CAMBRIDGE
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Cambridge science for Queensland 2nd Edition

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ISBN 978-1-009-40426-6

CAMBRIDGE
UNIVERSITY PRESS

Shaftesbury Road, Cambridge CB2 8EA, United Kingdom

One Liberty Plaza, 20th Floor, New York, NY 10006, USA

477 Williamstown Road, Port Melbourne, VIC 3207, Australia

314–321, 3rd Floor, Plot 3, Splendor Forum, Jasola District Centre, New Delhi – 110025, India

103 Penang Road, #05–06/07, Visioncrest Commercial, Singapore 238467

Cambridge University Press is part of Cambridge University Press & Assessment, a department of the University of Cambridge.

We share the University's mission to contribute to society through the pursuit of education, learning and research at the highest international levels of excellence.

www.cambridge.org

First published 2020
Second Edition 2023
20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

Cover and text designed by Shaun Jury
Typeset by QBS Learning
Printed in Singapore by Markono Print Media Pte Ltd

A catalogue record for this book is available from the National Library of Australia at www.nla.gov.au

ISBN 978-1-009-40426-6 Paperback

Additional resources for this publication at www.cambridge.edu.au/GO

Please be aware that this publication may contain images of Aboriginal and Torres Strait Islander people who are now deceased. Several variations of Aboriginal and Torres Strait Islander terms and spellings may also appear; no disrespect is intended. Please note that the terms 'Indigenous Australians' and 'Aboriginal and Torres Strait Islander peoples' may be used interchangeably in this publication.

Cambridge University Press & Assessment acknowledges the Aboriginal and Torres Strait Islander peoples of this nation. We acknowledge the traditional custodians of the lands on which our company is located and where we conduct our business. We pay our respects to ancestors and Elders, past and present. Cambridge University Press & Assessment is committed to honouring Aboriginal and Torres Strait Islander peoples' unique cultural and spiritual relationships to the land, waters and seas and their rich contribution to society.

About the authors

Dr Gemma Dale is a nationally certified lead teacher, working as a senior biology teacher at a Brisbane school. With over 16 years' experience teaching senior sciences in the UK and Australia, she also has a tertiary background in ecology and a Master of Science in Biodiversity and Conservation. She has also completed an education doctorate (EdD) specialising in scientific literacy.

Dr Gemma Dale
Lead author

Dr Brodie Reid teaches secondary science and Year 11 and 12 ATAR chemistry. He also has many years of experience teaching at the tertiary level and is an author of over ten academic publications. He has presented his research internationally, winning several awards along the way.

Dr Brodie Reid

The publisher thanks Victoria Shaw, Christopher Humphreys, Kyle Schellack-Potter, Naomi Sutanto and the Australian Nuclear Science and Technology Organisation for reviewing and contributing to this resource.

About the cover

Boronia grimshawii, commonly known as Grimshaw's boronia, is a rare shrub found only in an isolated area near Gayndah, Queensland. It is listed as vulnerable under Queensland's *Nature Conservation Act 1992.* The woody shrub grows to about two metres tall, and flowers from June to October. The distinctive four-pointed flowers are featured on the cover of this publication.

Boronia grimshawii

Contents

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Answers are available in the Interactive Textbook and the teacher resources.

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How to use this resource

Elements in the print book

Glossary
definitions of key terms are provided next to where the key term first appears in the chapter.

Explore!

Students are encouraged to conduct research online to find and interpret information.

Quick check

These provide quick checks for recalling facts and understanding content. These questions are also available as Word document downloads in the Interactive Textbook.

Learning goals

These are descriptions of what the student will learn throughout the section.

Did you know?

These are short facts that contain interesting information.

Science as a human endeavour

These are recent developments in the particular area of science being covered. They may also show how ideas in science have changed over the years through human discovery and inventions.

Section questions

Question sets at the ends of sections are categorised under four headings: Retrieval, Comprehension, Analysis and Knowledge utilisation. Cognitive verbs have been bolded. These questions are also available as Word document downloads in the Interactive Textbook.

Hands-on activities

Try this

Classroom activities help explore concepts that are currently being covered.

Making thinking visible

Visible thinking style classroom activities to help consolidate the concepts currently being covered.

Practical skills

These activities focus on developing one or two science inquiry skills, including using laboratory equipment. They can be conducted within one lesson. These activities are also available as Word document downloads in the Interactive Textbook.

Investigation

These longer activities focus on developing more than one area of the experimental design. They are likely to take more than a single lesson. These activities are also available as Word document downloads in the Interactive Textbook.

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End-of-chapter features

Chapter review

Chapter checklist

You can download this checklist from the Interactive Textbook to complete it.

Success criteria		Linked questions	Check
2.1	I can explain the reasons for classifying organisms.	7, 8	
2.1	I can group organisms on the basis of their similarities and differences.	9, 12, 15, 16	
2.1	I can use keys to identify organisms.	11, 13	
2.2	I can explain how biological classification has changed over time.	14	
2.2	I can classify using a hierarchical system.	1, 6	
2.2	I can use scientific convention when naming organisms.	4, 5	
2.2	I can describe the differences between the classification systems used by First Nations Australians and those used by contemporary science.	17	
2.3	I can recall the six kingdoms of living organisms.	2	
2.4	I can describe the difference between vertebrates and invertebrates.	10	
2.4	I can recall the seven classes of chordates.	3	

Chapter checklists help students check that they have understood the main concepts and learning goals of the chapter.

Chapter review question sets are categorised under four headings: Retrieval, Comprehension, Analysis and Knowledge utilisation. Cognitive verbs have been bolded. These questions are also available as Word document downloads in the Interactive Textbook.

Data questions

Apply

1 **Identify** the taxonomic group that is under the least threat using Figure 2.73.

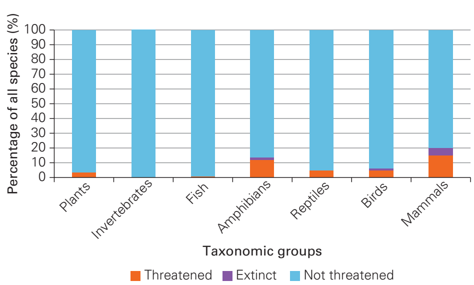
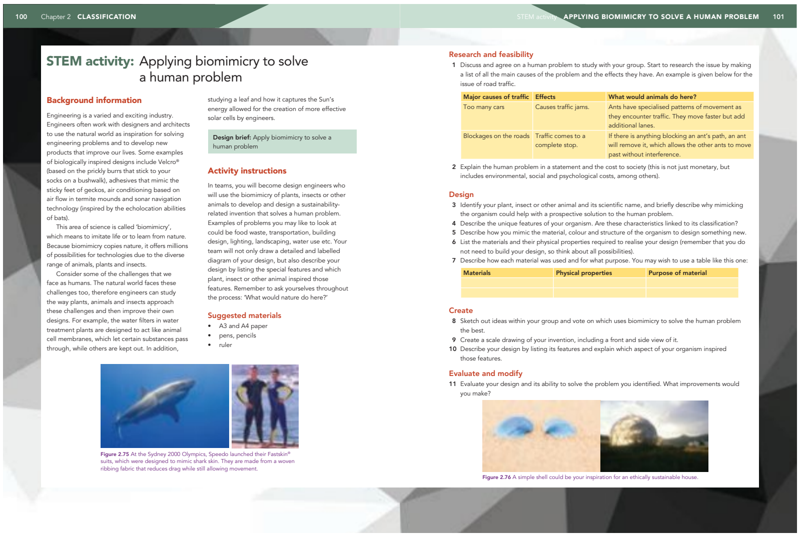


Figure 2.73 The conservation status of different taxonomic groups in Australia

Data questions help students apply their understanding, as well as analyse and interpret different forms of data linked to the chapter content. These questions are also available as Word document downloads in the Interactive Textbook.



STEM activities encourage students to collaboratively come up with designs and build solutions to problems and challenges.

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Links to the Interactive Textbook

VIDEO
These icons indicate that there is a video in the Interactive Textbook.

WIDGET
These icons indicate that there is an interactive widget in the Interactive Textbook.

WORKSHEET
Worksheets can be downloaded from the Interactive Textbook at the start of every section.

QUIZ
Automarked quizzes can be found in the Interactive Textbook for every section.

SCORCHER
Competitive questions can be found at the end of each chapter.

Overview of the Interactive Textbook (ITB)

The **Interactive Textbook (ITB)** is an online HTML version of the print textbook, powered by the Edjin platform. It is included with the print book or available as a separate digital-only product.

Definitions pop up for key terms in the text.

Quizzes contain automarked questions that enable students to quickly check their understanding.

Worksheets are provided as downloadable Word documents.

Videos summarise, clarify or extend student knowledge.

Widgets are accompanied by questions that encourage independent learning and observations.

Practicals are available as a Word document download, with sample answers and guides for teachers in the Online Teaching Suite.

Practical skills 2.1

Observing *Euglena*

Aim
To observe a single-celled organism under the microscope.

Be careful
Ensure proper microscope handling and use is observed.

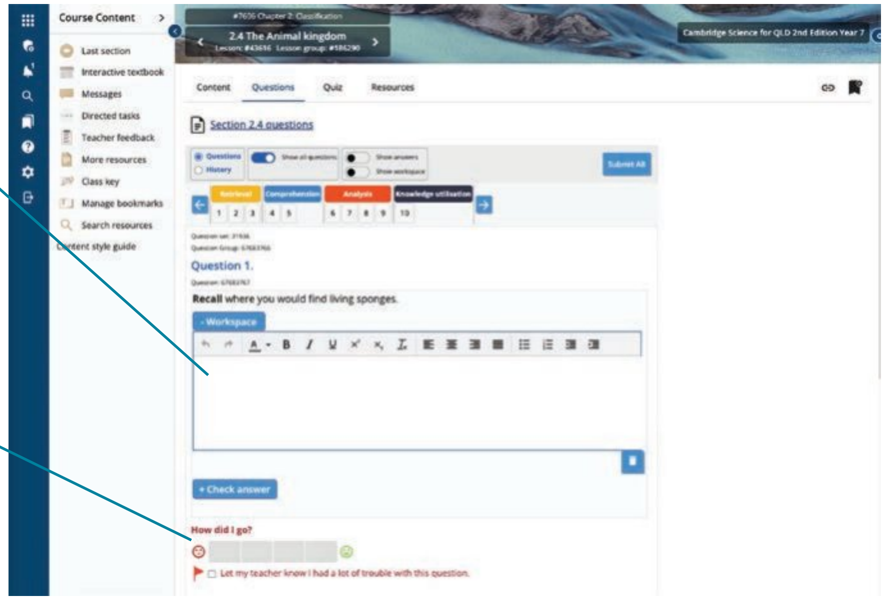
Materials
- *Euglena* sample
- pipette
- compound microscope
- dimple slide
- coverslip
- sharp pencil
- plain paper
- glycerol (optional)

Method
1. Set up the microscope on your bench.
2. Place a small drop of the *Euglena* sample into the dimple on the slide. One drop of glycerol can be added to slow the movement of the *Euglena*.
3. Lower the coverslip on an angle over the drop to protect the sample.
4. Place the slide onto the stage of the microscope and focus, using the lowest power magnification first.
5. Draw a scientific drawing of the *Euglena* you observe. Use a sharp pencil.
6. Use the internet to research the structure of *Euglena*. Label your scientific drawing.

Analysis
Euglena can make sugars like plants can, but they also have a simple 'eye' spot (sensitive to light, not a true eye). *Euglena* can also move, as you have observed. From your observations, justify whether you believe *Euglena* is more similar to animals or plants.

Workspaces enable students to enter working and answers online and to save them. Input is by typing, handwriting and drawing, or by uploading images of writing or drawing.

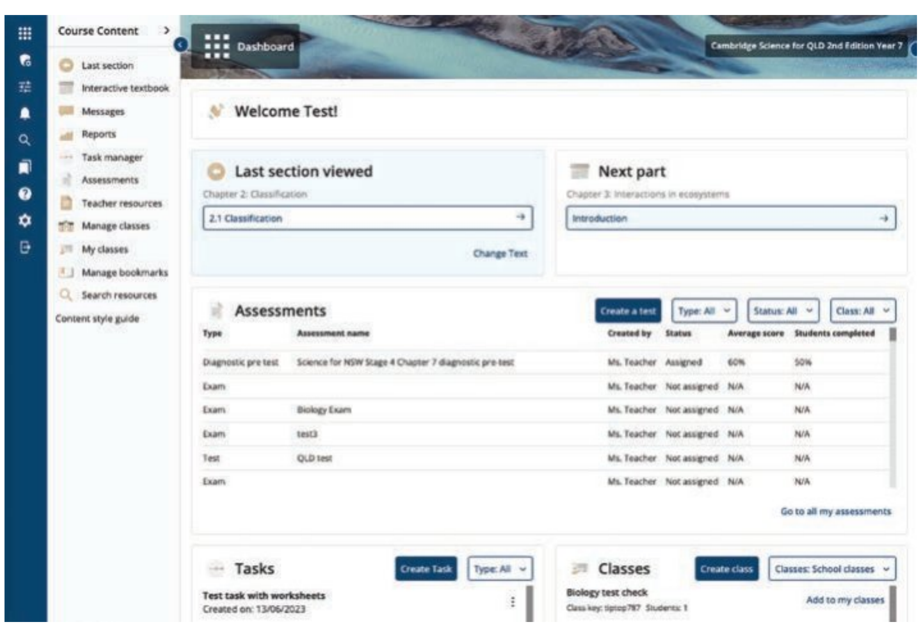
Self-assessment tools enable students to check answers, mark their own work, and rate their confidence level in their work. Student accounts can be linked to the learning management system used by the teacher in the Online Teaching Suite.



Overview of the Online Teaching Suite (OTS)

The Online Teaching Suite is automatically enabled with a teacher account and is integrated with the teacher's copy of the Interactive Textbook. All the assets and resources are in one place for easy access. The features include:

- **The Edjin learning management** system with class and student analytics and reports, and communication tools
- Teacher's view of a **student's working and self-assessment**
- **Chapter tests** and **worksheets** with answers as PDFs and editable Word documents
- Editable **curriculum grids** and **teaching programs**
- **Teacher notes** for Practicals, Try this, Explore! and STEM activities.
- **Diagnostic tools**, including ready made pre- and post-tests and intuitive reporting



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Chapter 1
Science skills

Chapter introduction

Every time you have been curious or observed something in our world or universe, you have started using a scientific method. Science is asking questions about the world around you and seeking to find answers in a systematic way. In this chapter, you will step into a science laboratory to work safely, and start the process of asking your own research questions and investigating them following a scientific method.

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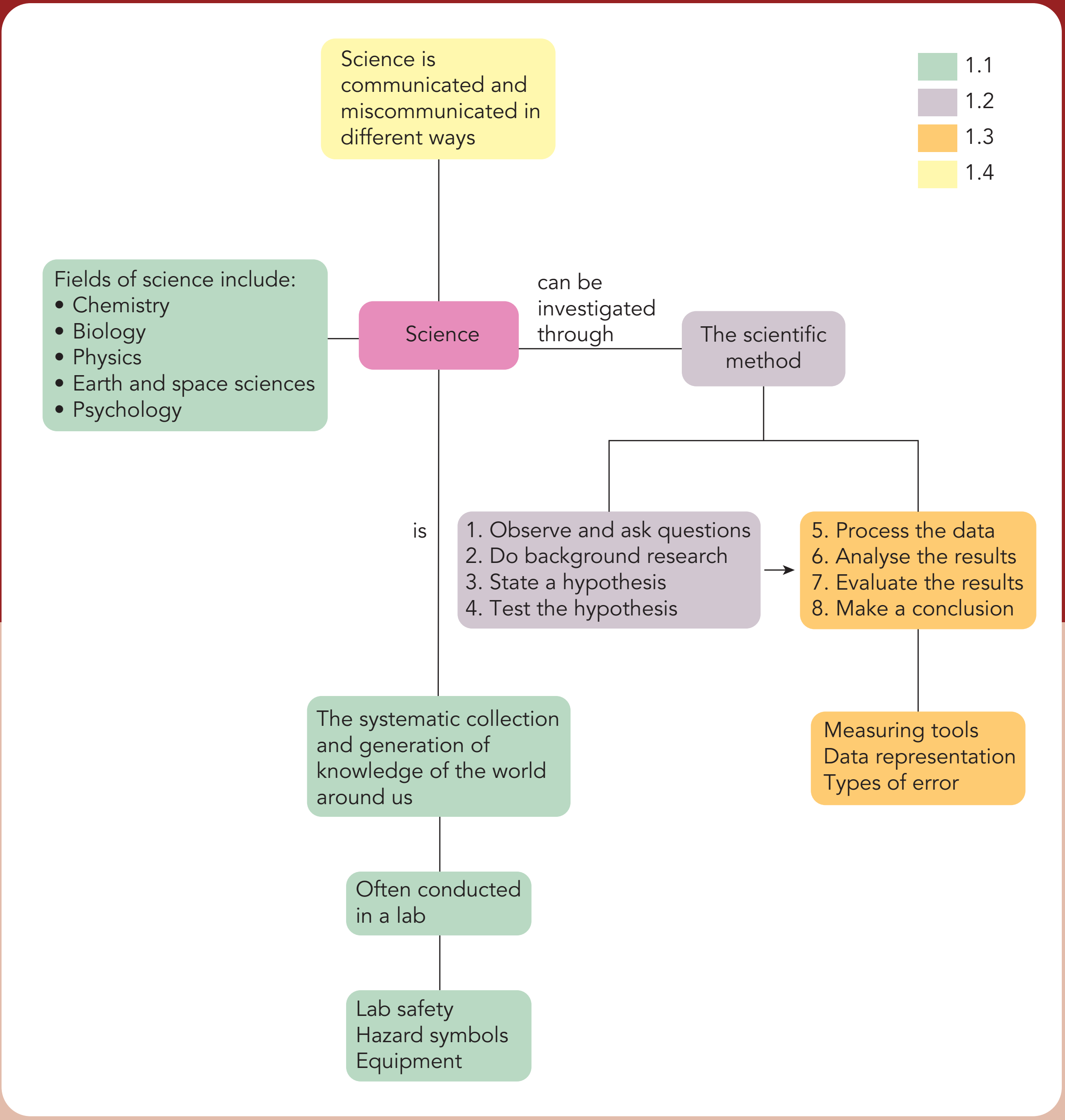
Concept map



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Glossary terms

Accuracy
Analyse
Anomalous
Bar graph
Bias
Biologist
Biology
Claim
Chemist
Chemistry
Concave
Condition
Continuous data
Controlled variable
Convex
Data
Dependent variable
Discrete data
Earth and space science
Experiment
Fair test
Geologist
Hypothesis
Independent variable
Inference
Investigable question
Knowledge
Line graph
Meniscus
Observe
Outlier
Parallax error
Peer review
Physicist
Physics
Precision
Predict
Qualitative
Quantitative
Random error
Relevant
Reproducible
Research question
Specific
Systematic error
Trend
Trendline/Line of best fit
Trial
Variable

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1.1 Working like a scientist

Learning goals

1. To be able to identify hazard symbols in a science laboratory.
2. To be able to identify and draw common laboratory equipment.
3. To be able to describe how to safely light a Bunsen burner.

DOC WORKSHEET What is science?

The word for 'science' comes from the Latin word for '**knowledge**', *scientia*. Science is not only a collection of knowledge that we have already gathered but also the process of gaining new knowledge. Science is used every day to answer questions, solve problems and create new technologies.

Scientists are curious and ask questions about the universe, how things work, why they work and what happens if you change things. By collecting and analysing information about the world around us, scientists can suggest answers to each question asked.

Scientists often use experiments to collect **data** in a controlled way. Data is the term used to group together anything they observe during an **experiment**. The data generated from observations and experiments allows scientists to draw conclusions, make recommendations and create models that explain the world around us.

In this chapter, you will explore the tools used by scientists in the laboratory, but not all science is conducted indoors! For example,

- **biologists** in the field observing organisms in their natural environment
- **chemists** collecting water samples from a lake
- **physicists** watching the night sky through a telescope
- **geologists** taking samples of rocks.

knowledge
the understanding of information

data
information in the form of facts or statistics gathered to answer a question or for further analysis

experiment
a controlled situation where data is gathered to answer a question

biologist
a person who works in the science field of biology

chemist
a person who works in the science field of chemistry

physicist
a person who works in the science field of physics

geologist
a person who works in the field of earth and space science

Figure 1.1 Scientists at work in the field

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biology
the study of living organisms and their interactions with their environment

chemistry
the study of matter, its properties, and the interactions between different substances

physics
the study of matter, energy, and their interactions with each other and the universe

earth and space science
the study of natural processes and phenomena occurring on Earth and in the universe beyond

Biology is the scientific study of living organisms and their interactions with each other and their environment. It encompasses a wide range of topics, including genetics, ecology, evolution and physiology.

Chemistry is the scientific study of the composition, properties and behaviour of matter. It involves the study of atoms and molecules, and their interactions with each other, as well as the laws and principles that govern chemical reactions.

Physics is the scientific study of matter and energy, and their interactions with each other. Physics seeks to understand the fundamental laws of the universe and to explain the behaviour of the natural world, from the smallest particles to the largest structures in the universe.

Earth and space science is the study of the natural processes that shape Earth, as well as the physical and chemical properties of the universe beyond Earth. This field includes geology, oceanography, meteorology and astronomy.

First Nations Australians in science

First Nations Australians have been asking scientific questions and collecting observational data on the Australian continent for thousands of years. Knowledge of Country/Place is extremely helpful in understanding the unique location that is Australia.

Explore! 1.1

Careers in science

The main fields of science that you will study in high school are biology, chemistry, physics, and earth and space science. But there is a branch of science in whatever you are interested in, as long as you can be curious and ask questions in that field. **Psychology** is a field of science that you can choose to study during Years 11 and 12. Psychology deals with the brain and investigates things such as emotions, behaviours and mental health conditions.

What other fields of study in science are there? What jobs can these fields of study lead to?

Conduct research to find five other scientific specialist areas or careers.

For example, over thousands of years, many groups of First Nations Australians have developed a deep understanding of:

- the unique seasonal cycles that occur not only in Queensland but also across the entire continent
- moon phases, and solar and lunar eclipses
- the use of native Australian plants for food and medicine
- the local Australian ecosystems and how they are affected by invasive species
- land and water resource management to protect flora and fauna biodiversity
- the cultural significance of Country/Place, and the protocol for scientists to respectfully conduct experiments on traditional lands.

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Some of these examples will be presented further throughout this text. If you would like more information at any time, you can start a link with your local Indigenous community by contacting either the Local Aboriginal Land Council (LALC) or the Local Aboriginal Education Consultative Group (AECG).

Explore! 1.2

First Nations heritage sites and artefacts

Many different groups of First Nations Australians have thousands of years of knowledge of Country/Place in Queensland, and there are some policies in place to protect and communicate this knowledge.

Research on the internet the following questions.

1 What is the 'Caring for Country' initiative and how can it support Queenslanders?
2 Are there laws to protect First Nations Australians' heritage sites and artefacts in Queensland?

Quick check 1.1

1 Recall the definition of 'science'.
2 State the name given to information gathered in science.
3 Name the controlled situation used in science to gather data.
4 Identify the field of science that would study:
   a an endangered animal
   b the distribution and origin of rocks
   c the composition of a new drug.

Safety in the laboratory

DOC WORKSHEET Identifying risks

Scientists can work 'in the field', out in the natural environment, but many scientists may also work in a laboratory. Here, they may conduct experiments that can be hazardous to humans. Thus, it is important that you know the safety basics and the tools that you will be using when you step into a scientific laboratory this year!

Laboratory safety rules are in place to protect experimenters from hazards such as cuts from broken glassware, burns from fire and exposure to dangerous chemicals. Referring to Figure 1.3 on page 8, spot the differences between the students who are ignoring the rules (top image) and those following the rules (bottom image). The class in the top image are making dangerous mistakes. Suggest what they might be. (The answers are on page 9.)

Figure 1.2 It is important to always wear appropriate personal protective equipment when working in a lab environment.

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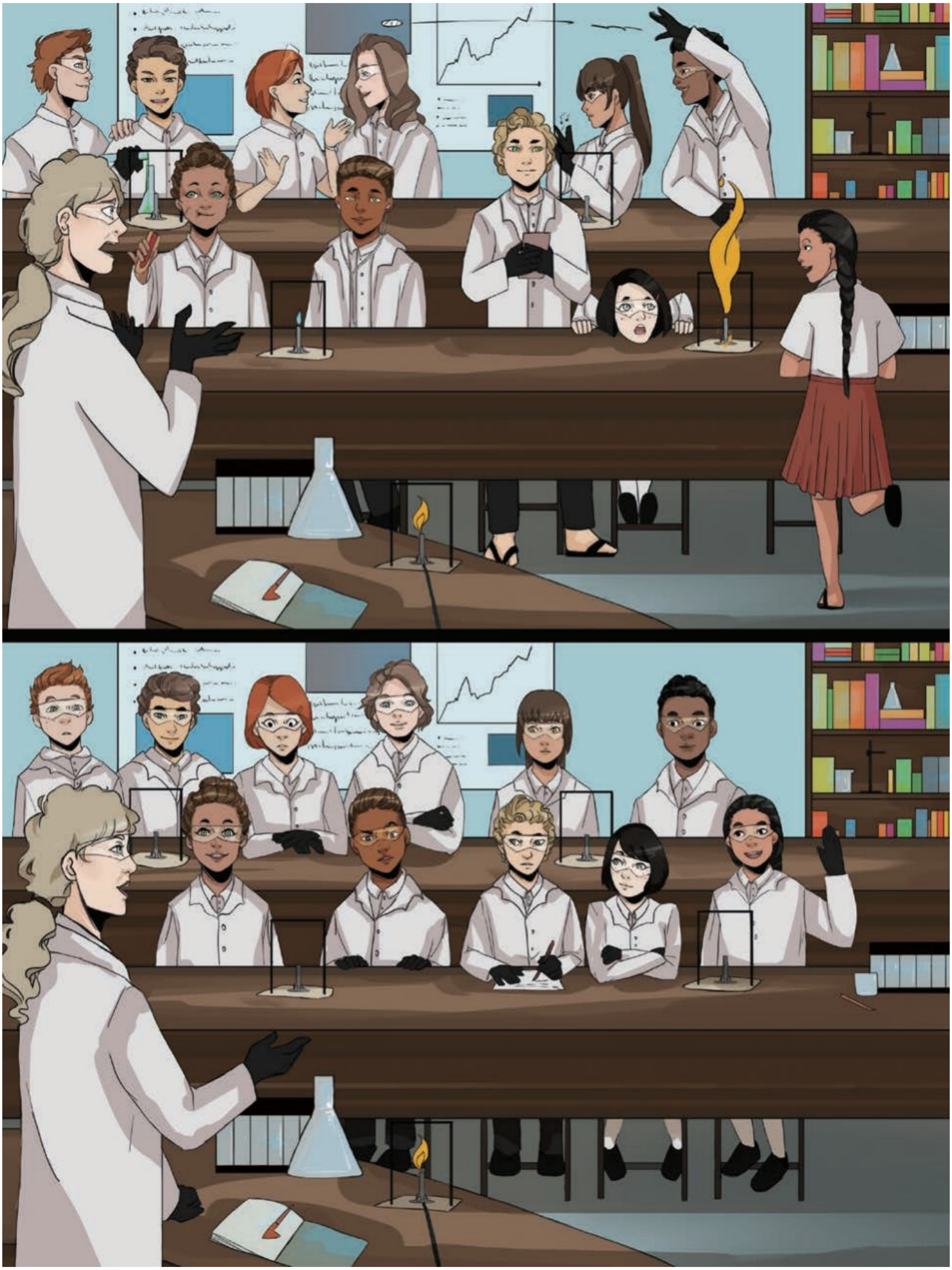

Figure 1.3 Good lab safety is essential.

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Photocopying is restricted under law and this material must not be transferred to another party.

The laboratory safety rules are as follows:

- Always wear safety glasses over your eyes (not on top of your head) when you are handling chemicals or glassware. Chemicals and broken glass can be damaging to your eyes.
- Always wear a lab coat that can protect your school uniform from stains and your skin from harmful chemicals.
- If you are given gloves by your teacher, wear them at all times. These will protect your hands from harmful substances. Always wash your hands after you have removed your gloves to be extra safe. Sometimes, safety glasses, lab coats and gloves are grouped together and called personal protective equipment (PPE).
- Always wear enclosed footwear to make sure that nothing can fall onto your feet.
- Use a safety mat/heatproof mat whenever you are using a Bunsen burner or chemicals to prevent damage to the bench and other equipment.
- Always follow your teacher's instructions.
- Never eat or drink in the laboratory to avoid accidental ingestion of harmful chemicals or pathogens.
- Never run in the laboratory to reduce the risk of spills, breakages or other hazardous situations that could harm you or others.

It is important that you follow the laboratory safety rules to keep yourself safe. But you should also stay focused on identifying hazards as they appear. For example, you might notice a slippery floor due to spilled water, or some broken glassware on the floor that hasn't been cleared. Hazards should be reported to your teacher immediately so that they can be managed and the risks minimised.

Hazard symbols

If you are using a hazardous chemical in the laboratory, it will have a hazard symbol on the container. The hazard symbol provides details on what type of risk the exposure to the chemical may cause to humans. These risks range from irritating the skin to exploding! Scientists use the information that hazard symbols provide when they are carrying out a risk assessment before conducting their experiment. Risk assessments show the hazard, the risk that the hazard poses and a way of managing those hazards. An example is shown in Table 1.1.

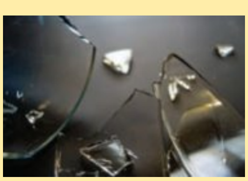
Type of hazard	Risk	Assess	Control
Glass 	There are many pieces of glass equipment in the lab.	Glass can get hot, form sharp edges that can cut if broken and can also be heavy.	• Always place glassware in the centre of the bench on a flat surface. • Allow to cool before handling. • Inform your teacher of breakages and avoid any broken glass.
Biological 	Biological material, such as organs for dissection, bacterial cultures, microbes or plants, are studied in the lab.	Any living or dead specimen could contain microorganisms that can make you sick.	• Make sure you wash your hands thoroughly. • Wear gloves when your teacher tells you to. • Dispose of all biological material in the correct way.
Chemical 	You will use many chemicals for experiments.	Some of these can be toxic, corrosive or irritate your skin.	• Make sure you always wear gloves and safety glasses and wash your hands. • Never get any chemicals in your mouth or eyes.

Table 1.1 Risk assessment table

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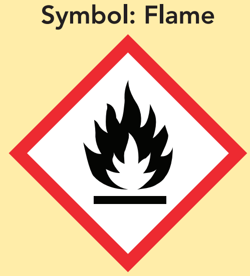
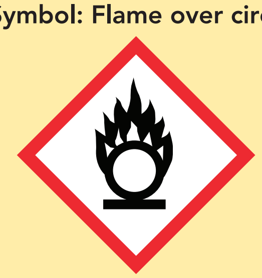
Name of hazard	Symbol	Meaning	Examples
Corrosive	**Symbol: Corrosion** 	This chemical causes skin corrosion/burns or eye damage on contact, or is corrosive to metals.	Sodium hydroxide Hydrochloric acid
Health hazard Also used to show substances that are hazardous to the ozone layer	**Symbol: Exclamation mark** 	This chemical will cause immediate skin, eye or respiratory tract irritations.	Many acids and alkalis
Flammable	**Symbol: Flame** 	This chemical will catch fire easily.	Ethanol Hexane
Hazardous to the environment	**Symbol: Dead tree and fish** 	The chemical will cause damage to living things in the environment, especially in soil, waterways or the atmosphere.	Copper sulfate
Explosive	**Symbol: Exploding bomb** 	This chemical is an explosive at risk of exploding, even without exposure to air.	Potassium Lithium
Oxidising	**Symbol: Flame over circle** 	These chemicals contain or act like oxygen, which causes other substances to burn or react more.	Potassium permanganate Nitric acid

Table 1.2 Chemical hazard symbols

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Name of hazard	Symbol	Meaning	Examples
Acute toxicity	**Symbol: Skull and crossbones** 	This substance will cause severe illness or death if it enters the body.	Mercury Lead
Serious health hazard	**Symbol: Health hazard** 	This chemical can cause serious long-term health hazards such as damage to organs, cancer or genetic defects if it is swallowed or enters airways.	Turpentine Petrol
Gas under pressure	**Symbol: Gas cylinder** 	These gases are stored under pressure and may leak, causing fire, poisoning, corrosion, suffocation or 'ice burns'.	Ammonia Liquid nitrogen

Table 1.2 *(Continued)*

Quick check 1.2

1 State the first thing you should do if you see a hazard in the science lab.
2 Recall the name of the safety equipment that will protect your eyes.
3 Sketch a hazard symbol that would be found on a bottle of highly flammable propanone.

Get to know your equipment

When conducting an experiment in the laboratory, the equipment used needs to ensure safety of the experimenter, but also to perform a specific task with precision. Some laboratory glassware for instance is used to measure specific quantities of substances, while others hold substances. You will need to know the names of the common equipment found in the laboratory as well as how to draw them in two dimensions (2D) for communication in laboratory reports.

Drawing your equipment

In Table 1.3 column 4, you will see the 2D drawings that show the dimensions of length or height and width. These are called scientific drawings and you use them when you draw the set-up for an experiment. Use the following rules when creating a scientific drawing.

- Use a sharp lead pencil.
- Use a ruler to draw a straight line (use freehand only for curves).
- Only draw in 2D.

DOC WORKSHEET Laboratory equipment

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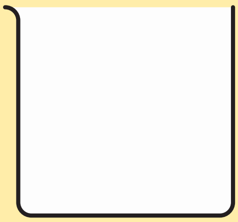
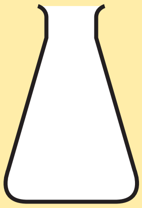
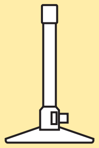
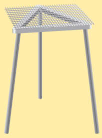
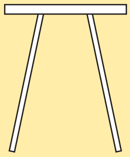
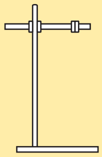
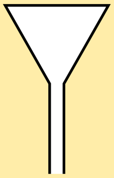
Equipment	What it is used for	How it looks	How it is drawn
Beaker	A common piece of equipment found in most labs. It comes in many sizes and is generally used for holding, mixing and heating liquids.		
Conical flask	This is similar to a beaker but its shape is different to reduce the likelihood of liquid spilling. It can be used to swirl liquids and prevent hot liquids from boiling over.		
Test tubes	These are used for holding small amounts of substances. As they do not have a flat bottom, a test-tube rack is used to hold them.		
Measuring cylinder	This is used to accurately measure volumes of liquids. It must not be used to mix or heat liquids.		
Bunsen burner	This is a common device used to add a controlled amount of heat to an object.		
Tripod	This is used to hold an object above a Bunsen burner flame while it is being heated. A wire gauze mat usually sits on top of the tripod.		
Bosshead clamp and stand	A retort stand and bosshead clamp are used to hold objects in place while testing.		
Funnel	This can be used to make it easier to transfer liquids into containers with narrow openings, or to separate substances in filtration.		
Evaporating dish	This is used to heat up and evaporate small amounts of liquid.		

Table 1.3 Some common lab equipment

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Heating equipment

Often in the laboratory, you will be required to heat materials in glassware such as a beaker. This can be achieved using a hot water bath or a microwave, but a Bunsen burner is normally used. Although not all Bunsen burners look the same, they all have the same parts, as shown in Figure 1.4.

Be careful

Remember these important safety points when using a Bunsen burner.

- Tie long hair back and secure loose clothing such as school ties.
- Roll up sleeves if they are too long.
- Never leave the Bunsen burner unattended.
- Turn the Bunsen burner to a yellow safety flame when not heating.
- Place the Bunsen burner on a heatproof mat.
- Wait for all equipment to be cool before handling.

The Bunsen burner

The temperature and intensity of the Bunsen burner flame can be controlled by changing the size of the airhole. This is adjusted by turning the collar. On lighting the Bunsen burner with a match, the airhole should be completely closed. This limits the amount of oxygen that can mix with the gas, and it produces a less hot 'safety flame'.

You will know that you have a safety flame as it burns with a yellow colour. When you are ready to increase the intensity of the flame, open the collar gradually to allow more oxygen to mix with the burning gas. This will produce a 'blue flame' that is considerably hotter than the safety flame. Remember, when not heating, the Bunsen burner should always be on a safety flame.

Figure 1.5 The Bunsen burner blue flame is produced when the airhole is fully open. It allows oxygen from the air to mix with the gas in the barrel producing a hotter flame.

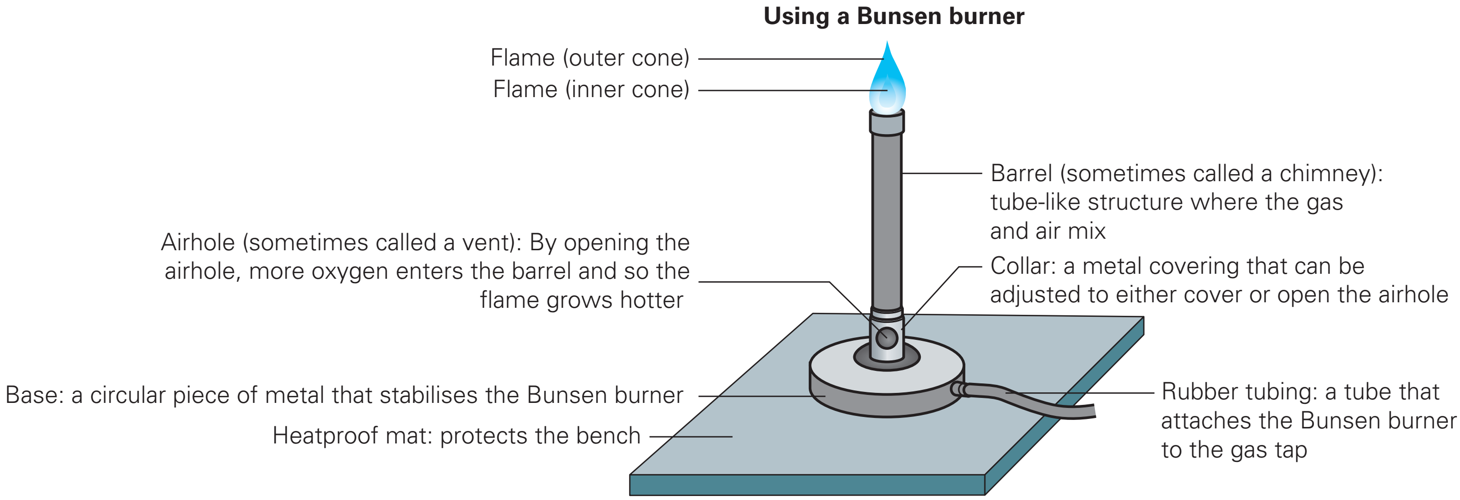

Figure 1.4 A Bunsen burner

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Practical skills 1.1

Using a Bunsen burner

> **Be careful**
> Ensure that you follow instructions to ensure general fire safety.

Aim

To practise the safe procedure for lighting a Bunsen burner.

Materials

- Bunsen burner
- matches
- heatproof mat

Planning

Read through the method and carry out a risk assessment. List the risks associated with this activity and suggest ways to control or minimise their impact.

1 Explain why the airhole is closed before turning on the Bunsen burner.
2 Explain why the match is struck away from the body.

Method

1 Attach the Bunsen burner rubber tubing to a gas tap.
2 Ensure the Bunsen burner hole is closed to give a safety flame.
3 Strike a match away from your body.
4 Turn on the gas.
5 Bring the match up towards the tip of the barrel mouth to light the flame.
6 Shake out the match and place on the heatproof mat.
7 When heating anything, twist the collar to open the airhole and produce a blue flame.
8 When the Bunsen burner is not being used for heating, twist the collar to close the airhole and produce a safety flame.
9 Ensure the gas is turned off at the end of any Bunsen burner practical. Allow the bunsen burner to cool completely before putting it away.

Practical skills 1.2

Heating water

> **Be careful**
> Ensure general fire safety instructions are followed. Ensure appropriate personal protective equipment is used when handling hot equipment.

Aim

To identify and use the appropriate equipment for heating water.

Materials

- 250 mL beaker
- boiling tube (large test tube)
- evaporating dish
- stopwatch
- Bunsen burner
- tripod
- gauze mat
- heatproof mat
- test tube tongs
- 250 mL measuring cylinder

continued …

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… continued

Planning

Read through the method and carry out a risk assessment. List the risks associated with this activity and suggest ways to control or minimise their impact.

Method

The diagrams in Figure 1.6 show how to set up your equipment for each test.

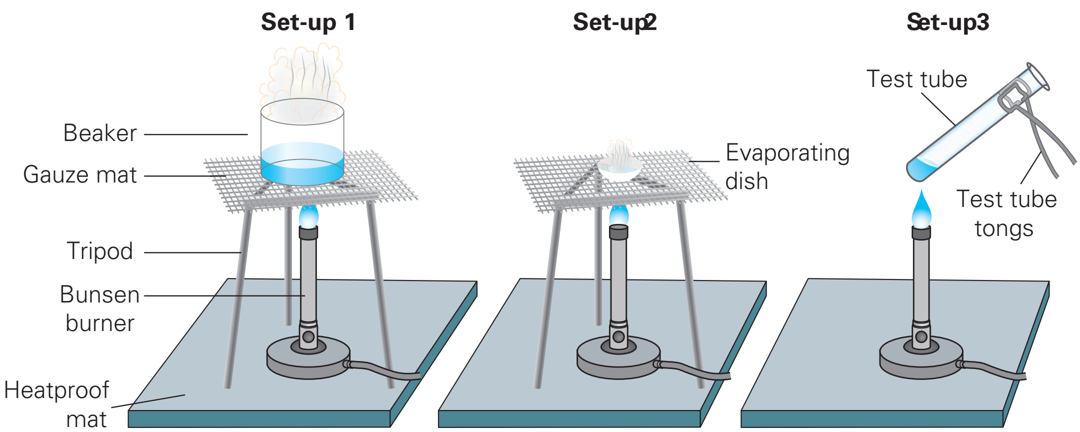

Figure 1.6 Experimental set-ups

Set-up 1

1 Add 30 mL of water to a beaker.
2 Place the beaker on the gauze mat over the tripod.
3 Light the Bunsen burner and measure the time taken for the water to reach boiling point.

Set-up 2

4 Fill an evaporating dish with water (not too close to the top to prevent it spilling) and pour into the measuring cylinder. Record the volume of water it can hold.
5 Repeat steps **1–3**, adding 30 mL of water to the evaporating dish.

Set-up 3

6 Fill a test tube with water and pour into the measuring cylinder. Record the volume of water it can hold.
7 Repeat steps **1–3**, adding 30 mL of water to the test tube.
8 Hold the test tube over a blue flame using test tube tongs. Point the test tube opening away from yourself and anyone else and move it in a circular motion above the flame until the water boils. Record the time it takes for the water to boil.
9 Wait until the water has cooled and measure the amount of water left in the beaker, evaporating dish and test tube.

Results

Copy and complete the following results table.

Container	Maximum volume of equipment (mL)	Volume of water left after boiling point was reached (mL)	Time taken to reach boiling point (s)
Beaker			
Evaporating dish			
Test tube			

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… continued

trend
a pattern in data that shows the general direction/shape of the relationship between the independent and dependent variables

Discussion

Analysis

1. Describe any **trends** in your results.
2. Identify the best piece of equipment for holding and heating a small sample of liquid (hint: consider the time taken to reach boiling point, and how much water was left after reaching boiling point).
3. Identify the best piece of equipment for evaporating some of the water.

Evaluation

Identify any challenges you faced and how you overcame them.

QUIZ

Section 1.1 questions

Retrieval

1. **State** three fields of science.
2. **List** three pieces of personal protective equipment you might use in the lab.

Comprehension

3. **Outline** the steps involved in safely lighting a Bunsen burner.

Analysis

4. **Organise** the lab equipment featured in this chapter into categories: containers; heating equipment; measuring tools; and others.
5. **Compare** the use of a conical flask and a beaker.

Knowledge utilisation

6. **Create** a risk assessment for an experiment where a Bunsen burner is used to heat water in a beaker.
7. **Discuss** why 'Caring for Country' initiatives are beneficial when managing land in Queensland.

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1.2 Scientific method

Learning goals

1. To recall the role of variables in a scientific experiment.
2. To be able to write a hypothesis in an appropriate style.
3. To understand the different stages of the scientific method.
4. To distinguish between quantitative and qualitative data.

DOC
WORKSHEET
Observation and inference

Asking questions, being curious and observing the world around you are key elements of science. However, conducting a scientific investigation to answer such questions requires a systematic approach that scientists use to conduct their experimental work. Often, many different scientists come together to collaborate and share their expertise to answer questions that they might have in common.

For example, the Queensland Government might want to collect data on the bleaching of coral in the Great Barrier Reef. Here is one example of how different scientists might work together.

A marine scientist could review related knowledge and provide a summary of background scientific research. The scientist might ask the **research question** 'what factors are causing the coral to bleach?' Then, the scientist can create a possible **hypothesis** about the cause of the coral bleaching.

Environmental scientists could then design an experiment to test the hypothesis. They could gather data about the temperature or pH readings of the ocean.

A marine chemist or physicist could join the team to **observe** the experimental procedure, and gather, analyse and evaluate the data.

The results could then be communicated back to the Queensland Government or written in a scientific journal.

Sometimes, researchers begin their work due to someone making a **claim**, which is sometimes a statement that has little evidence but may be worthy of study. Researchers can evaluate a claim by collecting further evidence through procedures like the above. What a scientific team effort!

research question
a question that can be answered practically through scientific investigation or through research

hypothesis
a proposed explanation or an educated guess that can be tested through further investigation and experimentation

observe
use senses and tools to gather information/data

claim
a statement or assertion that something is true or factual, which may require further investigation or evaluation to determine its validity

A scientific method

The process that the scientists have followed above is an example of a scientific method. Another example that you will follow in your high school studies is shown in Figure 1.7. It should be noted that there are many different methods to conduct science, but they all generally start with observing the world around us and asking questions.

Laboratory reports

The scientific method used in this chapter is matched with headings, shown in Figure 1.8, that you can use in a scientific laboratory report. The report includes a description of the method and a discussion of results written in the third person. The discussion should include a note of whether any results were discarded and why, and whether anything unexpected happened or did not work as intended.

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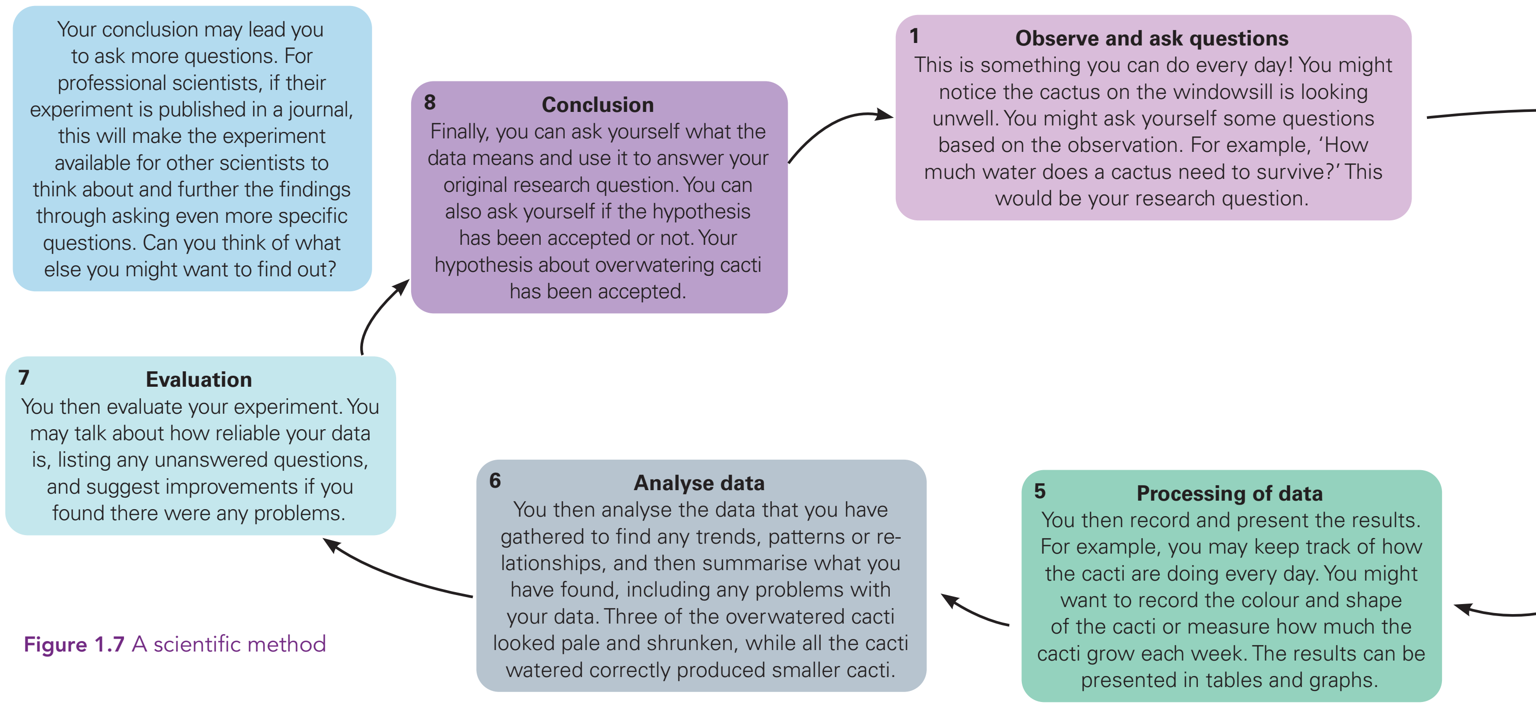

Figure 1.7 A scientific method

1. Observe and ask questions

A scientific method generally starts with an observation. Scientists observe the world around them and gather information using all of their senses: sight, hearing, smell, taste and touch.

Observations

Observations are only statements about the information gathered from your senses. They should not give any explanation, idea or opinion about why the observation has been made. For example:

- The grass is green.
- The flame is hot.
- The flower has a strong smell.

Inferences

inference
to link an observation with past knowledge and assign meaning to the observation

Once an observation has been made, an **inference** can be made. In the following examples, an observation is stated, followed by an inference.

Observation	Inference
Chloe has a longer long jump than Siloé.	Chloe is taller than Siloé.
Leon has an upset stomach.	Leon ate some off food.

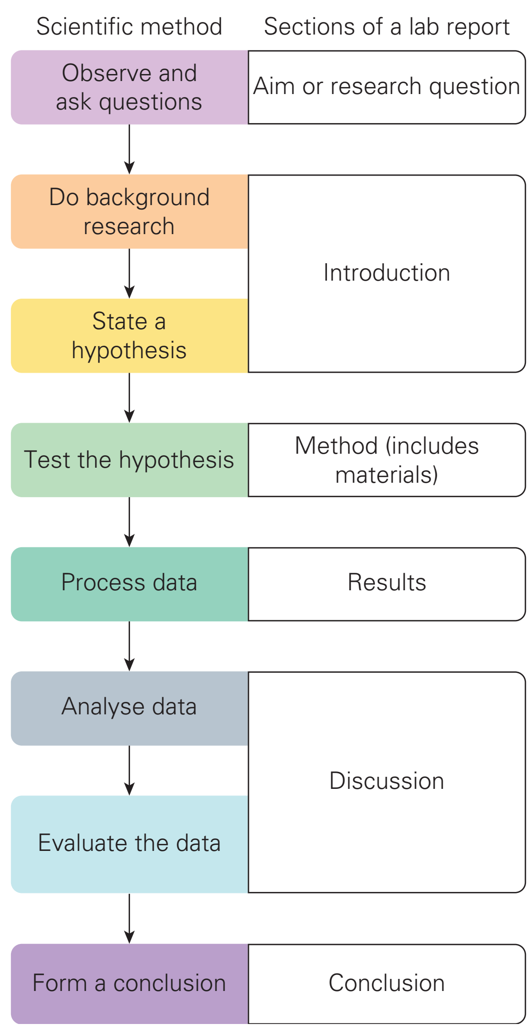

Figure 1.8 A scientific method matched to sections of a lab report

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2 Do background research
You might head to the internet to try to find suggestions to answer your questions. Professional scientists generally use **peer-reviewed** journal articles to see what other scientists in the past have found out and experiments that have been done. You may find out that plants can die from too much water!

3 State a hypothesis
You then come up with a prediction that can be tested. For example, 'Cacti (plural for cactus) that are watered five times the recommended amount will not do well'.

4 Test the hypothesis
This involves developing a series of steps in an experiment that can test the hypothesis. You need to formulate experimental methods that are safe, allow the collection of sufficient data and are carried out in such a way that there is no other explanation possible for the outcome except the one you are interested in. You may need to use 10 cactus plants of the same variety, placed on the same windowsill, and continue the experiment for one month. You may find a method that you need to modify to suit your own experiment.

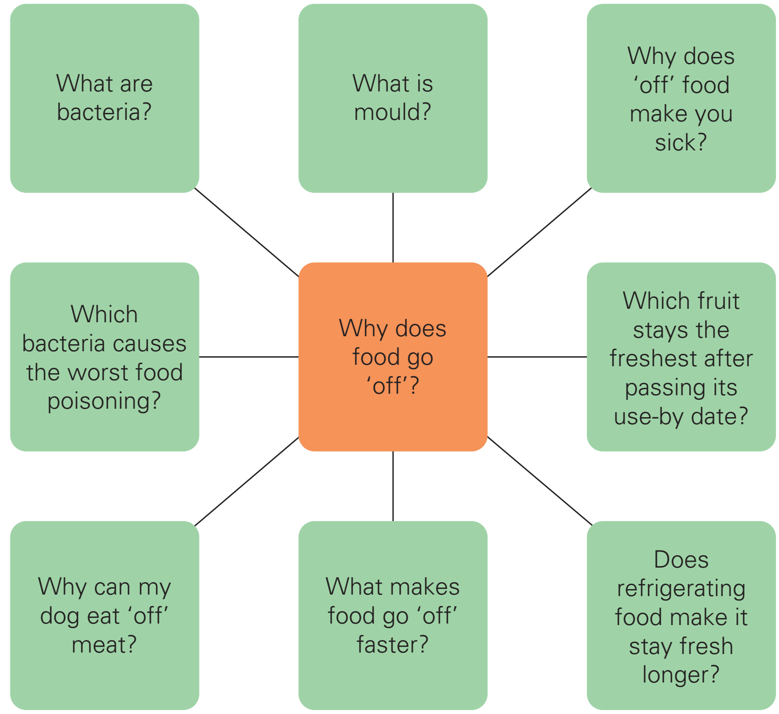

Figure 1.9 Identify the investigable and non-investigable questions in the figure.

These inferences provide a possible explanation to what was observed, but does that mean the inference is true? Not necessarily. But an inference allows a scientist to start to formulate a research question, to identify whether there is evidence to support the inference. For example:

- Does height affect how far someone can jump in long jump?
- Does eating off food cause an upset stomach?

Quick check 1.3

1 State three observations you might make at the beach.
2 Define the term 'inference'.
3 David observed that his wet washing dried quicker in direct sunlight compared to when it was hung in the shade. State an inference that David might make based on this observation.

Asking research questions

From inferences, research questions are created. A question to research can be about anything, such as: 'Why do people prefer red food over green food?' or 'Does listening to music help students focus in class?' Both of these are **investigable questions** that can lead to a possible scientific experiment. Investigable questions are questions that lend themselves to the collection of data through scientific investigation. They can be tested in an experiment because they are practical; you have both the time and the necessary materials to answer the question.

peer review
to read, check and give an opinion about something that has been written by another scientist or expert working in the same subject area

Investigable question
a research question that can be answered through completing an experiment

Some questions cannot be tested. Those that can't be tested are called non-investigable and are based around ideas. They are often open-ended and encourage thoughtful discussion and exploration of various perspectives. Try and identify the investigable questions in Figure 1.9.

Brainstorming in a group can be a great way to draw out all possible questions in a topic that might be tested and to distinguish them from non-investigable questions.

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Explore! 1.3

Ethics in research

As well as being practical, when research questions involve experimenting on humans or other organisms, ethics must be considered. One of the research questions on page 19 was 'Does eating bad food cause an upset stomach?' Consider doing this experiment. Would you be allowed to purposely cause someone harm by feeding them off food?

Use the internet to research some other ethical considerations that must be made when conducting experiments.

Figure 1.10 Feeding someone food that is off wouldn't be an ethical experiment.

specific
clearly defined or identified

relevant
connected to the topic being investigated

2. Do background research

Many research questions might have already been answered by other scientists! It is important to complete background research prior to designing an experiment as your research question might change when considering research that has already been done.

A web-based search of your question might turn up an overwhelming amount of information. But if you follow the steps below, you can refine your search.

1 Identify key words

A simple technique you can use to break down a research question is reading with a pen. See 'Try this 1.1' for ways to do this.

2 Develop specific and relevant research questions to answer

Questions you could investigate from the inquiry question shown in 'Try this 1.1' are:

1 What is palm oil?
2 What is palm oil used for?
3 Who farms palm oil?
4 Where is Indonesia?
5 Why is palm oil farmed in Indonesia?
6 What is the age range of the 'young people'?
7 How can farming in another country affect Australia?
8 What are the effects of palm oil farming?

3 Search for sources of information

Often when we have a question, other people have asked the same question and have conducted some form of research to find answers.

The internet is an effective resource for shared global information, but there are also some skills to use it effectively.

Try this 1.1

Reading with a pen

While reading about your research question, keep a pen handy.
Underline key words or phrases.
Circle words or phrases you don't understand.
? Put this next to something that raises a question.
! Put this next to something that surprises you.
Write important thoughts in the margin or around the question.

For example:
How does palm oil farming in Indonesia affect young people? living in Australia?

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Using the internet

The internet has so much information that it can sometimes be difficult to know whether the information you are reading is correct and without **bias**. It is important to always consider whether the information presented online from a text, image or video is provided as an opinion or whether it is based on fact. For example, if you are finding some background information on the use of petroleum oil in the world, you might find vastly different points of view in a web-based search from an oil company and a renewable energy company.

Searching

When searching for information, there are techniques you can use to help refine your search. For example, if you were researching the question 'What are the effects of palm oil farming?' you might use the techniques listed in Table 1.4. You can also search for different types of information using the common file types in Table 1.5.

Independent, dependent and controlled variables

Once the research question has been determined, a scientist can begin to design the experiment to answer the question. For an experiment to be a considered a **fair test**, only one thing in the experiment should be changed and one thing measured. The things that are changed and measured are called **variables**. For example, in our research question 'Does a person's height affect how far someone can jump in long jump?':

- the variable being changed is the height of the person. This is the **independent variable**.
- the variable being measured is the distance of their jump. This is the **dependent variable**.

bias
when a source of information is influenced by personal opinion or judgement

variable
a factor or condition that can be controlled, changed or measured in an experiment

independent variable
the variable that is deliberately changed during an experiment

dependent variable
the variable that is measured during an experiment (as it responds to the independent variable)

fair test
an experiment where all variables are kept constant except for the independent variable being tested

DOC
WORKSHEET
Identifying variables

Search technique	How?	Example
Finding exact matches for grouped words	Use quotation marks to group search words together.	"palm oil farming"
Search for exact matches in titles or headings	Type: intitle:"search word"	intitle:"farming palm oil"
Search for a file type (see Table 1.5 below)	Type: filetype:abbreviation for file type "search word"	filetype: pdf "palm oil"
Try different spellings	Sometimes words are spelled differently on US websites, so try spelling search words the American way.	*colour* (on Australian and UK websites) is spelled *color* on US websites
Try a variety of sources	Google is not designed to bring the most scientific pages to the front of your search, so try other search engines and databases.	Google Scholar Library search engines World Book Databases to which your school subscribes

Table 1.4 Search techniques

Use	File type
Presentations	pptx, pages, key, pez
Images	jpeg, psd, png, tiff
Documents	pdf, doc, pub

Table 1.5 Common file types and their uses

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The question is investigable because we can test the effect of height on long jump length. The question is practical as you would have enough time and the necessary materials to successfully answer the question.

In an experiment, we want to know if a change in the independent variables causes a change in the dependent variable. To show that the height of a person has an effect on the distance of a long jump, all other variables must be kept the same. These might include using the same long jump pit and the same tape measure, as well as completing the jump in the same weather conditions. These are the **controlled variables**. Failing to control other variables makes it difficult to determine the effect of the independent variable on the dependent variable.

controlled variable
the variable or variables that are kept the same during an experiment

hypothesis
an educated guess that can be tested through further experimentation

reproducible
able to be reproduced or copied

In a laboratory, you may have to make some assumptions about some variables that you would find very hard to control. You should assume that factors such as ambient temperature, the properties of materials used and the purity of substances are all constant.

3. State a hypothesis

A **hypothesis** is based on existing knowledge and observations. It is an educated guess that is written before conducting an experiment. For a hypothesis to be considered scientific, it must be capable of being tested and should be able to be accepted or rejected. It is typically written as a statement that can be tested through an experiment. You should not give a reason for your hypothesis. An appropriate way to set out a hypothesis is shown in Figure 1.11.

Points to remember when writing a hypothesis:

- A hypothesis is an educated guess about the outcome of the experiment.
- The hypothesis must be written as a statement that can be tested.
- It should consider how the independent variable will affect the dependent variable. The hypothesis is an if … and then … statement. See Figure 1.11.
- Do not use 'I think …'

4. Test the hypothesis

Writing a method

When an experimental procedure is designed, it is written as a step-wise method. These steps should be numbered and detail exactly what should be done in the experiment, including any materials and how much of each material was used. A method should be **reproducible**. So keep this is mind when writing your own method! When you write your scientific report, you will rewrite your experimental procedure in the past tense for the 'Method' section of your report.

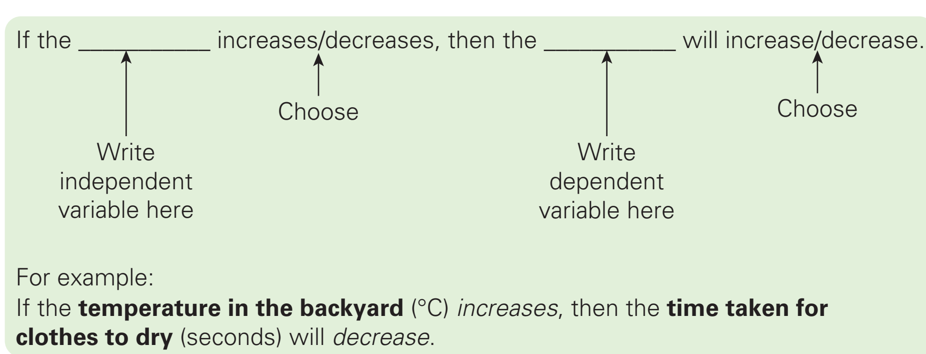

Figure 1.11 An example of setting out a hypothesis for the effect of backyard temperature on how long clothes take to dry

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The method should also clearly detail how you are changing the independent variable, measuring the dependent variable and controlling various other variables.

When you are writing an experimental procedure, think about how you would write the instructions for making a cake: the baker needs to know exactly how much flour, sugar, eggs and butter to add, in which order to add them, how to mix them, how long to cook the cake and at what temperature to cook it, otherwise the cake could be a disaster.

Also consider how many **trials** you will undertake. A reliable experiment should have at least three trials so that you can see if the experimental method is producing an **outlier**. This might indicate that it needs improvement.

It is important to detail how many different **conditions** will be used for the independent variable in the method. For example, suppose the research question is 'does temperature affect how long it takes a substance to melt?' Then the method could time how long equal amounts of the substance take to melt in the fridge, at room temperature, in direct sunlight and in a flame. This uses four different levels of 'temperature', which is the independent variable. This experiment is therefore said to have four experimental conditions.

Points to remember when writing a method:

1. Write the numbered steps in order.
2. Include specific names and sizes of equipment used and quantities measured.
3. Outline what will be changed in the experiment and how it is changed (independent variable).
4. Outline what results will be measured (dependent variable) and how this will be done.
5. Include the number of trials that will be carried out.
6. Write in the third person (do not use you/I/we).

trial
a run-through of an experimental method that is usually repeated several times, to obtain data than can averaged, to reduce any effect of variables not being completely controlled

outlier
an extreme data value that is very different from the other data and could be the result of faulty procedure

condition
the different levels of the independent variable

qualitative
a form of data that is a descriptive measurement

quantitative
a form of data that is a numerical measurement

Types of data

The next step in our scientific method is to decide what type of data we will be gathering when testing our hypothesis. Generally, we can classify data observed in an experiment into two categories: **qualitative** and **quantitative** observations.

DOC
WORKSHEET
Qualitative vs quantitative

Quick check 1.4

1 Describe some features of an investigable question.

2 a Decide if the following questions are investigable or non-investigable:
 - i How do plants grow?
 - ii Do sugary drinks cause tooth decay?
 - iii What stops ice from melting?
 - iv Do butterflies prefer yellow flowers?
 - v Does sleep help students?

 b Change the non-investigable questions into investigable questions, then examine others' questions in your class. Are they the same?

