 toothpicks
- Vinegar
- 0.1 M iodine solution
- Universal indicator
- Unknown powder

Method

Part A

- Using a separate spatula for each substance, place a small sample of each of the known powders in the dimples of the white spotting tiles as shown in Figure 1.

Baking soda	Baking soda	Baking soda	Baking soda
Cream of tartar	Cream of tartar	Cream of tartar	Cream of tartar
Corn starch	Corn starch	Corn starch	Corn starch
Baking powder	Baking powder	Baking powder	Baking powder

Figure 1 Use a white spotting tile to test for a new substance being formed.

- Use a pipette to add 4 drops of water to each of the first column of powders. Use a clean toothpick to mix the powder and liquid

if required. Copy Table 1 and record any evidence of a chemical reaction in it.

- Use a clean pipette to add 4 drops of vinegar to each of the second column of powders. Use a clean toothpick to mix the powder and liquid if required. Record any evidence of a chemical reaction in your table.
- Use a clean pipette to add 4 drops of iodine to each of the third column of powders. Use a clean toothpick to mix the powder and liquid if required. Record any evidence of a chemical reaction in your table.
- Use a clean pipette to add 4 drops of universal indicator to each of the fourth column of powders. Use a clean toothpick to mix the powder and liquid if required. Record any evidence of a chemical reaction in your table.

Part B

- Using a spatula, place a small sample of the unknown powder in four of the unused dimples of the second white spotting tile.
- As you did in Part A, use the water, vinegar, iodine and universal indicator to test the sample of the unknown powder. Use a clean toothpick to mix the powder and liquid if required.
- Copy Table 2 and record any evidence of a chemical reaction in it.

Results

Copy Table 1 and Table 2 and use them to record your results.

Table 1 Evidence of chemical reactions in Part A

Test solution	Water	Vinegar	Iodine	Universal indicator
Baking soda				
Cream of tartar				
Corn starch				
Baking powder				

Table 2 Evidence of chemical reactions in Part B

Test solution	Water	Vinegar	Iodine	Universal indicator
Unknown powder				

Discussion

- Compare** a chemical reaction change to a physical reaction change.
- Describe** the chemical reaction change that occurred for each of the test powders.
 - Baking soda
 - Cream of tartar
 - Corn starch
 - Baking powder
- Compare** the results of the mystery powder to the tests you made in Part A. **Identify** the mystery powder.
- Select** one of the powders that did not change when water was added. **Identify** if this lack of change means that a chemical reaction will never occur between the powder and water. **Justify** your answer by defining chemical change, providing an example of a chemical change that occurs slowly, and relating it to the powder and water.
- Use** your answer to question 4 to **identify** an assumption that was made during this experiment.

Lesson 6.13

Chemical reactions can break bonds and re-form new bonds

Key ideas

- In a chemical reaction, the starting substances are called reactants.
- The products are the final substances formed and can have new properties.
- In chemical changes or reactions, the atoms in the reactants separate from each other and bond together in different combinations to form new products.



Learning intentions and success criteria



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

Chemical reactions

A chemical change can also be described as a **chemical reaction**. The substances that you start with are called **reactants**. They react or change to produce new substances. The substances that you finish with are called **products**. They are produced in a chemical change. There may be more than one reactant and product for each chemical change (Figure 1).

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

Chemical reactions are all around us. They not only occur in factories and laboratories – they take place in our homes and in our bodies. Every process in your body requires chemical changes. Cooking food changes it chemically so it is more edible and easier to digest.

Reactions in cooking

Preparing and cooking food involves many physical and chemical changes to the food. There are other similarities between chemistry and cooking – some of the techniques used in cooking, such as heating, mixing and filtering, are similar to the tasks of a chemist.

There are many chemical reactions in the kitchen. Baked vegetables and meat turn brown as the sugars are caramelised. The sugar is the reactant, and the caramel is the product. Usually, the sugar comes from the breakdown of the starch granules into starch molecules, followed by a chemical change into a sugar. Other chemical changes involve the breakdown of proteins in meat. A few vitamins may be destroyed by some cooking methods.

Some chemical changes are caused by microorganisms. Sour milk forms when a bacterium converts milk sugar (lactose) into an acid (lactic acid). The taste of sour milk is unpalatable and the large numbers of bacteria in the milk may make you sick. Cheese is made by fungi and bacteria that consume the sugars in milk and cause the protein to thicken. In making yoghurt, the bacteria act as a culture (a colony of microorganisms) that is transferred to the new medium (milk).

Other chemicals are added to our food, including flavourings, colourings, antioxidants and preservatives. These help to improve the food's appearance and increase its shelf life. Processed foods usually show a list of these additives on the packet (Figure 2).

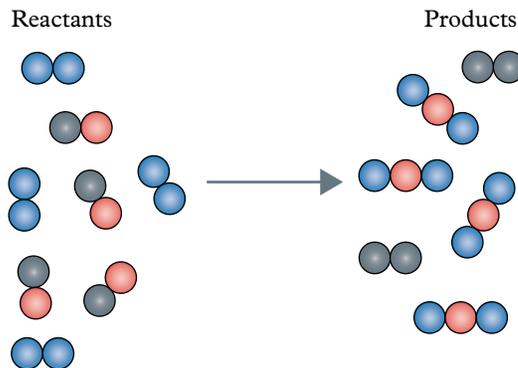


Figure 1 Reactants in a chemical reaction become products.



Figure 2 Some processed foods have artificial chemicals added to them.

Combustion

combustion a reaction that involves oxygen and releases light and heat energy

Burning is a chemical reaction. The scientific word for burning is **combustion**.

Magnesium is a metal that can burn fairly easily, giving off a lot of heat and bright, white light. When a magnesium ribbon interacts with the oxygen in the air, the reactants are magnesium and oxygen. The chemical reaction takes place when we see the magnesium ribbon burn. After the ribbon has burnt, we are left with a white powder, magnesium oxide, as the product of the reaction.

Aboriginal and Torres Strait Islander Peoples carefully control the burning of plants and wood so that there are only small amounts of oxygen as a reactant. This means that good-quality charcoal is produced (the product) that can then be used for black pigment (Figure 3) or to improve the properties of glues for spears or axe heads.



Figure 3 The Adnyamathanha people of the Flinders Ranges in South Australia used charcoal as part of paintings in the Yourambulla Caves.

Testing for substances

We can use our understanding of chemical reactions forming new substances to test for contaminants in water. Metal sulfate is an example of a contaminant. It can form in soil and leak into water. If exposed to air, the metal sulfate can release acid. We can test for a metal sulfate by mixing a small amount of the contaminated water with barium chloride. When the two of them mix, a new substance, barium sulfate, forms. We can see this new substance because it is a solid.



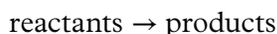
Other tests use similar methods. A chemical reaction producing a change in colour or a new solid can be used to show if a reactant is present. A swimming pool needs chlorine in it to help kill disease-causing bacteria. Most pool owners test their water for chlorine by adding a chemical reactant to a water sample. If chlorine is present, the two chemicals react to produce a colour change. This new colour can be compared to a chart to see if enough chlorine is present (Figure 4).



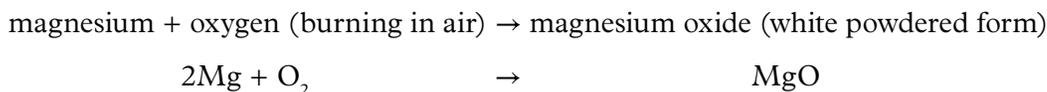
Figure 4 When testing pool water for chlorine, pool owners look for a chemical (colour) change.

Chemical equations

Scientists use a shorthand technique to describe what happens to reactants and products in chemical reactions. This is called a chemical equation. The reactants are written on the left-hand side and the products are written on the right-hand side. An arrow represents the chemical change.



For magnesium ribbon burning in air, the chemical reaction could be represented by the following chemical word equation and chemical symbol equation:



The final product is 2MgO.

Check your learning 6.13



Check your learning 6.13

Retrieve

1 **Define** the following terms.

- Reactant
- Product

Comprehend

- 2 **Describe** the purpose of the arrow in a chemical equation.
- 3 **Explain** why it is unnecessary to write an equation for a physical change.

Analyse

- 4 **Contrast** (the differences between) reactants and products.
- 5 **Identify** the reactants and the products in the following chemical reactions.
 - a Iron ore is made into a steel ship.
 - b Bread is made from flour.
 - c Freezer bags made from polythene are manufactured from ethene.
 - d Nitrogen fertilisers are made from nitrogen gas and hydrogen gas.

- 6 Plants can have difficulty growing in soil that has too much acid. The chemicals in a soil testing kit will often change colour when added to acidic soil. **Use** your understanding of chemical reactions to **explain** how a soil testing kit works.

Skills builder: Planning investigations

- 7 Plan an investigation that explores the rate of one chemical reaction (for example, rusting) under different conditions.
 - a **Identify** the dependent variable, independent variable and any controlled variables. (THINK: What are you changing or measuring in your investigation? Which other variables might need to be controlled?)
 - b **Develop** a method for your investigation and **create** a scientific diagram of the experimental set-up. (THINK: What is a logical order for each step in the method?)

Lesson 6.14

Experiment: Comparing reactants and products

Aim

To examine the physical and chemical properties of reactants and products

Materials

- 2 test tubes
- Test-tube rack
- Marker pen
- Piece of magnesium ribbon (1 cm)
- 1 pea-sized sample of magnesium oxide powder
- 10 mL measuring cylinder
- 20 mL of 1 M hydrochloric acid

Method

- 1 Place two test tubes in a test-tube rack. Label one test tube Mg (magnesium) and the other MgO (magnesium oxide).
- 2 Add the samples (magnesium ribbon and magnesium oxide powder) to the appropriate test tubes.
- 3 Examine each sample by looking and carefully moving the sample in the bottom of the appropriate test tube. Copy Table 1 and use it to record your observations.
- 4 Add 10 mL of 1 M hydrochloric acid into each test tube in the test-tube rack.
- 5 Observe any reactions. Record your observations in your table.

Results

Include your completed Table 1 in your results.

Write a short statement describing each sample and how it reacted with acid.

Table 1 The properties of magnesium and magnesium oxide

Substance	Colour	State	Shiny/Dull	Reaction with acid
Magnesium (Mg)				
Magnesium oxide (MgO)				

Discussion

- 1 **Compare** the physical properties of magnesium and magnesium oxide.
- 2 **Compare** the chemical properties of magnesium and magnesium oxide.

Conclusion

Explain what you know about the physical and chemical properties of reactants and products.

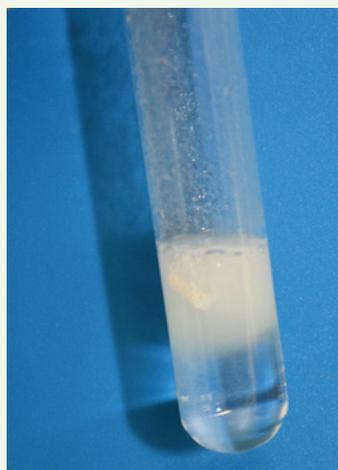


Figure 1 Magnesium ribbon reacting with hydrochloric acid

Lesson 6.15

Chemical reactions can be sped up and slowed down



Learning intentions and success criteria



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

Key ideas

- The rate of a reaction can be sped up or slowed down.
- Factors that can increase the rate of a reaction include increasing the surface area of the reactants, increasing the temperature and concentration of substances and adding a suitable catalyst.

The effect of temperature

For substances to react, their particles must collide with each other. This is known as the **collision theory**. In the collision theory, the more collisions that happen between the particles, the more likely it is that they will react.

One way to increase the number of collisions between particles is to increase the temperature (Figure 1). When heat energy is added to the substance, the particles gain kinetic energy and therefore move more quickly. To slow down a reaction, the temperature can be reduced so that the particles have less kinetic energy and have less chance of colliding.

This means a substance that has a lower melting point or boiling point is often more reactive than a substance that is hard and inflexible.



Figure 1 An increase in temperature causes reactant particles to move faster.

collision theory a theory stating that the particles involved in a chemical reaction must collide in order to react

The effect of concentration

The number of particles trapped in a small area – the **concentration** – also has an effect. More concentrated substances will react more easily, again due to the collision theory. A more concentrated substance has more particles available to collide with particles from another substance (Figure 2).

For instance, to increase the rate of a reaction between a solid substance and one in solution, increasing the concentration of the solution will mean that there are more particles in the solution to collide with the particles in the solid.

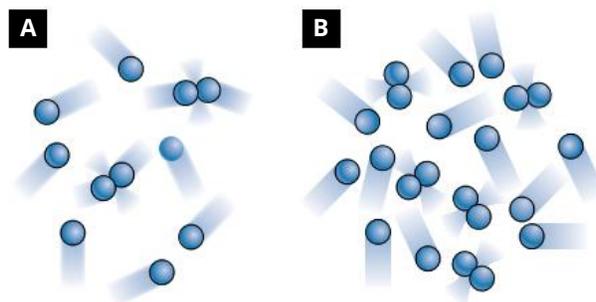


Figure 2 (A) At low concentrations there are few collisions between particles. (B) At high concentrations, the number of collisions between particles is greater.

concentration the number of active molecules in a set volume of solution

The effect of surface area

When a solid reactant is physically cut into smaller pieces, it will react faster. This is because the smaller reactant pieces have a larger total surface area, which means that the reactant particles have a greater chance of interacting with each other (Figure 3).

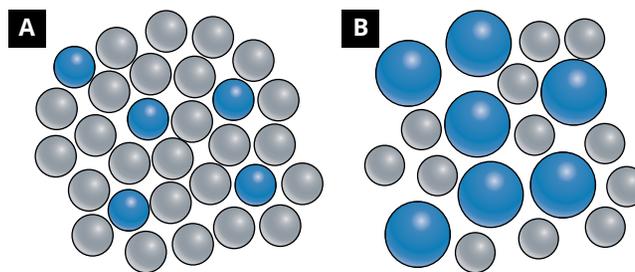


Figure 3 (A) More reactants can interact or touch each other when the reactant pieces are small. (B) Large reactant pieces have less total surface area to make contact with other reactants.

The effect of catalysts

Some substances are more reactive than others. This means the chemical properties of the substances make them more likely to corrode, rust or react with other substances. In these instances, the reactive substances are the reactants.

Special substances that increase the rate of a reaction without becoming used up by it are known as **catalysts**. These catalysts can be added to reactants to make a reaction happen faster.

Enzymes are types of catalysts that help speed up reactions in living things. We have many enzymes in our bodies that help to speed up chemical reactions. For example, enzymes found in the digestive system help break down food. Enzymes are very “fussy” and only work with one type of reactant, and so will only catalyse one reaction each. They act like landing strips for reactants, allowing the chemicals to collide with each other more easily.

Enzymes are responsible for the ripening of fruit. When a piece of fruit is cut and left exposed to the air, enzymes help the oxygen react with the fruit and make it turn brown. This enzyme can be blocked by adding vitamin C (Figure 4).



Figure 4 Adding lemon juice or salt to cut apples stops them from going brown. Lemons contain vitamin C.

catalyst a substance that increases the rate of a chemical reaction without undergoing any permanent chemical change

enzyme a protein that speeds up the rate of chemical reactions; a type of catalyst

Check your learning 6.15



Check your learning 6.15

Comprehend

- 1 Explain** the collision theory in your own words.
- 2 Describe** how the surface area of a solid reactant affects the rate of a chemical reaction.
- 3 Describe** the effect enzymes have on the rate of a reaction.
- 4 Describe** what happens to the number of particles when you increase the concentration of a substance.
- 5 Explain** how increasing the concentration of reactants increases the rate of a reaction.
- 6 Explain** why increasing the rate of a reaction does not change the total amount of product produced.

◀ Analyse

- 7 **Consider** how the particle model of matter helps to explain the rate of reactions.



Figure 5 Why does roasting a marshmallow make it go brown?

Lesson 6.16

Experiment: Effect of particle size on reaction rates

Aim

To observe how particle size affects the rate of a reaction

Materials

- Filter paper
- Electronic balance
- 2 small pieces of marble chips
- 2 small beakers
- 10 mL graduated cylinder
- Dilute hydrochloric acid (1 M HCl)
- Timer
- Stirring rod
- Mortar and pestle

Method

- 1 Place a piece of filter paper on the electronic balance and record the mass.

- 2 Place a small piece of marble onto the filter paper. Measure and record the combined mass (Figure 1).



Figure 1 Weighing the marble allows you to calculate the mass lost in the reaction.

- 3 Place the marble piece into a beaker and add 5.0 mL of 1 M hydrochloric acid (HCl). Record the time.
- 4 Stir the marble and the acid occasionally.
- 5 Time how long it takes for the reaction (gas bubbles being produced and the marble piece becoming smaller) to stop.

- 6 When the reaction stops, filter the remaining solution using the original filter paper.
- 7 Allow the filter paper to dry overnight and measure the mass.
- 8 Now select a piece of marble the same size as the first. Grind the marble piece into a fine powder using the mortar and pestle (Figure 2).



Figure 2 Grinding the marble creates smaller particles.

- 9 Place another piece of filter paper onto the electronic balance and record the mass. Place the ground-up marble onto the filter paper. Measure and record the combined mass.
- 10 Place the ground-up marble into a small beaker and add 5.0 mL of 1 M HCl. Record the time.
- 11 Stir the marble and the acid occasionally.
- 12 Time how long it takes for the reaction to stop.
- 13 When the reaction stops, filter the remaining solution using the original filter paper.

- 14 Allow the filter paper to dry overnight and measure the mass.
- 15 Calculate the mass lost in the first reaction by subtracting the mass of the filter paper after the reaction from the combined starting mass.

- 16 Calculate the percentage of calcium carbonate in the marble using the following formula.

$$\frac{\text{mass lost in the first reaction}}{\text{starting mass of marble in the first reaction}} \times \frac{100}{1}$$

- 17 Repeat these calculations for the ground-up marble.

Results

Construct an appropriate table for your results.

Discussion

- 1 **Identify** which type of marble dissolved faster (large chip or ground powder).
- 2 **Explain** why small pieces of marble react faster than one large piece.
- 3 **Explain** why stirring is necessary.
- 4 **Explain** whether grinding up the marble changed the amount of calcium carbonate in the sample.

Conclusion

Explain what you know about how particle size affects reaction rate.

Lesson 6.17

Experiment: Speeding up reactions with enzymes

Background

Hydrogen peroxide breaks down into oxygen and water slowly over time. Yeast has a catalyst that speeds up this reaction.

Aim

To investigate the effect of enzymes on breaking down hydrogen peroxide

Materials

- 2 × 200 mL beaker
- 10 mL hydrogen peroxide (3%)
- Wooden splint
- Matches
- 1 packet of dried yeast

Method

- 1 Fill one beaker with 10 mL of hydrogen peroxide (3%).
- 2 Light a wooden splint and then blow it out. Place the glowing splint in the top half of the beaker.
- 3 Record your observations.
- 4 Add the yeast to the second beaker.
- 5 Add 10 mL of the hydrogen peroxide (3%) into the beaker containing the yeast.
- 6 Repeat steps 2 to 3 for the second beaker.

Results

Record your observations in a table.

Discussion

- 1 **Describe** whether the breakdown of hydrogen peroxide into oxygen and water was noticeable.
- 2 **Describe** what happened to the rate of hydrogen peroxide breakdown when the yeast was present.
- 3 **Describe** the effect the gas produced had on the glowing splint.
- 4 **Identify** the gas that would cause this reaction.

Conclusion

Explain what you know about how enzymes affect the rate of a chemical reaction.

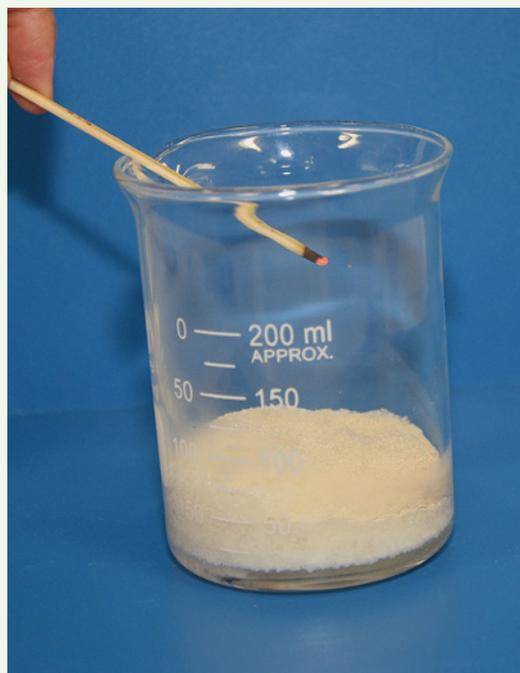


Figure 1 Yeast in action

Lesson 6.18

Science as a human endeavour: Many substances exist because of the work of scientists

Introduction

It is easy to forget just how much we rely on manufactured products in our lives. Increasingly, many substances and materials are processed (changed) or manufactured before they are used. These substances, such as medicines, electronic components, polymers and composite materials in aircraft, only exist because of the work of scientists changing them from their original state to one that you can use.

Pharmaceuticals

Pharmacies (also called “chemist shops”) are where medicines are prepared and dispensed. A pharmacist (also called a “chemist”) has studied chemistry, but has specialised in the study of medicines and their effect on the body (called “pharmacology”).

Oil refinery

Petroleum, or crude oil, is an important product in our society. Oil is pumped from the ground and carried in pipelines or tankers to refineries, where it is separated into its many different components. The crude oil mixture is converted into high-value products, such as petrol, diesel, vitamins, medicines, paint, putty and ink, as well as a very large number of different plastics. “Plastic” is the common name for all the different polymers used in construction, clothes, shoes, furniture, surfboards, phone cases and many more products.



Figure 1 Many everyday items are the result of carefully considered chemistry.



Figure 2 Pharmacists are chemists with a specialisation.



Figure 3 All these products come from petroleum.

Glues and adhesives

Glue was used in ancient Babylon 2,500 years ago when King Nebuchadnezzar used bitumen (also called “asphalt”) to hold building stones together. Later, plant gums, egg white and animal products (such as gelatine) were used for gluing paper and wood. The paints used by the old masters were made using egg white, which helped to hold the parts of the paint mixture together.



Figure 4 Older paints contained egg white to help hold the paint together.

In the World War I, aircraft were made of wood. The wood was glued with casein glue (casein is a protein in milk) and albumin (a protein in egg white).

Nowadays, many synthetic glues are used. Once, shoes were made of layers of leather nailed and sewn together; now these layers are mostly glued. Glue is used to hold many things together, including the chips in chipboard and the layers in MDF board, and plywood in a lot of furniture. Even the brake linings in cars are glued (bonded).



Figure 5 A glue is any substance that sticks things together.

Dyes

Before the use of dyes, all clothes had the same colour – the off-white colour of natural fibres, such as raw cotton, silk and wool.

The first purple dye was obtained from the shells of murex whelk sea snails. It took 12,000 snails to make just 1.4 g of purple dye, which is enough to colour the trim of one Roman emperor’s toga. For this reason, purple clothes were traditionally reserved for high-ranking officials. The whelk almost became extinct as a result of being hunted for its dye.

The soldiers in the British Army used to be known as “redcoats” because their uniform included a red coat, which was dyed red using the liquid extracted from scale insects. This red dye, called carmine, is still available today in supermarkets, but it is now made synthetically.

The first synthetic (or artificial) dye was discovered accidentally by William Perkin in 1856. He named his dye after its colour, mauve. Soon, many other coloured dyes had been discovered and were being manufactured.

Computer printers use dyes when they print photographs. Modern inks do not fade, so modern photographs last longer than paintings made many years ago.

Test your skills and capabilities

Using design thinking to solve problems

Making casein glue requires you to use science inquiry skills and design thinking to produce the glue.

Not all glue needs to be super strong. Dr Spencer Silver was a chemist who researched glues for the 3M company. His job was to make new, stronger glues. Unfortunately, one of his glues was so strong it curled up into small spheres. Because it was stuck to itself, the glue just peeled off everything else. Another scientist who worked at 3M, Art Fry, used to sing with his church choir each week. Each week he would become frustrated that the bits of paper that marked the songs he was going to sing would fall out of his book. When Art and Spencer were talking one day, they came up with the idea of small bits of paper that could be glued to the pages of a book and then peeled off when they were finished. They tried many different chemical reactions until they found one that produced the right product. Thus, Post-It® notes were invented.

The cycle of design thinking involves empathy (understanding someone's problem from their point of view), ideation (thinking of possible solutions to a problem), building and testing a prototype, and communicating the results. **Identify** and **describe** each of these stages in the invention of Post-It notes.

Skills builder: Problem solving

- 1 **Consider** the purple dye produced to colour a Roman emperor's toga. **Develop** a question about this process that scientists could test. (THINK: What aspects could scientists test or improve by using their scientific knowledge?)



Figure 6 Dyes, like the colour in this British soldier's coat, originally came from living organisms. Today they are mostly synthetic.

Lesson 6.19

Experiment: Making casein glue

Background

Casein is a protein in milk. It can be extracted from milk and chemically changed so it has the properties of a glue. It is also considered biodegradable.

Aim

To improve the manufacture of casein glue

Materials

- Full cream milk (70 mL for each group of students)
- 250 mL beaker
- Tripod
- Bunsen burner
- Heatproof mat
- Gauze mat
- Matches
- Safety glasses
- Thermometer
- Heatproof glove
- Vinegar (20 mL)
- Stirring rod
- Sieve
- Disposable cleaning cloth
- 15 mL warm water
- ½ teaspoon baking powder
- Icy-pole sticks (for gluing together)

Method

- 1 Pour 70 mL of milk into the 250 mL beaker.
- 2 Place the tripod and the Bunsen burner on the heatproof mat. Place the gauze mat and then the beaker on top of the tripod.
- 3 Safely light the Bunsen burner and move it under the tripod on the heatproof mat. Open the collar on the Bunsen burner to produce a blue flame.
- 4 Wearing safety glasses, heat the milk **to no more than 50°C**. Use a heatproof glove to remove the milk from the heat.
- 5 Slowly add 20 mL of vinegar to the milk, stirring gently. Do not stir vigorously as you will break up the curd (lumpy bits) being formed. The curd should clump as much as possible.
- 6 Set up the sieve over the sink or a large beaker. Put a piece of disposable cloth over the sieve.
- 7 Gently pour the mixture through the cloth and sieve to filter the whey (liquid) from the curds (lumps of mainly protein). Once it has stopped dripping, very gently squeeze the cloth to remove any excess liquid.
- 8 Return the solids to the original 250 mL beaker and crush the curds with a glass stirring rod to break them up as much as possible.
- 9 Add 15 mL of warm water and stir until it has an even consistency. Add ½ teaspoon of baking powder.
- 10 Take your sample and two icy-pole sticks to your bench.
- 11 Spread your sample between the sticks and press them together. Leave them overnight and then test how well your glue has worked.

Inquiry: Choose one of the questions to investigate.

- What if skim milk was used?
- What if soy milk was used?
- What if more vinegar was used?
- What if more baking powder was added?

You will now design your own experiment to answer your inquiry question.

- 1 **Develop** a prediction or hypothesis for your inquiry.
- 2 **Identify** the (independent) variable that you will change from the first method.
- 3 **Identify** the (dependent) variable that you will measure and/or observe.
- 4 **Identify** two variables that you will need to control to ensure a fair test. **Describe** how you will control these variables.
- 5 **Develop** a method for your experiment and write it in your logbook.
- 6 **Construct** a table to record your results.
- 7 Show your teacher your planning (for approval) before starting your experiment.

Results

Record your observations and measurements in a table.

Discussion

- 1 **Explain** why it is important to wear safety glasses in this experiment.
- 2 **Identify** the reactants and products in this experiment.

- 3 **Describe** how you could compare the strength of different glues.
- 4 **Describe** why some people may prefer to use a biodegradable glue.
- 5 **Describe** how a biodegradable glue could be used in sustainable packaging.

Conclusion

Describe what you know about making glue.



Figure 1 Casein from milk can be used to make glue.

Lesson 6.20

Science as a human endeavour: Physical and chemical changes are used to recycle household waste

Introduction

Understanding the difference between physical and chemical change can help us to understand which objects can be recycled. Objects that can undergo physical change can be easily recycled because the changes are reversible and new shapes can be formed. Chemical change can be used to create new materials that can be used again. These two processes can be used to reduce the amount of rubbish that goes into landfill areas.

Types of plastic

As you discovered in Lesson 6.18 Science as a human endeavour: Many substances exist because of the work of scientists (page 245), plastics are made from a chemical reaction with crude oil. This is hard to recycle and, as most plastic products are only designed to be used for 1 year, they often end up in landfill. However, recycling the chemicals in the plastic is often cheaper than the drilling, extracting and processing of oil needed to create new products.

All plastics belong in one of seven groups (Figures 1 to 7). Many plastics are not **biodegradable**; this means that when they end up in landfill or are disposed of it takes a long time (up to thousands of years) before they begin to break down. Some plastics have such strong bonding that they do not ever naturally break down. To protect our environment, it is crucial that we switch to biodegradable plastics and recycle the plastics we use.

biodegradable
capable of being decomposed by bacteria or other living organisms and reabsorbed into the natural environment

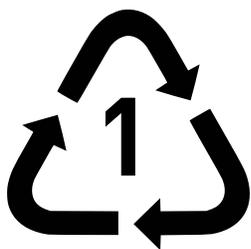


Figure 1 Polyethylene terephthalate (PET or PETE) is the plastic used to make soft drink bottles and oven-ready meal trays.



Figure 2 High-density polyethylene (HDPE) is used to make milk and juice bottles, some washing-up bottles, toys and grocery bags.



Figure 3 Polyvinyl chloride (PVC) is used to make clear food packaging, shampoo and medication bottles, and food trays.



Figure 4 Low-density polyethylene (LDPE) is used to make grocery bags, bin liners, bread bags and frozen food bags.



Figure 5 Polypropylene (PP) is used to make microwave meal trays, sauce bottles, yoghurt containers and medicine bottles.

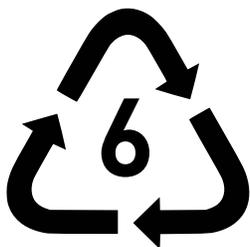


Figure 6 Polystyrene (PS) is used to make foam meat or fish trays, coffee cups, plastic cutlery and sandwich boxes.



Figure 7 Group 7 contains all other plastics, including nylon and fibreglass, that cannot be recycled.

Physical recycling of plastics

Mechanical recycling, also called physical recycling, is broken into several steps.

- 1 Cutting the large pieces of plastic using shears or saws.
- 2 Shredding the plastic into small flakes.
- 3 Separating the contaminants in cyclone (centrifuge) separators.
- 4 Floating off the plastics according to their density.
- 5 Extruding the plastic by heating it to a melting state and forcing it into long strands.
- 6 Cooling the strands and cutting them into small pellets so that the plastic can be reused for new products.



Figure 8 Water bottles use plastic.

Chemical recycling of plastics

Chemical recycling involves creating a chemical reaction that causes the long polymer molecules that make up the plastic to break into smaller molecules called monomers. This requires a lot of energy because it is trying to reverse the initial chemical change that created the plastic. As the initial reactants (crude oil) become more expensive, the chemical recycling of plastics will become a more attractive option.

Recycling of metals

Metals such as iron can be easily recycled using physical change. The metal can be heated until it melts, and then reshaped into its new form. One of the problems with recycling metals, such as iron, is that they easily rust. You will have seen rust on cars, food tins, tools, fences, roofs and bridges.

Rust is the most common type of corrosion.

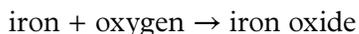
Corrosion is a chemical reaction between a substance and its environment. Rusting refers to the corrosion of iron and steel objects when they are exposed to air. These materials tend to rust very easily and, once the reaction starts, it is difficult to slow or stop.



Figure 9 A can undergoes a physical change when it is compacted.

corrosion the gradual destruction of materials by a chemical reaction with their environment

The rust is a reddish-brown compound called iron oxide that forms from the reaction of iron with oxygen, as shown in the following equation.



Test your skills and capabilities

Evaluating recycling approaches

There are many different approaches to recycling plastics and other forms of rubbish produced in your household.

These include:

- separating the different types of plastic into different bins so they can be recycled separately
- collecting foodstuffs in a separate bin so they can be composted
- recycling plastic bags into new carpeting, floor mats and tiles
- recycling old jeans into new materials
- burning plastic to produce heat for electricity
- breaking down the toxic chemicals in batteries to be recycled
- allowing metals to rust completely.

Select one of these approaches to recycling and research if it occurs in your area.

- 1 For your selected recycling method, **identify** how much money it costs to recycle your product, if any toxic by-products are produced (cost) and how useful the product would be to your community (benefit).
- 2 **Compare** (the similarities and differences between) your chosen recycling method and another approach researched by someone else in your class.
- 3 **Identify** which approach is the most important by comparing the pros and cons of each.

Lesson 6.21

Review: Physical and chemical change

Summary

Lesson 6.1 All matter is made up of atoms

- All matter is made up of atoms.
- Scientists refine models over time.

Lesson 6.2 Elements are made up of one type of atom

- An element is a pure substance with one type of atom.
- The periodic table organises elements according to their chemical and physical properties.

Lesson 6.4 Atoms bond together to make molecules and compounds

- Molecules are groups of two or more atoms that are bonded together.
- When the atoms are different elements bonded together, they can also be called compounds.
- Elements and compounds can be represented by chemical formulas, while mixtures cannot.

Lesson 6.6 Matter can be modelled

- Elements are represented by symbols.
- Compounds and molecules are represented by formulas.
- Mixtures are represented by percentages.

Lesson 6.7 Physical change is a change in shape or appearance

- A physical change occurs when the molecules remain the same but the substance has different properties.
- A change in state (solid, liquid or gas) is a physical change.
- Physical changes are easily reversed.

Lesson 6.9 Chemical change produces new substances

- Chemical changes can cause heat or light to be produced.
- Chemical changes can cause an object to change colour.
- Chemical changes can cause a new gas or solid to be formed.
- When a chemical change occurs, a new substance is formed.

Lesson 6.13 Chemical reactions can break bonds and re-form new bonds

- In a chemical reaction, the starting substances are called reactants.
- The products are the final substances formed and can have new properties.
- In chemical changes or reactions, the atoms in the reactants separate from each other and bond together in different combinations to form new products.

Lesson 6.15 Chemical reactions can be sped up and slowed down

- The rate of a reaction can be sped up or slowed down.
- Factors that can increase the rate of a reaction include increasing the surface area of the reactants, increasing the temperature and concentration of substances and adding a suitable catalyst.

Review questions 6.21



Review questions

Retrieve

- Identify** which of the following describes a chemical change.
 - Breaking glass
 - Burning toast
 - Melting ice
 - Mixing sand and water
- Identify** the new substance produced in a chemical reaction.
 - The chemical
 - The result
 - The product
 - The reactant
- Identify** which of the following describes how a physical change is different from a chemical change.
 - A physical change refers to rusting or cooking processes.
 - A physical change requires heat.
 - A physical change is permanent.
 - A physical change is easily reversible.
- Identify** which of the following can be represented by a formula.
 - Colloid
 - Suspension
 - Compound
 - Solute
- Recall** which of the following scientists generated the first version of the periodic table that ordered the elements according to their mass, and grouped them in groups and periods.
 - Democritus
 - Dalton
 - Mendeleev
 - Lavoisier

Comprehend

- Define** the term “reactant” (in a chemical reaction).

- Use** the particle theory to **explain**:
 - melting
 - sublimation
 - freezing
 - condensation.
- Describe** the changes that might be observed during a chemical change.
- Use** your knowledge of particles to **explain** why most physical changes can be reversed.
- Describe** four ways to speed up a chemical reaction. **Use** the particle theory to explain why each method works.
- Explain** why nylon is described as a synthetic material.
- Explain** why chemists would never write a chemical equation for the melting of chocolate.



Figure 1 Chocolate can be easily burnt.

- In one experiment, you observed the reaction between copper sulfate solution and iron to make copper and iron sulfate solution.
 - Copy and complete the following table and **summarise** the changes observed in this reaction.

Name of reactants	Description	Name of products	Description

- Use** the information in the table to **explain** why this is an example of a chemical change.

14 Dyes can be synthetic or natural in origin.

- Describe** one advantage and one disadvantage of using natural dyes.
- Describe** one advantage and one disadvantage of using synthetic dyes.



Figure 2 Dyes involve soaking materials in a solution.

Analyse

15 **Identify** the number of hydrogen atoms in a HCl molecule.

- One
- Two
- Three
- None

16 **Identify** an object in your home or classroom that is made from PVC.

17 **Contrast** a physical change and a chemical change.

18 **Contrast** a group and a period in the periodic table.

Apply

19 The following are descriptions of interactions that occur around us in our daily lives.

Describe what the products of these interactions might be and **evaluate** whether the changes described are useful or harmful.

- A bike is left out in the rain so that parts of the bike that are made of steel are in contact with water for a few hours.
- A barbecue fuelled by propane gas is turned on.
- A hairdresser applies bleach to someone's hair.

20 **Create** a drawing of a reactant and a product that represents a chemical change.

21 **Identify** which of the diagrams in Figure 3 shows:

- a mixture of an element and a compound
- a mixture of two elements
- a pure element.

Justify your decisions (by defining each term and describing how this matches the diagram).

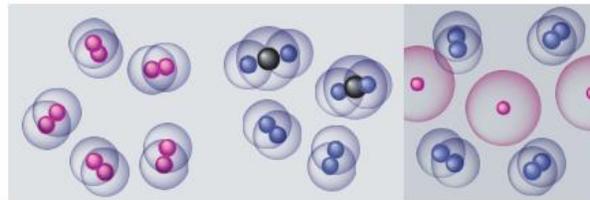


Figure 3 Two-dimensional diagrams can be used to represent elements and compounds.

22 A biochemical reaction is a chemical reaction that occurs in a living thing. **Identify** one biochemical reaction and **describe** its purpose.

23 Think about your morning routine, from when you wake up to when you arrive at school.

Discuss how the things you complete in your routine would be different if you were only allowed to use all-natural materials. You might want to think about brushing your teeth, wearing your school uniform, eating breakfast, your school bag and travelling.



Figure 4 Can everything you use be replaced with all-natural materials?

24 Substances can change when they interact with each other. In each of the following situations, a change is described. For each change, **determine** the interactions that have caused the change to occur. The first one has been done for you.

- Glue makes a bond between two pieces of wood.

Possible answer: The glue interacts with the oxygen in the air, which causes it to set hard, which joins the two pieces of wood together.

- b** Sugar turns into caramel.
- c** Charcoal burns in air to form the gas carbon dioxide.
- d** Starch is digested in our stomach to form simple sugars, such as glucose.
- e** A loaf of bread rises in an oven as carbon dioxide gas is produced.

Social and ethical thinking

25 An environmental action group wants to ban the use of certain chemicals in your school.

Either:

- a** Write a letter to your school principal **proposing** why you think this would be a good idea.

Or:

- b** Write a letter to the leader of the environmental group **proposing** why you think this is a bad idea.

Critical and creative thinking

26 The use of chemistry to produce new materials has affected people's lives in a range of ways.

- a** **Discuss** how new materials have changed the type of clothes that people wear.
- b** **Discuss** how new materials have changed the type of food that people eat.

27 **Describe** a chemical change that may be harmful to the environment if it is allowed to occur in an uncontrolled way. **Create** a poster that describes the danger and offers a solution.

Research

28 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.

Versions of the periodic table

Dmitri Mendeleev arranged the elements in the first version of the modern periodic table.

- **Compare** his arrangement with the current version of the periodic table.
- **Identify** and describe two other versions of the periodic table.
- **Identify** the name of the scientist(s) that proposed each periodic table.
- **Explain** why they arranged the periodic table in this way.

Gas warfare

In World War I, deadly gases were used as a weapon by both sides.

- **Identify** one of the gases used in World War I.
- **Identify** who used this gas as a weapon.
- **Describe** how this gas was produced in the field.
- **Describe** the properties of the gas that made it useful as a weapon.
- **Describe** the effects of the gas on the soldiers.
- **Explain** how the impact of gas warfare led to the development of the Geneva Protocol and the Chemical Weapons Convention international arms control treaty.

Explosives

Explosions are chemical reactions that release enormous amounts of light, heat and sound very quickly. Dynamite is one of the first explosive chemical reactions that was controlled.

- **Identify** the person who developed dynamite from nitroglycerine.
- **Explain** why they were trying to control the chemical reaction.
- **Describe** how dynamite was used in mining.
- **Describe** how dynamite was used in wars.
- The person who developed dynamite was horrified at how their discovery was

used in war. **Identify** how the money they accumulated was used to “benefit humankind”.



Figure 5 Dynamite is an explosive.

Soil testing

Some plants grow better in soils that contain certain amounts of nutrients. Gardeners who know this can test the soil to determine the amount of nutrients in the soil.

- **Investigate** a soil test that has a colour change if it is positive.
- **Investigate** the chemical reaction that causes this colour change.
- **Identify** the name of the nutrient and its chemical formula.
- **Describe** what will happen to a plant if this nutrient is not present.

- **Describe** how this nutrient could be added to the soil if it is needed.



Figure 6 This soil is growing healthy plants.

Barbecue fuels

Most home barbecues burn liquefied petroleum gas (LPG) as the fuel. This is the gas that can be bought in cylinders at hardware and camping stores.

- **Identify** the chemicals that are present in LPG.
- **Compare** gas barbecues and solid fuel barbecues.
- **Describe** the safety precautions that must be followed when storing LPG cylinders.

- **Describe** what could happen if an LPG cylinder is exposed to high temperatures.