3 Describe some features of a reproducible investigation.

4 Construct a method for making a cup of tea. Give your method to a classmate for them to review while you review theirs. Provide feedback to your classmate on their method. Is it fully reproducible?

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	Data type	
	Qualitative observations	**Quantitative observations**
Definition	Qualitative observations are descriptive and usually come from our senses, such as what we see, hear, smell, taste and feel, and are often used to describe the physical characteristics or properties of something being tested. They refer to a type, which might be represented by a name, letter or number code. For instance the swimmers may be called Ali and Tom, or A and B, or Lane 1 and Lane 2, etc.	Quantitative observations are numerical values or counts that are expressed as numbers and are often measured with tools such as thermometers, measuring cylinders or (in this example) stopwatches.
Example	Ask who is a better swimmer or ask observers to rate their swimming style on a scale of Poor / Fair / Excellent.	Record the times of the swimmers in seconds using a stopwatch.
Accuracy	This description could be very detailed but each person who watched the race might give a slightly different description and so qualitative descriptions are harder to compare. They are subjective (open to interpretation or opinion).	This may be a more reliable piece of data as a number is objective (not open to interpretation or opinion). It can be easily compared to other observations; for example, the next time they race each other, even if a different person is collecting the data. Repeated measurements are also helpful to see if there are outliers.

Table 1.6 Comparing the properties of qualitative and quantitative observations, using swimmers as an example

Quick check 1.5

1 State the kind of observation that is gathered using measurement tools.
2 State the kind of observation that is descriptive, and not a numerical value or count.
3 Describe the possible strengths of using qualitative data.
4 Explain why it is useful to make repeated observations and trails.

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Making thinking visible 1.1

Think, pair, share: Quantitative data versus qualitative data

1 **Pair** up with someone in the class and **think** about how you could describe them quantitatively and qualitatively. Write your thoughts in the table below.
2 **Share** and compare your thoughts with your partner.
3 Team up with another pair in the class and share your pair's observations of each other and compare with the observation made by the other pair.

Feature	Qualitative observation	Quantitative observation
Age		
Height		
Favourite colour		
Pets		
Siblings		

After you have completed the activity, share your findings with the rest of the class.

1 Identify which features were easiest to describe qualitatively.
2 Identify which features were easiest to measure quantitatively.
3 State a reason why a scientist would use qualitative measurements.

The *Think, pair, share* thinking routine was developed by Project Zero, a research centre at the Harvard Graduate School of Education

Investigation 1.1

Vitamin C in fruit juices

Aim

To develop observations and inferences based on a simple task.

Research question

Do citrus fruits contain a higher concentration of vitamin C than other types of fruit?

Be careful

Ensure appropriate signage is displayed during and after hotplate usage.

Do not taste or drink any of the fruit juices.

Materials

- cornstarch
- beaker × 2
- test tubes – enough to test each variety of juice – in a test tube rack
- sticky labels and pen or magic marker to label the test tubes
- pipette
- hotplate
- iodine
- water
- various fruit juices (e.g. orange, lemon, pineapple, tomato, apple, blueberry, kiwi), of which at least two should be citrus and at least two should be non-citrus

Planning

1 You need to provide some background information to the investigation. Complete some research and write a brief paragraph to explain the importance of vitamin C in a balanced diet.
2 Identify the independent variable in this investigation.

continued …

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... continued

3 Identify the dependent variable in this investigation.
4 Identify the controlled variables in this investigation.

Method

1 Add 1 tablespoon of cornstarch to a beaker.
2 Mix with enough water to make a paste-like consistency.
3 Add 250 mL of water to the beaker and bring to the boil on a hotplate. This is your starch solution.
4 Add 75 mL of distilled water and 10 drops of starch solution to another beaker.
5 Add drops of iodine to this solution until it turns a dark blue-black. This is now your vitamin C indicator.
6 Add 5 mL of the indicator solution to a test tube and label it with the juice being tested and the trial number.
7 You can now add the first sample of fruit juice drop by drop to the indicator solution. The more vitamin C present in the juice, the fewer the number of drops to turn the indicator solution colourless. Count and record the number of drops that it took to remove the blue colour. Keep the test tube in the rack.
8 Repeat steps **6** and **7** with a new test tube for the next juice or trial. Continue until all juices have been tested.
9 If time permits, carry out three trials for each type of juice.
10 Now make inferences to explain your observations based on your prior knowledge or experience.

Results

Complete the results table.

Juice	Number of drops taken to cause a colour change			
	Trial 1	Trial 2	Trial 3	Average

Discussion

Analysis

1 Plot a column or bar graph of the number of drops vs. type of fruit juice.
2 Describe any trends in your results. Is there any pattern between the type of fruit (e.g. citrus vs non-citrus) and the number of drops needed for a colour change? Or is there another pattern present, such as the colour of the fruit?
3 Another variation is to add the same volume of juice to each test tube and compare. Using your results from the drop-wise experiment, predict what you think the results of that experiment would be.

Evaluation

Consider your method and suggest any improvements that you could make if you were to do it again.

Conclusion

Answer your research question, using data from the experiment to support your statement.

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Section 1.2 questions

QUIZ

Retrieval

1 **Recall** how an observation is different to an inference.

2 **Define** qualitative data and quantitative data.

Comprehension

3 **Classify** the following pieces of data as qualitative or quantitative.

   a Tami scored 74% on the test. Aidan scored 90% on the test.

   b Students mixed two chemicals and recorded what they saw. Aaron wrote down, 'The mixture went blue'. Hannah wrote down, 'The mixture went a dark greenish-blue. The test tube felt warm to the touch. Small bubbles appeared.'

   c A scientist recorded the number of times a dingo ate in a 24-hour period.

Analysis

4 A tennis ball is dropped from various heights and a student measures the time taken for the ball to hit the ground. **State** an appropriate hypothesis for this experiment, using an 'if … and then … ' statement.

5 A scientist undertook the following experiment.

   Step 1: Observed that a pot plant seems to grow better the closer it is to a window.
   Step 2: Conducted an experiment where a flowering plant was placed on the windowsill and a cactus was placed in a dark room. The flowering plant was watered and the cactus was not. The flowering plant was also given fertiliser but the cactus was not.
   Step 3: Collected the data and concluded that plants grow better when they are exposed to more sunlight.

   a **Identify** a mistake in the scientist's method.

   b **Describe** whether this was a fair test.

Knowledge utilisation

6 For the pot plant experiment in Question 5, **discuss** the changes to the experiment required to ensure the experiment is fair.

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1.3 Conducting and analysing an experiment

WORKSHEET
Taking measurements

Learning goals

1. To be able to identify appropriate tools for measuring precise quantities.
2. To be able to use appropriate data representation for continuous and discrete data.
3. To be able to construct a table and graph of results for an experiment.
4. To be able to evaluate and conclude the findings from an experiment.

accuracy
how close a measurement is to the true value

precision
how close measurements are to each other

Now that an investigation has been designed, it is time to conduct the experiment and analyse the results to answer our original research question. But when conducting an experiment, it is important that we use the right tools for the job!

Measuring tools

When scientists use tools to collect data, it's important to select and use equipment that is appropriate to the investigation so that the results are accurate.

Accuracy is the closeness of a measurement to the true value and there are many pieces of equipment available to help increase this. The choice will depend on what you want to measure. For example, you should select a thermometer that can measure within the range of temperatures expected or select an appropriate-capacity measuring cylinder for the volume of liquid needed in the experiment.

Length

You can use rulers to measure the length of a straight object. You can also use measuring tape for a non-straight object or even a trundle wheel for large distances. It is important to use the most **precise** tool and unit when measuring. For example, if you are measuring the size of a snail, you would use a ruler and millimetres. If you are measuring the size of a person, you would use a measuring tape and centimetres, and if you are measuring the length of the school grounds, you would use a trundle wheel and metres. The ruler has smaller markings and greater precision than the trundle wheel. Some professions use a laser distance measuring tool. This tool uses a laser to make even more precise distance measurements. Digital tools tend to generate more precise data.

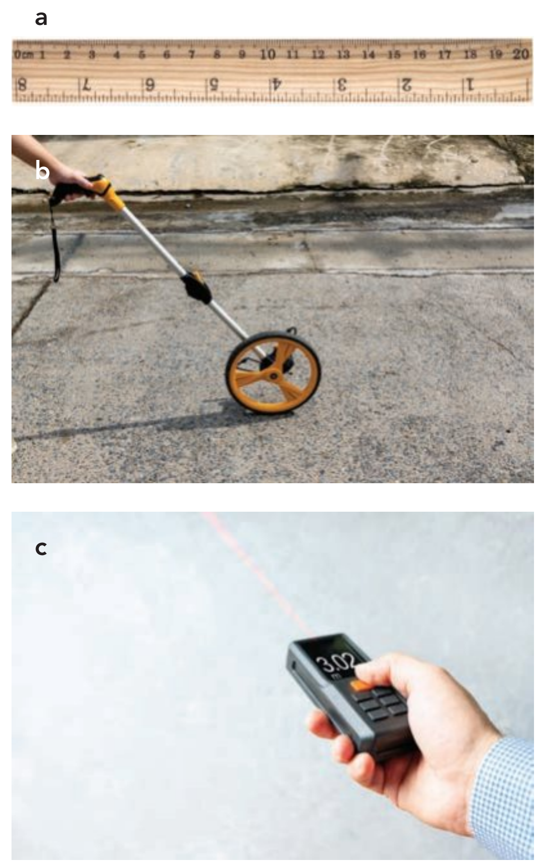

Figure 1.12 **(a)** A 20 cm ruler, **(b)** a trundle wheel and **(c)** a laser distance measure for precise distances. Generally, to measure the length of an object, you use the units millimetre (mm), centimetre (cm), metre (m) or kilometre (km).

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Volume

In mathematics, volume is commonly measured in units of cubic centimetres (cm^3) or cubic metres (m^3). However, in a laboratory it is usually the volume of a liquid that needs to be measured, and so units of millilitres (mL) and litres (L) are used.

Volumes can be measured using a measuring cylinder, but if precise measurements need to be made, a special piece of equipment called the pipette can be used.

Figure 1.13 **(a)** A measuring cylinder and **(b)** a scientist using a glass pipette for dispensing a volume of liquid

Temperature

Temperature in a laboratory is usually measured using a thermometer in units of degrees Celsius (°C). For more precise measurements, a digital thermometer probe can be used. Sometimes, scientists may use digital tools such as sensors that can record environmental data periodically.

Figure 1.14 Many weather monitoring systems employ data loggers.

Time

Scientists use stopwatches for precisely recording time values. Stopwatches are great for measuring time in seconds (s), minutes (min) or hours (h), but they can also be used for experiments lasting days.

Mass

Electronic scales precisely measure mass in the laboratory. The units of milligrams (mg), grams (g) and kilograms (kg) are used to measure mass. Larger masses can be measured in tonnes (1 tonne = 1000 kg). Force meters may also have a reading available for mass, and this type of equipment will be discussed later in this text.

Figure 1.15 The liquid in the glass thermometer shown uses the measurement unit Celsius (°C). The thermometer with a red coloured liquid is modern and uses alcohol, while the thermometer with the grey coloured liquid is mercury. Why might mercury thermometers have been phased out of production?

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Practical skills 1.3

Reading equipment

Aim
To practice taking readings using specific pieces of equipment.

Materials

Station 1
- spring balances 100 g, 500 g, 1 kg, 5 kg
- 100 g masses

Station 2
- 3 sugar cubes
- electronic balance

Station 3
- 2 ice cubes
- 50 mL water
- beaker
- thermometer

Station 4
- stopwatch

Station 5
- ruler
- A4 sheet of paper

Method
In groups of three, rotate through the stations, taking individual readings and filling out the results table. Alternatively, you could work alone and collect results from two other people.

Station 1
1. Place the mass onto each spring balance and measure the mass in grams.
2. Copy and complete the table shown in the results section.

Station 2
1. Measure the mass of one sugar cube using the electronic balance.
2. Keep the sugar cube on the electronic balance and zero the balance.
3. Add two more sugar cubes and record the mass.

Station 3
1. Place 50 mL of water into a 250 mL beaker.
2. Use the thermometer to measure the initial temperature.
3. Add two ice cubes, wait for 30 seconds and then measure the temperature.
4. Record the results in your table.

Station 4
1. Attempt to stop the stopwatch at exactly 2 seconds.
2. Record the results from three attempts.

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Station 5

1. Measure the diagonal length of the A4 sheet of paper.
2. Measure the width of the A4 sheet of paper.
3. Measure the length of the A4 sheet of paper.
4. Record the results from three attempts.

Results

Station	Person 1 reading	Person 2 reading	Person 3 reading	Mean
1: 100 g balance (g)				
1: 500 g balance (g)				
1: 1 kg balance (g)				
1: 5 kg balance (g)				
2: initial (one cube) (g)				
2: (zero)				
2: (two cubes added) (g)				
3: (°C) initial				
3: (°C) final				
4: first try (s)				
4: second try (s)				
4: third try (s)				
5: diagonal (mm)				
5: width (mm)				
5: length (mm)				

Evaluation

1. Station 1: Decide when each of the spring balances would need to be used in an experiment.
2. Station 2: Explain why it is important to zero the electronic balance before each use.
3. Station 3: Propose a reason why it is important to think about time when measuring temperature.
4. Station 4: Explain why it is important to do multiple trials and average the results.
5. Station 5: Discuss why millimetres were used for units to measure the paper, rather than metres.
6. If there were differences in the temperatures recorded by different people at station 3, suggest possible reasons for the differences.

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random error
an error that is caused by factors that cannot be easily controlled by the experimenter

systematic error
an error that causes measurements to differ from the true result by a consistent amount, often due to faulty or uncalibrated equipment

meniscus
the surface of a liquid in a container

concave
a surface that curves inwards

convex
a surface that curves outwards

parallax error
an error caused by not reading liquid measurements at eye level, which leads to measurements being too high or too low

Minimising error

Errors are differences between the values we observe and what is true. Errors can cause results that are inaccurate, or even false. **Random errors** are unpredictable and are generally made by the experimenter, such as not timing something correctly. **Systematic errors** are consistent and may be caused by faulty equipment or problematic methodology. For example, a scale that consistently reads 20 grams higher than the actual mass of an object. This error is consistent, meaning that every time the scale is used, the readings will be 20 grams higher than the actual mass, regardless of the object being weighed.

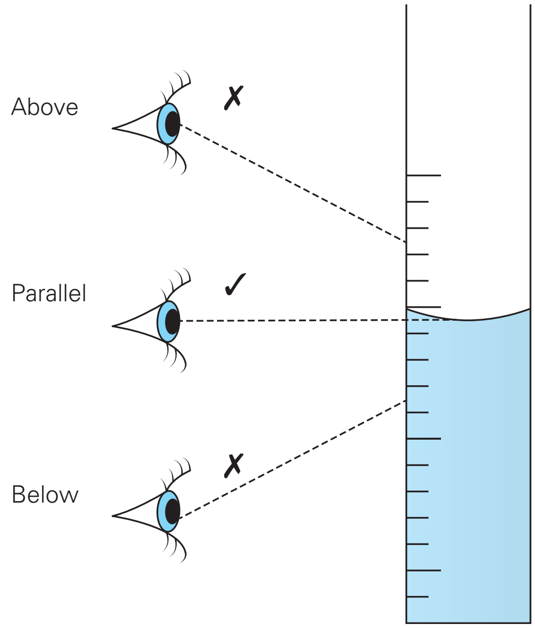

Figure 1.17 How parallax error can occur

Meniscus

When measuring liquid volumes in measuring cylinders or pipettes, it is common for the liquid to curve at the position of reading volume. This curve is called the **meniscus** and it is when the liquid interacts with the sides of the glassware to make either a **concave** or a **convex** shape (see Figure 1.16).

In your experiments, you will come across both types of meniscus and it is important to know where to take a reading of volume to be accurate and precise. For a concave meniscus, take the reading from the bottom of the meniscus and for a convex meniscus take the reading from the top.

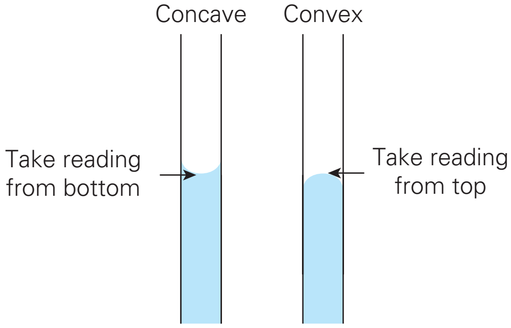

Figure 1.16 Reading a meniscus

Parallax error

When making a measurement from the meniscus of a liquid, you can also encounter an error known as **parallax error**. This occurs when you are making a reading of volume from a meniscus without being at eye level with the meniscus.

Quick check 1.6

1. Define the term 'meniscus'.
2. Explain why measurements are taken from either the top or the bottom of the meniscus.
3. Explain how a concave meniscus forms.
4. Describe how you would minimise parallax error.

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That is, your eye line should be parallel to the position at which you are taking the reading. Not doing so can result in inaccurate data being recorded.

5. Processing data

When data from an experiment is collected, it is important to represent it in such a way that it can be easily analysed. The analysis of the data will help you answer your research question and provide evidence to support or not support your hypothesis. Data is usually first recorded in an organised table and then represented in a graph. The appropriate data representation to use depends on the type of data (quantitative or qualitative) that was collected.

Quantitative data: continuous vs discrete

Quantitative data can be classified as either continuous data or discrete data. Table 1.7 lists the differences between **continuous** and **discrete** quantitative data as well as the appropriate graph type to represent the data.

Displaying data in tables

WORKSHEET Displaying data

It is a good idea to construct a table before the experiment begins, so you can record the data as you go.

All tables have:

- a title that describes what is in the table (not 'Results table')
- lines drawn with a ruler
- column headings showing the unit that is measured.

Data for all trials should be included in the table, as well as means, differences or changes (if appropriate to the experiment). Units should only appear in the column headings.

Example of how to set up a table

An example of a table of data is shown in Figure 1.18. The title of this table is: 'How the mass of sodium bicarbonate added to vinegar affects the height of bubbles produced over time.'

The values in a table should all be written to the same number of decimal places.

continuous data quantitative data points that have a value within a range; this type of data is usually measured

discrete data quantitative data points that have whole numbers; this type of data is usually counted

	Continuous data	Discrete data
Features	Usually measured	Usually counted
	Takes any value within a range, e.g. might have decimal places	Usually takes whole-number values
Examples	*Human height* If you measured the height (in metres) of every person in the classroom, the data might look like: 1.75, 1.77, 1.80, 1.83, 1.99 … *Other examples:* time, weight, temperature (measured with a thermometer or temperature probe)	*Number of plants* If you counted the number of plant seedlings that grew in an experiment, the data might look like: 1, 0, 5, 8, 17 … It is impossible to have 1.39 plants. You can only have whole numbers. *Other examples:* number of siblings, number of crystals formed after a chemical reaction
Usual graph	Line graph	Bar graph

Table 1.7 The differences between continuous and discrete quantitative data

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The **independent variable** is placed in the left-hand column.

Table: How the mass of sodium bicarbonate added to vinegar affects the height of bubbles produced over time

Mass of bicarbonate (g)	Height of bubbles (mm)			
	Trial 1	Trial 2	Trial 3	Mean
1.0	89	91	90	90
2.0	105	104	106	105
3.0	139	141	140	140
4.0	162	165	159	162

The **dependent variable** is placed in the top row, and results for each trial are shown.

If multiple trials are recorded, then you should also include a column for the mean (average) value.

Figure 1.18 How to set up a table of data

✔

Time (s)	Volume of liquid (mL)
1.0	89.1
2.0	105.2
3.0	139.0
4.0	162.5

✘

Time (s)	Volume of liquid (mL)
1.0	89.1
2.0	105.2
3.0	139
4.0	162.5

Figure 1.19 Data values in a column should all have the same number of decimal places.

In Figure 1.19, the table on the left is correct, but the table on the right is wrong because the third value, 139, is not given to the same number of decimal places as the other data.

When collecting data, you should consider the spread of your repeated measurements. If there is wide variation in your data after you repeat a measurement several times, it may be due to random error. This would be considered lower quality data. Once you have recorded your data in a table, it is good practice to write a short sentence summarising what the table shows.

For example, from the table in Figure 1.19, you could say:

'The results provide evidence that, as time (s) increases, the volume of liquid (mL) also increases.' Note that units should always be included.

Quick check 1.7

1 Identify the mistake in each of the following tables.

a

Time (s)	Temperature
0	40°C
60	50°C
120	60°C
180	70°C

b

Distance (km)	Time (s)
1	66.6
2	140.00
3	293.45
4	603.32

2 Construct a table to show the following data. Include an appropriate title.
Max is making toffee. He is using a thermometer to measure the temperature of the sugar. At 5 minutes, he finds that the temperature of the sugar is 100°C. At 10 minutes it is 108°C, at 15 minutes it is 115°C and at 20 minutes it has reached 122°C.

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3 Anna measures how long it takes a bottle of water to freeze when the freezer is set at different temperatures. She records her results in the table opposite.

Identify the mistake in the table.

Time to freeze (h)	Freezer temperature (°C)
6	–2
4	–4
3	–6
2	–8

Calculating the mean

Calculating a mean is an important way to find out the average value of a set of numbers. It helps us to understand the data and compare different sets of numbers.

Worked example 1.1

A pool owner takes five temperatures in a pool: one from each corner and one from the middle of the pool. The temperatures were 17°C, 15°C, 13°C, 16°C and 15°C. Calculate the mean (average) temperature of the pool.

Solution	Explanation
17°C + 14°C + 14°C + 16°C + 14°C = 75°C	The sum of the measurements is 75°C.
Mean = $\frac{75°C}{5}$ = 15°C	Divide the sum by the number of measurements, which in this case is five.

Practical 1.2

Testing paper planes

Aim

To test how the size of a paper aeroplane affects the distance it can travel by recording data from multiple trials.

Materials

- A4 paper
- scissors
- measuring tape

Method

1 Define the following for your experiment: independent variable, dependent variable and controlled variables. Create a table of results for your experiment.

2 Construct a hypothesis for your experiment. Predict how the independent variable will affect the dependent variable.

3 Follow the steps shown in Figure 1.20 to produce a paper aeroplane.

4 Cut up the paper, so you have A4, A5, A6 and A7 sized rectangles to make different sized paper aeroplanes. Planes made from bigger pieces of paper will have a bigger mass and a bigger wing span.

5 Throw the first aeroplane and measure the distance travelled until it hits the ground.

6 Record your measurement in the results table.

7 Throw this plane two more times, recording your result each time.

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… continued

8 Repeat steps **5–7** for each of the four different planes.

9 Calculate the mean for each set of results.

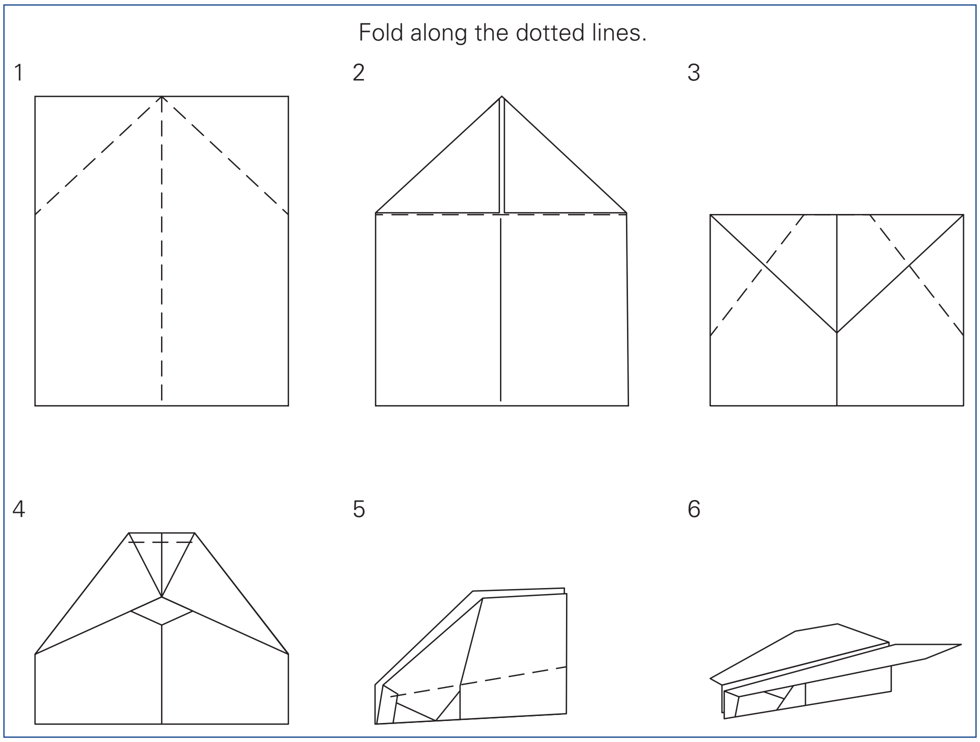

Figure 1.20 How to make the paper aeroplane

Results

Write a short summary of what your data shows.

Discussion

1 Now that you have completed the experiment, identify other variables that you should have controlled that may have affected your results.

2 Identify one variable that you were not able to control, that could have affected your results (one potential source of error).

3 Suggest two other independent variables that you could change, other than the size of the aeroplane.

4 Explain the reason for conducting multiple trials and calculating the mean of your results.

DOC WORKSHEET Using spreadsheets

Displaying data in graphs

Line graphs

Now that you have data from your experiment in a results table, you can display the data in a graph to easily show any possible patterns, trends or relationships that your experiment has uncovered.

Graphs can also allow you to easily identify any **anomalous** results in your data.

A *scatter plot* is a way of displaying how one quantitative variable changes in response to another quantitative variable, by plotting points. When the points are connected, it is called a **line graph**. Line graphs are generally used with continuous data, as they show how the data points continue on from one another. The lines at the side and bottom of a graph are called the axes. When you transfer data from a table, place the independent variable on the x-axis (horizontal axis) and the dependent variable on the y-axis (vertical axis).

anomalous
an outlying result that does not fit in with the pattern of the other results

line graph
a type of graph used to display continuous data

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Table A The speed of a car over a period of time

Time (s)	Speed (m/s)
0	0.0
2	1.4
4	2.6
6	4.4
8	6.8
10	6.6
12	8.2
14	9.6

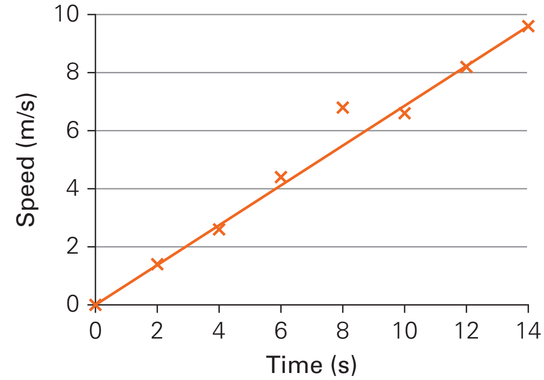

Figure A The speed of a car over a period of time.

Figure 1.21 A table and figure showing the speed of a car over a period of 14 seconds. Note that in the graph representation of this table, very small crosses have been used to mark the data points. Can you find the anomalous result?

A **trendline** can be drawn as a line that is an average of the plotted points on a scatter plot. To draw a trendline, draw a straight line that goes through as many data points as possible. You can use a ruler to help you. An example of a trendline is shown in Figure 1.21.

The lines at the side and bottom of a graph are called the axes. When you transfer data from a table, place the independent variable on the *x*-axis (horizontal axis) and the dependent variable on the *y*-axis (vertical axis).

When writing table and graph titles in science, it is important to provide a clear and concise description of what the table or graph is showing. The title should be located above the table, but below a graph. It should include a brief description of the variables being plotted or compared.

Bar graphs and column graphs

Bar graphs and column graphs are a way of displaying how a quantitative discrete dependent variable (for example, heart rate) changes in response to a qualitative independent variable (for example, species of animal).

trendline/line of best fit
a line drawn to show an average of plotted points

bar graph
a type of graph used to display the frequency of a qualitative variable (category)

Bar graphs and column graphs are similar; often one is chosen over the other simply due to how the information is best displayed. In column graphs, categories are listed along the *x*-axis and numbers along the *y*-axis in column graphs, while on bar graphs it is the other way around.

Bar and column graphs have spaces between the bars – the bars do not touch each other.

An example is shown in Figure 1.22.

Table B Heart rates of different mammals

Animal	Heart rate (beats/min)
Camel	35
Horse	41
Human	70
Rabbit	210
Mouse	670
Rat	750

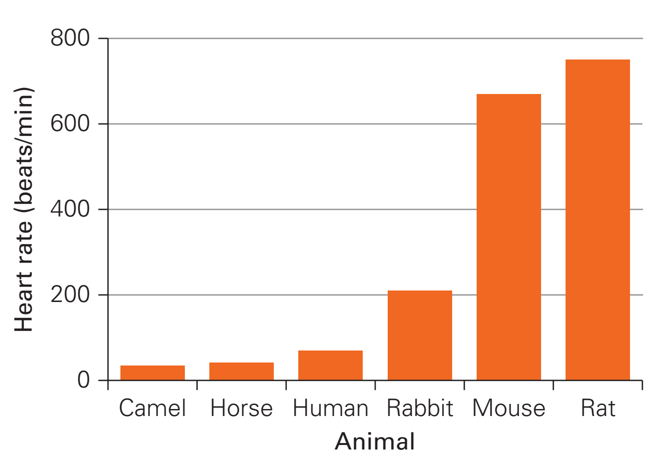

Figure B.1 Heart rates of different animals

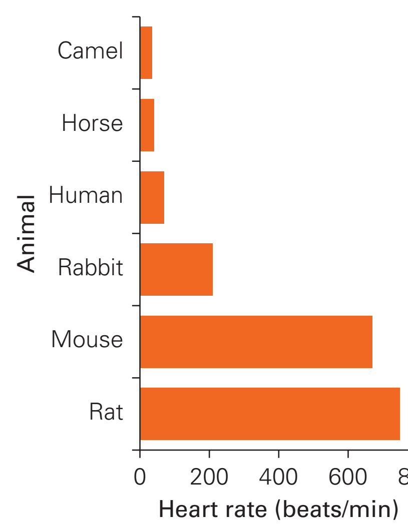

Figure B.2 Heart rates of different animals

Figure 1.22 A data table, column graph and bar graph showing heart rates of different mammals

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6. Analysing data

These graphical data representations show a relationship between the independent variable and the dependent variable and allow the scientist to describe a trend. A trend can be positive, negative or neutral and it can be determined by plotting the data on a graph. If the points on the graph closely follow a straight line or a curve, there may be a trend present. For example, in the column graph in Figure 1.22, the trend that might be identified is that the smaller the size of the animal, the faster the heart rate in beats/min.

7. Evaluation

In the evaluation section of your report, you can discuss any challenges you faced during the experiment and suggest improvements that can enhance your method. It is important to provide a brief description of the encountered problems and offer specific solutions to overcome them. For instance, you can recommend using more precise equipment, adjusting variables, or changing procedures to improve accuracy and reliability. By including these details, you demonstrate your understanding of the scientific method and your ability to critically assess your own work. Writing a thorough evaluation can also help others who may want to replicate your experiment in the future.

8. Conclusion

A conclusion is a short logical paragraph that ends a scientific report. It summarises the findings of the investigation and should include the following ideas:

- evidence that accepts or rejects the hypothesis
- a statement that answers your research question
- some data to justify your answer to the research question.

Worked example 1.2

Suppose that you were watching a race, and you noticed that the racer named Trent beat the one named Lewis. This was an observation of the world around you. If you were interested in why that happened, you might carry out further research by the following procedure.

Practical Report section	Example	Explanation
Research question	Do more training hours improve race performance?	The question needs to able to be investigated scientifically and answered safely. The question has an independent and a dependent variable, which are easily measured.
Introduction-rationale	Runners who train for more than four hours a week reduce their race time by an average of ten minutes. Runners who add three days of strength training to their weekly program increase their leg strength and improve race performance.	This is your background information. You need to use the internet and books to find scientific information that provides information about what you're studying. Make sure you use reputable websites and give a reference link for anything you use. The sentences shown are an example of what could be included.
Hypothesis	An increase in training hours will increase race performance and decrease the time taken to finish a 10 km race.	This is where the research question is changed into a hypothesis that can be tested.

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<table>
<tr><th>Practical Report section</th><th>Example</th><th>Explanation</th></tr>
<tr><td>Methodology</td><td>

<u>Variables</u>
Independent variable: number of training hours.
Dependent variable: time taken to finish a 10 km race.
Controlled variables: participants are the same age, same athletic abilities and receive the same amount of training. The same race distance is used for all participants.

<u>Risk assessment</u>
All runners must wear suitable footwear during the race.

<u>Method</u>

1. Gather a group of eighteen 12-year-old males who will participate in the study.
2. Provide each participant with a logbook to note down their training time and the type of training they did.
3. Instruct the participants to record their training time and type for a certain period of time leading up to the race.
4. On race day, record the time taken for each participant to finish the race.
5. Collect and analyse the data recorded in the logbooks and race results.

</td><td>This is where you design your investigation. You need to consider the variables (i.e. what you will change and what you will measure), a risk assessment and a method.
The number of training hours is the independent variable because it is the variable that we change to see what effect it has on the dependent variable.
The time taken to finish a 10 km race is what we predict will change as a result of the training hours change. This makes time taken to finish a 10 km race the dependent variable.</td></tr>
<tr><td>Results</td><td>

Table: Relationship between training hours and race completion time

Number of training hours (hours)	Time taken to finish a 10 km race (minutes)
4	102
7	92
10	86
15	80
21	72
32	59

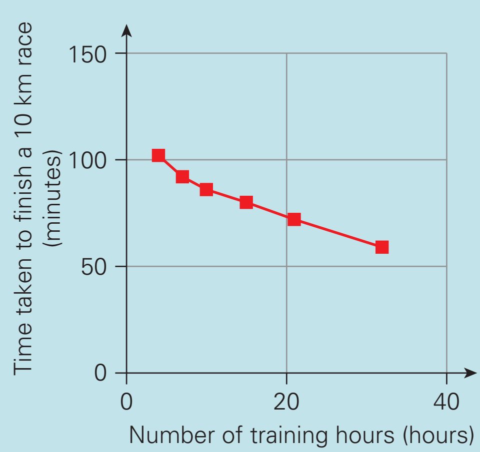

Figure: Training hours vs. race completion time

</td><td>You need to present your results in tables and graphs.</td></tr>
</table>

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Practical Report section	Example	Explanation
Analysis	As the number of training hours increases, the time taken to finish the race decreases. For example, when athletes trained for four hours, it took them 102 minutes to finish a race, whereas when athletes trained for 32 hours, it took them 59 minutes to finish the race.	You need to look at your data and identify any trends, patterns or relationships. Include data to justify the trend you have identified.
Evaluation	The investigation only considered 18 male runners completing one 10 km race. Although the participants were all 12 years old, they were all different heights and had different diets. Their training also varied. Some completed only running training, whereas others also swam or did strength training. To improve the investigation, a bigger number of participants is required. Each participant should eat the same diet and complete the same type of training. The investigation could be extended by also considering female runners, or looking at different race distances.	This section is where you consider any issues with your method and suggest potential improvements for any future investigation. If the data is inconclusive, it could mean that there are more variables that need to be controlled.
Conclusion	In conclusion, the results show that more training hours improve race performance. This is shown by the data: runners who only trained for four hours completed their race in an average of 102 minutes, whereas the runners who trained for 32 hours finished their race in an average of 59 minutes. The hypothesis of 'an increase in training hours will increase race performance' is accepted. The data could also be used to improve race performance in teen boys.	You need to answer your research question, justifying it with data that you collected. This will allow you to accept or reject your hypothesis.

Science as a human endeavour 1.1

Doing scientific research

All scientists, regardless of their field, have common tasks that they conduct. These tasks include working collaboratively, classifying objects into groups of smaller things and making observations and inferences. However, one of the most exciting parts about being a scientist is making a new discovery. This is exactly what happened when scientists from Griffith University and the Queensland Museum worked together to identify new species of trapdoor spiders in Southeast Queensland. The team discovered four new species of spider

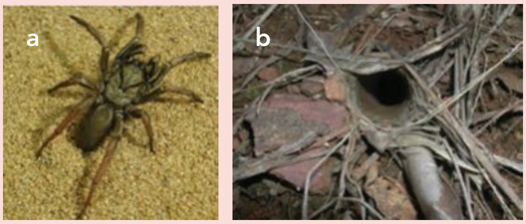

Figure 1.23 (a) A Brisbane trapdoor spider, *Arbanitis longipes* and **(b)** its burrow

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in 2019, and **predicted** that there were more to be discovered. In 2023, the same team discovered another species of trapdoor spider in the Brigalow Belt of central Queensland.

The team of scientists spent time in the laboratory working with chemicals and machines to **analyse** the genetic components of the different spiders. They also spent lots of time out in the field exploring many new areas to find the elaborate burrows that the spiders build.

predict
to make an estimate about a possible future event or outcome

analyse
examine something to find meaning, what it is made of or a relationship with other things

The most recently discovered spider was named *Europlos dignitas*; 'dignitas' meaning 'dignity' or 'greatness,' with female spiders being almost five centimetres long. The life of a scientist can be extremely varied and exciting.

Figure 1.24 Different species of trapdoor spiders are found all around the world, and can build their burrows from a wide range of materials.

Section 1.3 questions

Retrieval

1 **Recall** a measuring tool that can be used for a volume of liquid.

2 **Define** continuous data and discrete data.

Comprehension

3 **Identify** the type of graph that should be used for an experiment that measures the mass of different animals.

Analysis

4 **Describe** the trend in the data presented in Figure 1.25.

Knowledge utilisation

5 **Justify** why a line graph was chosen to be an appropriate data representation for this data.

6 **Propose** what a meniscus would look like if the molecules of a liquid inside a container were equally attracted to themselves and the container.

QUIZ

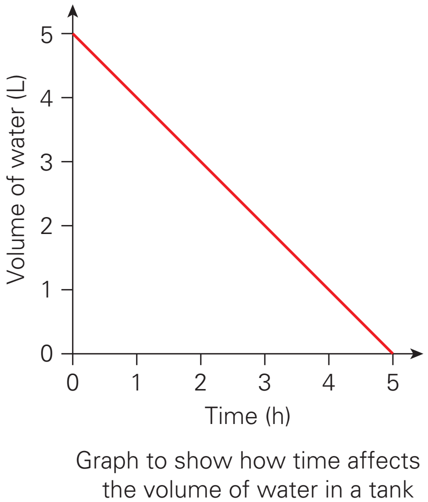

Figure 1.25 A line graph representation for data in an experiment

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1.4 Science communication

WORKSHEET
Conducting research

Learning goals

1. To be able to identify the purpose and target audience of a scientific text.
2. To be able to determine the credibility of a source.

Effective science communication

Every day, scientists must communicate with a wide range of people, whether it be through writing papers and proposals, giving talks or educating others. Sometimes the audience may also be a specialist in a scientific area, but often, scientists are communicating with members of the public.

To be successful, scientists must learn how to communicate effectively. A scientist who is an effective communicator should be able to transmit their message in a way that people can easily understand. The ability of scientists to effectively explain the significance and importance of their work to their colleagues can improve their chances of getting a job or receiving a research grant. They can produce better research papers that may inspire or educate others.

When scientists can effectively communicate with members of the public, it strengthens public support for science, fosters an understanding of its broader relevance to society, and promotes more informed decision-making at all levels, from the government to communities to individuals. It also makes science accessible to all, improving diversity and inclusivity.

Scientists communicate their findings in a variety of ways to reach different audiences effectively. One common method is through oral presentations, which allow researchers to present their findings in person to other scientists or interested groups. Posters are another effective means of presenting research and often contain visual aids such as diagrams, graphs and images. Diagrams and animations are useful for illustrating complex processes or phenomena. Reports, both scientific and practical, are a common way for scientists to share their findings in a written format. News articles and infographics can be used to present scientific information to a broader audience in a more accessible way. For example, a scientist may present their findings on the effects of climate change through an oral presentation at a scientific conference, a poster at a local community event, a report published in a scientific journal, or an infographic shared on social media to reach a wider audience.

Making thinking visible 1.2

Tug for Truth: Protecting endangered species

It is claimed that the effective science communication of endangered species has led to policies and regulations related to fishing catch and hunting limits. Use the internet to research this claim and complete the activity below.

- What is your personal opinion on this statement?
- Draw a tug of war diagram on the board. Use two different coloured post-it notes to add evidence that supports this claim and those that refute this claim.
- Do you have any new ideas or questions about the claim?

The *Tug for truth* thinking routine was developed by Project Zero, a research centre at the Harvard Graduate School of Education

Science miscommunication

Even scientists can have problems understanding one another when scientific papers are written in very research-specific language. But when dealing with the public, poor, biased or incorrect communication about science can have a serious impact on progress in many areas of society.

Science miscommunication most commonly takes place on the internet, and it is important to remember that not all information found online is trustworthy. When searching for information, you should look for a credible or reliable source.

Secondary sources

When you find some information, you can use the CRAAP test to check whether you should use that information. The CRAAP test takes into account the currency, relevance, authority, accuracy and purpose of the information.

When you use the CRAAP test, you give each of these factors a score of 0, 1, 2 or 3. You then have to add up all the scores. You should aim to use sources that have total scores of at least 13. Table 1.8 explains how to apply the CRAAP test.

WORKSHEET
CRAAP analysis

	Description	Score			
		0	1	2	3
C	**Currency:** How old the information is • When was the information published or posted? • When was the last time the information was updated? • Is any of the information out of date or does it use old terms? • Do the links work?	No date is given.	The information is over three years old; no date of revision or update is given.	The information has been created or updated within the last three years.	The information was created less than two years ago. Sources referenced are current.
R	**Relevance:** How well the information matches what you are researching • Does the information answer your question or link to the topic? • Who is the information aimed at? • Is the information worded at an appropriate level for you to understand?	There is no relevance to the topic I'm researching.	It has a small amount of information about the topic I'm researching.	It has a large amount of information about the topic I'm researching.	It can fully help me understand the topic I'm researching.

Table 1.8 The CRAAP test

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	Description	Score			
		0	1	2	3
A	**Authority:** The writer of the information • Who is the author/publisher/source/sponsor? • Have the authors stated why they are experts? (Dr/Professor/experience) • What are the author's qualifications in the topic? • Is contact information provided, such as a publisher or email address? • Does the URL reveal anything about the author or the source? • Is the information linked to a biased organisation?	No author is identified.	The author is identified, but no credentials are given.	The author is named, and their contact details are given. The publisher is identified.	The author and publisher are identified and respected, and all contact details and credentials are listed.
A	**Accuracy:** How correct or truthful the content is • Where does the information come from? • Is the information supported by evidence? • Has the information been reviewed or refereed by an expert? • Can you verify any of the information by checking another source? • Is the writing free of emotion? • Are there spelling, grammar or other errors in the writing?	There are no links to sources or a citation list. Information is difficult to understand, contains errors and may be incomplete.	There are no links to sources or a citation list. Information contains spelling and grammar errors.	There are links to sources or a citation list. Information is easy to understand and contains only minor spelling issues.	There are links to sources or a citation list. Information is corroborated with other sources. It contains no errors, and is written well and in a concise way.
P	**Purpose:** The reason the information exists • What is the purpose of the information? • Do the authors make their intentions or purpose clear? • Is the information fact, opinion or propaganda? • Is the information biased? • Does the writer's point of view appear objective and neutral?	The purpose is biased, and therefore is personal. There may be too much advertising.	The purpose is to persuade or sell something to a reader.	It offers some factual information, but there may be some advertising.	The purpose is to present factual information in a balanced way.

Table 1.8 *(Continued)*

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Try this 1.2

Using the CRAAP test

The aim of this activity is to research an inquiry question and use the CRAAP test to assess the usefulness of the resources you find.

1 Define 'adaptation'.
2 Outline one reason why it is important for animals to have adaptations.
3 Copy and complete the following table.

Australian animal characteristics	Animal 1	Animal 2
Common name		
Scientific name		
Where found in Australia		
Description of habitat		
Description of adaptation		
Type of adaption (behavioural, physiological, structural)		
Outline of how the adaptation allows the animal to survive in its habitat		

4 Compile a sources list.
   a List the search terms you used for searches (at least three terms).
   b Name and score three of your sources.
   c Identify the best source of information you have accessed.
   d Compare the best source to the worst source.

Explore! 1.4

One-in-100-year events

The 2022 South East Queensland floods were labelled a 'one-in-100-year' event, but what does it mean when a natural disaster is described as a 'one-in-50-year' or 'one-in-100-year' event?

Many people might think it means that another flood would not happen for 99 years, but this is incorrect. After experts described the floods as a one-in-100-year event, many people took to social media to point out that their area had suffered from multiple one-in-100-year events. In fact, the same term was applied to the 2011 Brisbane floods.

Figure 1.26 A street in Yeronga flooded during the 2022 Brisbane floods

In fact, a one-in-100-year event simply means that the event has a 1% or one in a 100 chance of happening in any single year.

While this may be easily understood by scientists and mathematicians, it can be misleading for members of the public. People may think that once they have lived through one natural disaster, they need not worry because the next one will not happen for another 99 years. But from a mathematical perspective, the probability of experiencing a similar event is the same every year. This fact could be more effectively communicated if the public were told they had a 1% chance of flooding every year.

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QUIZ

Section 1.4 questions

Retrieval

1 The CRAAP test assesses the quality of a piece of information. **State** what the letters stand for.

Comprehension

2 **Explain** the domains a CRAAP test assesses by copying and completing the table.

Domain	What is being assessed?
Currency	
	Does the information address your research question? Is it written for the right audience?
Authority	Who is the author and are they appropriately qualified?
Accuracy	
	Is the information fact or opinion? Are the author's intentions clear? Is the information free from bias?

Analysis

3 You are reading a story on the internet and some evidence has been cited to support the claim being made in the headline. This is different to what you read on another website the day before. **Describe** how you would evaluate this conflicting evidence to decide what was true.

Knowledge utilisation

4 **Discuss** why people may post incorrect stories or comments about science on the internet. You should consider people who post such things deliberately and those who may not realise their posts are incorrect.

Chapter review

Chapter checklist

You can download this checklist from the Interactive Textbook to complete it.

Success criteria		Linked questions	Check
1.1	I can identify hazard symbols in the science laboratory.	12	
1.1	I can identify and draw common laboratory equipment.	3	
1.1	I can describe how to safely light a Bunsen burner.	10	
1.2	I can identify independent, dependent and controlled variables.	9a	
1.2	I can write a hypothesis in an appropriate style.	9	
1.2	I can distinguish between quantitative and qualitative data.	9c	
1.2	I can describe each stage of the scientific method or sections of a lab report.	11	
1.3	I can select the most appropriate piece of measuring equipment when collecting data.	2, 5, 7	
1.3	I can recognise the difference between systematic and random errors.	8	
1.3	I can choose the appropriate data representation for collected data.	13	
1.4	I can identify the purpose and target audience of a scientific text.	15	
1.4	I can determine the credibility of a source.	14	

Review questions

Retrieval

1 **Recall** three science safety rules.
2 **List** two pieces of equipment used to measure length.
3 **Draw** the following laboratory equipment: beaker, measuring cylinder, Bunsen burner.
4 **State** four different fields of study in science.

Comprehension

5 **Explain** why it is important to choose the best piece of measuring equipment for a task.
6 **Describe** how a convex meniscus is formed.
7 **Identify** a piece of equipment and unit of measurement that could measure:
   a the length of an ant
   b the weight of a Bunsen burner
   c the volume of liquid in a cup of coffee.

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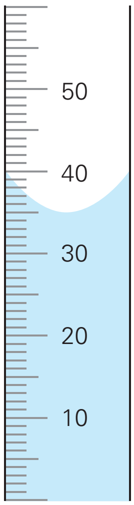
8 A depiction of a measuring cylinder is shown below.
  a **Identify** the amount of liquid in the container and explain your answer, with reference to the meniscus. The graduations are in mL.
  b A student measured 20 mL of water from a measuring cylinder 10 times. When weighed, the samples of water fluctuated above and below the 20 g mark. **Describe** whether this fluctuation is due to random or systematic error in the measurement.



Analysis

9 A student set out to test paper plane wing size and the distance the plane travels.
  a **Identify** the variable she is changing (testing) and how it might be measured.
  b The student notices that planes with larger wing sizes appear to fly higher, and she yells out to her laboratory partner, 'They must capture more wind!' **State** whether this is an observation, an inference or both.
  c The student records distance flown in metres, using a tape measure. **Deduce** if this is qualitative or quantitative data.
  d The laboratory partner remarks that the testing is not fair as they took it in turns to fly the planes and he is a better thrower. **Analyse** the method and describe how the students could improve this experiment to make it fairer.

10 **Explain** the reason the airhole of a Bunsen burner is closed when it is not in use.

11 **Create** a flow chart showing the stages of the scientific method.

Knowledge utilisation

12 A bottle of arsenic acid requires hazard symbols to warn scientists of the risk of using the substance. Arsenic acid is corrosive, acutely toxic, a health hazard and an environmental hazard. **Sketch** the hazard symbols that are required on the bottle of arsenic acid. Use Table 1.6 to aid your response.

13 **State** which type of graph would be most suitable to represent the data collected in an experiment with the hypothesis: If the volume of water supplied (mL) increases, the length of a bean sprout will also increase (cm) over five days.

14 You are expected to use credible sources in your assessments. **Describe** a credible source.

15 **Discuss** how a scientific news article presented by the local news station may differ from one written by a scientist for their colleague.

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Data questions

You can measure 100 mL of water in a measuring cylinder by filling the glassware to the 100 mL line and making sure that the water level is read correctly from the bottom of the meniscus. Some Year 7 students measured out 100 mL of water in a measuring cylinder and weighed the amount of water on an electronic balance. They repeated this experiment 10 times and the results are shown in Table 1.9.

Trial	Mass of water (g)
1	100.0
2	96.5
3	100.0
4	100.0
5	99.7
6	100.8
7	100.3
8	99.9
9	99.7
10	104.2

Table 1.9 Mass of 100 mL of water measured in a measuring cylinder and weighed on an electronic balance

Apply

1 The experiment was conducted at a temperature at which 1 mL of water has a mass of 1 g. Use this information to **determine** what the accurate value for the mass of 100 mL of water should be.

2 **Identify** two results that are considered furthest away from the accurate value.

Analyse

3 Use the data in Table 1.9 to **describe** the differences in the collected results.

Interpret

4 **Deduce** whether the differences in results identified in Question 3 could be from the measuring cylinder or the electronic balance or both.

5 **Infer** why there might be considerable differences in the collected data.

6 If the students were to repeat this experiment 10 more times, **predict** whether the results would change.

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Chapter 2
Classification

Chapter introduction

When you organise your clothes, your kitchen cupboards or your documents, you are unknowingly grouping things together based on similarities. This process is called classification. In this chapter, you will explore the way scientists use classification systems to share their knowledge and group all the living organisms on Earth.

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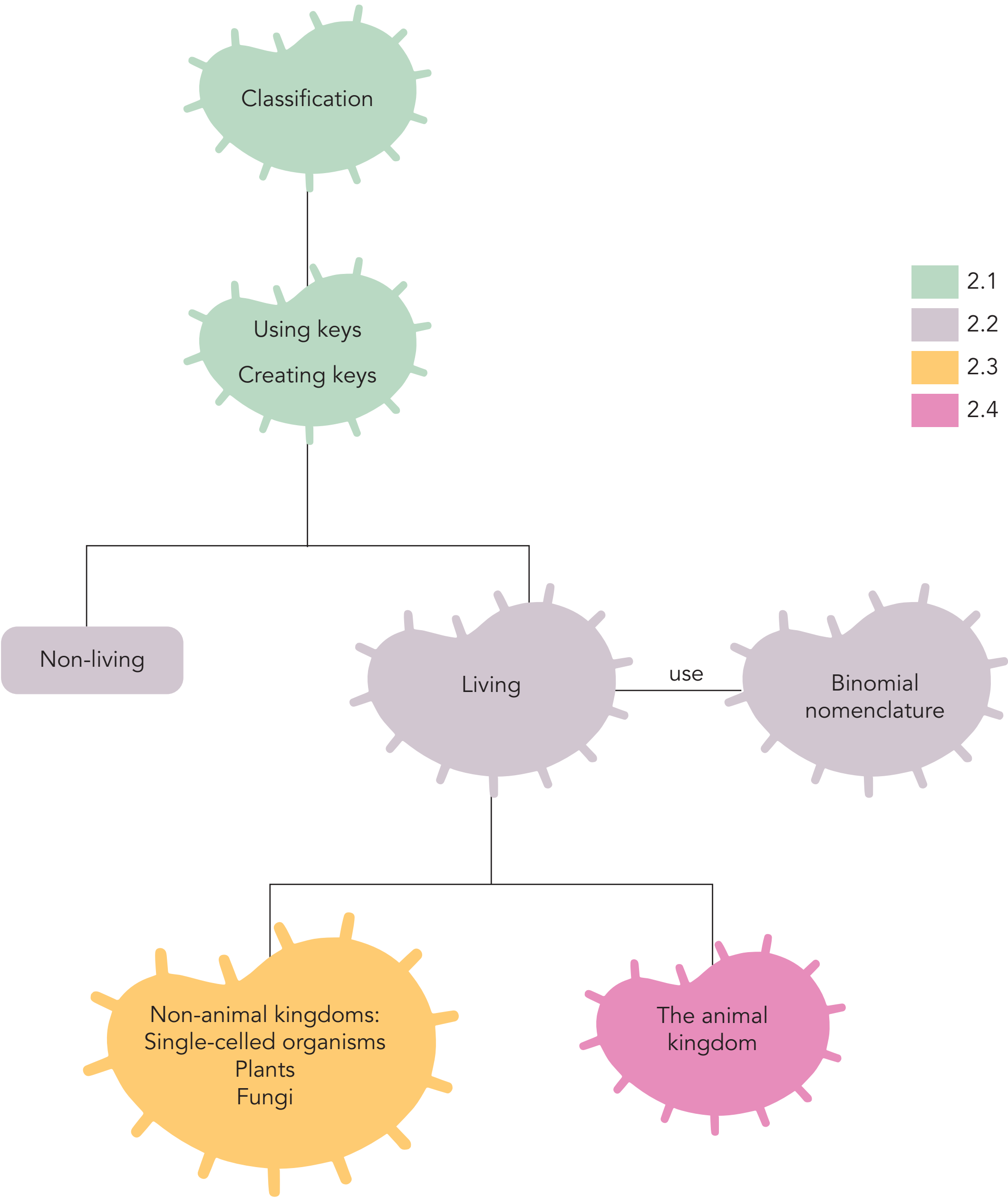
Concept map



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Curriculum

Investigate the role of classification in ordering and organising the diversity of life on Earth and use and develop classification tools including dichotomous keys (AC9S7U01)	
observing and identifying the similarities and differences of particular features within and between groups of organisms	2.1
creating and modifying a dichotomous key to classify organisms into groups and groups within groups	2.1
naming and classifying species using scientific conventions from the Linnaean hierarchical classification system, such as kingdom, phylum, class, order, family, genus, species	2.2, 2.3, 2.4
considering the reasons for classifying living things, such as identification and communication	2.1, 2.2
examining how biological classification has changed over time through improvements in microscopy	2.2
using provided dichotomous keys to identify organisms surveyed on a field trip	2.1, 2.2
investigating First Nations Australians' systems of classifying living things and how these systems differ from those used by contemporary science	2.2

Glossary terms

Anomalous
Bilateral symmetry
Binomial nomenclature
Botanist
Cell
Characteristic
Class
Classification
Dichotomous key
DNA
Domain
Ectothermic
Endothermic
Eukaryote
Extremophile
Family
Genre
Genus
Hierarchical
Invertebrate
Kingdom
Metamorphosis
Microbiologist
Misnomer
Morphology
Non-vascular
Order
Organism
Parasite
Phylum
Prokaryote
Qualitative
Quantitative
Radial symmetry
Sessile
Species
Taxonomy
Unicellular
Vascular
Vertebrate

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2.1 Classification

Learning goals
1. To be able to explain how classification is useful to identify living organisms.
2. To be able to interpret and construct a dichotomous key.

WORKSHEET
Drawing keys

Classification is the process of organising things into groups based on similar characteristics. You do this every day without even thinking about it.

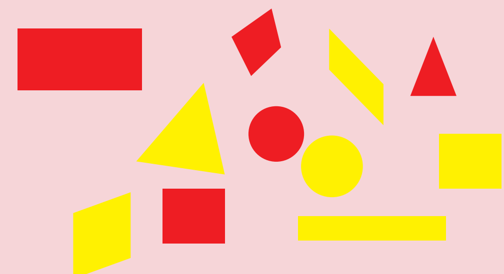
Imagine visiting a library where all the books were placed randomly on shelves in no order. It would be almost impossible to find what you were looking for! This is why classification is necessary. Libraries split books into fiction and non-fiction and arrange the books by the author's surname from A to Z. They may further separate books into **genre**.

People are also classified in many ways. How many times have you been asked your year level, subject choice, house group or date of birth? These are all ways that you can be placed into a group.

Making thinking visible 2.1

Think, pair, share: Classification

Look at the image below.



1. **Think** about and decide how many groups are in the picture.
2. **Pair** with someone else in your class and **share** your answer.
3. Compare your answer with others in your class.
4. Discuss why different people may have different answers.

The *Think, pair, share* thinking routine was developed by Project Zero, a research centre at the Harvard Graduate School of Education

Figure 2.1 Libraries are a place where classification is important; otherwise, how would you be able to easily find the book you need?

classification
the grouping of similar objects or organisms together

genre
a category used to group media such as music, art or books

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How to classify

When classifying, you should make observations about the things being classified and consider their **characteristics**. This will allow you to then group the things with the most similarities together.

characteristic
a feature or quality of something

Consider the toys in Figure 2.2. What are their observable characteristics? How could you classify or group them? Which toys are most similar and could be grouped together?

Figure 2.2 Even toys can be classified based on their observable characteristics.

Try this 2.1

Observing characteristics

Practise observing the different characteristics or features of living things. Describe the features of each animal and compare your observations with your classmates. Did you observe the same features?




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Did you know? 2.1

Not actually a bear … or a cat!

Some common names given to animals can be confusing because they suggest something that is not the case. The binturong (*Arctictis binturong*), commonly known as the bearcat, is neither a bear nor a cat, despite sharing many similarities with both animals. Instead, its closest relative is the genet (*Genetta genetta*). Some other animal **misnomers** include the flying fox, honey badger and electric eel. Can you think of any more?

misnomer
a wrong or inaccurate name

Figure 2.3 A binturong (*Arctictis binturong*) taking a rest

Figure 2.4 A common genet (*Genetta genetta*) on a branch

Unlocking classification

Before you explore some of the different ways you can classify in Section 2.2, it is important to understand how to use a tool used by biologists called a **dichotomous key**. These keys rely on a series of yes/no questions based on observable features to identify living organisms. The term 'dichotomous' refers to the branching into two that occurs with each question, leading the user to the correct **organism** name. As users move through the key, each subsequent question becomes more specific, building upon general characteristics.

dichotomous key
a tool used to identify organisms, where there are a series of questions with only two alternatives

organism
a living thing

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Figure 2.5 shows six different species of snakes from Queensland and the branching key in Figure 2.6, or the alternative version in Table 2.1, can be used to determine their names. Imagine you are a scientist researching the eastern bandy-bandy. You have been sent a photo of Organism 3 as shown in Figure 2.5 but are not sure if it is the eastern bandy-bandy. To determine if you have the correct organism, you must use the key in Figure 2.6. Can you work out whether Organism 3 is the eastern bandy-bandy? Start at the top and at each step in the process, make a yes/no decision. At each stage, the key gives you two options based on the organisms you are looking at, allowing you to narrow down the possible choices. If the organism falls into one category, move to the next question. There is no right or wrong way to start a key, as long as the question is specific to the organisms being classified. A key can also be drawn as a table. Test whether you get the same answer using the key in Table 2.1 as you do when using the branching key in Figure 2.6.

Figure 2.5 Some Queensland snake species. Use the key in Figure 2.6 to identify them.

1a	Solid black top	Go to Question 2
1b	No solid black top	Go to Question 3
2a	Red belly	Red-bellied black snake
2b	No red belly	Eastern small-eyed snake
3a	Striped body	Go to Question 4
3b	No striped body	Go to Question 5
4a	White stripes	Eastern bandy-bandy
4b	No white stripes	Common death adder
5a	Green belly	Common tree snake
5b	No green belly	Coastal taipan

Table 2.1 A dichotomous key in table format to identify the Queensland snake species in Figure 2.5

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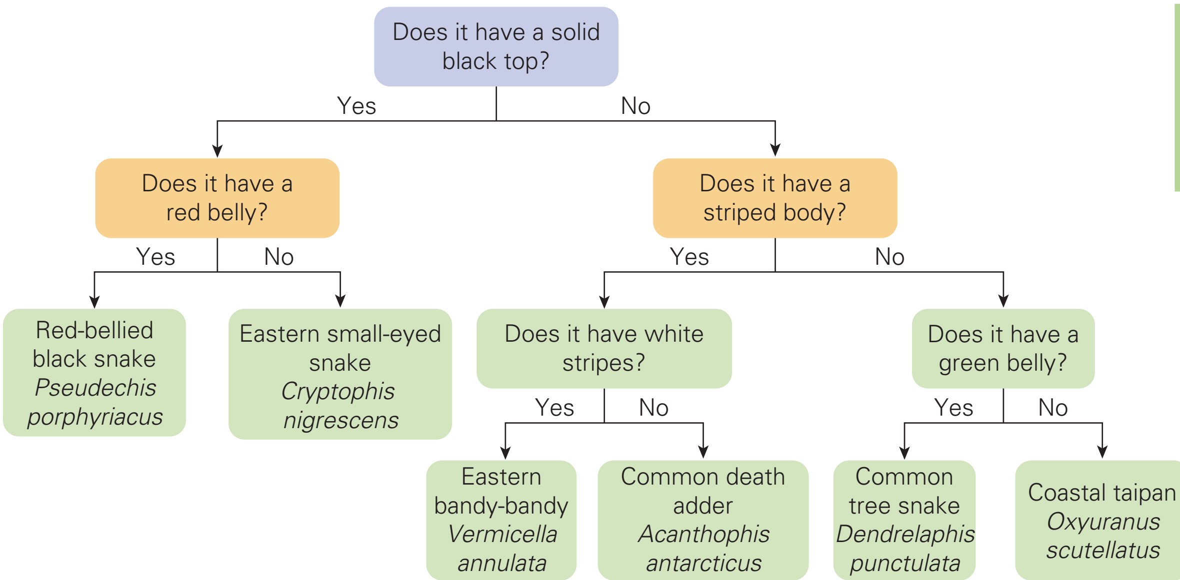

Figure 2.6 A branching dichotomous key for classifying the Queensland snake species in Figure 2.5

WIDGET
Classifying Australian animals

Quick check 2.1

1. Define the term 'classification'.
2. Explain how a 'dichotomous key' works.
3. Use the dichotomous key of Queensland snakes in Table 2.1 and Figure 2.6 to answer the following questions.
   a. List the characteristics of the common tree snake.
   b. Identify snakes 1 to 6 in Figure 2.5.
4. Discuss why it is particularly important to classify animals such as snakes.

Creating a key

Here are some things to think about when creating a key.

Will the characteristics change over time?

Grouping organisms based on what they look like considers an organism's **morphology**. However, some characteristics, like colour, size and shape, are not so useful for making a key as these characteristics can change over time, or with the seasons. For example, think about your hair colour – was it the same colour when you were born? Will it change as you get older? Another example from the animal world is the Arctic fox (Figure 2.7). Its winter coat is white for camouflage when there is snow on the ground, while in summer it completely changes to grey-brown!

morphology the form and structure of organisms

VIDEO
How quickly do these animals change appearances?

Figure 2.7 **(a)** An Arctic fox with its winter coat (white), **(b)** summer coat (grey-brown) and **(c)** one where the fox is in moult between winter and summer. It looks like three different animals!

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Try this 2.2

Making a branching dichotomous key

As a class, discuss some ways to group animals by listing different characteristics. Based on these characteristics, create groups of similar animals, using everyone's favourite animal. Are there different ways you could classify or group the animals? Challenge a classmate to find a certain animal using one of the grouping methods you come up with. Now try to make a branching dichotomous key based on one of the ways you chose to group your animals. Test it on a classmate to see if it works.

qualitative
a form of data that is descriptive

quantitative
a form of data that is a numerical measurement

Are the characteristics specific?

The Queensland snake key in Figure 2.6 is focused on a specific characteristic of the snakes at each stage. This is important to remember when constructing a key, otherwise scientists may get different answers when they use the same key. If you designed a key based on the individuals shown in Figure 2.8, you could describe their age as young or old. This would not be a dichotomous classification, though – what someone else calls young may be different from what you call young! The term **qualitative** is used when a characteristic is described in this way. The term **quantitative** is used when a characteristic is measured or described using numbers. Starting your key with 'Is the individual younger than 20?' would be better as there are only two options to choose from in this case, and the answer is clearer.

Figure 2.8 People can be described (qualitative) or measured (quantitative), but to classify, you need to make sure the characteristic is clear and measurable (i.e. quantitative) where possible. How could you classify these people?

Narrowing down the choices

You need to make sure that the features of the organism you are choosing are unique to that organism or at least different from a few of the other options. If you were to classify the animals shown in Figure 2.9, you could not use 'spotted' as a defining feature.

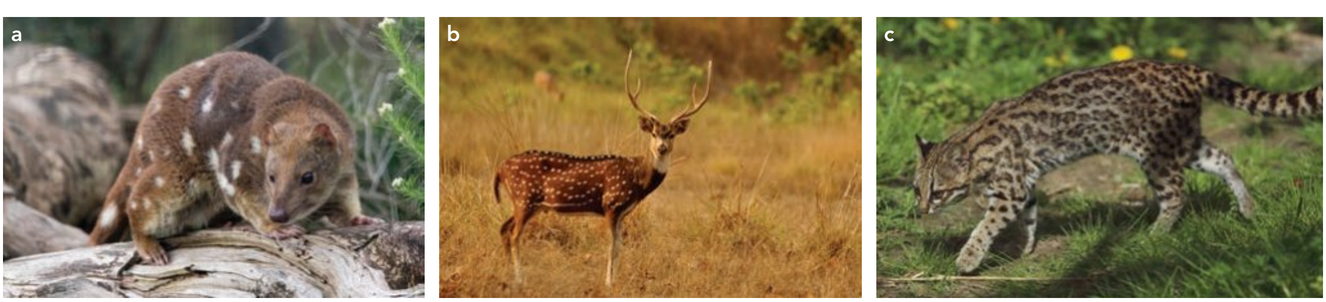

Figure 2.9 Can you name these spotted animals? a) Tiger quoll b) Chital c) Oncilla

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Quick check 2.2

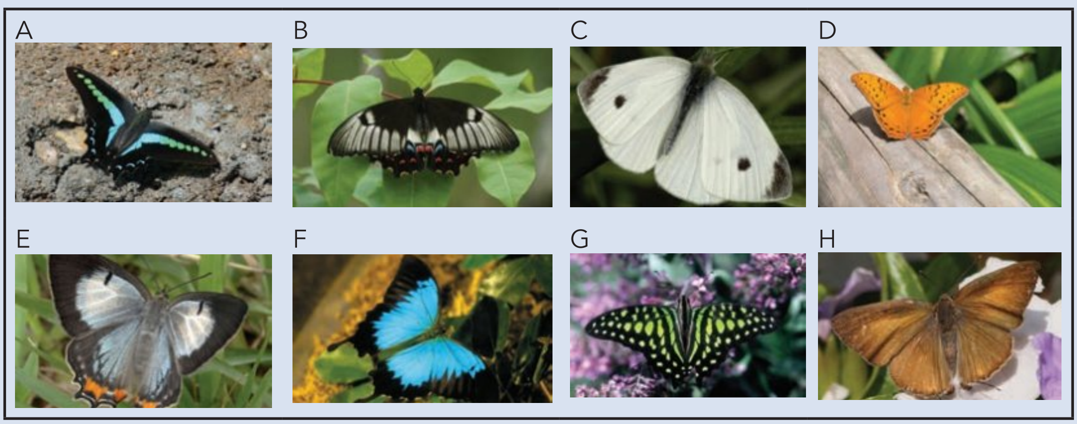
1. Summarise the main points to remember when selecting characteristics to create a dichotomous key.
2. Define the terms 'qualitative' and 'quantitative'.
3. When making a dichotomous key, discuss whether the characteristics need to be qualitative or quantitative.
4. In the table below, give an example of a quantitative description that would match each qualitative description for the characteristics.

Characteristic	Qualitative	Quantitative
Size	Tall	
Fur thickness	Thin	
Ear size	Short	
Tail length	Long	

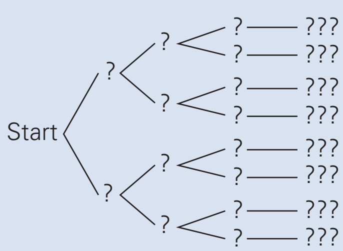
Try this 2.3

Creating a key for butterflies

The diagram below shows eight different butterflies found in Queensland (A–H).



1. Observe the different butterflies and describe their main differences.
2. Use the main difference between the butterflies to separate them into two groups. Create and label a tree diagram, shaped like the example on the right, on a piece of paper to show these divisions.



3. Separate each group into two further groups, and then continue until there are eight individual butterflies on the final level of the tree diagram.
4. Use the differences you have identified to construct a dichotomous key for the insects.
5. Pass the key to a classmate and get them to use it on your butterflies to make sure it is easy to follow. In other words, your classmate should arrive with the eight butterflies in the same categories at the bottom of the diagram, as you intended.
6. After you have tested the key, make any alterations that you need to for it to work. Look at the other keys students have made – did you use the same features as each other when deciding how to separate the butterflies?
7. Explain the main difficulties you faced when you constructed your key.
8. Discuss the reason for any changes you made after testing the key with a classmate.

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QUIZ

Section 2.1 questions

Retrieval

1 **Define** the term 'classify'.
2 **Recall** the term given to a key that has two possible options at each stage.
3 **Select** which three of the following features would be the most clear and foolproof options to use when creating a dichotomous key to identify types of animals.
   A Short legs vs. long legs
   B Smooth scales vs. spiny scales
   C Big vs. little
   D More than 0.65 m long vs. less than 0.65 m long
   E Blue spots on wing vs. no blue spots
   F Dark purple colour vs. light purple colour

Comprehension

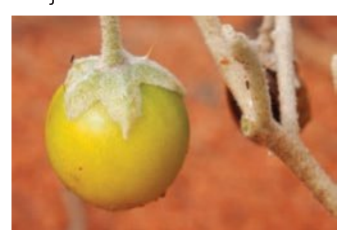
4 **Explain** why scientists need to classify living things.
5 **Explain** why the shape of an animal may not be the best defining feature to focus on when creating a key. Suggest at least three other features that would be more useful.

Analysis

6 First Nations Australians use many native fruits for medicinal purposes. Some of these are shown below.

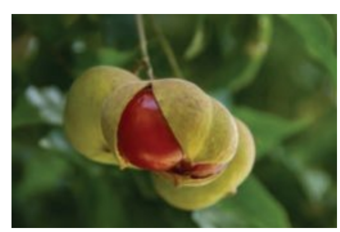
Finger lime


Quandong


Kutjera


Riberry


Red bush apples


Small leaf tamarind


   a **Classify** the native fruits into two groups based on a specific characteristic. Outline the features of each fruit that led you to your classification.
   b Now use the images again to **classify** these native fruits but this time into three groups. Outline the features of each native fruit that led you to your classification.
   c Ask to see the groups your classmates came up with and **compare** with yours.
7 **Distinguish** between qualitative characteristics and quantitative characteristics.
8 When you are older, you may be interested in buying a second-hand car. Most likely, you will begin your search online on a car sales website. The state you live in might be one of the first things you enter to narrow down your search.
   a **Elaborate** on the other features or characteristics you may need to use to refine your search.
   b **Reflect on** whether other people would follow the same search pattern.

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Knowledge utilisation

9 Copy the following table.

a **Decide** whether the features are good or weak descriptors to use in a dichotomous key for humans.

b **Justify** your choices.

Feature	Good or bad descriptor	Justification
Blue or brown eyes		
Short hair		
160–170 cm tall		
Likes dogs		
Size 7 shoe		

10 Megafauna are large animals that roamed Earth approximately 2.5 million to 11 700 years ago. The cause of the extinction of Australian megafauna has been argued about for over 150 years, with no agreement being reached. Some researchers argue that megafauna became extinct due to the arrival of the First Nations Australians. Other researchers suggest that it was due to environmental change.

a Use the internet to research how large the following Australian megafauna were, then **create** a dichotomous key for them.

Diprotodon optatum

Varanus priscus

Dromornis stirtoni

Palorchestes azael

Thylacoleo carnifex

Simosthenurus occidentalis

b Consider the following statements that have been taken from scientific articles and **categorise** them into those that support or those that don't support the idea that First Nations Australians caused the extinction of Australian megafauna.

i New methods to directly date bones and teeth of extinct species show that megafauna fossils and Aboriginal tools do not all date from the same period.

ii Proteins taken from fragments of prehistoric eggshell discovered in the Australian sands confirm that the continent's earliest humans consumed the eggs of a two-metre tall bird that became extinct 47 000 years ago.

iii Extreme climate change causing a loss of water and increased drying drove the extinction of megafauna species.

iv A diverse collection of fossils have showed that megafauna still survived 47 000 years ago, after humans had spread around the continent.

v Rock art depicts marsupial lions, giant kangaroos and other megafauna.

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vi Evidence suggests that more than 1000 years of human occupation passed before a rapid warming event occurred, and then the megafauna were extinct within a hundred years.
vii Drying out of vast inland lakes may have caused Australia's megafauna extinction.
viii Megafauna had lived through several previous ice ages without any problems.
ix Low-intensity hunting of Australian megafauna (e.g. the killing of one young mammal per person per decade) could have resulted in the extinction of a species in just a few hundred years.
x When people arrived in Australia, they altered the landscape with fire so significantly that it drove the megafauna to extinction.

2.2 Classifying living things

Learning goals

1. To be able to classify a living organism using a hierarchical system.
2. To be able to recognise how biological classification has changed over time.
3. To be able to use scientific conventions to name organisms.
4. To explore classification systems used by many First Nations Australians.

DOC WORKSHEET Classifying striped animals

VIDEO The seven criteria of living things

Is it alive?

One of the most basic ways of classifying that can be used is whether something is 'living' or 'non-living'. MRS GREN is an acronym for the processes performed by all living things and is used as a set of criteria to determine if something is living or non-living. Can you work out what these processes are? The flowchart in Figure 2.10 will give you some clues. However, sometimes it is not so easy to decide if something is living or non-living. A kangaroo jumping across a paddock is obviously living. But some non-living things may also show some of the seven processes of living things. For example, a car can move, and it gets rid of waste gases, and crystals can grow when conditions are right.

For something to be living, it must show *all* the seven processes of living things. It is also important to remember that a non-living object is one that has never been alive. Something that is dead used to exhibit all the processes of living things. The first characteristic in the acronym, movement, needs some explanation. Movement from one location to another is easy to see, such as the kangaroo jumping across a paddock, but sometimes movement can be difficult to observe.

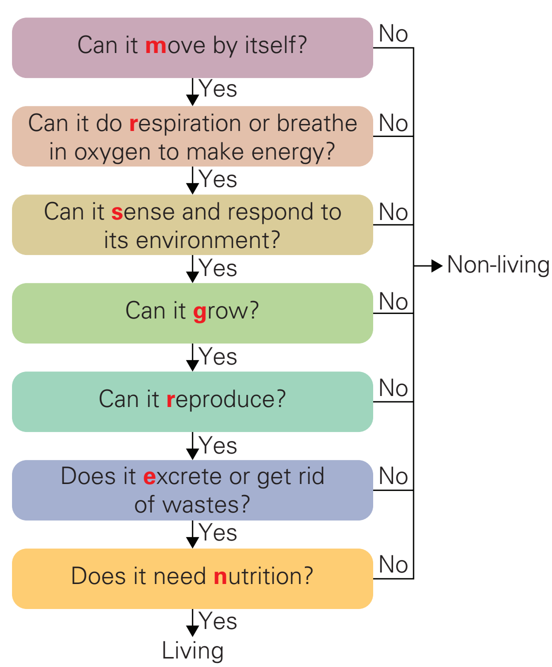

Figure 2.10 Unless all seven life processes are met, a thing cannot be classified as 'living'.

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Examples are a change in orientation (e.g. plants moving leaves towards the light); parts of the organism moving in relation to the whole (e.g. flowers opening and closing); or internal movement, such as movement of sap or movement seen inside **cells** with a microscope.

cell
the smallest unit of life that makes up all living things

Did you know? 2.2

The eighth characteristic of living things
Although MRS GREN is commonly used, there are some issues with it. Fire is non-living, but some people may argue that it meets all seven life processes. See if you can work out how.

It is for this reason that some scientists have named an eighth characteristic: all living things have cells. Perhaps we should we move to MRS C GREN?

Quick check 2.3

1 State the characteristics that all living things share and describe an example for each.
2 Explain what non-living means.
3 Distinguish between non-living and dead.
4 Copy and complete the table below.
   a Tick if the characteristic is present.
   b Classify the object as living, non-living or dead.

Object	Tick if the characteristic is present							Living? Non-living? Dead?
	M	R	S	G	R	E	N	
Fire								
Whale								
Yeast								
Scooter								
Squashed mosquito								
Newspaper								
Pot plant								

Did you know? 2.3

Are you related to a strawberry?
Every living organism has evolved from a common ancestor. Scientists have discovered this by studying the similarities in **DNA**. DNA is found in every living cell and gives the cell or organism instructions on how to grow and function.

continued …

DNA
stands for deoxyribonucleic acid, a chemical present in cells of living things that carries genetic information

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… continued

On average, humans share about 90% of our DNA with mice. This is not surprising as we both have eyes, hearts, legs and many other similarities. This is why mice are used in laboratories for human disease research. However, we humans also share about 60% of our DNA with strawberries. This does not indicate relation, however, rather similarities in cell processes. Can you see how classifying by DNA might not be the only answer?

Figure 2.11 Despite similarities in DNA, humans, mice and strawberries are quite different!

Taxonomy

So far, you have learned that classification is the process of sorting things into groups. Now you are going to look at how biologists use classification to identify and name organisms, some of which are shown in Figure 2.14. By grouping organisms based on their similarities and differences, biologists can more easily assign a name to a new species or determine the relationship between different organisms. **Taxonomy** is the study of relationships between organisms and formally classifying and naming them based on these relationships. Taxonomy used to simply consider the physical similarities between organisms, but now also considers genetic similarities.

taxonomy
a branch of science that groups and names organisms based on their relationships

DOC
WORKSHEET
Reading with a pen

Explore! 2.1

First Nations classification systems

The classification systems used by different groups of First Nations Australians differ in many respects from Linnaean taxonomy (discussed later in this section). Nothing is seen in isolation; rather, everything is interconnected. One common feature of this type of classification is the inclusion of criteria that links the organism's use, age, stage in life cycle, sex, social status and totemic association. Totemic refers to a spiritual connection between a group of people or an individual and a specific animal, plant or natural object.

First Nations Australians may classify plants and animals as being edible or inedible, or as being totemic or non-totemic. Many living things are grouped based on their use and this can be further grouped based on if the organism is alive or dead. For example, when the native cherry (*Exocarpus cupressiformis*) is alive, its sap can be used to treat snake bites, but when dead, its wood is used to make spear-throwers.

Figure 2.12 First Nations Australians art showing an emu, the totem of the Karingbal people

Living things are sometimes sorted into groups based on features such as form and function. These groupings are not always based on relatedness as used in contemporary science. Investigate why some groups of First Nations Australians in Queensland may classify turtles, barramundi and dugong in the same group.

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Did you know? 2.4

When two species become six

Australian gliders are a group of marsupials that belong to the possum family. One of the distinguishing features of Australian gliders is their specialised gliding membrane, known as a patagium. This acts as a wing-like structure, allowing gliders to effortlessly glide through the air, often over considerable distances.

In 2020, DNA analysis confirmed that the greater glider and sugar glider are actually three different species each, increasing the number of Australian possum species by four. The greater glider has been split into the northern greater glider (*Petauroides minor*), central greater glider (*Petauroides armillatus*) and southern greater glider (*Petauroides volans*). The sugar glider is now split into the sugar glider (*Petaurus breviceps*), Krefft's glider (*Petaurus notatus*) and the savanna glider (*Petaurus ariel*).

Figure 2.13 Northern greater glider (*Petauroides minor*)

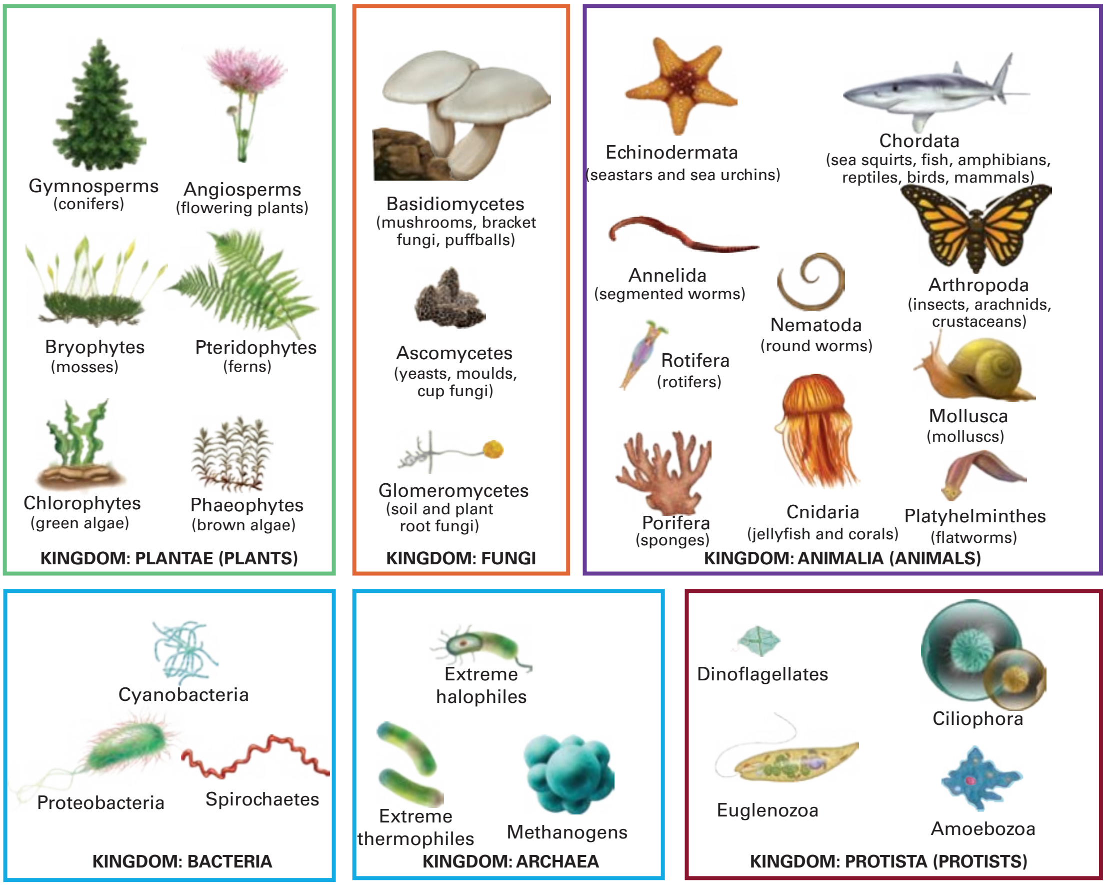

Figure 2.14 The six-kingdom classification of living organisms, with some representative groups within each. Note that there are many more groups than the ones shown, especially in the kingdoms Bacteria, Archaea, Protista and Fungi.

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Scientists have classified nearly 2 million species on Earth, but current estimates for the number of species that actually exist ranges hugely. One widely quoted estimate is that there are 8.7 million species in existence, but this can range from 5 million to 1 trillion! There are also many more extinct species to classify. Of the 4 billion species that have existed on Earth, 99.9% are now estimated to be extinct. That's a lot of organisms that scientists need to classify!

botanist
a scientist who studies plants

hierarchical
where smaller groups are placed within larger groups, with no overlap between groups

kingdom
the highest and broadest classification on the Linnaean taxonomic rankings

phylum
the taxonomic ranking below kingdom and above class

class
the taxonomic ranking below phylum and above order

order
the taxonomic ranking below class and above family

family
the taxonomic ranking below order and above genus

genus
the taxonomic ranking below family and above species

species
the most specific taxonomic ranking below genus

Carl Linnaeus

A major step in taxonomy was taken 250 years ago by the Swedish **botanist** Carl Linnaeus. In his twenties, Linnaeus realised that the classification system used at the time was not working. Animals were being categorised by whether they were wild or tame, or if they were big or small. One scientist classified animals by their usefulness to humans, another by if they thought the animal was noble. Plants were being given names that were overly descriptive. For example, the scientific name for the cutleaf groundcherry during this time was *Physalis amno ramosissime ramis angulosis glabris foliis dentoserratis*!

At the start of his research, Linnaeus intended to give each plant a name and a number, but quickly realised that this was not going to work. Instead, he sorted organisms into **hierarchical** groups based on their physical similarities. He called the largest group 'kingdom' and this was then divided into phyla, and so on, all the way to the smallest group, 'species'. An example of this is shown in Figure 2.16. The levels of classification that he developed were **kingdom**, **phylum**, **class**, **order**, **family**, **genus** and **species**. He managed to classify over 13 000 organisms during his life and the basis of his classification system is still used today. In fact, Linnaeus is known by many as the Father of Taxonomy.

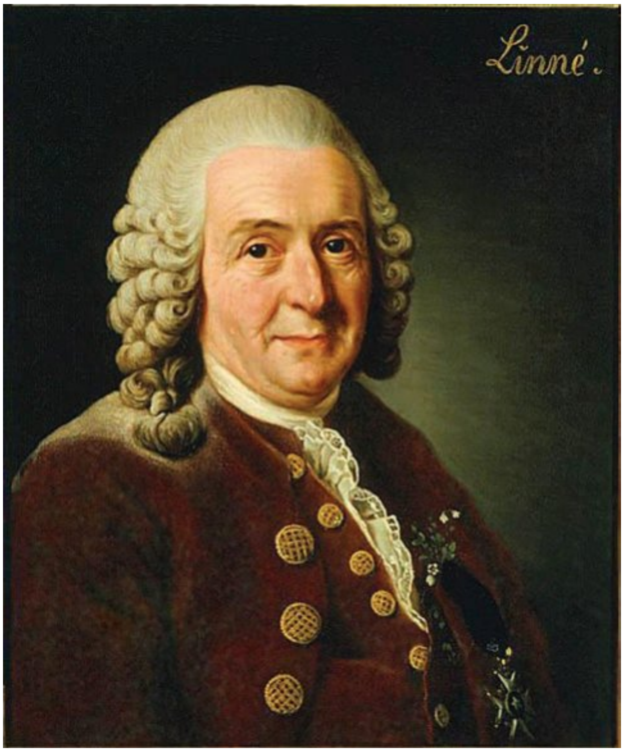

Figure 2.15 Carl Linnaeus

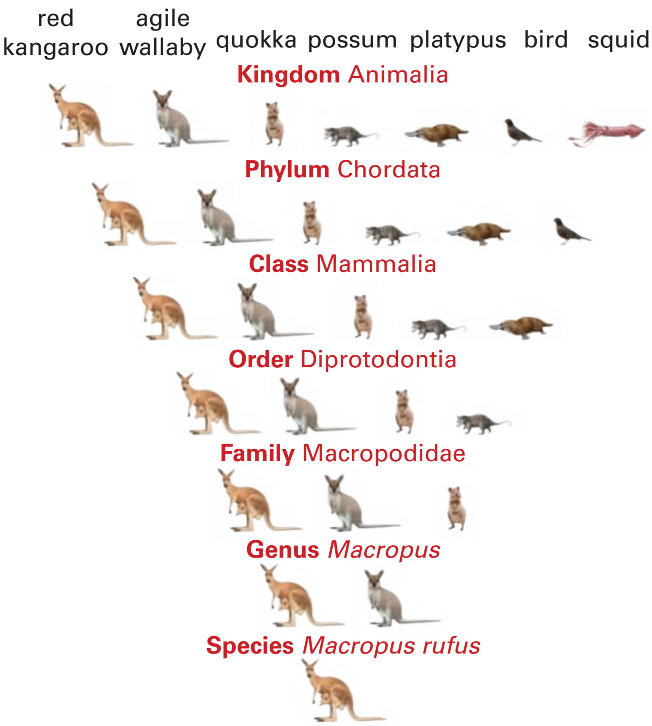

Figure 2.16 Linnaeus' hierarchical classification system: as you move down the levels, the organisms become more similar and share more characteristics.

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Try this 2.4

Classification mnemonics
The order and names of Linnaeus' different levels of classification can be remembered by using a mnemonic device such as **King Phillip Comes Over For Great Spaghetti**, or **Kittens Prefer Cream Or Fish Generally Speaking**. Try to make up your own mnemonic to remember each level.

Robert Whittaker

Linnaeus recognised only two kingdoms in his classification system: animals and plants. In 1969, Robert Whittaker proposed a five-kingdom classification system: animals, plants, fungi, protists and monera.

Carl Woese

Carl Woese was a **microbiologist** who studied the genetic information (DNA) of bacteria and discovered that there are more differences between different bacteria than previously known. He noticed that many microorganisms that looked and behaved like bacteria were something entirely different. He called these organisms Archaea.

In 1977, Woese suggested that all life should be classified under three major **domains** consisting of Bacteria, Archaea and Eukarya. Combined with the five-kingdom model, this created a six-kingdom model, where the kingdom Monera was replaced by Bacteria and Archaea.

Explore! 2.2

Changes in classification
Classification of many species continues to be argued as scientists discover new information or interpret evidence in new ways. Scientists have suggested hierarchical groupings such as empires, superkingdoms and dominiums.

Even when species are being classified, arguments can be complex. Species can have their classification changed, but only after a lot of information has been collected. One reason why species are being re-examined is because of DNA analysis. This new information can change ideas of how closely two species are related and so change their classification. By analysing DNA, we can see that even things that don't look alike can be classified together. Research the link between the whale and hippo; the elephant, manatee and hyrax; and the horse and rhino.

microbiologist a scientist who studies very small living things like bacteria

domain the highest taxonomic rank above kingdom and even more broad

Quick check 2.4

1. Define the term 'taxonomy'.
2. Explain why the classification system is constantly being updated.
3. Recall the names of the six kingdoms.
4. Discuss how Woese's proposal changed the way organisms are classified.

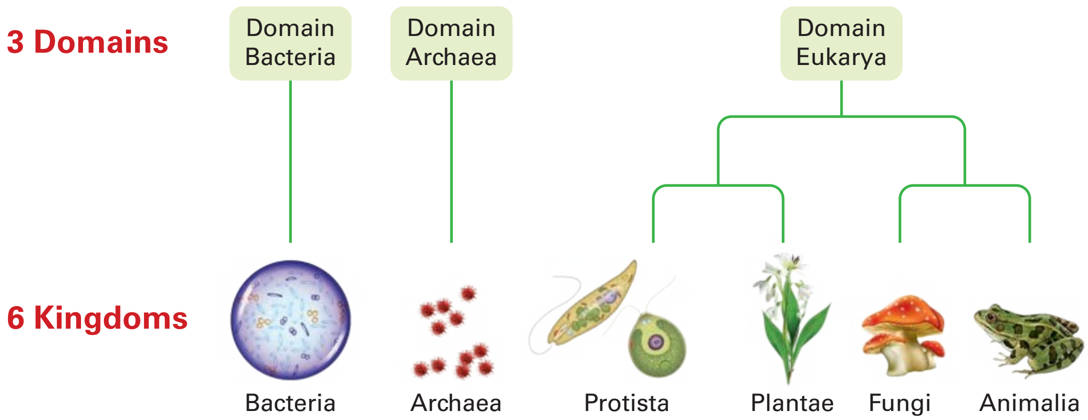

Figure 2.17 The links between Woese's domains and kingdoms

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Binomial nomenclature

Another reason for classification is to enable clear communication among scientists. Between the 15th and 17th centuries, scientists usually conducted their work in two languages. When discussing their work in conversation, they used their native language, but Latin was used when writing about their work or corresponding with scientists elsewhere. Latin did not belong to any specific country and scholars worldwide could access it. It essentially became the universal language of the time.

binomial nomenclature a system of naming in which two names are used to identify an individual species of organism

In Linnaeus' classification system discussed earlier in this section, all species were given a specific two-part name using a form of Latin or Ancient Greek. This replaced much longer names such as the one for the cutleaf groundcherry given previously. Linnaeus renamed it *Physalis angulata*, from the Ancient Greek *phusallís*, meaning bladder, and the Latin *angulāre*, meaning to make angled.

Figure 2.18 Look at the picture and decide why Linnaeus chose to call the cutleaf groundcherry *Physalis angulata*.

By the 19th century, French, English, and German made up most of the scientists' communication and published work. By the 20th century, only English was common. However, we still use Linnaeus' system of naming organisms, which is known as **binomial nomenclature**. The use of a standardised classification system allows scientists to discuss and share information about organisms across different fields and locations, ensuring that scientific knowledge is accurate and consistent.

Why are scientific names important?

In everyday life, it is rare to use the scientific names of plants and animals because the words are often hard to pronounce and remember. If you were asked to identify the organisms in Figure 2.19 as *Phascogale tapoatafa*, *Dendrobium bigibbum* or *Petroica goodenovii*, you probably would not be able to. However, if you were to use their common names – brush-tailed phascogale, Cooktown orchid and red-capped robin – it would be much easier.

You may ask, why can't you just use the common name? Well, the Cooktown orchid is also known as the mauve butterfly orchid, and the brush-tailed phascogale can be known by its traditional name of tuan, but also as the common wambenger, the black-tailed mousesack or the black-tailed phascogale!

Figure 2.19 (a) Brush-tailed phascogale (*Phascogale tapoatafa*), **(b)** Cooktown orchid (*Dendrobium bigibbum*), **(c)** red-capped robin (*Petroica goodenovii*)

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Some common names for animals are also repeated all over the world, but they are not the same species. For example, the red-capped robin is a completely different species from the European robin (Figure 2.20). In fact, they are not even in the same family! It is likely that the name originated from European colonial settlers, who saw a bird with red patches and named it after the most common bird with red patches from their country of origin.

How to write scientific names

When writing an organism's scientific name, there are a few rules that need to be followed.

- The first part of the name (genus) is written with a capital letter.
- The second part of the name (species) starts with a lowercase letter.
- If you are typing a name, *italics* should be used.
- If you are writing the name by hand, you should underline the name.

For example, the organisms in Figure 2.21 are all different types of frog native to Australia, southern New Guinea and some Torres Strait Islands. The genus name (first part of the name) for all these species, *Limnodynastes*, is Latin, meaning *'Lord of the Marshes'*. As you can see from Figure 2.21, they share many similarities but are all unique. That is why the species (the second part of the name) is also used to identify specific organisms.

Figure 2.20 European robin (*Erithacus rubecula*)

Common name	Fawn-footed melomys
Kingdom	Animal
Phylum	Chordate
Class	Mammal
Order	Rodent
Family	Muridae
Genus	*Melomys*
Species	*cervinipes*
Scientific name	*Melomys cervinipes*

Table 2.2 Although known by the descriptive common name of fawn-footed melomys, First Nations Australians may know it as corrill, recorded from Minjerribah, or cunduoo, recorded from Richmond River, New South Wales.

Figure 2.21 **(a)** *Limnodynastes dorsalis*, **(b)** *Limnodynastes peronii*, **(c)** *Limnodynastes salmini* and **(d)** *Limnodynastes tasmaniensis*

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Try this 2.5

Classifying Australian mammals

Look up the following scientific names of some Australian mammals. Use the internet to find out their taxonomic classification (kingdom, phylum, class, order, family, genus and species). Can you determine which species are more closely related to each other? How does their classification tell you this?

- *Potorous tridactylus*
- *Tachyglossus aculeatus*
- *Sminthopsis murina*
- *Planigale ingrami*
- *Pseudantechinus mimulus*
- *Notamacropus agilis*
- *Ornithorhynchus anatinus*
- *Planigale maculata*

Did you know? 2.5

Assassin flies: The new Marvel avengers

In recent years, instead of using names derived from meaningful Latin or Greek words, scientists have started using made-up or fun Latin names as more species are discovered. Scientists are struggling to keep up with the discovery of many thousands of new bacterial species, and the traditional method has left a backlog of 50 000 species. Scientists have designed an AI-powered computer system that was taught the grammatical rules of Latin, allowing it to generate fake Latin names for these unnamed species. Engineers have enforced some rules to ensure it doesn't produce offensive terms in any language!

There is a fun aspect of naming in a traditional way, though! Five newly discovered flies in Australia have been named after characters from the Marvel universe by CSIRO scientists. All five species are robber flies, which are assassins of the insect world.

Scientific name	Marvel character	Translation
Daptolestes bronteflavus 	Thor	Blonde thunder
Daptolestes illusiolautus 	Loki	Elegant deception
Daptolestes feminategus 	Black Widow	Woman wearing leather
Humorolethalis sergius 	Deadpool	Derived from the Latin for *humorosus*, meaning wet or moist, and *lethalis* meaning dead. It also sounds like lethal humour.

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Quick check 2.5

1. Define the term 'binomial nomenclature'.
2. When looking at a list of scientific names, describe how you would know which organisms were most similar.
3. Discuss some of the difficulties scientists would experience if they only used the common names of organisms.
4. State two reasons why we classify organisms.

Science as a human endeavour 2.1

Animals that do not fit the mould

Some animals are so unusual that they are difficult to fit into the taxonomic groups. One example you will be familiar with is the platypus. When scientists at the British Museum first laid eyes on a platypus that was sent to them in the late 18th century, some of them thought the specimen must be a hoax. With morphology like an otter, but with the bill of a duck, the tail of a beaver, webbed feet and the ability to lay eggs, the platypus displays features common to mammals, birds and reptiles, all in one creature. The platypus was named *Ornithorhynchus anatinus*, meaning 'bird-snouted flat-foot'.

The platypus was placed in the class of mammals, but in an order called Monotremata, alongside the echidnas. This is a unique group, different from the mammals that give birth to live young. Instead, monotremes lay eggs. They also produce milk for their young by secreting it from pores on their stomachs.

Figure 2.22 (a) An adult echidna and **(b)** two baby platypus (known as puggles) sucking from pores on a milk patch in the mother's pouch

Try this 2.6

Taxonomy exercise

Find out the kingdom, phylum, class, order, family, genus, species and scientific name of the platypus. Then, in a table, research and list the characteristics of a mammal in one column, a bird in another column and a reptile in a third column. Complete some research into the characteristics of the platypus. Now use your table and highlight which characteristics the platypus shares with mammals, birds and reptiles.

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Try this 2.7

Creating an animal

In this activity you will create a new animal. You may draw it or use an online app.

1 Obtain sketch paper and pencils or search for 'make new animals' on the internet.
2 Draw your animals or use an online animal building tool to create a new animal with features of many different types of animals (e.g. Switch Zoo).
3 Take a screenshot or photo of your creation and then create a description of the animal. Your description should include:
   - Name of animal
   - How it uses the features you have chosen
   - Habitat: aquatic, terrestrial, both
   - Warm blooded or cold blooded
   - Behaviours
   - How its offspring are born
   - Diet
   - How long it lives.
4 Classify your animal into a group (insect, bird, mammal, bird, reptile etc.).
5 Using your description, justify why you classified your new animal as you did.

QUIZ

Section 2.2 questions

Retrieval

1 **Name** the person who is often called the 'father' of taxonomy.
2 **Recall** the six kingdoms.
3 **State** the seven characteristics of living things.
4 **State** the seven levels of Linnaean classification, from general to specific.
5 The scientific name for the giant petaltail, found in Queensland, is *Petalura ingentissima*. **Identify** which country or countries in which this name applies.

Figure 2.23 The giant petaltail's common name refers to its unique tail. One of the world's largest dragonfly species, it is found only in Queensland and dates back almost 200 million years.

6 **Recall** the main problems with the classification system that was used before the Linnaean system.
7 **Recall** what you have learned about scientific names.

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Comprehension

8 Imagine you saw a platypus in the wild for the first time. **Describe** how you would classify it and why.

Analysis

9 **Critique** the way the following binomial names have been written.
- calyptorhynchus lathami
- Litoria Cooloolensis
- ornithoptera Richmondia
- *Grantiella picta*

Knowledge utilisation

10 **Predict** how closely related each fish in Figure 2.24 is to the clownfish on the left, based on physical characteristics. Give reasons for your answer.

Figure 2.24 Tropical fish

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2.3 Non-animal kingdoms

WORKSHEET Kingdoms

VIDEO Kingdoms Archaea, Bacteria and Protista

Learning goal
To be able to distinguish between (or list) the six kingdoms of living organisms.

Prokaryotes

Most living organisms on Earth are **unicellular**, meaning they exist as single cells. Unicellular organisms are microscopic, meaning they are too small to see without a microscope. Unicellular organisms can be **prokaryotes** or **eukaryotes**. All prokaryotes are unicellular and very simple, have no nucleus and are protected by a cell wall. Due to the work of Carl Woese, prokaryotes are divided into two distinct groups: the bacteria and the archaea. These two groups are ancient and have a lot in common, but they are genetically quite different.

unicellular
consisting of one cell

prokaryote
a unicellular organism that lacks a nucleus

eukaryote
an organism that contains a nucleus

extremophile
an organism that thrives in conditions of extreme temperature, pH or chemical concentration

VIDEO What are archea?

Figure 2.25 Biological classification has changed over time through improvements in microscopy. Antonie Van Leeuwenhoek crafted his own microscope lenses, which were powerful enough for him to discover protists in 1674 and bacteria in 1683.

Archaea
- Prokaryotic
- Oldest form of life on Earth, dating back 3.5 billion years
- Many are **extremophiles**, able to survive in a range of hostile environments
- Majority of species are found in the oceans.

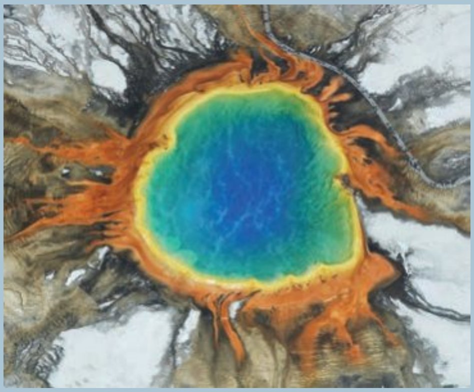

Figure 2.26 The Grand Prismatic Spring in Yellowstone National Park is the largest hot spring in the USA. The water temperature is 70°C and the vibrant colours are due to mats of growing archaea that thrive in this harsh environment.

Eukaryotes

Eukaryotes are a diverse group of organisms that share a fundamental characteristic: their cells contain a nucleus and other membrane-bound organelles with specialised functions. This feature makes them different from prokaryotes. Eukaryotes include a wide range of organisms, from single-celled protists to multicellular animals and plants.

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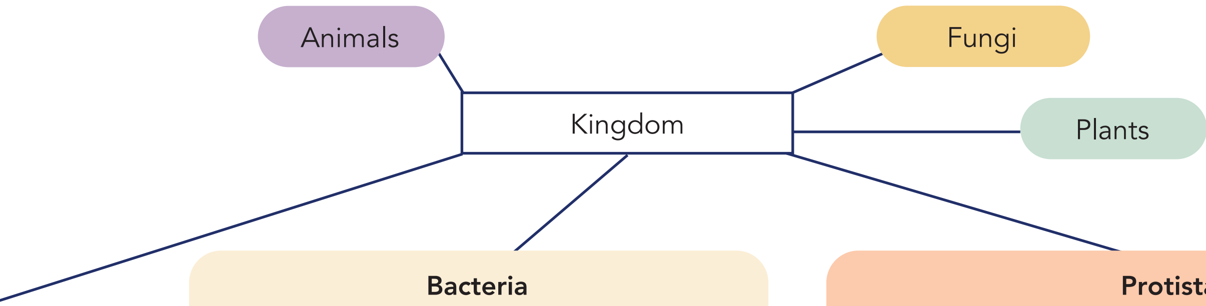

VIDEO What are protists?

Bacteria

- Prokaryotic
- Not as old as archaea, appearing about 2.5–3 billion years ago
- Human bodies are home to approximately 100 trillion 'good' bacteria, mostly found in the gut.
- Decompose waste material
- Can increase the productivity of soil
- Used to produce food (miso, tempeh, cheese, yoghurt) and industrial materials
- Some are disease-causing.

Figure 2.27 *Legionella longbeachae* bacteria is often found in soil and can cause legionnaires' disease if contaminated dust is inhaled. In 2022, Queensland health authorities advised gardeners to wear a mask and gloves when handling soil or potting mix, after a spike in legionnaires' disease cases.

Protista

- Eukaryotic
- Mostly unicellular but can be multicellular
- A group of organisms that do not fit into any other kingdom: some scientists call this kingdom the junk drawer! As a result, organisms in this kingdom are very diverse.
- Many are **parasites** and cause disease, such as *Plasmodium* that causes malaria or *Giardia* that causes giardiasis.
- Phytoplankton protists are photosynthetic and produce almost half of the oxygen on Earth.

parasite
an organism that lives in or on another organism and takes its food from its body

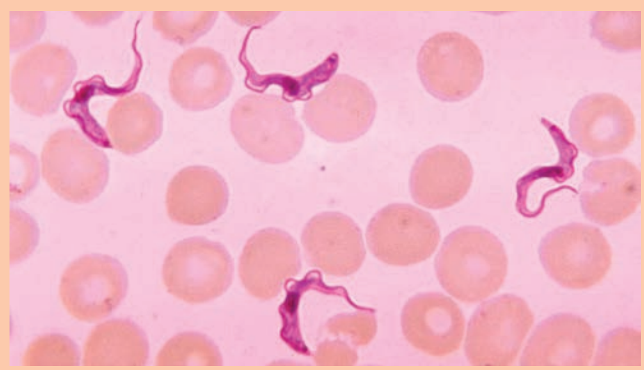

Figure 2.28 *Trypanosoma* protists in the blood of a patient suffering from African trypanosomiasis, also known as sleeping sickness. The protists are parasites that are transmitted to humans by tsetse fly bites.

Did you know? 2.6

Archaea and climate change

Archaea that live in the digestive tracts of many animals are known as methanogens because they produce methane gas. Methane is a greenhouse gas that has been linked to increasing global temperatures due to its ability to trap heat.

University of Queensland scientists have found that some native animals that eat plants release less methane than livestock species when they digest food. By understanding why this happens, scientists are hoping to decrease methane production caused by agriculture and positively impact climate change.

Figure 2.29 Kangaroos produce less methane than cows, yet they both eat grass.

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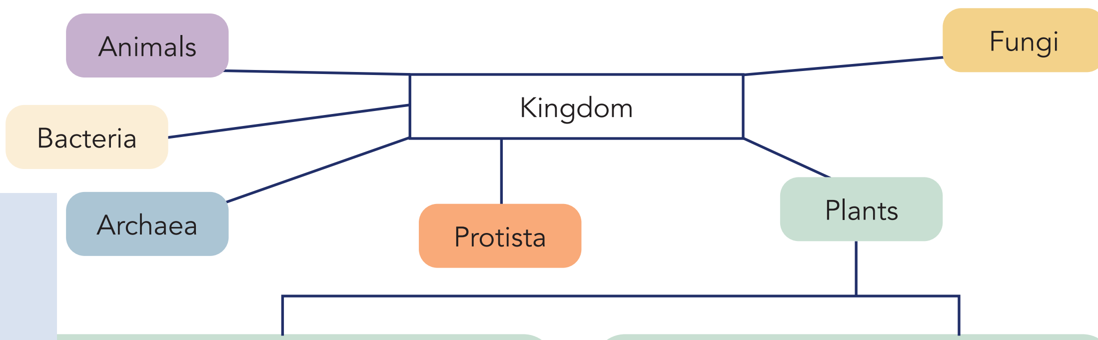
Quick check 2.6

1 State a difference between a prokaryote and a eukaryote.
2 Define the term 'microscopic'.
3 Summarise the key characteristics of bacteria.
4 Name an organism in the Protista kingdom.
5 Decide whether all single-celled organisms are harmful.

Plants

Plants use energy from the Sun to convert water and carbon dioxide into substances that are the foundation of all life on Earth.

As producers, they start most food chains and are a source of energy for other organisms. You will learn more about this in the next chapter.



non-vascular not containing veins or specialised fluid vessels

vascular containing veins or specialised fluid vessels

Non-vascular

Non-vascular plants do not have specialised cells that can transport water and nutrients from one part of the plant to another. All the plants in this division share some common characteristics:

- Cannot grow very big
- Often found spread across rocks or the ground in cool, moist, shaded areas
- Reproduce using spores (a single-celled reproductive unit)
- Include mosses, liverworts and hornworts, and some algae.

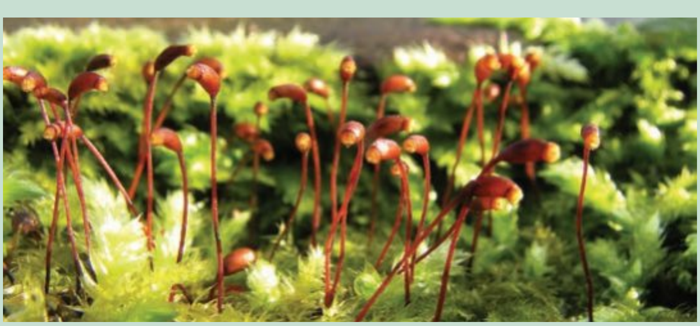


Figure 2.30 Mosses are small, flowerless plants that grow in clumps. As they don't have roots, they absorb water and nutrients through their leaves. They reproduce using spores, which are often released from stalks.

Vascular

Vascular plants have specialised vascular tissue made of specialised cells that can transport water and nutrients around the plant. Ferns, non-flowering plants and flowering plants all have vascular tissue that make up stems and roots.

Figure 2.31 The veins that you can see on leaves are special pathways for water and nutrients to flow called xylem (for water transport) and phloem (for sugars and nutrients).

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Figures 2.30 to 2.34 show how plants in the plant kingdom can be further classified based on whether they have vascular tissue and if they produce seeds.

Flowering plants

- Plants that produce flowers and fruits that allow them to reproduce
- Use brightly coloured flowers and sweet nectar to lure insects, birds and other animals that can help spread pollen to produce seeds.

Figure 2.32 Flowering plants are the dominant type of plant on Earth.

Ferns

- Some of the earliest land plants, existing on Earth for approximately 360 million years
- Reproduce using spores
- Do not produce seeds
- Grow well in moist, humid, shaded areas.

Figure 2.33 The fossil record shows us that ferns appeared millions of years before dinosaurs.

Non-flowering plants

- Include cycads and conifers
- Reproduce using seeds that are exposed or in cones, not enclosed in fruit
- Male cones produce pollen that fertilises female cones. Female cones protect the seeds.

Figure 2.34 The Wollemi Pine is an ancient non-flowering, seed-producing conifer that is only found in the remote canyons of Wollemi National Park, west of Sydney.

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Did you know? 2.7

Vegetable or fruit?

Flowering plants produce fruits, and when you think of fruit, you may think of apples, oranges and pears. But did you know that there are many more categories of fruit? In the kitchen, many plants that people would consider a vegetable are actually fruits.

The most famous example is probably the tomato. In 1893, the US Supreme Court had to rule whether imported tomatoes should be taxed under a rule that only applied to vegetables and not fruits. The court decided that tomatoes were vegetables, despite them being fruit!

Figure 2.35 How many different fruits can you see?

Capsicums, coconuts, cucumbers, pumpkins, corn kernels, peas and peanuts are all fruits!

Explore! 2.3

Traditional knowledge of plants

It is estimated that as much as 84% of the plants in Australia are endemic to the country. Many different groups of First Nations Australians across Australia have a vast knowledge of the medicinal properties of these plants, built over millennia. Through trial and error over many generations, they have come to understand which plants are dangerous to consume, which have medicinal value, and what processes are required to make toxic plants safe.

Figure 2.36 Gumby gumby trees (*Pittosporum angustifolium*) are one of many plants used by Uncle Steve Kemp to produce medicinal products.

Consider the following questions:

- Why do the plants used as medicine vary in different parts of Australia?
- What is the *Biodiscovery Act 2004*?
- The Queensland Government reformed the Biodiscovery Act in September 2020 to recognise and protect the traditional knowledge of First Nations Australians. Explain why it is important to introduce protections for the use of traditional knowledge in biodiscovery.
- Uncle Steve Kemp, a Ghungalu Elder, runs a 'bush pharmacy' located in Woorabinda. A CQ University project is researching the properties of his medicine, with the partnership ensuring that the intellectual property rights and any potential commercial opportunities remain within the local community. Discuss the potential ethical, environmental, social and economic implications of such partnerships.

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Quick check 2.7

1 Define the terms 'vascular' and 'non-vascular'.
2 Recall if organisms in the plant kingdom are unicelled or multicellular.
3 Recall the groups of plants that produce seeds.
4 Copy and complete the following table to summarise the characteristics of different plant groups.

Characteristics	Non-vascular	Vascular		
		Ferns	Non-flowering	Flowering
Roots and stems				
Maximum height				
Spores or seeds				
Flowers or no flowers				
Examples				

Explore! 2.4

Traditional land management

The rubber vine (*Cryptostegia grandiflora*) is a flowering plant that is listed as a Weed of National Significance. It can spread quickly, forming dense thickets that smother native vegetation and prevent native animal access to waterways. Research how traditional land management practices have been effective in controlling major weeds such as rubber vine and parkinsonia (*Parkinsonia aculeata*).

Practical skills 2.1

Observing *Euglena*

Be careful

Ensure proper microscope handling and use is observed.

Aim

To observe a single-celled organism under the microscope.

Materials

- *Euglena* sample
- pipette
- compound microscope
- dimple slide
- coverslip
- sharp pencil
- plain paper
- glycerol (optional)

Method

1 Set up the microscope on your bench.
2 Place a small drop of the *Euglena* sample into the dimple on the slide. One drop of glycerol can be added to slow the movement of the *Euglena*.
3 Lower the coverslip on an angle over the drop to protect the sample.
4 Place the slide onto the stage of the microscope and focus, using the lowest power magnification first.
5 Draw a scientific drawing of the *Euglena* you observe. Use a sharp pencil.
6 Use the internet to research the structure of *Euglena*. Label your scientific drawing.

Analysis

Euglena can make sugars like plants can, but they also have a simple 'eye' spot (sensitive to light, not a true eye). *Euglena* can also move, as you have observed. From your observations, justify whether you believe *Euglena* is more similar to animals or plants.

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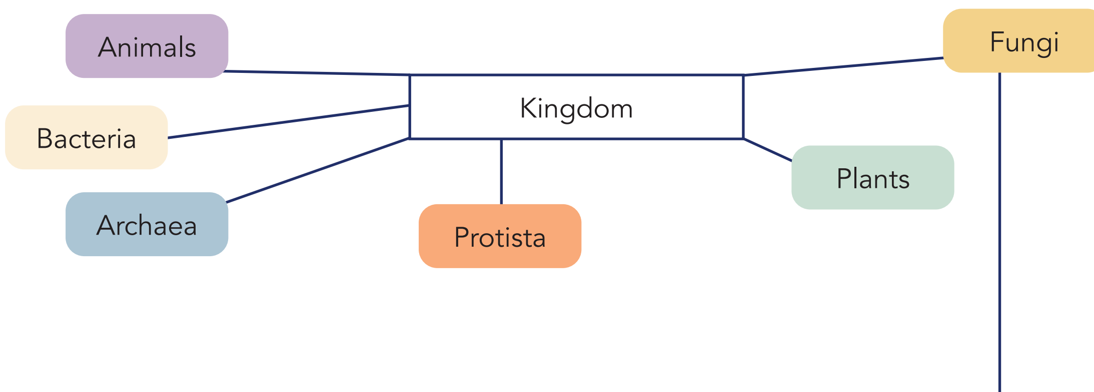
VIDEO
The importance of fungi

Fungi

Fungi are a group of organisms that include mould, mushrooms and yeast. They are not producers so cannot produce their own food. Instead, they digest organic material and absorb the nutrients. Fungi reproduce by spreading spores. Fungal cells are surrounded by a rigid cell wall made of chitin that provides structural support and protection and distinguishes them from other organisms.

Fungi (as well as some bacteria, archaea and protists) are decomposers and grow well in warm, moist conditions. They have one of the most important roles on Earth. By decomposing waste material and dead matter, they release vital nutrients that can be recycled back into the ecosystem.



Unicellular fungi

Yeast is a unicellular fungus used in breadmaking and alcohol manufacturing.

Figure 2.37 In breadmaking, yeast feeds on the sugars in flour and releases carbon dioxide that makes the bread rise.

Multicellular fungi

Multicellular fungi grow as thread-like filaments called hyphae. They can be moulds made of very fine threads, or larger fungi that have fruiting bodies that you would recognise as mushrooms.

Figure 2.38 The desert shaggy mane (*Podaxis pistillaris*) is a fungus that was used by many First Nations Australians desert tribes for body painting and to darken the white hair in old men's beards.

Explore! 2.5

Ants farming fungi

Research *Leucoagaricus gongylophorus* and its special relationship with leaf-cutting ants.

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Science as a human endeavour 2.2

Deadly fungi

In October 2022, a researcher from James Cook University confirmed the first-ever sighting of a poison fire coral fungus in Far North Queensland. *Podostroma cornu-damae* is one of the world's deadliest fungal species and the only one that can poison a human from touch. When even a small amount is touched or eaten, it can cause your skin to peel off, your hair to fall out, your brain to shrink, and many other potentially lethal symptoms.

Figure 2.39 Poison fire coral fungus (*Podostroma cornu-damae*)

Did you know? 2.8

***Cordyceps*: the zombie fungus!**

There are over 400 different species of *Cordyceps* fungi, each targeting a particular species of insect. When *Cordyceps* spores attach to an insect, they start to grow throughout the body. Sometimes, the fungi take over the brain of the insect and control its movement! The fungus will then emerge from the insect and spread its spores to other insects in the area.

Figure 2.40 *Cordyceps locustiphila* fungi target grasshopper species

Try this 2.8

Classification super-challenge!

To check if you know the key characteristics of the different kingdoms, try this super challenge! Read the description, see if you can identify the kingdom the organism belongs to and then find a picture of a possible organism that fits the description.

Description	Kingdom	Picture
I am a single-celled organism. I live in the large intestine of mammals like humans to help food break down. I reproduce very quickly.		
I am a multicellular organism that uses sunlight to make my own food. I grow flowers to produce seeds inside of fruits.		
I cause dead animals to really reek when I slowly digest their tissues, producing methane. I am a single-celled organism with no nucleus in my cell.		
I am a unicellular organism that can move and live in pondwater. My body is covered with little hairs to help me move and I can swim very fast. I eat bacteria.		
I make my own food using the sunlight and I am multicellular. I get my nutrients from insects I can catch in my folding leaves.		

Quick check 2.8

1. Recall the characteristics of fungi.
2. State the characteristics that plants and fungi have in common.
3. Do some research and identify some examples of fungi that can be both beneficial and dangerous to humans.
4. State the conditions that are best for mould or fungi to grow.

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Investigation 2.1

Fungi are all around us

Be careful

Make sure you do not open or puncture the bag once growth has begun. Ensure that growing conditions remain under 30°C for safety considerations.

Aim

To design a method to fairly investigate how different factors affect the growth of mould on bread.

Time period

Approximately 1 week

Background information

Recall that fungi produce spores in order to reproduce. This means that fungal spores are in the air all around us every minute of the day. You inhale these spores with every breath you take, and they try to grow in your lungs. Luckily, humans have a brilliant immune system that can fight them off. The food we store at home, on the other hand, does not have an immune system, so fungi that land on it can grow very easily. Most of the fungi that grows on food is known as mould. It is important to store food in an environment that slows down mould growth as much as possible, such as a cool pantry or a fridge or freezer. This keeps the food edible for longer.

Materials

- slices of bread, or 3+ pieces per independent variable group, which are near or past their 'best before' date and preferably with no preservatives
- zip-lock bags
- paper towels
- sticky labels
- permanent markers
- sticky tape

Planning

1. Read the background information section and identify an environmental factor that affects the growth of mould on food at home.
2. Create a research question that can be easily and safely investigated.
3. Identify one independent variable to test, based on your research question. Describe the different groups that you will set up for the experiment.
4. Identify the dependent variable and how you will measure it.
5. Develop a hypothesis by predicting how a change in the independent variable will affect the resulting dependent variable.
6. Identify the controlled variables and describe how these will be managed.

Method

1. After a few minutes exposed to air to pick up some spores, place each piece of bread into a zip-lock bag and seal the end well.
2. Cover the seal with a layer of sticky tape to prevent anyone opening it. DO NOT OPEN AGAIN – This is a safety issue as breathing in mould can be dangerous.

continued…

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...continued

3 Label each bag with the following information:

Group number:
Description:
Date:
Student/s name:

4 Set up three bags for each independent variable group that you planned in the planning section.
5 Monitor each group for 5–7 days.
6 If any part of the set-up is changed over that time, then note the reason for this.

Data processing

1 Collect each bag. DO NOT OPEN for safety reasons.
2 Measure the estimated percentage coverage of fungal growth for each independent variable group and record the results in a table. Your teacher may direct you to create your table on a spreadsheet.
3 Calculate the average of the three growth measurements for each independent variable group.
4 Graph the mean of each group's data on paper. Your teacher may direct you to create your graph on a spreadsheet.

Analysis

1 Describe any trends, patterns or relationships in your results table.
2 Identify any **anomalous** results that you found.
3 Analyse how much variation was observed between the measurements within each group.

anomalous
an outlying result that does not fit in with the pattern of the other results

Evaluation

Reliability

1 Describe how the set-up or method was adjusted, if at all, once the experiment was started.
2 Critique your management of the controlled variables. Were they managed properly to ensure they did not change and affect the measurements?

Improvements

3 Were there any obvious sources of error or parts of the procedure that caused the data to be less accurate than it could have been? Describe any changes that could be made to the method to improve the quality of the data in future experiments.

Conclusion

Answer your research question, using data from the experiment to support your statement.

1 Propose a valid conclusion that can be drawn from these results.
2 Justify this conclusion using data from your results.
3 State whether your hypothesis is supported or not.

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QUIZ

Section 2.3 questions

Retrieval

1 **State** three examples of fungi.
2 **Recall** what 'hyphae' are.
3 **State** the kingdom that *Penicillium* mould belongs to.
4 **Identify** why animals depend on bacteria and fungi.

Comprehension

5 **Explain** the adaptations of flowering plants that help them to reproduce.
6 **Describe** the difference between prokaryotes and eukaryotes.

Analysis

7 **Distinguish** between unicellular and multicellular organisms.
8 **Classify** each of these species by placing them into the correct kingdom.
  a *Streptococcus pneumoniae* is an organism that can make you very sick. It belongs to the second oldest kingdom and is made up of single cells.
  b *Trypanosoma evansi* is a single-celled organism that needs to digest other organisms to survive. Its cells have specialised structures inside of them.
  c *Osmunda regalis* is an organism that uses the Sun to make sugars and reproduces using spores. This organism has specialised vascular tissue.
  d *Tremella fuciformis* is an organism that reproduces using spores and is a parasite of other organisms to gain food.
  e *Haloferax volcanii* is a single-celled organism that can survive in extreme environments that no other organism could survive in.

Knowledge utilisation

9 In the past, fungi were considered to be part of the plant kingdom. **Propose** reasons why this might have been the case.
10 Suzi discovered that a piece of bread left in a zip-lock bag had developed a black fuzzy mould-like substance. She decided to investigate the factors affecting mould growth. She used the same brand of bread and zip-lock bags. She placed the sealed bags in environments with different temperatures.
  a **Determine** the variable she was changing or testing (independent variable).
  b **Determine** the variable she was measuring (dependent variable).
  c **Propose** some examples of variables she kept the same or controlled.
  d **Propose** two other variables she could test with a similar experiment to assess what factors affect the growth of mould.

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2.4 The animal kingdom

Learning goals

1. To be able to describe the difference between invertebrates and vertebrates.
2. To be able to recall seven classes of chordates.

DOC WORKSHEET Grouping

DOC WORKSHEET Animal kingdom

The animal kingdom is the largest kingdom, with over a million classified species. It might surprise you to know that most of the animals on our planet are microscopic and look nothing like the animals you are more familiar with, like birds, mammals and fish. All organisms that are placed in the animal kingdom share some defining features that set this kingdom apart from the others.

All animals:

- are eukaryotes, so have cells with a nucleus and membrane-bound organelles
- are multicellular (made up of more than one cell working together)
- eat other organisms or their products to gain energy
- can independently move their location if they are motile, or their body parts if they are **sessile**.

Figure 2.41 A dust mite is an example of a microscopic animal

Phyla in the animal kingdom

There are currently 35 recognised phyla (plural of phylum) in the animal kingdom, but here we will focus on the nine key ones, as shown in Table 2.3. Animals can be classified based on whether or not they have a backbone. A **vertebrate** is an animal with an internal backbone or endoskeleton, while an **invertebrate** is an animal with no internal backbone. Instead, invertebrates may have a hard outer casing called an exoskeleton. Despite vertebrate and invertebrate being important terms to know and understand, they are not used as an official level in the classification system.

sessile
fixed in one place and not able to move

vertebrate
an animal that has a backbone

invertebrate
an animal that does not have a backbone

ANIMAL KINGDOM		
Phyla (scientific name in brackets)	**Examples**	**Invertebrate or vertebrate**
Poriferans (*Porifera*)	Sponges	Invertebrates (they have no backbone)
Cnidarians (*Cnidaria*)	Jellyfish, sea anemones, coral	
Platyhelminths (*Platyhelminthes*)	Flatworms	
Nematodes (*Nematoda*)	Roundworms	
Annelids (*Annelida*)	Earthworms	
Molluscs (*Mollusca*)	Shelled animals	
Arthropods (*Arthropoda*)	Insects, spiders, crustaceans	
Echinoderms (*Echinodermata*)	Seastars, sea urchins	
Chordates (*Chordata*)	Fish, amphibians, reptiles, birds, mammals	Mainly vertebrates, but some invertebrates

Table 2.3 Summary of nine key phyla in the animal kingdom. Note that eight of the nine phyla (excluding chordates) contain only invertebrates.

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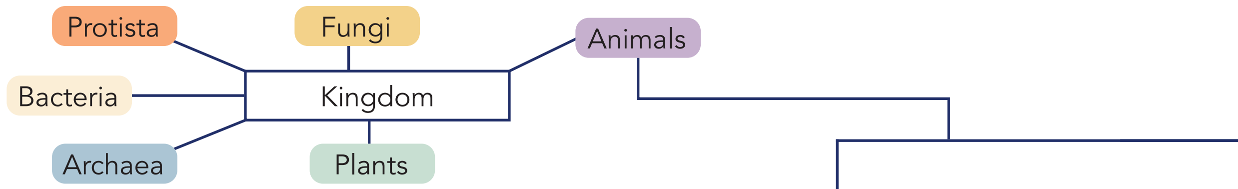

Invertebrates

Poriferans

(pron. *pore-if-er-ans*)

- Sponges (from the Latin *porus* meaning pore, and *fera* meaning bearing)
- Simple animals with no organs
- Sessile
- Feed by filter-feeding, drawing water through their pores and straining it to capture food.

Figure 2.42 The yellow tube sponge with its simple tube for filtering water

Cnidarians

(pron. *nigh-dare-ee-ans*)

- Stinging aquatic invertebrates (from the Greek *knidē*, meaning nettle, a stinging plant)
- Include anemones, coral and jellyfish
- Soft, hollow body
- Have stinging cells that are used for feeding and defence
- Can replace lost or damaged parts by regeneration.

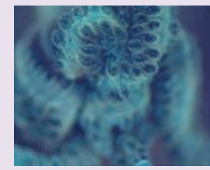

Figure 2.45 Queensland Museum scientists recently described a coral species that can only be found on the Sunshine Coast. After DNA analysis, the species is now part of a new genus and is known as *Latissimia opalia*.

Platyhelminthes

(pron. *plat-ee-helm-in-thees*)

- Flatworms (from the Greek *platy*, meaning flat, and *helminth*, meaning worm)
- Soft, unsegmented bodies
- Have flattened shapes to allow them to easily obtain oxygen and nutrients
- Most species can be cut in half and then regrow new bodies
- Many are parasites.

Figure 2.43 Flatworms come in many different colours

Nematodes

(pron. *nee-ma-toads*)

- Roundworms (from the Greek *nematos*, meaning thread)
- The most abundant animals on Earth
- Soft, unsegmented bodies
- Many species are parasitic.

Figure 2.46 The roundworm *Caenorhabditis elegans* was the first multicellular organism to have its entire DNA sequenced.

Annelids

(pron. *an-e-lids*)

- Ringed worms (from the Latin *anellus*, meaning little ring)
- Three main groups: earthworms, leeches and polychaetes that live in the ocean
- Soft, segmented bodies
- Need a moist environment, can survive on land.

Figure 2.44 Have you ever noticed more earthworms above the soil after heavy rain? It was previously thought that they moved to the surface to avoid drowning, but it is now believed they mistake the sound of rain for moles and move to the surface to avoid the predators!