Figure 7 A home barbecue with a gas cylinder

Module

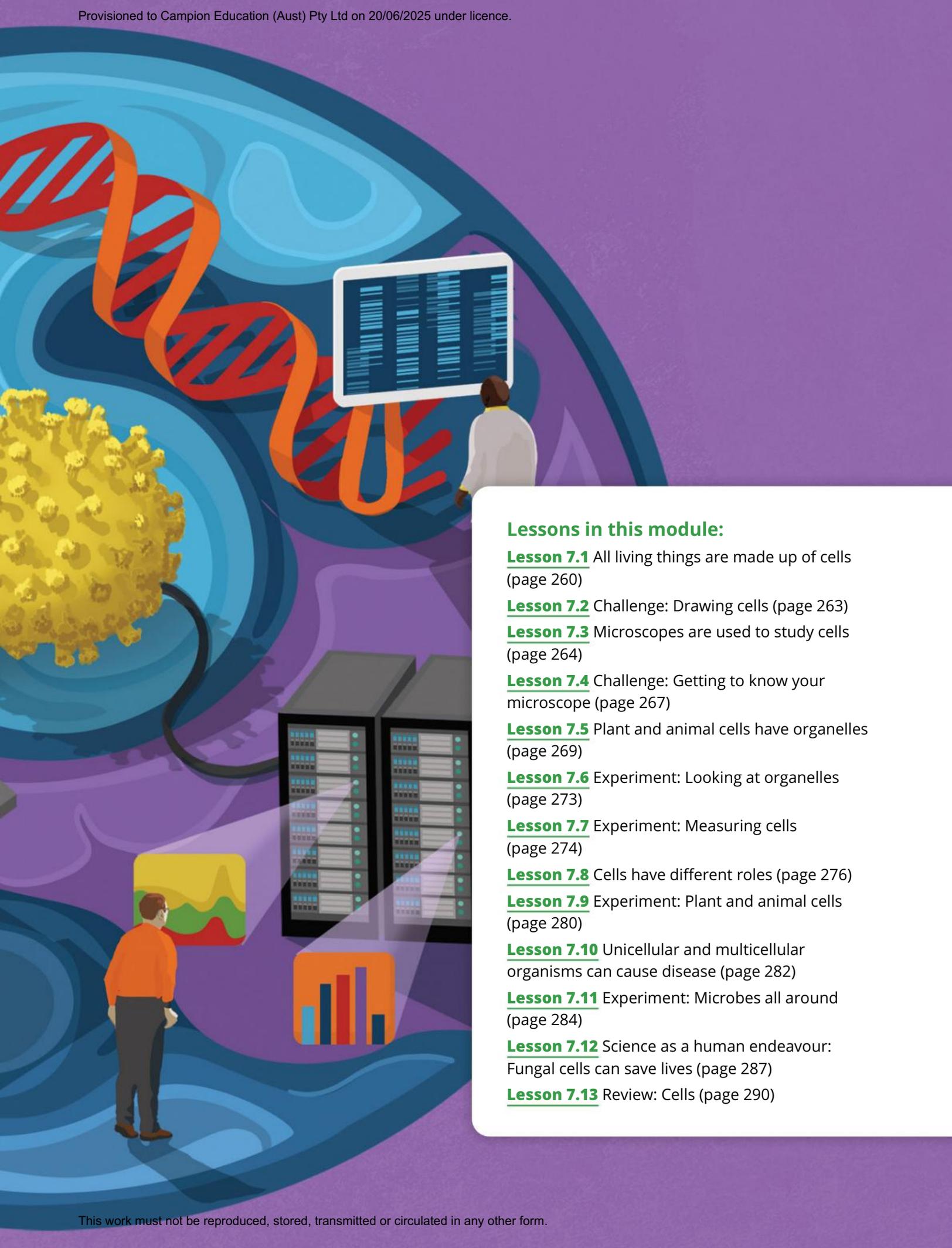
7

Cells



Overview

Cell theory explains that cells are the basic units of life, consisting of one or more cells that perform specific functions. Microscopes can be used to explore plant, animal, bacterial and fungal cells to understand their size and role in larger systems. Understanding cells allows scientists to explore the social, ethical and economic impacts of making the muscle and fat cells in lab-grown meat widely available for people to eat.



Lessons in this module:

Lesson 7.1 All living things are made up of cells (page 260)

Lesson 7.2 Challenge: Drawing cells (page 263)

Lesson 7.3 Microscopes are used to study cells (page 264)

Lesson 7.4 Challenge: Getting to know your microscope (page 267)

Lesson 7.5 Plant and animal cells have organelles (page 269)

Lesson 7.6 Experiment: Looking at organelles (page 273)

Lesson 7.7 Experiment: Measuring cells (page 274)

Lesson 7.8 Cells have different roles (page 276)

Lesson 7.9 Experiment: Plant and animal cells (page 280)

Lesson 7.10 Unicellular and multicellular organisms can cause disease (page 282)

Lesson 7.11 Experiment: Microbes all around (page 284)

Lesson 7.12 Science as a human endeavour: Fungal cells can save lives (page 287)

Lesson 7.13 Review: Cells (page 290)



Learning intentions
and success criteria



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

Lesson 7.1

All living things are made up of cells

Key ideas

- Microscopes allow scientists to see the building blocks of life (cells).
- Cell theory states that all living things are made up of cells; cells are the basic unit of life and structure; all living cells are created from existing cells.

Introduction

Scientists have not always known that living things are made up of cells. It was the invention of the microscope in the mid-seventeenth century that allowed us to see the building blocks of life – the tiny units that form every living thing. Microscopes showed that each and every living thing is made up of **cells**.

cell (in biology)
the building block of
living things

Discovering cells

When Robert Hooke published his book *Micrographia* in 1665 it became a bestseller. Hooke had made one of the first microscopes. With it, he observed many types of living things and made accurate drawings of what he saw.

Hooke's most famous achievement was his diagram of very thin slices of cork (Figure 1). He was surprised to see that, under the microscope, the cork looked like a piece of honeycomb with "holes". He called the small hole-like structures "cells" because they reminded him of the small rooms in a monastery, which were also called cells. Hooke had discovered the first plant cells.

Although some called *Micrographia* "the most ingenious book ever", others ridiculed Hooke for spending so much time and money on "trifling pursuits".

Thankfully for us, and for the whole science of **microbiology**, Hooke ignored the name-calling and kept experimenting with microscopes.

It was because of Hooke's contribution to microbiology that other scientists went on to develop a further understanding of cells.

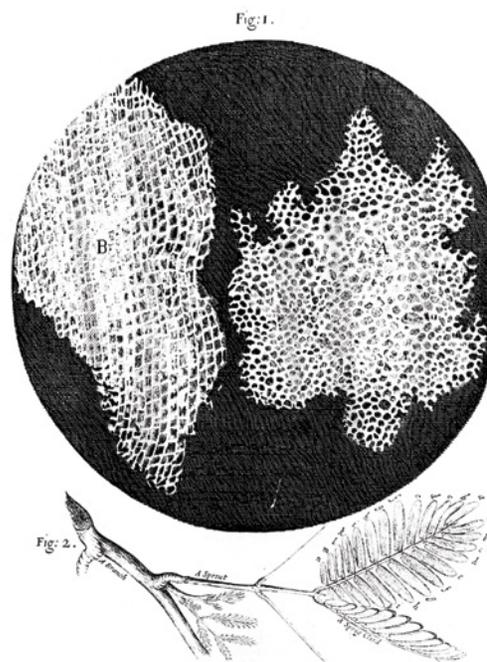


Figure 1 Robert Hooke's drawing of cork

microbiology the
science involving the
study of microscopic
organisms

Cell theory

Cell theory describes the properties of cells and their role in living things. It was first proposed in 1839 by two German biologists, Theodor Schwann and Matthias Schleiden. In 1858, Rudolf Virchow concluded the final part of the classic cell theory. The combined cell theory included the following principles:

- All organisms are composed of one or more cells.
- Cells are the basic unit of life and structure.
- New cells are created from existing cells.

Any living thing that has more than one cell is referred to as **multicellular** (Figure 2A). There are many living things, such as bacteria, that consist of only one cell. These are called single-celled or **unicellular** organisms (Figure 2B).

Microorganisms, which are also often referred to as microbes, are organisms that can only be seen under the microscope – they can be unicellular or multicellular.

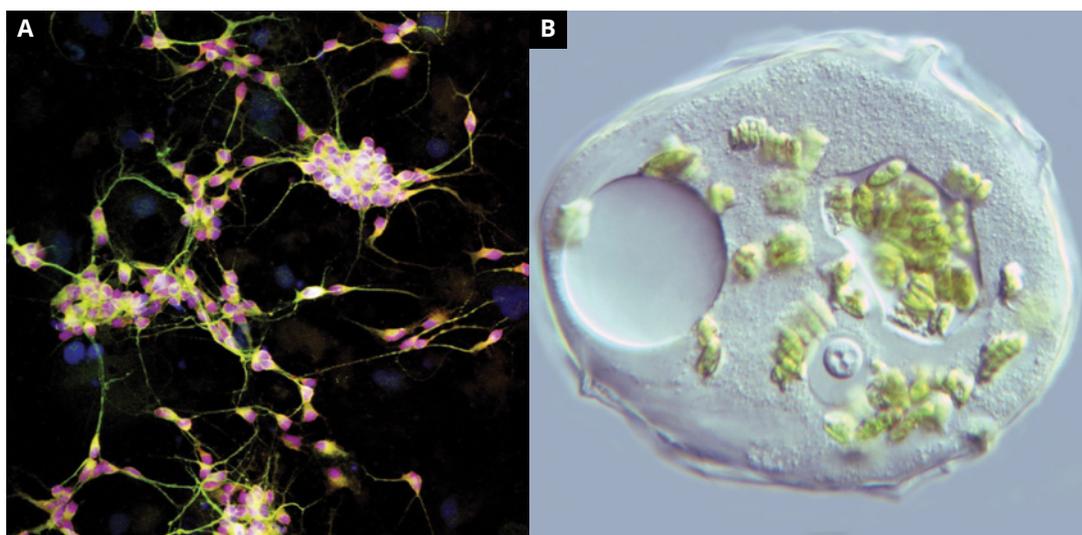


Figure 2 (A) Human nerve cells are part of multicellular humans, but (B) the amoeba is a unicellular organism.

Why are cells so small?

The outside surface of a cell is called the **cell membrane**. It controls what can move in (nutrients) or out (waste) of the cell.

Large cells have more difficulty staying alive than small cells. Large cells need to move nutrients a long way to reach the centre of the cell. Small cells do not need to make the nutrients travel as far and this makes it easier for all parts of the small cells to stay healthy and alive.

The total space inside the cell is referred to as the cell's volume, while the size of the membrane is called the surface area. As a cell increases in size, both its volume and its surface area increase. The problem is that the volume increases much more than the surface area. Eventually the volume becomes so big that it is difficult for nutrients to get into the centre of the cell and for wastes to get out. We compare the relationship between the amount of surface area and the volume of a cell through a fraction: the **surface area to volume ratio**. Small cells have a large surface area compared to their volume (a large surface area to volume ratio) and are, therefore,

cell theory theory that explains the relationship between cells and all living organisms

multicellular an organism that has two or more cells

unicellular an organism that consists of one cell; an example is bacteria

microorganism a living thing that can only be seen with a microscope

cell membrane the barrier around a cell that controls the entry and exit of substances into and out of the cell

surface area to volume ratio the relationship between the area around the outside of a cell and its volume, as a fraction

better able to survive. This explains why unicellular organisms are so small. A single cell must do all the same things that a larger organism does.

The cell membrane is particularly important because it provides a barrier between the inside of the cell and the external environment. All the nutrients needed to keep the cell alive, and the waste products made by the cell, are transported across the cell membrane.

It is essential that the cell membrane provides a large surface area for the transport of so many molecules into and out of the cell (Figure 3).

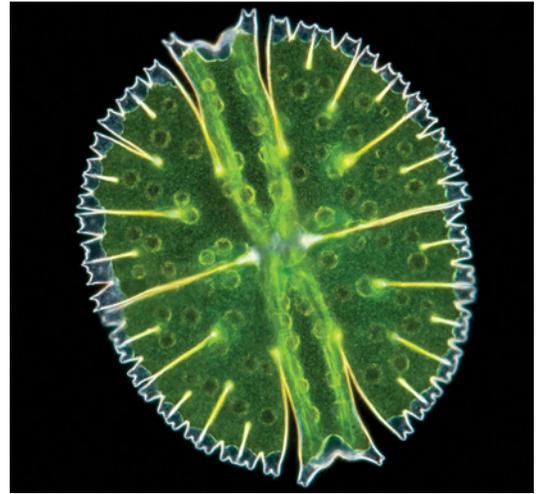


Figure 3 The irregular shape of this unicellular organism (called a desmid) maximises the surface area to volume ratio.

Check your learning 7.1



Check your learning 7.1

Retrieve

- 1 **Name** the person who invented one of the first microscopes.
- 2 **Recall** why cells are called “cells”.
- 3 **Define** the term “multicellular”.
- 4 **Name** five multicellular organisms.
- 5 **Identify** three things that all unicellular organisms have in common.
- 6 **State** the three principles of cell theory.

Comprehend

- 7 The common house dust mite is a microorganism. **Recall** whether you would be able to see this animal without a microscope. **Explain** your answer (by

defining the term “microorganism” and linking the definition to the need for a microscope).

- 8 **Explain** whether a cell with a bigger surface area to volume ratio would be able to meet its requirements for nutrients effectively.
- 9 **Explain** why unicellular organisms are very small.

Skills builder: Communicating

- 10 **Construct** a scaled timeline to show the contribution of different scientists to the cell theory. (THINK: What information do you need to include to help someone understand the development of cell theory over time?)

Lesson 7.2

Challenge: Drawing cells

Aim

To identify the different structures of different cells

What you need:

- Microscopes
- Prepared slides
- Pencil
- Paper
- Several stations set up around the laboratory with microscopes adjusted to show different kinds of cells

Caution

Do not attempt to adjust any of the microscopes. Ask your teacher or laboratory technician to adjust the microscope if you think it has been bumped or has gone out of focus.

What to do:

- 1 Look carefully at each specimen. Write down its name and a sentence that describes what you see.
- 2 Make a very simple pencil sketch of a single cell that you can see. Draw the outside edge of the cell first, including any bumps or unusual shapes you notice.
- 3 Draw two more cells that are close to your original cell. (Do not attempt to draw every cell that you see.)
- 4 If you can see anything inside the cells (it may only be a dark dot), mark this on your sketch.
- 5 Label any parts that you can identify.

Questions

- 1 **Identify** and describe the cell that, in your opinion, was the most unusual.
- 2 **Identify** the cells that had walls around them.
- 3 **Identify** the cell that was the smallest.
- 4 **Identify** the cell that was the largest.
- 5 **Compare** the cells you viewed through the microscope with the images of the cells in Figure 1.
- 6 **Describe** some of the difficulties of drawing cells seen through a microscope.

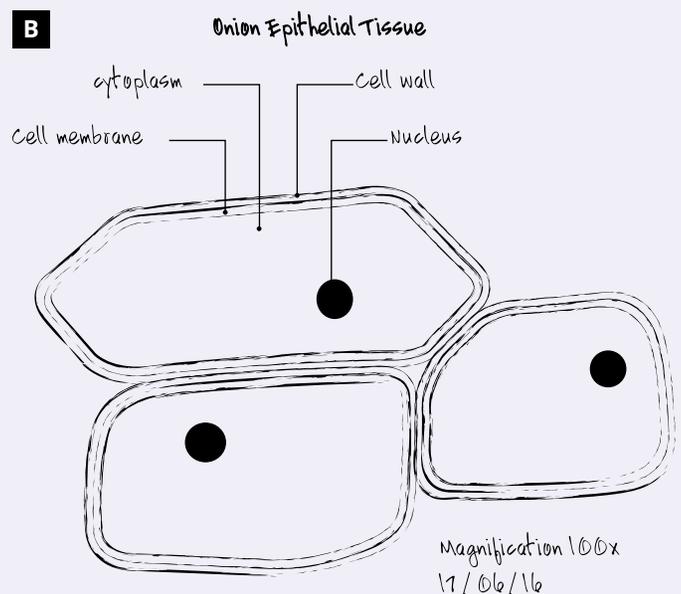
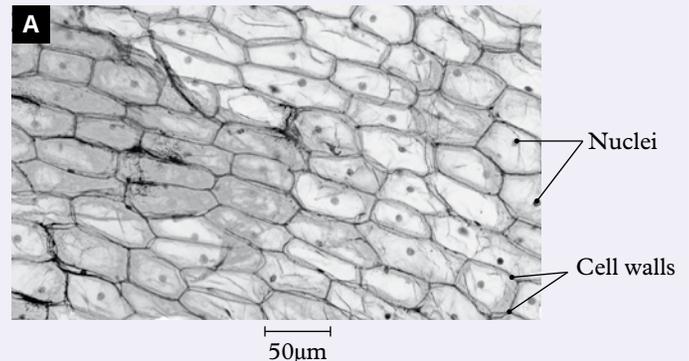


Figure 1 (A) Onion cells through a microscope (B) Drawings of the cells seen through a microscope



Learning intentions
and success criteria



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

Lesson 7.3

Microscopes are used to study cells

Key ideas

- A microscope is an instrument that uses lenses to magnify the size of objects.
- The science of investigating small objects using a microscope is called microscopy.

Types of microscopes

microscope an instrument with lenses, used for viewing very small objects

electron microscope a microscope that uses electrons (tiny negatively charged particles) to create images

microscopy the study of living things that can only be seen with a microscope

stereomicroscope a microscope with two eyepieces that uses low magnification

compound light microscope a microscope with two or more lenses

eyepiece where the eyes are placed when using a microscope

monocular using one eye; a type of microscope

binocular using two eyes; a type of microscope

objective lens lens in the column of a compound light microscope

stain substance, such as iodine, used to make cells more visible under a microscope

As a science student, you will probably use a light **microscope** in your laboratory. You may also work with images produced by different types of microscopes, such as light microscopes and **electron microscopes**. The study of small objects using a microscope is called **microscopy**.

Light microscopes

There are two common types of light microscope – the **stereomicroscope** and the **compound light microscope**. The stereomicroscope is used for viewing larger objects, such as insects (Figure 1A). It can magnify up to 200 times and shows a three-dimensional view.

The compound light microscope is used to look through thin slices of specimens (Figure 1B). It can magnify up to 1,500 times. Its view is two-dimensional. The specimen must be thin enough to allow light to pass through it.

The stereomicroscope has two **eyepieces** to look through, whereas the compound light microscope can have one or two eyepieces. The word **monocular** is used to describe a microscope with one eyepiece (mono = one).

Microscopes with two lenses are called **binocular** (bi = two). The compound light microscope uses two lenses (one in the eyepiece and one further down the column, called the **objective lens**).

Most cells are clear or transparent so a **stain**, such as iodine, can be used to help make them more visible.

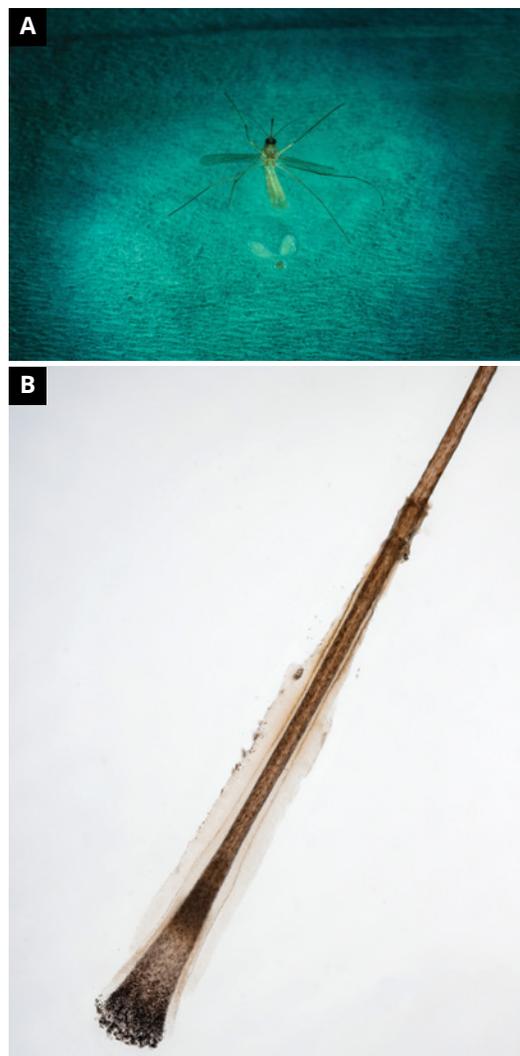


Figure 1 (A) An insect, as seen under a stereomicroscope (B) A human hair root as seen under a compound light microscope

Electron microscopes

An electron microscope uses electrons (tiny negatively charged particles) to create images. The first electron microscope, the transmission electron microscope (TEM), was invented in 1933 to help study the structure of metals. The scanning electron microscope (SEM), developed later, uses a beam of electrons to scan across the surface of a specimen. A computer is used to create the image, showing details of the specimen's surface (Figure 2).

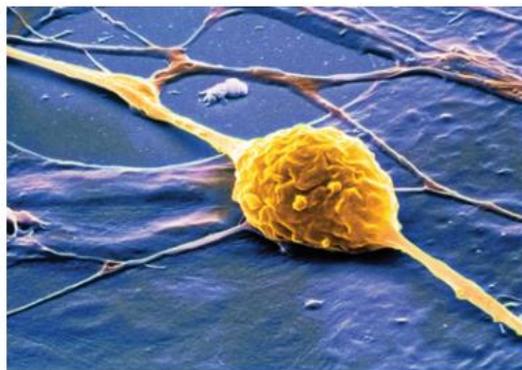


Figure 2 Image of a nerve cell under a scanning electron microscope (SEM)

Electron microscopes can magnify up to a million times. Using this technology, many more details of the cell can be seen and understood.

Using a compound light microscope

Figure 3 shows the parts of a monocular compound light microscope. Microscopes are fragile instruments that must be treated with care.

- Always use two hands to carry a microscope – one hand around the main part of the instrument and the other underneath it.
- Some microscopes have a built-in lamp. Others have separate lamps that need to be set up so they shine onto the mirror. Adjust the mirror to project the light through the stage onto the specimen. Do not allow sunlight to shine directly up the column.
- Place the slide on the stage, then select the objective lens with the lowest magnification.
- Look from the side and adjust the coarse focus knob so that the objective lens is just above – and not touching – the slide. Check which way you must turn the knob to move the objective lens away from the slide.
- Use the coarse focus knob to bring the specimen into view. Use the fine focus knob to help you see it more clearly.
- If you want a higher magnification, rotate the objective lens to a higher magnification.
- Draw what you see (as a record) using a sharp grey pencil.
- Work out the total magnification.
- Write the magnification next to your sketch.
- Label and date the sketch.

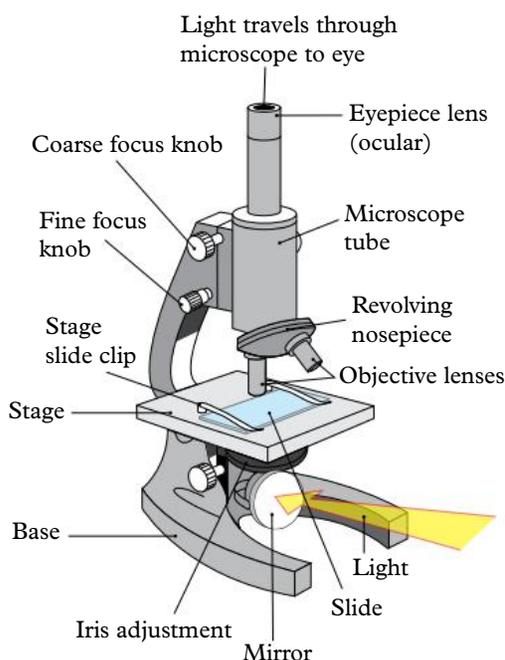


Figure 3 Parts of a compound light microscope

Magnification calculations

Using different combinations of lenses means you can magnify your object by different amounts. To calculate the total magnification of a compound light microscope, multiply the magnification of the eyepiece lens by the magnification of the objective lens (Worked example 7.3A and Table 1). These figures are marked on each lens.

Worked example 7.3A Calculating magnification

Calculate the final magnification of a cell that can be seen when using a $\times 4$ objective lens and a $\times 10$ eyepiece lens.

Solution

$$\begin{aligned} \text{Magnification} &= \text{eyepiece lens magnification} \\ &\quad \times \text{objective lens magnification} \\ &= 10 \times 4 \\ &= 40 \end{aligned}$$

The cell was magnified 40 times larger than normal.

Table 1 The total magnification of a microscope can be determined by multiplying the magnifications of the eyepiece and the objective lens.

Eyepiece magnification	Objective lens magnification	Total magnification
$\times 5$	$\times 10$	$\times 50$
$\times 10$	$\times 20$	$\times 200$

Check your learning 7.3



Check your learning 7.3

Retrieve

- Define** the term “microscopy”.
- Recall** why very thin samples should be used under a light microscope.

Analyse

- Identify** the type (or types) of microscopes in your science laboratory.
- Infer** why you should look from the side when first adjusting the coarse focus knob.
- Compare** (the similarities and differences between) stereomicroscopes and compound light microscopes.

- Contrast** (the differences between) a TEM and an SEM.
- Copy the following magnification table into your notebook and **calculate** the missing values.

Eyepiece magnification	Objective lens magnification	Total magnification
$\times 5$		$\times 100$
	$\times 20$	$\times 300$
$\times 10$	$\times 50$	

Lesson 7.4

Challenge: Getting to know your microscope

Aim

To develop the skill of using a microscope

Caution

Always use two hands to carry a microscope – one hand should be around the main part of the instrument and the other underneath it.

What you need:

- Compound light microscope
- Microscope slide
- Small piece of newspaper
- Scissors
- Eyedropper
- Small beaker of water
- Glass coverslip
- Pencil
- Paper
- Small piece of tissue paper
- 1 cm piece of sticky tape (transparent)
- Strand of hair (use your own)

What to do:

- 1 If your microscope has a separate lamp, set it up so that it shines onto the mirror. Adjust the mirror to project the light through the stage onto the specimen. (Remember not to allow sunlight to shine directly up the column.)
- 2 Place the slide on the microscope stage, then select the objective lens with the lowest magnification first.
- 3 Cut out two small words from a piece of newspaper (Figure 1).
- 4 Place the cut-out newspaper on the microscope slide and add two drops of water to help it “stick” to the slide.
- 5 Place one edge of the glass coverslip on the slide next to the sample. Gently lower the other side of the coverslip over the sample (Figure 2). By gently lowering the coverslip, you should avoid air bubbles getting trapped under it. This type of slide preparation is called a wet mount.
- 6 Look from the side and adjust the coarse focus knob so that the objective lens is just above – and not touching – the slide. Check which way you must turn the knob to move the objective lens away from the slide.
- 7 Use the coarse focus knob to bring the specimen into view (Figure 3). Find one letter from the newsprint to focus on.
- 8 Move the slide slightly towards your body and observe what happens.
- 9 Move the slide slightly to the left and observe what happens.
- 10 Increase the magnification by rotating the objective lens to a higher magnification.
- 11 Draw a diagram of the newspaper letter (as a record) using a sharp lead pencil. Never colour or shade areas; if absolutely necessary, use dots or lines instead.

- 12 Calculate the total magnification.
- 13 Write the magnification next to your sketch.
- 14 Label and date the sketch.
- 15 Remove the newspaper slide from the microscope stage and prepare another three slides using tissue paper, sticky tape (Figure 4) and a strand of hair from your head. Add a drop of water and carefully place a coverslip over each sample as you did in step 5.
- 16 Place one slide on the microscope stage at a time. Look through the microscope and carefully adjust the focus as needed.
- 17 Repeat steps 11 to 14 for the tissue paper, sticky tape and hair slides.

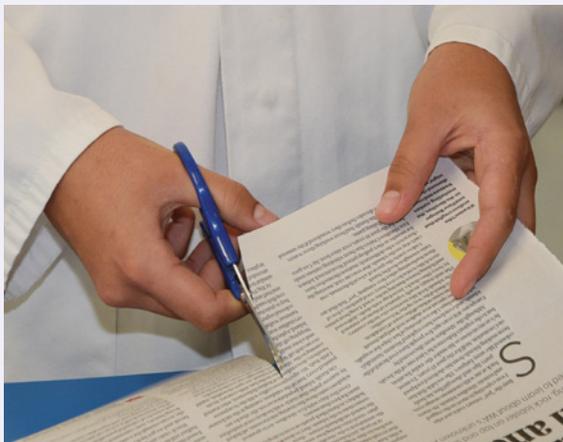


Figure 1 Use scissors to cut out words from the newspaper.



Figure 2 Gently lower the glass coverslip down until it is flat.



Figure 3 Carefully adjust the focus of the microscope.



Figure 4 Repeat with a piece of sticky tape.

Questions

- 1 **Describe** the direction (right way up or upside down) of the letters on the newspaper with and without the microscope.
- 2 **Describe** the features you could see on the tissue paper and sticky tape that you could not see with the naked eye.
- 3 **Construct** a series of cause-and-effect graphic organisers, similar to that shown in Table 1, to record the results of your experiment when you moved the slide in different ways. For example, the cause link may be “move the slide to the left”. Then write what happened in the effect link.

Table 1 Cause-and-effect graphic organiser

Cause	→	Effect
What did you do to cause the change you observed?		What effect did it have?

Lesson 7.5

Plant and animal cells have organelles



Learning intentions and success criteria



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

Key ideas

- A cell is the smallest basic unit of life.
- All cells have a membrane, cytoplasm and genetic material (DNA).
- All plant and animal cells are made up of smaller organelles.

Cell structures

There are many different types of cells in all multicellular organisms. These cells will have different sizes (Figure 1) and structures (Figure 2), which will determine their function in the body. All cells, regardless of what type of organism they are found in, share the same basic structure. This basic structure includes three key features.

- **Cell membrane** – this acts like the “skin” of a cell, forming a barrier around the cell. It controls the entry and exit of things into and out of the cell.
- **Cytoplasm** – this is the jelly-like fluid and structures inside the cell membrane. It helps provide structure to the cell and contains many dissolved nutrients and waste products.
- **DNA (deoxyribonucleic acid)** – this contains the instructions for every job your cells need to do and is passed from one generation to the next. The code for half your DNA came from your mother, and the other half came from your father. The same complete set of DNA is found in every one of your cells. Plant and animal cells keep their DNA surrounded by a membrane to form a **nucleus** (the control centre of the cell).

cytoplasm the jelly-like fluid inside the cell membrane that contains dissolved nutrients, waste products and organelles

DNA (deoxyribonucleic acid) a molecule that contains all the instructions for every job performed by the cell; this information can be passed from one generation to the next

nucleus an organelle that contains all the genetic material (DNA) of a cell; control centre of a cell

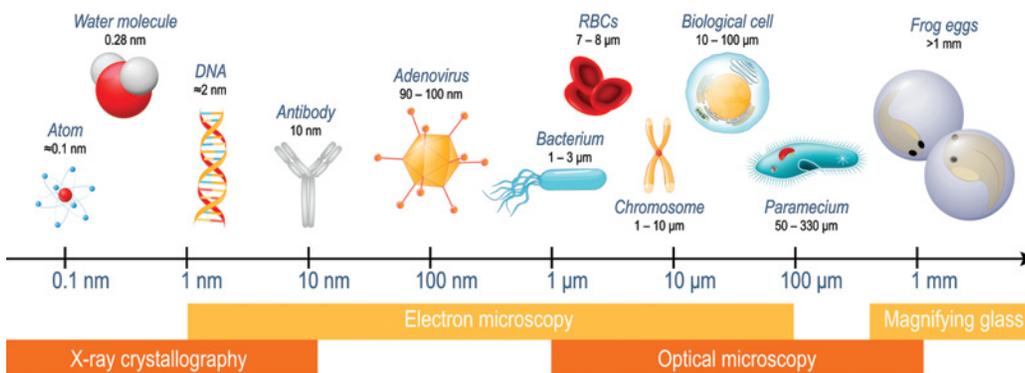


Figure 1 The relative sizes of particles and cells

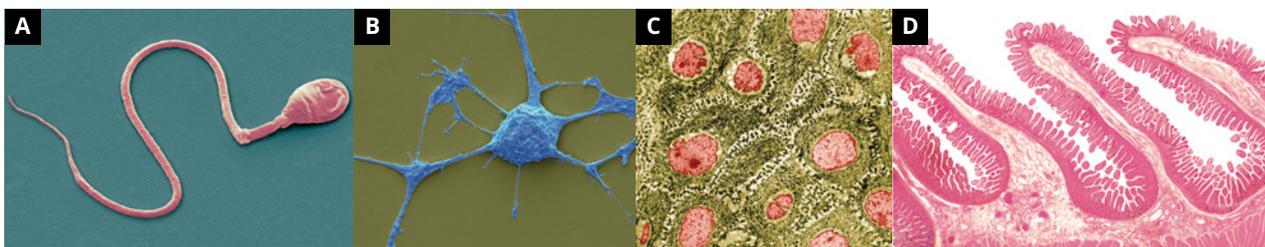


Figure 2 Cells can be different shapes and sizes: (A) sperm cell, (B) nerve cell, (C) skin cells and (D) intestinal cells.

A closer look at organelles

organelle

specialised structure that has a specific function in a cell

ribosome

organelle that makes proteins

Some cells need special areas or **organelles** (mini-organs) to help them do special things (perform functions) (Figure 3 and Figure 4). These functions are necessary for the cell to survive. Some organelles, such as **ribosomes**, are part of the cytoplasm, whereas other organelles are separated from the fluid in the cytoplasm by a membrane, much like the cell membrane. These organelles, such as the nucleus and chloroplasts, are called membrane-bound organelles.

Let's take a closer look at four very important organelles that are in some cells – the mitochondria, cell wall, chloroplasts and vesicles.

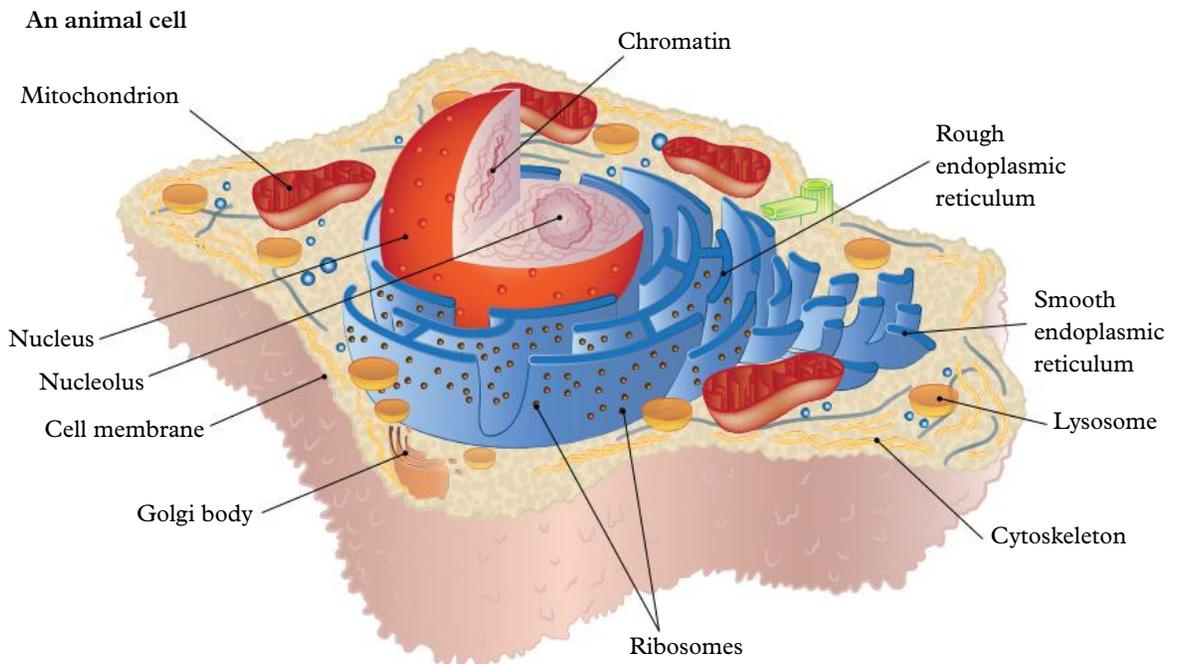


Figure 3 Some key parts (organelles) of an animal cell

A plant cell

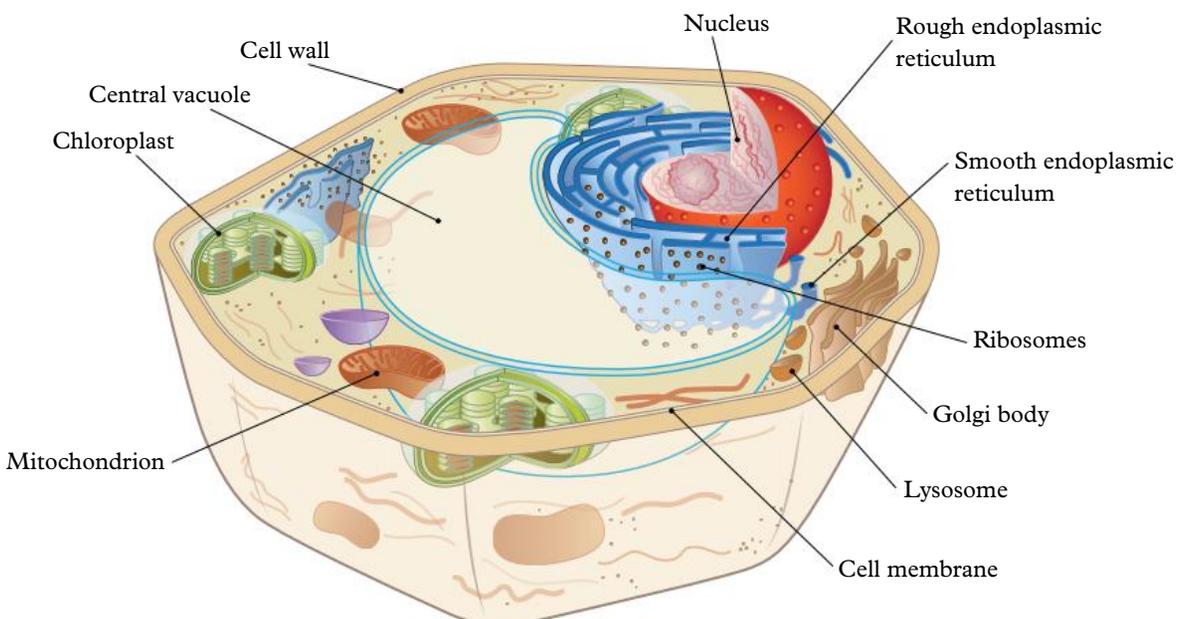


Figure 4 Some key parts (organelles) of a plant cell

Mitochondria

Mitochondria (singular “mitochondrion”) are the powerhouse of the cell. They are the site of energy production in the cell. There may be several thousand mitochondria in a cell depending on what the cell does. For example, skeletal muscle cells contain a lot of mitochondria to make sure we have enough energy to run and jump when we need to.

Mitochondria are rod-shaped organelles with an inner and an outer membrane (Figure 5). The inner membrane is folded to increase the surface area of the membrane. An important chemical reaction called **cellular respiration** occurs inside the mitochondria. This reaction involves the rearrangement of the atoms in glucose (from the food we eat) and oxygen to produce water, carbon dioxide and energy. This energy is used by our bodies to help us move and grow.

Cell wall

Cell walls are not found in animal cells. They are found around the outside of plant cells, fungal cells and bacterial cells (Figure 6). The cell wall is important for helping the cell keep its shape, especially in fresh water. Fresh water can easily enter a cell, making the outside membrane swell and possibly burst. If the cell is surrounded by a cell wall, the membrane cannot burst.

Chloroplasts

Chloroplasts are only found in plant cells and some unicellular organisms (Figure 7). These organelles are like microscopic solar panels that transform solar energy into chemical energy.

Chloroplasts are usually green because of a molecule called **chlorophyll** (Figure 8). Chlorophyll uses the Sun’s light energy to rearrange molecules of carbon dioxide and water into glucose (a sugar) and oxygen. This chemical reaction is called **photosynthesis**.

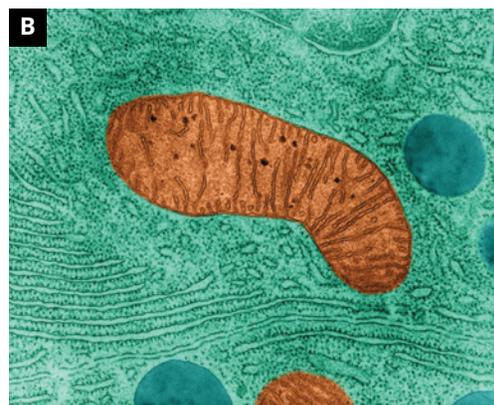
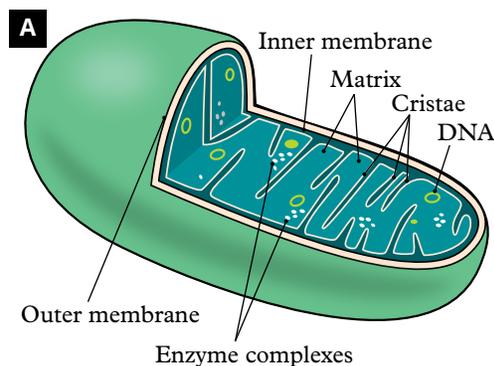


Figure 5 (A) Schematic diagram showing the structure of a mitochondrion (B) Electron micrograph of a mitochondrion.

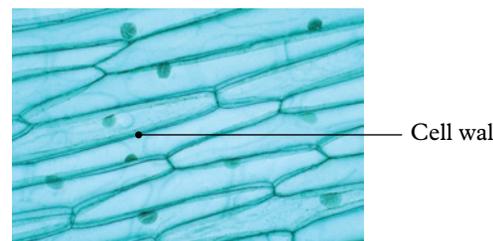


Figure 6 Light micrograph of plant cells showing the cell walls

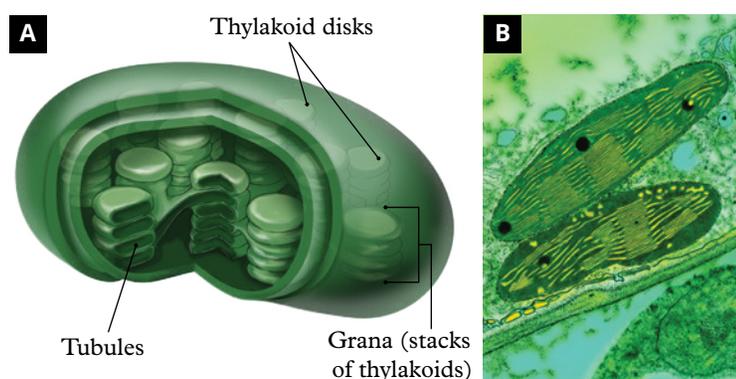


Figure 7 (A) Schematic diagram showing the structure of a chloroplast (B) Electron micrograph of chloroplasts.

mitochondrion
powerhouse
organelle of a cell;
the site of energy
production (plural:
mitochondria)

**cellular
respiration** the
chemical reaction
between glucose and
oxygen that produces
carbon dioxide, water
and energy

cell wall the
outer protective and
support structure of
cells in plants, fungi
and prokaryotes

chloroplast
organelle found
in plant cells that
transforms solar
energy into chemical
energy

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

photosynthesis
chemical process
plants use to make
glucose and oxygen
from carbon dioxide
and water

vesicle an organelle surrounded by a membrane and used by cells to store materials; a vacuole is a type of vesicle found in plant cells

vacuole organelle that stores water and other materials, including wastes

Vesicles

Vesicles are organelles that are used by plant and animal cells to store water, nutrients and waste products. A membrane surrounds the vesicle, separating the substances from the rest of the cell. Plant cells usually have one large vesicle called a **vacuole**. Animal cells may have many small vesicles.



Figure 8 The chlorophyll in plants uses the Sun's light energy to create glucose and oxygen.

Check your learning 7.5



Check your learning 7.5

Retrieve

- 1 **Recall** the function of the cell membrane.
- 2 **Name** the organelle in which cellular respiration occurs.
- 3 **State** three things that are stored in a vacuole.
- 4 **Identify** three organelles that are surrounded by a membrane.

Comprehend

- 5 **Describe** the features of all living cells. (HINT: Remember MR N GREWW from Year 7.)
- 6 **Describe** the role of the cell wall in plants.
- 7 **Explain** the function of chlorophyll.

Analyse

- 8 **Identify** the reactants (present at the start) and products (present at the end) for the chemical reaction called photosynthesis.
- 9 **Contrast** (the differences between) the structure of animal and plant cells.

Apply

- 10 **Explain** where you would be more likely to find large numbers of mitochondria: in a muscle cell or a bone cell. **Justify** your answer (by explaining the function of

mitochondria in a cell, explaining what each cell does and deciding which cell would need the mitochondrial function most).