Molluscs

(pron. *mol-usks*)

- Soft-bodied invertebrates with a muscular foot or tentacles (from the Latin *mollis*, meaning soft)
- Includes squid, snails, slugs, octopuses and oysters
- Have a mantle (a cover or outer layer), and for some it forms a shell
- Have a radula, a scraping device for eating.

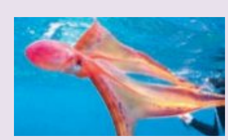

Figure 2.47 In 2022, a blanket octopus was spotted for only the fourth time ever! It was seen off Lady Elliot Island on the Great Barrier Reef.

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Vertebrates

Arthropods

(pron. *arr-throw-pods*)

- Invertebrates that have an exoskeleton, segmented bodies and paired jointed limbs (from the Greek *arthron*, meaning joint; and *podos*, meaning foot)
- Include insects, spiders, scorpions, millipedes, crustaceans (crabs, lobsters, prawns)
- Make up 80% of all animal species
- Have complex sensory organs such as compound eyes and antennae for hunting and detecting threats.

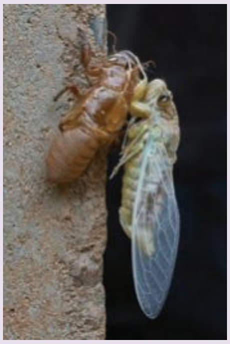

Figure 2.48 A cicada with its moulted exoskeleton, known as its exuvia. At least once during their life, all arthropods must moult.

Echinoderms

(pron. *eek-ine-o-derm*)

- Marine invertebrates with a hard, spiny or bumpy covering (from the Latin *echino*, meaning spiny; and *derm*, meaning skin)
- Includes sea stars, sea urchins, sea cucumbers, brittle stars and feather stars
- Have specialised organs, but no brain and no blood
- Most have **radial symmetry**.

Figure 2.49 Scientists have estimated that there are approximately 3 million sea cucumbers on Heron Island in the Great Barrier Reef. They also calculated that they produce 64 000 000 kg of poo a year! This waste is important for the health of coral reefs.

Chordates

(pron. *core-dates*)

The word chordate is derived from the Latin *chordatus,* meaning having a spinal cord, which was originally taken from *chorda*, meaning string.

The chordate phylum contains the most complex animals. At some point in a chordate's life, they possess a notochord (this becomes a backbone, although note that some chordates do not have backbones and are therefore invertebrates), gills on the neck, a nerve running up the back and a tail. Humans are chordates, although you may be wondering why you don't have gills or a tail! This is because humans only have these features before birth.

We do have a long nerve running up our back called the spinal cord. The spinal cord connects the brain to the rest of the body and is protected by bones called vertebrae. Run your fingers down your back to feel your vertebrae. You may remember that animals with such bones are called vertebrates. Humans, all other mammals, fish, reptiles, amphibians and birds all belong to the chordate phylum but are further grouped into classes based on their similar characteristics.

Figure 2.50 A five-week-old human embryo, where a tail can clearly be seen. Through foetal development, the tail will disappear, and we are left with just the tailbone. In rare cases, babies can be born with tails!

radial symmetry
a form of symmetry where an organism's body can be divided into identical parts around a central axis

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Did you know? 2.9

Darwin's worm experiment

Worms may be more intelligent than you think. Charles Darwin noticed that earthworms do not choose leaves randomly to take to their burrow. He set up an experiment with different shaped leaves, and later with different width paper triangles and found that earthworms would pull the triangles by the points to make it easier to fit into their burrows.

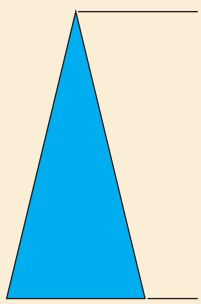

Figure 2.51 Although the base has the largest surface area, Darwin found that worms preferred to pull the paper triangles from the point to make it easier to fit into their burrows.

Did you know? 2.10

Protecting native species

Much of Queensland's native flora and fauna is protected by law. All native birds, reptiles, mammals and amphibians are protected, alongside some invertebrates, freshwater fish and the grey nurse shark.

Figure 2.52 The Australian east coast grey nurse shark (*Carcharias taurus*) population is estimated to be no more than 2000 individual sharks. It is one of Australia's most endangered species.

Explore! 2.6

Dame Jane Goodall's behavioural studies

> *'Change happens by listening and then starting a dialogue with the people who are doing something you don't believe is right.'* – Jane Goodall

Chimpanzees are chordates in the mammal class. In her research on the species, Dame Jane Goodall made five ground-breaking discoveries:

- They make and use tools.
- They hunt and eat meat.
- They show acts of compassion.
- They engage in war.
- They have strong maternal bonds.

Explore why Dame Goodall's communication of these findings changed viewpoints about what it means to be human and set the standard for how behavioural studies (especially on chordates) are conducted.

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Symmetry

When classifying animals into their correct phyla, their symmetry can be considered. Radial symmetry means you can draw an imaginary line in several directions through the centre of the animal and you will get identical halves. **Bilateral symmetry** means you can only draw an imaginary line in one position to get identical halves.

bilateral symmetry
a form of symmetry where an organism's body can be divided into two identical halves

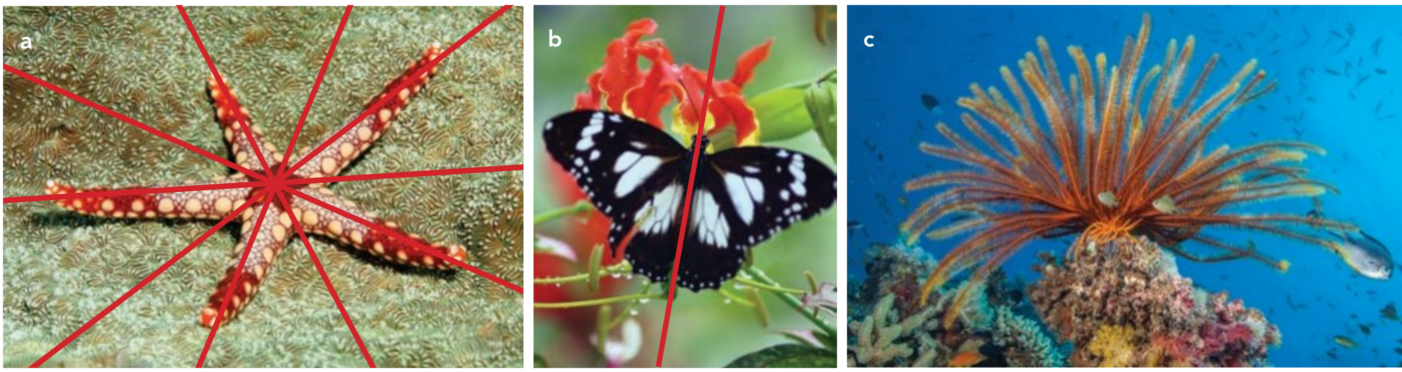

Figure 2.53 **(a)** The Necklace sea star shows radial symmetry because it can be separated into identical halves in many directions. **(b)** The Marsh Tiger butterfly shows bilateral symmetry because it can be separated into identical halves in one direction. **(c)** Can you tell what type of symmetry the crinoid shows?

Quick check 2.9

1 Recall how many recognised phyla there are in the animal kingdom.
2 State the characteristics of all animals.
3 Recall the most abundant animals on Earth.
4 Describe the difference between radial and bilateral symmetry.

Explore! 2.7

Asymmetrical animals

Most but not all animals have symmetrical body shapes. Investigate and find examples of animals that do not have symmetrical bodies.

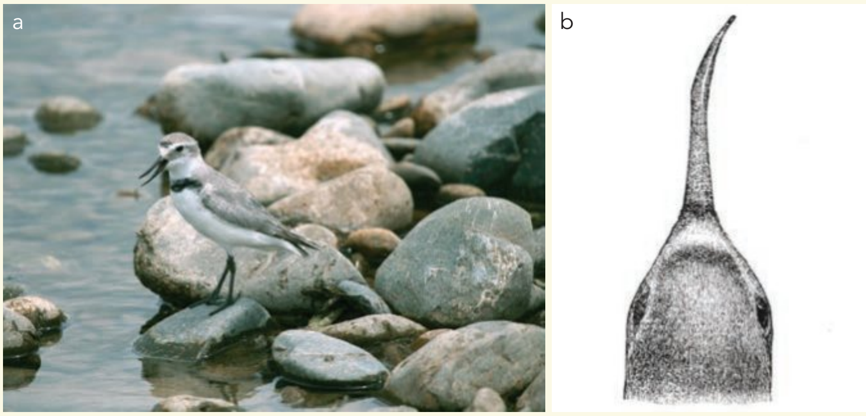

Figure 2.54 The wrybill is the only species of bird with a beak that is always bent sideways to the right, and therefore is not bilaterally symmetrical.

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Try this 2.9

Types of symmetry

Look at each of the following animals then decide whether they show radial symmetry, bilateral symmetry or no symmetry.

Practical skills 2.2

Dissecting a member of the Mollusca phylum

Be careful

Ensure that disposable gloves and a lab coat or apron are worn when the squid is being handled.

Aim

To explore the anatomy of the squid and observe its simple organ system.

Materials

- 1 squid
- dissecting tray (plastic chopping board)
- dissecting scissors
- probe
- newspaper
- 11 toothpicks
- 11 sticky labels
- gloves
- lab coat
- optional: dissecting microscope
- recommended: laminated copies of Squid Internal and External Anatomy for reference during dissection.

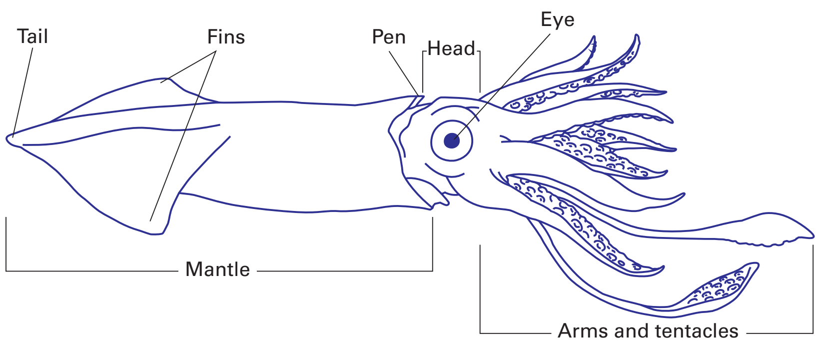

Figure 2.55 External anatomy of the squid

Method

1 Create 11 toothpick label flags with the toothpicks and sticky labels, by folding the labels over like a flag at the top of each toothpick. Add each of the following to the labels: heart, ink sac, gills, tentacles, arms, eyes, mantle, pen, fins, siphon, gonads.

External anatomy

2 Place the squid on the dissecting tray and lay it out flat.
3 Study the external anatomy diagram in Figure 2.55. Place your toothpick labels to identify all the external parts of your squid.
4 Count the number of arms the squid has. Arms are different from the tentacles, as they are shorter and have suction pads all the way along them.

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…continued

5 Count the number of tentacles the squid has. Tentacles are longer than the arms and only have suction pads at the end.
6 Pick up the squid and hold the mantle like an ice-cream cone. Allow the arms to spread backwards over your hand. This will expose the mouth of the squid.
7 Locate the beak of the squid. It will be hard and brown.

Internal anatomy

8 Place the squid back on the dissecting tray and use the scissors to cut the mantle upwards from the tentacles to the top.
Be careful to cut away from the centre of the squid so you don't damage its organs.
9 Open up the mantle of the squid, like opening a book.
10 Locate the gills, ink sac, heart and gonads and label them using your toothpicks.
Be careful not to puncture the ink sac at this point, as it will spill all over the squid.
11 Once you have labelled all the internal parts of the squid, try to remove each organ very carefully and place around the dissecting tray.

Optional

12 Locate and remove the pen. The pen is a hard, transparent part of the squid's internal anatomy. It is the remains of a shell and offers support for the squid when moving. It is located in the centre of the mantle. Once you locate the pen, you should be able to peel it away from the surrounding tissue using your fingers.
13 Remove the ink sac from the squid. Place it on a dish to catch any mess, and try popping it with a toothpick. Use the pen of the squid or the toothpick to write your name on a piece of paper.
14 If you have successfully located and removed the beak and radula, observe these structures under a dissecting microscope.

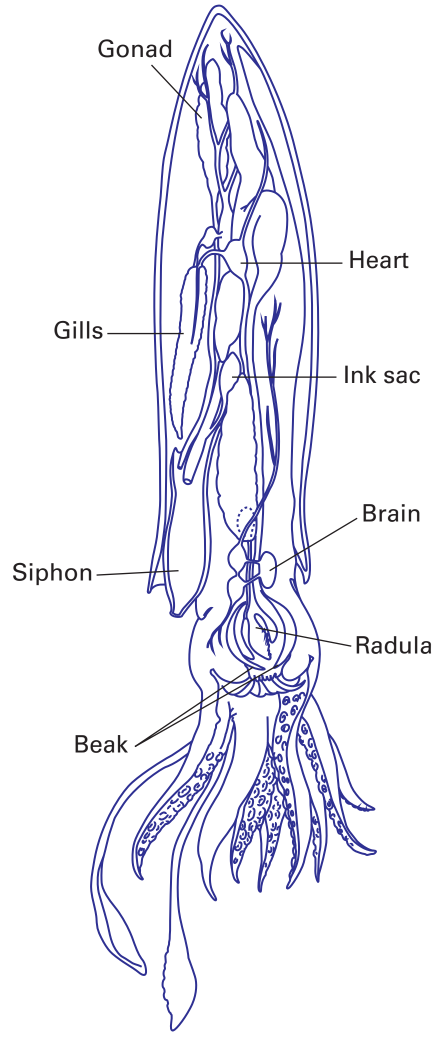

Figure 2.56 Internal anatomy of the squid

Data processing

1 Develop a table to record the following:
  a Main features identified (see method)
  b Number (how many times was this feature observed)

Analysis

1 Squids are classified in the class of Cephalopoda, which comes from the Greek words for 'head-foot'. Discuss how this name relates to the squid's anatomy.
2 Squids are classified in the phylum of Mollusca, which includes all shellfish. Discuss a probable reason for why the squid is classified this way when it does not have a shell.
3 Propose a reason why it would be beneficial for a squid to be able to produce ink.

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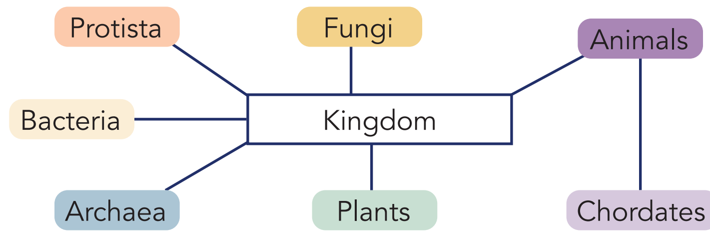
Classes in the phylum Chordata

We know there are six kingdoms, which are divided into phyla, and as we move through the hierarchical classification, the next level is class. You will now take a closer look at the seven classes of the Chordate phylum: Agnatha, Chondrichthyes, Osteichthyes, Amphibia, Reptilia, Aves and Mammalia (Figures 2.57 to 2.66).



Agnatha (jawless fish)

(pron. *ag-na-tha*)

- Jawless, eel-like aquatic vertebrates
- Include lampreys, hagfish and many extinct species
- Oldest chordates and known as 'living fossils' as they have not changed in millions of years
- Often parasites or scavengers.

Figure 2.57 Lamprey teeth are used to help it attach to its prey. New teeth will grow and replace the old ones.

Osteichthyes (bony fish)

(pron. *ost-ee-ick-thees*)

- Fish with skeletons made from bone tissue
- Include salmon, tuna, eels, trout and clownfish
- Possess scales, paired fins and gills
- **Ectothermic** – the temperature inside their bodies is controlled by the temperature of their environment.

ectothermic
a cold-blooded organism that cannot regulate its internal temperature

metamorphosis
the process of transformation from an immature form to an adult form

Figure 2.58 The Australian or Queensland lungfish is one of the oldest species on Earth. Its distinctive characteristic is the presence of a single lung that gives the fish its name. When oxygen levels are low, the lungfish can rise to the water's surface and breathe air.

Chondrichthyes (cartilaginous fish)

(pron. *con-drik-thees*)

- Fish with skeletons made of cartilage (softer and more flexible than bone)
- Include sharks, skates and rays
- Have fins on the sides of their bodies (lateral fins) and on their backs (dorsal fins).

Figure 2.59 In 2022, scientists tracking a great white shark found that he swam more than 10 000 km in just 150 days.

Amphibia (amphibians)

- Ectothermic
- Live on both land and water (from the Greek *amphibios* meaning 'living a double life')
- Include toads, frogs, newts and salamanders
- Require water or a moist environment and use their moist skin and lungs to breathe air
- Undergo **metamorphosis** (a change in form, allows them to transition from an aquatic to a terrestrial or semi-terrestrial life).

Figure 2.60 Forty-one per cent of amphibian species worldwide are threatened with extinction. Projects such as the citizen science FrogID app encourage people to upload audio recordings of frog calls to a database. The data is improving scientists' understanding of Australia's unique frog species.

Try this 2.10

Dichotomous key app

The use of digital tools, such as the FrogID app explained in Figure 2.60, has several benefits in encouraging public participation. With just a smartphone and the app, anyone can become a citizen scientist and contribute to real scientific research. Use the internet to research how you could use similar technology to design a dichotomous key app that allows the community to classify plants and animals in their local area.

Reptilia (reptiles)

- Ectothermic vertebrates with waterproof scales
- Include snakes, lizards, turtles and crocodiles
- Most lay leathery eggs
- Have lungs for breathing.

Figure 2.61 Proserpine River has the highest density of crocodiles in Queensland. Unusually, despite their territorial nature, the crocodiles do not seem to fight, puzzling researchers with their lack of scars and scratches.

Aves (birds)

(pron. *ah-vays*)

- Have feathers covering their body
- Lay hard-shelled eggs
- Have a beak with no teeth
- Winged, but not all birds can fly
- **Endothermic**.

endothermic a warm-blooded organism that can regulate its body temperature

Figure 2.62 The cassowary has grown too large to fly and has adapted to a life on the ground.

Mammalia (mammals)

- Feed their offspring milk
- Have a covering of hair or fur
- Possess three small bones in the middle ear
- Endothermic
- Have three subclasses based on how they produce offspring: placentals, monotremes and marsupials.

Figure 2.63 The northern bettong, an endangered marsupial found only in North Queensland

Placentals give birth to well-developed young. Through pregnancy, nutrients and wastes are exchanged between mother and foetus through a cord attached to the mother's placenta. Most mammals are placental mammals, including humans.

Figure 2.64 The spectacled flying fox is a placental mammal.

Marsupials give birth to live young (called joeys) at a very early stage of development. The young will climb from the birth canal to the pouch, where they will latch onto the mother's nipple and remain there until they are fully developed. Marsupials include kangaroos, wombats, possums and koalas. They are only found in Australasia, South America and, in smaller numbers, in Central America and North America.

Figure 2.65 A kangaroo joey attached to its mother's nipple

Monotremes lay eggs with leathery shells, like reptiles. They have highly modified beaks or snouts, and adults have no teeth. They feed their young with milk secreted from glands, not nipples. The only monotremes that exist today are four species of echidna and the platypus.

Figure 2.66 Echidnas don't need teeth. They feed with their 15 cm-long tongues.

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Explore! 2.8

Are all chordates vertebrates?

Chordata is the only phylum that contains vertebrate animals. Most, but not all, chordates are vertebrates. Search on the internet for a chordate that is not a vertebrate.

Making thinking visible 2.2

Interacting with living things

Biologists often interact with living things, both in the laboratory and the field. Ideas about ethics have changed over time, and now there are regulations surrounding how we interact with living things.

Analyse: What factors contributed to its current state? What individuals or forces could have initiated or shaped these transformations?

Forecast: In what other ways could this evolve in the future?

Innovate: Change presents obstacles. If you could transform the challenges brought about by these changes into opportunities, what possibilities do you envision? What innovative solutions could be generated?

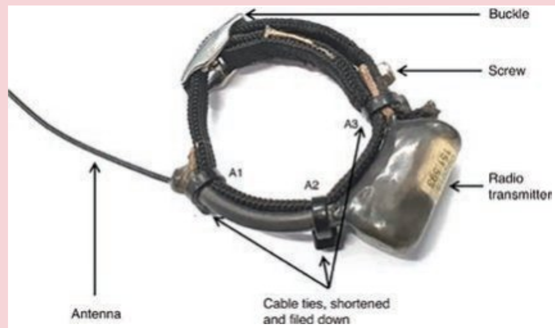

Figure 2.67 Radio-collaring mammals is helpful in collecting data on animal movement and behaviour, but it increases stress and may cause injury. When researching wallabies, Alexandra Ross created a tracking device from a store-bought elastic cat collar. The collar stretches, allowing a snagged animal to free itself without choking.

The *What can be* thinking routine was developed by Project Zero, a research centre at the Harvard Graduate School of Education

Did you know? 2.11

The Rock Chicks

Each year, amateur palaeontologists known as the Rock Chicks – Cassandra, Sally and Cynthia – meet to search for fossils on a remote Western Queensland property owned by Cassandra. In 2022, they discovered the head and body of a 100-million-year-old plesiosaur, a marine reptile (Figure 2.68). Plesiosaurs inhabited Western Queensland between 145 and 65 million years ago, when most of the state was a shallow sea.

Figure 2.68 Consider the fossil in the picture. Why do you think it's rare for the head and body of plesiosaurs to be found together?

Try this 2.11

Which phylum?

Use the information about each of these species to decide which phylum they should belong to.

1 *Asaphus kowalewskii* is an extinct member of the largest phylum. All the members of this phylum had an exoskeleton, segmented body and jointed limbs.
2 *Ailurus fulgens* has a long tail and a nerve cord that runs down its back. This nerve cord is protected by hard bones.
3 *Monanchora arbuscula* is an animal that obtains food by filtering seawater through pores on its body.
4 *Pseudoceros susanae* is a colourful animal that is completely flat. It has bilateral symmetry and can be cut in half and survive.
5 *Cassiopea andromeda* has a soft body and a specialised cell called a nematocyst (pron. nee-ma-toe-sist) that fires a stinging spine at its target like a harpoon.
6 *Pisaster ochraceus* has radial symmetry and cannot survive in fresh water. It digests its prey by pushing its stomach out of its mouth.

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Quick check 2.10

1 Describe two differences between amphibians and reptiles that allow reptiles to live away from water.
2 Identify the difference between birds and reptiles that allows birds to survive in more environments than reptiles.
3 Recall how an amphibian gets oxygen from the air.
4 Name two members of the Osteichthyes class.

Did you know? 2.12

Unique marsupials

Wombats are an example of a marsupial in the mammal class. They have developed a number of different adaptations that make them unique. Aside from having distinctively cube-shaped faeces, they have a sturdy rump that serves multiple purposes. It is used for defence, burrowing, bonding, mating, and potentially crushing the skulls of enemies against the burrow's roof. However, the exact functionality of this behaviour is still under debate. The wombat's rear end consists of four fused plates, surrounded by cartilage, fat, skin and fur. The animals utilise their backside to block their burrows, preventing predators from entering and safeguarding their more vulnerable body parts.

Figure 2.69 Australia is home to three existing species of wombat: the common wombat (shown here), the southern hairy-nosed wombat and the northern hairy-nosed wombat.

Wombats have also developed a pouch that faces in the opposite direction from the pouches of other marsupials to protect their young from dirt when the mother is digging a burrow.

Try this 2.12

Identify the chordate class

1 *Pseudonaja textilis* is an ectotherm with a skin made of waterproof scales. This animal lays leathery eggs that do not need to be submerged in water.
2 *Vulpes lagopus* is an endotherm that is covered in fur. It gives birth to fully developed young and feeds them on milk.
3 *Trichoglossus moluccanus* is a colourful animal that is an endotherm. It possesses several adaptations including wings and feathers, which allow it to fly.
4 *Litoria caerulea* can survive on land but will always be found near a body of water as it needs to keep its skin moist, and can only lay its eggs in water.
5 *Thunnus albacares* is a marine animal that has specialised fins, a jaw with teeth and a bony skeleton.

Try this 2.13

Exploring the animal kingdom

Use your preferred web browser to research any four living species that you want. Your choices should each be from a different phylum.

Make a cue card for each one. Print out a small picture of the species, and include the following information for each one.

- Common name
- Scientific name
- Phylum
- Characteristics of the phylum
- Three features of this species
- Three interesting facts about it

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Now you have gathered information on your animals, it is time to play 'Two truths, one lie' with a partner.

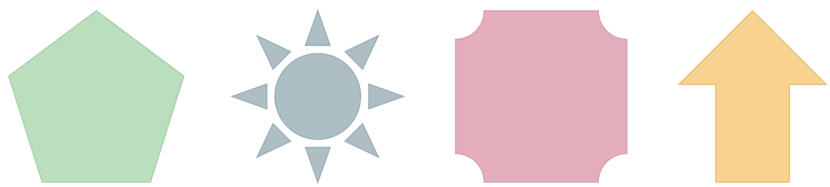
1 Choose two facts about each of your chosen species and create one lie about the species.
2 Read the two truths and one lie out to your partner to see if they can correctly guess the lie.
3 Swap after each animal to give your partner a chance to trick you.
4 When you have played this game with your partner, swap partners and play again.

QUIZ

Section 2.4 questions

Retrieval

1 **Recall** where you would find living sponges.
2 **Name** three examples of arthropods.
3 **State** whether each of the following shapes has bilateral or radial symmetry:



Comprehension

4 **Describe** the difference between a vertebrate and an invertebrate.
5 **Explain** why reptiles can live in deserts, while amphibians can't.

Analysis

6 **Differentiate** between the following animals:
  a jellyfish and earthworm
  b kookaburra and koala
  c frog and tuna.
7 The sea pig (*Elpidiidae scotoplanes*) is an unusual animal that lives on the bottom of the ocean. It can only survive in salty water. It has feeding tentacles and five to seven pairs of feet. Its body has bilateral symmetry and is soft.
  a **Identify** which animal phyla the sea pig shares features with.
  b **Categorise** the phyla that the sea pig belongs to, and give reasons for your answer.
8 **Compare** animals found in the Reptilia and Aves classes.
9 The pangolin is one of the world's most illegally traded animals. Its body is covered in hard scales, it is nocturnal, and it gives birth to live young that feed on milk from their mother. As an adult, it eats mainly ants and termites, which it captures with a tongue that is so long it is attached to a pelvic bone. Use this information to **decide** what class the pangolin belongs to. Give reasons for your answer.

Figure 2.70 A sea pig, *Elpidiidae scotoplanes*

Figure 2.71 A Cape pangolin, *Smutsia temminckii*

Knowledge utilisation

10 **Discuss** the reason why many animals that live in water are ectotherms rather than endotherms.

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Chapter review

Chapter checklist

You can download this checklist from the Interactive Textbook to complete it.

Success criteria		Linked questions	Check
2.1	I can explain the reasons for classifying organisms.	7, 8	
2.1	I can group organisms on the basis of their similarities and differences.	9, 12, 15, 16	
2.1	I can use keys to identify organisms.	11, 13	
2.2	I can explain how biological classification has changed over time.	14	
2.2	I can classify using a hierarchical system.	1, 6	
2.2	I can use scientific convention when naming organisms.	4, 5	
2.2	I can describe the differences between the classification systems used by First Nations Australians and those used by contemporary science.	17	
2.3	I can recall the six kingdoms of living organisms.	2	
2.4	I can describe the difference between vertebrates and invertebrates.	10	
2.4	I can recall the seven classes of chordates.	3	

Review questions

SCORCHER

Retrieval

1 **Recall** the term used to describe the broadest group of living organisms in Linnaen classification.
2 **Name** the kingdoms in the Linnaean taxonomy.
3 **Name** the seven classes of chordates.
4 **Identify** the language that the scientific names for genus and species names are mostly taken from.
5 **Recall** the correct way to write the genus and species name of the domestic cat. Hint: the unformatted name is felis catus.
6 **Identify** the missing words marked a–e:
   kingdom, a, b, c, d, e, species

Comprehension

7 **Summarise** why it is useful to classify organisms and give them a unique universal scientific name.
8 **Explain** the effect of using qualitative descriptions in a dichotomous key.
9 Mosses and fungi both produce spores when reproducing. **Describe** two differences between these organisms.

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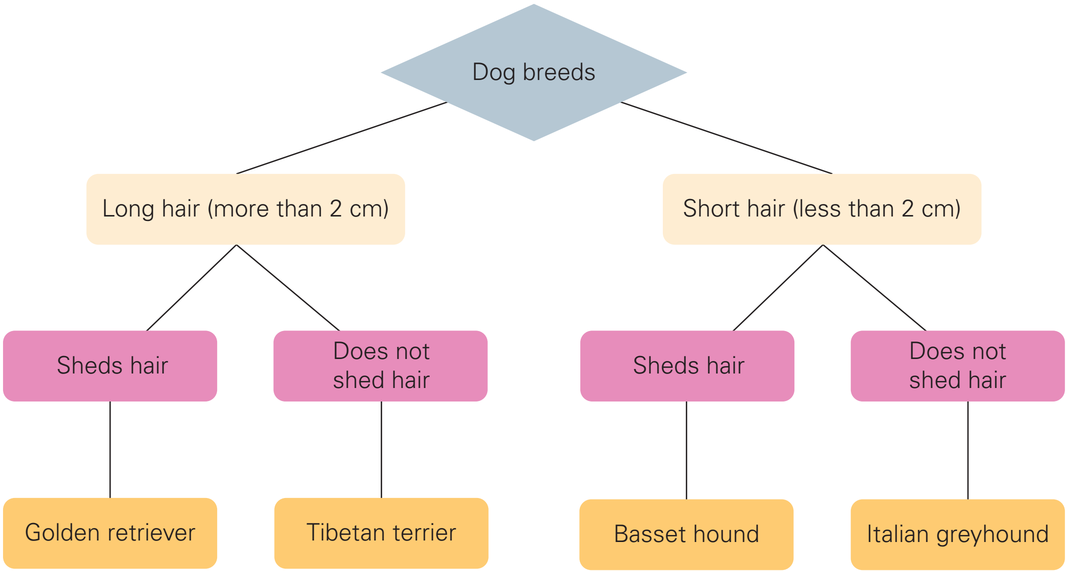
10 **Explain** why the soldier crab, *Mictyris longicarpus,* is classified as an invertebrate animal.

Figure 2.72 A soldier crab, *Mictyris longicarpus*

11 Each step of the key below can be used to describe an organism. Use it to **describe**:
   a a Tibetan terrier
   b an Italian greyhound.



Analysis

12 **Organise** the following objects into three groups and give each group a name that best describes the objects you have placed in that group.
skateboard pen spoon scissors pencil bicycle car paint plate

Knowledge utilisation

13 **Create** a dichotomous key to classify the contents of your pencil case.
14 The number of kingdoms has changed over time. **Propose** why it is likely that the levels of classification will continue to change.
15 *Euglena* are single-celled organisms that can detect light, can swim and are able to photosynthesise. **Discuss** why it would be difficult to classify this organism.
16 Scientists used to classify all life as plants or animals. **Justify** in which kingdom (plants or animals) you would place fungi, based on what you have learned in this chapter.
17 **Discuss** how First Nations Australians classify living things.

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Data questions

Apply

1 **Identify** the taxonomic group that is under the least threat using Figure 2.73.

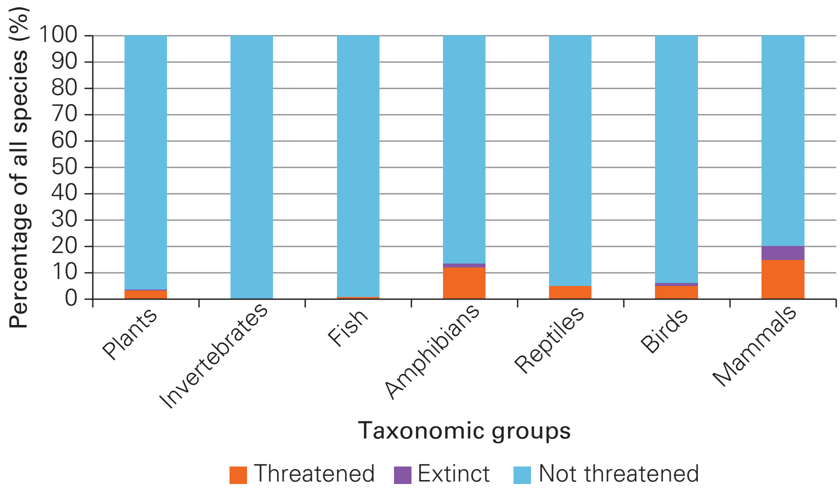

Figure 2.73 The conservation status of different taxonomic groups in Australia

2 There are 828 bird species in Australia. 6% of these species are considered as threatened. **Calculate** the number of species of birds that are considered as threatened.

3 **Calculate** the average rate of mammal extinctions per year from 1800–1920 using Figure 2.74.

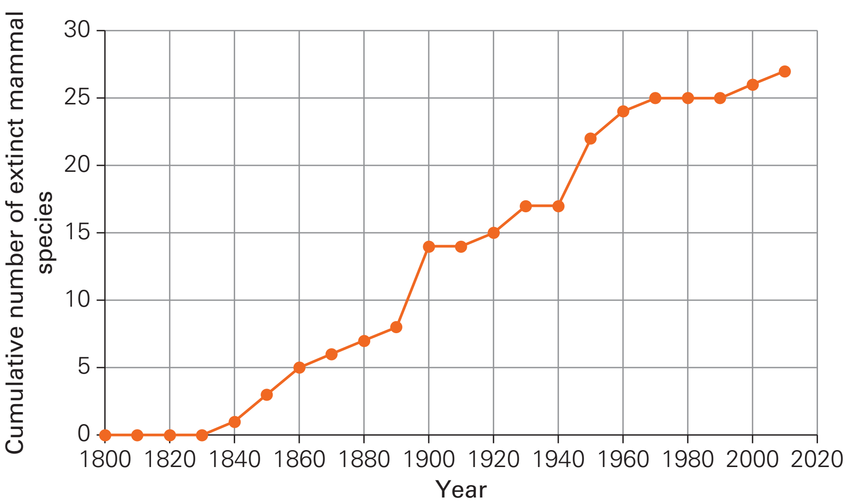

Figure 2.74 The cumulative number of extinctions of mammal species in Australia since 1800

Analyse

4 **Organise** the taxonomic groups in the Figure 2.73 from most threatened to least threatened.

5 **Contrast** the number of extinct and threatened species in mammals with the number of extinct and threatened species in amphibians in Figure 2.73.

Interpret

6 **Predict** the number of extinct Australian mammal species in the year 2020, using Figure 2.74.

7 **Infer** the two worst decades for Australian mammal extinctions using Figure 2.74.

8 **Justify** your answer to Question 7.

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STEM activity: Applying biomimicry to solve a human problem

Background information

Engineering is a varied and exciting industry. Engineers often work with designers and architects to use the natural world as inspiration for solving engineering problems and to develop new products that improve our lives. Some examples of biologically inspired designs include Velcro® (based on the prickly burrs that stick to your socks on a bushwalk), adhesives that mimic the sticky feet of geckos, air conditioning based on air flow in termite mounds and sonar navigation technology (inspired by the echolocation abilities of bats).

This area of science is called 'biomimicry', which means to imitate life or to learn from nature. Because biomimicry copies nature, it offers millions of possibilities for technologies due to the diverse range of animals, plants and insects.

Consider some of the challenges that we face as humans. The natural world faces these challenges too, therefore engineers can study the way plants, animals and insects approach these challenges and then improve their own designs. For example, the water filters in water treatment plants are designed to act like animal cell membranes, which let certain substances pass through, while others are kept out. In addition, studying a leaf and how it captures the Sun's energy allowed for the creation of more effective solar cells by engineers.

Design brief: Apply biomimicry to solve a human problem

Activity instructions

In teams, you will become design engineers who will use the biomimicry of plants, insects or other animals to develop and design a sustainability-related invention that solves a human problem. Examples of problems you may like to look at could be food waste, transportation, building design, lighting, landscaping, water use etc. Your team will not only draw a detailed and labelled diagram of your design, but also describe your design by listing the special features and which plant, insect or other animal inspired those features. Remember to ask yourselves throughout the process: 'What would nature do here?'

Suggested materials

- A3 and A4 paper
- pens, pencils
- ruler

Figure 2.75 At the Sydney 2000 Olympics, Speedo launched their Fastskin® suits, which were designed to mimic shark skin. They are made from a woven ribbing fabric that reduces drag while still allowing movement.

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Research and feasibility

1 Discuss and agree on a human problem to study with your group. Start to research the issue by making a list of all the main causes of the problem and the effects they have. An example is given below for the issue of road traffic.

Major causes of traffic	Effects	What would animals do here?
Too many cars	Causes traffic jams.	Ants have specialised patterns of movement as they encounter traffic. They move faster but add additional lanes.
Blockages on the roads	Traffic comes to a complete stop.	If there is anything blocking an ant's path, an ant will remove it, which allows the other ants to move past without interference.

2 Explain the human problem in a statement and the cost to society (this is not just monetary, but includes environmental, social and psychological costs, among others).

Design

3 Identify your plant, insect or other animal and its scientific name, and briefly describe why mimicking the organism could help with a prospective solution to the human problem.
4 Describe the unique features of your organism. Are these characteristics linked to its classification?
5 Describe how you mimic the material, colour and structure of the organism to design something new.
6 List the materials and their physical properties required to realise your design (remember that you do not need to build your design, so think about all possibilities).
7 Describe how each material was used and for what purpose. You may wish to use a table like this one:

Materials	Physical properties	Purpose of material

Create

8 Sketch out ideas within your group and vote on which uses biomimicry to solve the human problem the best.
9 Create a scale drawing of your invention, including a front and side view of it.
10 Describe your design by listing its features and explain which aspect of your organism inspired those features.

Evaluate and modify

11 Evaluate your design and its ability to solve the problem you identified. What improvements would you make?

Figure 2.76 A simple shell could be your inspiration for an ethically sustainable house.

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Chapter 3
Interactions in ecosystems

Chapter introduction

Despite now being in secondary school, you are not as independent as you might think. You are part of a global ecosystem that is made up of several smaller ecosystems. In fact, you are an ecosystem yourself, supporting many trillions of organisms who live on or in your body! You play a small role in a larger interdependent system where organisms depend on each other and the physical aspects of their environment to provide them with what they need to survive. In this chapter, you will look at the interaction of organisms and their environment. You will also explore how any activity that disturbs the interconnectedness will affect ecosystems.

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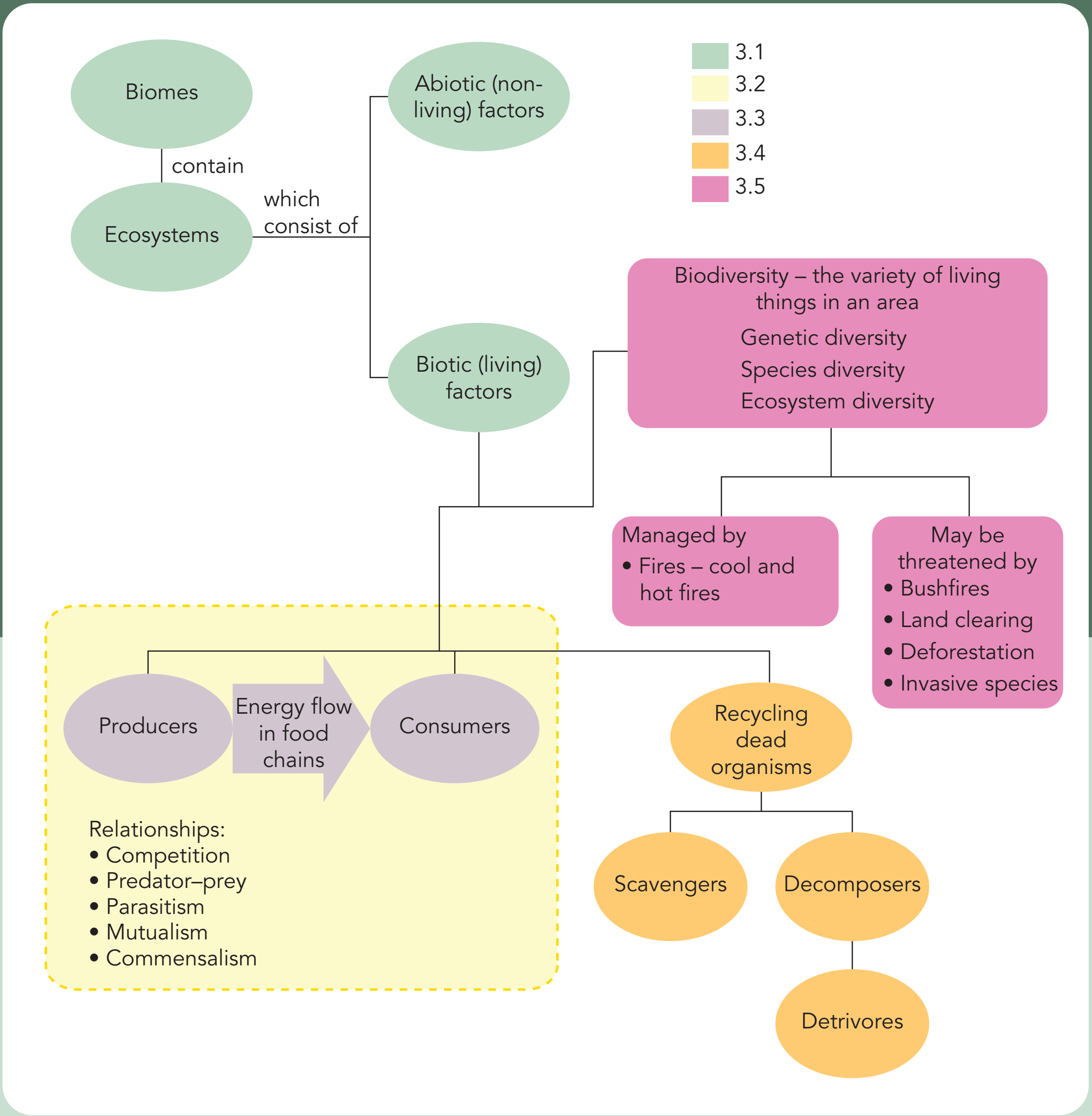
Concept map



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Curriculum

Use models, including food webs, to represent matter and energy flow in ecosystems and predict the impact of changing abiotic and biotic factors on populations (AC9S7U02)	
analysing food webs to show feeding relationships between organisms in an ecosystem and the role of microorganisms	3.3, 3.4
modelling how energy flows into and out of an ecosystem via the pathways of food webs	3.3
predicting the effects on local ecosystems when living things such pollinators or predators are removed from or die out in an area	3.1, 3.3
examining how events such as seasonal changes, destruction of habitat or introduction of a species impact abiotic and biotic factors and cause changes to populations	3.1, 3.2, 3.5
investigating First Nations Australians' responses to invasive species and their effect on food webs that many communities are a part of, and depend on, for produce and medicine	3.5
considering how First Nations Australians' fire management practices over tens of thousands of years have changed the distribution of flora and fauna in most regions of Australia	3.5

Glossary terms

10% rule
Abiotic
Abundance
Adaptation
Apex predator
Biodiversity
Biological control
Biome
Biopiracy
Biotic
Calicivirus
Carnivore
Cellular respiration
Citizen scientist
Chemotroph
Commensalism
Community
Consumer
Decomposer
Detritivore
Detritus
Ecological niche
Ecosystem
Egestion
Energy
Environment
Excretion
Firestick farming
Food chain
Food web
Greenhouse gas
Habitat
Herbivore
Herbivory
Interdependence
Interspecific
Intraspecific
Invasive species
Mesopredator
Microorganism
Mutualism
Omnivore
Parasitism
Pathogen
Photosynthesis
Pollinator
Population
Predator
Prey
Primary consumer
Producer
Rewilding
Scavenger
Secondary consumer
Symbiosis
Tertiary consumer
Trophic level

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3.1 Biomes and ecosystems

WORKSHEET
Biotic and abiotic

VIDEO
Biotic and abiotic features

Learning goals

1. To be able to recognise the difference between biotic and abiotic factors in an ecosystem.
2. To be able to state the various levels of organisation in an ecosystem.

A **biome** is an area of Earth that has a particular climate and certain types of living things. We classify biomes based on the physical **environment** and the main type of organisms that are found there.

Broadly, the five major biomes on Earth are aquatic, desert, forest, grassland and tundra.

Within biomes, there are different **ecosystems**. For example, within the broad forest biome, there are taiga forest ecosystems, temperate coniferous and broadleaf forest ecosystems, and tropical coniferous and broadleaf forest ecosystems. An ecosystem can be described as an area where living organisms interact with each other and the surrounding non-living environment. While a biome is a broad classification of an area, an ecosystem considers the interactions within that biome. All parts of an ecosystem are linked and even the smallest of changes can produce large effects.

Describing ecosystems

When scientists discuss ecosystems, they are referring to the interactions between the living (**biotic**) and non-living (**abiotic**) features within an area. Biotic factors consist of populations of different organisms plus the organic matter produced by them. Even though waste material such as faeces and bones is not living, it is considered biotic because it came from living things. Abiotic factors include physical things such as rocks and sand, but also things that can be measured such as temperature, wind speed and pH.

biome
a large environment that is classified based on various abiotic factors and the organisms that are found there

environment
the physical conditions in which an organism lives

ecosystem
the interrelationship between living and non-living components of a specific area

biotic
relating to the living things in an ecosystem

abiotic
relating to the non-living things in an ecosystem

Try this 3.1

Biomes

Using the photos a–e, work in small groups to decide what would classify a particular area into one of the five biomes. Consider the climate and type of organisms that you would find there.

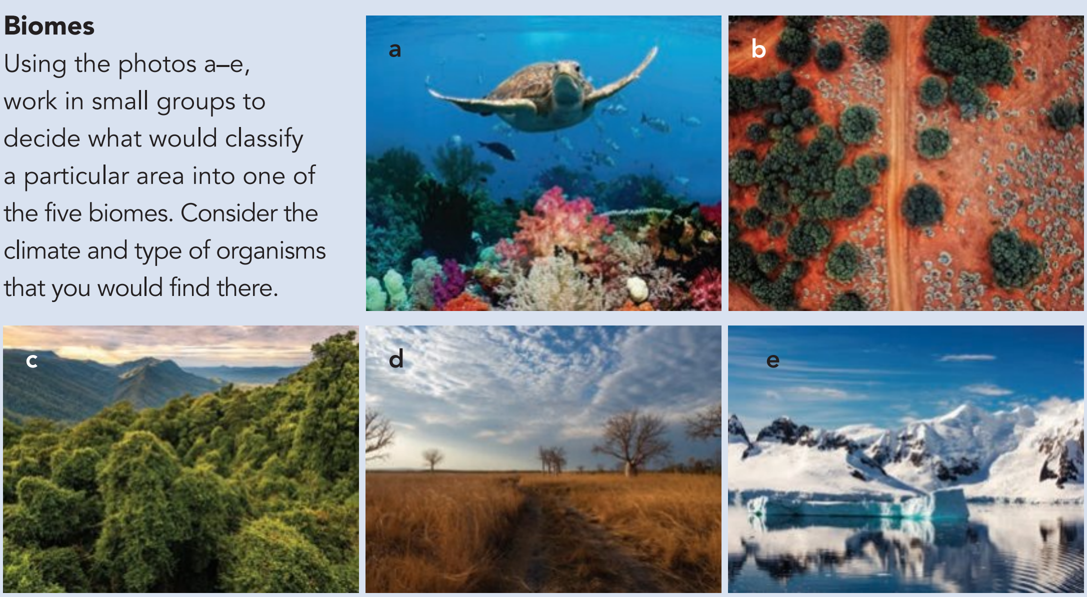

Figure 3.1 Biomes can be broadly divided into five main types: **(a)** aquatic; **(b)** desert; **(c)** forest; **(d)** grassland; **(e)** tundra.

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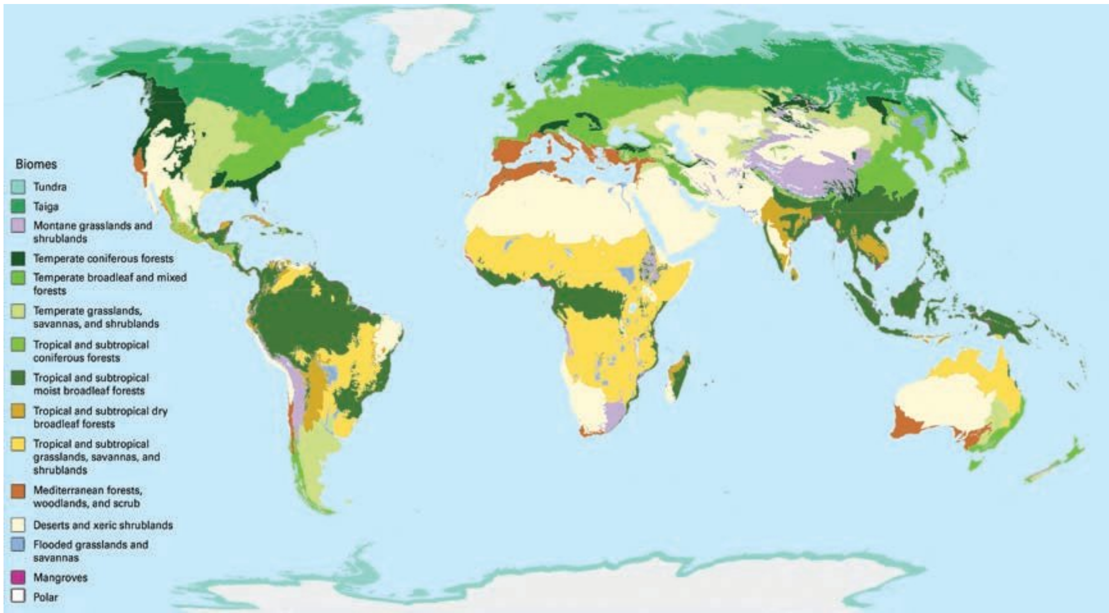

Figure 3.2 A world map showing different ecosystems

Some examples of biotic and abiotic features are listed in Table 3.1.

Biotic	Abiotic
Animals	Temperature
Plants	Light
Fungi	Water
Protists	Salinity
Bacteria	Humidity

Table 3.1 Some examples of biotic and abiotic features of ecosystems

If you are trying to decide if a feature of an environment is biotic or abiotic, you can remind yourself of the life processes displayed by all living things (see Figure 3.3) that you learned about in Chapter 2.

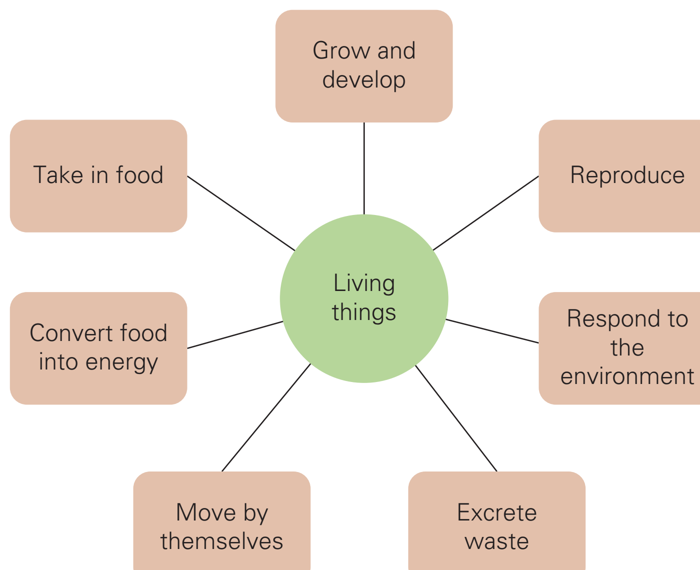

Figure 3.3 All living things demonstrate these seven processes

Habitats

All organisms have a specific set of needs that they require to survive and reproduce, and the area where they live that provides these needs is called their **habitat**. Each ecosystem is made up of many individual habitats that are the perfect places for specific organisms to survive. If you consider an ecosystem as a suburb where an organism lives, then the habitat is the organism's address in that suburb.

habitat
the place where an organism lives

Some of the requirements that an organism needs to survive:

- food
- water
- shelter
- space to live
- other similar organisms for reproduction.

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Try this 3.2

Desert ecosystems

A desert is an example of a biome, made up of the following desert types: hot and dry, semi-arid, coastal and cold. Munga-Thirri National Park, also known as the Simpson Desert, is a hot and dry desert that spans 1 012 000 hectares in the Queensland outback, making it the state's largest protected area. List as many biotic (living) and abiotic (non-living) features of this type of ecosystem as you can. The images in Figure 3.4 may help to inspire you. After you have tried on your own, chat with your classmates to see what other ideas they had that you can add to your two lists.

Figure 3.4 Three images of Munga-Thirri National Park

Figure 3.5 (a) Habitats can range in size from a single skin pore to huge forests. After studying human skin, scientists have discovered that each pore contains a single variety of *Cutibacterium acnes* bacteria.; **(b)** How many different habitats can you spot at Babinda boulders?

adaptation a characteristic that helps an organism survive in its environment

Every organism has its own habitat requirements. Some animals can survive in more than one habitat. Other animals are limited to specific habitats and may have **adaptations** that allow them to survive there. Although they prefer to live by the edges of forests next to grasslands, dingoes can be found in every habitat across every state of Australia except Tasmania. They are only limited by their access to water. However, the koala has adaptations that allow it to only eat toxic eucalyptus leaves so will only be found in habitats that support eucalyptus trees.

Adaptations can be classified into three types: structural, behavioural and physiological.

Structural adaptations are physical or anatomical features of an organism that enhance its chances of survival. For example, plants have protective thorns to reduce the risk of predation, and kangaroos have a long tail and powerful hindquarters for efficient locomotion.

Behavioural adaptations are actions taken by animals to increase their success in their environment. For instance, many species exhibit nocturnal behaviour to decrease the risk of predation.

Figure 3.6 The dingo can survive in a wider range of habitats than the koala.

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community
a group of animals or plants that live or grow together

population
all organisms of a particular species or group who live in one area

abundance
the number of individuals of a species within a community or ecosystem

Physiological adaptations are processes that occur within an organism's body systems or cells, improving its chances of survival. For instance, desert animals have highly efficient kidneys that enable them to conserve water in their arid environments.

Levels in an ecosystem

When scientists discuss the biotic aspects of an ecosystem, they can be described at different levels from large to small: **community**, **population** and individual. Table 3.2 summarises each level.

Level of organisation	Description
Community	A group of different organisms that live in the same area. For example, a community that is found on the Fitzroy River consists of mangrove trees, which provide shelter for the young and adults of many fish species. They also provide roosting and feeding opportunities for birds and bats. Their root network provides a habitat for crabs, snails, worms and insects.
Population	A group of the same species of an organism living in the same area. Their total number is called their **abundance**. For example, there is a population of bridled nailtail wallaby living in Taunton National Park, central Queensland.
Individual	One living organism

Table 3.2 The levels of organisation in an ecosystem

Did you know? 3.1

Threatened communities in Queensland

In Queensland, there are seven critically endangered communities and fourteen endangered communities.

One critically endangered community is the Mabi Forest, found on the Atherton Tableland. The name comes from the local First Nations Australian name mabi or mapi for Lumholtz's tree-kangaroo (*Dendrolagus lumholtzi*), a mammal found in this habitat. Research the other species that live in this unique community and decide why the Mabi Forest is considered critically endangered.

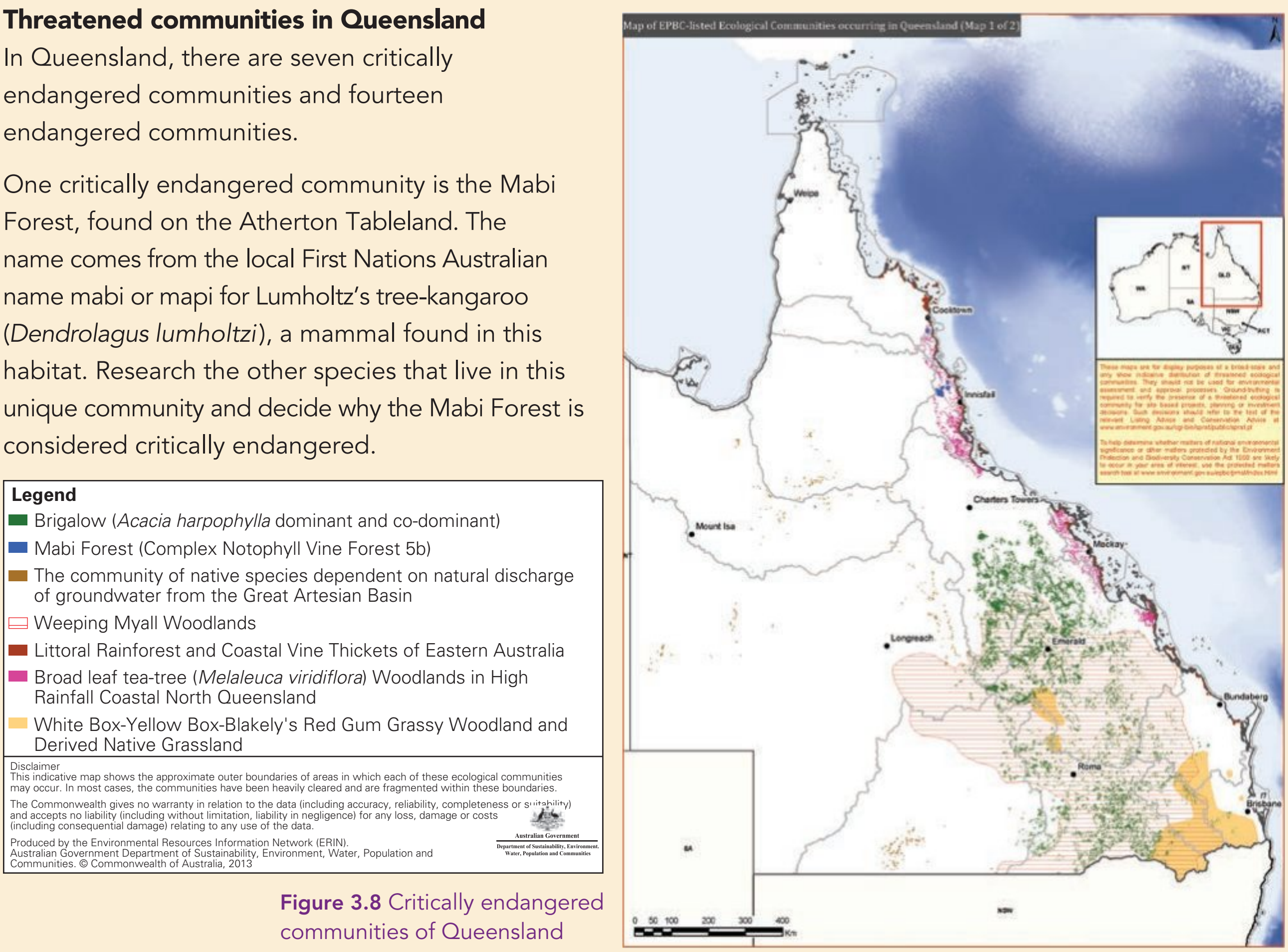

Figure 3.8 Critically endangered communities of Queensland

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Try this 3.3

Ecosystems

In small groups, come up with five different ecosystems and write them down. Then, as a class, list them on the board, avoiding any repetitions. Discuss whether some areas can be further broken down into several habitats.

Figure 3.7 Cape Tribulation, where rainforest meets reef. This is an example of many habitats in one area.

Quick check 3.1

1. Define these terms: ecosystem, biotic, abiotic, habitat.
2. Name four different types of ecosystems.
3. Name three examples of biotic and abiotic factors in an ecosystem.
4. Discuss what makes a habitat a home for a particular organism.

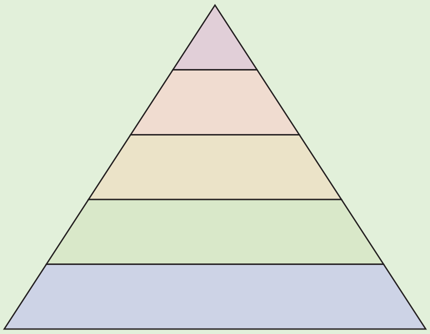
Try this 3.4

Demonstrating the organisation of ecosystems

Select a Queensland organism you find interesting. Some endangered examples are the Julia Creek dunnart, the mahogany glider and the northern bettong. On a piece of A3 paper, put the name of this organism in a small circle in the centre of your page – this is your individual. You may like to include a picture of your organism. Now draw a larger circle around your individual. This will be your population. Continue to add examples of each level of organisation as you work all the way up to a biome.

Quick check 3.2

1. Define the terms 'environment', 'community' and 'population'.
2. Name a specific habitat and propose a community, population and individual that would be found in that habitat.
3. Draw a pyramid like the image shown. Sequence the following terms to demonstrate the levels of organisation: individual, ecosystem, biome, population, community.



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Making thinking visible 3.1

Compass points: Laboratory-grown meat

Laboratory-grown meat sounds like something from a sci-fi movie, but we are closer than you might think to being able to easily buy it in your local supermarket.

greenhouse gas
a gas that traps heat in the atmosphere, leading to global warming

Making laboratory-grown meat is based on tissue engineering. Scientists take cell samples from animals and then identify nutrients required for the cells to grow. They are grown in a nutrient bath, and it takes about two weeks for the sample to grow to the desired size. The meat is then made into a finished product, such as a burger or steak.

Some of the proposed benefits of laboratory grown meat include:

- It's estimated that **greenhouse gas** emissions can be reduced by up to 96%.
- Improved animal ethics.
- Reduction in land required for livestock and growing livestock feed. Agriculture is the biggest cause of land clearing in Australia, and Queensland has one of the highest rates of clearance. The most recent available data shows that Queensland cleared 418 000 hectares in just one year. This is like clearing an area of forest and bushland the size of 154 Gabba stadiums every single day.
- Decreased water use. Agriculture accounts for over 70% of global water use and, by 2050, the UN predicts that 6 billion people will experience water shortages mainly due to an increasing global population.
- Addresses global food hunger. By 2050, the global population is expected to reach 9.8 billion, placing food production under greater stress.

Figure 3.9 Beef produced from cells and grown in a petri dish, compared to the real thing

Figure 3.10 One of the biggest global drivers of deforestation is agriculture.

Studies have shown that laboratory-grown meat will be cost-effective and ready for widespread consumption by 2030, but there are social, ethical and economic implications to consider.

Complete the Compass points activity about laboratory-grown meat:

E = Enthusiastic
What generates enthusiasm within you regarding this concept? What are the potential benefits?

W = Worries
What causes concern about this idea? What are the potential drawbacks?

N = Need for information
What other details or facts are necessary to evaluate this idea? What additional knowledge would aid in assessment?

S = Suggestion for progress
What is your current viewpoint or proposal regarding this idea? How can you continue to assess this concept?

The *Compass Points* thinking routine was developed by Project Zero, a research centre at the Harvard Graduate School of Education

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Section 3.1 questions

QUIZ

Retrieval

1 **Identify** the components of an ecosystem, from largest to smallest.
2 **Identify** some abiotic features found at the Great Barrier Reef.
3 **Identify** three biotic features of the Great Barrier Reef.
4 **Define** the term 'habitat'.
5 Look at Figure 3.11 and **identify** parts of the ecosystem such as communities, abiotic and biotic factors, populations and habitats.

Figure 3.11 The Glasshouse Mountains, Sunshine Coast hinterland

Comprehension

6 **Describe** how biomes are classified.
7 **Describe** the adaptations of a shark that make it suited to its environment.

Analysis

8 **Compare** the terms 'ecosystem' and 'environment'.
9 Using a Venn diagram, **compare** abiotic and biotic factors in an ecosystem. Give an example of each.

Knowledge utilisation

10 Environmental conditions are changing in ecosystems every day. **Propose** what changes in abiotic factors occur in a desert ecosystem over the course of a day and how these changes would affect the biotic parts of the ecosystem.
11 'All populations living together within a community interact with one another and with their environment to survive and maintain a balanced ecosystem.' **Decide** if you agree with this statement. Give reasons for your decision.

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3.2 Interactions between organisms and their environment

WORKSHEET
Interactions between organisms

Learning goal
To be able to describe five different species interactions in an ecosystem.

ecological niche
the role and space that an organism fills in an ecosystem, including all its interactions with the biotic and abiotic factors of its environment

interdependence
the dependence between different species in a community

symbiosis
a long-term close interaction between two organisms of different species

interspecific
occurring between members of different species

intraspecific
occurring between members of the same species

predator
an organism that obtains food by killing and consuming other organisms

prey
an organism hunted and killed by another organism for food

herbivory
the consumption of plants

Abiotic factors affect the overall distribution and abundance of organisms within an ecosystem. Some organisms have a narrow tolerance range for a certain abiotic factor, such as temperature, and this will determine where they can live.

The role and space that an organism fills in an ecosystem, including all its interactions with the biotic and abiotic factors of its environment, is known as its **ecological niche**. This includes its habitat, feeding relationships and interactions with other organisms.

These species interactions within the community may help, harm or have no effect on the organisms involved. In some cases, some organisms may require other organisms to survive; this is known as **interdependence**. Competition, predation and **symbiosis** are the three main types of species interactions.

Competition

VIDEO
Interspecific and intraspecific relationships

Organisms occupying the same ecological niche will compete with one another for resources that are in limited supply. This occurs when different organisms require the same resources to survive, such as food, space, shelter and mates. **Interspecific** competition is competition for resources between members of different species. For example, kangaroos and sheep compete for grass as their major food source. In contrast, **intraspecific** competition occurs between members of the same species.

Quick check 3.3

1 Define the terms 'interspecific competition' and 'intraspecific competition'.
2 Describe what happens when two species are competing for food, and one species is better adapted or stronger.

Predation

A predator–prey relationship occurs when one organism, known as the **predator**, kills and eats another organism, known as the **prey**. **Herbivory** is a type of predation where the prey is a plant. It is unusual for predators to depend upon one species of prey, so if one prey species reduces in supply, the predator can prey upon other species. For example, dingoes prey on rabbits, but can also eat other small mammals. The relationship between predator and prey is usually balanced, but occasionally this can change. For example, favourable conditions may lead to an increase in the prey population, which in turn can lead to an increase in the number of predators. If a period of adverse conditions occurs to reduce the prey population, predators will turn to another prey species and there may be an increase in intraspecific competition among the predators.

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WORKSHEET Predator–prey relationships

Try this 3.5

Predator–prey relationships

Feral rabbits do have natural predators such as the red fox; however, their ability to reproduce quickly has seen rabbits continue to thrive within Australia. Generally, if there is a shortage of prey, then there will be fewer predators surviving in that environment. Another predator and prey relationship occurring in the deserts of Australia is that of the red kangaroo and the dingo. The dingo is the apex predator in this biome and although they do not usually prey on kangaroos, they will hunt and kill them when food is scarce. Using Figure 3.12, answer the following questions.

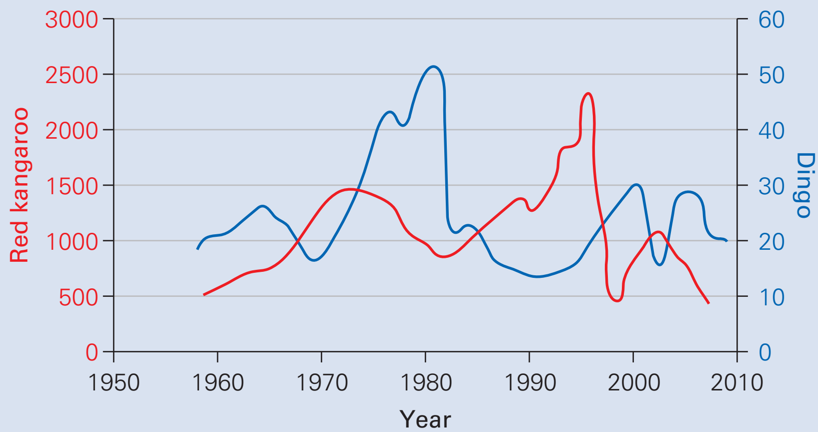

Figure 3.12 Population sizes over time for the dingo (in blue) and the red kangaroo (in red)

1. When was the greatest abundance of red kangaroos?
2. What happens to the dingo population as red kangaroo numbers increase?
3. Examine what happens to the dingo population size when the red kangaroo population size decreases.
4. Describe the pattern of the predator–prey relationship shown in the graph.
5. Identify and discuss a factor, other than the red kangaroo population, that may influence the size of the dingo population.
6. Identify and discuss a factor, other than the dingo population, that may influence the size of the red kangaroo population.

Symbiosis

Symbiosis is an interaction where individuals from two different species share a close and long-term relationship with each other. There are three major types of symbiosis: mutualism, commensalism and parasitism.

Mutualism

Mutualism is a symbiotic relationship between two organisms in which both benefit from the association. For example, plants have a mutualistic relationship with **pollinators**. Some plants, like grasses, are pollinated by wind, but many flowering plants rely on insects, birds or small mammals to transfer pollen from one plant to another. In a plant–pollinator relationship, the pollinator benefits as it feeds on the nectar provided by the flower. In return, the plant benefits as the pollinator transferring pollen allows the plant to reproduce.

mutualism a symbiotic relationship where both organisms benefit

pollinator an organism that moves pollen from one plant, or part of a plant, to another

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Figure 3.13 The relationship between the goby fish and the alpheid shrimp is mutualistic.

commensalism
a symbiotic relationship where one organism benefits and the other neither benefits nor is harmed

parasitism
a symbiotic relationship where a parasite benefits from living on or in a host (which is harmed)

Another example is the alpheid shrimp and goby fish. Alpheid shrimps are near-blind, so they dig burrows to stay safe. However, when above ground, they are vulnerable to predators. When foraging or excavating outside of their burrows, a goby fish will stand guard at the entrance to the burrow. The shrimp will always be in antennal contact with the goby fish tail, which the fish will flick whenever there is danger. Both members of the relationship benefit: the goby fish gets a burrow to live in, while the shrimp is warned of predators.

Commensalism

Commensalism is a symbiotic relationship in which one organism benefits, while the other organism is not affected (neither is harmed nor benefits). These types of relationships are much rarer than mutualism or parasitism. One example is that of the pearl fish and sea cucumber. The pearl fish spends its day in the intestines of the sea cucumber, emerging at night to feed on small crustaceans.

Figure 3.14 Army ant raids are a coordinated hunting swarm of thousands and sometimes millions of ants. The ants spontaneously move out of their nest, moving together across the forest floor to hunt for food.

The pearl fish is protected from predators while inside the sea cucumber, who does not appear to be harmed. Other examples include birds following army ants when they raid forest floors. During the raid, birds will feed on the flying insects that are stirred up.

Parasitism

Parasitism is a symbiotic relationship in which one species benefits and the other is harmed. The species that benefits is called the parasite and the one that is harmed is the host. The host is harmed, but rarely killed, as then the parasite would die too! Instead, the parasite survives on or in the host, taking nutrients or growing and reproducing in organ systems, causing disease.

There are two main types of parasites: ectoparasites and endoparasites. 'Ecto' means outer or external, so ectoparasites live on the surface of other organisms; for example, lice or ticks. 'Endo' means inner or internal, so endoparasites are found living inside other organisms; for example, worms or protozoans.

The main types of interactions are summarised in Table 3.3.

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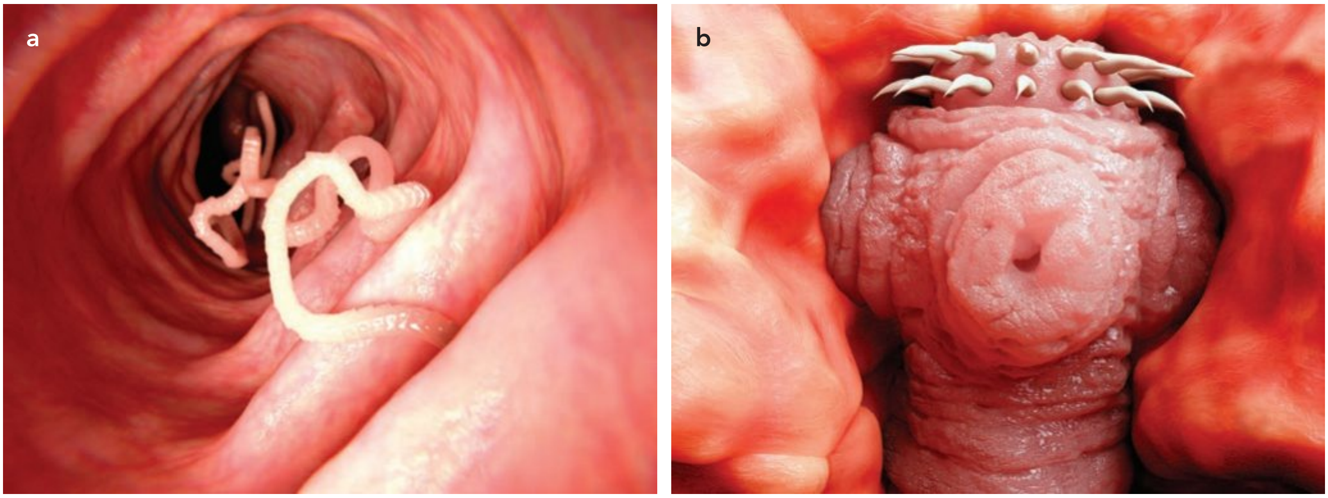

Figure 3.15 These tapeworms are endoparasites that inhabit the digestive tracts of animals (including humans). Tapeworms use their specialised hooks to anchor themselves in the intestine and absorb nutrients through their body wall. Disturbingly, they can grow to several metres in length, but they do not necessarily cause symptoms.

Interaction	Species 1	Species 2	Example
Competition	Harm	Harm	Kangaroos and sheep both compete for grass.
Predation	Benefit	Harm	Crocodiles prey upon insects, fish, frogs, lizards, crustaceans and small mammals.
Herbivory	Benefit	Harm	A koala eating eucalyptus leaves
Parasitism	Benefit	Harm	The mange mite burrows into the skin of wombats where it lays its eggs and causes irritation.
Mutualism	Benefit	Benefit	The boxer crab carries a pair of small anemones in its claws. When a predator approaches, the crab waves the anemones around, deterring the predator due to the stinging tentacles. The anemones benefit as they get small particles of food from the crab during feeding.
Commensalism	Benefit	No effect	Cattle egrets walk close to where cattle are grazing because the cattle stir up insects from the vegetation that the egrets can eat.

VIDEO Relationships between organisms

Table 3.3 Summary of some of the different interactions that occur in an ecosystem. The bottom three interactions are symbiotic interactions.

Figure 3.16 Examples of **(a)** parasitism, **(b)** mutualism and **(c)** commensalism

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Making thinking visible 3.2

Connect, extend, challenge: Interactions with living things

Biologists must often interact with living things, both in the laboratory and the field. Ideas about ethics have changed over time, and now there are regulations surrounding interactions with living things.

Despite their large size, whale sharks are hard to track. Previously, DNA samples were taken with a harpoon, which was expensive and invasive.

But whale sharks shed their DNA directly into the ocean via skin, faeces, mucus and other biological material. This is called environmental DNA or 'eDNA' and scientists are now simply analysing seawater samples to track individual whale sharks. This is a cheaper and more ethical option to monitor species.

Complete the 'Connect, extend, challenge' activity below.

After reading about interacting with living things, reflect on the following:

- How do the concepts and details connect to your existing knowledge?
- Which new insights did you gain from the text that expanded your understanding or encouraged you to consider new perspectives?
- What questions arise for you after processing this information?

Figure 3.17 A scientist using a harpoon to collect a whale shark DNA sample

The *Connect, extend, challenge* thinking routine was developed by Project Zero, a research centre at the Harvard Graduate School of Education

Quick check 3.4

1 Complete the following table, describing the types of relationships between organisms. Use a smiley face, sad face or neutral face to represent how each organism is affected.

Relationship	Definition	Organism 1	Organism 2
Competition			
Mutualism			
Commensalism			
Parasitism			

2 Contrast an ectoparasite and an endoparasite.

Try this 3.6

What is the interaction?

Look at each of the following images and, with a little research, decide which type of interaction is being demonstrated.

Figure 3.18 Examples of different types of interactions between organisms: **(a)** a leech on human skin, **(b)** two kangaroos fighting and **(c)** a lemon shark with a remora fish on its back

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Section 3.2 questions

QUIZ

Retrieval

1 **Define** the terms 'parasitism', 'mutualism' and 'commensalism'.

2 Using what you have learned about interactions in ecosystems, **name** an example of each of the following interactions in which humans are involved.
- a mutualism
- b parasitism
- c commensalism
- d predator–prey
- e interspecific competition
- f intraspecific competition

3 When there is a large increase in the population size of an animal that is prey, **recall** what tends to happen to the population size of the predators.

Comprehension

4 **Explain** what is meant by an organism's 'ecological niche'.

5 A bee feeds on the nectar from a flower. **Explain** why this is an example of mutualism.

Analysis

6 Look at the graph in Figure 3.19:
- a **Identify** which line colour represents the population of dingoes over time.
- b **Determine** the population of dingoes in the year 2000.
- c **Identify** the year that had the largest dingo population.
- d **Identify** the pattern between the two populations with reference to the terms 'predator' and 'prey'.
- e **Deduce** the population of red kangaroos when the population of dingoes was at its peak.
- f **Infer** why the red kangaroo population was greatest in the mid-1990s.
- g In the year 2015 the red kangaroo population fell to a trough of approximately 300 in this region. **Predict** how the dingo population might have changed in this time.
- h **Predict** the populations of red kangaroos and dingoes in 2030 given the data in the graph.

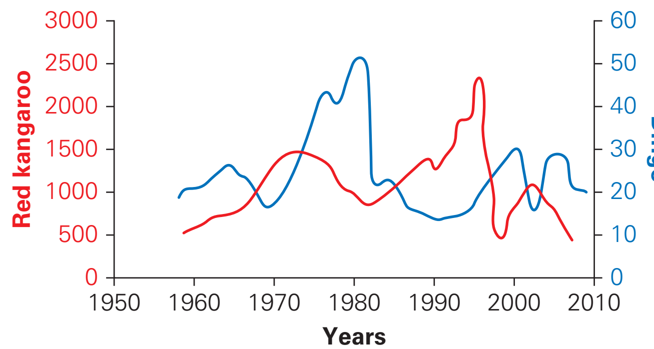

Figure 3.19 Red kangaroo and dingo populations from 1950 to 2010

7 **Compare** an ectoparasite and an endoparasite, providing examples for each.

8 **Examine** the role of mutualistic relationships within ecosystems, using examples not already used in this chapter.

Knowledge utilisation

9 **Justify** the importance of both interspecific and intraspecific competition within an ecosystem.

10 **Decide** whether the following descriptions are examples of mutualism, commensalism or parasitism.
- a A man has tinea (a fungus) growing between his toes.
- b A woman notices her cat looks very bloated. She takes it to the vet and they suggest deworming the cat, as it probably has tapeworm.
- c Small fish swim around on the back of whale sharks for protection from predators.
- d Birds stand close to wild buffalo and eat the insects that are stirred up as the buffalo graze.

11 If all the predators from an area were removed, **discuss** the positive and negative effects on the ecosystem.

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3.3 Food chains and food webs

WORKSHEET
Food web

Learning goals

1. To be able to analyse food webs to show feeding relationships.
2. To be able to describe how energy flows through an ecosystem.
3. To be able to predict the effects on ecosystems when living things are removed from an area.

Energy

When it comes to **energy**, ecosystems are not closed. They need a constant input of energy, and the ultimate source of energy for most ecosystems is sunlight. Plants convert this light energy and can make their own food. The chemical energy in the food can then be used by the plant. Animals cannot produce energy directly from the Sun. Instead, they must eat plants or other animals that eat plants to gain the chemical energy trapped in food.

energy
the ability to do work

cellular respiration
the chemical process by which cells release energy from food

Once an organism has acquired its food, it can release the energy trapped at a cellular level in a process called **cellular respiration**.

Figure 3.20 All the energy in an ecosystem originally came from sunlight.

Figure 3.21 The plant can convert light energy into its own food, but the spider must hunt for its own food.

This is the cellular respiration word equation:

glucose + oxygen → energy + carbon dioxide + water

The energy produced in cellular respiration is used for all the processes in each living organism. Organisms use the energy to grow and reproduce, repair and replace their structures, and respond to their environment. A common mistake is to think that plants do not perform cellular respiration because they make their own food. In fact, they must do cellular respiration, otherwise the chemical energy in the food they produce would never get released.

Quick check 3.5

1. Define the term 'energy' in your own words.
2. Explain what energy is needed for.
3. Explain why cellular respiration is a necessary process carried out by all living things.
4. Name the inputs and outputs of the process of cellular respiration.

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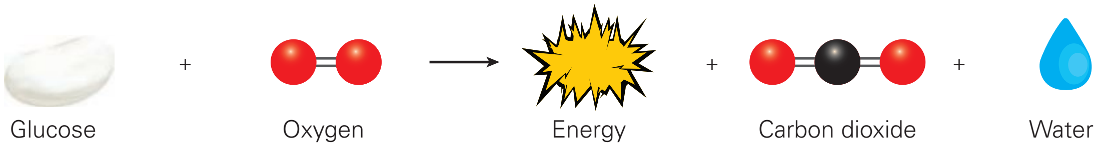

Figure 3.22 The process of cellular respiration

Producers

Plants make their own food through a process called **photosynthesis**. Using the light energy from the Sun, water and carbon dioxide from the atmosphere and nutrients from the soil, they chemically make their own food. Since they make their own food, they are called **producers**.

This is the word equation for photosynthesis:

$$\text{carbon dioxide} + \text{water} \xrightarrow{\text{light}} \text{glucose} + \text{oxygen}$$

Plants then break down the sugars in the process of cellular respiration, which then releases energy. This energy is used to grow, reproduce and repair themselves.

Figure 3.23 Plants will bend towards the light to increase photosynthesis.

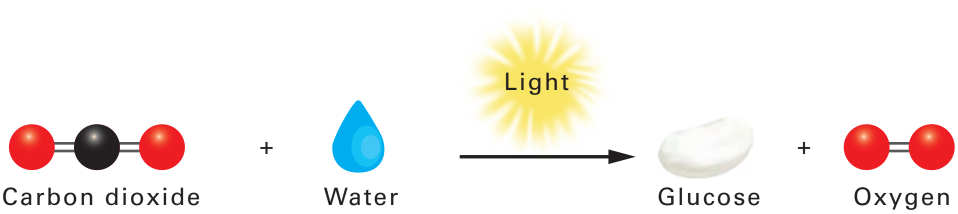

Figure 3.24 Photosynthesis

photosynthesis
the process by which a plant uses the energy from the light of the Sun to produce its own food

producer
an organism capable of producing food from photosynthesis

Quick check 3.6

1. Discuss why plants are called producers.
2. Explain why photosynthesis is a process carried out by plants.
3. Name the inputs and outputs of the process of photosynthesis.

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Investigation 3.1

Observing photosynthesis

Be careful

Bromothymol blue can be harmful when inhaled. Blow into the balloon and then use the balloon to bubble carbon dioxide into the water. Do not blow directly into the solution. Ensure the room is well ventilated and wear appropriate personal protective equipment.

Aim

To investigate the effect of changing light intensity on photosynthesis

Time period

Approximately 2–3 days

Prior understanding

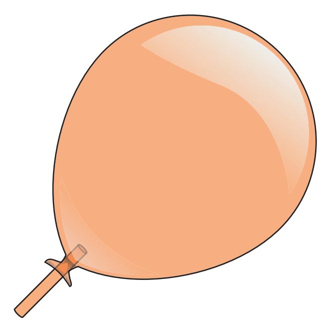
Photosynthesis uses carbon dioxide (CO_2), water and light energy to make glucose and oxygen. Aquatic plants extract dissolved carbon dioxide from the water to photosynthesise. A way to measure the amount of dissolved carbon dioxide in the water is to add the indicator bromothymol blue. Water will appear yellow when a high concentration of carbon dioxide is present and turn to blue as the concentration of dissolved carbon dioxide is reduced.

Materials

- aquatic plant
- bromothymol blue solution (acts as an indicator to show if photosynthesis is occurring)
- 4 small conical flasks
- 500 mL beakers
- large measuring cylinder
- straws
- balloons
- aluminium foil or stopper

Method

1 Pour 320 mL of water into a 500 mL beaker.
2 Add enough drops of bromothymol blue solution to turn the water a pale blue colour.
3 Blow up a balloon and insert a straw into the end of it as shown, pinching it shut to hold in the air.
4 Dissolve carbon dioxide into the water by inserting the straw into the beaker and gently releasing the air into the solution, causing it to bubble through for approximately 1 minute until the water turns pale yellow.



5 Label each conical flask with the following information:

Group 1: Control	Group 2: Light	Group 3: Control	Group 4: Dark
Description: No plant in light	Description: Plant in light	Description: No plant in dark	Description: Plant in dark
Date:	Date:	Date:	Date:
Student/s name:	Student/s name:	Student/s name:	Student/s name:

6 Measure out 80 mL of bromothymol blue + water solution from step **4** and pour it into one of the four conical flasks. Repeat this for each of the three remaining flasks.
7 Add a 7 cm piece of the aquatic plant to the Group 2 and Group 4 flasks. Use the straw to gently push the plants into the water to make sure they are submerged.

continued …

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… continued

8 Cover each flask with aluminium foil or a stopper.

9 Copy the table shown in the results section into your science book.

- Label the independent variable and its groups in the table.
- Label the dependent variable in the table.

10 Record the initial colour of the water in each flask.

11 Position the flasks as described on the label.

- Group 1 and Group 2 flasks next to a window
- Group 3 and Group 4 flasks in a cupboard away from any light.

12 Observe the flasks after 2–3 days. Has the colour changed?

Results

	Dependent variable		
Independent variable	**Initial water colour**	**Final water colour**	**Change in dissolved carbon dioxide?** • None • Some reduction • Substantial reduction
Group 1 ______________			
Group 2 ______________			
Group 3 ______________			
Group 4 ______________			

Analysis

1 Identify any trends, patterns or relationships in your results.

2 Explain what a change of colour means in terms of whether photosynthesis is occurring in the plant. What does it mean when the solution is yellow? What does it mean when the solution is blue?

Evaluation

Limitations

1 Discuss if there was any change in the control flasks. Explain why you think that is.

2 Explain the importance of having flasks with no aquatic plants.

Improvements

3 Did you have any errors during this experiment that you could have minimised? Propose any changes that could be made to the method to improve the quality of the data in future experiments.

Conclusion

State a conclusion about the relationship between light and photosynthesis in plants.

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consumer
an organism that obtains food from consuming other organic material

herbivore
an organism that eats only plants

omnivore
an organism that is naturally able to eat both plants and meat

carnivore
an organism that eats only meat

Consumers

Organisms which cannot create their own food from sunlight must eat either plants or animals for energy. These organisms are called **consumers**. Some organisms get their energy from directly eating plants, while others will eat other animals that have already eaten plants. Organisms that eat only plants are called **herbivores**. Organisms that eat both plants and other animals are called **omnivores**. Organisms that eat only other animals are called **carnivores**.

Figure 3.25 (a) Pademelons are herbivores. **(b)** Brush-tailed possums are omnivores. **(c)** Kookaburras are carnivores.

Try this 3.7

How do I get my food?

Complete some research and organise the Queensland organisms in Figure 3.26 into producers, herbivores, carnivores or omnivores.

Dugong

Bush-stone curlew

Rakali

Torresian crow

Callistemon

Platypus

Figure 3.26 Queensland organisms

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Did you know? 3.2

Life deep under the sea

Up until around 35 years ago, scientists believed that all life relied on energy gained from photosynthesis. Research on underwater volcanic vents, far deeper than light could penetrate, uncovered some unusual bacteria species. Instead of using light, the bacteria use chemicals produced by the vents to create chemical energy. This is a process known as chemosynthesis and these species are known as **chemotrophs**.

chemotroph
an organism that obtains energy through chemical processes in its environment

However, chemotrophs can also be found in areas away from volcanic vents, surviving on the hydrogen sulphide produced by decomposing whale carcasses. You may know the smell of this gas if you've ever smelled rotten eggs or a stink bomb!

In 2022, 230 pilot whales became stranded at a beach near Macquarie Harbour in Tasmania. Sadly, these mass whale strandings happen regularly and scientists are unsure why. Although some of the whales were saved, many died. Males can weigh approximately 2300 kg and take a long time to decompose, so authorities had to decide what to do with the remaining carcasses.

The carcasses were towed 40 km out into the Indian Ocean, before being dropped in the deep water. At these depths, food sources are not common, so 'whale fall' is more important than you might think. Some research suggests that 43 different species can be supported by just one whale carcass.

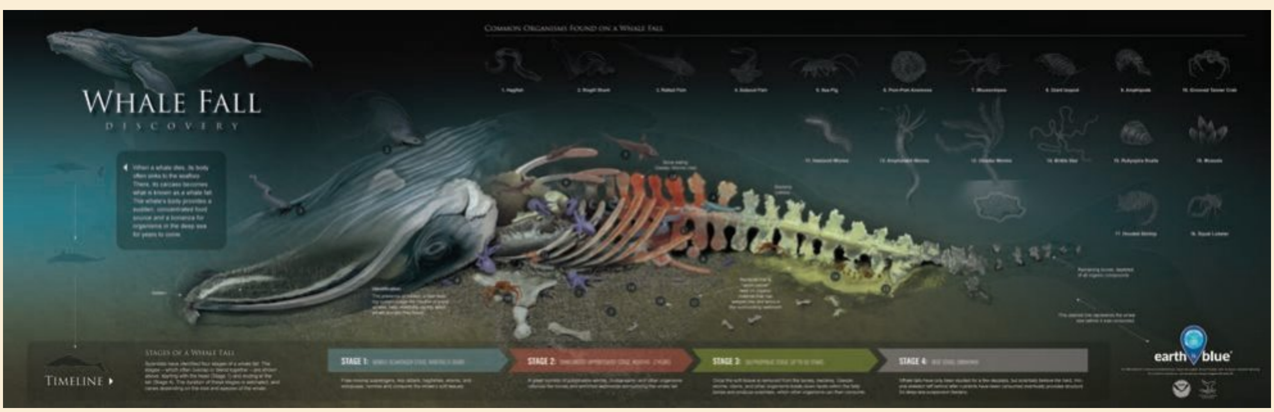

Figure 3.27 Stages of whale fall

Identifying types of consumer

One way that biologists can identify if a consumer is a carnivore, herbivore or omnivore is by looking at their teeth. Members of each type of consumer display similar features to others in that group.

Humans are natural omnivores, which means that we have evolved to eat both plants and animals. This is why we have a range of different teeth. At the front of our mouth are the incisors. These are sharp, flat, cutting teeth. They are used to bite or shear off pieces of food. Herbivores use these teeth to nibble away at plants and, as they are used constantly, they tend to wear down. Due to this, the incisors of animals like rabbits and wombats continue growing throughout their lives. Other herbivores such as cattle and sheep lack upper incisors. Instead, they cut grass with their lower jaw incisors against a dental pad.

VIDEO
Recycling in the deep ocean

The long, sharp, pointed teeth next to incisors are called canines. They are near the front of the mouth and are used to hold and tear at food. Carnivores have large, well-developed canines that they use to catch and kill their prey. Many herbivores lack canines as they do not hold and tear at the food they eat. Carnivores also have carnassial teeth, modified paired teeth that are used for shearing meat.

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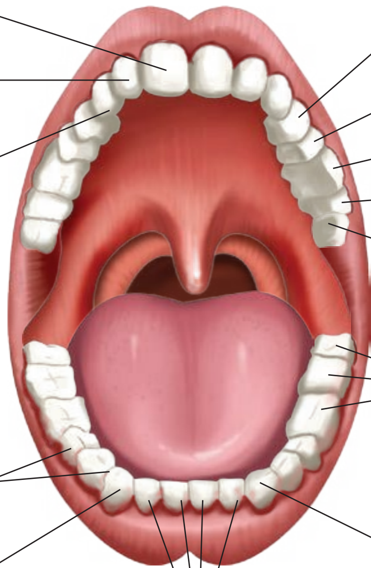

Figure 3.28 Human teeth identify us as omnivores.

The flat teeth at the back of your mouth are known as pre-molars and molars. These teeth are for chewing and grinding and are found in herbivores, carnivores and omnivores. Herbivores have large, almost flat molars that allow them to grind plant material into very small pieces before swallowing.

Figure 3.29 The dental pad of a grazing animal

Figure 3.30 Elephant tusks are elongated incisors!

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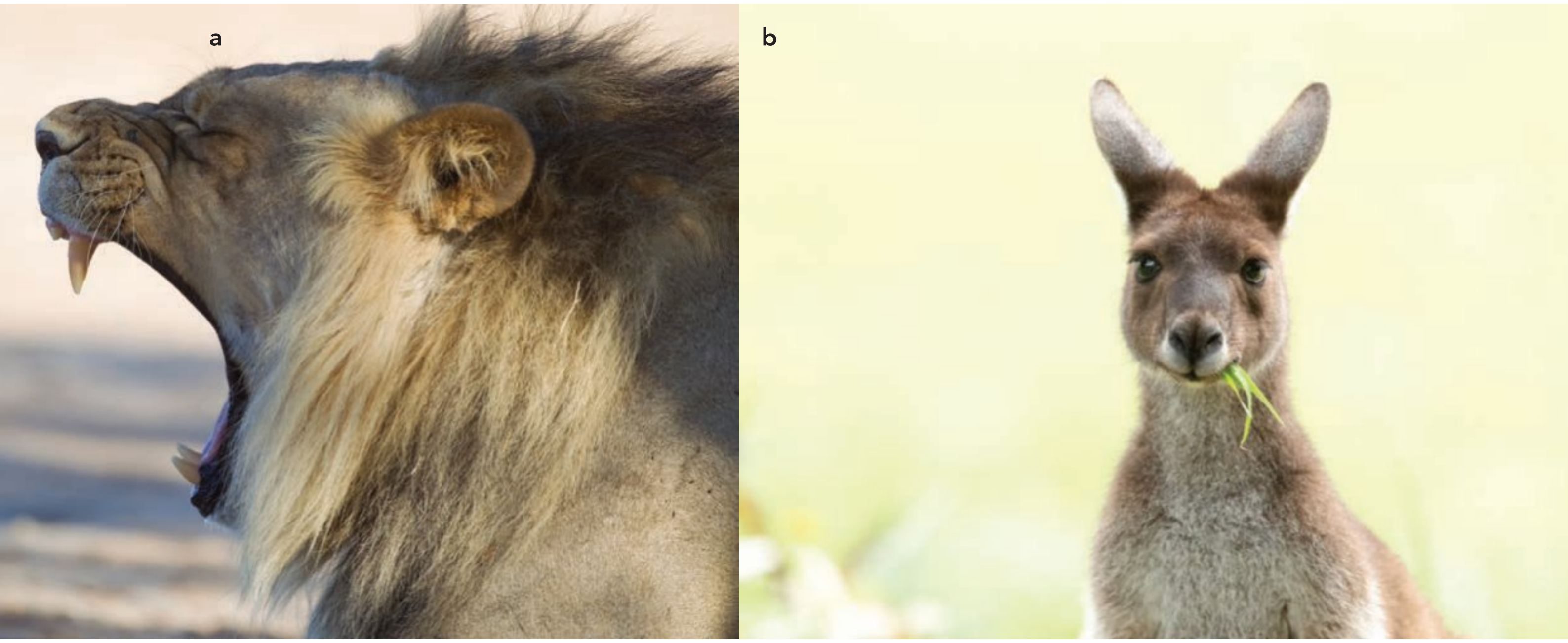

Figure 3.31 (a) Lion canines can grow up to 10 cm long.; **(b)** The molars of kangaroos replace themselves when they wear down. They fall out and their rear molars move forward.

Try this 3.8

Animal teeth

Look at the animal skulls below. You may be able to identify some of the animals you see but take on the role of a scientist and check their teeth. Do they have incisors? Canines? Molars? Can you confirm what the animal might eat and therefore have more evidence as to what the animal is? You may like to tabulate your observations and then compare with your classmates.

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Quick check 3.7

1. Define the term 'consumer' in your own words.
2. There are three main types of consumer.
   a. Name the three types.
   b. State what each group eats.
3. Examine the images in Figure 3.32 and for each determine:
   i. the type of teeth
   ii. the structure and function of the teeth
   iii. the animal types in which those kinds of teeth are found.

Figure 3.32 Images of different types of teeth

VIDEO Australian apex predators

Food chains: Who eats whom?

food chain
a sequence of living things that shows their feeding relationship and the flow of energy between them

Food chains show the feeding relationships in an ecosystem. Each organism is food for another organism – they are interdependent. The energy trapped in an organism will be passed to the organism that feeds on it. The arrows show the flow of energy through the food chain.

An example of a simple food chain would be:

grass → mouse → hawk

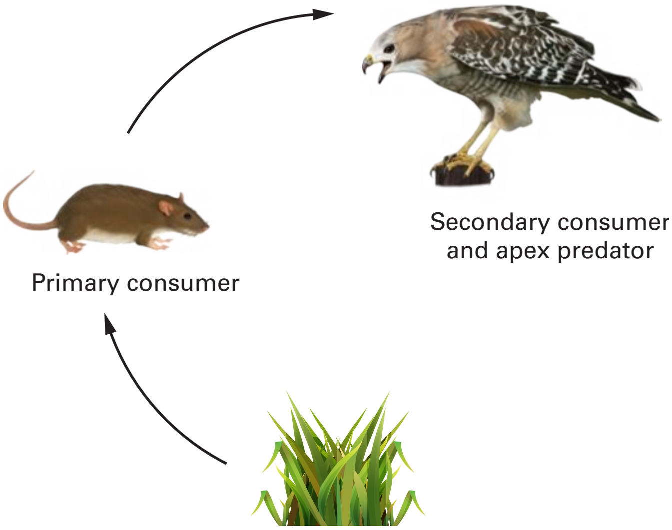

Figure 3.33 A hawk is an example of an apex predator as it has no natural predators

The food chain in Figure 3.33 introduces some new terms, which are explained in Table 3.4.

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Term	Definition	Example
Primary consumer	The first consumer in the food chain that eats the producer and is therefore always a herbivore	Termites eat a wattle tree (producer)
Secondary consumer	A consumer that eats the primary consumer or herbivore. Are usually carnivores, but can be omnivores.	Numbat eats the termites (primary consumer)
Tertiary consumer	A consumer that eats the secondary consumer	Dingo eats the numbat (secondary consumer)
Apex predator	A consumer at the top or end of the food chain that usually has only humans as a possible predator	Dingo

Table 3.4 Consumers can be classified into these groups based on their position in a food chain

primary consumer an organism that eats plants

secondary consumer an organism that eats primary consumers

tertiary consumer an organism that eats secondary consumers

apex predator a predator at the top of a food chain

Figure 3.34 Numbats are secondary consumers

Quick check 3.8

1 Define the term 'food chain'.
2 Recall where the Sun should go in a food chain and why.
3 Draw an Australian food chain of your choice and identify the producer, primary consumer, secondary consumer, tertiary consumer and apex predator.
4 Recall what sort of information you can find out from looking at a food chain.

Try this 3.9

What food chains can tell us

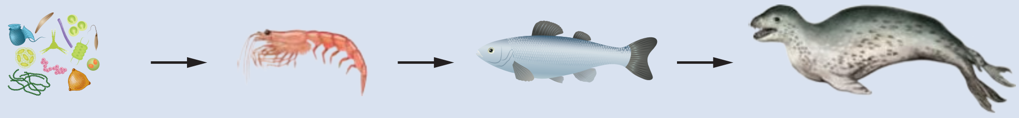

Figure 3.35 What does this food chain tell us?

1 State what the arrows show the flow of.
2 Identify where all the energy originally comes from.
3 Identify the producer, first consumer, second consumer, tertiary consumer and apex predator.
4 Identify the herbivore.
5 Predict what would happen if:
   a fairy penguins moved into the area and ate all the krill before the fish could get to it
   b a local commercial fishing company over-fished the area
   c chemicals running off farmland killed all the phytoplankton.

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food web
a group of interconnected food chains

trophic level
refers to an organism's level or position in a food web. It is based on an organism's feeding habits, where producers occupy the first trophic level

10% rule
when energy is passed from one trophic level to another, only 10% of the energy will be passed on

egestion
the process of removing undigested waste material from the body in faeces

excretion
the process of removing metabolic waste from the body

Food webs

There are many different types of organisms in any habitat and most communities are not made of single food chains. A **food web** is made up of interconnected food chains and represents multiple pathways through which energy can flow through an ecosystem.

Although there are many food chains displayed in the food web in Figure 3.36, there is a maximum of four organisms in each food chain.

Energy flows in one direction up the food chain but is lost from each **trophic level** as it passes from the producers to each consumer. Typically, only 10% of the energy is passed on to the next trophic level and is therefore available to the next consumer. This is known as the **10% rule**. The rest of the energy is lost to the environment in the following ways:

- Energy is lost as heat when the organism respires.
- Not every part of the organism is eaten. Roots and tough woody parts of plants, and the bones of animals, are not directly consumed.
- Consumers cannot digest all the food they eat (for example, cellulose in plants or the hair and fur of animals), so the chemical energy in this food is lost in **egestion**.
- **Excretion** causes energy to be lost in waste products.

This means that there can only be a limited number of animals at the top of the food chain as there is less energy available for them. Figure 3.38 shows this loss of energy. Note that kcal is a unit of energy. It is equal to about 4000 joules.

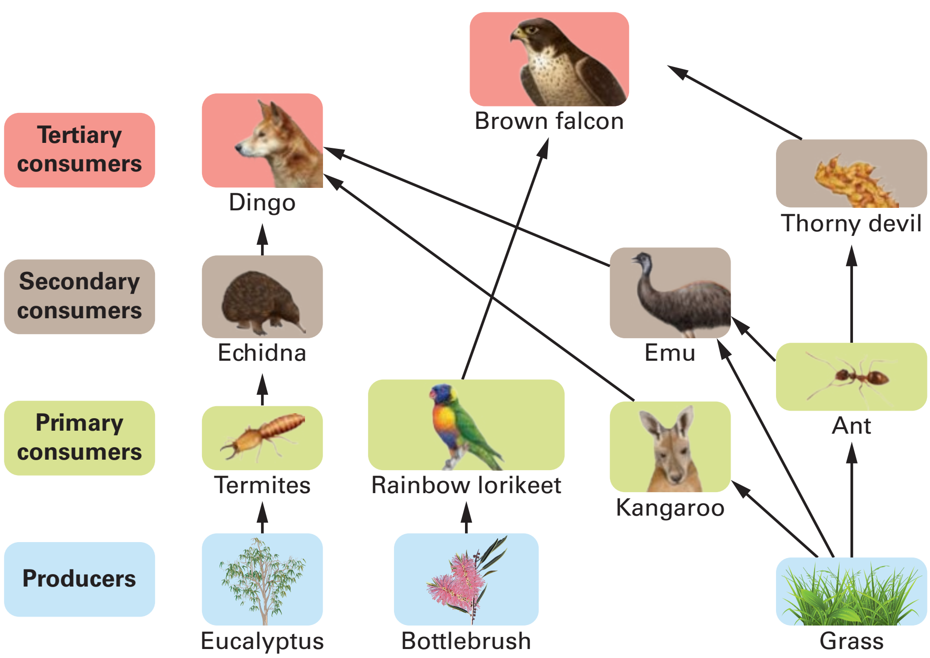

Figure 3.36 An example of an Australian food web

WIDGET
Food web

Did you know? 3.3

Hindgut fermentation

Members of the Lagomorpha family such as rabbits and hares are herbivores, eating mostly grass. However, this cellulose-rich diet is difficult to digest and so a lot of energy is lost in their faeces. The animals can access this energy though, with a special type of digestion called hindgut fermentation. In short, they eat their own faeces and digest it a second time to maximise the energy they can get! If you ever spot any rabbit droppings, you may notice that there are two different types: small round black ones, and bigger softer ones. The bigger ones are called cecotropes and are the ones that are eaten.

Figure 3.37 Rabbits eat their own cecotropes.

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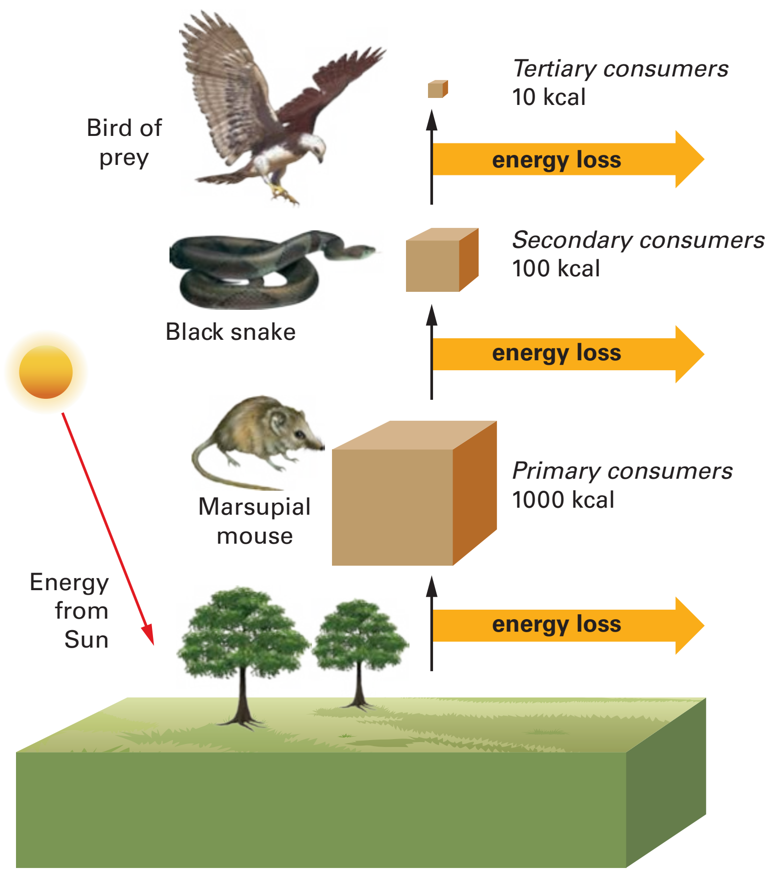

Figure 3.38 The energy flow and loss through a food chain

Worked example 3.1

Use Figure 3.38 to answer the following questions.

a If the snake consumes 350 kcal of energy, and it is eaten by the eagle, calculate how much energy would be available to the eagle.

b Calculate how much energy was originally available to the mouse from the producers.

Working	Explanation
a energy for eagle = 10% × 350 kcal $= \frac{10}{100} \times 350$ kcal OR 0.1 × 350 kcal = 35 kcal	By the 10% rule, only ten per cent of 350 kcal will be available to the eagle. 10% is equivalent to $\frac{10}{100}$ or 0.1.
b $350 \text{ kcal} = \frac{10}{100} \times$ energy for mouse energy for mouse $= \frac{100}{10} \times 350$ kcal = 10 × 350 kcal = 3500 kcal	If the snake had 350 kcal available, and that was ten per cent of what was available to the mouse, then the mouse would have had 3500 kcal available to it.

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Quick check 3.9

1 Explain what a food web is.
2 Recall what organisms need energy for.
3 Describe how energy is lost from an organism or a food chain.
4 Summarise what you notice about the amount of energy (kcal) that is passed on from the producers to the primary consumers and from the primary consumers to the secondary consumers.
5 *Challenge question*: Using Figure 3.38, calculate how much energy is passed on as a percentage of the original amount of kcal.

Try this 3.10

Food web model

Model the flow of energy in food webs from producer to consumers using the following materials:

- photos of producers, primary consumers, secondary consumers, tertiary consumers and apex predators, in the normal ratio of these types of organisms in the wild
- different coloured balls of yarn
- scissors

Instructions

1 Each student will be allocated a photo.
2 Stand in a circle as a class. A student with a photo of a producer will take the end of the piece of yarn. The piece of yarn will represent the flow of energy along the food chain.
3 The producer should choose what primary consumer it wishes to be eaten by and pass that person the ball of yarn. (The producer should keep hold of the end of the yarn.)
4 The primary consumer will then choose the secondary consumer they wish to be eaten by and pass them the ball of yarn.
5 Repeat this process with the secondary consumer.
6 When the yarn reaches the apex predator, cut it, but each person in the chain should keep hold of it.
7 Take a photo each time a food chain is made, so that the development of the web can be seen.
8 Start a new chain, by starting a new piece of yarn in a different colour. Try to pick different organisms at first, but you can also re-use organisms. Repeat this process many times, starting with different producers.
9 A complex web will form between you and your classmates.
10 Discuss the complex nature of the food web you have produced as a class.
11 Ask one organism in the food web to 'die' by dropping the string. Discuss as a class the effect that the loss of that organism from the ecosystem would have on the remaining organisms.

Discussion

1 Follow one of the threads of yarn and write down a food chain.
2 Describe the effect that removing a producer from this food web would have.
3 Explain why an ecosystem with many types of organisms would be able to cope with the loss of one species.
4 Critique whether your model of a food web accurately depicts a real ecosystem.
5 Propose one way in which this model could be improved.

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Explore! 3.1

How Tasmanian devils can change ecosystems

The dingo is Australia's largest carnivorous mammal, first appearing on the mainland between 5000 and 3500 years ago. During this time, the Tasmanian tiger and Tasmanian devil, two marsupial predators, went extinct from the mainland but remained on Tasmania, somewhere the dingoes never colonised. This suggests that dingoes probably contributed to the extinction of these marsupial predators.

Dingoes are widely regarded as pests in Australia because they prey on livestock, so their populations are often managed using poisoned bait, trapping and shooting. There is some evidence that reducing dingo populations can affect other species.

A reduction in dingo numbers has been connected to increases in the abundance of invasive predators such as the red fox and feral cat (known as **mesopredators**). It has also led to increases of herbivores like kangaroos and wallabies that consume large amounts of vegetation. This then causes a decline in small and medium sized native mammals due to increased mesopredator predation and reduced food supply. Research suggests that cats kill more than 2 billion wild animals in Australia each year. One study estimated that in just a single day, Australian cats kill 1.3 million birds, 1.8 million reptiles and over 3.1 million mammals.

In 2020, 26 Tasmanian devils were reintroduced to the mainland at Barrington Tops, New South Wales, and it is suggested that they can be used as an alternative apex predator and will deter or disrupt the hunting of mesopredators. They are not as great a threat to livestock as dingoes, but by competing directly with feral cats and foxes, they have positive effects on smaller mammals. Native mammals enrich soil, increase plant diversity and disperse seeds, helping forest regeneration. As scavengers, Tasmanian devils can also help keep ecosystems free from disease, and by burying leaf litter, they help reduce fuel loads and make bushfires less intense.

The reintroduction of Tasmanian devils to the mainland may also save the endangered species. Their population has been devastated over the past few years due to devil facial tumour disease (DFTD), an infectious cancer. It is hoped by **rewilding** disease-free individuals, the species may again thrive on the mainland.

Figure 3.39 In Queensland, the dingo is a restricted invasive animal.

Figure 3.40 Tasmanian devils are ecosystem engineers that restore and rebalance ecosystems, benefiting other native wildlife.

Figure 3.41 European colonisers tried to introduce foxes to Tasmania and failed every time, possibly because Tasmanian devils were already established there.

mesopredator
a predator in a mid-ranking trophic level, which usually hunts smaller animals

rewilding
the process of protecting an environment and returning it to its natural state, for example by bringing back wild animals that used to live there

continued …

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... continued

Research the ecosystem changes that may be brought about by the reintroduction of Tasmanian devils.

1 Name four organisms that are affected by the presence of dingoes.
2 Explain why foxes were never successfully introduced to Tasmania by European colonisers.
3 Explain why Tasmanian devils are described as 'ecosystem engineers'.
4 'The impact of producers on an ecosystem is greater than that of apex predators.' Evaluate this statement and give your opinion.

QUIZ

Section 3.3 questions

Retrieval

1 **State** how the flow of energy is represented in a food chain.
2 **State** the process by which plants produce their own food.
3 **Name** the components that plants need to make food.
4 **Define** these terms:
   a carnivore
   b herbivore
   c omnivore
5 Look at the food web in Figure 3.42.
   a **Identify** three food chains in the food web.
   b **Identify** the producers and apex predators based on the diagram.
   c **State** the organisms that dingoes eat.
   d **Identify** any organisms that are secondary and tertiary consumers.

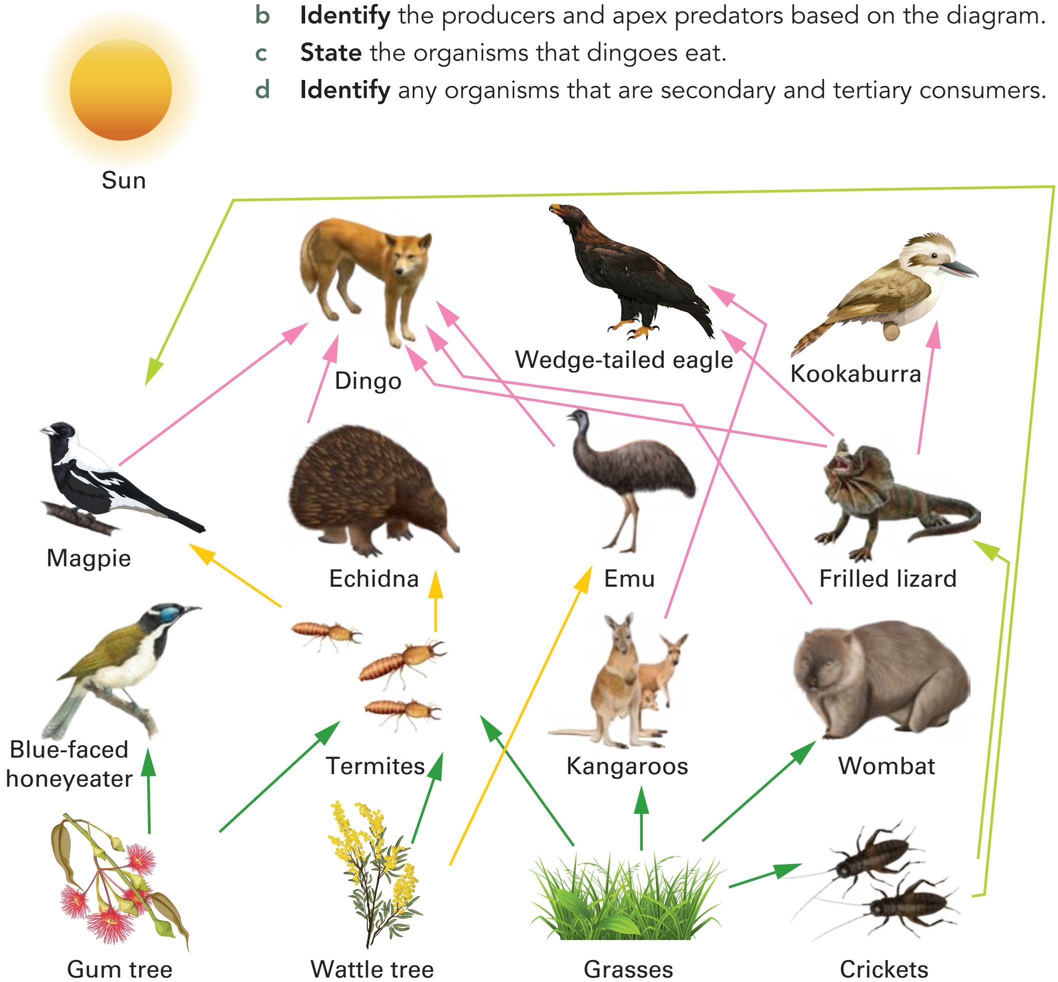

Figure 3.42 A food web

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Comprehension

6 **Explain** why all food chains must contain a producer.

7 **Describe** the impact on the ecosystem in Figure 3.42 if a fungus killed all the grasses.

8 The blue-faced honeyeater is a pollinator. **Describe** the impact on the ecosystem in Figure 3.42 if the blue-faced honeyeater was removed.

Analysis

9 **Compare** a herbivore to an omnivore.

10 **Distinguish** between food chains and food webs and then determine why food webs are more useful to scientists.

Knowledge utilisation

11 Look at the ecosystems in Figure 3.43 and **discuss** which food web is more likely to survive an environmental disaster.

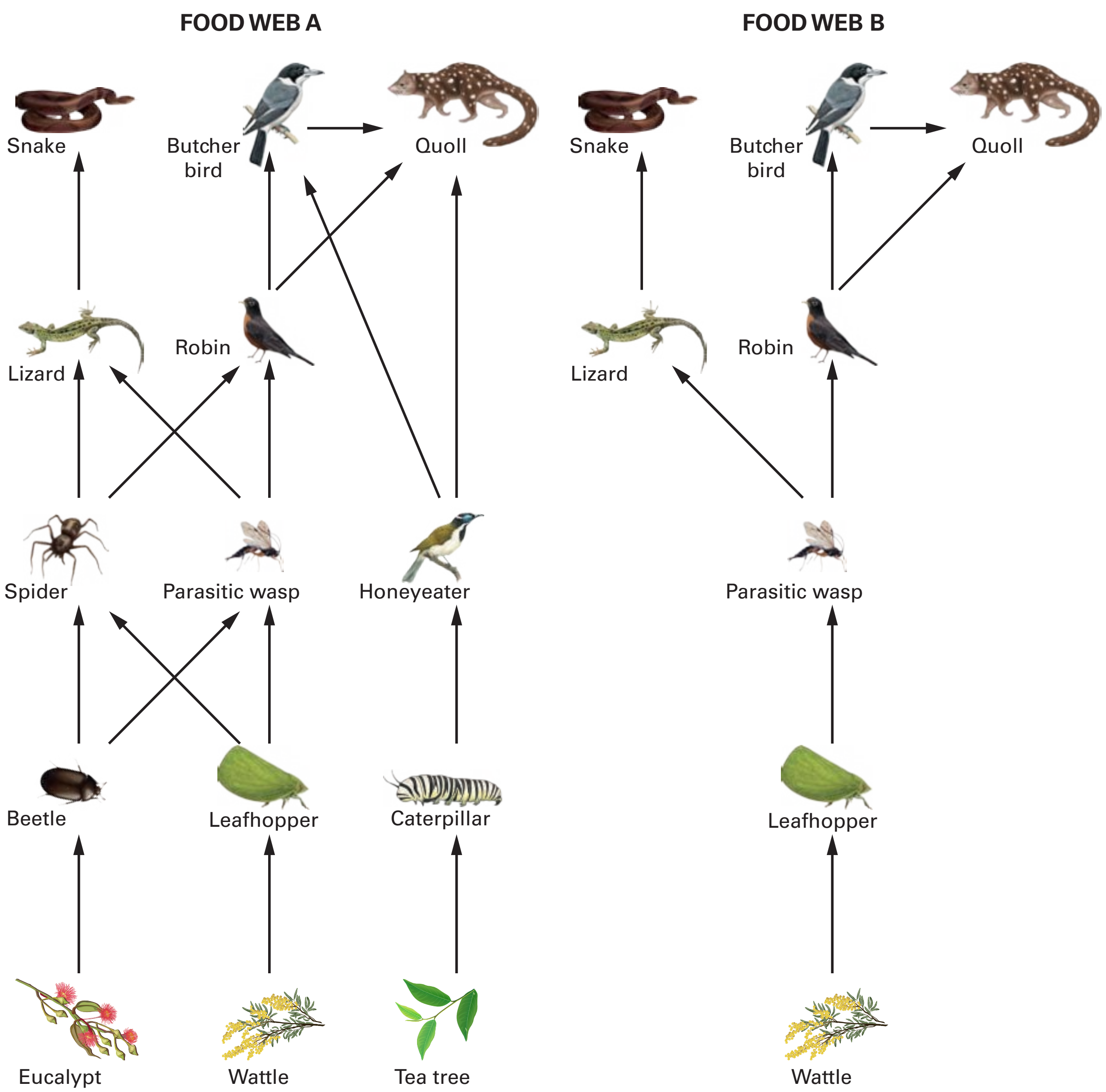

Figure 3.43 Two different ecosystems support these two food webs.

12 **Propose** a reason that a herbivore would not be able to eat meat easily.

13 **Predict** two effects of removing a predator from a food web.

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3.4 Recycling in ecosystems

DOC
WORKSHEET
Decomposer and scavengers

Learning goals

1. To understand the role of microorganisms in an ecosystem.
2. To be able to classify organisms according to their position in a food chain.

scavenger
an organism that feeds on dead animals that it has not killed itself

detritivore
an organism that feeds on dead or decaying organic matter

detritus
dead organic waste or debris

decomposer
an organism such as a bacterium or fungus that breaks down organic material

You already know consumers get their energy from producers or other consumers, and that producers get their energy from the Sun. This is the basis of the green food web, which is based on energy initially gained from green plants.

Any energy that is within an organism is not trapped in it forever. The energy is passed to the next trophic level when the organism is eaten, but some parts of the organism and the organism's waste may not be eaten. This material, as well as dead organisms, becomes **detritus** and starts the brown or detritus food chain.

All living things within an ecosystem can therefore fall into three categories:

- organisms that make their own food (producers)
- organisms that eat other living organisms (consumers)
- organisms that contribute to recycling dead and waste material (**scavengers**, **detritivores** and **decomposers**).

The brown food chain is directly linked to the green food webs found in every ecosystem. When detritus is included in a food web diagram, it shows the complex and important interaction that decomposers have in an ecosystem.

Scavengers

Scavengers start the recycling process of dead animals. They don't directly kill their prey, instead eating carrion, or animals that have been killed by other predators. Normally, they don't eat things that have been dead for a long time but do use their heightened sense of smell to locate carrion. They may also follow predators and feed on their leftovers.

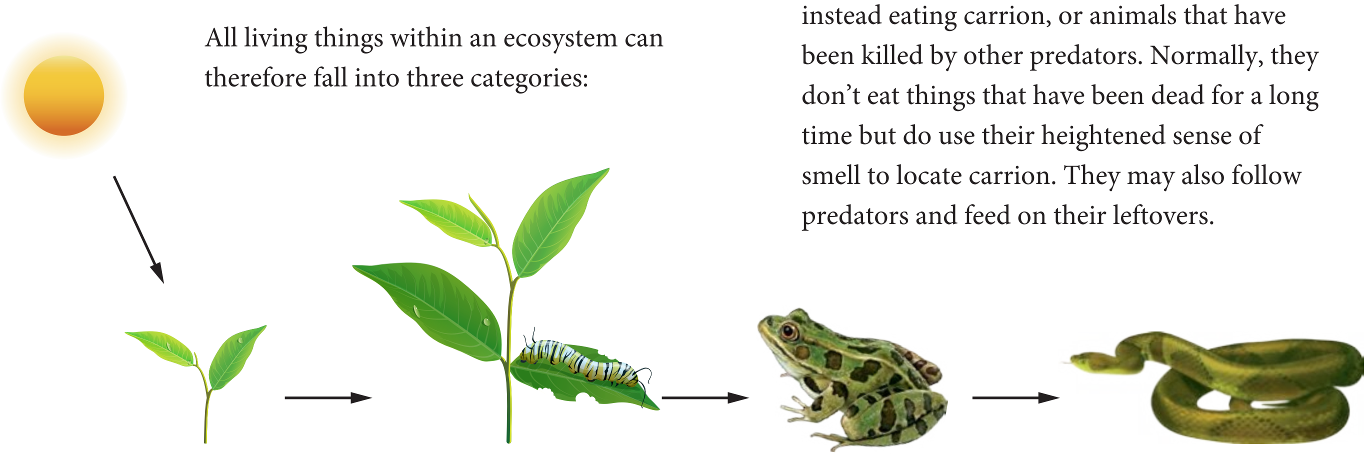

Figure 3.44 Green food chain

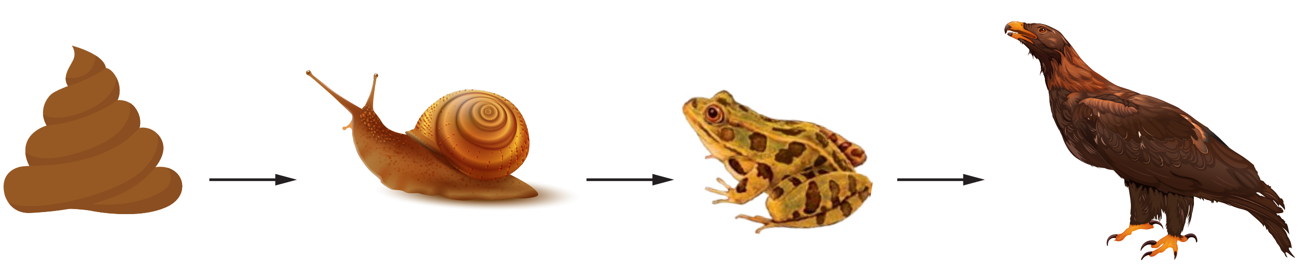

Figure 3.45 Brown food chain

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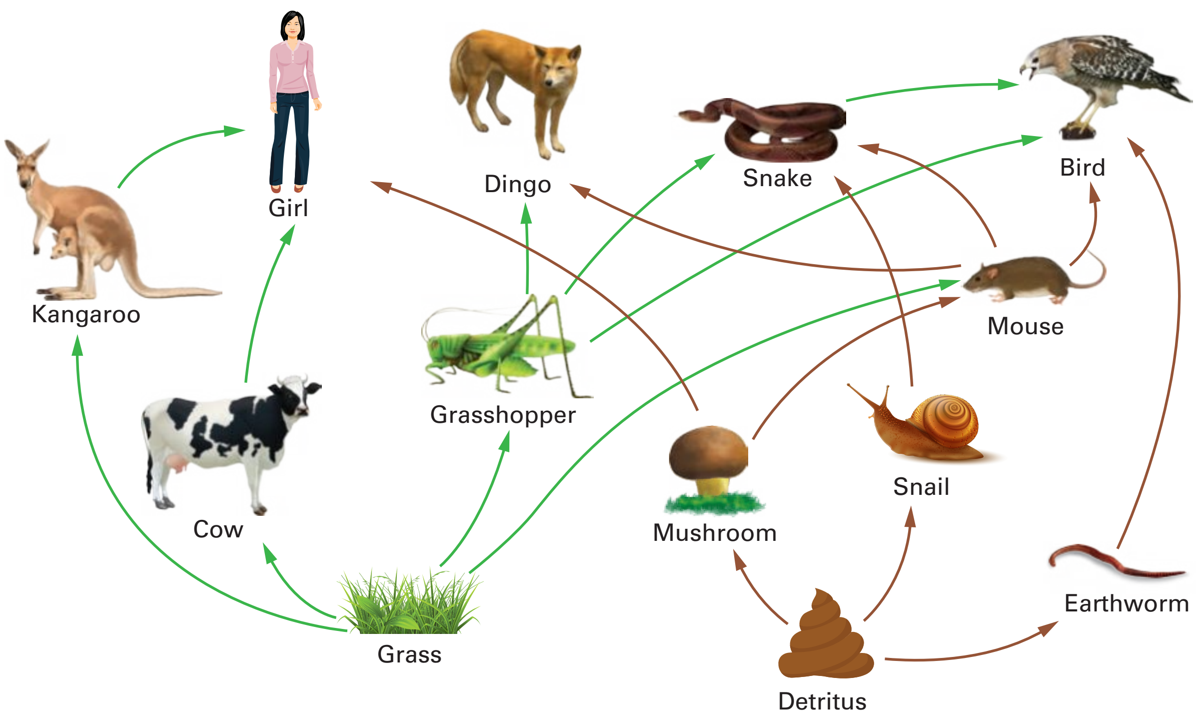

Figure 3.46 Combined green and brown food webs

Did you know? 3.4

Scavengers detecting gas leaks

Natural gas used for cooking and heating has no odour and is invisible. After a gas leak at a Texas school killed nearly 300 students and teachers in 1937, it became common practice to add foul-smelling gases that would allow humans to detect the presence of natural gas.

One of these pungent gases is called ethanethiol and is the same gas that is released by carrion. The turkey vulture is a scavenger that finds its food by smell, so they are sometimes found gathering around leaking pipelines. With nearly five million kilometres of gas pipeline in the USA, there are now more modern ways to track pipeline leaks, but turkey vultures were once used by natural gas companies to pinpoint pipeline leaks.

Figure 3.47 Scientists discovered that turkey vultures find their food by smell and not sight when an oil worker mentioned that the birds congregated at gas leaks along the pipeline!

Scavengers can be found anywhere in the world – on land and in marine environments. In Australia, they include monitors (carnivorous lizards), spotted-tail quoll, dingoes and Torresian crows. The role of scavengers is vital for any ecosystem as they contribute to the decomposition process by breaking down carrion into smaller pieces.

Figure 3.48 Meat ants are such effective scavengers that farmers in rural Australia can use them to remove animal carcasses from their land.

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Detritivores

Detritivores are also involved in recycling nutrients. They have mouthpieces that help speed up decay by ingesting detritus, which they then digest and egest. These smaller sized pieces increase the surface area available for decomposers to break down. Detritivores include beetles, flies, slugs, snails and earthworms. Marine detritivores include crabs, lobsters, sea stars and sea cucumbers.

microorganism
an organism that can only be seen through a microscope

Figure 3.49 Decomposition provides the nutrients to support new life.

Decomposers

Decomposers gain their energy by breaking down already dead organisms. Bacteria and fungi are examples of decomposers. Often **microorganisms**, they secrete chemicals called enzymes that break down the dead organisms and can then absorb the products. When decomposers break down organic matter, nutrients are released back into the soil, which plants then use to grow. This then supports a new green food chain.