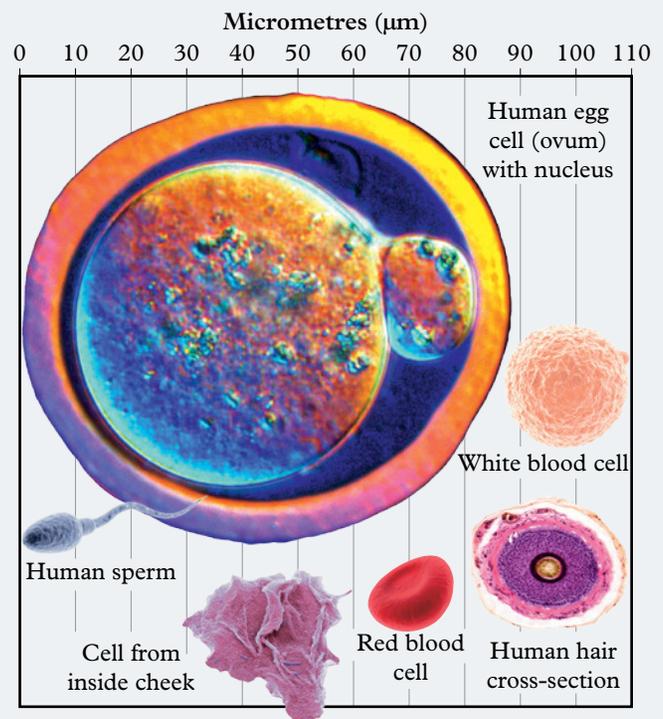


Figure 9 Different types of cells are different sizes and are measured in micrometres (μm). One micrometre is equivalent to one-thousandth of 1 mm.

Lesson 7.6

Experiment: Looking at organelles

Aim

To prepare slides to view the organelles in the cells of a brown onion and an *Elodea canadensis* plant

Study tip

You may wish to review Lesson 7.4 Challenge: Getting to know your microscope (page 267) for slide and microscope use.

Materials

- Onion wedge
- 3 glass slides
- Eyedropper
- Small beaker of water
- 3 glass coverslips
- Light microscope
- Pencil
- Paper
- Methylene blue stain or iodine
- Leaf from an *Elodea canadensis* plant
- Blotting paper

Method

Onion skin cells – unstained

Light microscopes depend on the light being able to pass through the specimen. When preparing a slide, it is important that the specimen is as thin as possible.

- 1 Between the fleshy layers of an onion there are some thin, transparent layers. These layers are one cell thick. Peel off a layer of this skin and put it onto a microscope slide.

- 2 Add one drop of water and then gently lower the coverslip so that no air bubbles are trapped.
- 3 Place the slide on the microscope stage and carefully adjust the focus as needed.
- 4 Draw and label what you see through the microscope. Try to identify the nucleus, which contains the DNA, and the cell membrane, cell wall and cytoplasm.
- 5 Keep this slide for use in Lesson 7.7 Experiment: Measuring cells (page 274).

Onion skin cells – stained

Stains are often used on specimens because they add contrast to the image. Some highlight a particular feature of the cell.

- 1 Use another thin layer of onion skin to prepare a second slide as above.
- 2 Add a drop of methylene blue stain or iodine instead of the water before lowering the coverslip. Lower it carefully so that no air bubbles are trapped. Be careful not to get the stain on your skin or clothes because it is very hard to remove.
- 3 Draw and label what you see through the microscope.
- 4 Keep this slide for use in Lesson 7.7 Experiment: Measuring cells (page 274).

Elodea canadensis cells

- 1 Pick a small green *Elodea canadensis* leaf and put it onto a microscope slide.
- 2 Add one drop of water and then gently lower the coverslip so that no air bubbles are trapped.
- 3 Draw and label what you see through the microscope. Try to identify the cell membrane, cell wall and cytoplasm.



Figure 1 Adding iodine to the slide

Results

Include your labelled diagrams under the “Results” heading in your notebook.

Discussion

- 1 **Describe** how the use of a stain changes the image of the onion cells.
- 2 Both types of cells viewed are from plants. **Explain** why there are differences between each of the cell types. (HINT: Consider which part of the plant the cells come from.)
- 3 **Explain** why it is often difficult to identify the nucleus in the *Eloдея canadensis* cells.
- 4 The *Eloдея canadensis* cells contain another structure that is very prominent. **Identify** and describe the function of this structure.
- 5 **Explain** why it is not necessary to stain the *Eloдея canadensis* cells.

Conclusion

Explain what you know about the organelles in onion cells and *Eloдея canadensis* cells.

Lesson 7.7

Experiment: Measuring cells

Aim

To measure the size of various plant and animal cells using a mini-grid

Materials

- Onion cell slide (prepared in Lesson 7.6 Experiment: Looking at organelles (page 273))
- Light microscope

- Mini-grid slide or 1 mm graph paper photocopied onto a transparency
- Other various prepared slides, such as human blood, nerve cells, leaf epidermis

Method

- 1 Place the onion cell slide on the microscope stage and carefully adjust the focus as needed.

- 2 Once in focus, estimate the number of cells that can fit lengthways across the field of view (the circle of light seen down the microscope). Record your estimate.
- 3 Gently remove the slide and insert the slide containing the mini-grid. Adjust the focus so that the lines can be clearly seen.
- 4 Each box is 1 mm in length. Determine the length of the field of view by counting how many 1 mm boxes fit across the light field.
- 5 Use this measurement to calculate the average length of one onion cell by estimating how many cells fit across the light field.

$$\text{length of cells} = \frac{\text{number of cells that can fit lengthways}}{\text{field of view length (mm)}}$$

- 6 Repeat steps 1 to 5 for each of the other prepared slides.

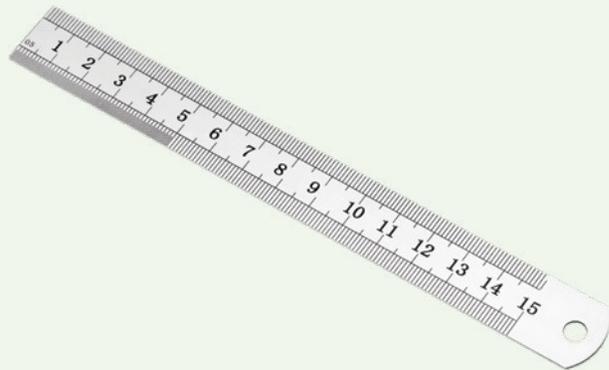


Figure 1 Time to measure up

Results

List the cells viewed from smallest to largest in size.

Discussion

- 1 **Identify** the number of micrometres (μm) in 1 mm.
- 2 **Compare** the ranking of cell size in this experiment to Figure 1 from Lesson 7.5 Plant and animal cells have organelles (page 269).

Conclusion

Describe what you know about the relative sizes of plant and animal cells.

Lesson 7.8

Cells have different roles



Learning intentions and success criteria



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

Key ideas

- All cells can be split into two groups: prokaryotes and eukaryotes.
- Prokaryotes (bacteria) do not have organelles or a nucleus.
- Eukaryotes have a nucleus and different organelles that are used to divide them into kingdoms.

Prokaryotes and eukaryotes

Cells are classified into two main groups – prokaryotic cells and eukaryotic cells.

Prokaryotic cells belong in the kingdom Monera. They are the most primitive cellular forms on Earth and are unicellular (single cells). They are much simpler than eukaryotic cells and do not have many of the organelles described in Lesson 7.5 Plant and animal cells have organelles (page 269). For example, they have no nucleus, and their genetic material (DNA) is found free in the cytoplasm. Prokaryotes include all the bacteria found on Earth.

Eukaryotic cells are more complex cells and are found in organisms from each of the other four kingdoms – Animalia, Plantae, Fungi and Protista. Eukaryotic cells keep their genetic material in a nucleus and have the membrane-bound organelles described in Lesson 7.5 Plant and animal cells have organelles (page 269). Most eukaryotes are multicellular.

Table 1 and Table 2 list some of the characteristics of prokaryotic and eukaryotic cells.

Table 1 Characteristics of prokaryotic cells

Characteristic	Monera
Number of cells	Unicellular
Cell wall	Present
Genetic material	Present
Nucleus	Absent
Mitochondria	Absent
Chloroplasts	Absent
Large vacuoles	Absent
Ribosomes	Present

prokaryotic cell

cell that does not have a nucleus or membrane-bound organelles; bacteria and archaea are made up of a single prokaryotic cell

eukaryotic cell

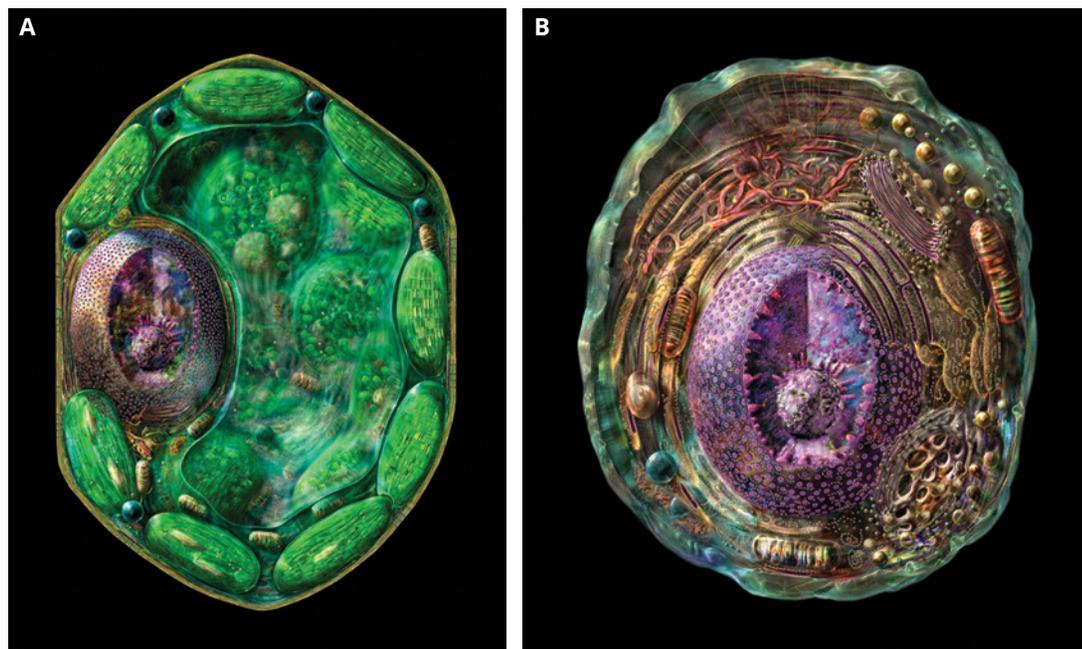
complex cell that contains a nucleus and membrane-bound organelles; protists, fungi, plants and animals have eukaryotic cells

Table 2 Characteristics of eukaryotic cells

Characteristic	Animalia	Plantae	Fungi	Protista
Number of cells	Multicellular	Multicellular	Multicellular, some unicellular (e.g. yeasts)	Multicellular or unicellular
Cell wall	Absent	Present	Present	Present in some
Genetic material	Present	Present	Present	Present
Nucleus	Present	Present	Present	Present
Mitochondria	Present	Present	Present	Present
Chloroplasts	Absent	Present	Absent	Present in some
Large vacuoles	Absent	Present	Absent	Present in some
Ribosomes	Present	Present	Present	Present

Plant cells

When we look at whole-organism plants and animals, it's fairly easy to see that they are different. Once microscopes started to become more powerful, scientists could see differences between plant and animal cells (Figure 1). Plant cells use their chloroplasts to photosynthesise and need cell walls to provide structure. Many plant cells also store their nutrients in large vacuoles (large spaces surrounded by a membrane).

**Figure 1** Typical (A) plant and (B) animal cells

Fungal cells

Fungi, such as mushrooms, are often mistaken for a type of plant. Using a microscope, scientists are able to see that fungal cells are different from plant cells. For example, fungal cells don't have chloroplasts, so they cannot photosynthesise, and

they don't have large vacuoles filled with liquid (Figure 2). Instead of making their own glucose, fungi such as mushrooms need to absorb their nutrients from the soil.

Protists

Protists (kingdom Protista) are a mixed group of organisms that are mostly unicellular (the whole organism is made up of just one cell). Many live in water, some are photosynthetic (they make their own food, like plants), some eat other organisms and some cause diseases. Depending on where it lives and its food sources, a protist's shape or structure will have evolved to suit its environment. The protists in Figures 3 to 6 have structures particular to their lifestyles.

Contractile vacuole (excretes water and waste)

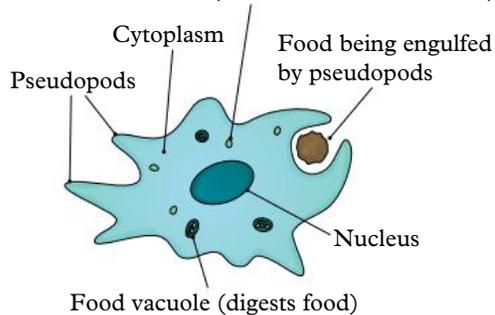


Figure 3 An amoeba can change the shape of its blobby body, creating foot shapes for movement and mouth shapes for swallowing food.

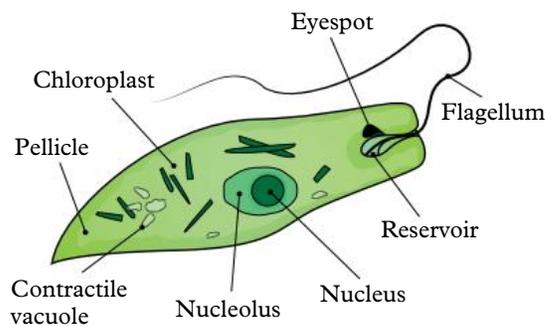


Figure 5 *Euglena* move quickly when they need to, with a bullet-shaped body and a long tail called a flagellum to whip them into action.

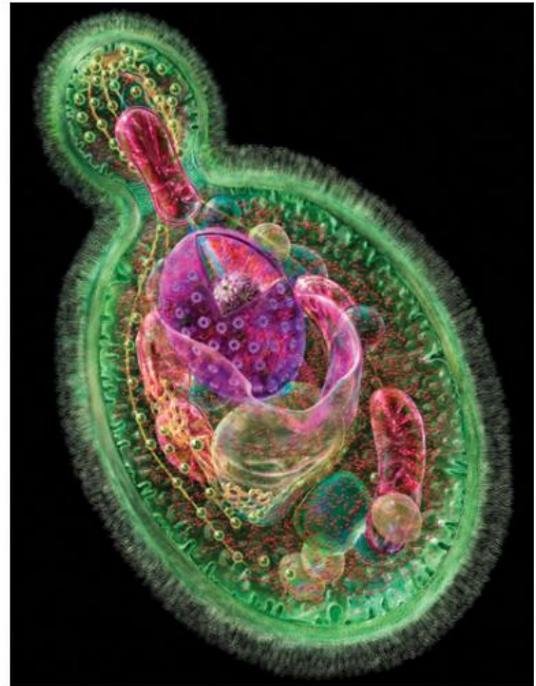


Figure 2 Cells in kingdom Fungi have cell walls and nuclei, but no chloroplasts.

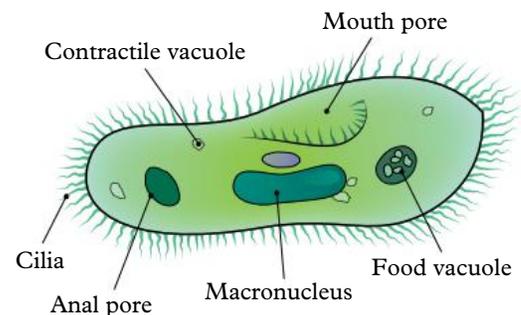


Figure 4 *Paramecium* move slowly with lots of tiny hairs called cilia that act like miniature oars.

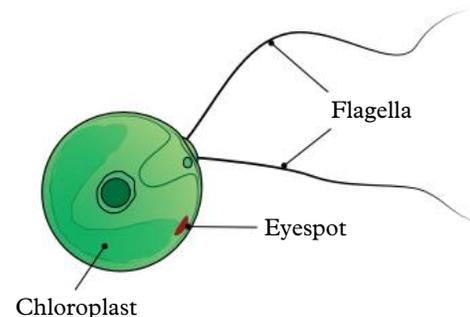


Figure 6 *Chlamydomonas* have an eyespot to detect light and two flagella to swim.

Animal cells

Unicellular organisms, such as bacteria, are made of one cell only. Multicellular organisms, like us, are made of more than one cell and often many billions of cells. The different cells in a multicellular organism communicate and work together to produce a functioning organism. Their different roles in the body mean they have different sizes and shapes. All animal cells have a nucleus and organelles, but no chloroplast or cell wall.

Check your learning 7.8



Check your learning 7.8

Retrieve

- 1 **State** where the genetic material is found in a prokaryotic cell.
- 2 **Recall** an example of a unicellular organism and a multicellular organism.

Comprehend

- 3 **Describe** the two main differences between eukaryotic and prokaryotic organisms.
- 4 **Illustrate** a cell that would be found in a mushroom (eukaryotic fungal cell). Label all of the organelles.

Analyse

- 5 **Identify** the kingdom that contains cells with a variety of cell shapes and structures and is often referred to as “the rest” of the cells.
- 6 Table 2 shows that plant cells contain chloroplasts. Although a typical plant cell

contains chloroplasts, they are not found in all plant cells.

- a **Infer** why some cells in a plant root may lack chloroplasts.
- b **Identify** the part of a plant where you would expect to find cells with chloroplasts.

Skills builder: Planning investigations

- 7 A student wanted to compare fungal cells to plant cells under the microscope. **Identify** a list of equipment the student would need to conduct this investigation and **develop** a step-by-step method they should use. (THINK: What does the student need to do step by step? Think through what equipment they would need at each phase.)

Lesson 7.9

Experiment: Plant and animal cells

Aim

To compare plant and animal cells

Materials

- Brown onion or apple or banana
- Microscope slide
- Iodine in dropper bottle
- Glass coverslip
- Light microscope
- Pencil
- Paper
- Prepared slide of animal cells

Method

- 1 Peel off a very thin piece of onion skin so that it looks a bit like cling film.
- 2 Place the skin on the microscope slide and add a tiny drop of iodine. This stains parts of the cells to make them easier to see.
- 3 Place one edge of the cover slip onto the slide and carefully lower it so that no air bubbles are trapped underneath.
- 4 Place the slide on the microscope stage.
- 5 Focus the microscope.
- 6 Draw three onion cells that you observed. Write down the total magnification and label the diagram.
- 7 Remove the slide and place the prepared slide of animal cells under the microscope. Focus the microscope.
- 8 Draw three cells that you observed. Write down the total magnification and label the diagram.
- 9 Use a small piece of a banana to smear a thin layer across a new microscope slide.



Figure 1 Peeling an onion



Figure 2 Adding iodine to onion skin

- 10 Add a drop of iodine to the banana smear and gently lay a coverslip over the top.
- 11 Place the slide on the microscope stage and focus the microscope.
- 12 Draw three banana cells that you observed.
- 13 Prepare a thin slice of the apple.
- 14 Add a drop of iodine to the apple slice and gently lay a coverslip over the top.
- 15 Place the slide on the microscope stage and focus the microscope.
- 16 Draw three apple cells that you observed.

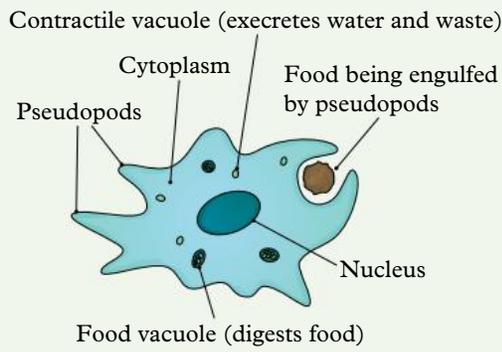


Figure 3 Placing the cover slip on the slide

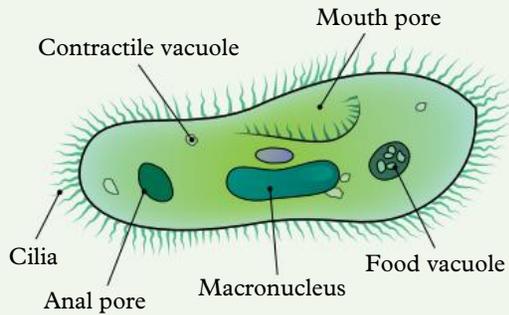


Figure 4 Focusing the microscope

Results

Include your cell diagrams under the “Results” heading in your notebook. Add the magnification and label any cell parts that you can identify.

Discussion

- 1 Explain** the purpose of staining the onion skin cells.
- 2 Compare** your two sketches with the images of plant and animal cells in Figure 1 in Lesson 7.8 Cells have different roles (page 277). **Identify** the differences and similarities between the cells.
- 3 Construct** a Venn diagram like the one in Figure 5 to show how plant and animal cells are similar and how they are different.

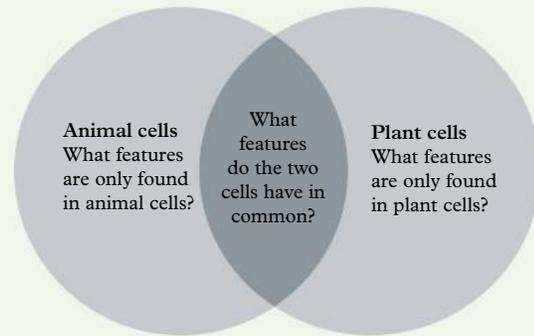


Figure 5 A Venn diagram can be used to show the similarities and differences between animal and plant cells.

Conclusion

Describe what you know about plant and animal cells.

Lesson 7.10

Unicellular and multicellular organisms can cause disease



Learning intentions and success criteria



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

Key ideas

- Non-dangerous bacteria that live on or in your body are called natural flora.
- Pathogens are cells that cause disease in other organisms.
- Infectious pathogens can be passed between organisms.
- Bacteria reproduce through binary fission.

Introduction

Unicellular organisms, such as bacteria, are living in and around us all the time. The average adult human has 1 kilogram of non-human life inside their large intestine alone. Some bacteria and microbes are essential for keeping your body healthy and working correctly. Others can be deadly. Figure 1 shows different bacteria found in the human body.

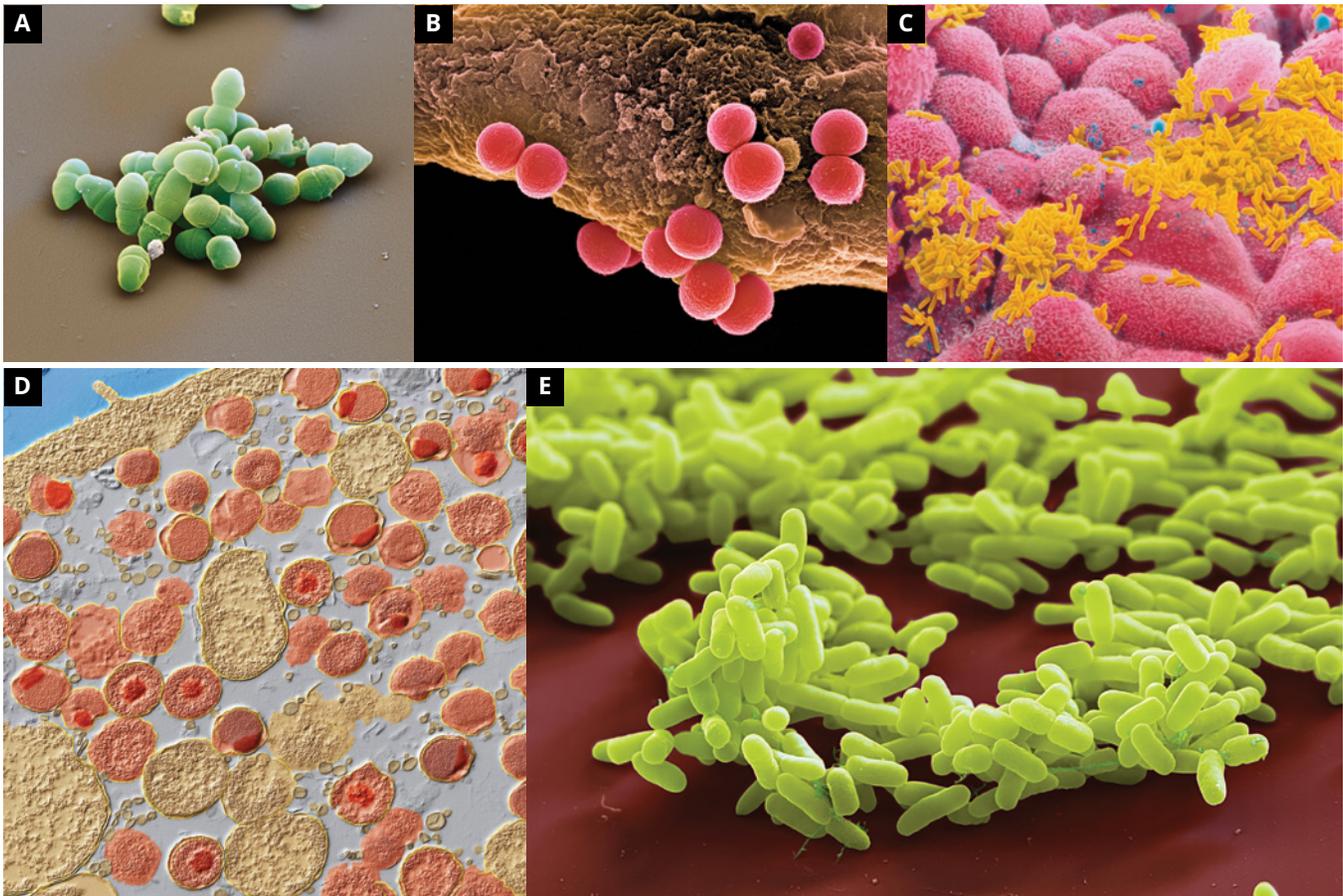


Figure 1 (A) *Staphylococcus epidermidis* on the skin. (B) *Staphylococcus aureus* in the hair. (C) *Haemophilus influenzae* in the nose. (D) *Chlamydia trachomatis* in the eye. (E) *Escherichia coli* in the intestines.

Microbes essential for health

The microbes that live happily on or in our bodies are referred to as **natural flora**. The careful balance between natural flora and the microbes in our environment is important to our health. The right amount of natural flora will protect us against foreign invaders, while too much of the natural flora can make us ill.

Bacteria in our intestines help our bodies digest food and provide vitamins to keep us healthy. The bacteria on our skin act as a protective coating, preventing disease-causing bacteria from growing.

Microbes causing disease

We have all been sick before. Some forms of sickness are caused by pathogens. A **pathogen** is a microorganism that can potentially cause a disease. An **infectious disease** is one where the pathogen is passed from one organism to another. Infectious diseases are described as being contagious. Pathogens always live on a host organism, such as a human, other animal or plant.

You will investigate pathogens in more detail in Year 9. The **symptoms** of a disease are the changes that occur to a host due to the disease.

Harmful microbes can be viruses, fungi, protists or bacteria. Viruses are considered by most scientists to be non-living pathogens because they cannot survive and reproduce outside a host cell. Instead, they need to invade a cell and use the cell's organelles to reproduce. They are not cells and are much smaller than cells. Viruses are hard to treat with medications because they hide inside our cells. They cannot be treated with antibiotics.

Fungi, protists and bacteria are living organisms made up of cells. Fungi can be unicellular (single-celled) or multicellular. Most protists are unicellular. Bacteria are unicellular. All these microbes can invade the body and cause disease. You are probably familiar with some diseases caused by harmful microbes. Fungi can cause ear infections and infections such as tinea, which is also known as athlete's foot. Protists can cause malaria and dysentery. Bacteria cause diseases such as tuberculosis (also known as TB), pneumonia, Legionnaires' disease and cholera. Diseases caused by bacteria can be treated with antibiotics, which kill the bacterial cells or stop them from reproducing. Microbes causing some of these diseases are shown in Figure 2.

natural flora
microbes that live in or on our bodies

pathogen microbe that can potentially cause a disease

infectious disease disease caused by the passing of a pathogen from one organism to another; also known as a contagious disease

symptom a physical sign of a disease or condition

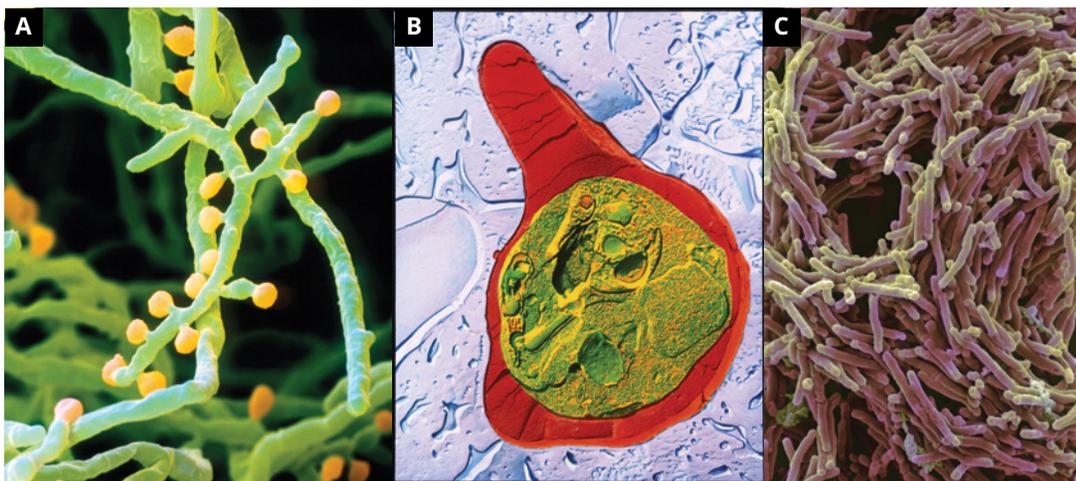


Figure 2 (A) *Trichophyton mentagrophytes* – cause of ringworm and tinea. (B) A red blood cell infected with malarial parasites. (C) Tuberculosis bacteria.

Bacterial growth

binary fission

a form of asexual reproduction used by bacteria; the splitting of a parent cell into two identical daughter cells

Bacteria reproduce using a process called **binary fission** (binary = two; fission = split). As the name suggests, a bacterial cell grows slightly larger and then splits in two. This is a very quick process, sometimes taking as little as 20 minutes. This can be represented on a graph such as the one in Figure 3.

Most bacterial growth is stopped at temperatures below 4°C and above 60°C. For this reason, your fridge should be kept below 4°C, and cooked food waiting to be served should be stored above 60°C.

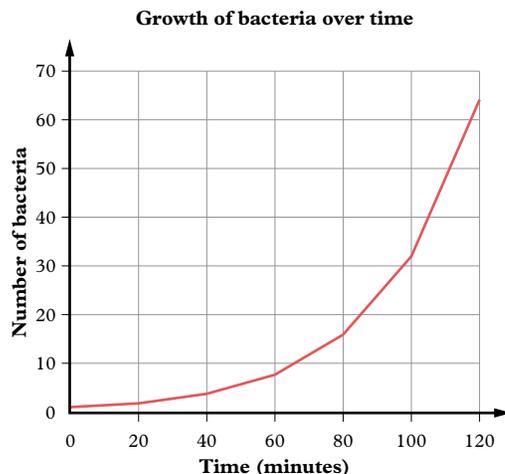


Figure 3 The number of bacteria cells can double every 20 minutes.

Check your learning 7.10



Check your learning 7.10

Retrieve

- 1 **Identify** the type of microorganism that your digestive system relies on.
- 2 **Define** the term “pathogen”.
- 3 **Identify** the four main types of pathogens.
- 4 **Recall** whether each of the types of pathogen is unicellular, multicellular or not a cell.

Comprehend

- 5 **Describe** the process of binary fission.

Analyse

- 6 **Contrast** (the differences between) natural flora and pathogens.
- 7 It is not recommended that food be left out of the fridge for more than 3 hours. **Use** the definition of “binary fission” to **infer** why.

Lesson 7.11

Experiment: Microbes all around

In this experiment you will investigate whether common detergents can kill the bacteria found in the local environment. Most human pathogenic bacteria and fungi (those that are potentially harmful to humans) grow optimally at 37°C. For this reason, samples

should be sealed with paraffin wax or tape prior to incubation and destroyed immediately after analysis.

Caution

Do not open the agar plate after incubation.

Aim

To determine the effectiveness of detergents in killing or restricting bacterial growth

Materials

- 3 Petri dishes containing nutrient agar (called an “agar plate”)
- Marker pen
- 2 sterilised swabs
- Paraffin wax strips
- Incubator set at 37°C
- Plastic bag

Method

Note: Two of the agar plates are to be used for growing microbes – Plate 1 is to be used in the first method and Plate 2 is to be used in the inquiry. Plate 3 is the negative control plate. The negative control plate should not be opened at any stage of the experiment but must be incubated alongside the sample plates.

- 1 Label the underside of each agar plate (around the edges) with your initials, the date, and the plate number (1 to 3). This allows you to see if any colony growth has occurred in the centre of the plate.
- 2 Decide on a site around the school to be tested for microbes.
- 3 Keep the swabs sterile (germ-free) until you reach the site.
- 4 Rub the sterilised swab over the site. Open Plate 1 and gently rub the swab across the surface of the agar in both directions (Figure 1). Take care not to damage the surface of the agar.
- 5 Quickly place the lid on Plate 1 and seal it with a wax strip.
- 6 Prepare Plate 2 following the Inquiry steps below.
- 7 Incubate Plate 1 and Plate 2, along with the control plate, at 37°C for two to three days. Do not open the agar plates again.



Figure 1 Carefully wipe the swab over the agar plate.

Inquiry: What if a detergent was spread over the surface of the agar plate?

Plan and conduct an experiment that answers the inquiry question.

- 1 **Select** a detergent that you would like to test.
- 2 **Develop** a prediction or hypothesis for your experiment.
- 3 **Identify** the (independent) variable you will change from the first method.
- 4 **Describe** how you will know if the detergent is effective in killing/restricting bacterial growth on Plate 2. (This is your dependent variable.)
- 5 **Identify** two variables that you will need to control to ensure a reproducible test. **Describe** how you will control these variables.
- 6 **Develop** a method for your experiment and write it in your logbook.
- 7 **Construct** a table to record your results.
- 8 Show your teacher your planning (for approval) before starting your experiment on Plate 2.

Discussion

- 1 **Describe** the growth on your sample plates after the incubation period. A labelled diagram may help you to do this. **Identify** any growth of bacteria and fungi that may be growing on your sample plates.
- 2 If your sample plates showed evidence of bacterial growth, **describe** any differences in colour, shape and size of the bacterial colonies.
- 3 **Identify** whether your detergent was effective in controlling bacterial growth. **Justify** your answer by describing the differences in bacterial or fungal growth that occurred between the plates.
- 4 **Describe** why there may be some differences between the growth on your plates and those of other students.
- 5 **Explain** why it is important that both the swab and the plate are sterile and are only exposed to the environment for a short period while collecting the sample.
- 6 If the negative control plate was sterilised appropriately prior to the beginning of this activity and then incubated alongside the sample plate, it should have shown no bacterial or fungal growth. **Explain** the purpose of the negative control plate.

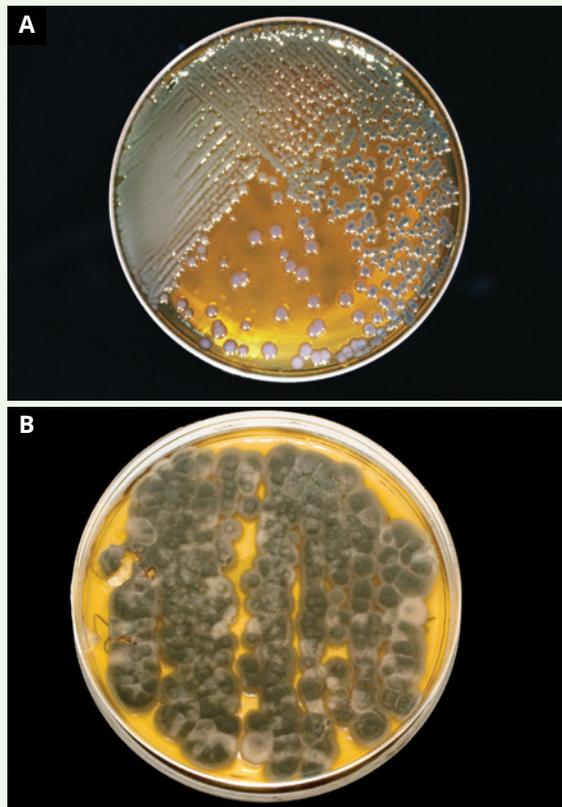


Figure 2 (A) Bacterial colonies growing on an agar plate
(B) Fungi tend to have a dusty or fuzzy appearance.

Conclusion

Describe the conclusions that you can make about the effectiveness of your detergent.

Lesson 7.12

Science as a human endeavour: Fungal cells can save lives

Introduction

Have you ever scratched yourself on a bush, or pricked yourself with a needle? Before the discovery of antibiotics, such a simple break in the skin could have been enough to kill you.

The discovery of penicillin

It has been accepted for over 3,000 years that some fungal cells can kill bacteria. Alexander Fleming (Figure 1) is credited with discovering the specific chemical responsible for this.

In 1928 Fleming was trying to grow bacteria on special agar plates as part of his research. Bacteria usually grow very well across the top of agar plates. However, this day Fleming failed to clean up after his experiment and left an agar plate open on his bench before leaving for a holiday. When he returned from his break, a small spot of mould had started growing in the centre of the plate. All around the mould was a clear circle where the bacteria were unable to grow. Fleming concluded that the mould (*Penicillium*) was producing a molecule that prevented the bacteria from growing (Figure 2). The molecule, which was named penicillin, had the ability to stop bacterial growth by preventing the bacteria from repairing or making a new cell wall.

Producing penicillin

It took ten more years and the work of Howard Florey (an Australian) (Figure 3) and Ernst Chain (Figure 4) to develop a way to separate the penicillin and produce it on a large scale. They were part of a team of specialists brought together to grow the mould, extract the penicillin, purify it and trial its treatment on patients.



Figure 1 Alexander Fleming

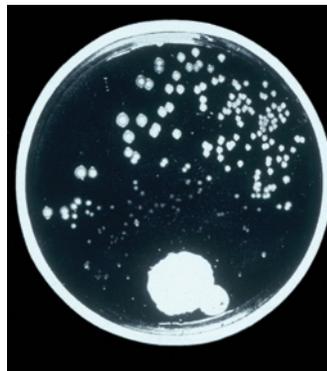


Figure 2 *Penicillium* mould growing on Fleming's agar plate



Figure 3 Howard Florey



Figure 4 Ernst Chain

In May 1940, Fleming’s group infected eight mice with streptococcal bacteria. Four of the mice were treated with penicillin. These mice survived, while the mice without the penicillin died.

This led the researchers to trial the penicillin on their first patient. Albert Alexander’s whole face was swollen after being scratched by a rose thorn. One eye had been removed and the other lanced to drain the pus. Within one day of being given penicillin, Alexander started to improve. Unfortunately, Fleming’s group did not have enough penicillin to finish the treatment and the patient suffered a relapse and died.

The researchers tried treating children next, as smaller doses could be used and the treatment could last longer. Eventually their purification methods and resulting treatment were successful (Figure 5). They were awarded a Nobel Prize in 1945 for their work.

The use of penicillin as an antibiotic revolutionised health care and the lives of many people who, without such treatment, would have died from bacterial infections.

The timeline of knowledge development about mould as a treatment for bacterial infection is shown in Figure 6.

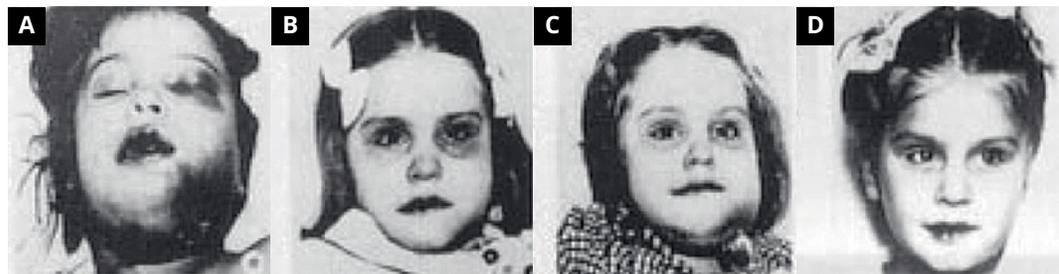


Figure 5 These photos from 1942 show the improvement of a child after penicillin treatment for a bacterial infection: (A) before treatment, (B) 4 days after treatment, (C) 9 days after treatment and (D) fully recovered.

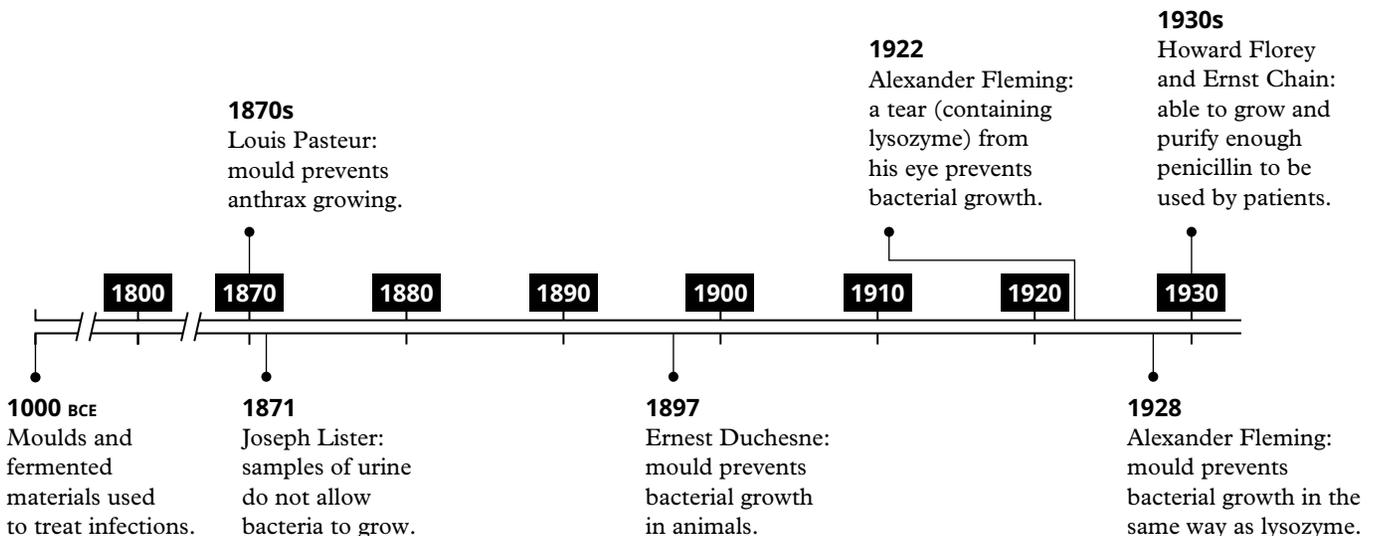


Figure 6 Penicillin timeline

Overuse of antibiotics

There are now many different antibiotics available, most of which are extracted from fungi. However, the overuse of antibiotics is a cause for concern. Because bacteria reproduce quickly, some strains of bacteria are becoming resistant to treatment. That is, they are not affected by antibiotics.

Scientists are continually searching for new types of natural and artificial antibiotics to treat these new “superbugs” that are resistant to all known antibiotics.

A dose of antibiotics destroys not only the harmful bacteria, but also the good bacteria in your body, so they should only be used to treat bacterial infections when absolutely necessary.

Test your skills and capabilities

Communicating with your audience

When you are sick, you visit the doctor. Doctors have many years of training to ask questions, observe disease symptoms, diagnose disease and decide if medication is needed. Doctors need to communicate their critical thinking to patients who do not have the same training or understanding. Doctors change the words about concepts so that their audience understands them.