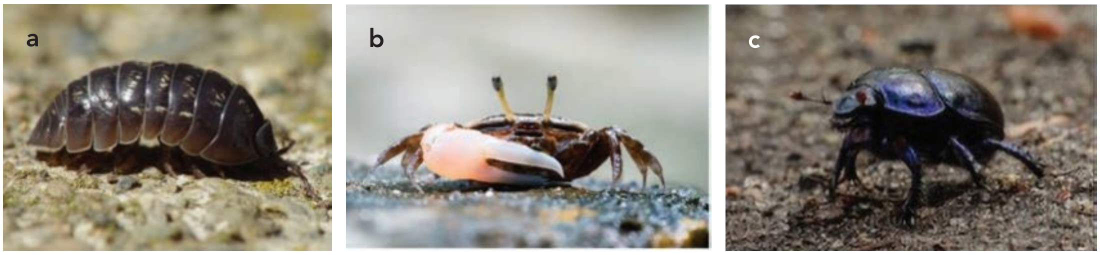

Figure 3.50 Examples of detritivores: **(a)** woodlice, **(b)** fiddler crabs and **(c)** dung beetles

Did you know? 3.5

Plastic-eating bacteria

Normally, bacteria spend their time breaking down dead and decaying organic matter, but scientists collecting plastic bottles outside of a recycling facility in Japan discovered a species that has developed a taste for a type of plastic called polyethylene terephthalate (PET). Named *Ideonella sakaiensis* after the Japanese city Sakai where it was found, the bacterium can use PET as its energy source. Scientists are now replicating and modifying the plastic-degrading enzymes in a lab so that they can be used on an industrial scale to break down plastics that would otherwise remain in the environment.

Figure 3.51 Globally, one million plastic drinking bottles are purchased every minute. It is hoped that the enzymes produced by *Ideonella sakaiensis* will help address the world's growing single-use plastic problem.

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Quick check 3.10

1 Define the terms 'scavenger' and 'decomposer'.
2 Define the term 'detritivore'.
3 Explain why plants rely on decomposers.
4 Distinguish between detritivores and decomposers.

Investigation 3.2

Friendly bacteria

Aim

To design a method to fairly investigate how different types of yoghurt affect the growth of harmful bacteria.

Time period

Approximately 1.5 weeks

Prior understanding

Harmful bacteria are in the air and on all surfaces around us. Raw food, such as fruits bought at the grocery store, can be contaminated by harmful bacteria due to handling. These **pathogens** do not usually cause a problem: when the fruit is consumed, the bacteria are destroyed either by the acidic environment of the stomach or by the good bacteria that live in each person's intestine. However, some bacteria evade these immune defences and cause food poisoning. It is recommended that fruits be washed well before consuming to avoid food poisoning. However, this is not easily done with soft fruits such as strawberries. Another option has been presented and requires investigation. Could covering fruit with yoghurt (which contains cultures of good bacteria) be used to disinfect soft fruit before consumption?

Be careful

Do not open the experimental container once the experiment begins. Do not consume any food products in the lab. Ensure all materials are disposed of in the appropriate manner.

pathogen
an organism that can cause illness

Materials

- different types of cultured yoghurt (3 is recommended)
- 1 strawberry or another type of soft fruit
- 4 sealable food containers
- 1 small paint brush

Planning

1 Develop a research question for this investigation.
2 Identify the dependent variable and state how it will be measured.
3 Identify the independent variable and describe the different groups that will be set up for the experiment.
4 Develop a hypothesis by predicting how a change to the independent variable will affect the dependent variable.
5 Identify the controlled variables and describe how these will be managed to prevent any controlled variables from affecting the measurements.

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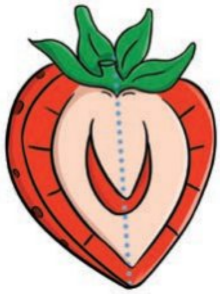
Method

1 Label each container with the following information:

Group number:
Type of yoghurt:
Date:
Student/s name:

2 Cut each strawberry into four pieces vertically as shown.



3 Leave one piece of strawberry untouched to use as a control (comparison) and paint each of the three remaining pieces with a different type of yoghurt.

4 Place each piece of strawberry in separate containers labelled with the yoghurt type.

5 Seal the container by placing the lid on tightly.

6 Monitor the experiment for 9 days, recording observations and taking photographs of each container, every 3 days.

7 If any part of the set-up is changed, then note the reason for this.

Results

1 Collect each container but DO NOT OPEN for safety reasons.

2 Measure the amount of bacterial growth (in terms of area) for each group and record the results. Your teacher may direct you to create a table and graph on a spreadsheet or on paper.

3 Calculate the mean measurement for each *independent variable group*.

4 Calculate the range for each independent variable group on the table.

5 Graph the mean of each group's data.

Analysis

Describe any trends, patterns or relationships in your results.

Evaluation

Reliability

1 Describe how much variation was observed between the measurements within each group.

2 Discuss whether the controlled variables were managed properly to ensure they did not change and affect the measurements.

Improvements

3 Describe changes that could be made to the method to improve the quality of the data in future experiments.

Conclusion

Discuss which yoghurt (if any) could best be used to disinfect soft fruit instead of washing it. Justify your answer by discussing your experimental results.

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Section 3.4 questions

QUIZ

Retrieval

1 **State** what happens to an organism in an ecosystem after the organism dies.
2 **Name** three examples of decomposers.

Comprehension

3 **Describe** why decomposers are an important part of an ecosystem.
4 **Describe** what could happen to the world if scavengers and decomposers did not exist.
5 A brown food chain that could be found on a coral reef is: detritus → snail → small fish → sea turtles. **Classify** each of the organisms in the food chain as decomposer, primary consumer or secondary consumer.
6 **Summarise** the role/s that scavengers can play in an ecosystem. Are they only scavengers or can they have other roles too?
7 Look at Figure 3.52 and use your knowledge of detritivores and decomposers to **describe** what is happening.

Figure 3.52 Decomposition in action

Analysis

8 **Compare** the role of a producer with the role of detritus.
9 **Distinguish** between a decomposer and a detritivore.

Knowledge utilisation

10 **Propose** a reason why decomposers can be found wherever there is life.
11 **Predict** how a food web would change if all the decomposers in an ecosystem died. Give reasons for your decisions.

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3.5 Human impact on ecosystems

DOC
WORKSHEET
Biopiracy

Learning goals

1. To be able to describe the different types of biodiversity.
2. To be able to describe how humans, including First Nations Australians, have affected biodiversity.

Biodiversity

When scientists look at all life on Earth, they start to talk about **biodiversity**. Biodiversity refers to the variety of all living things found in a specific area and is normally considered at three levels.

biodiversity
the variety of life that exists in an area

- Genetic diversity: This is the difference in the genes of one species. It is better if a species is very genetically diverse, as it improves their chance of survival.
- Species diversity: This is the variety and abundance (total number) of different species found in an area. Places like coral reefs and rainforests are considered extremely biodiverse because of the many different species that live in those ecosystems.
- Ecosystem diversity: This is the variety of ecosystem types found in an area.

As you discovered in Chapter 2, all life on Earth is categorised into six kingdoms. These kingdoms indicate the species diversity on our planet, which is increasing as new species are discovered. About 76% of all species have been classified into the animal kingdom, meaning this is the most diverse of all the kingdoms. Within the animal kingdom, the phylum Arthropoda is by far the most diverse, with the class Insecta making up about 75% of all animal species.

Explore! 3.2

Sustainable harvesting practices

Populations of dugong (*Dugong dugon*) and green turtle (*Chelonia mydas*) have suffered global population declines due to threats including boat strikes, marine pollution and habitat loss. In Queensland, the species is protected under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

Figure 3.53 The dugong is an important food source for certain groups of First Nations Australians.

For many First Nations Australians, turtle and dugong are culturally significant and are an important source of protein. Traditional owners of certain areas of Queensland hold a cultural responsibility to manage the impacts of human activity on the environment and have sustainably hunted the species for thousands of years. Dugong and turtle are hunted at specific times in their lifecycle, using knowledge about population density and dynamics to ensure populations remain sustainable and are protected for future generations.

Investigate how the dugong bone mounds of the Western Torres Strait islands may have supported sustainable harvesting practices.

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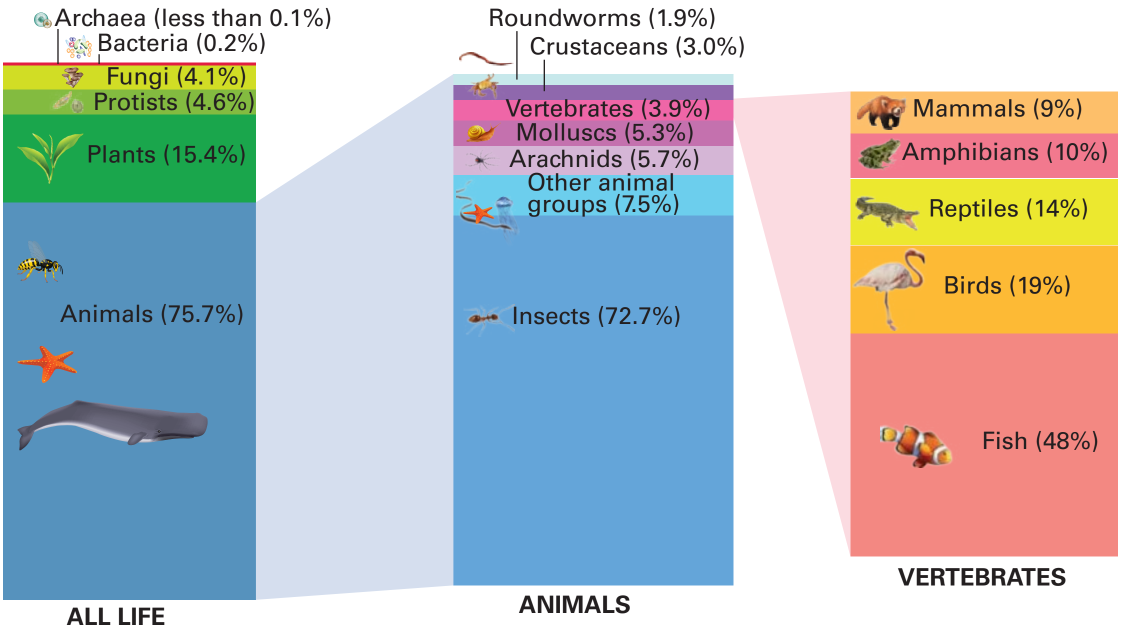

Figure 3.54 Species biodiversity on our planet (approximate percentages shown)

Try this 3.11

Wildlife reserves

Special wildlife reserves, like national parks, are created to protect areas of Queensland identified as containing exceptional natural and cultural resources and values. When building reserves for biodiversity conservation purposes, it has been suggested that larger reserves in more isolated locations may be better than multiple smaller ones. Discuss whether it is better to have a single large or several small reserves. Consider the advantages and disadvantages of both options.

Figure 3.55 Currumbin Valley is a small four-hectare reserve established in 2000. It is a remnant of the extensive ancient rainforests that used to cover South East Queensland.

Figure 3.56 Ethabuka is a 215 500-hectare reserve established in 2004. It has a wetland system of national significance and one of the highest numbers of reptile species in Australia, including the perentie, the country's largest goanna.

Threats to biodiversity

Sixty-eight major threats have been identified that can negatively impact Queensland's biodiversity. Alongside climate change, the most significant are:

- inappropriate fire regimes
- habitat clearance
- inappropriate grazing regimes
- introduced predators.

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Scientists can measure the biodiversity of ecosystems to monitor their stability. The more biodiverse an area is, the more likely an ecosystem will be able to recover from natural or human-caused threats such as disease, fire, habitat loss or introduced species. Therefore, when an area is extremely biodiverse, it is healthy.

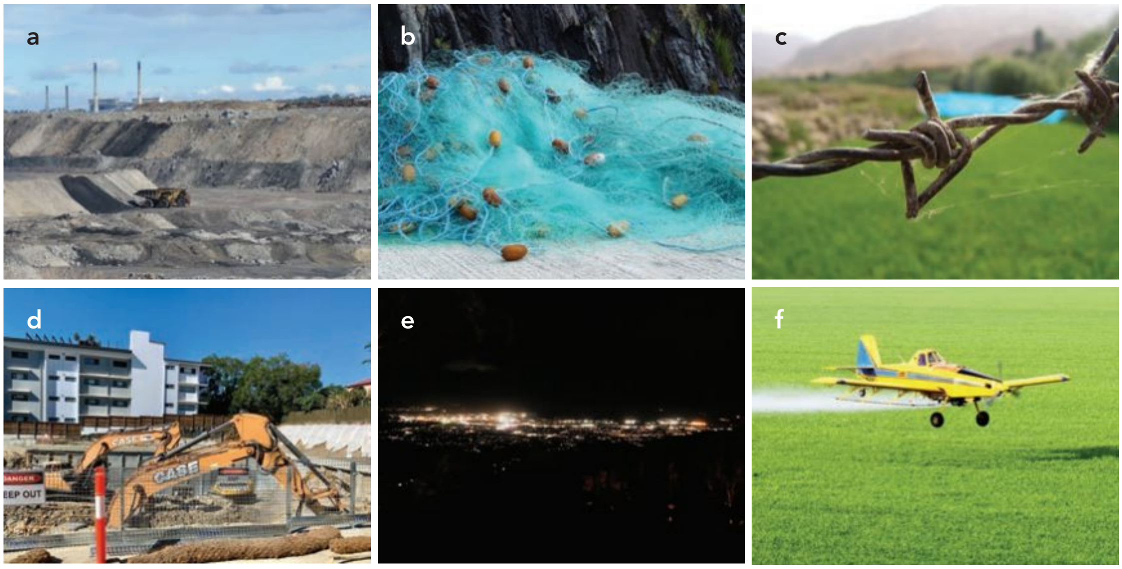


Figure 3.57 Can you work out some of the other threats to Queensland's biodiversity?

Investigation 3.3

Assessing biodiversity at your school

Aim

To compare the biodiversity of two different areas in the school grounds.

> **Be careful**
> Try to avoid biting and stinging insects.

Prior understanding

Biodiversity is a measure of how many different species live in an area and whether these species are equally abundant in numbers, or if one species dominates with a comparatively larger number of individuals. Healthy habitats have a higher biodiversity index. One biodiversity index that can be used is called the Menhinick index. It can be calculated using the following equation. Higher numbers indicate higher levels of biodiversity.

$$\text{Menhinick biodiversity index} = \frac{\text{number of species in survey area}}{\sqrt{\text{total number of individuals}}}$$

For example, in a survey recording 26 individual invertebrates belonging to five different species, the biodiversity would be

$$\text{biodiversity index} = \frac{5}{\sqrt{26}} = 0.98$$

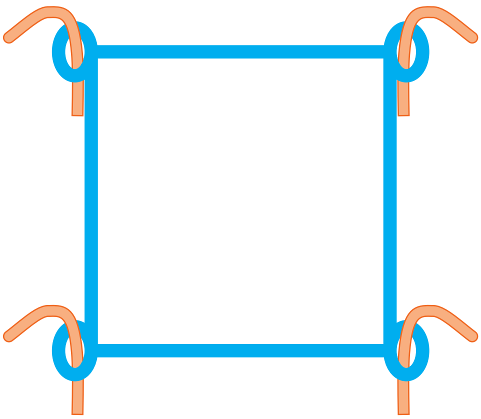
Materials

- Invertebrate Identification Key
- magnifying glass
- quadrats, if available, or if they are unavailable:

continued …

... continued

- four tent pegs and 4.5 m of fine stringline with loops tied every metre (the tent pegs must be able to fit through the loops). A one-metre quadrat can be created by pegging out the stringline into the shape of a square. Push the tent pegs through each loop to pin the corners to the ground.



Method

1. Choose two different survey areas to assess within the school grounds, such as a grassy area and a garden.
2. Take all equipment to the first survey area.
3. Randomly choose a spot to place your quadrat.
4. Take photos of any invertebrates you record. This will help you to later identify any species you cannot name.
5. Repeat steps **3** and **4** in another four random spots.
6. Move to the second survey area and repeat steps **3–5**.

Data processing

1. Develop a table to record the data from each survey area. Include a place to record survey area, type of invertebrate and number of individuals.
2. Identify any unknown invertebrates using an Invertebrate Identification Key. Record this data in the table.
3. Count the number of each invertebrate. Record this data in the table.
4. Calculate the total number of individual invertebrates found in each survey area.
5. Calculate the Menhinick biodiversity index (how biodiverse an area is) for each survey area by using the equation on the previous page. Show your working for each area.
6. Record the level of biodiversity for each survey area in the table.

Analysis

1. Contrast the Menhinick biodiversity index results for the two areas.
2. Identify the survey area that would be considered more biodiverse.
3. Discuss the reasons for any differences found when comparing the two survey areas.

Peer review

1. Swap your data with another group to give each other feedback on how easily the table can be used to compare the two survey areas. Your feedback should discuss the following:
   - how well the table is organised to compare the two survey areas
   - how clearly the biodiversity calculations have been written
   - any other suggestions to improve the quality of the data presented in the table.
2. After receiving feedback, make alterations to the table to address the identified issues and write up a final copy to present to the class.

Evaluation

Reliability

1. Compare the level of biodiversity calculated by each of the other groups. Determine how much variation was found between different group results.

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2 Compare the different types of species found in each survey area with other groups. Identify species that were not found consistently in each survey area.
3 Discuss if the biodiversity of the two survey areas can be reliably compared, based on your response to the previous question.

Improvements

4 Decide upon some changes that could be made to the method to improve the quality of the data in future experiments.
5 The equation only takes into account the number of different species, instead of the number of different species and their abundance. Complete some research to find a better equation that can be used to determine the level of biodiversity.

First Nations Australians land management

With our dry climate, bushfires are one of the most dangerous and threatening events that can happen to an ecosystem. However, they also play an important role in maintaining biodiversity. First Nations Australians have managed land with fire for millennia for cultural purposes such as hunting, ceremony and Country keeping.

firestick farming the cool burning of areas of bush in stages, by the application of firesticks, to encourage new growth

Firestick farming, cultural burning or cool burning involves low intensity fires carried out regularly to clear undergrowth. First Nations Australians have known for thousands of years that this will promote plant growth as the effective use of cool burns helped to change vegetation structure by reducing the density of plants like casuarina. Some plant species also require burning to activate their seeds.

The slow-burning nature of these fires allowed any animals hiding in burrows to come out into the open. With animals no longer in their burrows and less vegetation for them hide behind, people were able to hunt easily.

Firestick farming clears undergrowth, so created vast grasslands on high-quality soil, resulting in animals directly grazing in the area and being hunted for food. The careful selection of where and when burning occurred also resulted in a mosaic of trees and grasslands, preventing dangerous wildfires in eucalyptus forests.

Figure 3.58 Regrowth of eucalyptus trees after a bushfire. These shoots allow the tree to continue photosynthesising while the canopy recovers.

With the arrival of Europeans, much traditional burning practice was abandoned, and research has shown that in areas that were not maintained by Europeans as farmland, shrub-rich dense woodlands developed. This has caused an increase in the frequency and intensity of hot fires, worsened by climate change and population growth.

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Figure 3.59 Before European colonisation, First Nations Australians created a complex system of land management, involving creating a mosaic of burned and regenerating areas. By using fire as a tool, First Nations Australians planned plant growth through careful burn patterns, creating grasslands that they utilised to attract mobs of kangaroos to hunt.

Figure 3.60 Devastating hot fire

Hot fires burn areas of thick vegetation including trees and shrubs, which are important habitats for animals. These fires are very dangerous and destructive, moving quickly and killing everything in their path.

Quick check 3.11

1. Propose some causes of fire in Australia before First Nations Australians arrived.
2. Recall three main uses of firestick farming.
3. Describe how firestick farming helps to promote new plant growth.
4. Currently, we use controlled burns in winter to reduce natural bushfires in summer. Predict a problem with disrupting this natural event.

VIDEO Causes of bush fires

Making thinking visible 3.3

Looking five times two: First Nations tools

Australia's state and territory governments have broad responsibilities for recognising and protecting First Nations Australians' heritage, including archaeological sites and artefacts. In Queensland, the principal legislature is the *Aboriginal Cultural Heritage Act 2003* and the *Torres Strait Islander Cultural Heritage Act 2003*. Currently, there are over 56 531 culturally important site locations in Queensland. These sites are listed on a national Aboriginal and Torres Strait Islander cultural heritage database.

The picture shows a range of First Nations Australians' tools that were used for hunting and making food. Look at the image for 20 seconds, letting your eyes wander.

List 5 words or phrases about the image.

Once you have made a list, look at the image again and try to think of 5 more words or phrases to add to your list.

Figure 3.61 First Nations tools

The *Looking ten times two* thinking routine was developed by Project Zero, a research centre at the Harvard Graduate School of Education

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Science as a human endeavour 3.1

Using traditional knowledge


Figure 3.62 Members of the Queensland Indigenous Women Rangers Network undertaking drone training

Australia´s 2021 State of the Environment report recognises First Nations Australians' knowledge principles, including the benefits of fire, and their knowledge of endemic plant use for both culinary and medicinal purposes. Management of these valuable resources is necessary, especially where **biopiracy** is a potential risk.

biopiracy
when naturally occurring biological material is commercially exploited

In Queensland, the Indigenous Land and Sea Ranger Program supports First Nations organisations with grants to employ Indigenous Land and Sea rangers across the state's regional and remote communities. The program provides training and support for ranger groups. Their activities include a wide range of conservation services including cultural burns, feral animal and pest plant control, soil conservation, cultural heritage site protection and biodiversity monitoring.

In 2022, the members of the Queensland Indigenous Women Rangers Network was awarded a $1.8 million Earthshot prize for its work on protecting the Great Barrier Reef. The prize rewards innovative solutions to climate change and other environmental problems. The network combines 60 000 years of traditional knowledge with new technology. The women have used drones to collect data to educate people about coral bleaching and dieback and are working with the government to implement coral sanctuaries and regrowth projects.

Research contemporary Caring for Country programs and how they are key to defending Australian ecosystems, then contact your local Indigenous Land and Sea Ranger to learn about the projects they are doing in your area.

Explore! 3.3

K'gari (Fraser Island)

K'gari is a World Heritage–listed island located off the coast of Queensland. At 122 km long, it is the largest sand island in the world.

The conservation outlook of the island was assessed by the International Union for Conservation of Nature (IUCN) as 'good with some concerns' in the latest 2020 assessment cycle.


Figure 3.63 Platypus Bay, K'gari

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In small groups, examine how the following issues may cause the IUCN status of K'gari to change to 'significant concern' or 'critical'. Present your findings to your class.

- climate change
- sandmining
- logging
- fire
- introduction of invasive species (e.g. brumbies, cats and pigs)
- tourism.

Explore! 3.4

Green Games

In 2032, Brisbane will host the Olympic Games. These games will be the first 'climate positive' Olympics, and it is understood the next two summer games will also be climate positive. A 'climate positive' Olympics is one which absorbs or removes more carbon than it produces to become 'carbon negative'. One way that Brisbane will be able to do this is by using pre-existing buildings to host sporting events wherever possible. In some cases, new venues will have to be built, but many venues already exist.

Figure 3.64 An artist's impression of the proposed rebuild of the Gabba
Source: Queensland Government

For example, although the Gabba will be rebuilt to host athletics and the ceremonies, and a new Brisbane Arena is proposed to be built above Roma Street underground station to host swimming and waterpolo (in a temporary pool), Victoria Park will be temporarily repurposed to host freestyle BMX and cross-country equestrian events, and Ballymore Stadium will be upgraded to host hockey. There are many other venues located throughout South East Queensland that will be utilised for the range of different sports.

Figure 3.65 An artist's impression of the proposed Athlete Village development at Northshore Hamilton, Brisbane
Source: Queensland Government

Currently, the Athlete Village has been earmarked for Northshore Hamilton. As the International Olympic Committee (IOC) now requires host cities to incorporate sustainability into the games, your task is to research the proposed site of the Athlete Village and consider how it can be as sustainable as possible.

- Use the internet to find the location of the Athlete Village.
- What are the potential environmental issues the village may cause that could affect a local ecosystem? Write a letter to a newspaper editor outlining your findings.
- Do you think that the best decision has been made regarding the village's location? Why do you think this area was chosen?
- What do you like about the current design? What do you dislike about it?

continued …

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- Using A3 paper, work in small groups to design an environmentally friendly version of the Athlete Village.
  - Think about the following factors:
    - transport links to sporting venues
    - provision of food and the associated waste for 10 000 athletes
    - laundry services for 10 000 athletes
    - how the buildings could be designed to minimise their environmental impact. Remember, these are summer games: how are the athletes going to be kept cool without overreliance on air conditioning?
    - future usage of the site.

Invasive species

invasive species
an organism that is not native to an environment and causes harm to native organisms

biological control
the practice of introducing an organism into an ecosystem with the intention of limiting the spread of another organism

An **invasive species** is an introduced non-native organism that overpopulates and harms its new environment. The introduction of the species is usually done accidentally, but sometimes it is done on purpose. Australia has many invasive species such as foxes, camels, rabbits, goats, and feral cats and pigs. All these species were introduced by European colonists for hunting, farming or to make Australia feel more like Europe. Invasive species are one of the largest threats to Australian ecosystems and sometimes another species can be introduced to help control the invasive species population. This is known as **biological control**. Biological control uses the natural enemies of the invasive species. They can be bacteria, fungi, viruses or even parasites or predators.

Disastrous control

The cane toad originally comes from Puerto Rico but was brought to Australia in an attempt to manage beetles that were eating sugar cane crops in Queensland. The cane toad had been introduced to Hawaii for the same purpose with no issues. However, after they were released in the sugar cane plantations of north Queensland in 1935, their population exploded, and they quickly became a huge pest. Cane toads have many ecological impacts such as competing with native species for food and space. They are also poisonous and so kill

Making thinking visible 3.4

Circle of viewpoints: Weedy *Sporobolus*

Weedy *Sporobolus* or rat's tail grasses are invasive, fast growing weeds of pastures, roadsides and woodlands. Some *Sporobolus* grasses are native to Australia, and these do not pose a weed problem, but the five weedy species are unpalatable and lack nutrition for grazing livestock. They are difficult to distinguish from other pasture grasses and outcompete native plants for resources. Dr Tracey Steinrucken is collaborating with Biosecurity Queensland to biocontrol weedy *Sporobolus* grasses using endemic fungal pathogens.

1. Brainstorm a list of perspectives that different people in society might have on the introduction of biological controls (e.g. farmers, conservationists, First Nations Australians).
2. Choose one perspective to explore, using these sentences:
   - I am thinking of biological control from the perspective of ...
   - I think ... *describe the topic from your chosen perspective.*
   - A question I want to ask from this perspective is ...

The *Circle of viewpoints* thinking routine was developed by Project Zero, a research centre at the Harvard Graduate School of Education

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Explore! 3.5

Rabbit-proof fences

Rabbits were introduced to Australia in 1859 by a grazier in Victoria. They are considered a major pest, so much so that it is illegal to keep a rabbit as a domestic pet in Queensland. In 1996, the **calicivirus** was introduced as a biological control to reduce the massive rabbit population. However, some rabbits were immune to the virus, and foxes (another pest) had now lost a food source and so were eating native wildlife instead. Go online to investigate the following.

calicivirus
a virus that damages a rabbit's internal organs and can cause bleeding

1 Find out about the rabbit-proof fences built in Western Australia in the 1900s, as shown in Figure 3.66. Report on how they were used to try to limit the spread of plagues of rabbits.
2 Find out about the myxoma virus and its release in Australia in 1950 in an attempt to control the rabbit population. Summarise your findings.

Figure 3.66 Rabbit-proof fences were built to try to limit the devastation caused by rabbits. When completed, the rabbit-proof fences stretched 3256 km.

any predatory native species that eat them, such as quolls, snakes and crocodiles.

Figure 3.67 The cane toad was originally introduced as a biological control, but is now considered a pest.

Effective control

Not all examples of biological control in Australia have gone wrong. In 1840, European settlers brought a cactus known as the 'prickly pear' to Australia to use as a food source for a beetle that produced a red dye for the production of soldiers' uniforms. The cactus thrived in Australia and soon infested 30 million hectares around Brisbane.

Did you know? 3.6

Stress, wash and eat

The Australian white ibis are well known for feeding on food thrown away by humans, but they may well be developing a taste for something else. **Citizen scientists** have reported that ibis will use a 'stress and wash' technique so they can eat toxic cane toads.

citizen scientist
a member of the public that assists a professional scientist by voluntarily collecting data relating to the natural world

The ibis will pick the cane toad up by the neck and throw them about. This stresses out the toad, causing it to release a toxin called bufotoxin from the parotoid glands located around the neck. This is a normal defence response to any predator, and the thick,

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milky toxin easily sticks to the inside of an animal's mouth. That toxin is then absorbed into the body where it can lead to serious complications or even death.

Ibis have learned how to avoid the toxin though: after stressing the toads out so they create the bufotoxin, the ibis will then wash them in a creek, before swallowing them whole.

Figure 3.68 The Australian white ibis may be the answer to the cane toad crisis.

Research was undertaken to find an insect that could feed on the prickly pear, and after a global search, the cactus moth (*Cactoblastis cactorum*) was introduced as a biological control. In less than ten years, it was estimated that the larvae of the moth had consumed 1.5 trillion kg of cactus! Another benefit of the moth is that when there is no cactus left, it dies off because the cactus is its only food source. Several years after the introduction of the moth the cactus population was under control, even though it is still around today in smaller numbers. First Nations Australians may use cool fires to control the growth of invasive species such as African lovegrass (*Eragrostis spp*.) and lantana (*Lantana camara*).

Figure 3.69 Prickly pear plant

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Section 3.5 questions

QUIZ

Retrieval

1 **Name** the three types of biodiversity.
2 **State** four examples of an invasive species.
3 **Define** the following terms:
   a species diversity
   b genetic diversity
   c ecosystem diversity
4 **Identify** which phylum in the animal kingdom is most diverse.

Comprehension

5 **Describe** the use of 'firestick' farming by First Nations Australians.
6 **Explain** why some introduced species are classified as pests.
7 **Explain** why the cactus moth is referred to as an effective biological control.
8 **Describe** some of the impacts that humans are having on oceanic ecosystems.

Analysis

9 **Compare** the use of 'hot fire' and 'cold fire' burning techniques by First Nations Australians.
10 Go online to research the work a group is doing to counteract the impact humans are having on biodiversity loss. Try to choose a group that you may find interesting. Write a journal **reflection** of your findings.

Knowledge utilisation

11 Bushfires naturally occur in Australia and many organisms have adapted to cope with this. Natural bushfires may occur every 5–10 years. However, humans in many areas have decided to start controlled burns yearly to prevent larger bushfires. **Propose** how this might damage the ecosystem.
12 **Create** a list of pros and cons about the role of invasive species.

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Chapter review

Chapter checklist

You can download this checklist from the Interactive Textbook to complete it.

Success criteria		Linked questions	Check
3.1	I can recognise the difference between abiotic and biotic factors in an ecosystem.	4, 13	
3.1	I can state the various levels of organisation in an ecosystem.	5	
3.2	I can describe five different species interactions in an ecosystem.	8	
3.3	I can construct and interpret a food web to show feeding relationships.	12	
3.3	I can describe how energy flows through an ecosystem.	6	
3.3	I can predict the effects on ecosystems when living things are removed from an area.	14	
3.4	I can classify organisms according to their position in a food chain.	2, 3, 9, 10	
3.4	I can describe the role of microorganisms in an ecosystem.	11	
3.5	I can describe the different types of biodiversity.	7, 15	
3.5	I can describe how humans, including First Nations Australians, have affected biodiversity.	1	

Review questions

SCORCHER

Retrieval

1 **Identify** two natural and two human threats to an ecosystem.
2 **Name** the type of teeth that most herbivores are missing.
3 **State** what incisors are used for.
4 **Recall** the characteristics of all living things.
5 **Define** 'community' in an ecosystem.

Comprehension

6 **Describe** how energy is lost along a food chain.
7 **Explain** how high biodiversity could be a sign of a healthy ecosystem.
8 **Summarise** the five key interactions between species in an ecosystem. For each interaction, provide an example that was not mentioned in the text.
9 A producer is always part of a food chain. **Explain** how a producer fits into the brown food chain.

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Analysis

10 Copy Figure 3.70 into your notebook.

  a Use arrows to **connect** the interactions between each organism.

Figure 3.70 Various parts of a food web

  b **Classify** each organism as producer, consumer and decomposer. Each organism may have more than one label.

  c **Classify** (if any) the herbivores, carnivores, omnivores or detritivores.

11 **Compare** the roles of decomposers and consumers.

Knowledge utilisation

12 Using the pictures of organisms in Figure 3.71, **create** a food web.

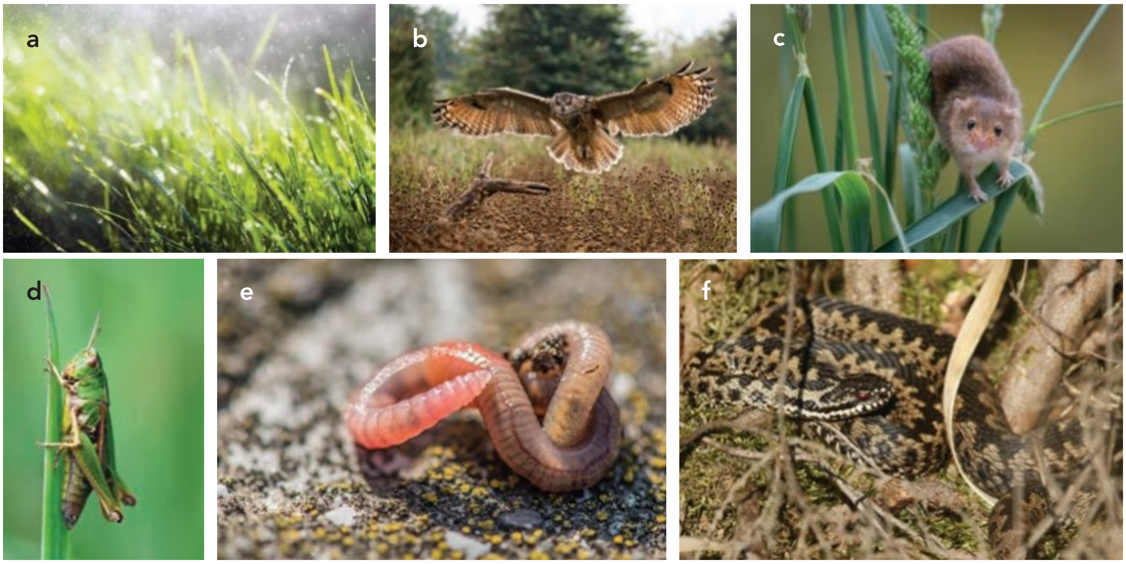

Figure 3.71 Various parts of a food web

13 A grassland ecosystem changes dramatically throughout the year. **Propose** several abiotic and biotic changes that may occur in a grassland ecosystem during summer and winter.

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14 Look at the food web in Figure 3.72. **Predict** what would happen if the mouse was removed from the food web.

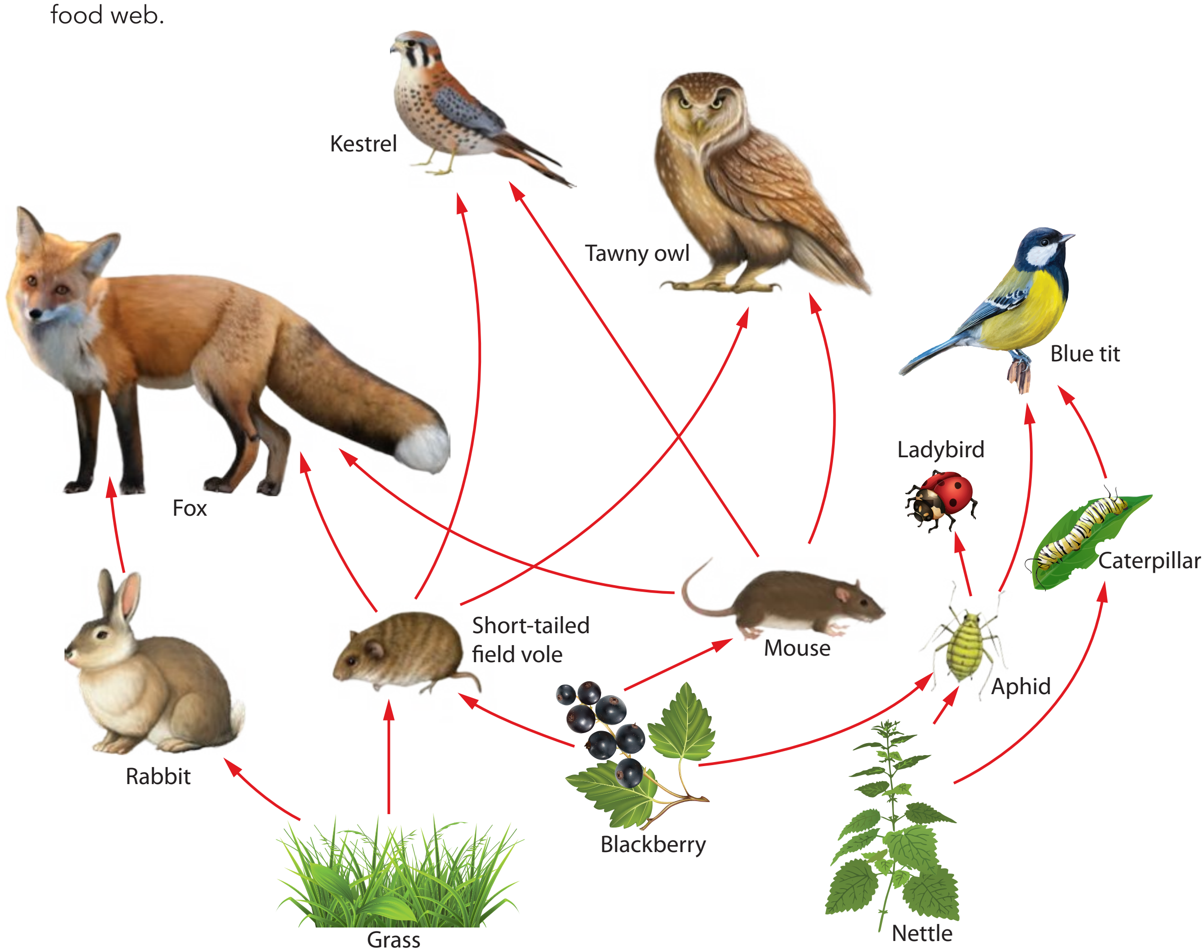

Figure 3.72 Various parts of a food web

15 A population of platypus located in Barrington Tops is more genetically diverse than a population located in Sundown National Park. **Predict** which population is more likely to survive if the environment changes.

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Data questions

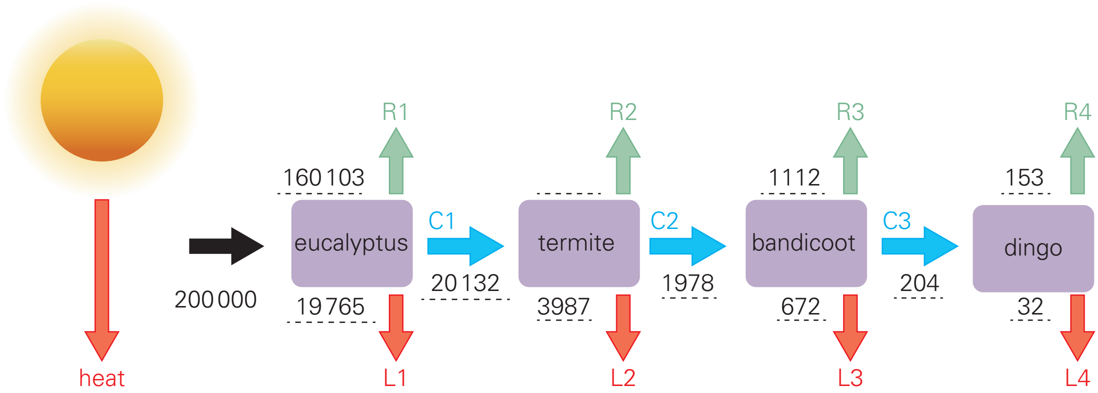

Figure 3.73 Energy transfer in an Australian food chain. All values are in kJ. Blue arrows (C1–3) represent energy transferred through the food chain; green arrows (R1–4) represent energy lost as heat and through respiration; and red arrows (L1–4) represent the energy lost as detritus (dead organic matter and waste).

Apply

1 **Identify** the secondary consumer in Figure 3.73.
2 **Calculate** the R2 value.
3 **Calculate** the efficiency of the energy transfer through the termite in Figure 3.73.

Analyse

4 **Organise** the efficiency of energy transfers (C1, C2 and C3) from highest to lowest, using Figure 3.73.

Interpret

5 **Deduce** why the food chain does not extend further than the dingo.
6 Geckos will also eat termites. They are far smaller than a bandicoot. **Predict** if the gecko's L3 value would be higher or lower than the bandicoot's L3 value in Figure 3.73.
7 **Justify** your answer to Question 6.

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STEM activity: Designing a cane toad trap

Background information

Queensland is home to many beautiful amphibians, but the cane toad is not one of them. It is classified as both an amphibian and a pest. Cane toads were introduced to Queensland in 1935 to control cane beetles, and the toads adapted quickly to the Australian environment. Cane toads are gluttonous feeders and can significantly reduce the population of native creatures. They have a toxic venom in their skin, which protects them from predators. Cane toads have no natural predators and are a threat to native animal species. Only human intervention can control and reduce the population.

Design brief: Create a prototype of a device that can be used to reduce the population of cane toads humanely

Activity instructions

In this task, you will investigate the different ways you can control the cane toad population. Then you will design and construct a prototype device that could be used by individuals and government organisations to trap cane toads or their tadpoles. You will need to consider the following information and design constraints.

1 The design and construction must be cost-effective.
2 The prototype must be constructed so that no animal (including the cane toad) is harmed.
3 The prototype must be able to be left in a way so that curious people cannot injure themselves from touching the device or possibly touching a captured cane toad/tadpoles.
4 The prototype device must be able to be transported for safe removal of toads/tadpoles.

Figure 3.74 A cane toad

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Suggested materials

- recyclable materials such as plastic bottles, containers, boxes
- duct tape
- scissors
- ruler
- balls the size of cane toads

Research and feasibility

1 Identify other animal species that live in the same ecosystem as cane toads. If necessary, research this information.
2 Research and explain what 'humane' means, and discuss in your group why your prototype design must be humane.
3 Research the lifecycle and identify why the cane toad has become such a pest in Queensland.
4 Research and identify the ways that the cane toad population can be controlled.

Design

5 Decide in your group the method you are going to use to reduce the population of cane toads. You may want to use a table like this one to list the positives and negatives of each method.

Method of control	Positive	Negative
Adult toad trap		
Tadpole trap		
Barrier		

6 Design your prototype device and label the key components of the design. How do the components of the design help your invention to be humane, safe, effective and affordable?

Create

7 Construct your prototype device using the available materials.
8 Test your prototype device for durability and get other groups to test how well it works.

Evaluate and modify

9 Discuss in your group how well your prototype device worked, and reflect on how effective you think it will be.
10 Evaluate if you now think that other methods of controlling the population would be more effective.
11 Would you like to make any changes to your prototype?
12 Present your prototype to the class and ask your peers how effective the prototype would be where they live, and what suggestions they can offer to improve it.

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Chapter 4
Planet Earth

Chapter introduction

In this chapter, you will find out more about the world you live in and investigate the motion of Earth, the Moon and the Sun through space. You will learn why a day is 24 hours long and why different countries have different time zones. You will also learn why there are seven days in a week and 365.25 days in a year, and why there are seasons, phases of the Moon, and solar and lunar eclipses. You will investigate how technology has been used to improve the observations made of the night sky and how these observations have given us a clearer picture of the structure of our solar system, our galaxy and the large-scale structure of our universe.

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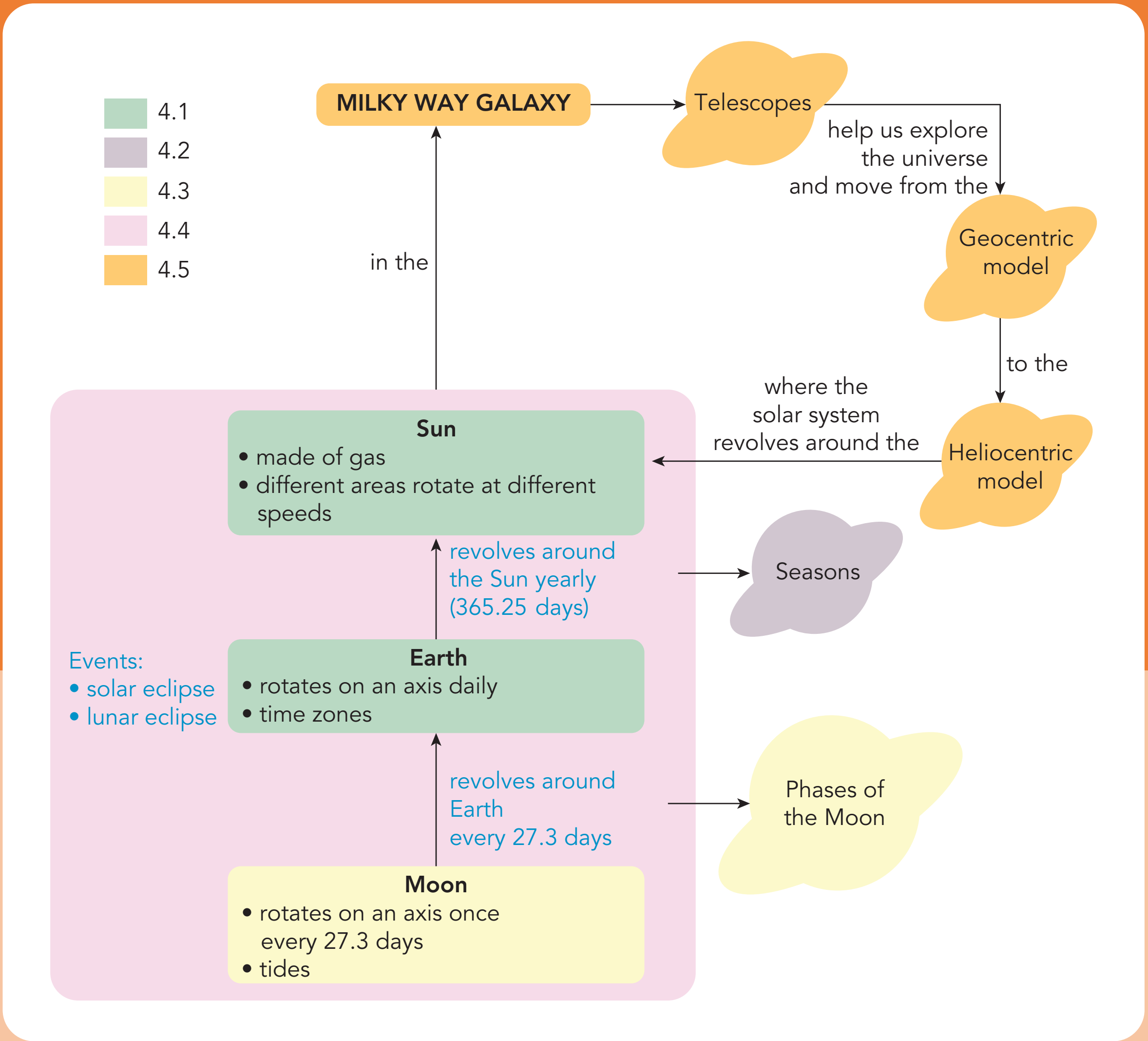
Concept map



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Curriculum

Model cyclic changes in the relative positions of the Earth, sun and moon and explain how these cycles cause eclipses and influence predictable phenomena on Earth, including seasons and tides (AC9S7U03)	
using physical models or virtual simulations to explain how Earth's tilt and position relative to the sun causes differences in light intensity on Earth's surface, resulting in seasons	4.1, 4.2, 4.5
examining the effect of the gravitational attraction of the moon and the sun on Earth's oceans and describing how the relative positions of the moon and sun with respect to Earth result in tidal variations	4.3
using physical models or virtual simulations to explain the cyclic patterns of lunar phases and eclipses of the sun and moon	4.3, 4.4
researching knowledges held by First Nations Australians regarding the phases of the moon and the connection between the lunar cycle and ocean tides	4.3
investigating First Nations Australians' calendars and how they are used to predict seasonal changes	4.3
researching First Nations Australians' oral traditions and cultural recordings of solar and lunar eclipses and investigating similarities and differences with contemporary understandings of such phenomena	4.4

Glossary terms

Annular eclipse
Apogee
Blood moon
Dawn
Deciduous
Dusk
Elliptical
Equator
Far side
Geocentric model
Gravitational field
Heliocentric model
Horizon
Leap year
Lunar eclipse
Mass
Northern hemisphere
Orbit
Partial eclipse
Penumbra
Perigee
Revolution
Solar eclipse
Southern hemisphere
Sunspot
Synchronous rotation
Syzygy
Telescope
Time zone
Total eclipse
Umbra
Waning
Waxing

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4.1 Our rotating Earth

WORKSHEET
Day and night

Learning goals

1. To be able to describe the effect of Earth's rotation on temperature and time zones.
2. To be able to state the rotation times for Earth, the Moon and the Sun.

The daily cycle

Have you ever thought about how much of your life is regulated by a daily routine? Much of this is determined by Earth, the Moon and the Sun.

Try this 4.1

The daily cycle

In small groups, think about and describe your observations of the Sun, Earth, the Moon and stars during a typical day.

For example, the day begins officially at midnight when the date changes. The new day starts in darkness. Most people are asleep as the dawn approaches. When the morning sun appears over the horizon, it is time for us to wake up. Birds announce the dawn, animals that hunt at night look for somewhere to hide and animals that are busy during the day get up to look for food. Now, keep going with the list, but remember to focus on the changes in the Sun, Earth and the Moon. List any other changes you have seen as the day or night progresses. Remember, you are only looking at what changes over a period of 24 hours, so do not include weather events because they do not repeat every day.

Figure 4.1 Mount Lindesay just after sunset. Temperatures generally increase during the day and decrease at night.

Did you know? 4.1

Flower cycles

Some flowers have a daily cycle. Daisies close their petals at night and open them again during the day. Arctic poppies and sunflowers turn their heads to follow the Sun as it moves across the sky.

Figure 4.2 Daisies have their petals open during the day (left) and close them as the light fades (right).

Try this 4.2

Finding out why

For this activity, you will need a round yellow balloon or ball, another smaller balloon or ball and a marker pen.

In small groups, choose a question from the list below and come up with an explanation to share with the rest of the class.

- Why does it get warmer during the day and colder at night?
- Why does the Sun appear to move across the sky?
- Why do stars appear to move across the sky at night?
- Why is there maximum risk of sunburn between 10 a.m. and 2 p.m.?
- Why does the length of your shadow change during the day?

To help with your explanation, use the larger yellow balloon/ball to represent the Sun and the smaller balloon/ball to represent Earth. Draw a map of Australia on the smaller balloon/ball with a small dot to represent your location.

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Our rotating Earth

Earth is a giant ball in space that is spinning anticlockwise (when viewed from the North Pole) slowly, one rotation per day. Sunlight shines on one side, while the other side is in darkness. The side of Earth facing towards the Sun experiences day and the side facing away experiences night. **Dawn** and **dusk** lie on the boundary between light and dark when the Sun is on the **horizon**. The Sun does not actually move across the sky. It appears to do so because Earth is rotating. The Earth rotates from the west to the east, which is why the Sun appears from the east and sets in the west.

dawn
the time of day when the Sun rises over the horizon and night turns into day

dusk
the time of day when the Sun drops below the horizon and day turns into night

horizon
the point where the sky appears to meet the land or the sea

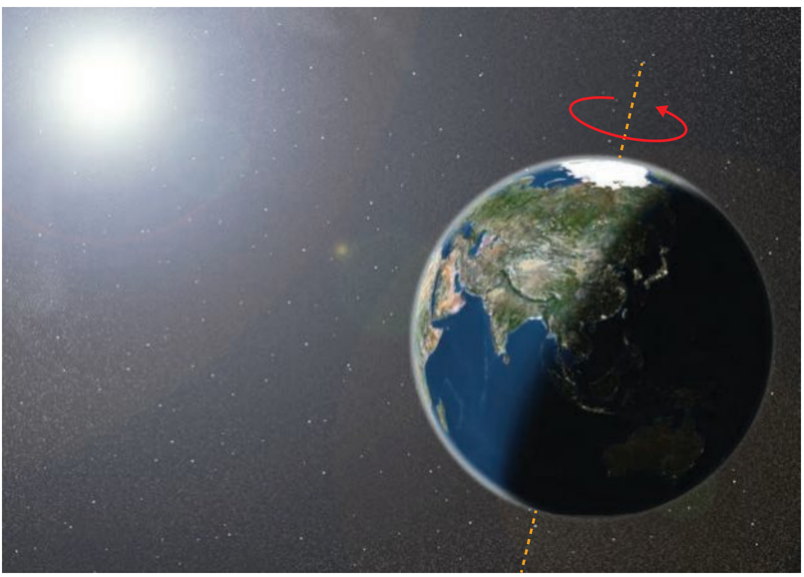

Figure 4.3 It is night-time in Australia as Earth turns on its axis with the Sun in the distance. This picture shows how day and night are caused by Earth's rotation.

Did you know? 4.2

Rotating planets
Venus rotates in the opposite direction to Earth, so on Venus the Sun rises in the west and sets in the east.

Did you know? 4.3

Speed of Earth's rotation
Because Earth is rotating anticlockwise, the whole state of Queensland is moving to the east at around 400 metres per second, which is faster than the speed of sound. You do not feel like you are moving because everything around you is moving as well. In addition to the motion caused by its rotation, Earth is also moving anticlockwise around the Sun at a speed of around 28 kilometres per second. If an aircraft could fly at that speed, it would get to London from Brisbane in about 10 minutes!

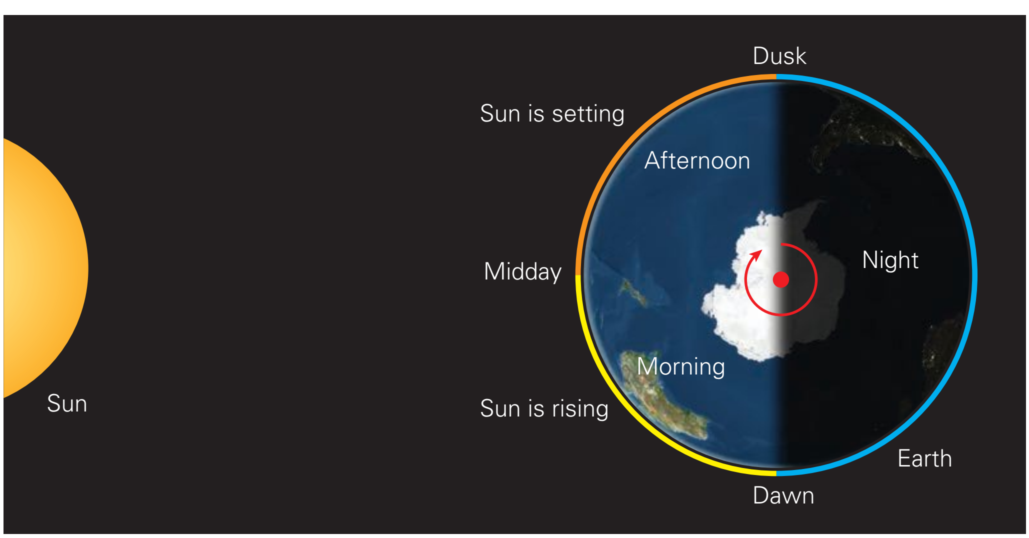

Figure 4.4 The view of Earth from above the South Pole. Earth is rotating clockwise from this pole. Different parts of the world experience morning (yellow), afternoon (orange) and night (blue). This image shows morning in Australia.

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Temperature and shadow changes

The Sun is a star and the temperature changes during the day are due to the position of the Sun in the sky. If you track one location on our spherical Earth, it is turning towards the Sun in the morning and away from the Sun in the afternoon. This means the temperature increases in the morning as the Sun rises in the sky and continues to increase throughout the day as the Sun provides heat. At night, there is no heat from the Sun in that location and the temperature falls until the next day when the cycle repeats again.

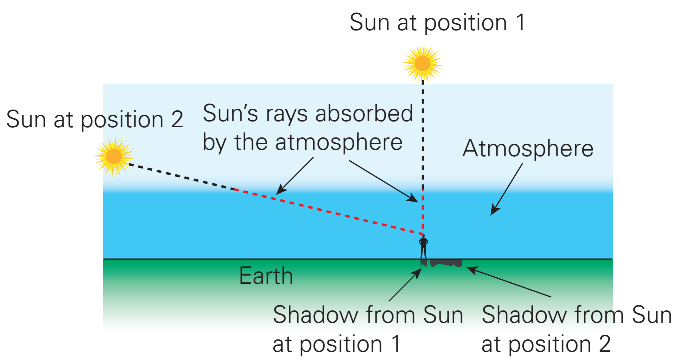

Figure 4.5 The Sun's rays pass through less atmosphere when it is close to being overhead. For this reason, the midday sunlight is more intense and more likely to cause sunburn. The length of your shadow also changes due to the angle of the rays.

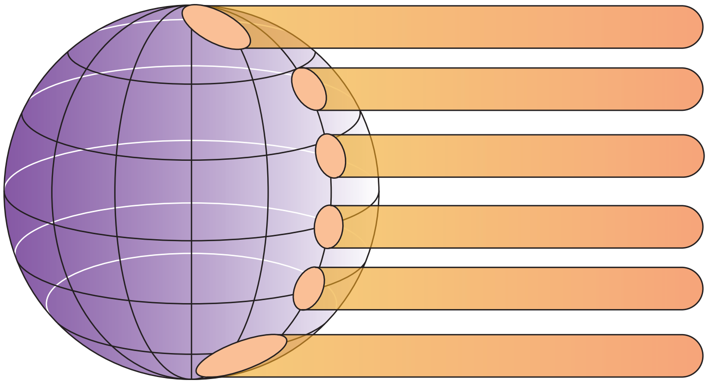

Figure 4.6 The angle of the Sun's rays also produces the different temperatures found around Earth. Equatorial regions are hotter than polar regions because they receive perpendicular rays (at a 90° angle).

Try this 4.3

Simulating the movement of the Sun

In a group, use a yellow balloon and a camera for this simulation. A simulation is a model of an event, or a way to see what happens without it actually happening.

1 Choose someone to be Earth and hold a camera.
2 Choose a second person to be the Sun by holding the balloon.
3 The person with the camera stands in front of the Sun and rotates slowly on the spot while recording a video.

What did you see? Did it appear as though the Sun is moving past the camera? What was the cause of the movement?

Did you know? 4.4

Antipodes

The place on the exact opposite side of the world to a region is called its antipode. The antipode of Brisbane can be found in La Frontera, located in the Canary Islands, off the coast of North Africa. If the Sun is setting in Brisbane, it will be rising at its antipode. If it is winter in Brisbane, it will be summer at the antipode.

Figure 4.7 The antipode of Brisbane is in La Frontera, Canary Islands.

VIDEO
Timelapse of stars in Australia

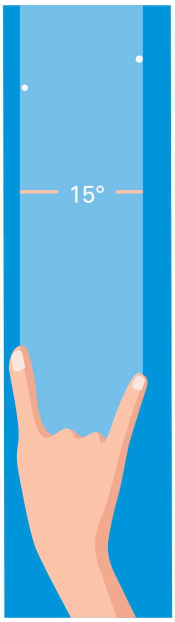

Figure 4.8 You can measure the distance stars travel in an hour by using your hand.

Positions of stars in the sky

Like the Sun, the stars do not move. Their movement is an illusion caused by Earth's rotation. To navigate around the night sky, it makes no sense to say that a star is 5 cm to the right of another. So, we measure angles (out of 360°) instead. But what if you don't have a protractor? No matter! You have an inbuilt one. Hold your hand out at arm's length and close one eye. Make a fist so you can see the back of your hand. Stick your index and little finger up and look at the night sky; this makes approximately 15° in the night sky. If you then stretch out your thumb and little finger, this is approximately 20°. One finger is 1°.

Did you know? 4.5

The changing night sky

The night sky appears differently over time. The current North Star is Polaris, but in about 13 000 years it will be Vega. This is due to a rotation of Earth's axis (precesses) caused by the combined gravitational pull of the Sun and the Moon. The period of precession is about 26 000 years.

Quick check 4.1

1. Define the following terms in your own words: rotation, dawn, dusk.
2. Explain why the Sun and stars appear to move across the sky, when they are not really moving.
3. Explain why it is cooler at night and warmer during the day.
4. Compare the effect on shadows when the Sun is directly overhead with when it is at a low angle in the sky.

Figure 4.9 The stars in the sky are not moving. It is Earth's rotation that makes them appear to move.

Time zones

It takes about 24 hours for Earth to complete one rotation, which is 360°. This means Earth is rotating at a rate of about 15° per hour. For this reason, Earth is divided vertically into 24 **time zones**, each of which is about 15° or 1 hour apart.

time zone
Earth is divided into 24 time zones, each about 15° of longitude and each one representing a time difference of 1 hour

At certain times of the year, there may be up to 38 time zones because of daylight saving of half or one hour differences. It does get complicated! Time zones are measured from Greenwich in the UK. The time in Greenwich is called Greenwich Mean Time or GMT.

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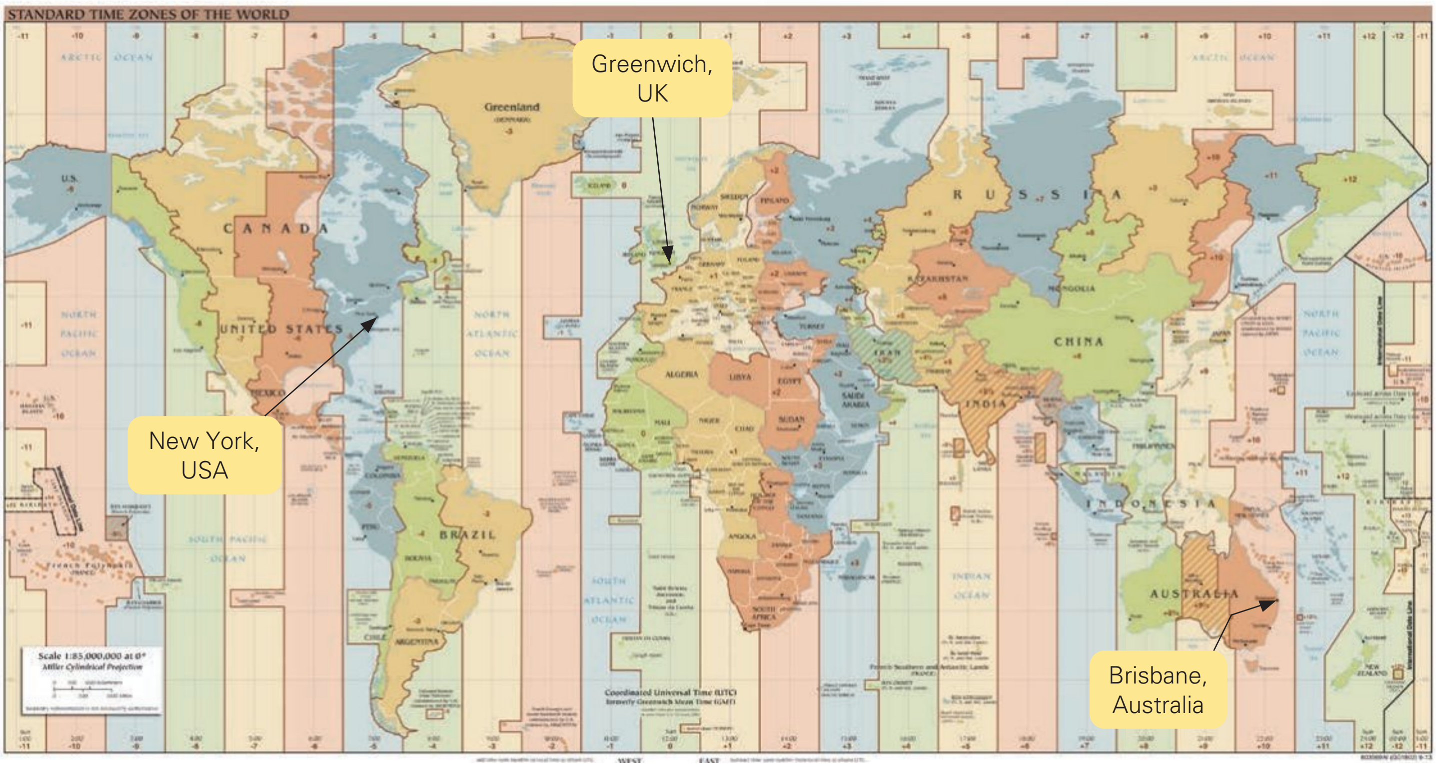

Figure 4.10 The time zones of the world. The state of Queensland is 10 hours ahead of GMT because it is about 150° east of Greenwich, whereas New York is 5 hours behind GMT because it is about 75° west of Greenwich.