Use your knowledge of viruses like influenza and how antibiotics kill bacteria to **create** a brochure that explains why a patient with influenza cannot be treated with antibiotics. Use the following hints to help you.

Hints:

- **Decide** the age of the person who will read the brochure.
- **Describe** how much they know about cells and viruses.

In your brochure:

- **Describe** the symptoms of influenza.
- **Compare** (the similarities and differences between) bacteria and viruses.
- **Describe** how antibiotics affect bacteria.
- **Describe** why antibiotics do not work on viruses.

Skills builder: Planning investigations

- 1 **Use** the information in this module to **outline** the method that Fleming followed to produce *Penicillium*. (THINK: What are the key features of a method?)



Figure 7 A type of penicillin can grow on orange peels.

Lesson 7.13

Review: Cells

Summary

Lesson 7.1 All living things are made up of cells

- Microscopes allow scientists to see the building blocks of life (cells).
- Cell theory states that all living things are made up of cells; cells are the basic unit of life and structure; all living cells are created from existing cells.

Lesson 7.3 Microscopes are used to study cells

- A microscope is an instrument that uses lenses to magnify the size of objects.
- The science of investigating small objects using a microscope is called microscopy.

Lesson 7.5 Plant and animal cells have organelles

- A cell is the smallest basic unit of life.
- All cells have a membrane, cytoplasm and genetic material (DNA).
- All plant and animal cells are made up of smaller organelles.

Lesson 7.8 Cells have different roles

- All cells can be split into two groups: prokaryotes and eukaryotes.
- Prokaryotes (bacteria) do not have organelles or a nucleus.
- Eukaryotes have a nucleus and different organelles that are used to divide them into kingdoms.

Lesson 7.10 Unicellular and multicellular organisms can cause disease

- Non-dangerous bacteria that live on or in your body are called natural flora.
- Pathogens are cells that cause disease in other organisms.
- Infectious pathogens can be passed between organisms.
- Bacteria reproduce through binary fission.

Review questions 7.13



Review questions

Retrieve

- 1 **Name** the first person to describe a cell.
- 2 **Identify** two types of microscopes.
- 3 **Define** the following terms.
 - a Nucleus
 - b Mitochondrion
 - c Chloroplast
 - d Binary fission
- 4 **Identify** which of the following is not found in an animal cell.
 - A Mitochondria
 - B A cell wall
 - C Cytosol
 - D A nucleus

- 5 **Recall** which important process takes place in the mitochondria of a cell.
 - A Photosynthesis
 - B Excretion
 - C Cellular respiration
 - D Cell division
- 6 **Identify** the term that describes an organism that catches a disease.
 - A Cell
 - B Pathogen
 - C Host
 - D Organism

Comprehend

- 7 **Explain** why multicellular organisms are made up of many cells instead of one large cell.
- 8 **Describe** the benefit of using a stain when viewing some specimens.
- 9 Cell walls are found in every plant cell on Earth. **Describe** the function of the cell wall.
- 10 **Describe** how our understanding of how living things function changed with the development of the microscope.
- 11 **Describe** the three key ideas that form “cell theory”.

Analyse

- 12 **Calculate** the magnification of a cell that is viewed with a “ $\times 40$ ” objective lens and a “ $\times 10$ ” eye-piece lens.
- 13 **Identify** the microscope most likely to have created the images in Figure 1. **Justify** your decision (by describing the features in the picture that are unique and deciding which microscope would allow these features to be seen).

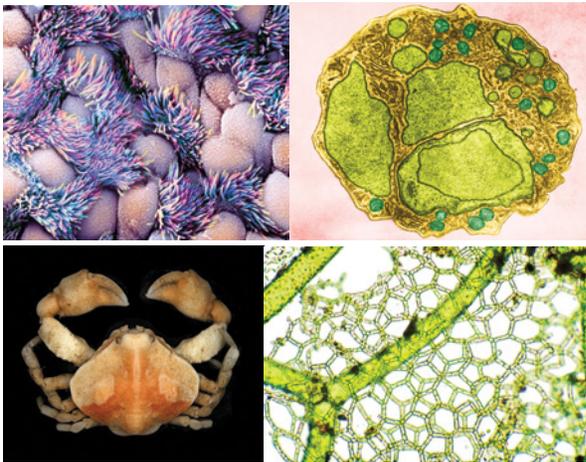


Figure 1 Microscopes allow us to see plant and animal structures that are not visible to the naked eye.

14 Identify the organelles in Figure 2.

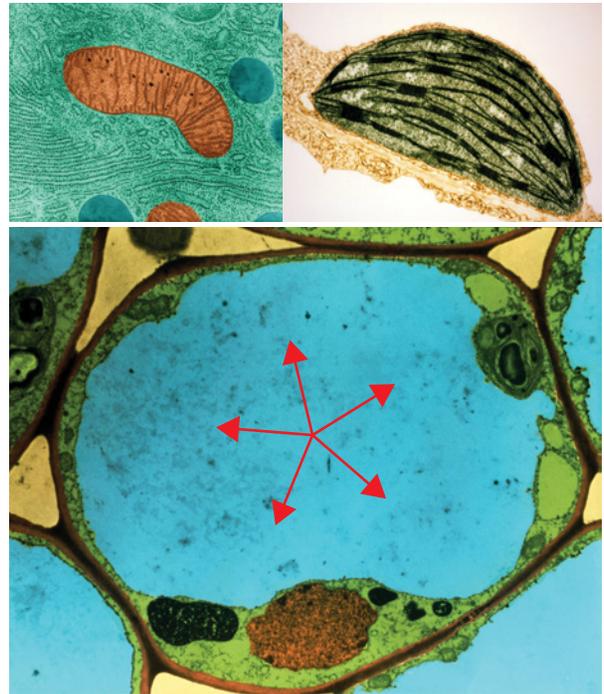


Figure 2 Organelles are specialised structures in cells.

- 15 **Compare** a mitochondrion and a chloroplast.
- 16 **Contrast** fungal cells and bacterial cells.
- 17 A cell membrane is “partially permeable”. This means that only certain substances can cross the membrane.
 - a **Identify** some substances that would need to get into the cell and some that would need to get out.
 - b **Explain** why these substances can reach the centre of a small cell easier than the centre of a large cell.

Apply

- 18 Two students prepare slides from different sections of a spring onion under a light microscope in their school laboratory. Tran views a section of the green leafy part and observes many chloroplasts within each cell, but has difficulty identifying a nucleus in each cell. Emily views a section of the white stem of the plant. She comments that a nucleus is clearly visible in most of the cells, but does not identify any chloroplasts.
 - a **Propose** why Tran observed many chloroplasts within each cell when they appeared to be absent from the cells viewed by Emily.

- b** Emily commented that she could identify a nucleus in most cells. **Discuss** whether it is possible for a plant cell not to have nucleus (by describing the function of a nucleus, describing the importance of a nucleus to the cell staying alive and deciding if it is possible for a plant cell to live without a nucleus).

- 19 Create** a short story about a virus. Your story needs to be from the point of view of a cell. The first line of your story is: “Once upon a time, a virus arrived for an uninvited visit”.
- 20 Use** the lenses from an old pair of reading glasses or a magnifying glass to **create** a model of a microscope. **Discuss** how your model is similar and different to Hooke’s microscope and modern compound microscopes.

Critical and creative thinking

- 21** Similes are often used in creative writing to compare two things using words such as “like” or “as”. **Discuss** the similarities that allow the following similes to be used.
- Cells are like building blocks.
 - The nucleus is like a control centre.
 - The mitochondrion is like a power station.

Social and ethical thinking

- 22 Discuss** why a doctor should not prescribe antibiotics for a viral infection by describing:
- the effectiveness of the antibiotics on making the person healthy
 - the long-term effects of overprescribing antibiotics on bacterial resistance.

Research

- 23** Choose one of the following topics for a research project. A few guiding questions have been provided for you, but you should add more questions that you want to investigate. Present your research in a format of your own choosing, giving careful consideration to the information you are presenting.

Linking big concepts

In this module, you examined the core concepts about cells – the form and features of living things are related to the functions that their cells perform.

Consider a creative way to **communicate** these concepts and **use** the descriptions of different cells provided in this chapter as examples, using as many of the keywords in the module as you can. You might use a concept map or mind map with each of the questions as major bubbles. You could choose to use diagrams only or draw a picture that shows all the aspects of the particles of life. The method of presentation that you select must enable you to share your ideas with others.



Figure 3 Represent the concepts in this module creatively.

Discovery of penicillin

The discovery of penicillin was considered an important factor behind the outcome of World War II. Soldiers who were injured on the battlefield could be patched up, given a shot of penicillin and returned to the battlefield again instead of having limbs amputated.

Create a newspaper article describing the importance of this major discovery.



Figure 4 The development of penicillin, 1940

Stem cells

Stem cells are cells in multicellular organisms that haven't become specialised yet – they're like blank canvases.

Investigate what scientists have learnt about stem cells, where they find them and what they hope to be able to do with them.

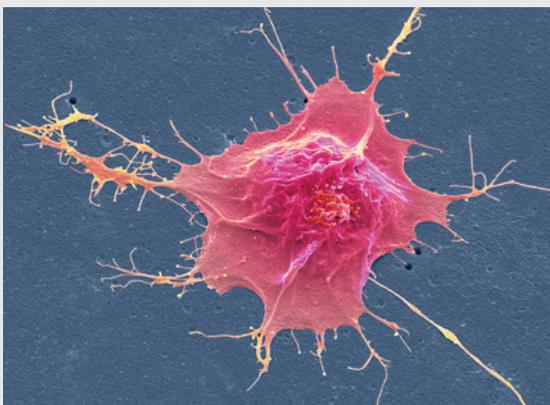


Figure 5 Scanning electron micrograph of a type of pluripotent stem cell

Plant cells

Plants do not have lungs to breathe. Instead, they have small pores called stomata that allow air to pass in and out of the plant. These stomata are made up of two guard cells that can change their shape.

- **Investigate** how stomata open and close in response to changing environmental conditions.
- **Describe** the conditions that allow the stomata to open.
- **Describe** the conditions that cause the stomata to close.
- **Describe** how the shape of the guard cells assists the opening and closing of the stomata.
- **Create** a model of two guard cells to illustrate how the cells function.
- **Explain** the model to others in your class.



Figure 6 Micrograph of a stomata on a purple and green leaf

Module

8

Surviving

Overview

The structure of cells, tissues and organs in both plants and animals is linked to their function, helping organisms survive. Specialised cells and tissues need to work together so that all the organs in a system can function effectively. Researching when things go wrong, such as how hardening arteries can cause heart disease, helps scientists understand their role in the body. Some organs are essential for life, and when they fail they may need to be replaced through transplantation of either a donor or artificial organ.





Lesson in this module:

Lesson 8.1 Systems are made up of cells, tissues and organs (page 296)

Lesson 8.2 The digestive system breaks down food (page 299)

Lesson 8.3 Experiment: Digesting protein (page 302)

Lesson 8.4 Experiment: What if an enzyme was boiled? (page 304)

Lesson 8.5 The digestive system varies between animals (page 306)

Lesson 8.6 Sometimes things go wrong with the digestive system (page 309)

Lesson 8.7 The respiratory system exchanges gases (page 311)

Lesson 8.8 Challenge: Measure your lung capacity (page 314)

Lesson 8.9 Challenge: Fish dissection (page 315)

Lesson 8.10 Sometimes things go wrong with the respiratory system (page 316)

Lesson 8.11 The circulatory system carries substances around the body (page 319)

Lesson 8.12 Experiment: Heart dissection (page 322)

Lesson 8.13 Sometimes things go wrong with the circulatory system (page 324)

Lesson 8.14 The excretory system removes waste (page 327)

Lesson 8.15 Experiment: Kidney dissection (page 328)

Lesson 8.16 Science as a human endeavour: Organs can be transplanted (page 330)

Lesson 8.17 Plants have tissues and organs (page 332)

Lesson 8.18 Challenge: Locating the xylem and phloem in a stem (page 334)

Lesson 8.19 Challenge: Modelling root cells (page 336)

Lesson 8.20 Experiment: Factors that affect transpiration (page 337)

Lesson 8.21 Review: Surviving (page 338)

Lesson 8.1

Systems are made up of cells, tissues and organs

Key ideas

- Anatomists study how the body works.
- Groups of cells that do a similar task are called tissues.
- Groups of tissues that work together are called organs.
- When groups of different organs work together, they are called a body system.



Learning intentions
and success criteria

The first anatomists

Evidence of the very first anatomists can be found in the X-ray paintings at Burrunggui on the lands of Gundjehmi-speaking people in Kakadu National Park. These diagrams of internal body parts were painted over 8,000 years ago. They show the different parts of the skeleton and the circulatory system of the painted person (Figure 1).

Other paintings at Injalak Hill show that the Kunwinjku people of West Arnhem Land were able to identify the internal organs and skeletons of birds, fish and mammals. These paintings were made over 6,000 years before the Egyptians removed organs during the mummification process.

Leonardo da Vinci

Leonardo da Vinci is famous as a painter and architect, but he also studied the human body. Da Vinci began studying the human body over 500 years ago through life drawing (drawing people standing in front of him) and by attending public dissections that were held by medical schools.

He was involved in both human and animal dissections and, from these, he created beautiful and highly accurate drawings.

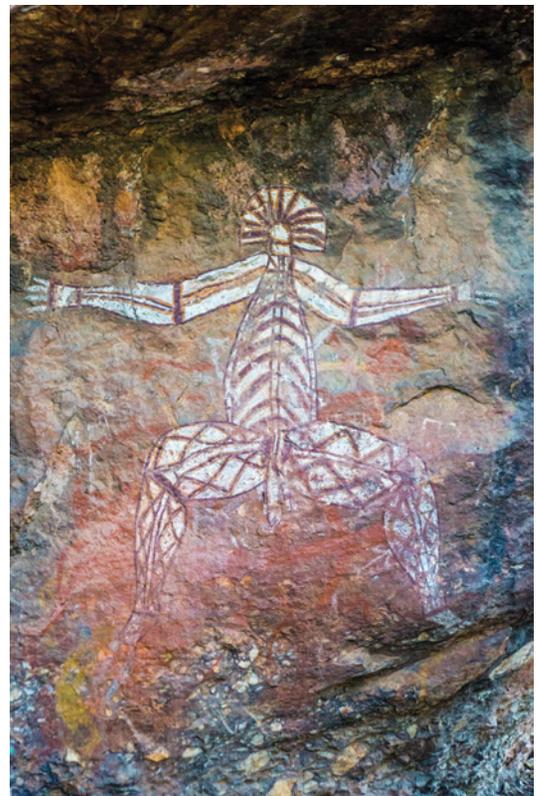


Figure 1 Internal parts of the body depicted in rock paintings at Burrunggui (Nourlangie), Kakadu, 8,000 years ago.

Cells

As you learnt in Module 7 Cells (page 258), cells are the basic unit of life. Human beings are made up of animal cells, which work together to produce a functioning organism. The development of the microscope by Robert Hooke in the 1600s led anatomists to examine how cells work together to form the different systems in the body, and they eventually discovered how our cells are organised to make us work (Figure 2).

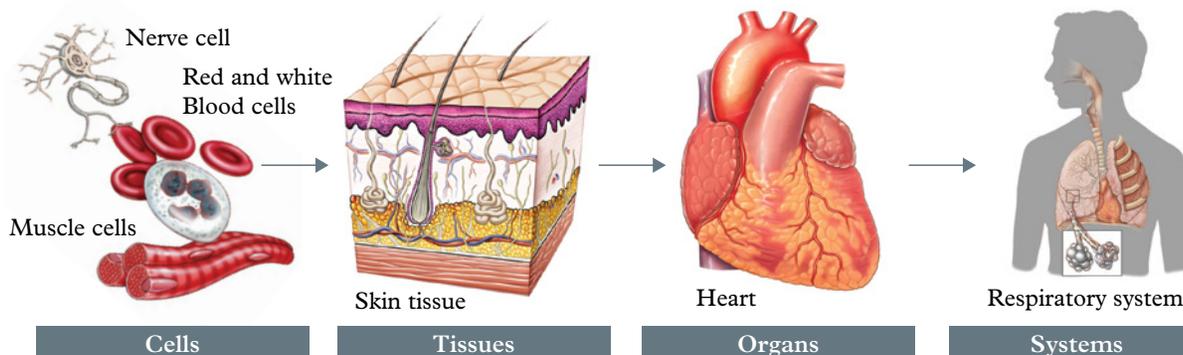


Figure 2 The different levels of organisation in the body

Tissues

Anatomists found that some similar looking cells work together to carry out a particular job or function. These groups of cells are called **tissues**. There are four types of tissue with different functions.

Connective tissue includes blood cells, fat cells, bone cells, tendons and ligaments. These cells are all surrounded by a material called a matrix. The matrix is made up of living and non-living components and can be solid or liquid. For example, cells in bone marrow are surrounded by solid bone, and cells in the blood are surrounded by liquid.

The cells in **muscle tissue** are able to cause parts of the body to move. For example, muscle cells in the heart enable it to beat, and muscle cells connected to the skeleton enable us to move.

Nervous tissue contains cells that allow the different parts of the body to pass on messages. This occurs through nerve cells.

The cells that make up **epithelial tissue** are usually large and flat, allowing them to cover a large surface. Epithelial tissues cover the outside and inside surfaces of the body and help protect the internal parts of the body from damage, bacteria and water loss.

Organs and systems

When the four types of tissues work together to do a particular job, they make an **organ**. Your heart is an example of an organ. It is lined with epithelial tissue to protect the surface. It contains blood (connective tissue) and nervous tissue to help the cells to communicate, and it contains muscle tissue to help it to move and beat.

tissue a group of cells that work together to carry out a particular function

connective tissue the group of cells that provide connections to other parts of the body

muscle tissue the group of cells that allow the body to move

nervous tissue the group of cells that pass on electrical messages

epithelial tissue the group of cells that cover and protect the body

organ a group of tissues that work together for a purpose

The heart is connected to another organ: blood vessels that also contain all four types of tissue. When groups of different organs work together to perform a particular function, they are called a **system** (Figure 3). These systems work together to maintain the health of an **organism**.

system a group of organs that work together for a purpose

organism a living thing; organisms can have one cell (unicellular) or many cells (multicellular)

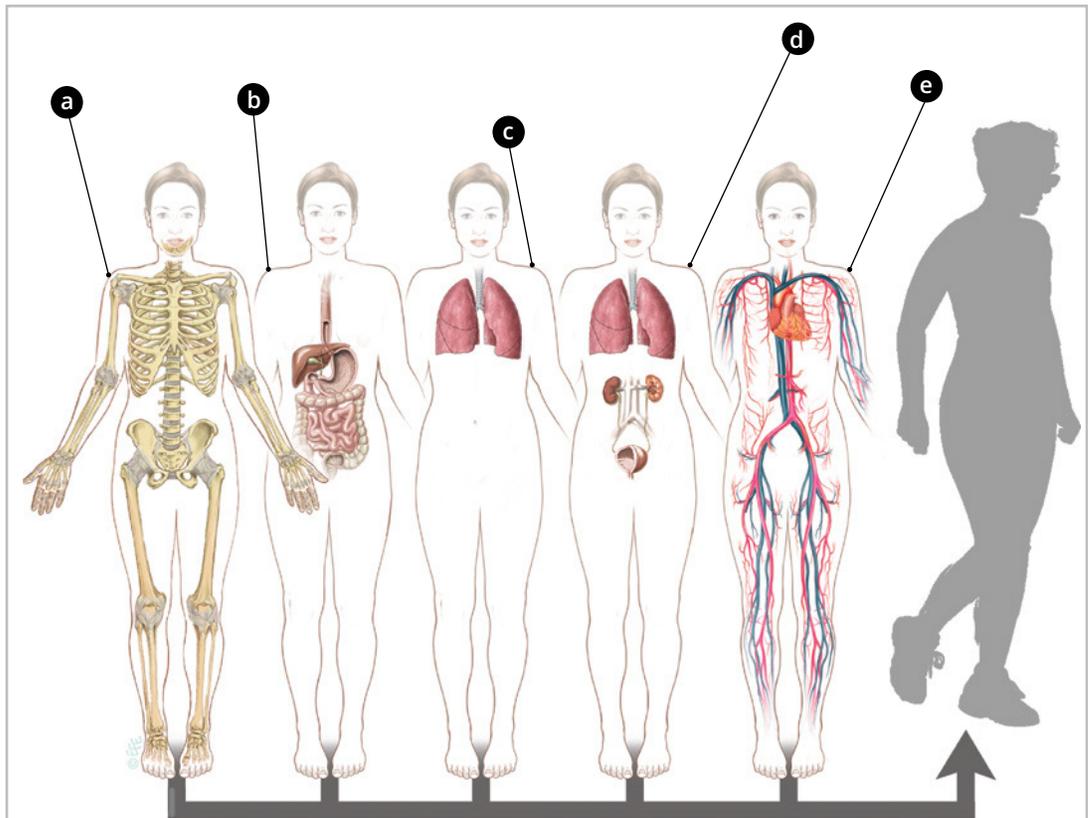


Figure 3 Our body systems work together.

- a** **Skeletal system:** all bones, including spine, skull, pelvis and ribs. Gives body structure and supports and protects other organs; provides attachment for muscles.
- b** **Digestive system:** mouth, stomach, small intestine, large intestine, rectum and anus. Breaks down food into substances small enough to be absorbed into the bloodstream; separates some waste.
- c** **Respiratory system:** lungs, windpipe and diaphragm. Filters oxygen from the air and transfers it to the blood so that it is taken to all other parts of the body; removes carbon dioxide from cells via blood back to the lungs.
- d** **Excretory system:** kidneys, liver, bladder, urethra, skin and lungs. Processes and filters out wastes and controls the amount and content of body fluid.
- e** **Circulatory system:** heart, veins and arteries. Carries oxygen and nutrients to cells and waste materials away from cells via the blood.

Check your learning 8.1



Check your learning 8.1

Retrieve

- 1 **Define** the terms “tissue”, “organ” and “system”.
- 2 **Recall** the age of the X-ray paintings at Burrungui.

Comprehend

- 3 **Explain** how cells, tissues, organs and systems are linked.

- 4 **Use** Figure 3 to **explain** how the circulatory system and digestive system work together.

Apply

- 5 **Infer** why surgeons need a thorough understanding of anatomy.
- 6 **Select** an organ and **investigate** how the four types of tissue work together so that the organ can function.

Lesson 8.2

The digestive system breaks down food

Key ideas

- Digestion is the process of breaking down food so that it can be used by the body.
- Physical digestion occurs when the body manually breaks apart food particles.
- Chemical digestion occurs when enzyme molecules break the chemical bonds in food.
- Nutrients are absorbed in the intestines.



Learning intentions and success criteria



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

The digestive system

Digested food and drink provide us with energy to live and the materials for our bodies to grow and repair. Your **digestive system** is made up of the digestive tract and other organs, including the liver, the gall bladder and the pancreas. The digestive tract is a long tube that starts at your mouth and ends at your anus. Food moves through each part of the tube from the oesophagus, stomach, small and large intestines and finally the rectum. The digestive tract and organs work together to break down the food you eat and liquid you drink so that it can be absorbed into your blood for transport to your cells. Food that is not needed by the body (such as fibre) stays in the digestive tract until it reaches the rectum. From there, it is released into the toilet through the anus as faeces. This process is called **digestion**. Figure 1 shows the structure of the digestive system and explains the way each part works.

digestive system
organ system that breaks down food and absorbs nutrients

digestion the process of breaking down food into nutrients

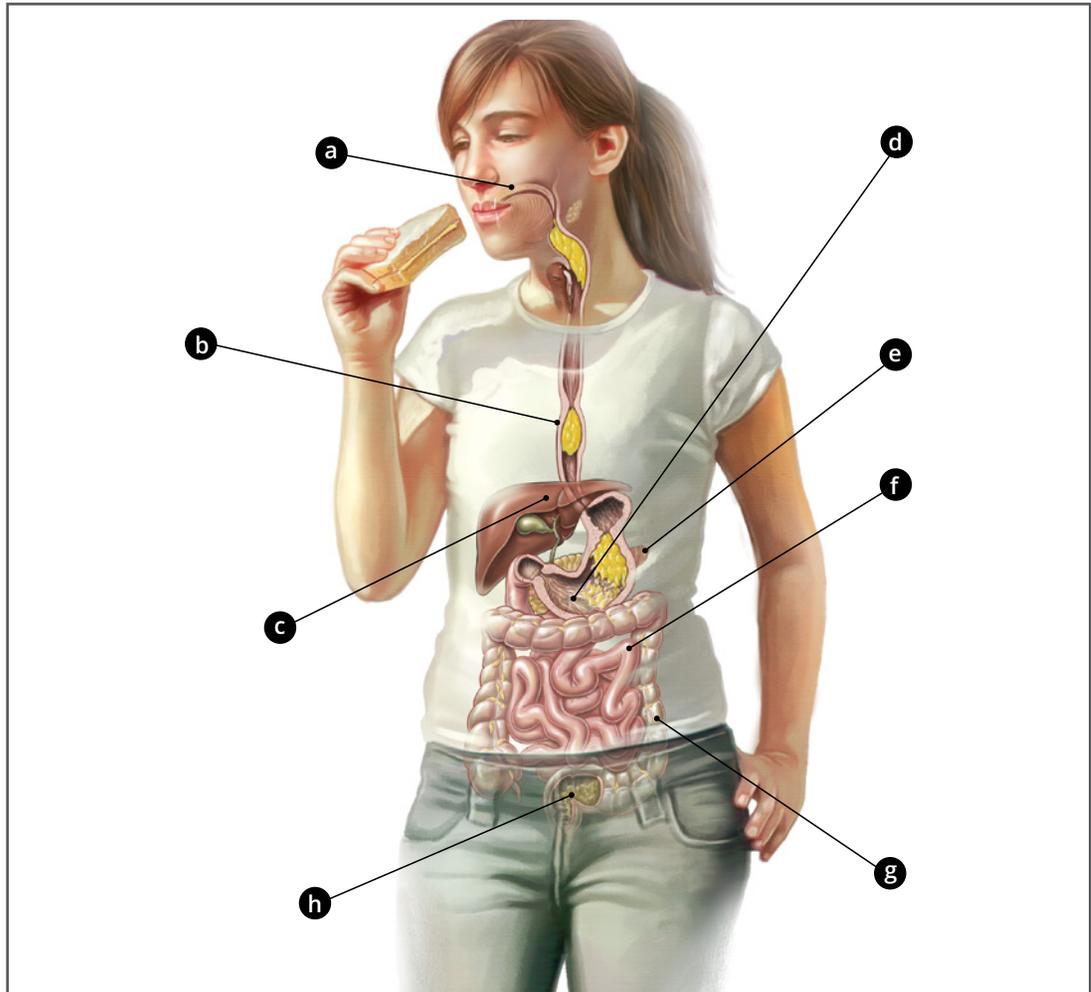


Figure 1 The structure of the digestive system with key parts labelled.

- a** **Teeth and mouth:** the teeth are responsible for the physical breakdown of food and the tongue is important in pushing the food towards the teeth. Salivary glands make saliva, which contains enzymes to start chemical digestion.
- b** **Oesophagus:** a tubular muscle that forces food down to your stomach in a process called peristalsis.
- c** **Liver and gall bladder:** the liver makes a mixture of chemicals called bile, which is used to digest fat and neutralise (deactivate) stomach acid. The bile is stored in the gall bladder until food reaches the small intestine. Bile is then released into the small intestine through a tube called the bile duct. Food does not travel through the liver.
- d** **Stomach:** stores food for about three hours while it uses stomach acid to help digest the food. The food in your stomach looks nothing like what you ate for dinner. It is very runny, warm and smelly, and has a totally different taste. This mixture is called chyme.
- e** **Pancreas:** makes pancreatic juice, which contains a mixture of digestive enzymes and also neutralises stomach acid. Food does not travel through the pancreas.
- f** **Small intestine:** called “small” because it is quite narrow. If you laid a small intestine out in a straight line, it would be approximately 5 m long. The small intestine is important because it absorbs the nutrients that all the cells of the body require. The ability to absorb nutrients is increased by projections, called villi, along the inner wall of the intestine that increase the surface area for absorption. Bacteria in the small intestine also help with digestion. Chyme takes about 5 or 6 hours to pass through.
- g** **Large intestine:** also called the colon, the large intestine is wider but shorter than the small intestine, approximately 1.5 m long. By the time the chyme reaches the large intestine, most nutrients have been absorbed into the bloodstream. However, some vitamins are absorbed from the large intestine. Water is also absorbed into the bloodstream from the large intestine. Chyme stays in the large intestine for up to 14 hours, or sometimes longer.
- h** **Rectum and anus:** the rectum is the final part of the journey for what is now solid, undigested food, or faeces. The rectum stores faeces until it starts to become full. As the rectum starts to stretch, messages are sent to the brain to make you realise that you need to use the toilet. Rectal muscles push the faeces out of the ring of muscle at the end of the rectum called the anus.

Physical digestion

Physical digestion starts in your mouth (Figure 2). Your teeth are responsible for the physical breakdown of your food. There are three main types of teeth in your mouth that do this work. The front ones are called incisors, the pointy teeth next to the incisors are called canines and the rest of your teeth, which are flatter, are called molars. Each type of tooth has an important function. The front incisors cut your food when you bite down, the canine teeth are for tearing meat, and the molars are good for chewing and grinding food into smaller pieces. Your tongue, a large muscular organ, can push your food upwards, sideways and backwards towards your teeth.

When you swallow your food, the muscles behind the food squeeze tight, and the muscles in front of the food relax. This forces the food to move in a process called **peristalsis**.

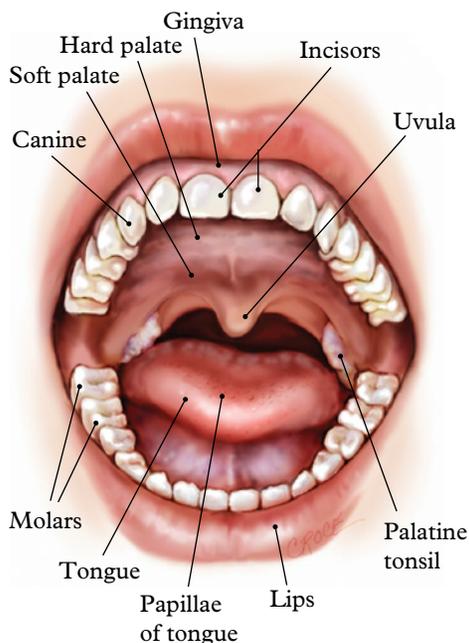


Figure 2 The teeth and mouth physically break down food.

physical digestion the physical break down of food into smaller pieces using the teeth and muscles of the digestive system

Chemical digestion

Chemical digestion also starts in your mouth. The saliva in your mouth is mostly water, but it also contains different types of enzymes. **Enzymes** are chemicals that can speed up a reaction (Module 6 Physical and chemical change (page 206)). In the digestive system, enzymes help break down the lumps of food into **nutrients** that are small enough to be taken in or absorbed through the cell membrane.

The stomach contains a mixture of gastric juices to help digest the food you have eaten. These juices include acid that kills any bacteria that may be in the food and an enzyme that digests the protein (found in meat and other foods) in your meal. The cells lining the inside of the stomach produce mucus to stop the acid from burning the stomach walls. The resulting mixture of acid, enzymes and partially digested food is called **chyme**.

Absorbing nutrients

Most nutrients from food are absorbed in the small intestine. The small intestine is narrow but quite long at around 5 metres. The inside of the small intestine is full of ridges called **villi** (Figure 3). Villi increase the surface area of the small intestine. The large surface area of the small intestine

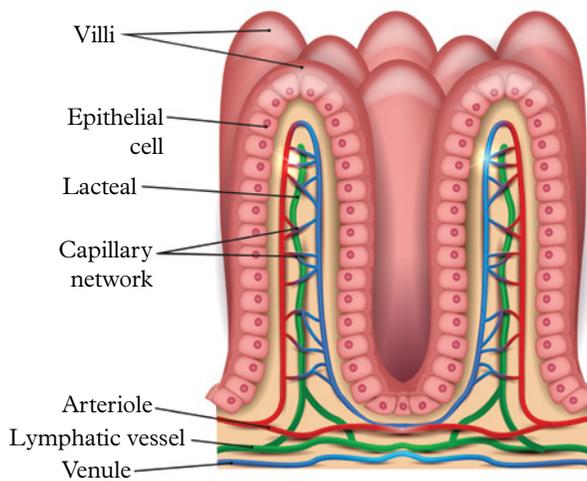


Figure 3 The small intestine has a large surface area because it is covered in tiny hair-like projections called villi. The villi allow nutrients to be absorbed more efficiently.

peristalsis the process of swallowed food being moved along the digestive tract by a wave of muscle contractions

chemical digestion the chemical break down of large food molecules into smaller, simpler molecules using enzymes

enzyme a protein that speeds up the rate of chemical reactions; a type of catalyst

nutrient substance in food that organisms need for energy, growth and other biological functions

chyme a mixture of acid, enzymes and digested food that leaves the stomach

villi small hair-like projection that increases the surface area of a membrane (plural: villi)

means that there is a lot of space for nutrients to pass over and more opportunity for nutrients to be absorbed.

Check your learning 8.2



Check your learning 8.2

Retrieve

- 1 **Recall**, in order, the organs of the digestive system that food moves through, from the mouth to the anus.
- 2 **Name** the organs that are involved in digestion but do not have food passing through them.

Comprehend

- 3 Teeth would look very nice if they were all the same size and shape. **Explain** the advantage of having different types of teeth in your mouth.
- 4 **Explain** how saliva makes it easier to eat dry crackers (Figure 4).
- 5 **Explain** the advantage of the intestine having villi.

Analyse

- 6 **Contrast** (the differences between) physical and chemical digestion.
- 7 **Contrast** (the differences between) the digestive system and the digestive tract.

Apply

- 8 **Propose** some tools that could work the same way as incisors, canines and molars.



Figure 4 Crackers are physically digested by teeth and chemically digested by enzymes in saliva.

Skills builder: Planning investigations

- 9 Two students were planning an investigation that involved members of their class eating different types of biscuits. **Explain** why this might be an unsafe activity for some of the students in their class. (THINK: How might food be dangerous?)

Lesson 8.3

Experiment: Digesting protein

Aim

To investigate the function of pepsin, an enzyme found in the stomach, and to establish the conditions under which pepsin functions best

For the record

Egg white is being used as the source of protein in this experiment.

Caution

Some students may have egg allergies.

Materials

- 4 test tubes and a test-tube rack
- Permanent marker
- Hard-boiled egg white
- Knife
- Ruler
- 10 mL measuring cylinder
- 1 mL pipette
- 1% pepsin solution
- Water
- Dilute hydrochloric acid (1 M HCl)
- Dilute sodium hydroxide solution (0.1 M NaOH)
- Rubber band
- Incubator (37°C)

Safety

Bring the materials to the test tubes, rather than risking them being dropped when carrying them around the room.

Caution

Take care when using the sharp knife.

Caution

Dangerous chemicals are involved. Pour carefully, clean up all spills immediately and rinse your hands if you come into contact with any chemicals.

Method

- 1 Label the four test tubes A, B, C and D with the permanent marker.
- 2 Collect some hard-boiled egg white. Cut four cubes of approximately 1 cm³ ensuring that the cubes are the same size.
- 3 Put a cube of egg white in each test tube.
- 4 Add 10 mL pepsin to tubes A, C and D.
- 5 Add 10 drops of water to tube B.
- 6 Add 10 drops of 1 M HCl to tubes A and B.
- 7 Add 10 drops of 0.1 M NaOH to tube D.

- 8 Add 10 drops of water to tube C.
- 9 Bind the four test tubes with a rubber band and label the test tubes with your initials.
- 10 Incubate the test tubes for at least 24 hours at 37°C.

Results

Copy Table 1 and use it to record your results. Record what was in each test tube by adding a tick or cross in the table. Provide very brief statements to describe your observations of the results.

Table 1 Investigating pepsin

Test tube	Egg white	Pepsin solution	HCl	NaOH	Water	Results
A						
B						
C						
D						

Discussion

- 1 This experiment is a “controlled” experiment. **Describe** what is meant by the term “controlled”.
- 2 **Explain** why combining the class’s data can improve the accuracy of the results.
- 3 **Construct** a sentence to explain how the comparison of test tubes relates to the human stomach for A and B, A and C, and A and D.
- 4 **Identify** the test tube(s) with the almost completely digested protein. **Describe** the appearance of the digested protein.
- 5 **Define** the term “enzyme”.
- 6 **Describe** the effect HCl alone has on the protein.
- 7 **Identify** the missing words in the following word equations to show what has happened in this experiment.
 - a Tube A: protein + _____ + _____ → amino acids

- b** Tube B: water + _____ + _____
→ _____
- c** Tube C: pepsin + _____ + _____
→ _____
- d** Tube D: pepsin + _____
+ _____ → _____

8 Explain why the body digests protein by describing what happens to the protein after it has been digested.

9 Predict what would happen if this experiment was repeated with carbohydrates instead of protein, leaving the rest of the experiment exactly the same.

Conclusion

Explain what you know about the function of pepsin and the conditions under which pepsin functions best.

Lesson 8.4

Experiment: What if an enzyme was boiled?

Background

The gelatine in jelly is a protein that can be broken up by an enzyme found in fresh pineapple or kiwi fruit. For this reason many packets of jelly come with a warning not to add fresh fruit to the jelly.

Aim

To determine what conditions are needed for an enzyme to digest protein

Materials

- Jelly crystals
- Boiling water to make up jelly
- Large beaker to make up jelly
- 3 × 100 mL beakers
- Fresh pineapple

- Boiled pineapple
- Tinned pineapple

Method

- 1 Make up the jelly according to the instructions on the packet.
- 2 Pour 50 mL of liquid jelly into three beakers.
- 3 Add a few pieces of the fresh pineapple to one of the beakers.
- 4 Place the beaker with fresh pineapple and the beaker with no fruit into the fridge.
- 5 Use the remaining beaker of jelly for the Inquiry.
- 6 Allow all three beakers to cool overnight in the fridge.
- 7 Record your observations in a table.

Inquiry: Choose one of the questions to investigate.

- What if the pineapple was boiled before being added to the jelly?
- What if tinned pineapple was added to the jelly?

You will now design your own experiment to answer your inquiry question.

- 1 **Develop** a prediction or hypothesis for your inquiry.
- 2 **Identify** the (independent) variable that you will change from the first method.
- 3 **Identify** the (dependent) variable that you will measure and/or observe.
- 4 **Identify** two variables that you will need to control to ensure a reproducible test. **Describe** how you will control these variables.
- 5 **Develop** a method for your experiment. Write this method in your logbook.
- 6 **Construct** a table to record your results.
- 7 Show your teacher your planning (for approval) before starting your experiment.

Results

Record your observations in your results table.

Discussion

- 1 **Describe** the difference between the jelly with the fresh pineapple and the jelly with no pineapple.
- 2 **Use** the term “chemical digestion” to **explain** your observations.
- 3 **Compare** your hypothesis to the results obtained in your inquiry.
- 4 **Suggest** an alternative reason for the results you obtained in your inquiry.

Conclusion

Explain why you should not add fresh pineapple to jelly.



Figure 1 Fresh pineapple

Lesson 8.5

The digestive system varies between animals

Key ideas

- Carnivores are organisms that eat meat.
- Herbivores are organisms that eat plant material.
- Omnivores, including humans, eat a variety of foods.
- The structure of the digestive system can be used to predict the type of food an animal eats.



Learning intentions and success criteria

Teeth tell a story

Before the invention of knives and forks, we used to tear our food apart with our fingers and teeth. Each type of tooth has a specific function. Incisors have a sharp knife-like or wedge structure, and animals such as rats and mice use their incisors to cut their way through food. Canine teeth are pointed and are useful in ripping lumps of meat apart. This is why many carnivores (meat eaters) have large canine teeth. Molars are flatter and are especially good at grinding plant food into small pieces so that it can be digested more effectively by enzymes.

Palaeontologists are scientists who study fossils, including the skulls and teeth of extinct animals. Palaeontologists use the teeth to predict what a fossilised animal ate when it was alive (Figure 1).

Herbivore hindgut

hindgut lower part of the digestive system; includes the caecum, colon and rectum

caecum a small dead-end pouch that connects the small and large intestines

The **hindgut** is the lower part of the large intestine and includes the **caecum**, colon and rectum. There is a lot of variation in the size and structure of the hindgut of animals and this variation is related to their diet. Carnivores usually have a small hindgut, while herbivores have a large hindgut. This is because plant material is harder to break down and takes longer to digest than animal material (meat).

Some plants, such as sugar cane, have a ready supply of the sugar that animals need for energy.

Other plants, such as potatoes, contain starch that our enzymes can break up for nutrients. Some parts of plants are very difficult to digest – physically or chemically.



Figure 1 This fossil has a lot of molars and a few incisors. This suggests that it belonged to a herbivore.

The outside of a plant cell is surrounded by a cell wall made of cellulose. Few animals have the enzyme (cellulase) that can break up this solid nutrient. Instead they rely on good bacteria to break it up for them. These bacteria live in the caecum, a pouch-like structure where food is stored until the bacteria can digest it. In many animals the caecum is found between the small intestine and the large intestine (Figure 2). This is a problem for the animal as it means the plant matter is digested after it passes through the small intestine where nutrients are absorbed. Many of the good nutrients end up in the faeces. Some animals, such as possums, rabbits, rodents and termites, eat their own faeces to get the extra nutrients that may have been missed the first time through.

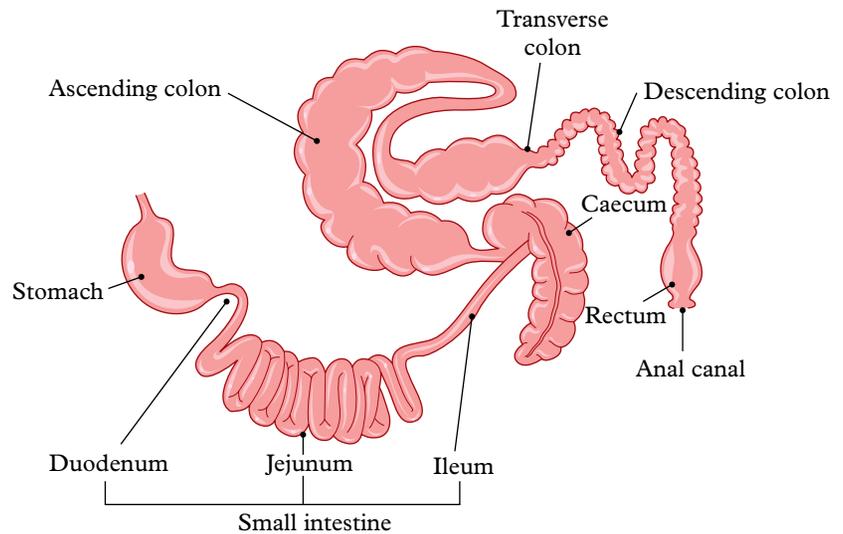


Figure 2 The caecum of a horse is found between the small intestine and the large intestine.

Ruminants

Ruminants are animals with hooves that have four chambers in their stomachs. A cow is an example of a ruminant (Figure 3). When a cow first swallows its food, the grass goes to the first stomach, which is called the **rumen**. This allows the grass to mix with different types of bacteria that can break up the cellulose in the plant's cell wall. The cow regurgitates the grass by bringing it back into the mouth to chew it over and over again to help the bacteria break down the nutrients. The second stomach (the **reticulum**) is involved in trapping any unwanted things the cow might have swallowed, such as rocks or wire. The third stomach (the **omasum**) has many leaf-like folds that filter fine particles and water into the fourth stomach (the **abomasum**). It is this last section that contains acid and enzymes, just like a human stomach.

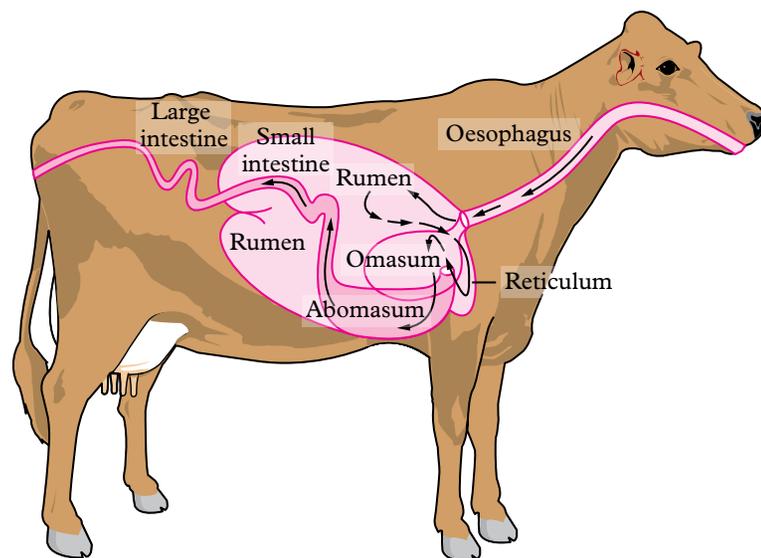


Figure 3 The four stomachs of a cow allow it to digest grass.

rumen the first stomach of a cow

reticulum the second stomach of a cow

omasum the third stomach of a cow

abomasum the fourth stomach of a cow

Check your learning 8.5



Check your learning 8.5

Retrieve

- 1 **Recall** why some animals eat their own faeces.

Comprehend

- 2 **Describe** two ways the structure of the digestive system in animals can be different.
- 3 **Explain** the function of each of the four stomachs found in a cow.

Analyse

- 4 **Examine** the images of the digestive systems of a carnivore, a herbivore and an omnivore in Figure 4.
 - a **Identify** the organs in each digestive system according to the animal's diet.
 - b **Describe** evidence from the diagrams that supports each of your answers.

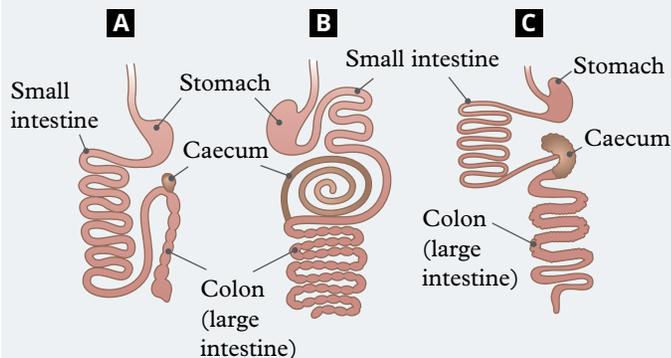


Figure 4 Digestive systems of three animals with different diets

- 5 **Identify** the possible diet of the fossils in Figure 5. **Describe** evidence from the photographs that supports each of your answers.



Figure 5 Photographs of fossils

Apply

- 6 **Investigate** the digestive system of an animal of your choice.
 - a **Compare** (the similarities and differences between) your selected digestive system and the digestive system of humans.
 - b **Explain** how the structure of your animal's digestive system allows it to digest the food it eats.

Lesson 8.6

Sometimes things go wrong with the digestive system

Key ideas

- Stomach ulcers are caused by the bacterium *Helicobacter pylori*.
- Gallstones stop bile leaving the gall bladder.
- People who do not have the enzymes to break down gluten have gluten intolerance.
- Constipation is a blockage in the large intestine.



Learning intentions
and success criteria

Stomach ulcers

For many years, **ulcers** (small open sores) (Figure 1) in the stomach lining were thought to be caused by too much rich, spicy food and stress. Patients would go to the hospital in a lot of pain from the stomach acid burning the other tissues around the ulcer. Because it was thought no bacteria could survive in the stomach's acidic environment, no one considered that bacteria could be the cause of the ulcers.

Two Australian scientists, Barry Marshall and Robin Warren (Figure 2), noticed that every patient who presented with symptoms of a stomach ulcer also had the bacterium *Helicobacter pylori* present in their stomach. In the early 1980s they did a series of experiments to show that the spiral-shaped bacteria caused damage to the cells lining the stomach, forming an ulcer. These bacteria can be killed by antibiotics. In 2005, Marshall and Warren were awarded the Nobel Prize for medicine (the highest prize in science).



Figure 1 A stomach ulcer

ulcer an open sore on the inside or outside of the body



Figure 2 Robin Warren and Barry Marshall

Gallstones

The gall bladder is a small pouch-like structure that stores the bile from

gallstone a hard substance or stone that is produced by the gall bladder

ultrasound a technique that uses sound waves to create images of structures inside the body

gluten intolerant unable to digest gluten

diarrhoea watery faeces

the liver. Bile contains many things, including a detergent-like substance that helps to physically break up the fat that leaves the stomach in the chyme. Occasionally, parts of the bile harden into a small **gallstone** that stops the bile from leaving the gall bladder (Figure 3). The amount of bile in the pouch increases, causing the gall bladder to swell up. This causes severe abdominal pain. If the stone cannot be shattered by **ultrasound**, or removed by surgery, the gall bladder may have to be removed. This means the person will have difficulty digesting fatty foods because of the lack of bile to break up the fats.



Figure 3 Gallstones

Gluten intolerance

Gluten is a small molecule found in many cereals and grains (Figure 4). Our bodies use enzymes to chemically digest the gluten so that we can use the nutrients it contains. Some people do not have this enzyme. This means that they cannot digest the gluten and that they are **gluten intolerant**. Gluten intolerance can cause a range of different symptoms, from blockages of the intestines to **diarrhoea** (watery faeces). Gluten intolerance is not an allergy. If a person is allergic to gluten (celiac disease), their body's immune system fights against the gluten. This can affect their whole body, not just the digestive system.



Figure 4 A number of grains contain gluten.

Constipation

Sometimes the large intestine becomes blocked. This can be caused by diet (not eating enough fibre, which is mostly found in fruits and vegetables) or by an infection. It usually starts with a small blockage, but as more food moves down the digestive system, it gets caught behind the blockage and gradually fills the large intestine. This causes pain and discomfort (Figure 5). Sometimes medication is needed to help the large intestine move the blockage. If it is not treated, the person may die.

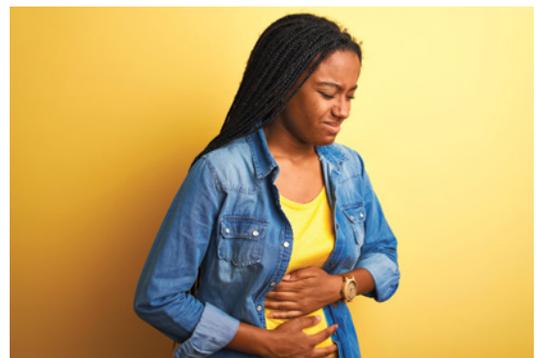


Figure 5 Constipation may cause pain and discomfort.

Check your learning 8.6



Check your learning 8.6

Retrieve

- 1 **Recall** what causes stomach ulcers and how they can be treated.

Comprehend

- 2 **Explain** what causes the pain that occurs with a stomach ulcer.
- 3 **Describe** a possible solution for constipation.

Analyse

- 4 **Compare** (the similarities and differences between) gallstones and gluten intolerance.
- 5 **Identify** one thing that all the malfunctions discussed in this topic have in common.

Apply

- 6 **Create** a flow chart summarising what happens when and after gallstones form.
- 7 A student often has a sore stomach. Sometimes, they need to leave class in a hurry to go to the toilet. The teacher notices that the student often leaves classes that happen after lunch. **Propose** two possible causes for the student's pain. **Explain** why this pain might become worse after eating. **Decide** which of these two reasons might be the likely cause of the pain and justify your answer.

Lesson 8.7

The respiratory system exchanges gases

Key ideas

- The respiratory system is the body system responsible for breathing.
- Air is inhaled down the trachea, the bronchi and the bronchioles into the alveolar sacs and eventually into our blood.
- Our lungs breathe in oxygen to be used by our cells for energy and breathe out carbon dioxide as waste.



Learning intentions and success criteria

respiratory system

organ system that brings oxygen in and sends carbon dioxide out of the body; site of gas exchange

cellular respiration

the chemical reaction between glucose and oxygen that produces carbon dioxide, water and energy

Why do we need oxygen?

The **respiratory system** makes sure that every cell in your body gets the oxygen it needs. Why do cells need oxygen? Most of the food we eat is broken down to glucose, a simple sugar. Oxygen is needed to release energy from glucose.

This process is called **cellular respiration**. It is a chemical reaction in which glucose and oxygen are converted to carbon dioxide, water and energy. This energy is then used for all the jobs cells need to perform, from making and breaking down substances to making new cells.

inhalation

bringing air into the lungs; breathing in

exhalation

pushing air out of the lungs; breathing out

You can see why people get confused about the difference between breathing and respiration. “Cellular respiration” is the chemical process that happens in cells, and “breathing” is the **inhalation** (breathing in) of oxygen and **exhalation** (breathing out) of carbon dioxide by your lungs and other organs in the respiratory system.

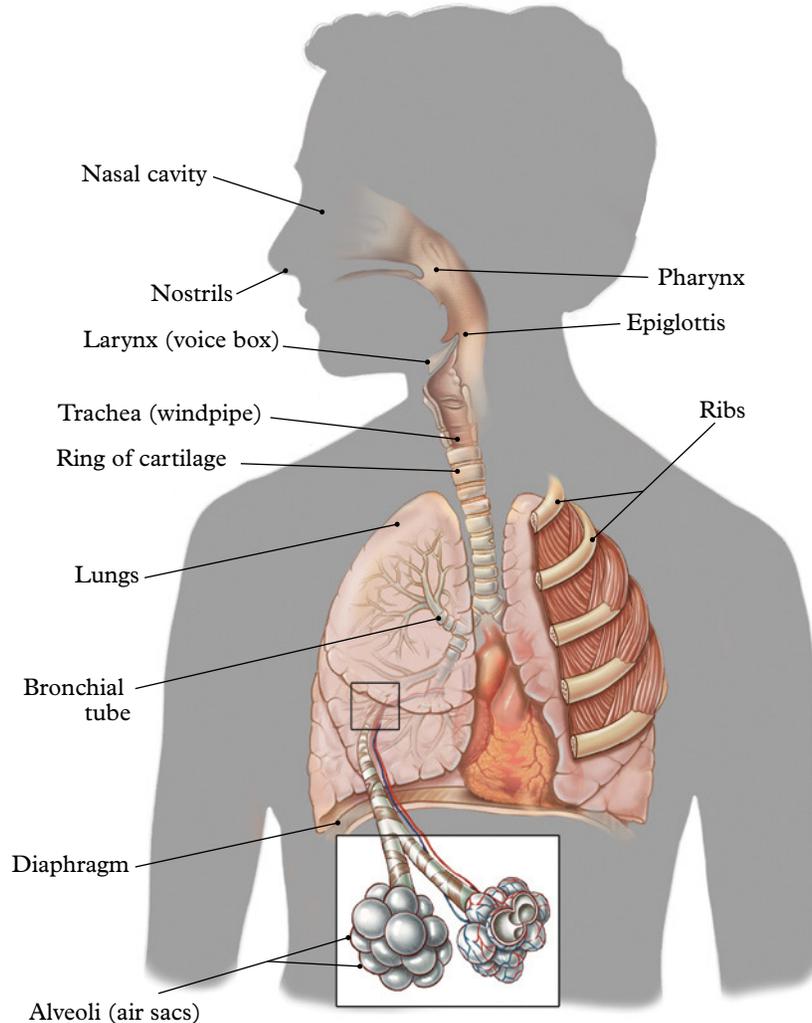


Figure 1 The structure of the respiratory system

pharynx the throat; connects the mouth to the oesophagus

epiglottis a flap of skin above the larynx that controls the passage of food and air, preventing food from entering the windpipe

trachea the large tube that connects the throat to the bronchi; carries air in and out of the body

bronchi air passages that carry air in and out of the lungs; airways

alveoli tiny air sacs in the lungs where gas exchange occurs

Where does the air go?

We breathe air in through our nose and mouth. Any dust and pollen we breathe in are trapped by hairs and wet surfaces as the air travels to our throat or **pharynx**. At the bottom of the pharynx is a trapdoor called the **epiglottis** that controls the passage of food and air. Food goes down the oesophagus to the stomach. Air goes down the **trachea** to the lungs.

The lungs

There are two lungs in our chest. They change in size every time we take a breath and they fill with air. The trachea branches into two to carry air into each lung. These branches are called **bronchi**. The lungs feel spongy to touch because they are home to millions of tiny air sacs called **alveoli** (singular “alveolus”). If these air sacs were unravelled and flattened, the lungs would have a surface area of approximately

half the size of a tennis court. Each tiny alveolus is covered by a mesh of even smaller blood vessels called **capillaries**. As well as the large surface area of the alveoli, this mesh of capillaries increases the surface area of blood vessels around each alveolus, allowing air to easily pass in and out of the blood.

Oxygen moves into the blood, whereas carbon dioxide (the waste product of cellular respiration) moves out of the blood (Figure 2). This process is called “**gas exchange**”.

capillary a blood vessel with a wall only one cell thick; allows substances to pass into and out of the blood

gas exchange the transfer of oxygen into cells and carbon dioxide out of cells

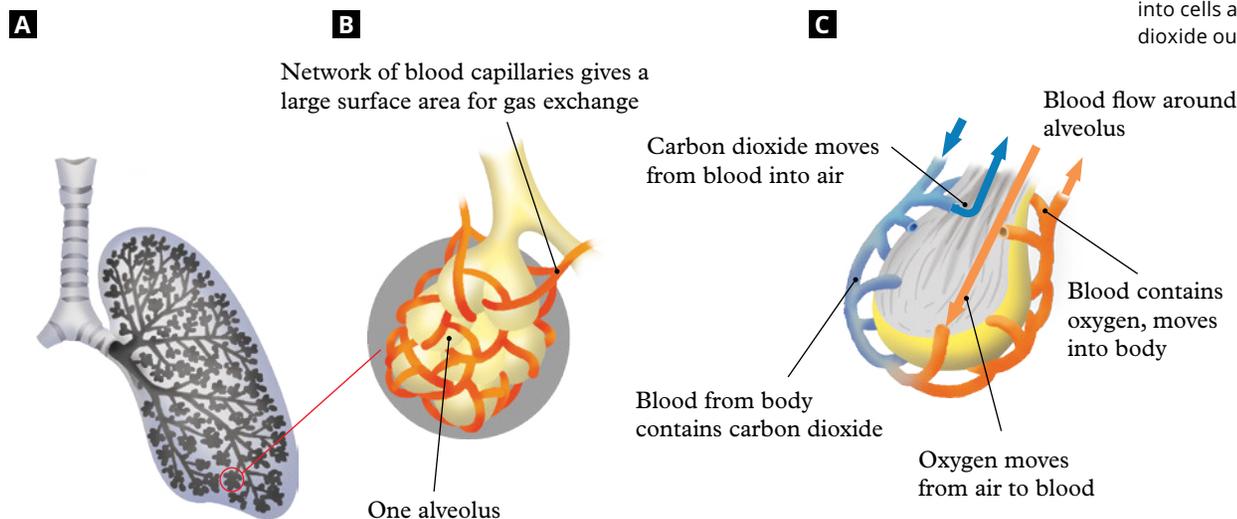


Figure 2 Gas exchange takes place in the alveoli.

The diaphragm

The **diaphragm** is a dome-shaped muscle that is attached to your ribs and moves up and down beneath your lungs. This muscle contracts down and relaxes up. The diaphragm also separates the heart and lungs from the stomach and digestive system. The lungs have no muscle tissue, so they cannot move on their own. Every time you breathe in, the muscles in the diaphragm and between the ribs work together to expand (make your chest larger). As the chest expands, the lungs also expand, pulling air in. When the muscles relax, the chest and lungs become smaller, allowing the air to move out again.

diaphragm a dome-shaped muscle attached to the ribs; moves up and down under the lungs

Other respiratory systems

As you learnt in Year 7, all living organisms exchange gases. The lungs in many animals, including mammals and birds, provide a large surface for oxygen to move into the blood and for carbon dioxide to move out. Other organisms have this gas exchange surface on the outside of their body. The gills of fish have water passing over a large surface area, allowing oxygen in the water to be absorbed into the blood of the fish and carbon dioxide to be removed. This water must constantly be replaced so that the fish have a fresh supply of oxygen.

Check your learning 8.7



Check your learning 8.7

Retrieve

- 1 **Define** the term “gas exchange”.
- 2 Gases constantly move in and out of the blood into the lungs. **Identify** the gases that move in and out of the respiratory system.
- 3 **Recall** the role that the epiglottis plays in the respiratory system.

Comprehend

- 4 **Create** a simple diagram showing how air travels down from the mouth and nose to the alveoli at the end of the branches of the bronchioles.
- 5 **Describe** the sequence of steps in breathing in (inhaling) and breathing out (exhaling).

- 6 **Explain** the advantage of the large surface area of the alveoli for gas exchange.

Apply

- 7 **Discuss** why we need to breathe.

Skills builder: Problem solving

- 8 **Identify** the missing cause and missing effect to complete the table. (THINK: How does the respiratory system function?)

Cause	Effect
A person's diaphragm is not working properly.	A person chokes on food in their trachea.

Lesson 8.8

Challenge: Measure your lung capacity

Caution

Tubing or bendy straws must be discarded after a single-person use.

Aim

To measure the capacity of a person's lungs

What you need:

- Access to a large sink or tub
- Water
- Large 5 L container with single litres marked
- 1 m of tubing or bendy straw

What to do:

- 1 Place 10 cm of water in the bottom of a sink.
- 2 Fill the container with water.
- 3 Tip the container upside down in the sink so that the opening is submerged. This will prevent the water from leaving the container. Take note of the water level in the container by checking the litre marks.
- 4 Place one end of the tubing under the opening of the container.
- 5 Take a deep breath and blow as much as you can into the tubing. As you blow air into the container, the water should be pushed out of the container and into the sink.

- 6 Measure how much air you are able to blow out of your lungs into the container by checking the water level.
- 7 Repeat steps 1 to 6 two more times.

Questions

- 1 **Explain** why the experiment needed to be repeated three times.
- 2 **Identify** two factors that could reduce a person's lung capacity.
- 3 **Compare** your results with those of other students in the class. **Identify** any

relationship between the height of a person and their lung capacity.

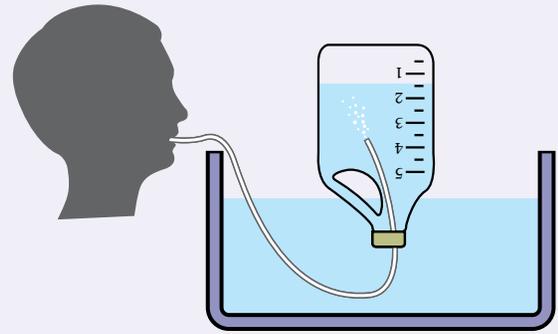


Figure 1 Experiment set-up

Lesson 8.9

Challenge: Fish dissection

Aim

To identify the respiratory organs in a fish

What you need:

- A fish (complete with internal organs) from a fishmonger or market
- Safety gear
- Newspaper
- Dissection board
- Dissection tools

Caution

Refer to Lesson 1.8 Skills lab: Dissecting a chicken wing (page 29) for dissection skills and safety guidelines.

Part A

What to do:

- 1 Use your dissection skills to open the abdomen and head of the fish.
- 2 Record your observations of the internal organs, using labelled diagrams.

Questions

- 1 **Identify** whether the systems are clearly separated or intertwined.
- 2 **Compare** the colour (dark red, light red or white) of the different organs.
- 3 **Explain** how an organ's blood supply could affect its colour.
- 4 **Explain** how the amount of blood supply is related to an organ's importance.

Part B

What to do:

- 1 Identify and remove the gills of the fish (Figure 1).
- 2 Reflect on the significant features of our lungs that make them such effective gas exchange organs.

Questions

- 1 **Compare** the structure of fish gills to lungs in a mammal (for example, a human).
- 2 **Compare** the function of fish gills and mammalian lungs.

- 3 **Explain** how the structure of fish gills allows them to function effectively.



Figure 1 Removing the gills

Lesson 8.10

Sometimes things go wrong with the respiratory system

Key ideas

- Small irritations in the upper respiratory system make us cough or sneeze.
- Asthma causes the bronchi and bronchioles to become smaller.
- Emphysema is caused by broken-down alveoli, preventing oxygen from entering our blood.
- Pneumonia is an infection that fills our lungs with fluid and blocks the flow of gases.



Learning intentions and success criteria

Coughing and sneezing

Every time you breathe in, you also take in small particles of dust, pollen and other matter. These particles are trapped by the cells lining our upper airways. Small **cilia** (hair-like structures) on the surface of the cells trap these particles and push them back to the top of the throat where they are swallowed. Larger particles trigger the diaphragm to contract quickly, making us cough (Figure 1). This pushes up the large particle before it enters the bronchioles.

cilia tiny hair-like structures on the surface of cells

Sometimes the particles get trapped by the hairs in our nose. This causes a message to go to our brain, which coordinates the muscles in the eyes, chest, stomach and diaphragm, making us sneeze. Some sneezes have been recorded at over 120 km/h.

Asthma

Asthma is quite common in our population, affecting more than one in ten Australians. Asthma usually starts when something in the environment irritates the airways. This causes the bronchi and bronchioles to narrow, making it harder for air to move into the lungs (Figure 2). When this happens, it is hard to breathe. Asthma attacks can be reversed by medications, such as Ventolin, that relax and open the airways (Figure 3).



Figure 1 We cough or sneeze to clear small particles from our airways.

asthma a disease of the respiratory system caused by narrowing airways

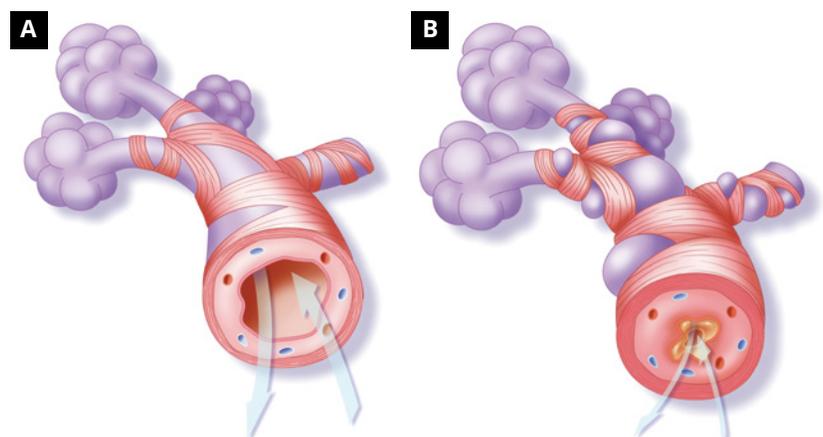


Figure 2 Asthma causes the bronchioles to become narrow: (A) normal airway and (B) asthmatic airway.



Figure 3 Ventolin is commonly used to control asthma attacks (blue). It can be inhaled through the mouth and nose. Other medications help prevent asthma (red).

Emphysema

Smoking involves breathing toxic chemicals and tar into the lungs (Figure 4). The tar is thick and sticky like honey, covering the inside of the alveoli and stopping oxygen from moving into the blood. The toxic chemicals kill the cells, destroying the alveolar sacs, and travel through the blood, causing problems in other parts of the body.

Emphysema is a disease that is caused by the inability of the collapsed alveoli to move air in and out. A person with emphysema struggles to breathe in enough oxygen to walk even 20 metres.

emphysema a disease of the respiratory system caused by broken down alveoli in the lungs

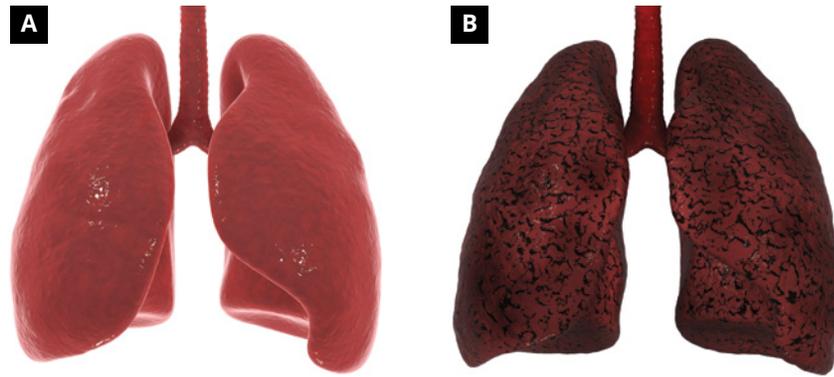


Figure 4 (A) Healthy lungs (B) A smoker's lungs

Pneumonia

pneumonia a disease caused by bacterial or viral growth in the lungs

Pneumonia is caused by a bacterial or viral infection in the lungs. The alveoli in the lungs fill with bacteria, pus and fluid. This prevents air from moving into the lungs. Anyone can contract pneumonia, but it tends to be most common in young children and the elderly. A short course of antibiotics (drugs that kill bacteria) can clear the lungs again, allowing the person to breathe.

Check your learning 8.10



Check your learning 8.10

Retrieve

- 1 **Recall** the cause of:
 - a a cough
 - b a sneeze.

Comprehend

- 2 **Describe** what happens in the lungs during an asthma attack.
- 3 **Describe** one health risk people take with their lungs and the consequences of this risk.

Analyse

- 4 **Contrast** (the differences between) the changes in the lungs for emphysema and pneumonia.

Apply

- 5 **Infer** why people with pneumonia feel tired all the time.
- 6 **Investigate** why it is physically impossible to keep your eyes open during a sneeze.

Skills builder: Problem solving

- 7 Some health experts argue that cigarettes should be banned given the known health risks. **Evaluate** this solution in small groups before bringing your group's thoughts to a class discussion. (THINK: Were there differing opinions? Why were their opinions different? Could a consensus be reached?)

Lesson 8.11

The circulatory system carries substances around the body

Key ideas

- The heart pumps the blood around the body.
- Blood contains red blood cells, white blood cells, platelets, plasma, nutrients and waste.
- Arteries carry blood away from the heart and veins carry blood back to the heart.
- Capillaries are thin-walled blood vessels where nutrients and waste move in and out of the blood.



Learning intentions and success criteria



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

The circulatory system

The role of the **circulatory system** (Figure 1) is to transport oxygen and nutrients (including glucose for cellular respiration) to all cells in the body, and to remove all waste products (including carbon dioxide). This occurs through the movement of blood from the heart to every part of the body, and back again.

circulatory system organ system that moves blood and lymph around the body, transporting oxygen and nutrients to the cells and removing waste products from the cells

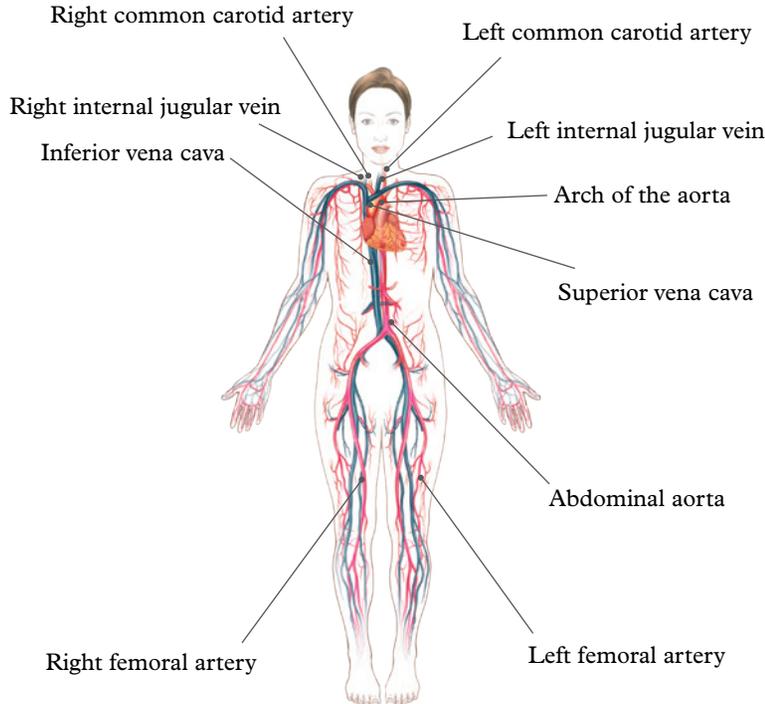


Figure 1 The structure of the circulatory system with key parts labelled.

The heart

heart organ that pumps blood around the body

atrium smaller, upper chamber of the heart (plural: atria)

ventricle large, lower chamber of the heart

aorta the major artery that carries oxygenated blood from the heart and divides into smaller arteries around the body

valve structure in the heart and veins that stops blood flowing backwards

blood connective tissue that carries oxygen, nutrients and waste around the body

red blood cell cell in the blood that carries oxygen around the body

plasma a straw-coloured fluid that forms part of the blood

white blood cell an immune system cell that destroys pathogens

platelet small disc-like cell in blood that is involved in forming clots

blood vessel a tube or vessel that carries blood around the body

artery a thick, muscular-walled blood vessel that carries blood away from the heart under pressure

arteriole smaller artery

capillary a blood vessel with a wall only one cell thick; allows substances to pass into and out of the blood

The **heart** is a large two-part pump about the size of your fist. It is made of four chambers: two **atria** at the top and two **ventricles** at the bottom. The ventricle on the right of the heart pumps blood to the lungs to “drop off” carbon dioxide and “pick up” oxygen. This oxygenated blood moves back to the left atrium and on to the left ventricle. The more muscular left ventricle pumps blood out through the **aorta** at the top of the heart and around the body (Figure 2).

Valves are like small gates that prevent the blood from moving backwards. They keep the blood moving in the right direction until it gets back to the right atrium of the heart.

Blood is connective tissue containing important cells, liquid and dissolved substances such as nutrients and waste.

- Oxygen is carried by the **red blood cells** from the lungs to all the cells of the body. Carbon dioxide is dissolved in the **plasma** (the straw-coloured liquid at the top of centrifuged blood).
- Nutrients and wastes are also dissolved in the plasma for transport to and from cells.
- **White blood cells** protect the body against infection and disease. The white blood cells use the blood to travel to the site of infection where they kill the pathogens (e.g. bacteria and viruses) causing the infection.
- **Platelets** are small cell-like packages that burst when exposed to breaks in the blood vessels. They clump together to fill the hole and glue the edges together.

Blood vessels

Blood travels through tubes called **blood vessels** (Figure 3). Blood vessels have different sizes and structures depending on the amount of blood they need to carry as well as the speed of the blood flow and whether the blood is picking up or dropping off substances.

Arteries are the largest blood vessels. Arteries have thick, muscular walls to cope with high pressure and to help pass blood along. Arteries carry blood away from the heart. The blood is at a higher pressure near the heart because it has just been pumped. Arteries branch into **arterioles** (smaller arteries).

Capillaries are possibly the most important of the blood vessels. Their walls are only one cell thick to allow substances to easily pass in and out of the blood. Capillaries connect the arteries and veins. They are sometimes referred to as a capillary bed when they are in large numbers surrounding an organ (Figure 4).

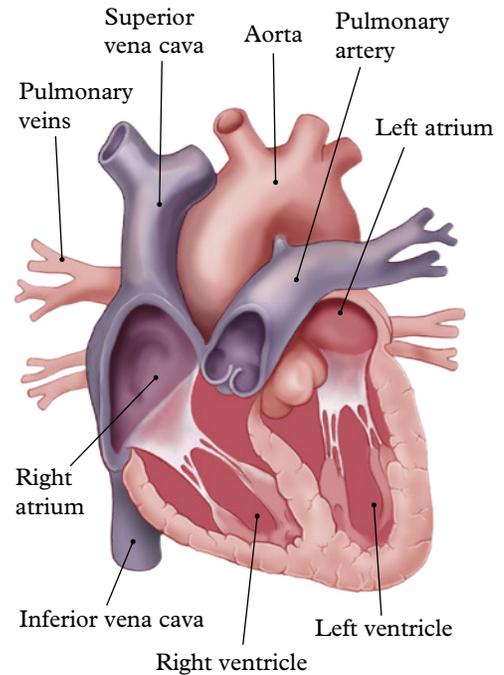


Figure 2 The heart and the major blood vessels that travel to and from the heart. The diagram uses a common convention that shows the veins in red and the arteries in blue.

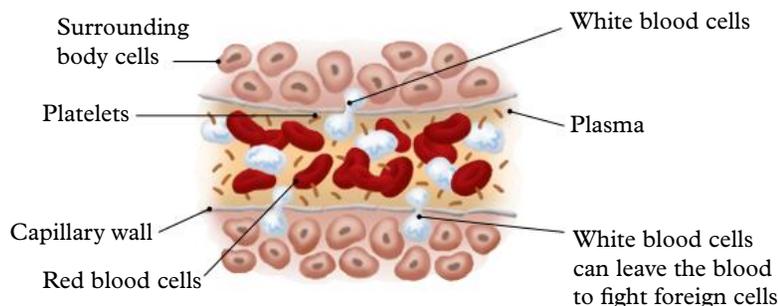


Figure 3 A cross-section of a blood vessel.

Veins carry blood back to the heart to be pumped elsewhere. These vessels are similar in size to the arteries, but only have a small amount of muscle in their walls. To avoid any blood going backwards due to a lack of pressure, veins contain one-way valves.

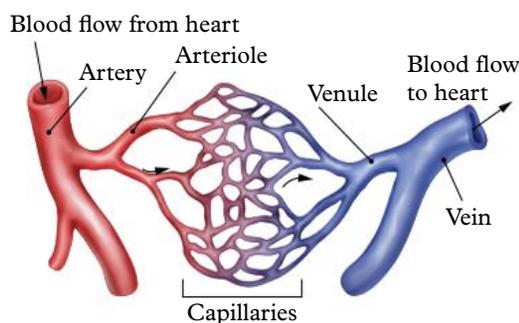


Figure 4 A capillary bed, showing the relationship between arteries, veins and capillaries.

vein a thin-walled blood vessel that carries blood back to the heart

Other circulatory systems

Not all organisms have large organised circulatory systems. Smaller organisms such as hydra (1 to 2 mm long) spend their life surrounded by water. They do not have a heart or blood vessels. Instead, gases diffuse in and out of their cells. Nutrients are partially digested in their small tube-like stomach, which has one opening, and are absorbed directly into the cells.

Insects have open-ended tubes that take in circulatory fluid at the back of the organism and small heart-like pumps that push the fluid forward to the brain. The fluid then leaves the tube and moves freely around the open cavity until it enters the open-ended tube once more. Other organisms, such as the octopus, have three hearts to control the movement of all the substances in their body.

Check your learning 8.11



Check your learning 8.11

Retrieve

- 1 Recall** the function of red blood cells, white blood cells and platelets.

Comprehend

- 2 Use** diagrams to **represent** how the three blood vessel types differ in their structure and function.

Analyse

- 3 Use** Figure 4 to:
 - a describe** the path a red blood cell takes as it moves through the body from the heart and visits two parts of the body
 - b rewrite** the pathway and **identify** the names of the veins and the arteries involved.

- 4 **Identify** the body system that supplies the nutrients that the circulatory system moves around the body.

Apply

- 5 Instead of the blood travelling directly from the lungs to the rest of the body, the blood returns to the heart first. **Discuss** one advantage of the blood returning to the heart before moving around the body.

Skills builder: Questioning and predicting

- 6 **Examine** Figure 3, a cross-section of a blood vessel.
- a List** three observations about Figure 3.
- b Develop** one scientific question based on one of your observations. (THINK: Make sure your question is specific and can be investigated.)

Lesson 8.12

Experiment: Heart dissection

Caution

Refer to Lesson 1.8 Skills lab: Dissecting a chicken wing (page 29) for dissection skills and safety guidelines.

Aim

To explore the structure and function of a heart

Materials

- Sheep, cow, ox or pig heart
- Safety gear
- Newspaper
- Dissection board
- Dissection tools

Method

- 1 Examine the outside of the heart and identify the left and right sides (Figure 1).

Your fingers will work better than a probe for this.

- 2 Use your fingers to feel the right side of the heart. Compare the thickness of the right and left sides (Figure 2). Feel the muscle in the centre of the heart.
- 3 Using a scalpel, cut open the right atrium and right ventricle. Pull back the wall and look inside to see the atrium and the ventricle. The ventricle is the chamber closest to the pointed end of the heart. The white tendons hold the valves in place.
- 4 Identify the arteries (Figure 3), and push a dissecting probe or your finger out through the artery leading from the right ventricle.
- 5 Cut open the left side of the heart. Locate the atrium, ventricle and tendons holding the valves.
- 6 Push a dissecting probe or your finger out through the artery leading from the left ventricle (Figure 4).



Figure 1 Identify the right and left sides of the heart.



Figure 2 Compare the thicknesses of the right and left ventricles.

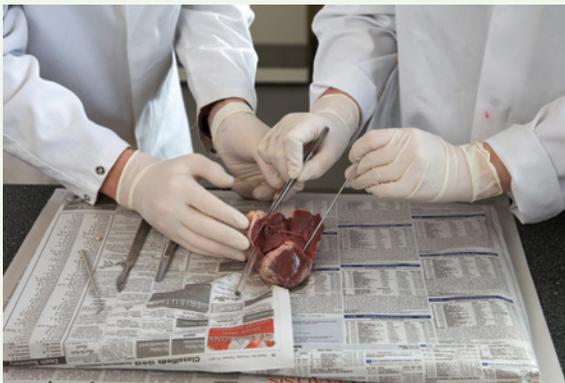


Figure 3 Use the dissecting probe to identify the arteries.



Figure 4 Identify the artery leaving the left ventricle.

Results

Record your observations using labelled diagrams.

Discussion

- 1 **Identify** the name of the artery from step 4.
- 2 **Identify** the name of the artery from step 6.
- 3 **Compare** the thickness of the artery wall with the thickness of a vein wall.
- 4 **Compare** the thickness of ventricle walls with the thickness of arterial walls.
- 5 **Explain** the difference between the left and right ventricle walls.

Conclusion

Explain what you know about the structure and function of the heart.

Lesson 8.13

Sometimes things go wrong with the circulatory system

Key ideas

- Damaged valves can affect the one-way direction of blood flow.
- Atherosclerosis describes the narrowing of the blood vessels as a result of plaque.
- Coronary heart disease is caused by blockages in the blood vessels in the heart muscle.
- Pericarditis occurs when the pericardium sac surrounding the heart becomes infected.



Learning intentions
and success criteria

Valve disease

The heart has a series of valves that prevent the blood from flowing backwards (Figure 1). When the atrium contracts, the ventricle fills with blood. The valve between the atrium and ventricle closes (causing a “lub” sound), which prevents the blood from flowing backwards. When the ventricle contracts, the blood is forced to flow out of the heart and into the aorta. The valve between the ventricle and the aorta then closes (the “dub” sound) keeping the blood in the large artery. Now the blood can only enter from the veins again. This is what creates the “lub-dub” sound you hear when you listen to your heart.

Sometimes these valves become damaged. They may become narrowed from scarring (stenosis), leak (regurgitation or insufficiency) or not close properly (prolapse).

This prevents the blood from flowing properly around the body. As a result, less oxygen and fewer nutrients get carried to the cells for energy. This makes the person very tired all the time.

Atherosclerosis

Atherosclerosis is a disease that results from the narrowing of the blood vessels. This narrowing is caused by a build-up of plaque on the inside of the arteries and veins

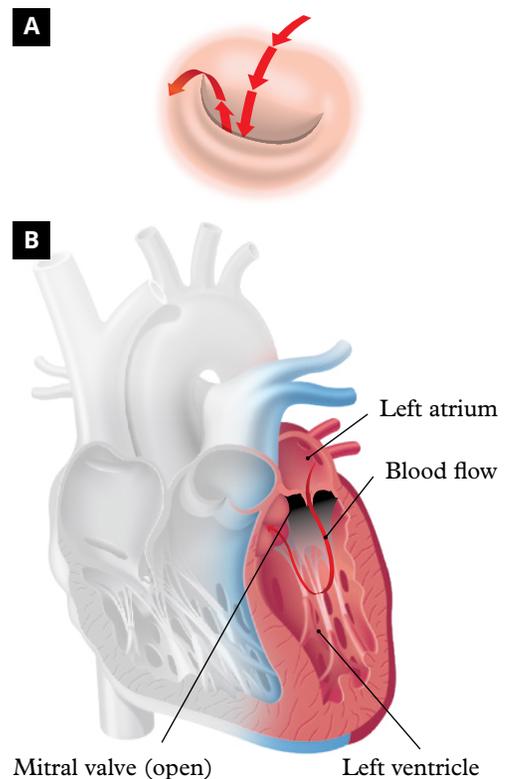


Figure 1 (A) The heart valve opens to allow blood to flow from the atrium to the ventricle. (B) Closing of the valve prevents the backflow of blood so that it can be pumped effectively around the body.

(Figure 2). Plaque consists of fat, cholesterol and other substances normally found in the blood. Layers of plaque are laid down over time, eventually hardening and restricting the blood flow. The symptoms depend on the part of the body affected by the narrowed blood vessel. If the blood vessel is in the heart, then a heart attack will follow.

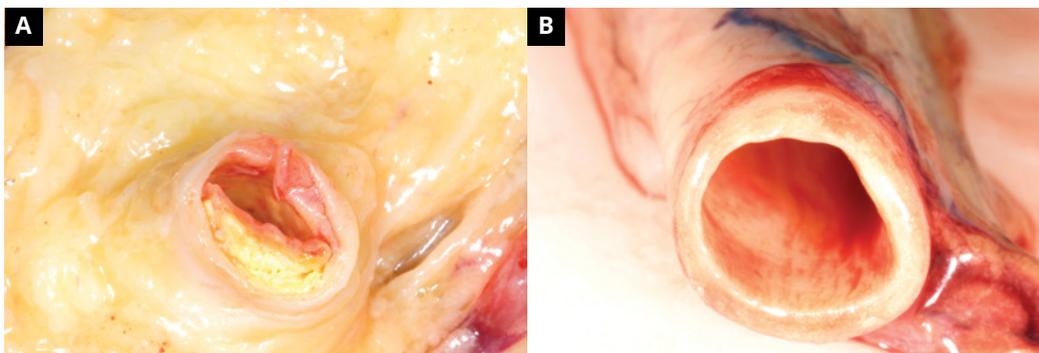


Figure 2 (A) A blocked artery and (B) an unblocked artery

Coronary heart disease

A heart attack is usually caused by coronary heart disease, which is fatty deposits blocking important blood vessels in the heart. “Coronary” refers to the heart’s own blood vessels. The “attack” occurs when the vessels become completely blocked or when a bit of the fatty deposit breaks off and travels into the heart. Heart muscle cells may be killed in the process (Figure 3).

So how can you keep your heart healthy? Eating less fatty food and more fibre is a really good start, but it’s not the only thing you can do.

The heart is a muscle and, like all muscles, it needs exercise to keep it strong. Regular exercise is all it needs (Figure 4). In people who are overweight or who smoke cigarettes, the heart needs to work much harder to do the same job. This is stressful for the heart. Elite athletes work their bodies very hard, so they need to make sure they have their hearts checked regularly by a doctor.