Some states and countries adopt daylight saving, which involves turning the clocks forward by an hour at the beginning of summer. There are two good reasons for daylight saving. Firstly, it delays the time of dawn in summer by an hour, so people can get an extra hour of sleep before being woken by the rising Sun. Secondly, daylight saving saves energy since the Sun goes down an hour later, so households use less electricity for lighting at night. In Australia, daylight saving is used in South Australia, New South Wales, the Australian Capital Territory, Victoria and Tasmania.

Explore! 4.1

Indirect effects of Earth's rotation

Some amazing things in our world are linked to our daily cycle but are not directly a consequence of Earth's rotation. Using the internet, research to find out more about these indirect effects. For example, why does the wind usually seem to blow from the sea during the day?

Figure 4.11 Why is the sky red at sunset? Clouds are illuminated by the Sun at sunset. The blue light from the Sun has travelled through the atmosphere and has been scattered, leaving only red light to illuminate the clouds. Red light does not scatter because it has a longer wavelength than blue light.

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Did you know? 4.6

Mars has blue sunrises and sunsets!

The Martian atmosphere is too thin to scatter blue light, but it is full of dust particles that scatter red light. This means that on Mars the sky is pink during the day, but at dawn and dusk the sunrises and sunsets are blue!

Figure 4.12 A blue sunset on Mars, taken by the NASA Mars Curiosity rover.

VIDEO
Animation of sun activity

Quick check 4.2

1 State by how many degrees Earth rotates in one hour.
2 State how many time zones there are.
3 Explain why it is necessary to have time zones.
4 Describe the advantages of daylight saving time.

Rotation of the Sun

The Sun also rotates but at a very different speed to Earth. Unlike Earth and the Moon, the Sun is not solid – it is a hot gas – so different parts of the Sun rotate at different speeds. The equator of the Sun rotates approximately once every 25 days, while the poles (top and bottom) rotate at a much slower rate, about once every 38 days. Even though 25 days sounds like a long time, the Sun is so big that the surface at the equator is still travelling at around 2 kilometres per second!

sunspot
feature on the Sun's surface that moves slowly across the surface

There are dark spots on the surface of the Sun called **sunspots**. These can be seen with special equipment and are seen to rotate with the surface, proving that the Sun rotates. You cannot look at the Sun directly to see sunspots – and it is *very* dangerous to look at the Sun, even with sunglasses.

Be careful

Never use binoculars or telescopes to look anywhere near the Sun.

Quick check 4.3

1 State how long one rotation of the Sun takes.
2 Explain how it is known that the Sun rotates.

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Try this 4.4

Ancient astronomy

Abu Abdallah Mohammad ibn Jabir ibn Sinan al-Raqqi al-Harrani al-Sabi al-Battani was born in 858 CE. He is regarded as a great astronomer whose discoveries played a large role in the development of science in the Middle Ages. Research the following:

- What did al-Battani use to be able to refine the existing values for the length of the solar year?
- How close was his calculation to the actual length of a solar year?
- How did al-Battani show that annular eclipses (where a ring of the Sun is still visible because the Moon is too close to Earth to shield the Sun completely) are possible?

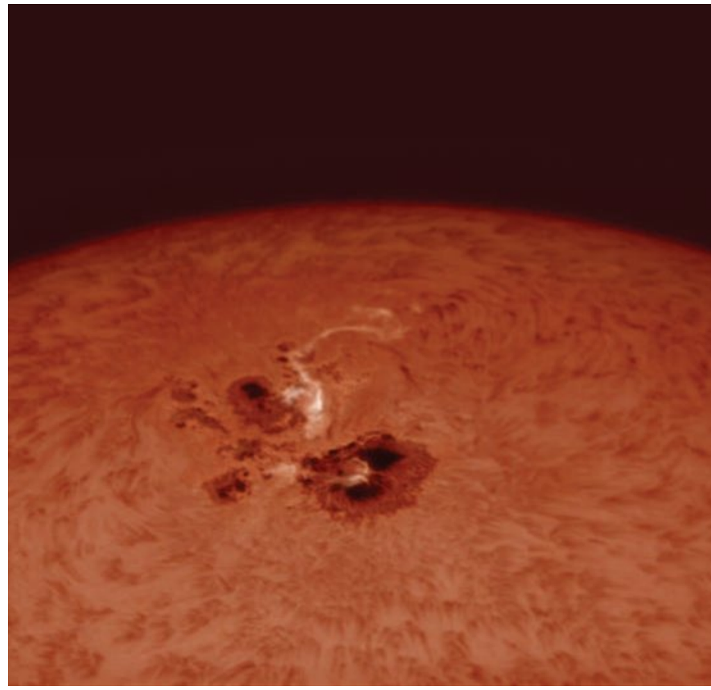

Figure 4.13 Sunspots, such as the one shown, stay visible for about 11 days as they cross the face of the Sun.

Section 4.1 questions

QUIZ

Retrieval

1 **Recall** how long it takes Earth to complete one full rotation.

2 **State** what time of day the Sun reaches its highest point in the sky.

3 **State** where time zones are measured from.

Comprehension

4 **Describe** how sunsets on Mars are different from those on Earth.

5 **Explain** how Earth experiences day and night.

6 **Explain** why the Sun, Moon and stars rise in the east and set in the west.

7 **Explain** how your shadow changes length over a day.

8 Find out what the current time is in Perth and Melbourne. **Explain** your findings.

9 At what time of the day is it most important to wear sunscreen and seek shade? **Explain** your answer.

10 **Describe** what would happen if Earth did not have different time zones.

Analysis

11 China is one of the largest countries in the world and should span five geographical time zones, but has only one (Beijing Standard Time). When it's 7 a.m. in Beijing, it's also 7 a.m. nearly 3000 km west in the Xinjiang region. **Critique** the decision to have one time zone in such a large country.

Knowledge utilisation

12 **Propose** some of the consequences of removing daylight saving time.

13 'If Earth stopped rotating, one side of Earth would be in total darkness all the time'. **Decide** whether you think this statement is true, giving your opinion on how life would be different if Earth did not rotate.

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4.2 Earth's yearly cycle

WORKSHEET
Seasons

Learning goals

1. To be able to recognise that gravity keeps planets in orbit around the Sun.
2. To be able to describe the cause of seasons in different regions on Earth.
3. To be able to recognise how First Nations Australians' calendars can be used to predict seasonal changes.

elliptical
oval-shaped

orbit
the curved path of a celestial object or spacecraft around a star, planet or moon

revolution
one complete orbit

leap year
a year that happens every four years and has an extra day on 29 February

mass
the amount of substance in an object that never changes, even in space

gravitational field
the region around a large object where another object can experience its gravity or pull

Apart from rotating on its axis, which results in the day–night cycle that repeats every 24 hours, Earth also orbits around the Sun following an **elliptical** path. It takes 365.25 days for Earth to travel around the Sun; the path is called an **orbit**. One complete orbit around the Sun is called a **revolution**. The calendar is simplified by using 365 whole days and adding an extra day once every 4 years. We call that year a **leap year**.

Earth orbits the Sun

An object with a large **mass** attracts an object with less mass and causes it to go into orbit if it is in its **gravitational field**. The Sun is 333 000 times heavier than Earth, so the gravitational field of the Sun causes Earth to orbit the Sun.

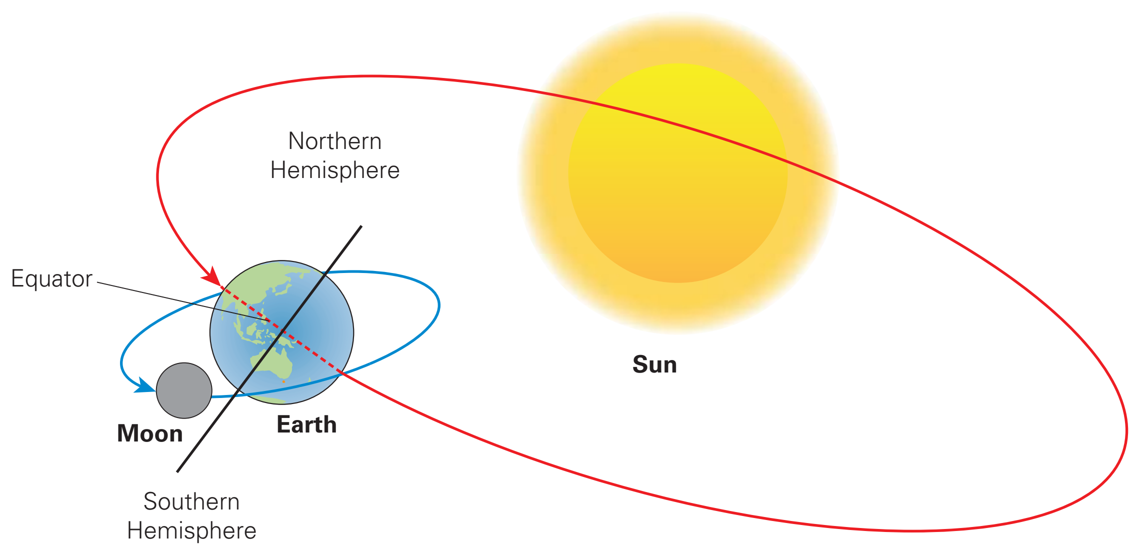

Figure 4.14 The Moon orbits around Earth, and Earth orbits around the Sun. Standing at the North Pole, these rotations appear to be anticlockwise.

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Seasons

You may have observed that over the course of a year, each day is slightly different. In the **Southern Hemisphere** where Australia is located, the day length decreases from January to June and increases from July to December. The shortest day occurs around 21 June. The longest day occurs around 21 December. The opposite happens in the **Northern Hemisphere** where the longest day is in June and the shortest day is in December. Interestingly, for places on the **equator**, the day length is always 12 hours every day of the year.

Southern Hemisphere
the half of Earth south of the equator

Northern Hemisphere
the half of Earth north of the equator

equator
an imaginary line drawn around the middle of Earth equidistant (halfway) between the North and South poles

Figure 4.15 Summer at Surfer's Paradise, Gold Coast

Figure 4.16 Autumn at Stanthorpe

Seasonal changes

What things do you observe throughout the year that are explained by the seasons changing? See how many of the following you came up with.

- The number of hours of daylight. During the year, the time the Sun rises and sets changes. In spring, the days get longer and in autumn, the days get shorter.
- The point on the horizon where the Sun rises and sets moves. The Sun always rises in the east and sets in the west, but the position varies, moving south in spring and north in autumn.

Figure 4.17 While it does not typically snow in Queensland, light snowfall has been reported in some areas such as Stanthorpe and the Granite Belt.

Figure 4.18 Spring on the way in New Farm, Brisbane

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- The average daily temperature is colder in winter and hotter in summer. The difference between average summer and winter temperatures increases with distance from the equator.
- The height of the Sun in the sky at midday increases in summer and decreases in winter.
- Some animals and plants change their behaviour and appearance at different times of the year. In winter, **deciduous** trees lose their leaves, some animals hibernate and others migrate. In the warmer months, birds nest and lay eggs, and plants produce flowers and then fruit though there are winter-flowering plants as well.

deciduous
a tree that loses its leaves in autumn and grows new ones in spring

- Seasonal changes also affect people. For example, farmers are heavily reliant on seasons for their livelihood. They can only sow and harvest at certain times of the year.

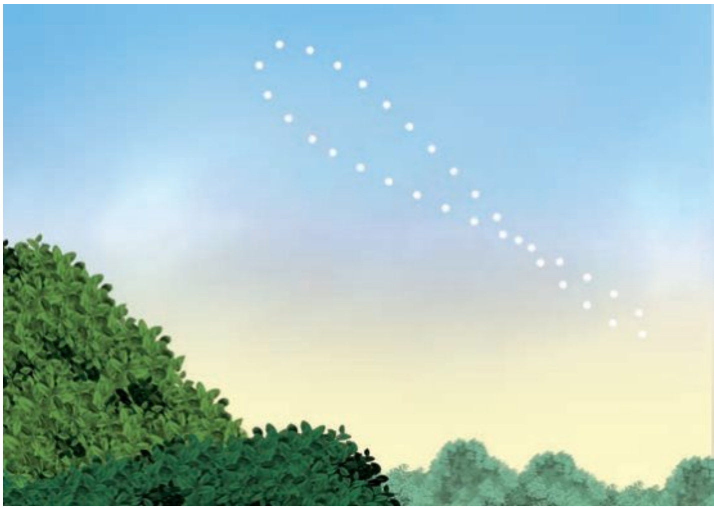

Figure 4.19 This illustrates the position of the Sun at the same time each week for a whole year.

Explore! 4.2

First Nations seasons

First Nations peoples have different ways of mapping the seasons, depending on where they live. In the far north of Queensland, the Yirrganydji people's calendar shows two distinct seasons: a wet season and a dry season. Kurrabana (the wet season) falls between November and May. This has two subseasons: Jawarranyji (storm time) and Jimburralji (cyclone time). Kurraminya (the dry season) spans May to November, and has three subseasons: Jinjim (cool time), Yiwanyji (windy time) and Wumbulji (hot time). Other Indigenous groups consider six separate seasons, dependent on subtle changes in weather. Use the Bureau of Meteorology website to research and then create a seasonal calendar for the Masig community in the Torres Strait.

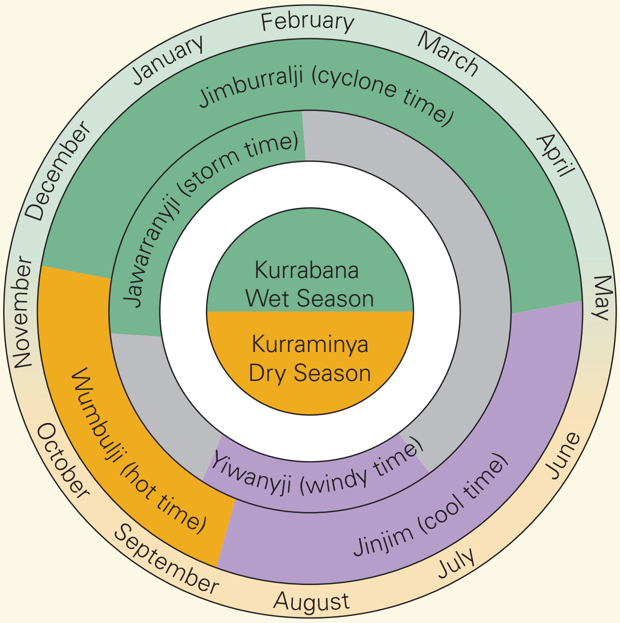

Figure 4.20 A Yirrganydji calendar marking the seasons

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Explore! 4.3

Daylight hours at different latitudes

Daylight hours depend on distance from the equator and how Earth orbits the Sun. The distance north or south of the equator is called latitude. Latitude is measured in degrees, starting with 0° at the equator. The North Pole is at 90°, or 90° North. The South Pole is at –90°, or 90° South.

Prediction

How do you think the number of hours of daylight in the summer changes as you go further north or south from the equator?

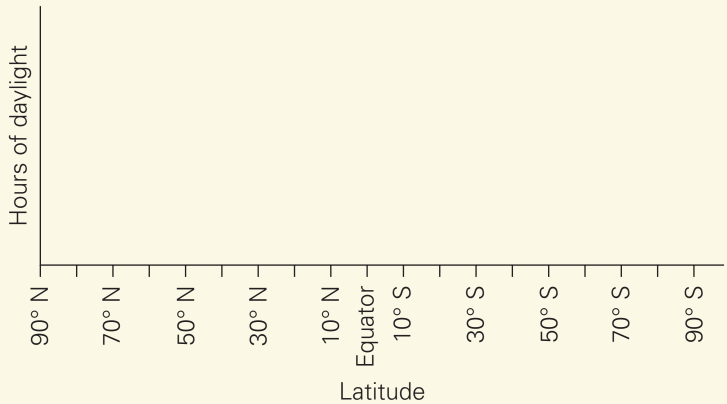
How do the number of hours of daylight vary in the winter?

Test your prediction

Use an atlas or website and select ten northern hemisphere cities from a range of different latitudes. Do the same with ten southern hemisphere cities. Note down the city and its latitude. You only need to write down the latitude to the nearest degree.

Use the internet to find out the number of hours of daylight for each city on 1 January and 1 July.

Draw a graph of latitude against the hours of daylight for January and July.



Can you identify any patterns in the proportions of a day spent in sunlight and in darkness and the seasons?

Figure 4.21 Sunset in Antarctica. The South Pole experiences several months of darkness during winter, where the Sun remains below the horizon.

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VIDEO
Earth's tilt and seasons

Earth's tilt causes seasons

Believe it or not, Earth's tilt can explain all of these observations! The axis of rotation of Earth passes through the North and South Poles. It is set at an angle of 23.5° from the vertical and the angle does not change as Earth goes around the Sun.

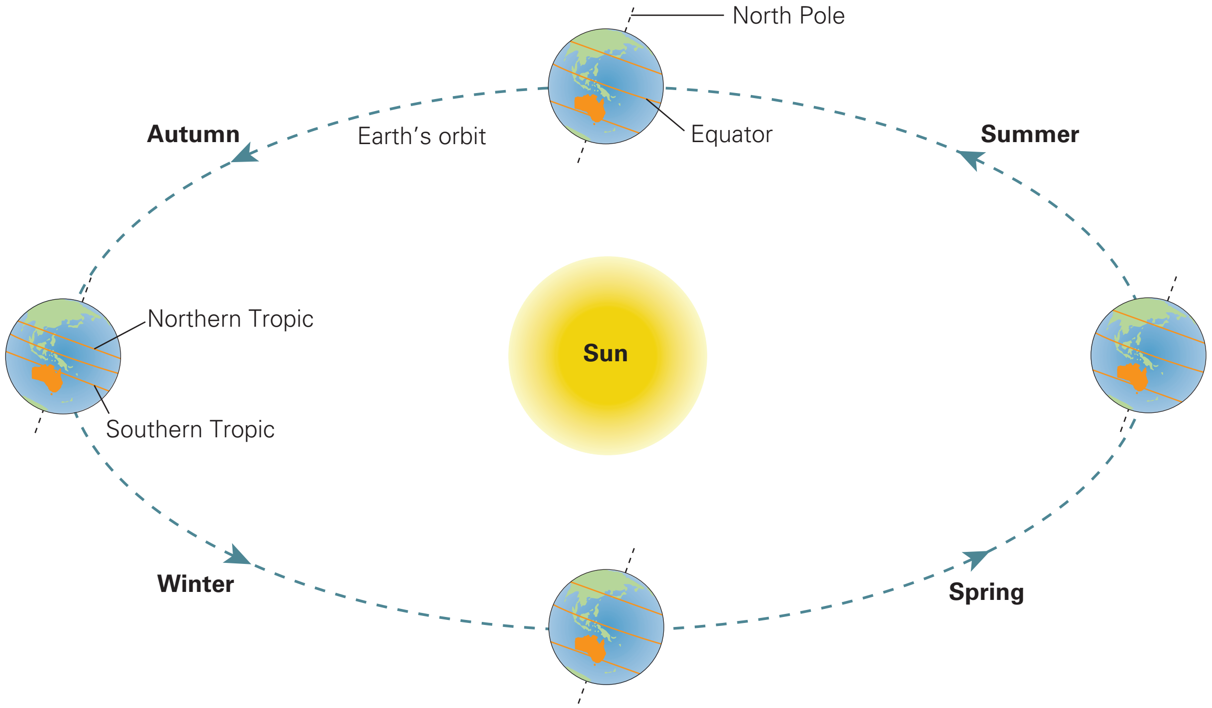

Figure 4.21 Seasonal arrangements of Earth and the Sun. The tilt of Earth causes the different seasons during the year. Australia is shown in orange.

Explore! 4.4

How do animals adapt to the seasons?

Figure 4.22 Black bears hibernate.

Figure 4.23 Greylag geese migrate.

The cycles of animal and plant life follow the seasons.

Research bird migration and animal hibernation. Select one species from each category and summarise your findings, including a picture and the reason why it hibernates or migrates.

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Investigation 4.1

Modelling the seasons

Aim

To investigate how the angle of Earth to the Sun affects the temperature of the area where the light hits.

Prior understanding

Light is energy from the Sun. Light rays can cause an area to heat up when they hit the surface of the area and are absorbed. When the Sun's rays hit Earth's surface close to the Equator, the energy is more direct (as it is closer to a 90° angle), so the area becomes warmer.

Be careful

Take care when handling light sources after extended use. They may be hot.

Take care when handling the opened can as it may have sharp edges.

Materials

- 1 opened aluminium can with small hole drilled in the side for the thermometer
- 1 thermometer
- adhesive putty
- lamp (a lamp used to heat reptile cages would be ideal)
- cylinder/rectangular shape to cover the lamp and direct light forward
- 1 m ruler or tape measure
- whiteboard with 1 cm graph paper or grid attached

Method

1. Attach a shade to the light to direct the light forward as much as possible.
2. Attach the thermometer through the hole in the can, making sure it is not touching the bottom. Secure in place with some of the adhesive putty.
3. Set up the equipment as shown in Figure 4.24. Keep the can upright, securing the bottom to the table with the adhesive putty.

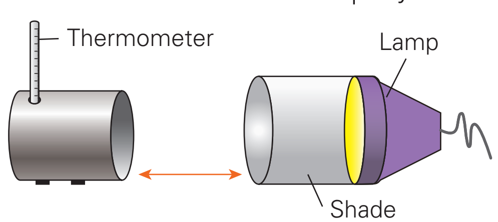

Figure 4.24

4. Copy the results table into your science book.
5. Measure the *direct, or straight position*.
   a. Measure the temperature inside the can and record.
   b. Turn on the light for 15 minutes.
   c. Measure the temperature inside the can and record.
6. Repeat steps **5a–5c** for two more trials, allowing the can to cool for a few minutes between each trial.
7. Place the whiteboard in front of the lamp and measure the diameter of the beam hitting the board, as shown in Figure 4.25**c**. Record the result.
8. Rotate the light until it is at an angle of 30° to the tin as shown in Figure 4.25**b**.
9. Repeat steps **5–7** to measure the *angled position* for both temperature and diameter, as shown in Figure 4.25**d**.

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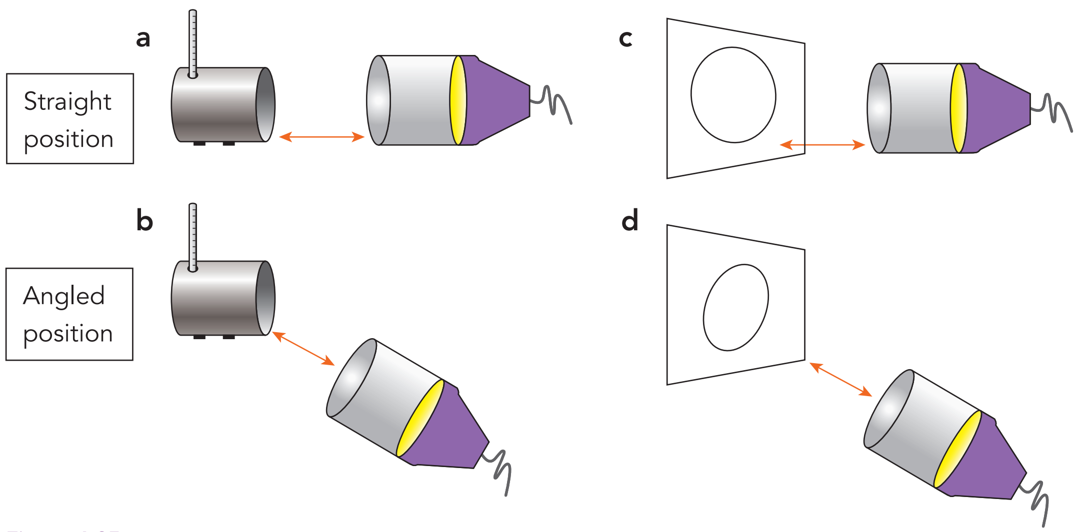

Figure 4.25

Results

Independent variable: Angle to the light		Dependent variables: Temperature (°C) Initial	Final	Change	Light: Diameter of the beam (cm)	Radius of the beam (cm)	Area of the beam (cm²)
Straight position	Trial 1						
	Trial 2						
	Trial 3						
	Mean						
Angled position	Trial 1						
	Trial 2						
	Trial 3						
	Mean						

Data processing

1. Add up your three initial temperatures for the straight position, then divide by three. This is the mean.
2. Repeat for the final temperatures and the change in temperature.
3. Repeat for the angled position data.
4. Divide your diameter data into two to calculate the radius.
5. Use this radius data to calculate the area, by using $A = \pi r^2$ (3.14 × radius^2).

Analysis

1. Describe the differences between the change in temperature when the lamp is in the straight position and when it is in the angled position.
2. Compare the area of the beam when it is in the straight position to when it is in the angled position.
3. Identify which position simulated the way the Sun hits the South Pole. Explain your reasoning.

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... continued

Evaluation

Reliability

1 Discuss how much variation was observed between the trials for each position.

Limitations

2 Identify any other factors (control variables) that may have changed and affected the results.

Improvements

3 Identify any changes that could be made to the method to improve the quality of the data in future experiments.

4 Discuss how the investigation could be extended in future experiments.

Conclusion

Develop a conclusion about the relationship between the area of the light beam and the temperature change.

Try this 4.5

How are the seasons caused?

Create an informative text for a younger audience to show how the tilt of Earth's axis, rotation of Earth on that axis, and the revolution of Earth around the Sun cause the seasons.

Quick check 4.4

1 Define the terms 'orbit', 'revolution' and 'elliptical' in your own words.
2 State how long it takes for Earth to orbit the Sun.
3 Describe things that change during the year due to the seasons.

Section 4.2 questions

QUIZ

Retrieval

1 **State** how long a complete cycle of all four seasons takes.
2 Based on your research from this section, **name** some creatures that are known to migrate with the seasons.
3 **State** the reason for the seasons on Earth.
4 **Construct** a diagram to help explain the progression of the seasons. Label each position with the corresponding season.

Comprehension

5 **Describe** how plants and animals act differently in summer from in winter.
6 **Describe** how the seasons are different in tropical north Australia.
7 **Describe** what the effect would be if the angle of tilt of Earth's axis of rotation was increased by 5°.

Analysis

8 It is winter in Australia. **Infer** what months are included in this season.
9 It is winter in China. **Infer** what months are included in this season.
10 It is autumn in Spain. **Infer** what months are included in this season.

Knowledge utilisation

11 Using Figure 4.20, which shows the Yirrganydji people's names for the seasons, **determine** how many weeks Yiwanyji lasts for.
12 This table shows hours of daylight in Brisbane on 30 April 2018.

Date	Sunrise	Sunset	Hours of daylight
30 April	6:12 a.m.	5:17 p.m.	11 h 4 min

Predict whether you expect the number of daylight hours to be more or less than 11 hours 4 minutes on 1 May.
13 The Sun lights up a tunnel containing a statue of Rameses, a pharaoh of Egypt who died in 1214 BC, only twice a year. **Propose** how the Egyptian sculptors might have seen in the dark to carve a statue of Rameses if the Sun only lights up the tunnel twice a year.
14 The summer solstice is when the Sun reaches its highest point in the sky, and the winter solstice is when the Sun reaches its lowest point in the sky. These are marked by the longest and shortest days respectively. **Propose** in which months these occur in the Southern Hemisphere, giving reasons for your answer.

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4.3 Movement of the Moon

Learning goals

1. To be able to explain the cyclic patterns of lunar phases.
2. To be able to describe how the relative positions of the Moon and the Sun result in tidal variations.

WORKSHEET
Phases of the moon

WIDGET
Phases of the Moon

VIDEO
Moon phases as seen from space

Recall that Earth orbits around the Sun because the Sun has greater mass. The mass of Earth is 81 times the mass of the Moon and so, for the same reason, the Moon revolves around Earth.

The phases of the Moon

Although the Moon looks bright, it does not give out any light of its own. All the light that comes to us from the Moon is reflected from the Sun. Only the half of the Moon that faces the Sun is bright; the other half is in shadow. The area of the bright side you can see from Earth depends on which phase the Moon is in. Figure 4.26 shows the names of the phases of the Moon. Note that between a new moon and a full moon, the Moon is **waxing**.

Between the full moon and a new moon, the Moon is **waning**.

Have you ever wondered how the Moon keeps the same face towards Earth? Observe the Moon over a period of two weeks. You will see that even though the phase changes, the craters and coloured areas on the Moon stay the same.

The reason the Moon always presents the same face to Earth is that the time taken for it to rotate once is the same as the time it takes to orbit Earth. The Moon takes about 27.3 days to orbit Earth – the same time it takes to rotate just once. This is known as **synchronous rotation**.

waxing
the period of about two weeks where the illuminated part of the Moon is increasing from a new moon to a full moon

waning
the period of about two weeks where the illuminated part of the Moon is decreasing from a full moon to a new moon

synchronous rotation
occurs when the rotation of an orbiting body is the same length of time as its revolution around a larger body

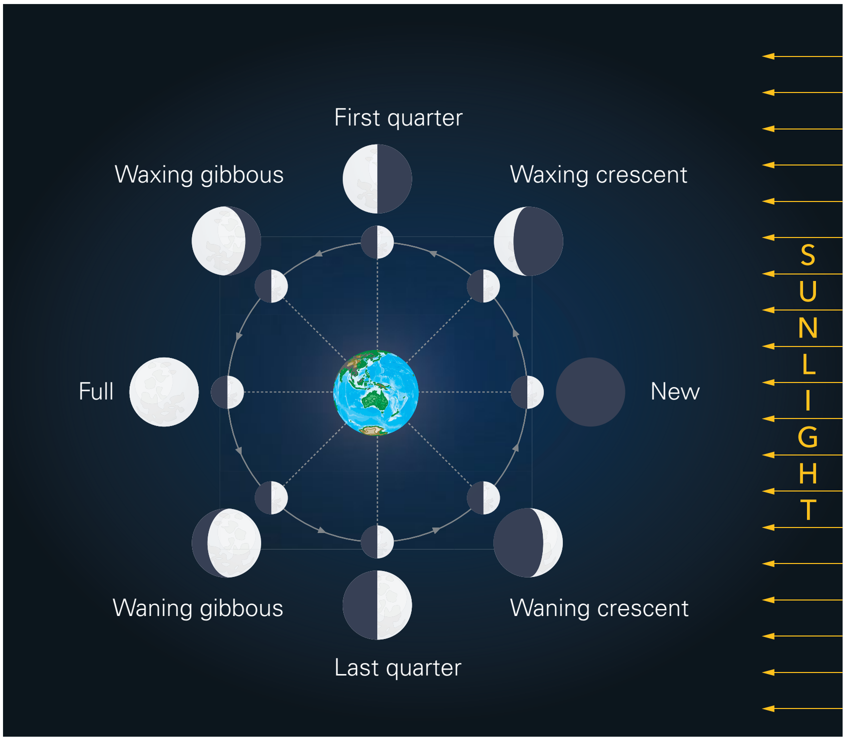

Figure 4.26 The phases of the Moon in the Southern Hemisphere

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Quick check 4.5

1 Explain how you can see the Moon if it does not give off any light of its own.
2 Explain why the Moon's surface always looks the same from Earth.

Science as a human endeavour 4.1

The days are getting longer!
The Moon is moving through space at a speed of one kilometre every second! It used to move much faster and was much closer to Earth. Over millions of years, it has slowly moved away and now moves more slowly around Earth. Scientists study rocks that are millions of years old to understand what planet Earth was like a long time ago. They have found that when the Moon was a lot closer to Earth, days on Earth were only 18 hours long! The further away the Moon is, the slower Earth rotates. But don't worry, at this rate scientists won't have to recalculate the length of a day for hundreds of millions of years!

Figure 4.27 The Moon used to be closer to Earth. It is moving away from us at a rate of 3.8 cm per year.

Moon orbit versus moon phase

One thing you might notice is that the time the Moon rises and sets is an hour later every day. You might also notice that each day the Moon's phase changes slightly. It takes 29.5 days (hence a month is about 30 days) to complete a cycle of phases from new moon to full moon and back to new moon. Recall that it takes 27.3 days for the Moon to rotate and orbit once around Earth. Why are they different?

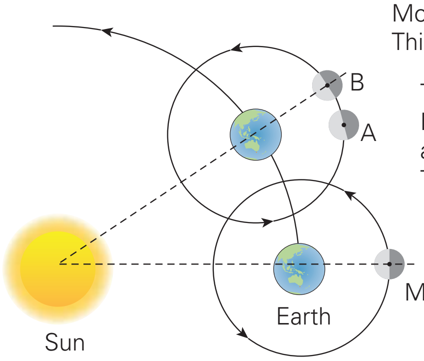

Figure 4.28 The time between full moons and the orbital period of the Moon is different by 2.2 days. It takes the Moon 2.2 days to move from A to B. The Moon has completed one orbit at A; the next full moon is at B.

If Earth was not orbiting the Sun, both times would be the same. This means the reason must be related to Earth's movement. A full moon occurs when Earth, the Sun and the Moon form a straight line. After the Moon has completed an orbit 27.3 days later, Earth has moved and the Moon is no longer in line with Earth and the Sun. To form the next full moon and to line up with Earth and the Sun again, the Moon has to keep moving for another 2.2 days.

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Explore! 4.5

How many times have astronauts landed on the Moon?

The lunar map on the right shows the face of the Moon with the NASA Apollo and Surveyor and Soviet Luna Moon landings labelled. The first Moon landing was Luna 9 in 1966 and the first crewed landing was Apollo 11 in 1969. Like most maps and pictures of the Moon, the North Pole is at the top.

Investigate the other times astronauts have landed on the Moon. Draw up a timeline to summarise all the landings you find out about. Include details of the date, landing location, country of origin and names of the space shuttles.

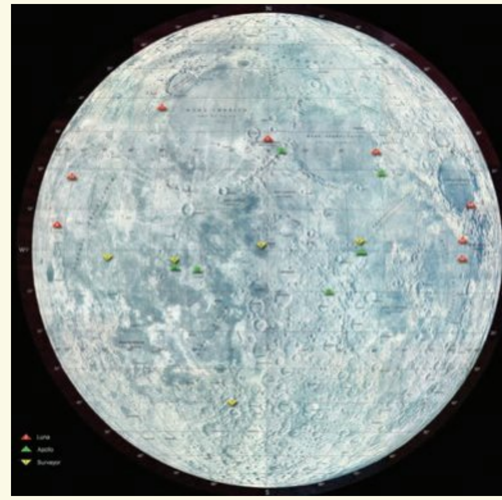

Figure 4.29 Soviet (red triangles) and USA (green and yellow triangles) lunar landing sites

Science as a human endeavour 4.2

What does the far side of the Moon look like?

Because the Moon always turns the same face towards Earth, the **far side** was not seen until spacecraft started to visit the Moon. The first images were seen in 1959 when the Soviet probe Luna 3 sent back pictures to Earth. Over the past 60 years, NASA has sent out many probes to explore the solar system and has obtained clearer images of the far side of the Moon.

far side
the face of the Moon that is always turned away from Earth; also called the dark side

Figure 4.30 Image of the far side of the Moon taken in 1959. Detailed maps have now been made of the far side but, as yet, no crewed mission has landed on its surface.

Figure 4.31 (a) The far side of the Moon and **(b)** the near side (Northern Hemisphere view). The dark patches visible on the Moon's surface are called seas. They are not made of water but were once liquid in the form of molten rock or lava that flowed out into low-lying areas on the Moon's surface.

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Quick check 4.6

1 Define the terms 'waxing' and 'waning'.
2 Explain how you can tell the Moon is moving through the sky.
3 State how long it takes to complete a full cycle of the Moon's phases.
4 How do scientists know what the far side of the Moon looks like?

Try this 4.6

Modelling the phases of the Moon

Using an electric lamp, an 8 cm polystyrene ball and a pencil, follow the instructions to model the phases of the Moon. Draw diagrams of your observations at each point in the cycle.

Be careful

Take care when handling light sources after extended use – they may be hot.

1 Stick the pencil into the foam ball so that the pencil can act as a handle. Place the lamp in the centre of a darkened room.
2 Extend your arm so you are holding the foam ball in front of you. The ball should be between your eyes and the lamp. The foam ball is modelling the Moon, the lamp is the Sun and your head is Earth. Note that the polystyrene ball does not generate light of its own; it reflects light from the lamp.
3 The Moon starts off in a 'new moon' position, as you can only see the unlit side.
4 Sweep your right arm in a clockwise direction to model the waxing moon phases. Move your head to the side to observe these phases. Record what you see in a results table.
5 Once the Moon is behind your head, it will be in the 'full moon' phase unless your head (Earth) is blocking the light and creating a lunar eclipse.
6 Switch the ball to your left hand and continue moving it clockwise back to the start to simulate waning phases of the Moon.

Describe where the ball was in relation to your head when it was at the following phases: new moon, full moon, waxing gibbous, waning gibbous, waxing crescent, waning crescent, first quarter, third quarter. Propose how you could improve this simulation.

The Moon affects the tides

Earth and the Moon orbit each other, spinning around a point between them. This affects the tides in two ways – the force due to gravity, which pulls Earth (and all of the water on it) towards the Moon, and opposing forces, which pull Earth (and all of the water on it) away from the Moon.

At any given time, there are two high tides and two low tides on Earth, but they are constantly changing position as the Moon and Earth rotate around each other. On the side of Earth closest to the Moon, the gravity of the Moon causes the water to bulge towards it – this is a high tide. On the opposite side of Earth, the centrifugal force causes the water to bulge away – this is the second high tide. If there is more water at the bulges, there must be less water elsewhere – so the regions halfway between the high tides experience a low tide.

Figure 4.32 Low tide in the Whitsunday islands

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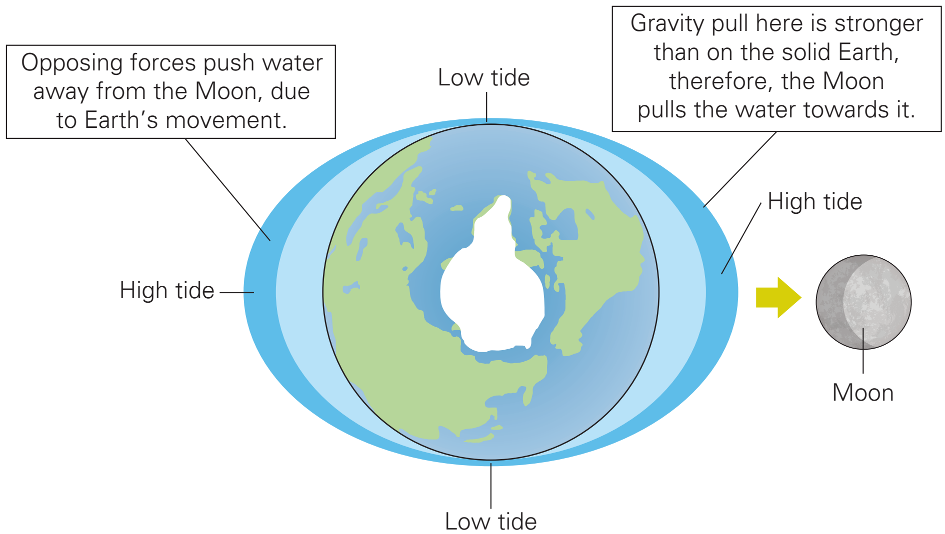

Figure 4.33 High tides are caused by the Moon's gravity and always occur on opposite sides of Earth, which means low tides must also occur on opposite sides.

Tide height is also affected by the Sun. The Sun's gravity is stronger than the Moon's, but the Sun is also 400 times further away than the Moon. This makes solar tides about half the size of lunar tides.

When Earth, the Moon and the Sun align (during a new moon or a full moon), the gravitational pull of the Moon and the Sun combine to create higher high tides and lower low tides. These are known as spring or king tides. Neap tides, on the other hand, occur when there is the smallest difference between high tide and low tide. This occurs when the Sun is at right angles to the Moon; the tides are weaker as the forces due to the Moon and the Sun are opposite.

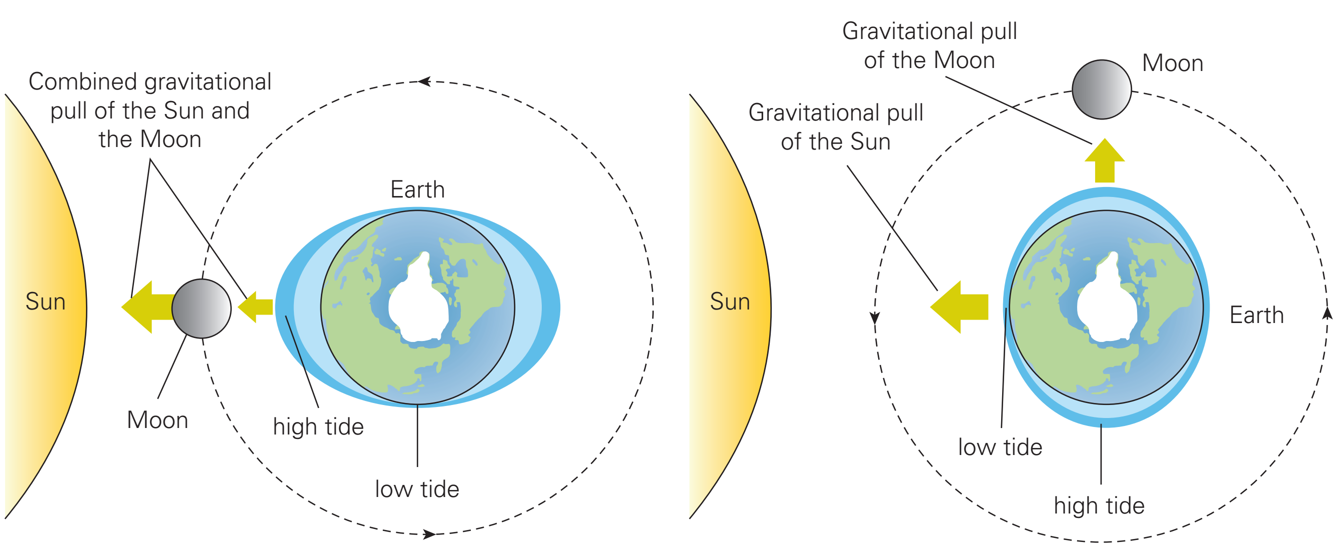

Figure 4.34 Left: Spring tide occurs when the Sun and the Moon are in line. Right: Neap tide occurs when the Sun and the Moon are at right angles.

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Explore! 4.6

Moon landing expedition

You are planning a Moon landing expedition. Astronauts will need to be on the Moon for four days to collect sufficient samples. They need to land on the part of the Moon that is illuminated by the Sun so they can see their surroundings. They will also be communicating with you using radio waves, so their transmitter must be pointed towards Earth.

1 During which phase(s) and where on the Moon would you want to land? Justify your choice using an annotated diagram.
2 You are planning the expedition three years in advance of the launch. Use a lunar calendar on the internet to select some dates when it would be appropriate to launch.

Did you know? 4.7

Hunting by the Moon

Yolngu people call the Moon Ngalindi, and traditionally describe water filling him as he rises, becoming full at high tide. When the water drains out of him, there is a lowering of the tides.

Coastal First Nations Australians link phases of the Moon to the different tides and use it to inform hunting, fishing and agricultural practices. Torres Strait Islanders observe the lunar phases to know the best times to go fishing and will avoid spring tides. High spring tides disturb sediment, meaning fish cannot see the bait and fishers cannot see the fish.

Explore! 4.7

Tidal warning systems

Sometimes, water levels can rise much higher than the normal high tide levels. This is due to storms or cyclones where strong winds force water up against the coast. Low-lying coastal areas are badly affected by such tidal or storm surges. About 80% of Queenslanders live in coastal areas at risk of flooding due to tidal surges. Climate scientists predict more frequent flood events along the Queensland coast in the next few decades due to the effects of climate change.

Figure 4.35 Coastal communities are at risk of tidal or storm surges

A warning system is an example of an emerging information system designed to protect communities. The Australian Warning System is a national approach to information and warnings during emergencies like bushfire, flood, storm, extreme heat and severe weather. Introduced in 2022, the system uses a nationally consistent set of icons.

Research one of the warning systems used in Australia.

Use a collaborative digital tool in your class to brainstorm ideas about how communities can be warned about a disaster.

Consider the advantages and disadvantages of warning systems and communication methods.

Use the UN Office for Disaster Risk Reduction (UNDRR) Stop Disasters Game (www.stopdisastersgame.org) to learn about the risks posed by natural hazards, and the importance of managing resources.

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Making thinking visible 4.1

Circles of action: Waste management

After every high tide we are reminded of just how badly we have polluted our oceans. However, in 2022, CSIRO researchers conducted coastal surveys that showed there was 29% less plastic on beaches than in 2013 when similar surveys were carried out. This is due to Queensland bringing in tougher bans on single-use plastic and the public having got better at sorting through household waste.

Use your local council website and find the Waste Management and Recycling page. Consider how your local council has:

- communicated the impact of waste materials on the environment
- encouraged recycling.

Undertake the following Circles of action activity.

What can be done to contribute to waste management …

- among your friends and family?
- in your community (your school, your street)?
- in the world (beyond your local environment)?

Figure 4.36 Lizzie the Litter Critter is one of Fraser Coast Regional Council's 'waste monsters' designed to encourage kids to learn good waste management habits.

The *Circles of action* thinking routine was developed by Project Zero, a research centre at the Harvard Graduate School of Education

Section 4.3 questions

QUIZ

Retrieval

1 **State** how fast the Moon is moving.
2 **State** how long the Moon takes to orbit Earth.
3 **Name** the phases of the Moon.

Comprehension

4 **Describe** the surface of the Moon.
5 **Explain** why the time taken for the Moon to orbit Earth is different to the time between full moons.
6 **Explain** why a half-lit moon is called a quarter moon.
7 **Explain** why the Sun and the Moon appear the same size in the sky.
8 **Illustrate** why the Moon takes 27.3 days to orbit Earth and yet there are 29.5 days from one full moon to the next.
9 **Explain** how it is possible for the Sun's equator to rotate at a different rate to the Sun's polar regions.

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Use the chart in Figure 4.37 showing the phases of the Moon for 2023 to answer Questions **10**, **11** and **14**.

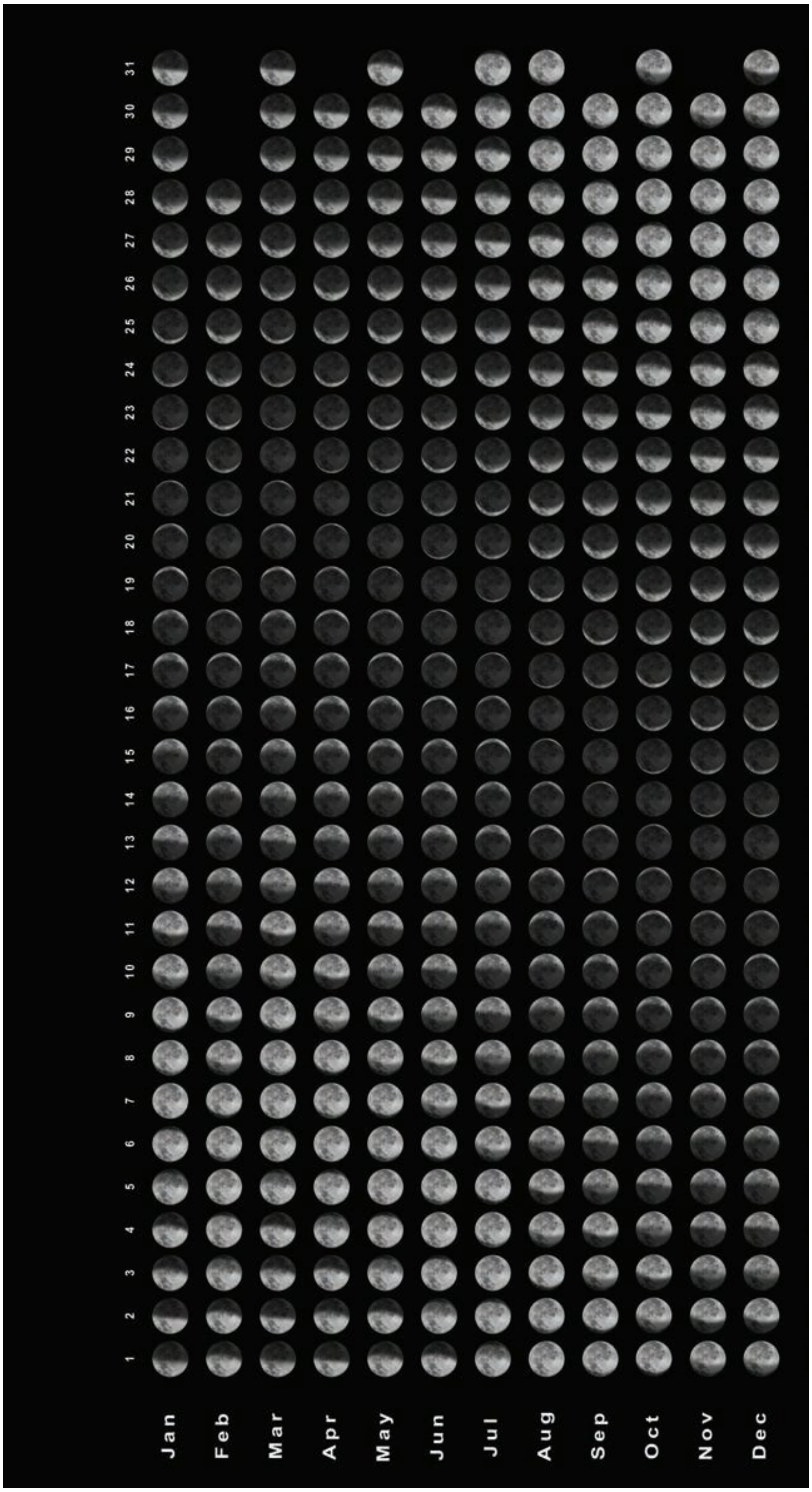

Figure 4.37 The lunar calendar for 2023

10 **Describe** the phase of the Moon on 15 August 2023.

11 **Describe** the phase of the Moon on 8 October 2023.

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Analysis

12 **Compare** the speed of the Moon today to the speed it travelled at millions of years ago.

13 **Identify** the approximate number of weeks from the first quarter phase to the last quarter phase of the Moon.

14 The saying 'once in a blue moon' is used when discussing anything that happens rarely. A blue moon occurs if there are two full moons in a month. **Analyse** Figure 4.37 to see if there were any blue moons in 2023.

15 Examine the tide table for Mooloolaba in Figure 4.38 to practice reading a tide table.

- **a** **Deduce** what the following symbols are on the tide table:

  ●, ◑, ○, ◐

- **b** **Describe** the relationship between the lunar cycle and tidal variations.
- **c** **Explain** why it may not be the best idea to go to the beach on Sunday 3 December for a picnic lunch.
- **d** A teacher is organising a field trip to the beach for students to study rock pools at low tide. The bus will leave school at 7:30 a.m. and it takes two hours to travel. They must leave the beach at 1 p.m. Identify a day that you would recommend that the class went on their field trip. **Justify** your answer.

Knowledge utilisation

16 **Predict** how the Moon would look if it had an atmosphere and experienced weather conditions.

December

	Time	m		Time	m
1	0340	0.33	16	0337	0.20
	1037	1.79		1035	1.99
FR	1722	0.57	SA	1717	0.41
	2239	1.10		2242	1.25
2	0421	0.43	17	0429	0.28
	1120	1.70		1127	1.93
SA	1811	0.60	SU	1814	0.42
	2327	1.07		2341	1.24
3	0508	0.52	18	0527	0.38
	1206	1.61		1222	1.85
SU	1903	0.62	MO	1912	0.43
4	0027	1.05	19	0050	1.25
	0605	0.61		0632	0.48
MO	1257	1.54	TU	1318	1.75
	1959	0.62		2009	0.41
5	0148	1.07	20	0206	1.31
	0715	0.69		0747	0.58
TU	1353	1.49	WE	1416	1.64
◐	2053	0.58	◑	2102	0.38
6	0309	1.14	21	0320	1.42
	0831	0.72		0908	0.63
WE	1449	1.45	TH	1515	1.54
	2142	0.52		2154	0.33
7	0410	1.26	22	0426	1.55
	0943	0.72		1027	0.65
TH	1542	1.43	SA	1614	1.45
	2224	0.45		2243	0.29
8	0459	1.39	22	0522	1.69
	1045	0.69		1137	0.62
FR	1630	1.41	FR	1710	1.37
	2300	0.38		2329	0.25
9	0539	1.53	24	0612	1.81
	1141	0.64		1237	0.58
SA	1714	1.39	SU	1803	1.32
	2334	0.30			
10	0616	1.66	25	0013	0.22
	1229	0.58		0658	1.90
SU	1757	1.37	MO	1329	0.53
				1853	1.28
11	0009	0.24	26	0054	0.21
	0654	1.78		0740	1.94
MO	1315	0.52	TU	1415	0.50
	1840	1.35		1939	1.26
12	0045	0.18	27	0133	0.22
	0733	1.89		0820	1.95
TU	1400	0.46	WE	1456	0.48
	1924	1.33	○	2021	1.26
13	0123	0.15	28	0212	0.24
	0815	1.96		0900	1.94
WE	1445	0.42	TH	1534	0.49
●	2009	1.32		2100	1.25
14	0205	0.14	29	0249	0.27
	0859	2.00		0936	1.90
TH	1532	0.40	FR	1611	0.51
	2057	1.30		2139	1.25
15	0249	0.15	30	0326	0.33
	0945	2.01		1013	1.84
FR	1623	0.40	SA	1646	0.53
	2147	1.27		2216	1.23
			31	0402	0.40
				1049	1.78
			SU	1723	0.55
				2256	1.21

Figure 4.38 Tidal calendar for Mooloolaba

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4.4 Eclipses

DOC
WORKSHEET
Eclipses

Learning goals

1. To be able to describe the cause of a solar and a lunar eclipse.
2. To understand First Nations Australians' oral traditions and cultural recordings of solar and lunar eclipses.

solar eclipse
an event when the Sun partly or completely disappears from view, while the Moon moves between it and Earth

lunar eclipse
a full Moon becomes dark as it enters Earth's shadow

syzygy
the occurrence in astronomy of three or more objects moving into a straight line

total eclipse
an event when the Sun is completely blocked by the Moon

umbra
the region in a shadow where the light is completely blocked

partial eclipse
an event when the Sun is partially blocked by the Moon

penumbra
the region in a shadow where the light is partially blocked

The motions of Earth around the Sun and the Moon around Earth are complex and require mathematics to describe them precisely. However, they are completely predictable. By looking for patterns in observations made over many years, ancient astronomers could anticipate with reasonable accuracy some of the events you are going to learn about, such as:

- **solar eclipses**, where the Moon blocks the light from the Sun and casts a shadow on a small part of Earth
- **lunar eclipses**, which occur when Earth's shadow blocks the light travelling to the Moon.

Solar eclipses

Once a month, in its orbit around Earth, there is a chance that the Moon may come exactly between Earth and the Sun. If this happens and the Sun, the Moon and Earth all line up, astronomers call it a **syzygy** and the result is a solar eclipse. Because the Moon is considerably smaller than Earth, a solar eclipse is only visible from a small region on Earth's surface.

Total versus partial eclipse

During a solar eclipse, the Moon blocks the light from the Sun on a small part of Earth's surface. A **total eclipse** is visible from the dark coloured central part of the shadow called the **umbra**. A **partial eclipse** occurs when the light from the Sun is partially blocked; it is visible from the area that is lightly shaded on Earth called the **penumbra**. Both the umbra and penumbra are so small that even if there is a solar eclipse most people won't see it.

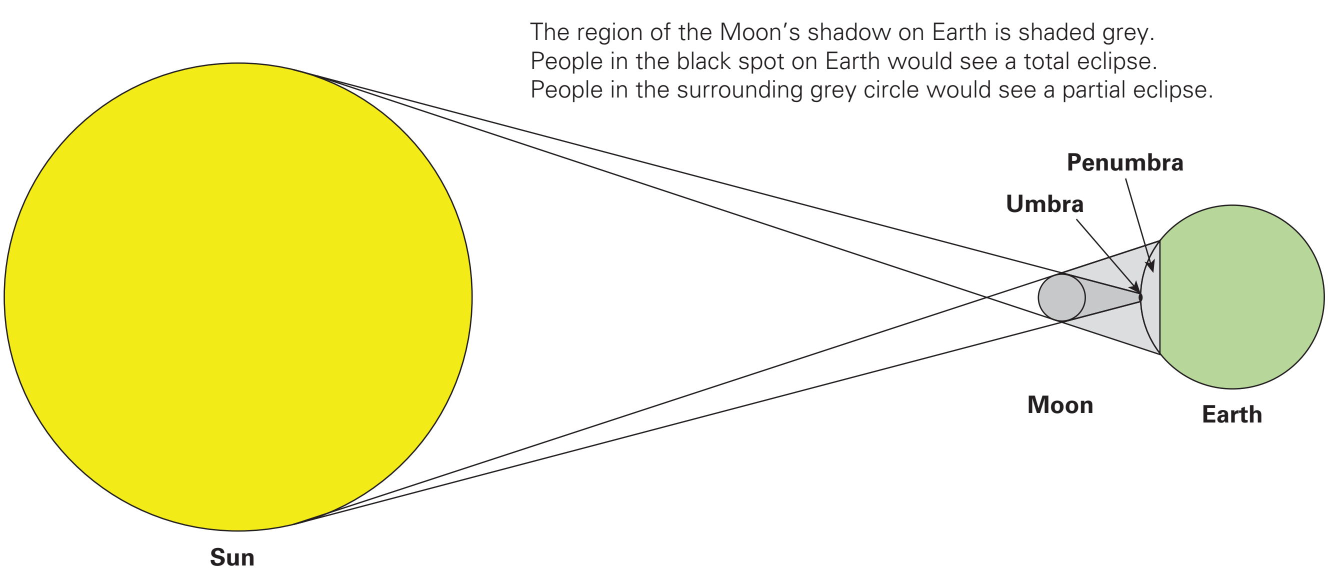

Figure 4.39 A solar eclipse occurs when the Moon comes between Earth and the Sun. This diagram is not to scale and the size of the shadow areas is greatly exaggerated.

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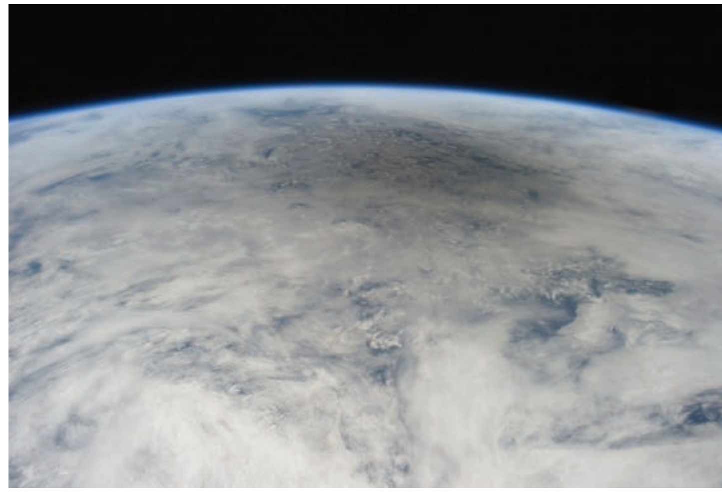

Figure 4.40 A solar eclipse photographed from the International Space Station. The Moon's shadow covers only a small fraction of Earth's surface.

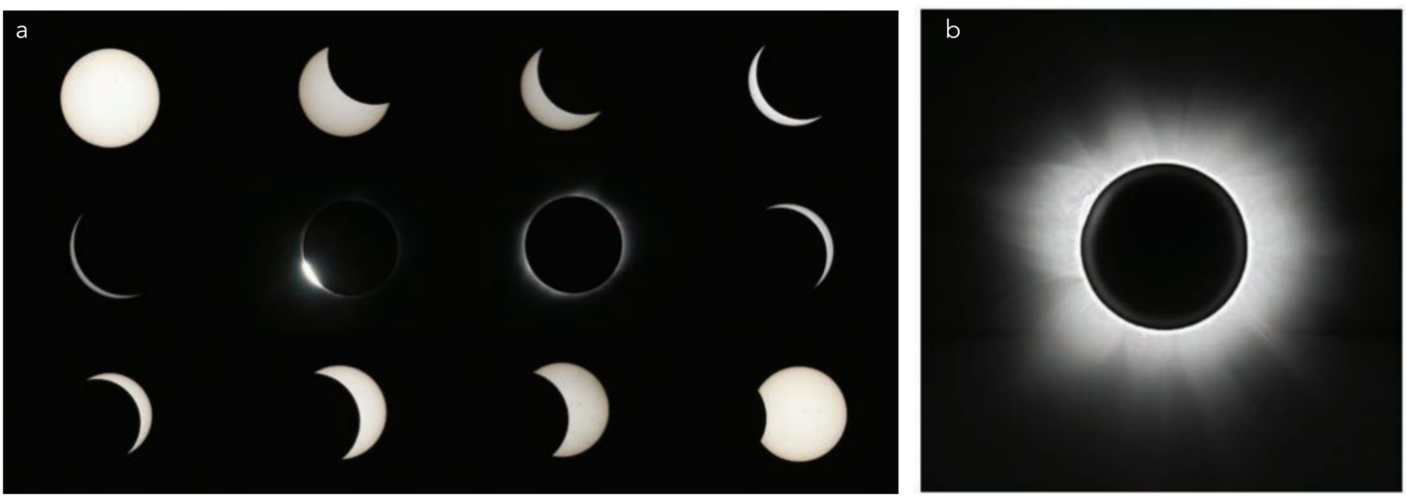

Figure 4.41 (a) A series of images showing the stages of a total solar eclipse, and **(b)** totality.

Try this 4.7

How far is it to the Sun?

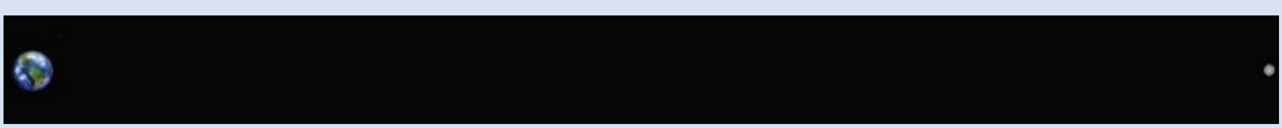

Figure 4.42 Earth and the Moon are drawn here to scale. The Sun is 400 times further away than the Moon.

Measure the distance from Earth to the Moon in Figure 4.42. Multiply the distance by 400 to work out how far away the Sun would be if it were also included in the picture. The distance between Earth and the Sun is known as 1 Astronomical Unit (1 AU). This prevents having to write huge numbers when we are measuring in kilometres.

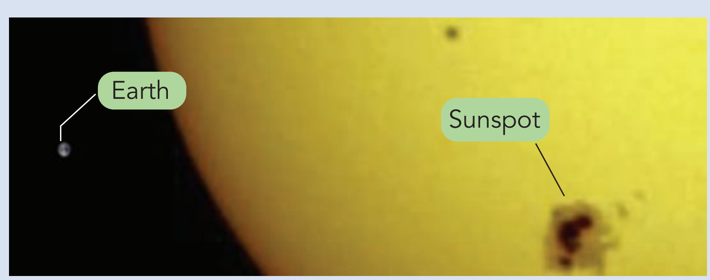

Figure 4.43 It might be tempting to think that the Sun is of a similar size to Earth because its light can be blocked by the Moon, but the Sun is much larger than Earth. In this image, Earth is placed next to a portion of the Sun to show their relative sizes.

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Annular eclipses

perigee
the point in the Moon's orbit when the Moon is closest to Earth

apogee
the point in the Moon's orbit when it is furthest from Earth

annular eclipse
an event when the Moon blocks the Sun but the Moon is further away and the outer edge of the Sun is still visible

The Sun is about 400 times bigger than the Moon but is also 400 times further away, so from Earth the Moon and the Sun appear to be about the same size. This means that the Moon is just big enough to hide the Sun when it passes in front. However, the orbits of Earth and the Moon are not perfect circles and the Moon's apparent size can vary by up to 12% in its orbit around Earth. If the solar eclipse occurs when the Moon is closest to Earth (**perigee**), the result is a total eclipse. If the Moon is at its furthest point (**apogee**), the result is an **annular eclipse**. The mathematical word for the shape you get when you cut a small circle from the centre of a larger circle is an annulus, so this type of eclipse is called an annular eclipse.