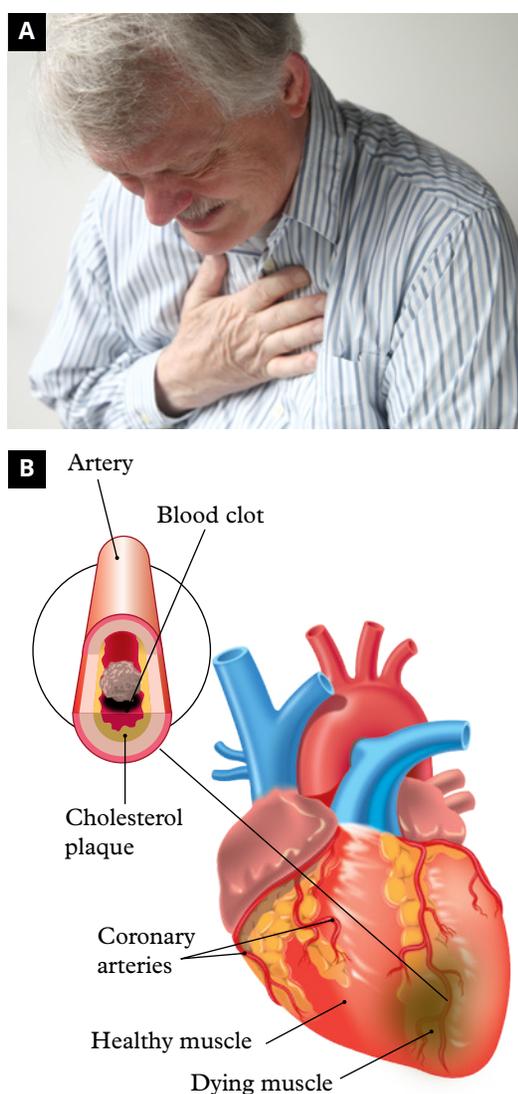


Figure 3 (A) Chest pain is often caused by (B) a blockage in the heart’s own blood vessels.



Figure 4 Exercise can help keep the heart healthy and strong.

Pericarditis

The pericardium is the thin sac that surrounds the heart and helps it move easily when it beats (Figure 5). Sometimes this thin layer of cells can become infected by bacteria, causing the sac to fill with fluid – a condition known as pericarditis. As a result, the heart cannot beat properly. This restricts the heart from filling properly with blood. Antibiotics are needed to help kill the bacteria so that the heart can start functioning again.

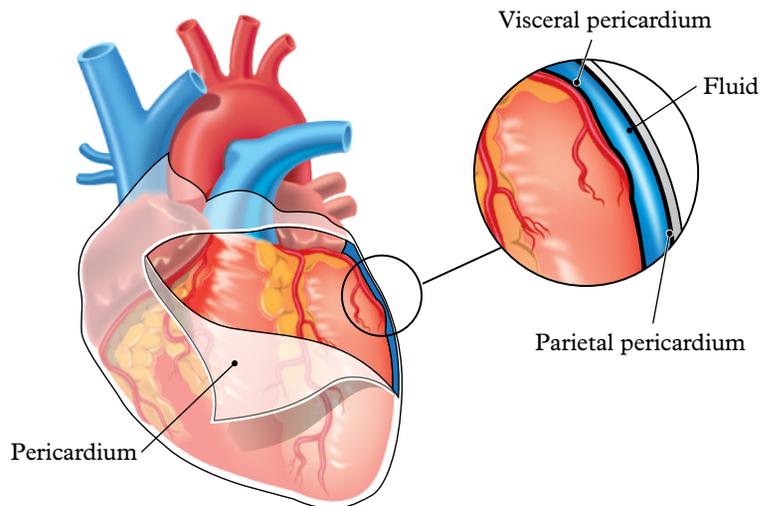


Figure 5 The pericardium reduces friction in a beating heart.

Check your learning 8.13



Check your learning 8.13

Retrieve

- 1 **Identify** what causes the “lub-dub” sound you hear when you listen to your heart.
- 2 **Recall** the cause of the following valve conditions:
 - a stenosis
 - b regurgitation or insufficiency
 - c prolapse.
- 3 **Recall** the function of the pericardium sac that surrounds the heart.

- 4 **Identify** two things you could do to ensure your circulatory system stays healthy.

Comprehend

- 5 **Explain** the link between atherosclerosis and coronary heart disease.
- 6 **Explain** why the heart muscle becomes damaged during a heart attack.
- 7 **Describe** how the function of the pericardium is affected when it fills with fluid during an infection.

Lesson 8.14

The excretory system removes waste

Key ideas

- The liver helps rid the body of nitrogen.
- The kidneys filter blood to remove waste, which is then excreted as urine.
- Sweating releases waste products from the body through the skin.



Learning intentions and success criteria



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

Introduction

The main organs of the **excretory system** are the kidneys, ureter, bladder, urethra, liver and skin (Figure 1). Lungs are also an important part of the excretory system because they **excrete** (remove) carbon dioxide, a waste product of cellular respiration.

All of the nutrients that are carried through the body by the circulatory system are used by cells. Cells undergo a series of chemical reactions called **metabolism**. Some of the chemical products produced during metabolism are toxic and need to be excreted from the body. Water is also important for controlling the waste because it can dilute harmful substances and their effects. It also moves substances quickly and is essential for keeping our body temperature just right.

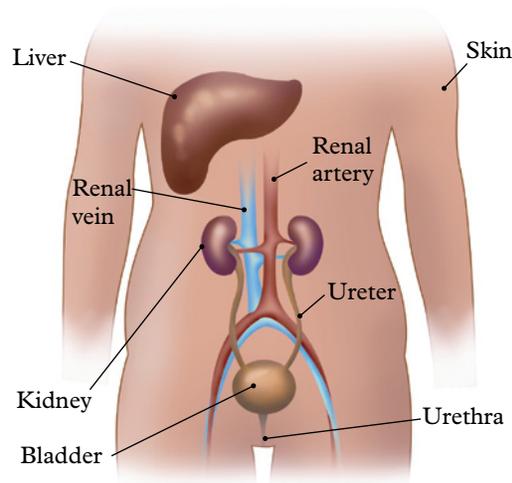


Figure 1 The structure of the excretory system with key parts labelled

excretory system organ system that processes and removes waste products from the body

excrete remove waste from the body

metabolism all the chemical reactions in the body

The liver

Molecules containing nitrogen are among the most toxic products in your body. When your body digests nitrogen-containing proteins, it breaks them down into smaller molecules called **amino acids**. The body cannot store the amino acids that it doesn't use immediately. Your liver breaks down these amino acids (and many other chemicals) into less dangerous substances. When the liver breaks down the nitrogen-containing amino acids, it produces a very toxic substance called **ammonia**. The liver then uses energy to change the ammonia into a safer substance called **urea**, which is also filtered by the kidneys for removal.

amino acid small molecule that makes up proteins

ammonia a chemical waste product (NH_3)

urea a chemical waste product produced in the body and removed in urine

The kidneys

You have two kidneys, one on each side of your lower back. They are approximately 10 cm long. Blood that is carrying waste products enters your kidneys to be filtered by the million tiny structures in the kidney called **nephrons**. At the end of this filtering process there are two main outputs: clean blood, which is recirculated around the body, and urine, which is excreted from the body.

nephron a tiny structure in the kidneys that filters the blood

The skin

The skin is the largest organ in the excretory system. The skin releases sweat, which contains waste products such as heat, salts and urea. If you lick your upper lip after exercise, you will taste the salt in your sweat.

Check your learning 8.14



Check your learning 8.14

Retrieve

- 1 **Recall** how waste products in the body are created.
- 2 **Name** three organs of the excretory system.

Comprehend

- 3 **Explain** how the liver and kidneys work together.

Apply

- 4 **Predict** the consequences of not drinking enough water. **State** how you would feel

if you didn't drink enough water and **explain** why.

Skills builder: Questioning and predicting

- 5 A scientist was conducting a study on the impact of exercise on the concentration of urine. They tested a group of marathon runners and a group of people who did not exercise. **Predict** what effect running a marathon would have on the quantity and concentration of urine. (THINK: What do you know about how the kidney works?)

Lesson 8.15

Experiment: Kidney dissection

Caution

Refer to Lesson 1.8 Skills lab: Dissecting a chicken wing (page 29) for dissection skills and safety guidelines.

Aim

To investigate the structure of a mammalian kidney and explore the various functions of the different parts

Materials

- Sheep's kidney
- Safety gear
- Newspaper
- Dissection board
- Dissection tools

Method

- 1 Place the whole kidney on the board and identify as many parts as possible.
- 2 Draw a labelled diagram.
- 3 Cut the kidney in half longitudinally (lengthways; Figure 1).
- 4 Draw a labelled diagram. Identify any key structures that you can see.

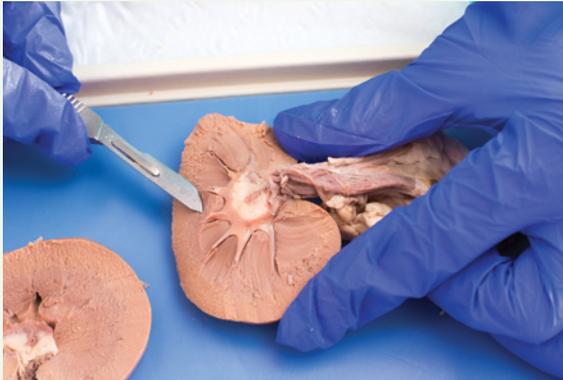


Figure 1 Sheep kidney cut in half longitudinally

Results

Record your observations using labelled diagrams.

Discussion

- 1 **Compare** the colour of the kidney on the outside with the colour on the inside.
- 2 The colour of the kidney gives an indication of the amount of waste products it contains. **Use** your answer to question 1 to **identify** whether the outside or inside of the kidney produces the most waste.
- 3 **Explain** why you cannot see any nephrons with your naked eye.
- 4 The medulla – the middle section of the kidney – has a stripy appearance. This is due to the collecting ducts heading in the same direction. **Identify** the function of the collecting ducts.

Conclusion

Describe what you know about the form and function of a mammalian kidney.

Lesson 8.16

Science as a human endeavour: Organs can be transplanted

Introduction

In this module, you have learnt that sometimes things go wrong with body systems. Treatments are available to treat many of the malfunctions, but sometimes these treatments do not improve a person's condition enough. In these cases, cell, tissue or organ transplantation might be considered.

Organ transplantation

During an **organ transplant**, a diseased organ is taken from a person's body and replaced with a healthy organ from another person's body. The person receiving the organ is called the **recipient** and the person giving the organ is called the **donor**. The heart, lungs, kidneys, liver, stomach, pancreas and intestines can all be transplanted.

organ transplant the replacement of a damaged organ with a healthy organ from an organ donor

recipient the person receiving a donated organ

donor the person giving an organ; usually deceased, sometimes living

ethics the series of rules that determines what is right and what is wrong

Ethical issues

Organ transplantation can be an effective solution to a serious problem, but it can challenge people's ethics. **Ethics** is the series of rules that determines what is right and what is wrong. Ethical issues associated with organ transplantation can arise at many different stages of the transplantation process, and they can involve recipients, donors, families and medical practitioners.

There are more people waiting to receive donated organs than there are organs available. Many people on the waiting list will not survive unless they receive a transplant. In line with ethical principles, the decision to offer one of these people an organ must not be affected by the potential recipient's race, religion, gender, social status, disability or age. Instead, the decision relies on how well the organ matches the recipient, how long the person has been waiting for a transplant, how urgent the transplant is, whether a good outcome is likely and whether the organ can be made available to the person in time.

Most commonly, organs are donated by people who are brain dead. This means that their brain is no longer able to keep their hearts and lungs functioning. Many people decide that they would be willing to offer their organs for donation and record this wish with the Australian Organ Donor Register before they become ill or have an accident. When a person dies, however, the family of the donor must also give their permission for organs to be removed. Ethical issues arise when the donor's family disagrees with the donor's wishes.

Kidneys and pieces of the liver can be donated by living people. Ethical issues raised by living donation are explored in this lesson's "Test your skills and capabilities" section.

Test your skills and capabilities

Consider the following ethical issue raised by organ transplantation and answer the questions. At each step, justify your answer.

A 15-year-old wants to donate one of their two kidneys to a sick school friend. The family of the potential donor does not want their child to put themselves at risk by donating the kidney.

To donate a kidney, the potential donor must undergo an operation where the kidney is removed through a cut in their side abdominal muscles that can affect the way they move for several weeks.

- 1 **Explain** why the potential donor may want to donate their kidney.
- 2 **Describe** how your life could be affected if you were the potential donor.
- 3 **Explain** why the family of the potential donor may not want their child to donate a kidney.
- 4 The recipient of the donated organ wants to give a gift to the potential donor. **Explain** why this could be described as selling the organ. **Consider** whether selling the organ is right or wrong.
- 5 **Evaluate** if the potential donor should give their kidney to their friend by considering how each person (the potential donor and their family and the recipient and their family) would be affected by:
 - a the kidney being donated
 - b the kidney not being donated.**Decide** which of these reasons is the most important.



Figure 1 When kidneys are unable to clean the blood, patients need to spend 6 hours a day, 3 times a week in dialysis.

Lesson 8.17

Plants have tissues and organs



Learning intentions and success criteria



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

Key ideas

- Plants are multicellular organisms that have specialised organs to help move water and nutrients around the plant.
- Roots use osmosis to absorb water from the soil.
- Stems transport water and nutrients around the plant.
- Leaves exchange gases and produce the sugars needed for energy.

root a plant organ involved in absorbing nutrients and water

osmosis the movement of water through a selective membrane from an area of low salt concentration to an area of high salt concentration; occurs in root cells

stem an organ that transports materials around a plant

vascular bundle a group of tubes in plant stems that carry water and nutrients around the plant

xylem the vascular tissue in plants that carries water from the roots to the rest of the plant

transpiration the process of water evaporating from plant leaves; causes water to move up through the plant from the roots

phloem the vascular tissue in plant stems that carries sugars around the plant

Roots

The **roots** of a plant are an organ that helps anchor a plant to the soil and allows it to absorb nutrients and water. Most root cells have a series of small hairs to increase the amount of surface area that can take in the water. First, the roots take mineral salts from the soil and store them in their cells. This makes the inside of the roots more “salty” than the soil. Water molecules are attracted to the mineral salts in the root cells. As a result, water moves through the root cell membrane and into the plant. This process is called **osmosis** (Figure 1).

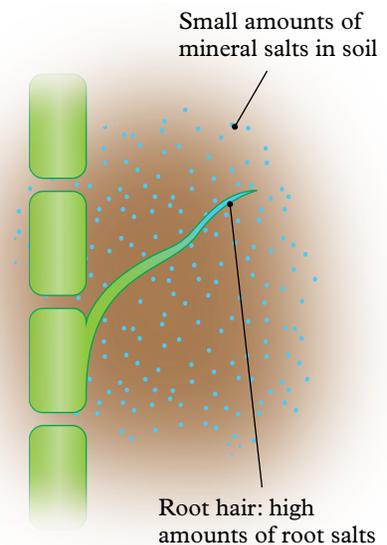


Figure 1 Water moves into the root hair by osmosis

Stem

The **stem** of a plant is the organ responsible for transporting water and nutrients between the leaves and roots. There are two main structures in the **vascular bundle** of the stem.

The **xylem** (*zi-lem*) is a straw-like structure that moves the water from the roots to the top of the plant. Water molecules like to stick together; you can see this in the way a drop of water forms a spherical shape. When water evaporates from the leaves at the top of a plant (**transpiration**), other water molecules move up to replace it. This can pull water molecules from the roots to the top of a tree.

The **phloem** (*flo-em*) is another network of cells in the plant stem, it transports the glucose (sugar) produced in the leaves to other parts of the plant. All plant cells need these sugars to produce the energy they need to stay alive.

Figure 2 shows the structure of a plant stem.

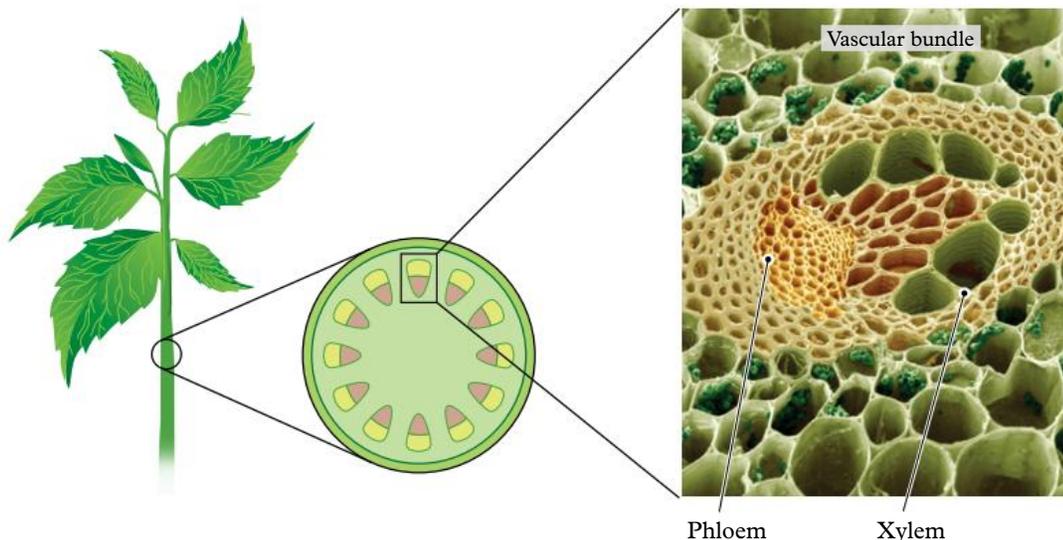


Figure 2 The structure of the stem of a plant

Leaves

The leaves of a plant are involved in exchanging gases. A plant needs carbon dioxide to produce the sugars it needs for energy. The carbon dioxide moves in and out of cells through small openings in the leaves called **stomata** (singular “stoma”) (Figure 3).

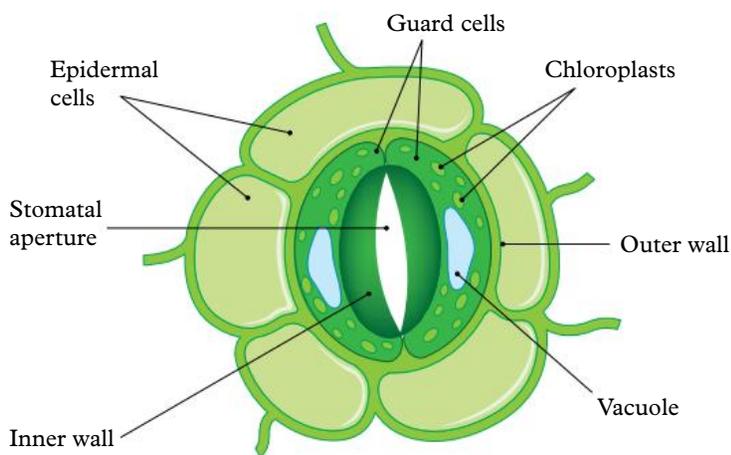


Figure 3 The structure of a plant stoma

A plant stoma has two specialised **guard cells** that can grow longer, forcing a hole to appear between them. This allows air to move in and out of the leaf. When it is too hot, the plant loses more water than the roots can replace. When the plant loses water, the guard cells become smaller, closing the plant’s stomata, and preventing further water loss.

When the sun is shining, the leaves convert the water from the roots and the carbon dioxide from the stomata into glucose and oxygen in a process called **photosynthesis**. Photosynthesis cannot happen without the help of **chlorophyll** – a green pigment in the leaves of plants. Chlorophyll is the reason most plants are green.

During autumn, some leaves lose their chlorophyll. This allows the other colours present in the leaves (reds, oranges and yellows) to appear (Figure 4).



Figure 4 Autumn leaves come in a range of colours

stomata tiny pores in the leaves and stems of plants that allow gas exchange between a plant’s cells and the environment (singular: stoma)

guard cell cell that opens and closes the stomata in the leaves and stems of plants to control gas exchange and water loss; found in pairs, with one guard cell on either side of each stoma

photosynthesis chemical process plants use to make glucose and oxygen from carbon dioxide and water

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

Check your learning 8.17



Check your learning 8.17

Retrieve

- 1 **Define** the term “osmosis”.

Comprehend

- 2 **Name** three organs found in most plants and **describe** their function (what they do).
- 3 **Explain** the role of stomata in photosynthesis.

Analyse

- 4 **Contrast** (the differences between) xylem and phloem.
- 5 **Identify** the system in humans that provides the same function as a plant stem.

Apply

- 6 Some florists sell blue orchids that are artificially coloured by putting white orchids in blue water (Figure 5). **Use** your knowledge of plant systems to



Figure 5 Artificially coloured orchids

determine how these orchids may have become blue.

Skills builder: Planning investigations

- 7 A student was asked to investigate the rate that tomato plants grow when they receive different amounts of water. They set up three pots and planted a tomato plant in each of them. Each day for a month, they watered pot 1 with 20 mL of water, pot 2 with 500 mL of water and pot 3 with 1 litre of water.
 - a **Identify** the independent and dependent variables in this investigation. (THINK: What factor is being changed, and what is being measured?)
 - b **Identify** an additional two variables that might need to be controlled in this investigation. (THINK: What might influence the results?)

Lesson 8.18

Challenge: Locating the xylem and phloem in a stem

Aim

To identify parts of the circulatory system of a plant

What you need:

- 500 mL beaker
- Water

- Blue or red food colouring
- Fresh stick of celery
- Scalpel
- Cutting board
- Permanent marker
- Magnifying glass

What to do:

- 1 Add 200 mL of water to the beaker.
- 2 Add 15 drops of food colouring to the water.
- 3 Cut the bottom 10 cm off the celery.
- 4 Place the top half of the celery in the beaker of coloured water.
- 5 Mark the water level with a permanent marker. Leave for two to three days.
- 6 Remove the celery from the water and use the scalpel to cut a transverse (horizontal) section of the celery stalk.
- 7 Locate the pathway by which the coloured water moved through the celery. Use a magnifying glass to observe the structures in the celery more closely.
- 8 Draw a labelled diagram of the celery cross-section.

Questions

- 1 **Describe** how the amount of water in the beaker changed after two to three days.
- 2 **Use** the term “transpiration” to **explain** your answer to the question 1.
- 3 **Identify** the name of the pathway that moved the coloured water through the celery.



Figure 1 (A) As water evaporates from the leaves, the coloured water replaces it. (B) The dye marks the path the water takes from the roots on a transverse cut in a celery stalk.

- 4 **Compare** the circulatory system you observed with the circulatory system in humans.

Lesson 8.19

Challenge: Modelling root cells

Aim

To model root cells of a plant

What you need:

- 15 cm dialysis tubing
- Water
- 10 mL measuring cylinder
- 5 mL of 2% starch solution
- Scales
- 200 mL beaker

What to do:

- 1 Soften the dialysis tubing by running water over the outside of it.
- 2 Tie a knot in one end of the tubing.
- 3 Add 5 mL of 2% starch solution to the tubing.
- 4 Seal the open end by tying a knot.
- 5 Wash the outside of the tubing with water.
- 6 Pat dry the outside of the tubing and use scales to determine its weight.
- 7 Place the tubing in the beaker. Add 100 mL water.
- 8 Leave overnight.
- 9 Remove the dialysis tubing from the water and carefully pat dry.
- 10 Determine the weight of the dialysis tubing.

Questions

- 1 **Contrast** the weight of the dialysis tube containing starch solution before and after soaking in water.
- 2 **Explain** the change in the weight of the tubing.
- 3 **Define** the term “osmosis”.
- 4 Use the term “osmosis” to **explain** how the dialysis tubing is similar to the cells in a plant root.
- 5 This challenge assumes that the dialysis tubing functions like the membrane and wall of a plant cell. **Describe** one way the dialysis tubing is not like a plant cell membrane or cell wall.

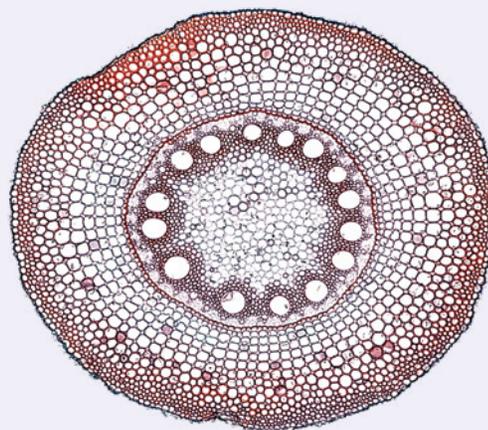


Figure 1 Cross section of a plant root under the microscope, showing cells in the root

Lesson 8.20

Experiment: Factors that affect transpiration

Aim

To determine the factors that affect the transpiration of water from plants

Materials

- 250 mL measuring cylinders
- Water
- Fresh celery stalks

Method

- 1 Add 100 mL of water to one of the measuring cylinders.
- 2 Discard the bottom 10 cm of a celery stalk and trim so that the end of it fits into the measuring cylinder.
- 3 Place the celery in the measuring cylinder (cut edge in the water, leaves facing up).
- 4 Mark the water level with a permanent marker. Leave for two to three days at room temperature.
- 5 Measure how much water has been lost by the celery stick.

Inquiry: Choose one of the questions to investigate.

- What if the celery was placed in sunshine?
- What if the celery was placed in wind? (A fan may be used.)
- What if the celery was placed in a humid environment? (A large clear plastic bag may be placed over the celery.)

You will now design your own experiment to answer your inquiry question.

- 1 **Develop** a prediction or hypothesis for your inquiry.
- 2 **Identify** the (independent) variable that you will change from the first method.
- 3 **Identify** the (dependent) variable that you will measure and/or observe.
- 4 **Identify** two variables that you will need to control to ensure a reproducible test. **Describe** how you will control these variables.
- 5 **Develop** a method for your experiment. Write this method in your logbook.
- 6 **Construct** a table to record your results.
- 7 Show your teacher your planning (for approval) before starting your experiment.

Results

Record your observations and measurements in your table.

Discussion

- 1 **Define** the term “transpiration”.
- 2 **Identify** two factors that you expect to affect transpiration.
- 3 **Compare** your results to your prediction or hypothesis. Use evidence from your results to support your answer.
- 4 **Describe** how you could use your results to care for the plants in your garden.

Conclusion

Explain what you know about the factors that affect transpiration.

Lesson 8.21

Review: Surviving

Summary

Lesson 8.1 Systems are made up of cells, tissues and organs

- Anatomists study how the body works.
- Groups of cells that do a similar task are called tissues.
- Groups of tissues that work together are called organs.
- When groups of different organs work together, they are called a body system.

Lesson 8.2 The digestive system breaks down food

- Digestion is the process of breaking down food so that it can be used by the body.
- Physical digestion occurs when the body manually breaks apart food particles.
- Chemical digestion occurs when enzyme molecules break the chemical bonds in food.
- Nutrients are absorbed in the intestines.

Lesson 8.5 The digestive system varies between animals

- Carnivores are organisms that eat meat.
- Herbivores are organisms that eat plant material.
- Omnivores, including humans, eat a variety of foods.
- The structure of the digestive system can be used to predict the type of food an animal eats.

Lesson 8.6 Sometimes things go wrong with the digestive system

- Stomach ulcers are caused by the bacterium *Helicobacter pylori*.
- Gallstones stop bile leaving the gall bladder.
- People who do not have the enzymes to break down gluten have gluten intolerance.
- Constipation is a blockage in the large intestine.

Lesson 8.7 The respiratory system exchanges gases

- The respiratory system is the body system responsible for breathing.
- Air is inhaled down the trachea, the bronchi and the bronchioles into the alveolar sacs and eventually into our blood.
- Our lungs breathe in oxygen to be used by our cells for energy and breathe out carbon dioxide as waste.

Lesson 8.10 Sometimes things go wrong with the respiratory system

- Small irritations in the upper respiratory system make us cough or sneeze.
- Asthma causes the bronchi and bronchioles to become smaller.
- Emphysema is caused by broken-down alveoli, preventing oxygen from entering our blood.
- Pneumonia is an infection that fills our lungs with fluid and blocks the flow of gases.

Lesson 8.11 The circulatory system carries substances around the body

- The heart pumps the blood around the body.
- Blood contains red blood cells, white blood cells, platelets, plasma, nutrients and waste.
- Arteries carry blood away from the heart and veins carry blood back to the heart.
- Capillaries are thin-walled blood vessels where nutrients and waste move in and out of the blood.

Lesson 8.13 Sometimes things go wrong with the circulatory system

- Damaged valves can affect the one-way direction of blood flow.
- Atherosclerosis describes the narrowing of the blood vessels as a result of plaque.

- Coronary heart disease is caused by blockages in the blood vessels in the heart muscle.
- Pericarditis occurs when the pericardium sac surrounding the heart becomes infected.

Lesson 8.14 The excretory system removes waste

- The liver helps rid the body of nitrogen.
- The kidneys filter blood to remove waste, which is then excreted as urine.
- Sweating releases waste products from the body through the skin.

Review questions 8.21



Review questions

Retrieve

- 1 **Recall** where chemical digestion occurs in the body.
- 2 **Identify** the disease that is caused by a build-up of plaque.
 - A Pneumonia
 - B Valve disease
 - C Atherosclerosis
 - D Asthma
- 3 **Recall** which body system removes wastes.
 - A Respiratory system
 - B Circulatory system
 - C Digestive system
 - D Excretory system
- 4 **Name** the gaseous waste product removed by the lungs.
- 5 **Identify** four things that the circulatory system transports around your body.
- 6 **Recall** where photosynthesis occurs in a plant.
 - A Leaf
 - B Stem
 - C Root
 - D Xylem

Lesson 8.17 Plants have tissues and organs

- Plants are multicellular organisms that have specialised organs to help move water and nutrients around the plant.
- Roots use osmosis to absorb water from the soil.
- Stems transport water and nutrients around the plant.
- Leaves exchange gases and produce the sugars needed for energy.

Comprehend

- 7 **Describe** the function of each of the four types of tissue.
 - a **Identify** where peristalsis occurs in the body.
 - b **Explain** how it causes food to move.
- 8 **Explain** how the human digestive system can “feed” all the other systems.
- 9 **Describe** how the respiratory system and circulatory system work together.
- 10 **Explain** why muscles need more blood during exercise.
- 11 Some people have had the valves in their heart replaced with prosthetic valves, either made from synthetic materials or transplanted directly from a pig or cow heart. **Explain** why it is important that the valves in a heart are functioning properly.
- 12 **Describe** what is meant by an “ethical issue”.

Analyse

- 13 **Contrast** organ and system.
- 14 **Contrast** cellular respiration and breathing.
- 15 Plants do not have a digestive system. **Identify** which organ helps the plant supply all its energy needs.
- 16 **Infer** why you would not expect to find chloroplasts in the roots of a plant.

Apply

17 Propose a possible motivation for the earliest studies of the human body.

18 Both plants and animals need to transport water around the whole organism. **Compare** how water travels into and out of a plant, and how an animal drinks and excretes water.

Critical and creative thinking

19 Sweating is often considered to be a bad thing. **Evaluate** this statement (by describing why people sweat, what is in the sweat, what would happen if a person was unable to sweat and deciding if the statement is correct).

20 Mangrove trees get rid of excess waste salt through their leaves. This salt is often seen as white crystals on the underside of the leaves. **Determine** the human system that this represents in the plant. Identify which organ(s) has the same function in humans.

21 Human dissections have always been used to teach medical students anatomy, but they are less common now than in the past. In many cases, real dissection has been replaced with computer animations and models. **Compare** the advantages and disadvantages of human dissection.

22 Imagine it is your job to **develop** a “user’s manual” for one of the systems covered in this module.

a List ten “Frequently Asked Questions” (FAQs) to go at the front of the manual.

b Suggest an answer to as many of your questions as you can. If you don’t know the answer, write down where you could find the answer or who you could ask.

23 Use your understanding of the different systems of the human body to **create** a concept map detailing the connections between the systems. An example has been provided in Figure 1 to help you get started.

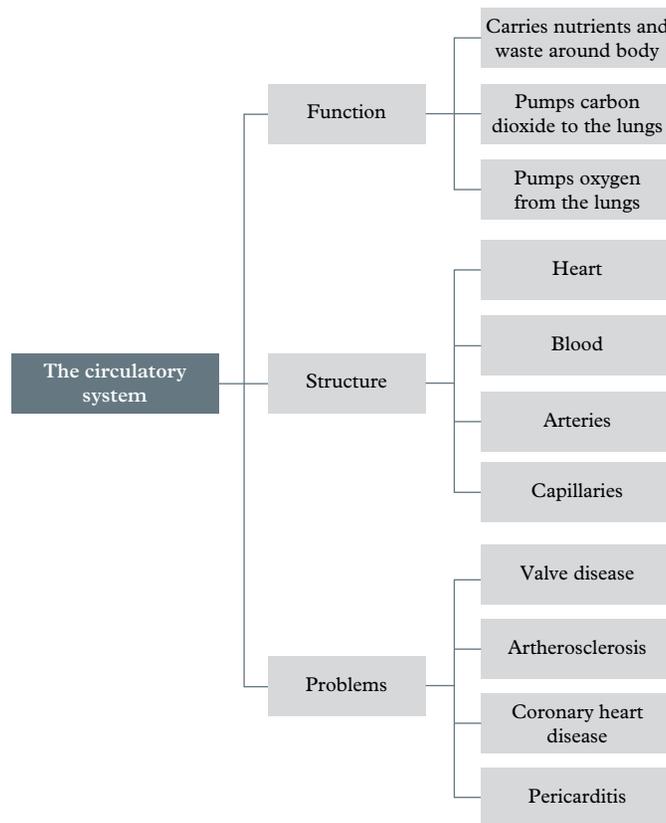


Figure 1 A concept map of the circulatory system

24 Presenting data to an audience can take many forms. An increasingly common way to present important information is in an infographic. Infographics are visual ways to present information so that the viewer can easily see what is important. This can be through the use of graphs, pictures and important figures. Many doctors’ waiting rooms have infographics to provide patients with information about possible diseases. An example is given in Figure 2.

Select one of the complications of the digestive system and plan an infographic that will pass the important information on to an audience.

a Consider why you are making the infographic. Is it to pass on information, or to get people to change their habits?

b Identify the key information about the disease and how it affects the digestive system. For example, what are the symptoms and how are people affected?

c Propose how the change in the digestive system causes the symptoms.

- d For people who have symptoms, **identify** what they should do. Should they look out for symptoms, change their diet or see a doctor?
- e **Create** an image that represents what is happening in the digestive system. **Consider** how much information needs to be passed on to the person reading the infographic. Try to keep the diagram simple.

- f Infographics use short phrases or sentences to pass on the key information. **Decide** the important information that you want people to remember and **summarise** it in short phrases or sentences. Carefully **consider** which words to use so that your audience will know what is important. Have you made the reason for making the infographic clear?

HEART ATTACK

WARNING SIGNS

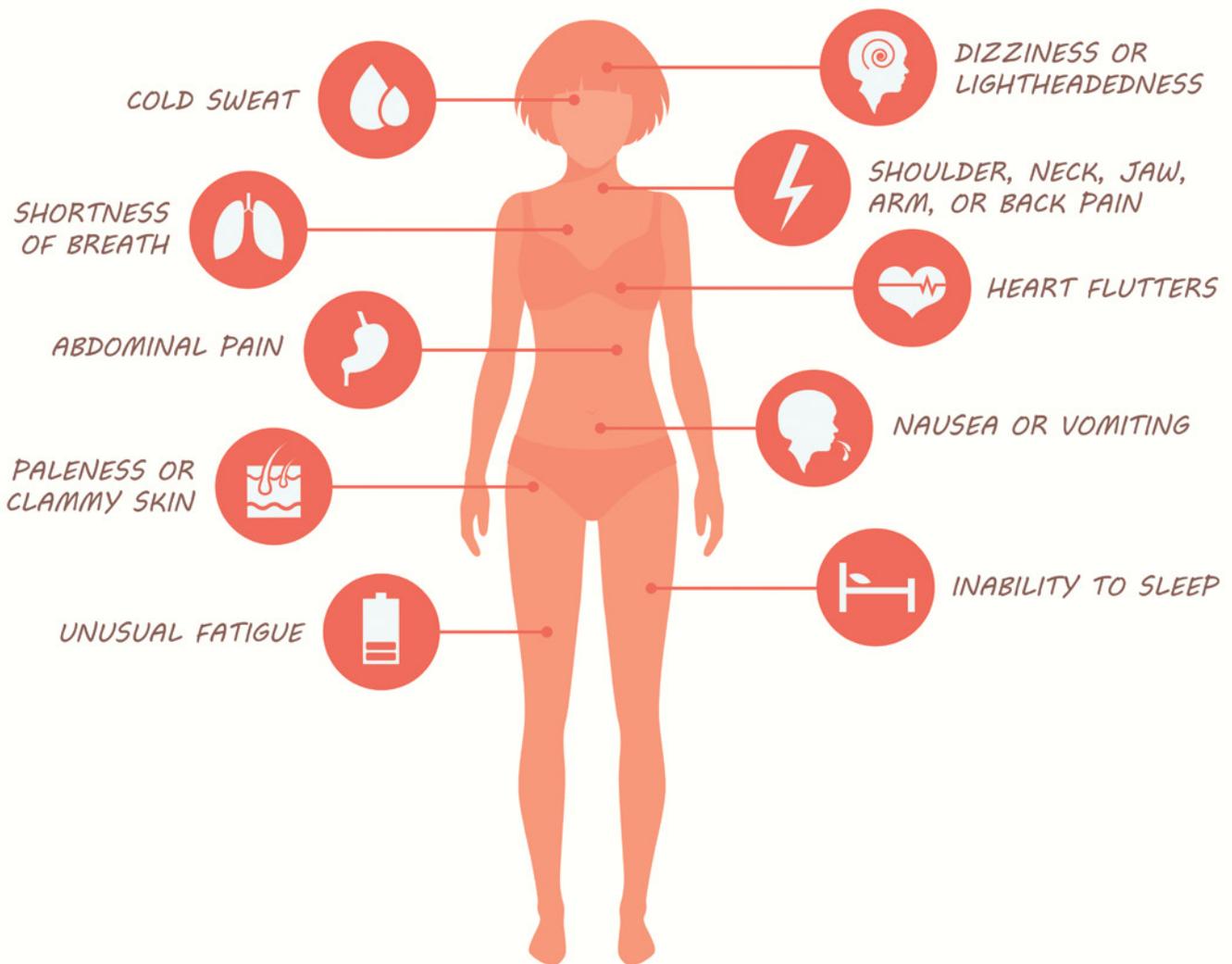


Figure 2 An infographic about heart attack warning signs

Social and ethical thinking

25 There are many diseases that affect the different organs in the body. Sometimes the only treatment available is an organ transplant. Replacement hearts and lungs can only be obtained from critically injured patients who have been confirmed as brain dead.

- Discuss** with a partner the advantages and disadvantages of organ donation.
- Explain** the reason why you would or would not sign up to be an organ donor.
- Explain** why you should let your family know of your decision.

Research

26 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.

Smoking bans

Many smoking bans, such as bans in workplaces, are related to the issue of second-hand smoke. This refers to how smoke affects people who are near a person who is smoking.

- **Investigate** the impacts of second-hand smoke.
- **Justify** your position on whether smoking bans should be extended or removed, or whether you think they are fine as they are now.



Figure 3 Smoking is banned in many public areas.

Artificial organs

When the organs in the body start to fail, their function needs to be replaced. This can be done through organ transplantation from another person, or the replacement of the organ with an artificial version.

- **Investigate** an artificial heart that is currently being used by surgeons.
- **Describe** the materials being used to construct the heart.
- **Explain** how the artificial heart is able to replace the original organ.
- **Create** a blog outlining why artificial hearts should be used by surgeons more often.

Non-vital organs

Some organs of the body (tonsils, appendix, gall bladder or reproductive organs) are considered non-essential, meaning that the loss of these organs will not cause death. This does not mean that these organs do not have important functions in the body.

- **Select** one of these organs to research.
- **Describe** the normal function of your chosen organ.
- **Describe** why this organ may be removed by a surgeon.
- **Describe** how a person without this organ may need to change their lifestyle or diet as a result of losing this organ.



Figure 4 A person who has repeated infections of their tonsils may need them removed.

Animal testing

Organoids are created when small groups of specialised cells become organised in a flask of nutrients in a lab. These small groups of tissues can be used to mimic almost any organ in the body.

- **Describe** how the development of organoids could affect the way scientists use animals to test their research.
- **Describe** the ethics of using organoids. **Explain** how this might change the way people view scientific research.
- **Compare** the cost of using live animals against the cost of producing and maintaining organoids.
- **Propose** an argument that could be presented to a research centre.

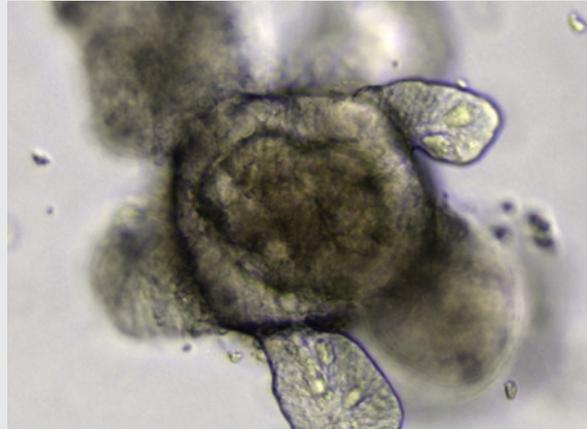


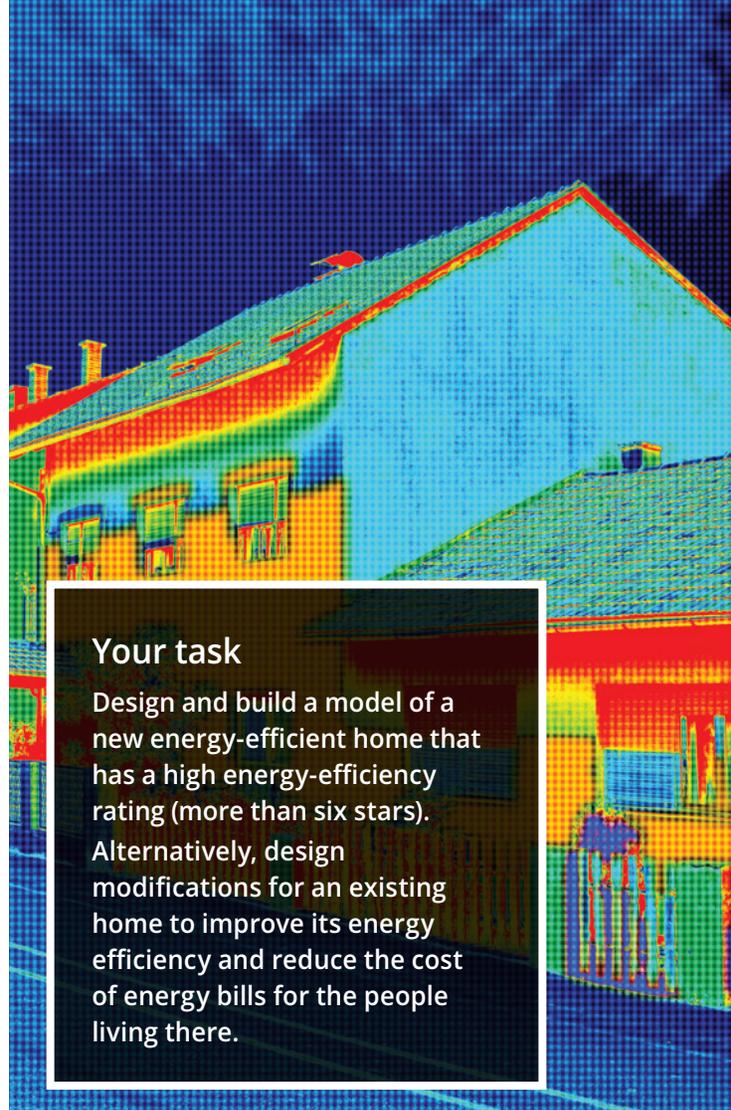
Figure 5 An organoid representing the intestines

How can we build more energy-efficient homes so that we live more sustainably?

Have you ever considered how much energy it takes to heat or cool your home? A study by the Australian Government found that homes contribute 10 per cent of Australia's total carbon emissions. Reducing the amount of energy needed to heat or cool a home will not only save people money on their gas and electricity bills, it will make housing more sustainable.

NatHERS

The Nationwide House Energy Rating Scheme (NatHERS) is a rating system that is used across Australia to identify the energy efficiency of new homes. It gives a star rating out of ten for thermal performance (where ten stars is the most energy efficient). Computer modelling software assesses the design to estimate the amount of energy needed to heat or cool the home. The assessment is based on the local climate, the orientation of the home and materials that will be used in construction. In much of Australia, new home designs must reach a minimum of seven stars to be approved for construction. There are many ways to improve the energy efficiency of your home. For example, if you insulate the walls, floors and roof, and use awnings (covers that extend over windows or doors), you can reduce the amount of energy needed to cool the home in summer. Or in cooler climates, if you design the home so that living areas are on the northern side, you can maximise the sunlight that is available to heat the home in winter.



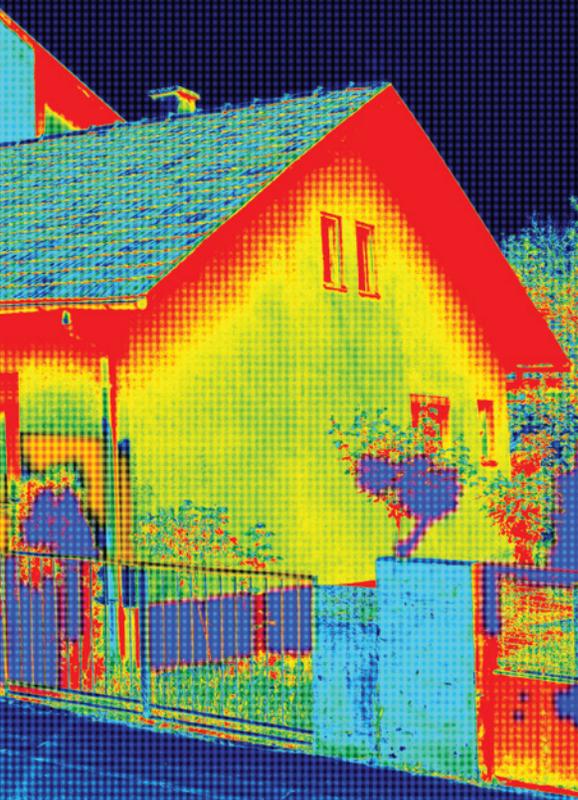
Your task

Design and build a model of a new energy-efficient home that has a high energy-efficiency rating (more than six stars). Alternatively, design modifications for an existing home to improve its energy efficiency and reduce the cost of energy bills for the people living there.

Figure 1 Infrared imaging shows warmer temperatures as red and cooler temperatures as blue. A building with insulation will lose less thermal energy to the outside environment in winter and will gain less thermal energy from the outside environment in summer.

Retrofitting homes

Not everyone wants to or can afford to build a new home. People who rent sometimes have little choice when it comes to the energy efficiency of their home, but this doesn't mean that they need to have large gas and electricity bills. There are things that they can do to reduce the movement of thermal energy in summer or winter. Covering the floor with rugs, preventing heat from moving in or out of windows, and controlling windows to manage airflow are all ways to make a home more energy-efficient and liveable.



HUMANITIES

In Geography this year, you will explore how the forecasted growth of Australia's cities could impact their liveability and the challenges city planners face in balancing the demands of the things people need with the impacts on the environment.

In Economics and Business, you will study the housing market, the interaction between businesses and consumers in meeting consumer demands and when the government intervenes in markets.

To complete this task successfully, you will need to study seasonal weather patterns at the location of your energy-efficient home, to improve energy use.

You will find more information on this in Module 5 “Urban life” of *Oxford Humanities 8 Victorian Curriculum*.



MATHS

In Maths this year, you will learn how to determine the area and volume of different shapes, using and converting between appropriate units. You will also learn skills for dealing with percentage changes in financial contexts. These skills will help you to quantify the costs and benefits of design features and predict the popularity of market incentives. You will perform calculations with and without digital technology.

To complete this task successfully, you will need to perform calculations for your model home, and then scale up to estimate the potential benefits of your design at a national level.

You will find help for applying these maths skills in Lessons 3.2 “Calculating percentages”, 3.3 “Mark-ups and discounts”, 8.3 “Area of quadrilaterals” and 8.4 “Area of a circle” of *Oxford Maths 8 Victorian Curriculum 2E*.



SCIENCE

In Science this year, you will learn about how energy can be transferred between objects and transformed (such as from the Sun's light energy to electrical energy). You will also examine earthquake resistant materials used in construction.

To complete this task successfully, you will need to identify how each element of a home's design can affect its heating and cooling needs, and how construction materials can affect a home's stability.

You will also need to identify the elements that can be changed in a new home design, and compare these to the elements that can be changed in an established home.

You will find more information on this in Module 3 “Plate tectonics” and Module 4 “Energy” of *Oxford Science 8 Victorian Curriculum*.

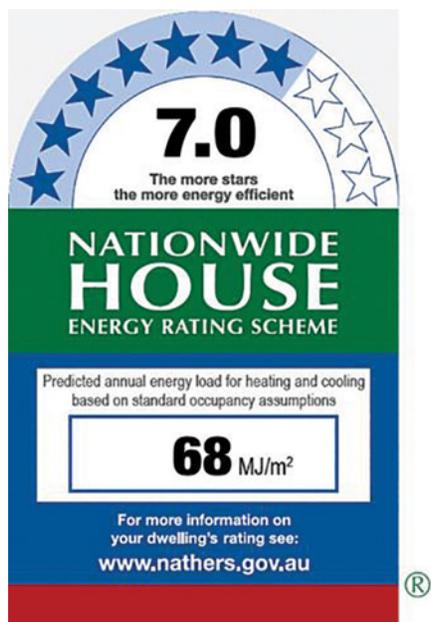


Figure 2 Energy rating schemes help consumers to understand the energy efficiency of products or appliances. The more stars, the more energy efficient the product or appliance is.

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? How big is their family and home?
- What factors might affect the liveability of the home?
- What do they need? What do they not need?
- What does it feel like to face these limitations on liveability? What words would you use to describe how it would feel to face these limitations?

To answer these questions, you may need to investigate using different resources, or even conduct interviews or surveys.

Define

Before you start to design your home modifications, 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 orientation of the land where the home will be built or modified (include the location of sunrise and sunset, the angle of sun in the middle of summer and winter and any existing shadows).
- 2 Describe any existing energy-efficient features of the current home or design.
- 3 Describe how you will measure any improvement in energy-efficient features of the home.

Ideate

Once you know who you're designing for, and what the criteria are, it's time to get creative!

- Outline the criteria or requirements your design must fulfil (for example, improving heating or cooling of the home).
- 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

Draw each individual design.

Include in the individual designs:

- a** labels for each part of the design
 - b** the materials you will use for the home's construction
 - c** a description of how the modifications will improve the energy star rating of the home
 - d** an estimation of the cost of applying the modifications.
- Present your design to your group.

Build the prototype

Choose and build two or three model homes for your group design (scale: 2 cm = 1 m).

Use the following questions as a guideline for your prototype.

- What materials will you need to build your model home?
- What skills will you need to build your model home?
- How will you test the effectiveness of your model home? (What will you compare it to?)
- How will you identify each energy-efficient feature of your model home?
- How will you collect data that supports your claims about energy efficiency?

Test

Use the scientific method to design and test the energy efficiency of your model home. You will test more than one design so that you can compare them, so you will need to control your variables between tests.

What criteria will you use to determine the success of your model home?

Conduct your tests and record your results in an appropriate table.

Communicate

Present your home design as though you are trying to get your peers to invest in it.

In your presentation, you will need to:

- construct a labelled diagram of your model home in its orientation, including the location of sunrise and sunset, the angle of sun in the middle of summer and winter, and any existing shadows
- describe the key energy-efficient features of your model home
- explain how each energy-efficient feature affects the liveability of your model home
- explain the principles that support your design (the importance of energy efficiency and how the existing landscape affected the design of the home)
- estimate the cost of implementing your design
- explain and quantify the benefits on a national scale if all new homes were to include your design features.

Online resources:



Student guidebook

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.

How can we use technology so that the impact of natural disasters is reduced?

Across the world, climate patterns are changing and weather events are becoming more extreme. In 2020, twenty per cent of Australia's forests were burnt, a record-breaking thirty named hurricanes developed over the Atlantic Ocean and an extreme monsoon season in Asia caused flooding across a quarter of Bangladesh. Australia is particularly prone to natural disasters. Bushfires, flooding, drought periods and cyclones dramatically affect people's lives and alter natural landscapes.

Natural disasters can be devastating for communities affected by them. Recovering from natural disasters also comes with huge economic costs. This can sometimes lead to a harmful cycle in which a nation gets stuck between experiencing disaster and responding to disaster.

Disaster management

Climate action is one of the 17 Sustainable Development Goals agreed to in 2015 by world leaders. One of the identified targets in combating climate change is to strengthen the resilience and adaptive capacity of all countries to natural disasters and hazards related to climate.

It is essential that communities prepare for disasters so as to reduce their impact. The United Nations Office for Disaster Risk Reduction (UNDRR) recommends using technology as part of disaster management. For example:

- warning systems in Japan that trigger emergency brakes in bullet trains if earthquakes are detected
- systems in sub-Saharan Africa that monitor rainfall data and analyse trends to forecast and build resilience to drought



Your task

Develop an innovative technology or strategy that will reduce the impact of natural disasters in your community. The technology or strategy should be useful and easy to use and address one (or more) of the steps of disaster management.

Figure 1 Hundreds of people (and animals) huddled on Malua Bay beach in NSW for almost 24 hours as bushfires tore through communities in the nearby Batemans Bay area.

- atlases in China that record the risk of natural disasters, using location data from spatial technologies such as GPS.

After the 2019–20 Australian bushfires, it was argued that satellite technology, drones and mobile phone apps would have been extremely helpful for fighting the fires and communicating with the people affected.

Disaster management should include four steps:

- **prevention** – reducing hazards before a disaster takes place, so its impact is not as severe (e.g. building schools that are earthquake resistant)
- **preparation** – training people so they know how to act when a disaster happens (e.g. running evacuation drills)
- **response** – taking action during a disaster (e.g. emergency crews and volunteers taking on emergency operations)
- **recovery** – taking action to help people rebuild their lives (e.g. restoring services in a community).

Disaster management is an ongoing process that can occur like a cycle between the phases of prevention, preparation, response and recovery.



Figure 2 Floodwaters near Sydney

HUMANITIES



In Geography this year, you will learn about landscapes and landforms and how they can be degraded by both human and natural causes. You will study a geomorphic hazard, its impacts on a place and various ways of responding to it.

In History, you might also study how past societies have dealt with disasters and managed their responses; for example, how Rapa Nui (Easter Island) inhabitants adapted to life without trees, how Shogunate Japan developed policies to sustain its forests, or how an unstable climate (including drought and heavy monsoons) affected the Khmer Empire.

To complete this task successfully, you will need to investigate a potential natural hazard in your local area. You will research any current disaster-response plans related to managing such an event and gain an understanding of how various people and businesses in the community would be impacted.

You will find more information on this in Modules 2, 16, 17 and 19 of *Oxford Humanities 8 Victorian Curriculum*.

MATHS



In Maths this year, you will consolidate and extend your skills in describing and interpreting. This will include creating and analysing plots of non-linear data, investigating the use of sampling methods and broadening your understanding of measures of spread. You will also perform calculations with percentage changes in financial contexts. You will analyse and represent data, both with and without digital technology.

To complete this task successfully, you will need to weigh up the costs of your disaster-management technology or strategy against its potential benefits, including by estimating the likelihood of natural disasters and the severity of their effects.

You will find help for applying these maths skills and statistics in Lessons 3.2 “Calculating percentages”, 3.3 “Mark-ups and discounts”, 6.5 “Plotting linear relationships” and 10.1 “Collecting data and sampling methods” of *Oxford Maths 8 Victorian Curriculum 2E*.

SCIENCE



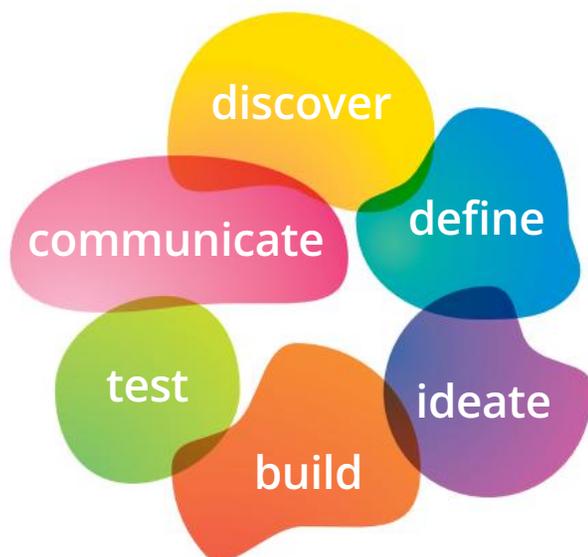
In Science this year, you will learn about how the energy of the Earth over long periods of time generates forces that can melt rocks, produce volcanoes and make diamonds. You will also learn how the kinetic energy in the air and waves can cause damage to the surrounding environments during cyclones and tsunamis. The Australian bush also contains large amounts of chemical energy that is transformed into thermal energy during the summer fire season.

To complete this task successfully, you will need to consider how energy is transferred and transformed during natural disasters. This understanding will allow you to predict and potentially reduce the impact of the disaster in your local community.

You will find more information on this in Module 2 “The rock cycle” and Module 4 “Energy” of *Oxford Science 8 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?
- What natural disaster could they face?
- How often could this disaster occur, and on what scale?
- 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?
- What could the cost of such a disaster be in terms of lives lost, income lost, damage to private property and public infrastructure, and environmental impact?

To answer these questions, you may need to investigate using different resources or even conduct interviews or surveys.

Define

Before you start to design your innovative strategy or technology, 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 Define the term “innovation”. Describe how much a strategy needs to differ from current practice to be considered innovative.
- 2 Describe how the natural disaster will affect the people in the community.
- 3 Describe how you could measure whether your solution will reduce the impact of the natural disaster.
- 4 Explain how you could determine what cost (price) should be acceptable for implementing your solution.

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 designed strategy or technology must fulfil (for example, how many people will be helped, how much they will be helped, how long they will need the help).
- 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

Draw each design strategy or technological idea. Label each stage of the strategy or part of the technology and explain how it will be used by the community.

Include in the individual strategy or technology:

- a** the timeline for the activation of the strategy or technology (i.e. how long after the disaster will the idea be ready to be used?)
- b** the number of people and materials that will be needed for the strategy or technology to reduce the impact of the natural disaster
- c** a description of how the community will benefit from the strategy or technology.

Present your strategy or technology to your group.

Build the prototype

Choose and build two or three versions of the prototype strategy or technology for your group design.

Use the following questions as a guideline for your prototype.

- What equipment do you have access to?
- What skills do you have or will you need, to make your prototype strategy or technology?
- How could you model your strategy or technology if equipment is not available?
- How could you test the effectiveness of the prototype strategy or technology with the community?

Test

Use the scientific method to design an experiment that will test the effectiveness of your prototype strategy or technology. Alternatively, conduct a survey of the community to determine their opinion of the usefulness of the prototype.

Conduct your tests or survey your community, and record your results in an appropriate table.

Consider how you could use the results of the experiment or survey to modify your design.

Communicate

Present your design to the class as though you are trying to get your peers to invest in your strategy or technology.

In your presentation, you will need to:

- describe how the natural disaster will affect your community
- describe your prototype strategy or technology
- describe how the prototype will reduce the impact of the natural disaster on the community
- describe the materials, people and money that will be required to have the required effect on the natural disaster.

Online resources:



Student guidebook

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 in the design cycle.



How to manage your project

This "how-to" video will help you to manage your time throughout the design cycle.



How to define a problem

This "how-to" video will help you to narrow your ideas down and define a specific problem.

Glossary

A

abomasum

the fourth stomach of a cow

abrasion

the process of wearing away a surface caused by friction between particles; a type of physical weathering of rock

accuracy

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

aim

the purpose of an experiment

alternating current (AC)

an electric current in which the direction of the current (flow of electrons) changes at regular intervals

alveoli

tiny air sacs in the lungs where gas exchange occurs

amino acid

small molecule that makes up proteins

ammeter

an instrument that measures electric current at a point in a circuit

ammonia

a chemical waste product (NH_3)

anomaly

a result that does not fit in with the pattern of data or what is normally observed

aorta

the major artery that carries oxygenated blood from the heart and divides into smaller arteries around the body

apparatus

equipment placed together for an experiment

artery

a thick, muscular-walled blood vessel that carries blood away from the heart under pressure

arteriole

smaller artery

assumption

statements or beliefs that are accepted as true without supporting evidence

asthma

a disease of the respiratory system caused by narrowing airways

atom

the smallest particle of matter; cannot be created, destroyed or broken down (indivisible)

atomic theory

the theory that all matter is made up of atoms

atrium

smaller, upper chamber of the heart (plural: atria)

B

binary fission

a form of asexual reproduction used by bacteria; the splitting of a parent cell into two identical daughter cells

binocular

using two eyes; a type of microscope

biodegradable

capable of being decomposed by bacteria or other living organisms and reabsorbed into the natural environment

blood

connective tissue that carries oxygen, nutrients and waste around the body

blood vessel

a tube or vessel that carries blood around the body

body wave

a seismic wave that travels through Earth (not at the surface)

boiling point

the temperature at which a liquid boils and becomes a gas

bronchi

air passages that carry air in and out of the lungs; airways

by-product

an extra or secondary product made in the manufacture or synthesis of something else

C

caecum

a small dead-end pouch that connects the small and large intestines

calibrate

check the accuracy of a measuring device against known measurements

capillary

a blood vessel with a wall only one cell thick; allows substances to pass into and out of the blood

catalyst

a substance that increases the rate of a chemical reaction without undergoing any permanent chemical change

categorical data

information that can be divided into groups or categories

causation

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

cell

(in biology) the building block of living things

cell membrane

the barrier around a cell that controls the entry and exit of substances into and out of the cell

cell theory

theory that explains the relationship between cells and all living organisms

cell wall

the outer protective and support structure of cells in plants, fungi and prokaryotes

cellular respiration

the chemical reaction between glucose and oxygen that produces carbon dioxide, water and energy

chemical digestion

the chemical break down of large food molecules into smaller, simpler molecules using enzymes

chemical potential energy

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

chemical reaction

a procedure that produces new chemicals; same as chemical change

chlorophyll

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

chloroplast

organelle found in plant cells that transforms solar energy into chemical energy

chyme

a mixture of acid, enzymes and digested food that leaves the stomach

cilia

tiny hair-like structures on the surface of cells

circuit diagram

a diagrammatic way to represent an electric circuit

circulatory system

organ system that moves blood and lymph around the body, transporting oxygen and nutrients to the cells and removing waste products from the cells

collision theory

a theory stating that the particles involved in a chemical reaction must collide in order to react

colloid

a type of mixture that always looks cloudy because clumps of insoluble particles remain suspended throughout it rather than settling as sediment

column graph

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

combustion

a reaction that involves oxygen and releases light and heat energy

command term

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

compound light microscope

a microscope with two or more lenses

compound

a substance made up of two or more types of atoms bonded together (e.g. water, H₂O)

concentration

the number of active molecules in a set volume of solution

conclusion

a statement that “answers” the aim of an experiment

condense

to change state from gas to liquid

connective tissue

the group of cells that provide connections to other parts of the body

continental crust

part of Earth’s crust that makes up the continents (landmasses)

continental drift

the continuous movement of the continents over time

continental shelf

a flat area under shallow ocean water at the edge of a continent

continent

a large, continuous landmass

continuous data

data that is measured and can be any value

convection

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

convection current

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

convergent boundary

the boundary between two tectonic plates that are moving together

core

the centre of Earth

correlation

a relationship between two or more things

corrosion

the gradual destruction of materials by a chemical reaction with their environment

corrosive

destructive to living tissues such as skin and eyes, or to some types of metals

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

crust

the lithosphere, or outer layer of Earth

current

the rate at which electrons flow; measured in amperes (amps; symbol “A”)

cytoplasm

the jelly-like fluid inside the cell membrane that contains dissolved nutrients, waste products and organelles

D**deposition**

the process whereby sediment from different forms of weathering accumulates in layers

derived units

units of measurement that are calculated using a combination of SI (international system) base units, e.g. cm³ for volume (base unit is cm), m² for area (base unit is m)

diaphragm

a dome-shaped muscle attached to the ribs; moves up and down under the lungs

diarrhoea

watery faeces

diatomic molecule

a molecule that consists of two atoms

dichotomous key

a diagram used in classification; each “arm” of the key contains two choices

digestion

the process of breaking down food into nutrients

digestive system

organ system that breaks down food and absorbs nutrients

diode

an electronic component that allows current to flow in one direction only

direct current (DC)

an electric current in which the direction of the current (flow of electrons) does not change

directly proportional relationship

a relationship between two variables in which the dependent variable increases as the independent variable increases

discrete data

data where the numbers can be separated into different groups

discussion

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

dissection

the process of cutting apart and observing something in order to learn more about it

divergent boundary

the boundary between two tectonic plates that are moving apart

DNA (deoxyribonucleic acid)

a molecule that contains all the instructions for every job performed by the cell; this information can be passed from one generation to the next

donor

the person giving an organ; usually deceased, sometimes living

E**elastic potential energy**

the energy possessed by stretched or compressed objects

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 energy

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

electricity

the movement of charged particles

electromagnetic

relating to the physical interaction between moving charged particles and the magnetic field that is created as a result

electron microscope

a microscope that uses electrons (tiny negatively charged particles) to create images

electron

a negatively charged particle that moves around in the space outside the nucleus

emphysema

a disease of the respiratory system caused by broken down alveoli in the lungs

enzyme

a protein that speeds up the rate of chemical reactions; a type of catalyst

epiglottis

a flap of skin above the larynx that controls the passage of food and air, preventing food from entering the windpipe

epithelial tissue

the group of cells that cover and protect the body

equipment

items used in the laboratory to conduct experiments

erosion

water, wind, and other natural forces causing rocks and earth to wear away

error

an inaccuracy or inconsistency in measurement

ethics

the series of rules that determines what is right and what is wrong

eukaryotic cell

complex cell that contains a nucleus and membrane-bound organelles; protists, fungi, plants and animals have eukaryotic cells

excrete

remove waste from the body

excretory system

organ system that processes and removes waste products from the body

exhalation

pushing air out of the lungs; breathing out

experiment

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

extrusive igneous rock

rock formed at Earth's surface by quickly cooling lava

eyepiece

where the eyes are placed when using a microscope

F**fault**

a fracture in rock where the tectonic plates have moved

foliation

layering in a rock that occurs when the rock is subjected to uneven pressure

fossil

preserved remains or traces of an organism

fossilisation

the process of an organism becoming a fossil

frost shattering

a process of weathering in which repeated freezing and melting of water expands cracks in rocks, so that eventually part of the rock splits off

fuse

a switch or wire that stops the flow of current if it starts moving too fast

G**gallstone**

a hard substance or stone that is produced by the gall bladder

gas exchange

the transfer of oxygen into cells and carbon dioxide out of cells

geologist

a scientist who studies the physical structure and history of Earth

gluten intolerant

unable to digest gluten

gravimeter

a device that measures the difference in gravity between one location and the next

gravitational potential energy

the energy possessed by an object raised to a height in a gravitational field

group

(in chemistry) a vertical list of elements in the periodic table that have characteristics in common

guard cell

cell that opens and closes the stomata in the leaves and stems of plants to control gas exchange and water loss; found in pairs, with one guard cell on either side of each stoma

H**hazard**

something that has the potential to put a person's health and safety at risk

heart

organ that pumps blood around the body

heat conduction

the process of transferring heat energy from one region to another without the movement of material

hindgut

lower part of the digestive system; includes the caecum, colon and rectum

hot spot

a region where Earth's outer crust is thin and the magma is hotter than the surrounding area

hypothesis

a proposed explanation for a prediction that can be tested

I**igneous rock**

rock formed by cooling magma and lava

index mineral

a mineral that only forms at a particular temperature and pressure; used to determine the history of the rock that contains the mineral

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

infectious disease

disease caused by the passing of a pathogen from one organism to another; also known as a contagious disease

inference

a conclusion based on evidence and reasoning

inhalation

bringing air into the lungs; breathing in

inhale

breathe in

intrusive igneous rock

rock formed underground by slowly cooling magma

inversely proportional relationship

a relationship between two variables in which the dependent variable decreases as the independent variable increases

K**kinetic energy**

the energy possessed by moving objects

L**laboratory**

a specially designed space for conducting research and experiments

lattice

a three-dimensional arrangement of particles in a regular pattern

lava

hot, molten rock that comes to the surface of Earth in a volcanic eruption

light-dependent resistor

an electronic component that decreases its resistance to electric current as light intensity increases (also known as a photoresistor)

light-emitting diode (LED)

an electronic component that converts electrical energy into light

line graph

a graph that uses lines to connect individual data points

line of best fit

the line on a scatter graph that passes through, or nearly through, as many data points as possible to show any overall trends in the data

liquefaction

the transformation of solid soil into a liquid-like substance when under pressure during an earthquake

logbook

a day-to-day record of all activities you did on your research project

M**magma**

semi-liquid rock beneath Earth's surface

magnetometer

a device that detects the difference in a magnetic field between one location and the next

magnitude

a measure of size or quantity; a measure of the size of an earthquake

mantle

the layer of molten rock beneath Earth's crust

mean

the average of a set of data

median

the middle value in a set of data

megafauna

large animal; many of Australia's megafauna became extinct during the Pleistocene

melting point

the temperature at which a solid becomes a liquid

metabolism

all the chemical reactions in the body

metamorphic rock

rock formed from other rock due to intense heat and pressure

method

a series of steps explaining how to do an experiment

microbiology

the science involving the study of microscopic organisms

microorganism

a living thing that can only be seen with a microscope

microscope

an instrument with lenses, used for viewing very small objects

microscopy

the study of living things that can only be seen with a microscope

mid-ocean ridge

a series of underwater mountains that form as a result of tectonic plates moving apart and allowing magma to rise to the surface

mineral

naturally occurring elements or compounds

mitochondrion

powerhouse organelle of a cell; the site of energy production (plural: mitochondria)

mixture

a substance made up of two or more pure substances mixed together

mode

the most common value in a set of data

molecular compound

a molecule that contains two or more different atoms bonded together (e.g. carbon dioxide, CO₂)

molecular element

a molecule that contains two or more of the same atoms bonded together (e.g. oxygen, O₂)

molecule

group of two or more atoms bonded together (e.g. a water molecule, H₂O)

monatomic

consisting of a single atom

monocular

using one eye; a type of microscope

multicellular

an organism that has two or more cells

muscle tissue

the group of cells that allow the body to move

N**natural flora**

microbes that live in or on our bodies

natural world

all living things in the world around us, including ecosystems and natural phenomena (e.g. plants, animals, oceans, ecosystems, weather patterns)

negative terminal

the point in the circuit where electrons flow out from

nephron

a tiny structure in the kidneys that filters the blood

nervous tissue

the group of cells that pass on electrical messages

nuclear energy

energy stored in the nucleus of an atom and released in nuclear reactors or explosions of nuclear weapons; much greater than the chemical energy released in chemical reactions

nucleus

an organelle that contains all the genetic material (DNA) of a cell; control centre of a cell

numerical data

data in the form of numbers

nutrient

substance in food that organisms need for energy, growth and other biological functions

O**objective lens**

lens in the column of a compound light microscope

observation

use of the senses to notice and gather information

ocean trench

a deep ditch under the ocean along a tectonic plate boundary

oceanic crust

part of Earth's crust that lies under the ocean

ohm

unit of electrical resistance; measure of resistance between two points of a conductor

omasum

the third stomach of a cow

onion-skin weathering

weathering of rock where the outside of the rock peels off

organ

a group of tissues that work together for a purpose

organ transplant

the replacement of a damaged organ with a healthy organ from an organ donor

organelle

specialised structure that has a specific function in a cell

organism

a living thing; organisms can have one cell (unicellular) or many cells (multicellular)

osmosis

the movement of water through a selective membrane from an area of low salt concentration to an area of high salt concentration; occurs in root cells

outlier

a data value that is outside the range of all the other results

P**parallax error**

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

parallel circuit

an electric circuit that has two or more pathways

particle theory

theory that explains the properties of matter (also called the “particle model”)

pathogen

microbe that can potentially cause a disease

peer review

the evaluation of work by one or more people with similar skills and backgrounds (peers)

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 their similar properties

peristalsis

the process of swallowed food being moved along the digestive tract by a wave of muscle contractions

pharynx

the throat; connects the mouth to the oesophagus

philosopher

a “lover of knowledge”; someone who studies ideas, theories and questions

phloem

the vascular tissue in plant stems that carries sugars around the plant

photoconductivity

the ability of a material to conduct electricity when it is exposed to light

photosynthesis

chemical process plants use to make glucose and oxygen from carbon dioxide and water

photovoltaic cell

an electrical device that converts light energy into electrical energy; see solar cell

physical digestion

the physical break down of food into smaller pieces using the teeth and muscles of the digestive system

physical world

all non-living things in the world around us, including the forces acting upon them (e.g. rocks, planets, energy, matter, and forces such as gravity and magnetism)

plasma

a straw-coloured fluid that forms part of the blood

plate tectonics

the theory that the surface of Earth consists of a series of plates that are continually moving due to convection, ridge push and slab pull

platelet

small disc-like cell in blood that is involved in forming clots

pneumonia

a disease caused by bacterial or viral growth in the lungs

polymer

a long-chain molecule formed by the joining of many smaller repeating molecules (monomers)

positive terminal

the point in an electric circuit where electrons flow into

potential difference

voltage; the difference in the electrical potential energy carried by charged particles between two different points in a circuit

potential energy

energy that is stored in an object due to its properties, position and the forces acting on it

potentiometer

a variable resistor that can adjust the output of voltage to a circuit and measure electric potential

precision

how close measurements of the same item are to each other

product

a substance obtained at the end of a chemical reaction; written on the right side of a chemical equation

prokaryotic cell

cell that does not have a nucleus or membrane-bound organelles; bacteria and archaea are made up of a single prokaryotic cell

properties

in chemistry, the characteristics or things that make a substance unique

pseudoscience

claims that are supposedly scientific but are made with no evidence to support them

pure substance

something that contains only one type of substance (e.g. a single element or a single compound)

Q**qualitative data**

data that can be measured using categories

qualitative observation

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

quantitative data

data that can be measured numerically

quantitative observation

an observation that uses a number, such as a measurement

R**radiation**

the transfer of energy through high energy particles such as electromagnetic waves

reactant

a substance used at the beginning of a chemical reaction; written on the left side of a chemical equation

reading error

an error that occurs when markings on a scale are not read correctly

recipient

the person receiving a donated organ

rectifier

an electronic component that converts alternating current (AC) to direct current (DC)

red blood cell

cell in the blood that carries oxygen around the body

reliable

consistency of a measurement, test or experiment

remote control

an electronic device used to operate a machine remotely (i.e. at a distance)

reproducible test

the ability to replicate the results of an experiment under similar conditions as the original test

resistance

a measure of how difficult it is for the charged particles in an electric circuit to move

respiratory system

organ system that brings oxygen in and sends carbon dioxide out of the body; site of gas exchange

results

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

reticulum

the second stomach of a cow

ribosome

organelle that makes proteins

Richter scale

a scale used to rate the magnitude of an earthquake

ridge push

the force pushing the edges of tectonic plates away from each other when a ridge crest has formed

rift valley

a deep valley that forms as a result of tectonic plates moving apart on land

rock

a naturally occurring solid substance that is made up of one or more minerals

rock cycle

the process of formation and destruction of different rock types

root

a plant organ involved in absorbing nutrients and water

rounding off

reducing the number of significant figures by increasing or decreasing to the nearest significant figure; for example, 7.6 cm is rounded up to 8 cm, 7.2 cm is rounded down to 7 cm

rumen

the first stomach of a cow

S**scatter graph**

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

science

the study of the natural and physical world

scientist

a person who studies the natural and physical world

sea-floor spreading

the theory that the middle of the ocean is spreading apart, forming new oceanic ridges

seismic geophysical testing

the collecting of geophysical data such as differences in magnetic fields and gravity fields between different geological locations

seismometer

a device used to measure the movement of the earth

series circuit

an electric circuit that has one pathway

short circuit

an electrical circuit where the charged particles travel a shorter and faster path from the intended circuit

SI system

an international system of measurement based on the metric system, with units such as kilogram, metre, kilometre

significant figures

the number of digits that contribute to the overall value of a number

slab pull

the force pulling a tectonic plate beneath a less dense tectonic plate

solar cell

a device that transforms sunlight directly into electrical energy; is usually in the form of a panel; also known as a solar panel

solidification

the process of a liquid turning into a solid

solution

a mixture of a solute dissolved in a solvent

sound energy

a type of kinetic energy produced when things vibrate, causing waves of pressure in the air or some other medium

stain

substance, such as iodine, used to make cells more visible under a microscope

stem

an organ that transports materials around a plant

stereomicroscope

a microscope with two eyepieces that uses low magnification

stomata

tiny pores in the leaves and stems of plants that allow gas exchange between a plant's cells and the environment (singular: stoma)

subduction

the movement of one tectonic plate under another tectonic plate

sublimation

a change of state from a solid directly to a gas

supercontinent

a landmass that is made up of most or all of Earth's land; Pangea is an example of a supercontinent

surface area to volume ratio

the relationship between the area around the outside of a cell and its volume, as a fraction

surface wave

a seismic wave that travels along the surface of Earth

suspension

a cloudy liquid containing insoluble particles

symptom

a physical sign of a disease or condition

system

a group of organs that work together for a purpose

T

tectonic plate

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

temperature-dependent resistor

an electronic component that changes its resistance to electric current with increasing or decreasing temperature

theory

an explanation of a part of the natural world that is supported by a large body of evidence

thermal energy

the scientific term for heat energy

tissue

a group of cells that work together to carry out a particular function

tor

a large, round rock produced by onion-skin weathering

trace fossil

fossilised traces of an organism that existed in the past (e.g. footprints)

trachea

the large tube that connects the throat to the bronchi; carries air in and out of the body

transferred

describes energy that has moved from one object to another

transform boundary

the boundary between two tectonic plates that are sliding past each other

transformed

describes energy that has changed into a different form

transpiration

the process of water evaporating from plant leaves; causes water to move up through the plant from the roots

true value

the actual value to be measured

tsunami

a series of large waves that result from an underwater earthquake

U

ulcer

an open sore on the inside or outside of the body

ultrasound

a technique that uses sound waves to create images of structures inside the body

unicellular

an organism that consists of one cell; an example is bacteria

urea

a chemical waste product produced in the body and removed in urine

V

vacuole

organelle that stores water and other materials, including wastes

validity

a measure of how accurately a method measures what it is intended to measure

valid experiment

an experiment that investigates what it sets out to investigate

valve

structure in the heart and veins that stops blood flowing backwards

vaporise

to change state from a liquid to a gas; evaporate

vapour

gaseous form of a substance that is normally solid or liquid at room temperature (e.g. water vapour)

variable

something that can affect the outcome or results of an experiment

vascular bundle

a group of tubes in plant stems that carry water and nutrients around the plant

vein

a thin-walled blood vessel that carries blood back to the heart

ventricle

large, lower chamber of the heart

vesicle

an organelle surrounded by a membrane and used by cells to store materials; a vacuole is a type of vesicle found in plant cells

villi

small hair-like projection that increases the surface area of a membrane (plural: villi)

volatile

describes a substance that easily becomes a gas

voltage

difference in electric potential energy; a measure of the strength of a current; measured in volts (symbol “V”)

voltmeter

an instrument that measures voltage at a point in a circuit

W

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

white blood cell

an immune system cell that destroys pathogens

X

xylem

the vascular tissue in plants that carries water from the roots to the rest of the plant

Z

zero error

an error that occurs when an instrument has not been adjusted to zero before the measurement is taken

Index

A

abomasum 307
 Aboriginal and Torres Strait
 Islander Peoples 7–12
 anatomists 296
 chemical changes, use
 of 229
 controlled burning 237
 Country 7
 heat by-product, using 169
 Indigenous science 8–11,
 68
 ochre 84, 229
 plants for food or medicine,
 identifying 71
 research protocols 25
 rocks, knowledge of 74, 80,
 88–9
 scientific knowledge and
 skills 7–12, 68
 seasonal calendars 8, 9
 abrasion 92
 accuracy 32, 33–6
 calculations 34
 data 46–9, 69
 equipment 34
 acid rain 92
 aim (of experiment) 59
 alternating current (AC) 189,
 199
 alveolus/alveoli 312–13, 318
 amino acids 327
 ammeter 189, 192
 ammonia 327
 amoeba 278
 amperes 192
 animal cells 277, 279,
 280, 290
 animal testing 343
 anomalies 48
 antibiotics 287–9, 309
 anus 300
 aorta 319
 apparatus 27
 arteries 320, 321, 324–5
 arterioles 320, 321
 artificial organs 342
 assumptions 53
 asthma 317
 astrology 15, 16
 astronomy 5, 9
 atherosclerosis 324–5
 atomic mass 213
 atomic number 213
 atomic theory 208–11

atoms 208, 211, 253
 modelling 220–2
 atrium/atria 320, 324
 axes (of graph) 43–4

B

bacteria 261, 271, 276, 279,
 282–90
 antibiotics killing 287–9, 309
 disease caused by 282–6
 reproduction 284
 bacterial growth 284
 balloon rocket 36–7
 barbecue fuels 257
 basalt 75, 76, 79–80
 batteries 151–5, 165, 168,
 178, 188
 chemical energy stored in
 168, 177, 188
 diagram 189
 series or parallel circuit 194
 voltage 197
 beaker 27
 bile 300, 309, 310
 bile duct 300
 binary fission 284
 binocular microscopes 264
 biodegradable 250
 biological rocks 83
 biological weathering 93
 biology 5
 bladder 327
 blood 319–21
 blood cells 320, 321
 blood vessels 320, 321, 324
 body waves 138
 boiling point 224
 branches of science 5
 bronchi 311, 312, 317
 bronchioles 311, 316, 317
 Bunsen burner 27
 by-product 168
 heat as 168–70, 181

C

caecum 306, 307
 calibrate 53
 capillaries 313, 320
 caramel, making 230–1
 carbon dioxide 216, 217,
 223, 225
 circulatory system 320
 plants 333
 respiratory system 298,
 311–13

casein glue 248–9
 catalysts 241
 categorical data 39
 causation 51, 52
 cave formation 84
 cell membrane 261, 262,
 269, 270
 cell structures 269–72
 cell theory 261, 290
 cell wall 270, 271, 277, 307
 cells 260–93, 297
 discovery of 260
 drawing 263
 measuring 275
 roles of 276–9, 290
 size 261–2
 structure 269–72, 290
 cellular respiration 271,
 311, 313
 Chain, Ernst 287, 288
 changes in matter
 chemical 227–35, 253
 physical 222–7, 228, 253
 reversible 222–3
 changing state 223
 chemical changes 227–35,
 253
 chemical digestion 301
 chemical energy 150, 151,
 152, 165
 battery storing 168, 177,
 188
 chemical equations 237–8
 chemical formulas 220–1
 chemical potential
 energy 158, 177
 chemical reactions 227–44,
 253
 breaking and re-forming
 bonds 235–9, 253
 catalysts 241
 definition 235
 explosives 257
 observing 231–3
 products 235, 236, 239
 rate, speeding or
 slowing 240–4, 253
 reactants 235, 236, 239
 chemical recycling 251
 chemical rocks 83–4
 chemical safety 23–4
 chemical symbols 212, 213
 chemical weathering 92
 chemistry 5
Chlamydomonas 278
 chlorophyll 271, 272, 333

chloroplasts 270, 271, 277
 chyme 300, 301
 cilia 316
 circuit diagrams 189, 190, 192
 circulatory system 298,
 319–26, 339
 definition 319
 problems with 324–6, 339
 variations between
 organisms 321
 claim, making 53
 coal 75, 76, 83
 collision theory 240
 colloids 222
 column graph 39–40
 combustion 236
 command terms 61–3, 69
 communication 7, 14, 59–65
 compact fluorescent lights
 184
 compound light
 microscope 264, 265
 compounds 216, 217, 253
 concentration 240
 chemical reactions, effect on
 240
 conclusion (in report) 60
 condensation/condense 224
 conduction (heat) 171
 conglomerate 75, 76, 83, 102
 conical flask 27
 connecting wire 189
 connective tissue 297
 constipation 310
 continent 119
 continent-to-continent
 collision 127
 continental crust 124,
 127, 129
 continental drift 122–3, 143
 continental shelf 124
 continuous data 39
 contractile vacuole 278, 281
 controlled variables 19
 convection 124, 171
 convection currents 124
 convergent boundaries 127–8,
 143
 cooking, reactions in 236
 copper carbonate 218–19
 copper treasure hunt 109–10
 core (Earth) 118, 143, 145
 coronary heart disease 325
 correlation 51–2
 corrosion 251
 corrosive liquids 24

- coughing 316
 Country 7
 crust (Earth) 119, 124, 127, 143, 145
 crystal healing 15
 crystals 76, 77, 81–2, 88
 current 192, 203
 altering 198–201
 alternating or direct 189, 199
 cytoplasm 269, 281
- D**
- da Vinci, Leonardo 296
 Dalton, John 208, 209
 data 38–9, 69
 accurate 46–9, 69
 anomalies 48
 logbook 55–7
 outliers 47
 qualitative/quantitative 38
 recording 37–46
 trends in 48–9
 types 39
 data points 44
 data tables 38
 Democritus 208
 dependent variables 19, 38, 44
 deposition (rocks) 93
 derived units 34
 design cycle 346–7, 350–1
 diaphragm 312, 313, 316
 diarrhoea 310
 diatomic molecules 212
 dichotomous key 44, 74
 digestion 299–311, 338
 chemical 301, 338
 physical 301, 338
 digestive system 298, 299–311, 338
 definition 299
 problems 309–11, 338
 variations between
 animals 306–8, 338
 digestive tract 299, 301
 diodes 199
Diprotodon optatum 100
 direct current (DC) 189, 199
 directly proportional
 relationship 41
 disaster management 105, 348–51
 discrete data 39
 discussion (in report) 60
 disease
 infectious 283
 organisms causing 282–6, 290
 symptoms 283
- dissection 27–31
 chicken wing 29–31
 equipment 28–9
 fish 315–16
 heart 322–3
 kidney 328–9
 dissection scissors 28, 31
 divergent boundaries 128–9, 143
 DNA (deoxyribonucleic acid) 269
 donor (of organ) 330
 Duchesne, Ernest 288
 dyes 246, 247
- E**
- Earth and space science 5
 Earth, layers of 118–21, 143, 145
 earthquakes 119, 124, 127, 131, 133
 Australia 134–5
 designing buildings for 138–43
 earthquake-resistant materials 140
 Japan 131
 L'Aquila 146
 liquefaction 140
 magnitude 131
 predicting 105
 San Francisco 127, 131
 tsunamis caused by 131
 elastic potential energy 157, 160
 electric bell 189
 electric cars 151, 178, 179
 electric circuits 188–205
 circuit diagrams 189
 definition 188
 series or parallel 192–6
 wiring a house 202
 electric current 189
 electrical energy 151, 152, 163–5, 188
 electric motor 189
 electricity 188–205
 definition 188
 generating 166–7
 electromagnetic, meaning 106
 electron 189
 electron microscopes 264, 265
 elements 209, 211–15
 periodic table 209, 210, 212–13, 253
 properties 212, 213, 214
 representing 220
 symbols 212, 220
- emphysema 317
 energy 150–85
 cannot be created or destroyed 165–6
 flow of 150–1, 154–6
 kinetic 150, 151, 161–5, 181
 nuclear 159
 potential 150, 157–61, 181
 solar 162, 177–80
 energy audit 171, 174
 energy chain 165
 energy efficiency 170–6, 181, 184
 rating systems 171, 344
 reducing consumption 170–2
 energy efficient homes 171–3, 344–7
 insulation 172
 passive design 171–2, 175
 window design 172
 energy transfer 150–6, 181
 entertainment, for 152
 heat as by-product 168, 181
 heat energy 171
 movement, for 151
 transferred, definition 150
 energy transformation 164–70, 181
 electricity generation 166–7
 heat as by-product 168–70, 181
 light to potential chemical 177
 representing 165, 168
 transformed, definition 164
 engineering
 earthquake-proof buildings 138–43
 energy use 185
 Indigenous science 10
 enzymes 241, 244, 301
 digestive 300, 301, 304, 306
 epiglottis 312
 epithelial tissue 297
 equipment 26–9, 68
 accuracy 34
 erosion 82, 112
 preventing 96–9, 112
 errors 32–3, 53
 ethics 24–5, 330–1, 342–3
Euglena 278
 eukaryotic cells 276, 277
 evaluation 14, 50–3, 69
 evaporating dish 27
 excrete, meaning 327
 excretory system 298, 327–9, 339
 exhalation 312
 experiments 27
 ethical issues 24–5
- planning and conducting 13, 21–6, 68
 reliable results 22
 reproducible test 22
 risk management 23–4
 valid 51
 explosives 257
 extrusive igneous rocks 79
 eyepiece 264
- F**
- fault 126, 127
 female scientists 71
 filter funnel 27
 fire drill method 169
 fish gills 313, 316
 flat earth theory 15
 Fleming, Alexander 287, 288
 Florey, Howard 287, 288
 flow diagrams 150, 151, 153–6, 165
 foliation 88
 forceps 28, 30
 fossilisation 100
 fossils 5, 100–3, 112
 frost shattering 92
 fungal cells 277–8
 fungi 277–8, 283, 284, 286
 killing bacteria 287–9
 fuse 194
- G**
- Gage, Matilda Joslyn 71
 gall bladder 300, 309–10
 gallstones 309–10
 gas exchange 313
 gas warfare 256
 gases 212
 chemical change producing 229
 monatomic and diatomic 212
 gastric juices 301
 gauze mat 27
 geochemical testing 108
 geochemistry 105
 geological mapping 105
 geologists 5, 74, 105, 112
 geophones 105
 geophysical testing 105–7
 glues and adhesives 246–9
 gluten intolerance 310
 gneiss 75, 76, 88
 grains (of rock) 75, 76, 77
 granite 75, 76, 79, 88
 graphs 39–44
 gravimeter 107
 gravitational potential
 energy 157–8
 group (chemical) 212
 guard cells 333

H

hazards 23
 heart 319, 320, 322–6
 heart attack 325, 341
 heat by-product 168–90, 181
 heat conduction 171
 heat energy 162–3, 171
 herbivore hindgut 306
 Hess, Harry 123
 hindgut 306
 Hooke, Robert 260, 297
 hot sport 132
 hybrid cars 178
 hydroelectric plants 166
 hypothesis 13, 15, 19–20, 53, 59

I

igneous rocks 78–81, 112, 114
 incandescent light globes 205
 independent variables 19, 38, 44
 index minerals 88
 Indigenous science *see*
 Aboriginal and Torres Strait
 Islander Peoples
 infectious diseases 283
 inferences 13, 15
 inhale/inhalation 23, 312
 insulation 172
 intestines 299, 300, 301
 intrusive igneous rocks 79
 inversely proportional
 relationship 41
 island formation 132

K

keys 44
 dichotomous 44, 74
 kidneys 327, 328–31
 kilowatt hours 171
 kinetic energy 150, 151, 152, 161–7, 181, 188

L

laboratory 27
 equipment 26–9
 safety in 23–4
 large intestine (colon) 299, 300, 310
 larynx 312
 lattice 223
 lava 79, 80, 133
 Lavoisier, Antoine and
 Marie-Anne 208
 Law of Octaves 209
 leaves 333
 legend 44

light-dependent resistors 200
 light emitting diodes (LED)
 199–200, 205
 light energy 150, 151, 162, 177–80
 light globe 189, 192, 305
 limestone 75, 76, 87, 102
 line graphs 41–2
 line of best fit 43
 liquefaction 140
 Lister, Joseph 288
 lithosphere 119, 143
 liver 300, 327, 330
 logbook 55–7
 Love surface waves 138
 lung capacity 314
 lungs 312, 313, 317–18

M

magma 78, 79, 87, 93, 112, 114, 119, 132
 magnesium 236, 239
 oxide 236, 238, 239
 magnetic striping 147
 magnetometers 106, 123
 magnification
 calculations 266
 magnitude (earthquake) 131
 mantle 119, 124, 132, 143, 145
 marble 75, 76, 87
 Marshall, Barry 309
 marshmallow slingshots 42, 57–8
 mathematical relationships 45
 “Matilda effect” 71
 mean 48
 measuring 13, 32–7, 69
 accuracy 32, 33–6
 cells 275
 equipment 32
 errors 32–3
 precision 32
 standard units 34–5
 measuring cylinder 27
 median 49
 megafauna 100–3
 melting chocolate 226–7
 melting point 224
 Mendeleev, Dmitri 209, 210, 220, 256
 metabolism 327
 metal tongs 27
 metals 209, 212, 213
 corrosion 251
 recycling 251
 metamorphic rocks 87–90, 112, 114
 method 60
 evaluating 52–3
 microbes 283–6

microbiology 260
 microorganisms 261
 microscopes 260, 264–8, 290
 eyepiece 264
 magnification calculations
 266
 monocular/binocular 264
 objective lens 264
 types 264–5
 microscopy 264
 mid-ocean ridge 129
 minerals 74
 change in 88–9
 locating and extracting
 105–9
 properties 74–6
 mitochondria 270, 271, 272, 277
 mixtures 217, 221
 mode 49
 modelling matter 220–2, 253
 models 45
 molecular compounds 216, 217
 molecular elements 216
 molecules 216, 220, 253
 monatomic gases 212
 monocular microscopes 264
 mouth 300, 301
 multicellular organisms 261, 269, 277, 279
 muscle tissue 297

N

Nationwide House Energy
 Rating Scheme (NatHERS)
 344
 natural disaster
 management 105, 348–51
 natural flora 283, 290
 natural philosophers 4, 208
 natural world 4
 science as study of 4–6, 68
 negative correlation 51
 negative terminal 189
 nephrons 328
 nervous tissue 297
 Newlands, John 209
 Newton’s cradle 167
 non-metals 209, 212, 213
 non-vital organs 342
 nuclear energy 159
 nucleus 269, 270, 277, 281
 numerical data 39
 nutrients 301, 321, 327

O

objective lens 264
 observations 13, 17–21, 68
 definition 18

logbook 55–7
 qualitative/quantitative 18
 obsidian 75, 76, 79, 80
 ocean-to-continent collision
 127
 ocean-to-ocean collision 127
 ocean trench 127
 oceanic crust 124, 127
 oceans, making 129
 ochre 84, 229
 oesophagus 299, 300, 307
 ohms 198
 oil refineries 245
 omasum 307
 onion-skin cells 273–4
 onion-skin weathering 92
 opalised fossils 101, 112
 organ transplants 330–1
 organelles 270–3, 290, 291
 organisms 298
 organoids 343
 organs 297–8
 artificial 342
 non-vital 342
 plants 332–6
 osmosis 332
 outliers 47
 oxygen 209, 211, 212, 216, 220, 221
 circulatory system 319, 320
 magnesium oxide 236–9
 molecular element 216
 respiratory system 298, 311–13

P

pancreas 301
 Pangaea 122, 128
 parallax error 32, 33
 parallel circuit 192–6
Paramecium 278
 particle size and reaction rate
 242
 particle theory 220
 passive design 171–2, 175
 Pasteur, Louis 288
 pathogens 283, 290
 peer review 59
 penicillin 287–8, 293
 pericarditis 326
 pericardium 326
 period (chemical) 212
 periodic table 209, 210, 212–13, 253
 peristalsis 300, 301
 petroleum 245
 pharmacists/pharmaceuticals
 245
 pharynx 312
 philosophers 4

- phloem 332, 334
 photoconductivity 200
 photoresistors 200
 photosynthesis 271, 333
 photovoltaic cells 178
 physical change 222–8, 253
 physical digestion 301
 physical weathering 92
 physical world 4
 science as study of 4–6
 physics 5
 planning and conducting
 experiments 13, 21–6, 68
 plant cells 277, 280, 290, 293, 333
 plant tissues and organs 332–6, 339
 leaves 333
 roots 332, 336
 stem 332, 334
 plaque on arteries 324–5
 plasma 320
 plastic 245, 250–1
 plate tectonics 122–47
 platelets 320
 pneumonia 318
 polymers 217
 positive correlation 51
 positive terminal 189
 Post-It notes 247
 potential difference 196
 potential energy 150, 157–61, 177, 181
 potentiometer 198
 precipitate 229
 precision 32
 predictions 13, 20
 primary body waves 138
 probe 29, 30
 products 235, 236, 239
 prokaryotic cells 276
 properties 74
 elements 212, 213, 214
 rocks 74–6, 112
 protein, digesting 302–4
 protists 277, 278, 283
 pseudoscience 15, 68
 pumice 75, 76, 79
 pure substances 217
- Q**
- qualitative data 38
 qualitative observations 18
 quantitative data 38
 quantitative observations 18
 quartzite 75, 76, 88
 “Queenslander” houses 172–3
 questions 13, 18–19
- R**
- radiation 171
 Rayleigh waves 138
 reactants 235, 236, 239
 reading error 32, 33
 recipient (of organ) 330
 recording data 37–46, 69
 recrystallation 88
 rectifier 199
 rectum 299, 300
 recycling 250–2
 red blood cells 320
 reliable results 22
 reliable science 50
 remote control 152
 reproducible test 22
 resistance 197–8, 203
 altering 198–201
 resistor 189, 198
 light-dependent 200
 temperature-dependent 201
 respiratory system 298, 311–18, 339
 definition 311
 problems 316–18, 339
 variations between animals 313
 results 26, 27, 60
 communicating 14, 59–65, 69
 comparing 46–7
 evaluation 14, 50–3, 69
 reliable 22
 reticulum 307
 retort stand 27
 retrofitting homes 344
 rhyolite 75, 76
 ribosomes 270, 277
 Richter scale 131
 ridge push 124
 rift valley 129
 risk management 23–4
 rock cycle 91–5, 112
 rocks 74–115
 age, calculating 100–3, 112
 identifying 74–8
 igneous 78–81, 112, 114
 metamorphic 87–90, 112, 114
 pressure affecting 82–4, 87–8, 93
 properties 74–6, 112
 sedimentary 82–6, 112, 114
 weathering/erosion 92–9, 112, 114
 root cell modelling 336
 roots 332
 rounding off 34
 Rube Goldberg machines 185
- rumen 307
 ruminants 307
 rust/rusting 251
- S**
- safety 23–4, 28
 sandstone 75, 76, 83, 102
 Sankey diagram 168
 scalpel 29, 30, 31
 scanning electron microscope (SEM) 265
 scatter graphs 42–3
 schist 75, 76
 Schleiden, Matthias 261
 Schwann, Theodor 261
 science, definition 4, 68
 scientific equipment 26–9, 68
 scientific method 13–17, 68
 communication 14, 59–65, 69
 evaluation 14, 50–3, 69
 importance 14–15
 measuring and recording 13, 32–46, 69
 observations and questions 13, 17–21, 68
 planning and conducting 13, 21–6, 68
 stages 13–14
 scientific report 59–60, 69
 scientific research *see also*
 experiments
 ethical issues 24–5
 measuring and recording data 13, 32–46
 planning and conducting 13, 21–6, 68
 protocols 25
 safety measures 23–4
 scientists 4, 5, 66
 scoria 75, 76, 80
 sea-floor spreading 123
 secondary body waves 138
 sediment 82
 sedimentary rocks 82–6, 112, 114
 fossils in 100–1
 seismic geophysical testing 105
 seismic refraction method 106
 seismometers 123
 series circuit 192–6
 shale 75, 76, 83, 102
 short circuit 194
 SI system 34
 significant figures 34, 35
 skeletal system 298
 skin 328
 slab pull 124
- slate 75, 76
 small intestine 299, 300, 301, 307
 smoking 317, 318, 325, 342
 sneezing 317
 soil erosion 96–9
 soil testing 257
 solar cars 179
 solar cells 162, 177
 solar energy 150–1, 162, 177–80
 solidification 225
 solution 221
 sound energy 163, 165
 spatula 27
 stain 264
 stalagmites and stalactites 84
 standard units 34–5
 STEAM projects 344–51
 stem 332, 334
 stem cells 293
 stereomicroscopes 264
 stirring rod 27
 stomach 299, 300, 301, 307
 stomach ulcers 309
 stomata 333
 subduction 124, 127, 128, 147
 subduction zones 147
 sublimation 225
 supercontinent 122, 128
 surface area and reaction speed 241
 surface area to volume ratio 261
 surface waves 138
 suspensions 221
 symptoms 283
 systems 298, 338
- T**
- tectonic plates 119, 122–47
 constructive or destructive 130–6
 convergent boundaries 127–8, 143
 divergent boundaries 128–9, 143
 fault 126
 forces causing movement of 122–5
 modelling boundaries 136–7
 plate tectonics 122–47
 transform boundaries 126–7, 143
 teeth 300, 301, 306
 temperature
 chemical reactions, effect on 240
 rocks, effect on 93

- temperature-dependent resistors 201
 test tube 27
 test tube holder 27
 test tube rack 27
 testing for substances 237
 thermal energy 162–3
 thermal fuses 205
 thermometer 27
 tissues 297
 plants 332–6
 title
 graph 43
 scientific report 59
 torch circuit 191
 tors 92
 trace fossil 100, 112
 trachea 312
 transform boundaries 126–7, 143
 transmission electron microscope (TEM) 265
 transpiration 332, 337
 trends in data 48–9
- tripod stand 27
 true value 32
 tsunamis 131, 132, 147
 tweezers 29, 30
- U**
- ulcers 309
 ultrasound 310
 unicellular organisms 261, 262, 276, 278, 279
 bacteria *see* bacteria
 disease caused by 282–6
 upwarping 129
 urea 327, 328
- V**
- vacuole 272, 277, 281
 valid experiment 51
 validity 13, 51
 valve disease 324
 valves (heart) 320
 vapour/vaporisation 224
Varanus priscus 100
- variables 19, 38
 vascular bundle 332
 veins 321
 ventricles 320, 324
 vesicles 272
 villi 301
 Virchow, Rudolf 261
 volatile substances 224
 volcanos 119, 124, 126, 127, 132–3
 Budj Bim National Park 147
 eruptions 132
 Hawaiian Islands 132–3
 predicting eruptions 105
 tsunamis and 132
 undersea 132
 voltage 196–8, 203
 voltmeter 189, 196, 197
- W**
- Warren, Robin 309
 watch glass 27
 water 216–17, 220–3
- weathering (rocks) 92–9, 112
 preventing 96–9, 112
 Wegener, Alfred 122, 123
 Western science 9
 white blood cells 320
 wiring a house 202
- X**
- x-ray paintings 296
 xylem 332, 334
- Z**
- zero error 32, 33
 zeroing scales 33
Zygomaturus trilobus 102, 103

Acknowledgements

Cover Image: SAM FALCONER, DEBUT ART/SCIENCE PHOTO LIBRARY **Module 1: Opener:** SAM FALCONER, DEBUT ART/SCIENCE PHOTO LIBRARY. Lesson 1.1: Fig. 1, Hein Nouwens/Shutterstock; Fig. 3, paleontologist natural/Shutterstock; Fig. 4, Quality Stock Arts/Shutterstock; Fig. 5, Darren Baker/Shutterstock; Fig. 6, Magic Orb Studio/Shutterstock; Lesson 1.2: Fig. 2, Imago/Alamy Stock Photo; Fig. 3, spline_x/Shutterstock; Fig. 4, Benny Marty/Shutterstock; Fig. 5, Andrew Bain/Alamy Stock Photo; Fig. 6, BlueSnap/Shutterstock; Lesson 1.3: Fig. 3, Sunnydream/Shutterstock; Lesson 1.4: Fig. 2, Shuttertum/Shutterstock; Fig. 3, Katcha_Natsarin/Shutterstock; Fig. 3, Halfpoint/Shutterstock; Fig. 4, chemical industry/Shutterstock; Fig. 5 (a), Gorodenkoff/Shutterstock; Fig. 5 (b), AndriiKoval/Shutterstock; Fig. 6, John John Lemon/Shutterstock; Lesson 1.6: Fig. 1 (a), Shuttertum/Shutterstock; Fig. 1 (b), New Africa/Shutterstock; Fig. 1 (c), Anwarul Kabir Photo/Shutterstock; Fig. 1 (d), Shuttertum/Shutterstock; Fig. 1 (e), Mehmet Cetin/Shutterstock; Fig. 1 (f), Pixel-Shot/Shutterstock; Fig. 1 (g), Hora Studio/Shutterstock; Fig. 1 (h), PixelSquid3d/Shutterstock; Fig. 1 (i), Peter Sobolev/Shutterstock; Fig. 1 (j), Chadchai Krisadapong/Shutterstock; Fig. 1 (k), Nataliass/Shutterstock; Fig. 1 (l), Rabbitmindphoto/Shutterstock; Fig. 1 (m), creativesunday/Shutterstock; Fig. 1 (n), Picture-Syndicate/Shutterstock; Fig. 1 (o), eczserapyilmaz/Shutterstock; Fig. 1 (p), Jan Kaliciak/Shutterstock; Fig. 2, borzywoj/Shutterstock; Fig. 3, oksana2010/Shutterstock; Fig. 4, Nikuwka/Shutterstock; Fig. 6, Contrail/Shutterstock; Fig. 7, Aireo/Shutterstock; Lesson 1.7: Fig. 1, Paradise studio/Shutterstock; Fig. 2, Brent Parker Jones Photographer/OUP; Fig. 3, Brent Parker Jones Photographer/OUP; Fig. 4, Brent Parker Jones Photographer/OUP; Fig. 5, Brent Parker Jones Photographer/OUP; Fig. 6, Brent Parker Jones Photographer/OUP; Fig. 7, Brent Parker Jones Photographer/OUP; Fig. 8, Brent Parker Jones Photographer/OUP; Fig. 9, Brent Parker Jones Photographer/OUP; Fig. 10, Brent Parker Jones Photographer/OUP; Fig. 11, Brent Parker Jones Photographer/OUP; Lesson 1.8: Fig. 1, i4lcocl2/Shutterstock; Fig. 4, Vladimka production/Shutterstock; Fig. 5, Travel mania/Shutterstock; Fig. 6, Joey Chung/Shutterstock; Lesson 1.10: Fig. 22, VectorMine/Shutterstock; Fig. 23, paaruOK/Shutterstock; Lesson 1.11: Fig. 1, arka38/Shutterstock; Lesson 1.12: Fig. 3, sevasaves1/Shutterstock; Fig. 4, litchima/Shutterstock; Fig. 5, Reproduced with permission of Elizabeth Tibbetts; Lesson 1.13: Fig. 1, PATRICK LANDMANN/SCIENCE PHOTO LIBRARY; Lesson 1.16: Fig. 1, Edcel Mayo/Shutterstock; Lesson 1.17: Fig. 3, Nomad_Soul/Shutterstock; Fig. 4, Pictorial Press Ltd/Alamy Stock Photo; Fig. 5, Indra Saputra Ahmadi/Shutterstock. **Module 2: Opener:** SAM FALCONER, DEBUT ART/SCIENCE PHOTO LIBRARY. Lesson 2.1: Fig. 1, Rob kemp/Shutterstock; Fig. 2, sumikophoto/Shutterstock; Fig. 3 (a), Anatoliy Karlyuk/Shutterstock; Fig. 3 (b), B art/Shutterstock; Fig. 4, Suzi Nelson/Shutterstock; Fig. 5, Leroy Harvey/Shutterstock; Fig. 6 (a), Tyler Boyes/Shutterstock; Fig. 6 (b), danimages/Shutterstock; Fig. 6 (c), bogdan ionescu/Shutterstock; Fig. 6 (d), Tyler Boyes/Shutterstock; Fig. 6 (e), Bragin Alexey/Shutterstock; Fig. 6 (f), Tyler Boyes/Shutterstock; Fig. 6 (g), Tyler Boyes/Shutterstock; Fig. 6 (h), Siim Sepp/Shutterstock; Fig. 6 (i), Rob kemp/Shutterstock; Fig. 6 (j), www.sandatlas.org/Shutterstock; Fig. 6 (k), Tyler Boyes/Shutterstock; Fig. 6 (l), Alexlukin/Shutterstock; Fig. 6 (m), Tyler Boyes/Shutterstock; Fig. 6 (n), www.sandatlas.org/Shutterstock; Fig. 6 (o), carolo7/Getty Images; Fig. 6 (p), Tyler Boyes/Shutterstock; Lesson 2.2: Fig. 1, Kamila Kozioł/Alamy Stock Photo; Fig. 2, Jorge Moro/Shutterstock; Fig. 3, Christopher Edwin Nuzzaco/Shutterstock; Fig. 4 (a), Robyn Mackenzie/Shutterstock; Fig. 4 (b), Danicek/Shutterstock; Fig. 4 (c), steve estvanik/Shutterstock; Lesson 2.4: Fig. 1, iceink/Shutterstock; Lesson 2.5: Fig. 2, Sarah2/Shutterstock; Fig. 3, TanArt/Shutterstock; Fig. 4, Siim Sepp/Shutterstock; Fig. 5, Geo-grafika/Shutterstock; Fig. 6, AG-PHOTOS/Shutterstock; Fig. 7, John Robinson/Alamy Stock Photo; Lesson 2.6: Fig. 1, Leene/Shutterstock; Lesson 2.7: Fig. 1, Core Knowledge® Foundation & ReadWorks; Fig. 2, saiko3p/Shutterstock; Fig. 3, LesPalenik/Shutterstock; Fig. 4 (a), Bragin Alexey/Shutterstock; Fig. 4 (b), Siim Sepp/Alamy Stock Photo; Fig. 5, Steven Nowakowski; Lesson 2.8: Fig. 1, Sarah2/Shutterstock; Lesson 2.9: Fig. 1, VectorMine/Shutterstock; Fig. 2 (a), Janelle Lugge/Shutterstock; Fig. 2 (b), Karin Wabro/Shutterstock; Fig. 2 (c), imageBROKER.com GmbH & Co. KG/Alamy Stock Photo; Fig. 3, Ryan McGinnis/Alamy Stock Photo; Fig. 4, geogphotos/Alamy Stock Photo; Fig. 5,

Leigh Prather/Shutterstock; Lesson 2.10: Fig. 2, Svitlana Kataieva/Shutterstock; Lesson 2.11: Fig. 1, Jandrie Lombard/Shutterstock; Fig. 3 (a), robertharding/Alamy Stock Photo; Fig. 3 (b), dpa picture alliance archive/Alamy Stock Photo; Fig. 3 (c), Matthew Taylor/Alamy Stock Photo; Fig. 3 (d), Neil Cooper/Alamy Stock Photo; Fig. 4, Scott Olson/Getty Images; Fig. 5, Nick Hawkes/Shutterstock; Fig. 7, gary corbett/Alamy Stock Photo; Fig. 8, 3445128471/Shutterstock; Fig. 9, Mark Wilson/Getty Images; Fig. 6, Stephane Bidouze/Shutterstock; Lesson 2.12: Fig. 2, Kaentian Street/Shutterstock; Lesson 2.13: Fig. 1, Science Photo Library/Alamy Stock Photo; Fig. 2, Stocktrek Images, Inc./Alamy Stock Photo; Fig. 4, The Natural History Museum/Alamy Stock Photo; Fig. 5, Michael C Westaway; Lesson 2.14: Fig. 1, MILLARD H. SHARP/SCIENCE PHOTO LIBRARY; Lesson 2.15: Fig. 2, Science Photo Library/Alamy Stock Photo; Fig. 4 (b), kevin nicholson/Alamy Stock Photo; Fig. 6, dpa picture alliance/Alamy Stock Photo; Lesson 2.16: Fig. 1, Mara Fribus/Shutterstock; Lesson 2.17: Fig. 1 (a), FabrikaSimf/Shutterstock; Fig. 1 (b), David Franklin/Shutterstock; Lesson 2.18: Fig. 1, Tyler Boyes/Shutterstock; Fig. 2, Rattachon Angmanee/Shutterstock; Fig. 3, Barbarajo/Shutterstock; Fig. 4, MagSpace/Shutterstock. **Module 3: Opener:** SAM FALCONER, DEBUT ART/SCIENCE PHOTO LIBRARY. Lesson 3.1: Fig. 4, steve estvanik/Shutterstock; Lesson 3.3: Fig. 1, Sueddeutsche Zeitung Photo/Alamy Stock Photo; Lesson 3.4: Fig. 3, Worldspec/NASA/Alamy Stock Photo; Fig. 4, Cavan Images/Alamy Stock Photo; Fig. 8, Joanna Rigby-Jones/Shutterstock; Fig. 9, NASA/Alamy Stock Photo; Lesson 3.5: Fig. 1, Everett Collection/Shutterstock; Fig. 3, Belikova Oksana/Shutterstock; Fig. 2 (b), Falcon video/Shutterstock; Fig. 4 (a), Mlenny/Getty Images; Fig. 4 (b), jonhortondesign/Getty Images; Fig. 4 (c), Mlenny/Getty Images; Fig. 4 (d), Panther Media GmbH/Alamy Stock Photo; Fig. 4 (e), steinphoto/Getty Images; Fig. 4 (f), Claudio Rossol/Shutterstock; Lesson 3.7: Fig. 5, NigelSpiers/Shutterstock; Fig. 6, DampTech Earthquake Protection; Lesson 3.9: Fig. 1, steve estvanik/Shutterstock; Fig. 2, Science Photo Library/Alamy Stock Photo; Fig. 4, Marco Iacobucci Epp/Shutterstock; Fig. 5, daulon/Shutterstock; Fig. 6, Tum Kia/Shutterstock. **Module 4: Opener:** SAM FALCONER, DEBUT ART/SCIENCE PHOTO LIBRARY. Lesson 4.1: Fig. 3, Dennis MacDonald/Alamy Stock Photo; Fig. 5, Matej Kastelic/Shutterstock; Fig. 7, Henk Graalman. Released under Creative Commons Attribution 4.0 International license <https://creativecommons.org/licenses/by/4.0/deed.en>; Fig. 9, Paul Mayall Australia/Alamy Stock Photo; Fig. 11, Science Photo Library/Alamy Stock Photo; Fig. 12, Tomislav Pinter/Shutterstock; Lesson 4.2: Fig. 1, 57stock/Alamy Stock Photo; Fig. 3, MilanB/Shutterstock; Fig. 5, aquariagirl1970/Shutterstock; Fig. 8, studiovin/Shutterstock; Fig. 7, Andrey Lobachev/Shutterstock; Lesson 4.3: Fig. 1, Andy Myatt/Alamy Stock Photo; Fig. 2, RyanJLane/Getty Images; Fig. 4, Chones/Shutterstock; Fig. 3, Erica Finstad/Shutterstock; Fig. 5, Science History Images/Alamy Stock Photo; Lesson 4.5: Fig. 2, Lana Langlois/Shutterstock; Fig. 1, aluxum/Getty Images; Fig. 3, MEDITERRANEAN/Getty Images; Fig. 4, Nigel Kinrade/Sports Illustrated/Getty Images; Fig. 5, Max4e Photo/Shutterstock; Lesson 4.6: Fig. 1, Somchai Som/Shutterstock; Fig. 2 (a), Maria Kovalets/Shutterstock; Fig. 2 (b), saiko3p/Shutterstock; Fig. 3 (a), nopow/Getty Images; Fig. 3 (b), Madmaxer/Getty Images; Fig. 3 (c), icefront/Getty Images; Fig. 3 (e), Andrea Danti/Shutterstock; Fig. 3 (d), taniascamera/Shutterstock; Fig. 4, VIAVAL TOURS/Shutterstock; Fig. 5 (a), Tamara Kulikova/Shutterstock; Fig. 5 (b), ssuaphotos/Shutterstock; Fig. 5 (c), andrea crisante/Shutterstock; Fig. 5 (d), JoeyPhoto/Shutterstock; Fig. 6 (a), set/Shutterstock; Fig. 6 (b), Sky Light Pictures/Shutterstock; Fig. 6 (c), Adam Harner/Shutterstock; Fig. 6 (d), JoeyPhoto/Shutterstock; Fig. 7 (a), Jurand/Shutterstock; Fig. 7 (b), Kodda/Shutterstock; Fig. 7 (c), CoolKengzz/Shutterstock; Fig. 7 (d), JoeyPhoto/Shutterstock; Fig. 8, Dario Lo Presti/Shutterstock; Lesson 4.7: Fig. 2, Lux Blue/Shutterstock; Lesson 4.8: Fig. 1, Global Warming Images/Alamy Stock Photo; Fig. 2, Bilanol/Shutterstock; Fig. 3, John Daniels/Alamy Stock Photo; Lesson 4.9: Fig. 1, Russell Hobbs; Lesson 4.11: Fig. 2, Joni Hanebutt/Shutterstock; Fig. 3, MARTIN BERNETTI/AFP/Getty Images; Fig. 4 (b), dpa picture alliance/Alamy Stock Photo; Fig. 4 (a), Hulton-Deutsch Collection/CORBIS/Getty Images; Fig. 5, Mark Boulton/Alamy Stock Photo; Fig. 6, Australian PV Institute (APVI) Solar Map, funded by the Australian Renewable Energy Agency, accessed from pv-map.apvi.org.au

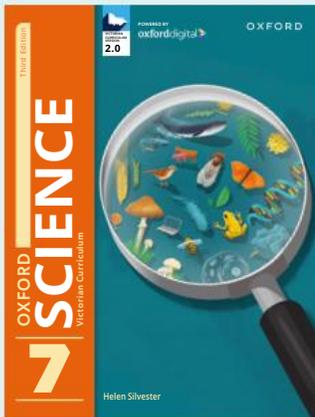
on 23 January 2025.; Lesson 4.12: Fig. 1, GrashAlex/Shutterstock; Fig. 4, Ljupco Smokovski/ Shutterstock; Fig. 5, Peshkova/Shutterstock; Fig. 6, Juice Flair/Shutterstock; Fig. 7, Archive PL/Alamy Stock Photo. **Module 5: Opener:** SAM FALCONER, DEBUT ART/SCIENCE PHOTO LIBRARY. Lesson 5.2: Fig. 1, Petr Malyshev/Shutterstock; Lesson 5.3: Fig. 2, Viktor Gladkov/Shutterstock; Fig. 4, stanislave/Shutterstock; Fig. 3, BlueRingMedia/Shutterstock; Lesson 5.5: Fig. 2, namatae/Shutterstock; Fig. 3, Flegere/Shutterstock; Lesson 5.6: Fig. 4, Feng Yu/Alamy Stock Photo; Fig. 6, Quality Stock Arts/Shutterstock; Fig. 7, lumenetumbra/Shutterstock; Lesson 5.7: Fig. 1, dny3d/Shutterstock; Lesson 5.8: Fig. 4, Ezume Images/Shutterstock; Fig. 5, Martin Kucera/Shutterstock; Fig. 6, Gorvik/Shutterstock. **Module 6: Opener:** SAM FALCONER, DEBUT ART/SCIENCE PHOTO LIBRARY. Lesson 6.1: Fig. 1, Stocktrek Images, Inc./Alamy Stock Photo; Fig. 2 (a), Ann Ronan Pictures/Print Collector/Getty Images; Lesson 6.2: Fig. 4, CHARLES D. WINTERS/SCIENCE PHOTO LIBRARY; Lesson 6.5: Fig. 1, bouybin/Shutterstock; Lesson 6.6: Fig. 6, Pif Paf Puf Studio/Shutterstock; Lesson 6.7: Fig. 1, AfriPics.com/Alamy Stock Photo; Fig. 2, science photo/Shutterstock; Fig. 5, CHARLES D. WINTERS/SCIENCE PHOTO LIBRARY; Fig. 4, Olga_Narcissa/Shutterstock; Lesson 6.8: Fig. 1, Brent Paker Jones Photographer; Fig. 2, MAHATHIR MOHD YASIN/ Shutterstock; Lesson 6.9: Fig. 2, NatashaPhoto/Shutterstock; Fig. 3, FabioFilzi/Getty Images; Fig. 4, Valentin Agapov/Shutterstock; Fig. 5, E. R. DEGGINGER/SCIENCE PHOTO LIBRARY; Fig. 6, Ted Foxx/Alamy Stock Photo; Lesson 6.10: Fig. 1, kcline/Getty Images; Lesson 6.11: Fig. 1, MARTYN F. CHILLMAID/SCIENCE PHOTO LIBRARY; Lesson 6.13: Fig. 2, AlphaAndOmega/Alamy Stock Photo; Fig. 3, robertharding/Alamy Stock Photo; Fig. 4, Luis Echeverri Urrea/Shutterstock; Lesson 6.15: Fig. 1, cosma/Shutterstock; Fig. 4, SorenP/Getty Images; Fig. 5, Phil McDonald/ Shutterstock; Lesson 6.16: Fig. 1, Brent Paker Jones Photographer R; Fig. 2, Brent Paker Jones Photographer R; Lesson 6.18: Fig. 2, Dmitry Kalinovsky/Shutterstock; Fig. 1 (a), Africa Studio/Shutterstock; Fig. 1 (b), Alaettin YILDIRIM/Shutterstock; Fig. 1 (c), DeanHarty/Shutterstock; Fig. 1 (d), Karkas/Shutterstock; Fig. 3 (a), StockPhotosArt/Shutterstock; Fig. 3 (b), BlackJack3D/Getty Images; Fig. 3 (c), shutswis/Getty Images; Fig. 3 (d), DustyPixel/Getty Images; Fig. 4, AISA - Everett/Shutterstock; Fig. 5 (a), alejandrodans neergaard/Shutterstock; Fig. 5 (b), atilayunal/Getty Images; Fig. 5 (c), Norman Pogson/Shutterstock; Fig. 5 (d), Craig Wactor/Shutterstock; Fig. 6, The National Trust Photolibrary/Alamy Stock Photo; Lesson 6.19: Fig. 1, Jackson Stock Photography/Shutterstock; Lesson 6.20: Fig. 8, Elnur/Shutterstock; Fig. 1, Tribalium/Shutterstock; Fig. 2, Tribalium/Shutterstock; Fig. 3, Tribalium/Shutterstock; Fig. 4, Tribalium/Shutterstock; Fig. 5, Tribalium/Shutterstock; Fig. 6, Tribalium/Shutterstock; Fig. 7, Tribalium/Shutterstock; Fig. 9, Artens/Shutterstock; Lesson 6.21: Fig. 1, Shaiith/ Shutterstock; Fig. 2, Karnwela/Shutterstock; Fig. 4, Bogdan Sonjachnyj/Shutterstock; Fig. 5, Nomad_Soul/Shutterstock; Fig. 6, sumroeng chinnapan/Shutterstock; Fig. 7, tab62/Shutterstock. **Module 7: Opener:** SAM FALCONER, DEBUT ART/SCIENCE PHOTO LIBRARY; Lesson 7.1: Fig. 1, World History Archive/Alamy Stock Photo; Fig. 2 (a), Science Photo Library/Alamy Stock Photo; Fig. 2 (b), M I (Spike) Walker/Alamy Stock Photo; Fig. 3, Science Photo Library/Alamy Stock Photo; Lesson 7.2: Fig. 1 (a), Claudio Divizia/Shutterstock; Lesson 7.3: Fig. 1 (a), Roger Eritja/Alamy Stock Photo; Fig. 1 (b), EYE OF SCIENCE/SCIENCE PHOTO LIBRARY; Fig. 2, Science Photo Library/Alamy Stock Photo; Lesson 7.4: Fig. 3, David Herraes Calzada/Shutterstock; Lesson 7.5: Fig. 1, Designua/Shutterstock; Fig. 2 (a), Science Photo Library/Alamy Stock Photo; Fig. 2 (b), Science Photo Library/Alamy Stock Photo; Fig. 2 (c), Science Photo Library/Alamy Stock Photo; Fig. 2 (d), Science Photo Library/Alamy Stock Photo; Fig. 5 (b), Science History Images/Alamy Stock Photo; Fig. 6, Choksawatdikorn/Shutterstock; Fig. 8, Greg Brave/

Shutterstock; Fig. 7 (b), Science Photo Library/Alamy Stock Photo; Fig. 9 (a), MARTIN OEGGERLI/SCIENCE PHOTO LIBRARY; Fig. 9 (b), Sebastian Kaulitzki/Shutterstock; Fig. 9 (c), STEVE GSCHMEISSNER/SCIENCE PHOTO LIBRARY; Fig. 9 (d), martan/Shutterstock; Fig. 9 (e), STEVE GSCHMEISSNER/SCIENCE PHOTO LIBRARY; Fig. 9 (f), Allex/Getty Images; Lesson 7.7: Fig. 1, Alex Churilov/Shutterstock; Lesson 7.8: Fig. 1 (a), Science Photo Library/Alamy Stock Photo; Fig. 1 (b), Science Photo Library/Alamy Stock Photo; Fig. 2, Science Photo Library/Alamy Stock Photo; Lesson 7.10: Fig. 1 (a), Science Photo Library/Alamy Stock Photo; Fig. 1 (b), Science Photo Library/Alamy Stock Photo; Fig. 1 (c), Science Photo Library/Alamy Stock Photo; Fig. 1 (d), Science Photo Library/Alamy Stock Photo; Fig. 1 (e), EYE OF SCIENCE/SCIENCE PHOTO LIBRARY; Fig. 2 (a), EYE OF SCIENCE/SCIENCE PHOTO LIBRARY; Fig. 2 (b), DR TONY BRAIN/SCIENCE PHOTO LIBRARY; Fig. 2 (c), A. DOWSETT, NATIONAL INFECTION SERVICE/SCIENCE PHOTO LIBRARY; Lesson 7.11: Fig. 1, Brent Parker Jones Photographer; Fig. 2 (a), Science Photo Library/Alamy Stock Photo; Fig. 2 (b), ggw/Shutterstock; Lesson 7.12: Fig. 1, Baron/Hulton Archive/Getty Images; Fig. 7, Fotos52/Shutterstock; Fig. 2, Science History Images/Alamy Stock Photo; Fig. 3, World History Archive/Alamy Stock Photo; Fig. 4, World History Archive/Alamy Stock Photo; Lesson 7.12: Fig. 1 (a), Science Photo Library/Alamy Stock Photo; Fig. 1 (b), BIOPHOTO ASSOCIATES/SCIENCE PHOTO LIBRARY; Fig. 1 (c), © Hans Hillewaert. Released under CC BY-SA 4.0; Fig. 1 (d), Science Photo Library/Alamy Stock Photo; Fig. 2 (a), Science History Images/Alamy Stock Photo; Fig. 2 (b), DR JEREMY BURGESS/SCIENCE PHOTO LIBRARY; Fig. 2 (c), J.C. REVY, ISM/SCIENCE PHOTO LIBRARY; Fig. 3, Viktar Malyschys/Shutterstock; Fig. 4, Everett Collection/Shutterstock; Fig. 5, STEVE GSCHMEISSNER/SCIENCE PHOTO LIBRARY; Fig. 6, S.Toey/Shutterstock. **Module 8: Opener:** SAM FALCONER, DEBUT ART/SCIENCE PHOTO LIBRARY. Lesson 8.1: Fig. 1, Nick Brundle Photography/ Shutterstock; Lesson 8.2: Fig. 4, homydesign/ Shutterstock; Fig. 3, TimeLineArtist/Shutterstock; Lesson 8.4: Fig. 1, Maks Narodenko/ Shutterstock; Lesson 8.5: Fig. 1, The Natural History Museum/Alamy Stock Photo; Fig. 5 (a), The Natural History Museum/Alamy Stock Photo; Fig. 5 (b), Noctiluxx/Getty Images; Lesson 8.6: Fig. 1, CNRI/SCIENCE PHOTO LIBRARY; Fig. 2, TONY ASHBY/AFP/Getty Images; Fig. 3, BSIP SA/Alamy Stock Photo; Fig. 4, Phanie - Sipa Press/Alamy Stock Photo; Fig. 5, Krakenimages.com/Shutterstock; Lesson 8.10: Fig. 1, George Rudy/Shutterstock; Fig. 2 (a), BSIP SA/Alamy Stock Photo; Fig. 2 (b), BSIP SA/Alamy Stock Photo; Fig. 3, Iryna Melnyk/Shutterstock; Fig. 4 (a), Kateryna Kon/Shutterstock; Fig. 4 (b), Kateryna Kon/Shutterstock; Lesson 8.12: 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 8.13: Fig. 1 (a), Science Photo Library/Alamy Stock Photo; Fig. 1 (b), Science Photo Library/Alamy Stock Photo; Fig. 3 (a), Alice Day/Shutterstock; Fig. 4, Andresr/ Shutterstock; Lesson 8.15: Fig. 1, Ozgur Coskun/Shutterstock; Lesson 8.16: Fig. 1, mailsopignata/Shutterstock; Lesson 8.17: Fig. 2, Science Photo Library/Alamy Stock Photo; Fig. 4, Juergen Faelchle/Shutterstock; Fig. 5, Lev Kropotov/ Shutterstock; Lesson 8.18: Fig. 1 (a), sciencephotos/Alamy Stock Photo; Fig. 1 (b), John Boud/Alamy Stock Photo; Lesson 8.19: Fig. 1, Mike Rosecope/Shutterstock; Lesson 8.21: Fig. 2, eveleen/Shutterstock; Fig. 3, doublelee/Shutterstock; Fig. 4, Photoroyalty/Shutterstock; Fig. 5, © 2015 Daniel St Johnston. St Johnston D (2015) The Renaissance of Developmental Biology. *PLoS Biol* 13(5): e1002149. <https://doi.org/10.1371/journal.pbio.1002149>. Released under CC BY 4.0 <https://creativecommons.org/licenses/by/4.0/deed.en>. **Prelims:** Peter Hermes Furian/Shutterstock. **Glossary:** Porstocker/Shutterstock.



The Earth is made up of four layers. The outer layer, on which we live, is the crust. The next layer down is the mantle, which is made up of molten rock. Then comes the outer core followed by the inner core. The inner core is a solid metal ball made of iron and nickel. It has a diameter of 2,442 kilometres!

Other titles in this series



visit us at oup.com.au or
contact customer support at oup.com.au/help