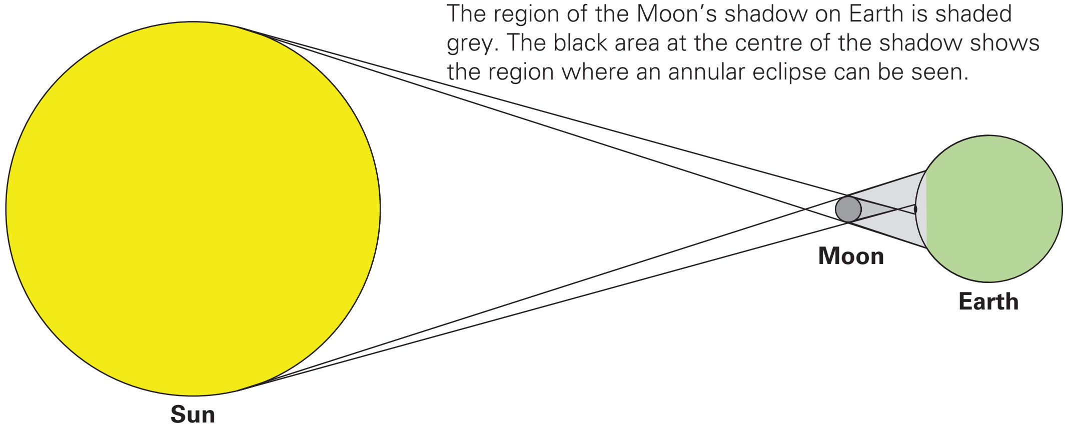

Figure 4.44 If the Moon is not at its closest to Earth at the time of the eclipse, the result is an annular eclipse. The dark area is where an annular eclipse can be seen; the lightly shaded region on Earth's surface experiences a partial solar eclipse (not to scale).

Figure 4.45 An annular solar eclipse seen through a cloud

Quick check 4.7

1 Define the term 'syzygy'.
2 Explain why a solar eclipse is visible from only a small part of Earth.
3 Explain the difference between a blue moon and a super moon.

Explore! 4.8

First Nations stories of the Sun and the Moon

In many First Nations Australians cultures, the Sun is a woman and the Moon is a man. Some traditional stories describe the Sun pursuing the Moon across the sky from day to day, occasionally meeting during an eclipse.

In Euahlayi culture, the Sun, Yhi, is pursuing the Moon man, Bahloo, who has rejected her advances. Sometimes, Yhi tries to kill Bahloo by eclipsing him. However, spirits that hold up the sky drive Yhi away.

Research the oral traditions of solar and lunar eclipses from the following groups of First Nations Australians:

1 the Lardil of Mornington Island
2 the Yolngu people of Elcho Island in Arnhem Land
3 the Wirangu of South Australia.

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Lunar eclipses

A lunar eclipse occurs when the Moon moves into Earth's shadow.

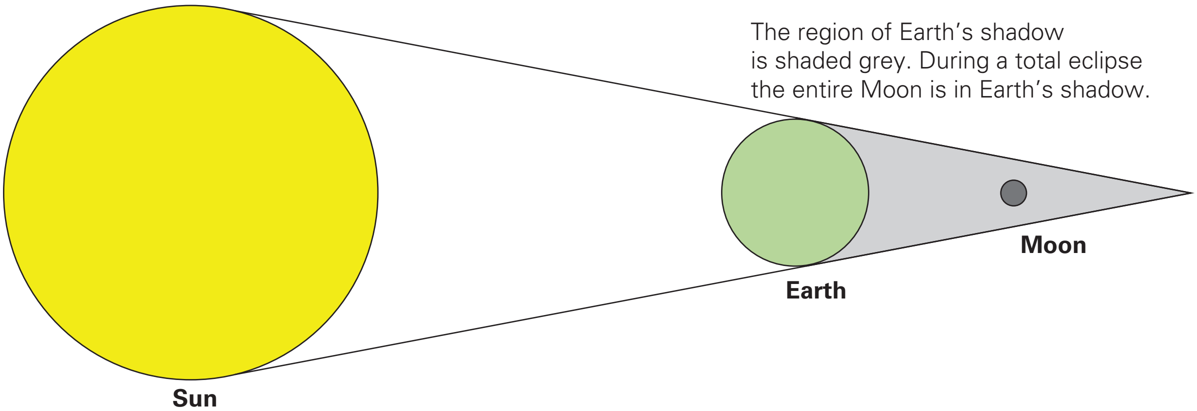

Figure 4.46 Earth is much bigger than the Moon, so Earth's shadow is big enough to cover the whole of the Moon.

Figure 4.47 A total lunar eclipse in progress. The round edge of Earth's shadow is visible.

Figure 4.48 When the Moon is completely in Earth's shadow during a total lunar eclipse it is called a **blood moon**. The red colour is due to red light being refracted (bent) by the atmosphere around Earth. Hence, only red light reaches Earth during the total eclipse.

blood moon
a name given to the Moon during an eclipse while it is completely in Earth's shadow

Comparison of solar and lunar eclipses

VIDEO
Solar and lunar eclipses

Although the Sun and the Moon are involved in both kinds of eclipses, solar and lunar eclipses are very different. A solar eclipse is a rare event and results in the sky turning dark during the day, whereas a total lunar eclipse happens at night and results in the full moon moving into Earth's shadow.

	Total solar eclipse	Total lunar eclipse
Duration	A few minutes	A few hours
Who can see it	A small area only	Everyone on Earth
Occurrence	Once every 18 months	1–2 per year
Safety	Special equipment required to view	Safe, anyone can watch, no special equipment required
Cause	Moon's shadow on Earth	Earth's shadow on the Moon
Moon phase	New moon	Full moon

Table 4.1 Differences between solar and lunar eclipses

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Try this 4.8

Modelling solar and lunar eclipses

Wang Zhenyi was a scientist born in 1768. At this time, the feudal customs of China hindered women's education, but she educated herself on subjects such as astronomy and mathematics.

Explore how Wang Zhenyi modelled a lunar eclipse using a lamp.

Draw a diagram to show how she arranged her equipment then use the materials listed to model a solar and lunar eclipse.

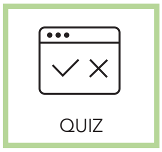
- high wattage lamp
- globe
- tennis or golf ball
- string

Record your observations of the shadows created in this model. Explain how you modelled a solar eclipse in this activity. Explain how you modelled the lunar eclipse. Predict what would happen if you change the size of the ball. Discuss how this model could be improved.

Be careful

Take care when handling light sources after extended use – they may be hot.

Figure 4.49 Wang Zhenyi



Section 4.4 questions

Retrieval

1 **Recall** the phase of the Moon when a lunar eclipse occurs.

2 **Recall** the phase of the Moon when a solar eclipse occurs.

Comprehension

3 **Describe** how solar and lunar eclipses are created.

4 **Explain** why a person is likely to see many more lunar eclipses in their lifetime than solar eclipses, even though both events occur with similar frequency.

5 **Describe** how our experiences on Earth would be different if the Moon was larger.

Analysis

6 **Compare** a partial and a total solar eclipse.

Knowledge utilisation

7 **Propose** why eclipses are so rare.

8 **Discuss** the factors that need to be considered when viewing solar eclipses and lunar eclipses.

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4.5 Exploring the universe

Learning goal
To be able to describe how models of the solar system have changed over time.

WORKSHEET
Models of the solar system

VIDEO
Our solar system

The solar system

Earth is one of eight planets that orbit the Sun. All the planets except Mercury and Venus have moons. Jupiter, which is the biggest planet, has more than 60 moons. The solar system is the name given to the Sun and all its orbiting planets, including Earth, as well as dwarf planets such as Pluto.

The invention of the **telescope** gave us much more information about the solar system. With the introduction of the telescope, scientists discovered that Jupiter had moons and Saturn had rings. Scientists were able to look further into the solar system and the planets Uranus (1781) and Neptune (1846) were discovered.

Figure 4.50 The solar system includes Earth. All the planets except Uranus and Neptune can be seen without a telescope.

telescope
an optical instrument for making distant objects appear nearer and larger, or an instrument that detects electromagnetic radiation from space

Explore! 4.9

Pluto's disqualification
Pluto, discovered in 1930, used to be considered a planet. Investigate why Pluto was reclassified as a dwarf planet in 2006. State the criteria that disqualified Pluto from being a planet.

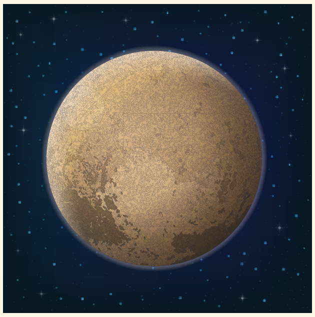

Figure 4.51 Dwarf planet Pluto

Figure 4.52 Jupiter and three of its moons: Ganymede, Europa and Callisto

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Science as a human endeavour 4.3

Geocentric versus heliocentric models of the solar system

Aristarchus of Samos, who lived from around 310 BCE to 230 BCE, developed the first known **heliocentric model** of the solar system; that is, all planets, including Earth, rotated around the Sun. His theory was rejected by many philosophers and astronomers at the time because they did not think such a thing could be physically possible.

heliocentric model
a model with the Sun as the centre of the solar system

geocentric model
a cosmological model where Earth was the centre of the universe

The most popular theory held by many astronomers in ancient times assumed that the Sun, planets, even the whole universe revolved around Earth. This model is called the **geocentric model** and was published in a book, *The Mathematical Collection*, by Ptolemy (Figure 4.53), an astronomer, geographer and mathematician who lived in 90–168 CE. All astronomers at that time used this model and it continued to be the preferred explanation of how the solar system works for more than a thousand years.

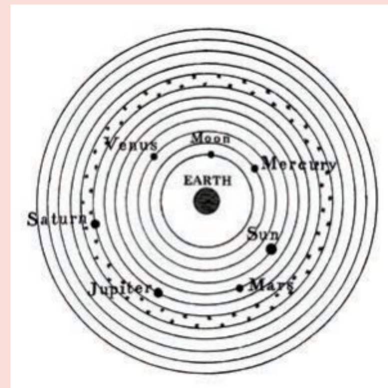

Figure 4.53 Historical artwork of the Earth-centred (geocentric) Ptolemaic cosmological model

It was not until the year 1543, approximately 1400 years after Ptolemy (and 1800 years after Aristarchus!) that Nicolaus Copernicus published his heliocentric model, borrowing from the work of Aristarchus. The model stated that, in fact, it is Earth that revolves around the Sun (Figure 4.54).

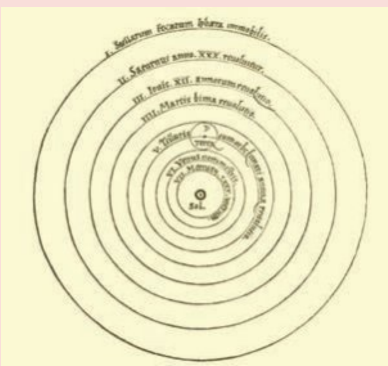

Figure 4.54 The diagram of Copernicus' heliocentric system, in Latin, as it appears in his book *De Revolutionibus orbium coelestium, On the revolutions of the heavenly bodies*, in 1543. 'Sol' is the Sun and 'Terra' is Earth.

In 1610, Galileo Galilei, an Italian astronomer, first looked at the heavens with a telescope and made observations confirming that the geocentric model was incorrect. About 150 years after Copernicus published his work, Isaac Newton (a physicist and mathematician) finally produced convincing proof that supported the heliocentric model.

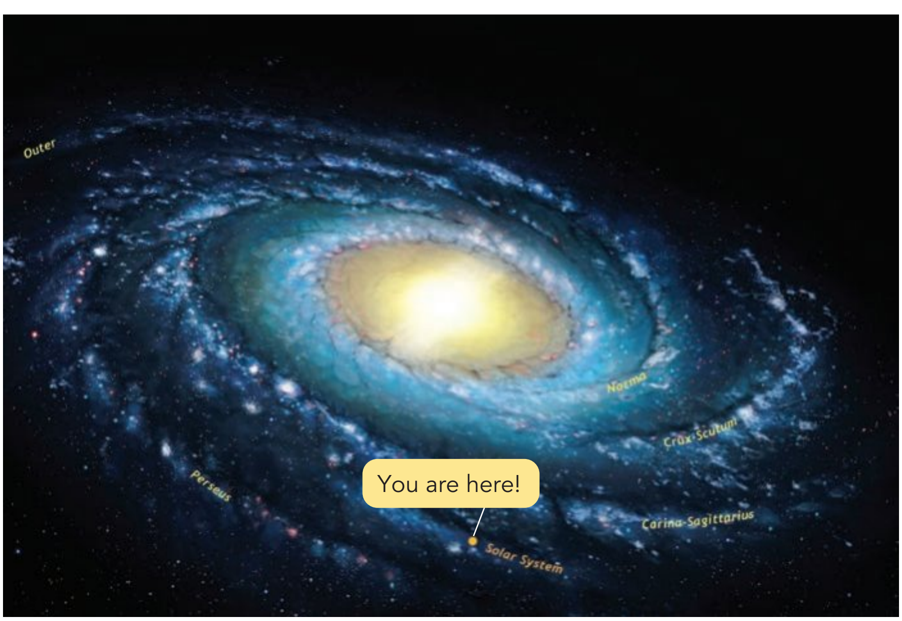

Figure 4.55 The Milky Way Galaxy showing the position of our solar system

Our galaxy

It was outside the solar system that the most exciting discoveries were made. The faint band of light that can be seen on dark moonless nights was found to be made up of countless individual stars and it was realised that our Sun is just one star in a galaxy of billions of stars called the Milky Way.

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Explore! 4.10

The celestial emu

First Nations Australians observe the positions of stars to predict seasonal change and inform themselves about plants and animals that may be used for food and medicine. For example, the position of the celestial emu in the sky is directly linked to the breeding behaviour patterns of emus in Australia. The constellation provides information about when emu eggs are available to eat.

When the celestial emu rises in the sky at dusk in April and May it informs certain groups of First Nations Australians that the emu breeding season has begun and it is the best time to harvest eggs. In June and July, the celestial emu appears horizontal at dusk. At this time, no egg harvesting occurs as most eggs have chicks in them.

You can use the Stellarium software to explore how the celestial emu looks at different times of the year. Set the date to the start of March and change the time to dusk. Find the celestial emu and start to move the date forward, keeping the time the same. Note how the constellation starts to change.

Complete some research about local First Nations communities in your area and find out what First Nations Australians perceive each celestial emu position to represent in their dreaming narrative.

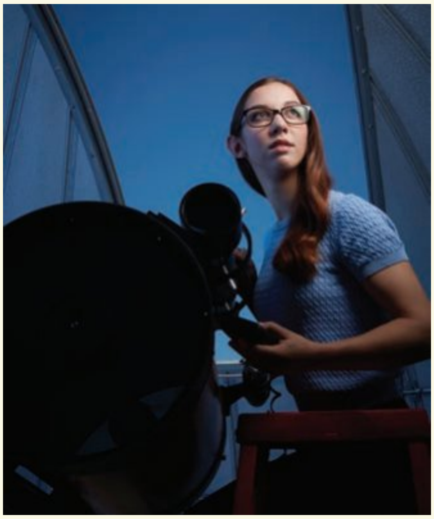

Figure 4.56 The Emu in the Sky dreaming story inspired Wiradjuri astrophysicist Kirsten Banks to share the astronomical knowledge of her ancestors. She regularly leads Aboriginal astronomy programs at the Sydney Observatory.

Try this 4.9

Making a telescope

Be careful
WARNING: Do not look at the Sun or any bright lights with a telescope.

Materials

- 2 cardboard tubes
- convex lens with 30 cm focal length
- convex lens with 5 cm focal length
- piece of card paper
- poster adhesive
- elastic bands

Method

1 Use poster adhesive or glue to fix the lenses to each of the cardboard tubes, as in Figure 4.57.
2 Wrap the piece of card around the tube with the lenses facing outwards. Secure with elastic bands.
3 Look at an object in the distance with your eye closer to the smaller lens. Focus the telescope by lengthening or shortening the tube. The length of the tube should be about 35 cm for viewing distant objects.

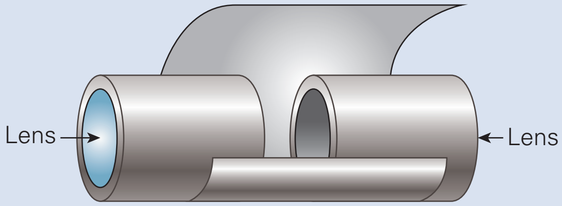

Figure 4.57 Make your own telescope.

Describe how well your telescope worked. Explain how simple telescopes like this have helped scientists throughout history.

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Improvements on the telescope

The telescope has had a serious influence on our understanding of the universe and our place within it. There have been several technological advances in telescope design over the centuries. The first big advancement in telescope design was an invention by Newton, who discovered a way to make powerful telescopes by replacing the lenses with mirrors. Over time, bigger telescopes were made that could see more detail. Observatories were built to house these giant telescopes on top of mountains to minimise the distorting effect of the atmosphere.

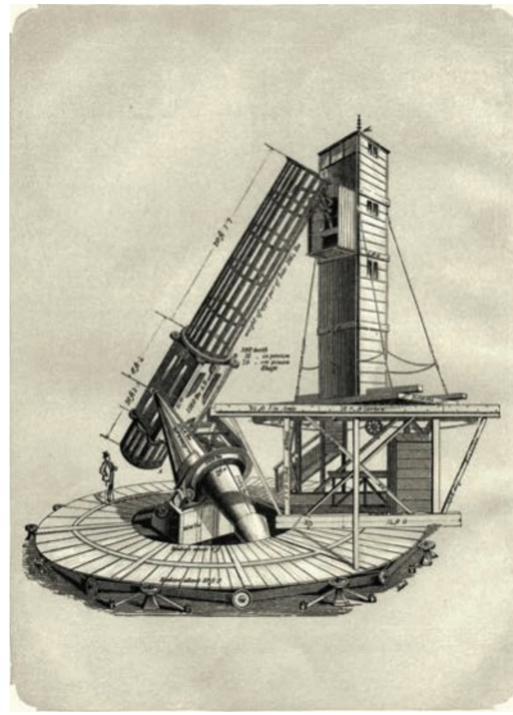

Figure 4.58 A sketch of a Newtonian telescope, 1870, a type of reflecting telescope that used two mirrors

While it is easy to measure the brightness of a star, more information can be obtained by attaching a spectrometer to a telescope. This allows astronomers to analyse the colours in the light from a star. The colour of a star indicates its temperature and, by looking at the temperature and sizes of many stars, astronomers realised that stars do not stay the same but evolve over time. Using this information, astronomers estimate that our Sun is about 4.6 billion years old and is expected to continue shining for a further 4.6 billion years.

Galaxies outside our own

Edwin Hubble was an American astronomer who made a significant contribution to astronomy in the 1920s. Not only was he the first to realise that our galaxy, the Milky Way, was just one of billions of galaxies in the universe but he also discovered that the galaxies were all moving apart from one another. Using this fact, he estimated that the universe formed 12–13 billion years ago in an event now called the Big Bang and that it has been expanding ever since.

Challenges for the future in astronomy

Scientists now have a very good understanding of the structure and history of the universe owing to the many observations made since the invention of space probes such as the Voyager 2, a probe that was launched from Earth in 1977 and left our solar system in 2018. However, there are still aspects of the universe for which science has no explanation, such as the nature of dark matter and the existence of dark energy.

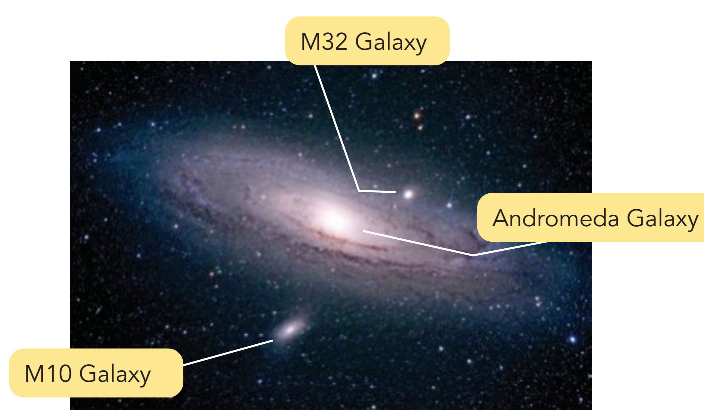

Figure 4.59 The Andromeda Galaxy. This nearby galaxy is similar in structure to the Milky Way. Two other galaxies (M10 and M32) are also visible.

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Try this 4.10

Stellarium

Use the Stellarium planetarium software program (available at stellarium.org) to simulate the sky from any place on Earth. Currently, two First Nations Australians' constellations are available: Boorong and Kamilaroi.

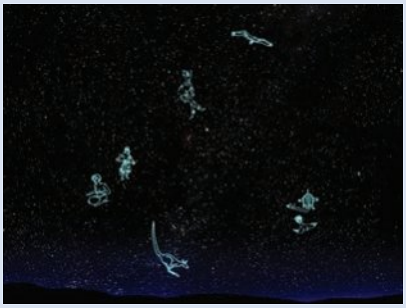

Figure 4.60 Some Boorong constellations of north-west Victoria

Science as a human endeavour 4.4

The Hubble Space Telescope

Hubble's contribution was recognised when a telescope launched into space was named after him. The Hubble Space Telescope takes images that are free from any distortion from the atmosphere, and, by using long exposure times, the images it takes are often both stunning and beautiful.

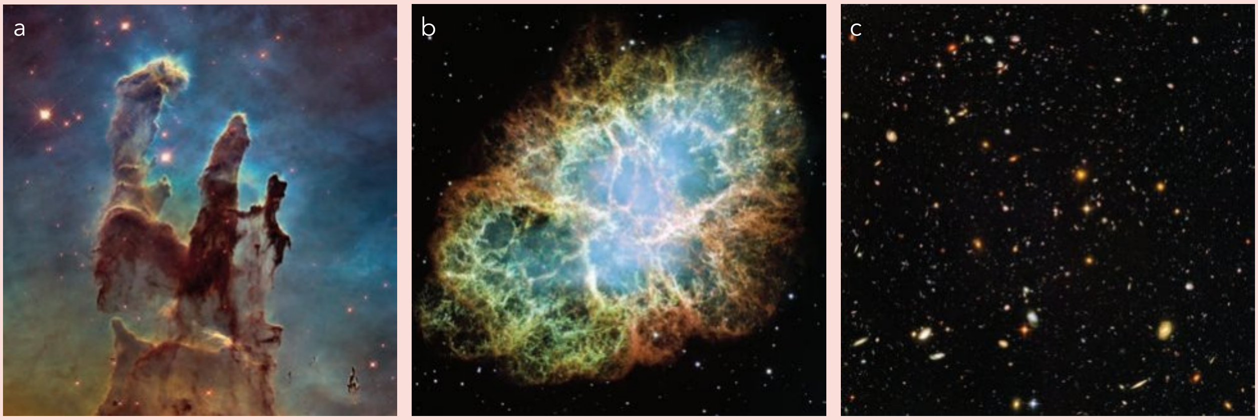

Figure 4.61 Images taken by the Hubble Space Telescope: **(a)** the Pillars of Creation, a star-forming region in our galaxy, **(b)** the Crab Nebula, the remains of a star that exploded in 1054 CE, **(c)** the Hubble Space Telescope shows that even the darkest patch of sky is found to be full of galaxies.

Science as a human endeavour 4.5

The LUVOIR

While the Hubble Space Telescope provided a huge leap forward in making more of the universe visible, it has just about reached the end of its useful life. A new concept for a telescope named LUVOIR (**L**arge **U**ltra**V**iolet, **O**ptical and **I**nfra**R**ed) can do much more than Hubble. It will be 15 metres in diameter and be able to collect 40 times the amount of light that Hubble could. Making use of the newest technology for telescopes today, it will provide much clearer pictures of the universe. It will be able to take pictures in the visible light spectrum (light that you can see) and also the ultraviolet and infrared spectrum (light that our human eyes cannot see).

It is hoped that LUVOIR will be able to analyse the atmospheres of planets orbiting other stars for signs of life!

Figure 4.62 Artist's impression of the LUVOIR telescope

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Section 4.5 questions

QUIZ

Retrieval

1 **Recall** what the solar system is made of.
2 **Recall** which galaxy Earth is in.

Comprehension

3 **Explain** how telescopes are able to help people see in more detail.
4 **Explain** why telescopes are built on top of mountains.
5 **Describe** the sorts of discoveries that can be made with telescopes.
6 **Explain** what the colour of a star can tell an astronomer.
7 **Explain** why is it important to have telescopes that can gather data on light other than visible light.

Analysis

8 **Compare** the geocentric and heliocentric models.
9 There are two main types of telescopes: reflecting and refracting. **Contrast** the two.
10 The table shows the ratios of mass, density and gravity on different planets.

Planet	Mass (10^{24}kg)	Density (kg/m^3)	Gravity (m/s^2)
Mercury	0.330	5249	3.7
Venus	4.87	5243	8.9
Earth	5.97	5514	9.8
Mars	0.642	6792	3.7
Jupiter	1898	1326	23.1
Saturn	568	687	9.0
Uranus	86.8	1270	8.7
Neptune	102	1638	11.0
Pluto	0.0130	2376	0.7

a **Identify** the planet with the largest mass.
b **Identify** the planet with the highest density.
c **Identify** the planet with the strongest gravity.
d **Describe** the effect that a planet's mass has on the gravity experienced on that planet.
e Density is the amount of matter in a given volume. If two planets were the same size, but one was much denser than the other, predict which would have a stronger gravitational pull. **Justify** your answer.

Knowledge utilisation

11 **Discuss** how telescopes have changed our understanding of the universe, including how our understanding of the universe might be different if the telescope had not been invented.

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Chapter review

Chapter checklist

You can download this checklist from the Interactive Textbook to complete it.

Success criteria		Linked questions	Check
4.1	I can describe the effect of Earth's rotation on temperature and time zones.	5, 8, 15, 18	
4.1	I can state the rotation times for Earth, the Moon and the Sun.	1, 4, 9	
4.2	I can recognise that gravity keeps planets in orbit around the Sun.	2	
4.2	I can describe the cause of seasons in different regions on Earth.	16, 18	
4.2	I can recognise how First Nations Australians' calendars can be used to predict seasonal changes.	6	
4.3	I can explain the cyclic patterns of lunar phases.	10	
4.3	I can describe how the relative positions of the Moon and the Sun result in tidal variations.	11	
4.4	I can describe the cause of a solar and a lunar eclipse.	12, 13, 17	
4.4	I can understand First Nations Australians' oral traditions and cultural recordings of solar and lunar eclipses.	3	
4.5	I can describe how models of the solar system have changed over time.	20, 21	

Review questions

SCORCHER

Retrieval

1 **Recall** the approximate number of times Earth spins in one month.
2 **Recall** what keeps planets in orbit around the Sun.
3 **Recall** what the Sun and Moon are considered as in many First Nations Australians' cultures.
4 **Recall** the approximate number of complete phase cycles of the Moon in one year.
5 **State** if the Sun rises first in Brisbane, Sydney, Melbourne or Perth, and why.
6 **State** the number of distinct seasons used by the Yirrganydji peoples of Far North Queensland.
7 The antipodes of a point is that point projected through Earth to the opposite side. **State** the antipodes of the North Pole.

Comprehension

8 **Describe** two reasons why the average winter temperature is higher in Brisbane than in Melbourne.
9 **Explain** why it is difficult to specify the time the Sun takes to rotate.
10 **Explain** why an eclipse can never occur during a quarter moon.
11 **Explain** what causes a spring (king) tide.
12 The Moon is slowly moving away from Earth. **Illustrate** a diagram to show why total solar eclipses will become less likely in the future.

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Analysis

13 **Contrast** the time taken for Earth to orbit the Sun with how long it takes the Moon to orbit Earth.

14 Seasons have been observed on Mars. The Martian polar ice caps, as in Figure 4.63, have been seen to grow and shrink with the changing temperature in a similar way to Earth's polar ice caps. What can you **infer** about the angle of tilt of the axis of rotation of Mars?

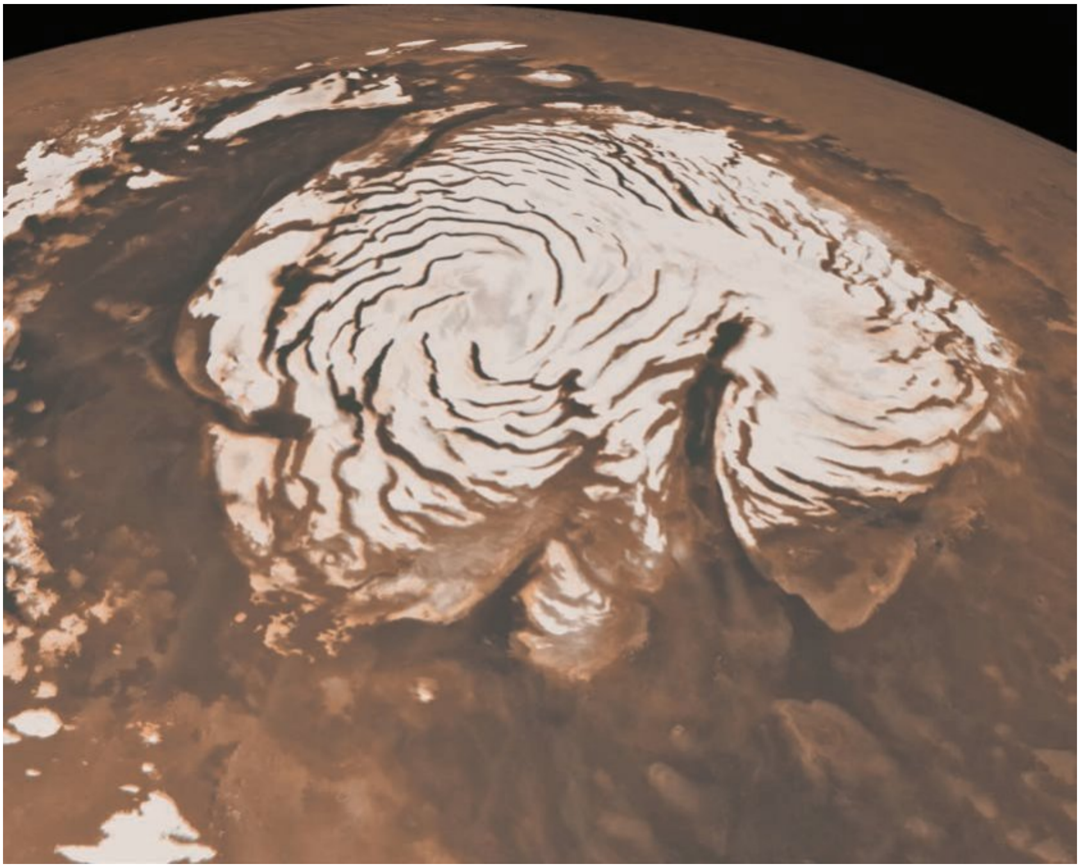

Figure 4.63 A polar ice cap on Mars

Knowledge utilisation

15 It is dark in Brisbane and daylight in Perth. **Determine** if it is morning or evening.

16 **Discuss** whether places near the equator experience seasons.

17 **Discuss** if a solar eclipse and a lunar eclipse could occur in the same month.

18 **Predict** how the seasons and hours of daylight at different locations on Earth would be different from now, if Earth did not have a tilt.

19 **Predict** what the night sky would look like on Saturn, which has 62 moons.

20 **Investigate** how telescopes have progressed through the years and write a brief summary of how the technology has changed.

21 There have been many things discovered about the universe throughout history. **Propose** what might be found in the future with developing technology.

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Data questions

Just like Earth's moon, the Moon, there are moons that orbit the planet Jupiter. In fact, Jupiter has 79 known moons! These vary in size and distance from the planet. The eight innermost moons and the periods of their orbits are shown in Figure 4.64.

Apply

1 **Identify** which of the moons in Figure 4.64 orbits furthest in distance from Jupiter.

2 Use the data to **determine** which moon takes approximately 1.8 days to complete a full orbit of Jupiter.

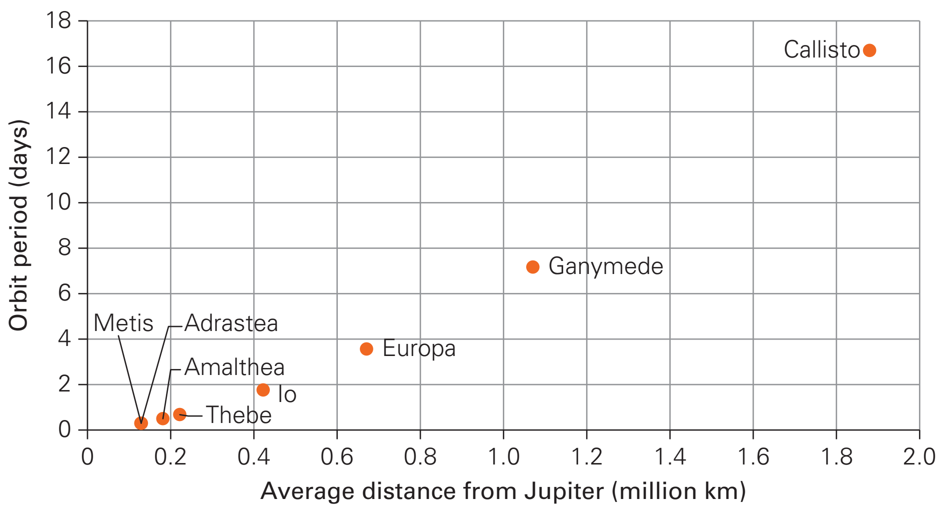

Figure 4.64 Orbital period of Jupiter's inner and Galilean moons

3 Adrastea has an orbit time of 0.3 days, whereas Amalthea has an orbit time of 0.5 days. **Calculate** the difference in the number of hours it takes these moons to orbit Jupiter.

Analyse

4 Galileo Galilei first discovered the four largest of Jupiter's moons in the 17th century, when he saw them through a telescope. They are those with an average orbit distance between 0.3 to 2 million km from Jupiter. **Categorise** the moons in Figure 4.64 as 'Galilean' or 'inner orbiting' (for those that orbit at distances other than 3 to 20 million km).

5 **Distinguish** the Galilean moons from the inner orbiting moons by referring to their possible size.

6 **Identify** the trend in the average distance of a moon from Jupiter and the time it takes for the moon to complete a full orbit of Jupiter.

Interpret

7 Jupiter's ninth moon is called Thermisto, and its average distance from Jupiter is approximately 7.3 million km. A student has estimated, based on the trend in Figure 4.64, that the orbital period for Thermisto would be approximately 20 days. Use the data to **deduce** whether this would be an accurate estimate.

8 Earth's moon, the Moon, has an average distance from Earth of approximately 0.4 million km and has an orbit period of 27.32 days. **Compare** this data point to those provided in Figure 4.64 for the moons of Jupiter. Does Earth's moon orbit period fit the trend identified in Question **6**?

9 **Justify** your response to Question **8** with an appropriate scientific explanation.

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STEM activity: Simulating the orbit of planets in the inner solar system

Background information

Have you ever wondered why Earth or other planets do not go flying off into outer space? Or how large bodies (planets!) have followed the Sun across the emptiness of space for billions of years? This is the best explanation scientists have come up with so far: *gravitational forces*. You will learn more about gravity in Chapter 5.

Gravitational forces operate in a very interesting way. It turns out that the larger an object, the more gravitational pull it has. So, in the case of our solar system, our Sun (as the most massive object within this system) possesses a powerful gravitational attraction on all the other objects in the solar system. In other words, all objects within the solar system are under the gravitational attraction of the Sun.

Now, you might remember that, here on Earth, the gravitational force pulls objects towards the centre of the planet. In other words, things (including you and me) are always falling to the ground. Here is a question for your curious mind: why aren't Earth and the other planets falling into the Sun?

It turns out that they are indeed falling, as the Sun's gravity pulls them towards it. But they were born in a vast rotating cloud of dust and have a huge amount of momentum directed in a straight line into deep space. The Sun's pull balances the momentum meaning they move in a curved path around the Sun, always falling towards it, but never reaching it. The closer a planet is to the Sun, the faster it needs to travel to prevent gravity pulling it into the Sun.

Design brief: Create a simulation of the solar system planets orbiting the Sun

Activity instructions

In this task, you will investigate how Kepler's laws of orbital motion explain why different planets orbit our Sun at different speeds. In a nutshell, Kepler's laws of orbital motion are straightforward, summarised as:

A planet's orbital speed changes, depending on how far it is from the Sun. The closer a planet is to the Sun, the stronger the Sun's gravitational pull on it, and the faster the planet moves.

We can observe the effects of Kepler's laws within our own solar system right now. Table 4.2 shows the relationship between distance and orbit of the planets Mercury, Venus, Earth and Mars.

Planet	Distance from the Sun (km)	Orbital period (days)
Mercury	55 000 000	88
Venus	105 000 000	225
Earth	150 000 000	365
Mars	228 000 000	687

Table 4.2 Distance and orbital period data for planets located in the inner solar system

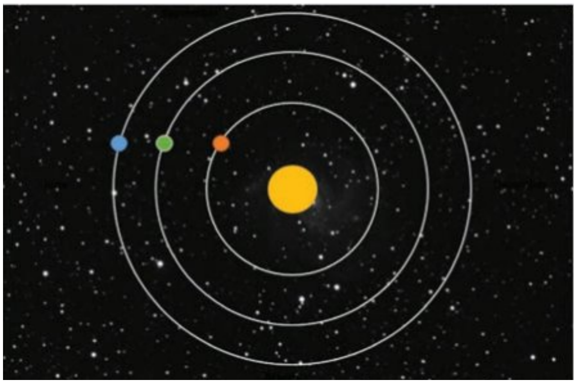

Figure 4.65 Model of the solar system

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Your task is to use Microsoft PowerPoint to create your very own simulation of the solar system (like the one shown in Figure 4.65), and to gain a visual understanding of how Kepler's laws of orbital motion apply to planets orbiting the Sun.

Suggested materials

- laptop
- Microsoft PowerPoint
- paper and pencil to perform simple calculations

Research and feasibility

1 Research our solar system, the names of the planets, their orbiting speed and distance from the Sun.

Design

2 Create a labelled model of the solar system. Include planet names, their orbital speeds and each planet's distance from the Sun.

Create

3 Use Microsoft PowerPoint to create your model.

4 Microsoft PowerPoint has given all planets within the inner solar system the same orbital period (2 seconds). However, you know that planets closer to the Sun (e.g. Mercury) have shorter orbital periods compared to planets located further away (e.g. Saturn). Therefore, you should make changes to your simulation to make it behave as closely as possible to the real solar system.

5 Assuming that, on your model, Mercury orbits your Sun in 2 seconds (orbital period = 88 days), estimate the number of seconds required for Venus (orbital period = 225 days) and Earth (orbital period = 365 days). After you finish your estimation, you can change the values (seconds) to make your simulation more realistic.

Evaluate and modify

6 Discuss with your group the challenges you have encountered throughout this project. List the strategies or actions that allowed you to overcome it.

7 Reflection is an integral and vital aspect of any project in the real world. In your honest opinion, list what you would like to have included, removed or modified from this challenge as well as ways to improve the way we visualise our solar system.

Extension

Planets in our solar system orbit the Sun like clockwork. For example, Mercury will always orbit the Sun in around 88 days, while Earth takes around 365 days to complete one orbit; this is due to the distance between the Sun and the planets (that is, the closer they are to the Sun, the shorter the time it takes them to complete one round of their orbit).

Now, imagine the following scenario: scientists just released news that the mass of our Sun has shrunk by half, while the distance between the Sun and the planets remained the same. The scientific community would be worried about this development since the Sun is at the centre of our solar system. Predict, using your own words and by reading the definition of Kepler's laws, whether the orbital period of planets would change at all in this new hypothetical scenario.

Now consider creating a model of the Sun-Earth-Moon system using Microsoft PowerPoint. Could you use your new skills to simulate a solar or lunar eclipse?

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Chapter 5
Forces

Chapter introduction

Whether you are walking, running, sitting in a vehicle, riding a bike or sleeping, forces are acting on you all the time. At school, forces are at work when you pick up a book, write a sentence or open a lunchbox. When you are standing perfectly still, forces act on you to make sure that you don't fall through the floor or fly up into the sky. In this chapter, you will explore how to measure and identify forces around you. You will discover how forces can be added together, or cancel each other out. In the final part of the chapter, you will learn about gravity and how Earth's gravity determines the orbit of the Moon.

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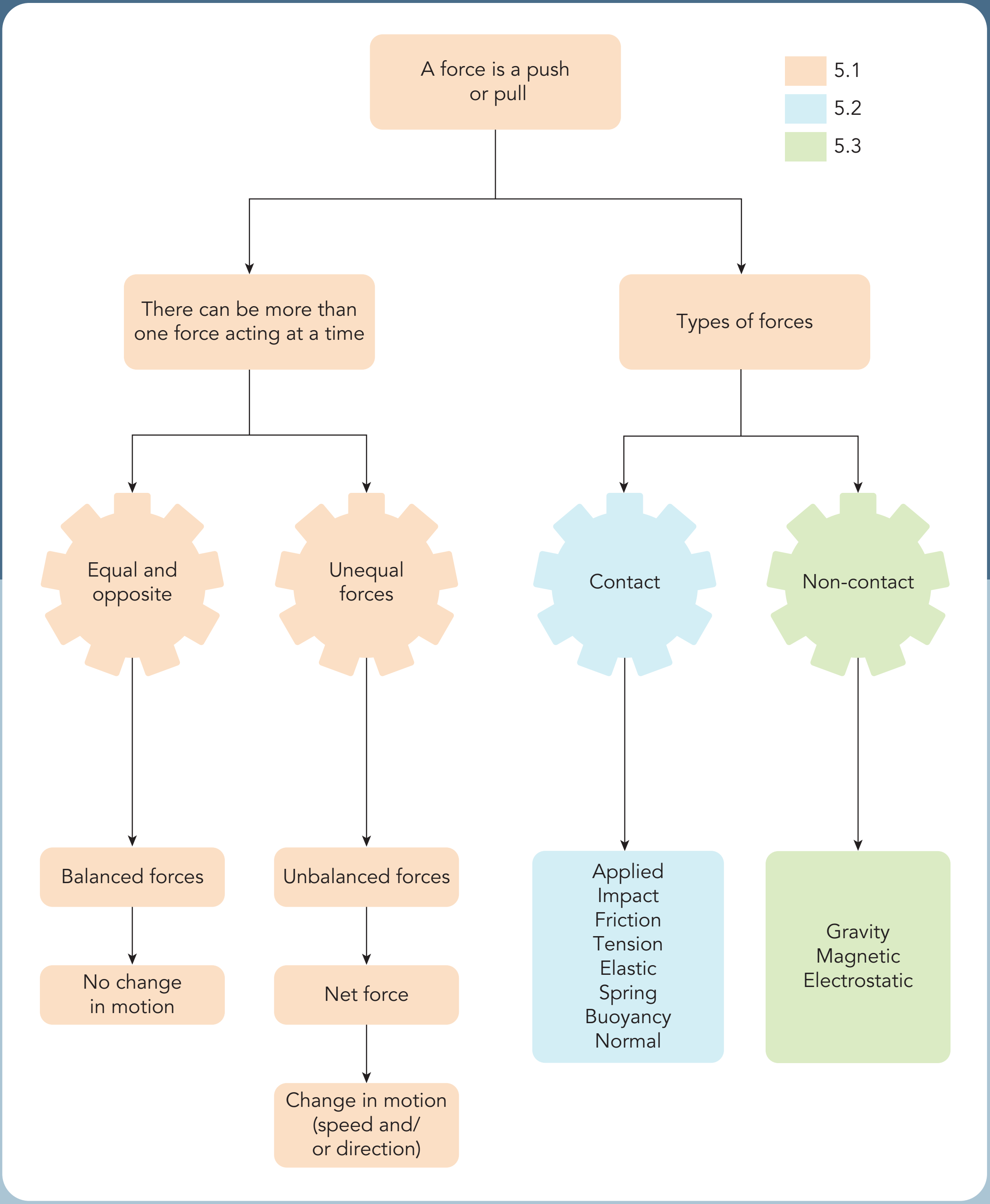
Concept map



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Curriculum

Investigate and represent balanced and unbalanced forces, including gravitational force, acting on objects, and relate changes in an object's motion to its mass and the magnitude and direction of forces acting on it (AC9S7U04)	
investigating the effects of applying different forces to familiar objects of the same and different mass	5.1
analysing the effect of balanced and unbalanced forces on an object's motion, such as starting, stopping and changing direction	5.1, 5.2, 5.3
measuring the magnitude of a force using a force meter and representing the magnitude and direction of forces acting on an object using force arrow diagrams	5.3
investigating how Earth's gravitational force is the attractive force that pulls objects to the centre of Earth and its magnitude is related to the mass of an object	5.2, 5.3

Glossary terms

Air resistance
Alloy
Anomalous
Applied force
Balanced forces
Brittle
Buoyancy
Drag
Elastic
Electromagnet
Electrostatic force
Field
Force
Force arrow diagram
Force meter
Friction
Gravity
Impact force
Magnetic field
Magnetic force
Mass
Mouldable
Net force
Newton
Normal force
Pull
Push
Repel
Rotate
Static electricity
Streamlined
Tension
Turning force
Unbalanced forces
Weight

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5.1 Forces acting on objects

WORKSHEET
Balanced and unbalanced forces

VIDEO
Forces acting on objects

Learning goals

1. To be able to recall the term 'force' and describe how forces are measured.
2. To be able to describe the impact of balanced and unbalanced forces on an object.
3. To be able to draw a force arrow diagram to indicate forces acting on an object.

A **force** acts on an object whenever something is given a **push** or a **pull**. Forces are constantly acting on you and you constantly apply forces to other objects. Forces are at work when playing sport or music, riding in a vehicle or simply standing completely still! For example, pressing piano keys, passing a rugby ball, riding the bus and sitting in a chair all involve forces at work. In the human body, muscles apply forces when body parts move. In nature, the forces from the flap of a bird's wings allow it to soar in the air, the sweep of a dolphin's tail moves it through the water, and a frog can push on the ground with its legs in order to jump.

force
a push, pull or twist in a specific direction

push
to exert a force towards something

pull
to exert a force away from something

Making thinking visible 5.1

Elaboration game: Forces in action

The drawing below illustrates many forces in action! In pairs, observe and describe specific forces demonstrated in the drawing.

1 One person in the pair identifies an action occurring in the drawing. The other person in the pair then expands on the first person's observation by adding more detail about how a force (a push or a pull) is present.
2 Repeat the game by identifying more actions taking place in the drawing. Make sure to take turns observing and elaborating until at least five actions have been observed.

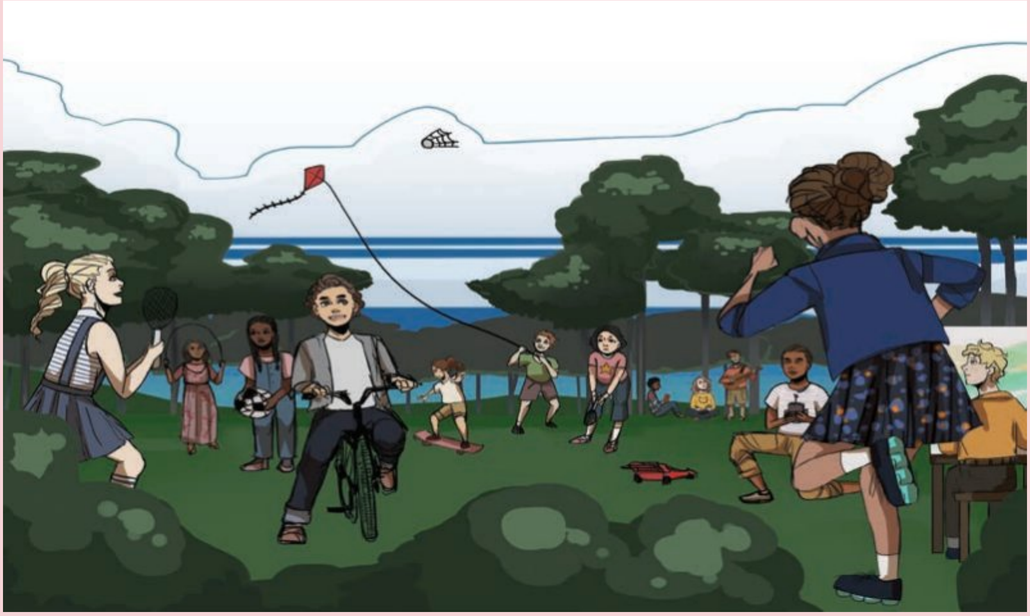

Figure 5.1 Having fun in the park means many forces are in action.

The *Elaboration game* thinking routine was developed by Project Zero, a research centre at the Harvard Graduate School of Education

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VIDEO Contact and non-contact forces

Table 5.1 gives a summary of some of the forces and associated terms.

Contact or non-contact	Type of force	Description	Example
Contact forces	Pushing	One object moves (or tries to move) another object, which it is touching, away from itself.	Pushing a trolley
	Pulling	One object moves (or tries to move) another object, which it is attached to, towards itself.	Pulling on a lead to move an animal
	Impact	The force of one object hitting another	Action of a cricket bat on a ball
	Friction	The force between two things rubbing together that makes them (or tries to make them) slow down relative to each other	Brake pads rubbing on the wheel of a bike
Non-contact forces (acting at a distance)	Gravity	The apparent force of attraction between two objects that have mass	The force that keeps you on the ground
	Magnetic	The attraction or repulsion between magnetic materials and/or moving objects with an electric charge	A magnet picking up bits of iron
	Electrostatic	The attraction or repulsion of objects that have an electric charge	Attraction of pieces of paper to a rubbed balloon

Table 5.1 Forces summary

Measuring forces

Forces are measured using a unit called the **newton** (N). One newton is approximately the force you need to keep a 102 g apple from falling to the ground.

newton
the unit of force; one newton is roughly equal to the force you need to keep an apple from falling

force meter
a piece of equipment that measures force in newtons (N)

gravity
a non-contact force describing the pull of any object with mass

weight
the force of gravity on an object; it is measured in newtons and changes in space

mass
the amount of substance in an object; mass never changes, even in space

A spring is a useful tool to measure a pulling force as it can be extended when a force pulls on it, and retract back to its starting position when the force is released. In your class, you may use an instrument called a spring balance or newton meter, which uses a spring to measure a pulling force. In this chapter this piece of equipment will be called a **'force meter'** to describe all different types of meters used. The larger the force being measured, the larger the spring will need to be in the force meter.

At home you have likely used bathroom scales or kitchen scales to measure a force due to **gravity**, which is often called **weight**. Weight is commonly confused with **mass** in this context, as typically household scales

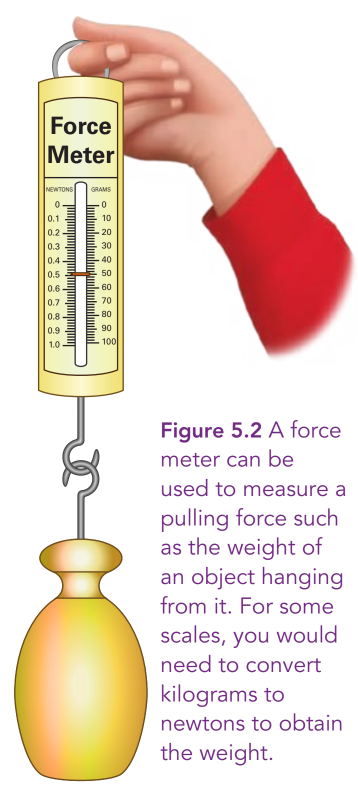

Figure 5.2 A force meter can be used to measure a pulling force such as the weight of an object hanging from it. For some scales, you would need to convert kilograms to newtons to obtain the weight.

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give a number in kilograms (kg), which is the unit of mass. An object's mass is related to the amount of material that it contains, measured in grams (g) or kilograms (kg), and it is the same everywhere in the universe. Its weight, on the other hand, depends on its mass **and** the strength of gravity at its location. The weight of an object is the pulling force of gravity, measured in newtons (N), whether it is falling or pressing down on the surface that it is resting on. Household scales actually measure the weight force, in newtons, acting on the equipment, and convert it to a mass in grams or kilograms.

On the surface of Earth, an object with a mass of 1 kilogram (kg) has a weight of about 9.8 newtons (N). So, if a force meter is labelled in N, it can also be used to measure mass in kilograms, approximately, with a conversion rate of 1 N = 0.102 kg. Thus, household scales can approximate a force acting on them using a conversion of 1 kg = 9.8 N. For example, if a 4 kg cat stood on a bathroom scale, its weight could be calculated as: $4 \times 9.8 = 39.2$ N.

Practical skills 5.1

Using a force meter

Aim

To select the most appropriate force meter.

Materials

- a range of force meters (e.g. 1 N, 5 N, 10 N, 50 N)

Method

1. Copy the results table into your science book.
2. Determine the force needed to complete the actions in the table.

Results

Action	Force required (N)
Hold your pencil case	
Drag this textbook across the table	
Remove a piece of sticky tape from your desk	
Open the lab door	
Drag your school bag across the floor	
Hold your school bag	

Analysis

1. State whether the forces applied to the items are push or pull forces.
2. Calculate the mass of your pencil case in kilograms by dividing its weight in newtons by 9.8.
3. Sequence the items in order from most to least force required to drag them.
4. Explain why the same force meter could not be used for all of the actions.

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force arrow diagram
a drawing showing the direction and size of forces acting on an object using arrows

tension
the force in a wire, cable or string when being stretched

balanced forces
forces of the same size but which act in opposite directions

unbalanced forces
a combination of one or more forces that has an overall effect, and which changes an object's motion

Force arrow diagrams

The direction and size of forces acting on an object can be illustrated by drawing a **force arrow diagram**. For example, look at the image of a hanging plant held by a hook in Figure 5.3. The plant is being pulled down due to the force of gravity, and the length of the arrow on the diagram represents the size of this force. What stops the plant from falling is a force called **tension**, which comes from the chain. The size of the tension force must be the same as that of gravity, and work in the opposite direction, to hold the plant in place. In other words, the forces of gravity and tension are equal and opposite, so they are **balanced**. On the diagram, the arrow for the tension force is drawn with the same size as the arrow for gravity, but pointing up.

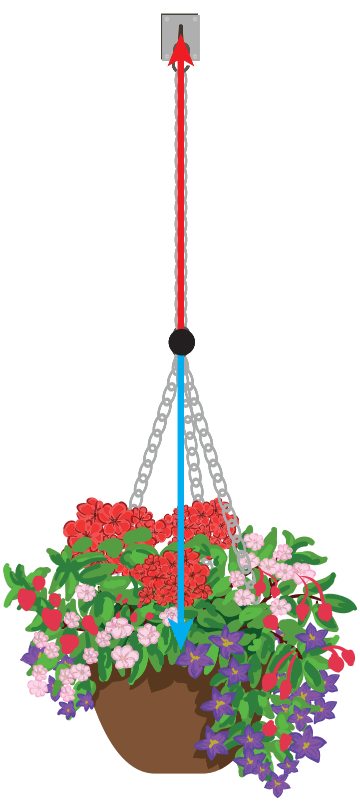

Figure 5.3 The tension in the chain pulling up (red) balances the pull down (blue) of the plant due to gravity.

In Figure 5.4, there are three flags and you can draw a force of gravity arrow for each one, with length proportional (corresponding) to their weight. For the forces to be balanced, the size of the tension force to hold the three flags up must equal the total of all their gravity forces. So on the diagram, the tension arrow is drawn as long as the three gravity arrows added together.

Interactions of forces

Forces can interact to work together, or cancel each other out. Imagine if you were trying to push a car on your own. It probably wouldn't move. But when a group of people come to help you push a car, the combined forces work together

Figure 5.4 The tension in the tape pulling up (red) is equal to the sum of the pull down (blue) forces of the three flags due to gravity.

and overcome the friction forces holding the car in place. On a force arrow diagram, the push forces of each person are added up and could be shown by one force arrow with a length equal to the total length of the individual force arrows.

Successfully pushing a car is an example of forces that are **unbalanced**, meaning that one is bigger than another. Unbalanced forces cause a change in movement. This change in movement can be seen by something slowing down, speeding up, changing direction, changing shape or rotating. On the other hand, in a tug of war or rugby scrum, the two teams apply forces in opposite directions (Figure 5.6). If the forces are equal in size, there will be no change in the movement. Equal and opposite forces are said to be balanced.

Figure 5.5 Friends combine forces to push a car at the beach. If the combined pushing force is larger than the friction force, the car will start to move.

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Figure 5.6 This tug of war doesn't move if the forces on either side of the rope are balanced.

Quick check 5.1

1. Define the following key terms in your own words: force, newton, balanced, unbalanced.
2. Identify which of the following activities use a push force and which use a pull force:
   a. catching a fish on a fishing rod
   b. holding your dog from running off on a lead
   c. cutting up salad vegetables for lunch
   d. writing in your exercise book
   e. typing on your computer
   f. lifting a heavy school bag
   g. passing a rugby ball
   h. strumming a guitar
3. Explain how a spring can be useful for measuring force.
4. Match each force to its approximate value if they are measured on Earth.

Weight of an apple	700 N
Weight of a car	1 N
Weight of an adult	100 N
Weight of a dog	7000 N

5. A hiker in Figure 5.7 exerts an upward force on his bag when he carries it, while the downward force is gravity.
   a. Decide if these forces are acting together or working against each other.
   b. Communicate this by drawing and labelling force arrows for this scenario.

Figure 5.7 A hiker carrying a backpack while overlooking Picnic Bay, Magnetic Island

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WIDGET
Fly a helicopter

Applying a force

Applying a force on an object often changes the motion of the object, but this is not always the case. There are four main results of applying a force on an object and it depends on whether the forces are balanced or unbalanced:

1. A force can balance another force so there is no change in its motion. For example, if the object is not moving, it will remain not moving. But if it is moving, it will continue moving at the same speed in the same direction. There is no *change* to its motion.
2. A force can change an object's speed to make it go faster or slower.
3. A force can make an object change its direction of motion or **rotate**.
4. A force can change an object's shape by moulding, bending, stretching or breaking it.

rotate
to turn or spin on an axis

Try this 5.1

Observing forces

Use the materials listed to perform the tasks listed in the table below.

- rubber band
- lump of modelling clay
- tennis ball
- bar magnet
- paperclip
- inflated balloon
- plastic counter

Draw the table in your book and record your observations.

Task	Observations	
	Change in motion or shape	Force that caused the change
Stretch the rubber band.		
Squash a lump of modelling clay.		
Drop a tennis ball and catch it when it bounces.		
Bring a bar magnet close to the paperclip.		
Use your hands to compress an inflated balloon (be careful not to pop it).		
Rub an inflated balloon against your head and then hold it near your hair.		
Use your fingers to flick a plastic counter across a table.		

1 A force can balance another force.

Forces may act on an object in opposite directions with equal magnitude and thus cancel one another. In these cases, the forces acting an an object are balanced, and there will be no overall effect on the object's motion. So if the object was stationary (not moving), it will continue to be stationary when balanced forces are applied. If the object is moving, it will continue to move in the same direction with the same speed when balanced forces are applied. Let's look at a few real-world examples.

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What forces act on a pencil case when it is resting on a surface such as a desk? The weight of a pencil case is balanced by the desk pushing up on it. This force is equal and opposite to the weight, so they are balanced. If the pull of the pencil case's weight down due to gravity was bigger than the push up of the desk, the pencil case would fall through the desk. What would happen if the desk pushed up more than the pencil case is pulled down?

The force of the table surface pushing up against the pencil case is often referred to as the **normal force** or 'support force'. This type of force is used to describe the force of any surface that supports a resting mass.

An object floating in water, like the unicorn floatie in Figure 5.9, has an upwards force called **buoyancy** (buoyant force) that balances the pull of gravity on the ball down (its weight force). Consider what would happen if the weight force was larger than the buoyant force.

normal force
the force that prevents solid objects from passing through each other, sometimes called the support force

buoyancy force
the buoyant force experienced by an object that is partially or fully submerged in a fluid, e.g. water or air

Figure 5.8 The weight force of the pencil case (blue) is pulling down towards Earth due to gravity. This is balanced by the normal force of the desk pushing back at it (red).

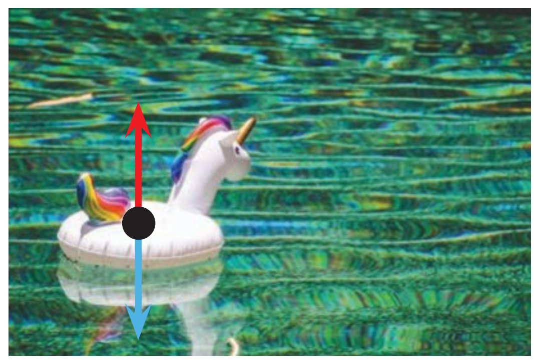

Figure 5.9 The weight of the unicorn floatie (blue) is balanced by the buoyant force of the water (red).

Try this 5.2

Balancing Rock

This rock formation is known as Balancing Rock and is a geological formation found in Chillagoe, Queensland.

1. If these are two rocks, identify where the forces are acting.
2. Are the forces balanced or unbalanced?
3. What is the evidence that allowed you to come to this conclusion?

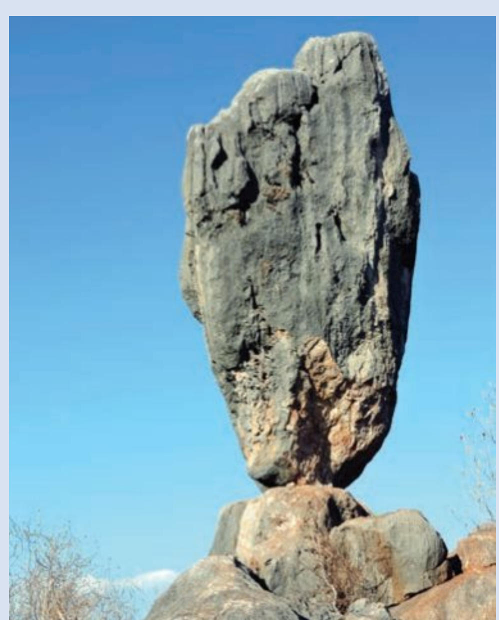

Figure 5.10 Balancing rock, Chillagoe, Queensland

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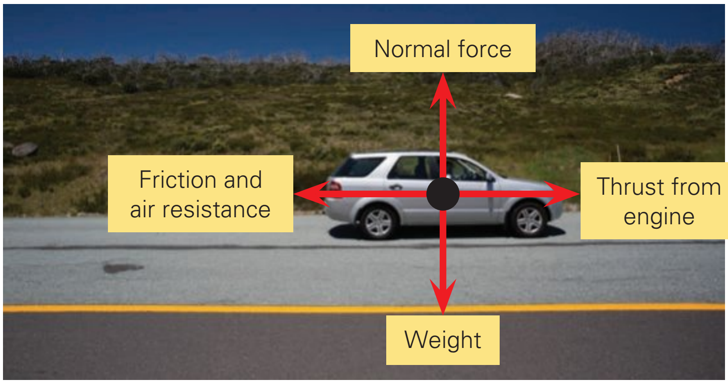

Figure 5.11 When the forces on the car are balanced, the car travels at a constant speed.

Figure 5.12 When the force of the wind on the sail balances the drag force through the water, a sailboat moves at a constant speed.

air resistance
the frictional force of the air

friction
a contact force opposing motion due to the interaction between two surfaces

net force
the sum of all forces acting on an object

drag
the frictional force of a liquid or gas

So far, we have looked at examples where balanced forces act on stationary objects to keep them stationary. However, this is not always the case, as balanced forces can also act on moving objects. For example, if a car is travelling at a constant speed in a straight line on a flat road, there are four main forces that act on it as it moves. The force of the road against the wheels pushes the car forward, while **air resistance** and a force called **friction** pull it backwards, balancing the forwards force. The weight force of the car pulls it down and the road surface pushes it back up with a normal force, balancing the weight force. The car will continue to travel at a constant speed, neither speeding up nor slowing down as all forces are balanced. The overall force on an object is called the **net force**. In this case, the forces are balanced and the car has no net force and will travel at a constant speed. If the car was to speed up, slow down, stop or change direction, this would require a non-zero net force, resulting in unbalanced forces acting on the car.

The same could be true of a sailboat gliding through the water in a race. The continuous force of the wind on its sail pushes the sailboat forward, while the **drag** force of the water balances the forward force, pulling the sailboat backwards and so it travels at a constant speed.

Quick check 5.2

1. A skydiver jumps from a plane and begins falling towards Earth while speeding up. Decide if the forces on them are balanced or unbalanced.
2. A drone is hovering in the sky. Its weight is pulling it down and the force of its rotors is pushing it upwards. Decide if these two forces are balanced.
3. A swimmer is racing from one end of the pool to the other at a constant speed. Describe the forces acting on the swimmer, and if the forces are balanced or unbalanced.
4. Draw a sailing boat, like the one in Figure 5.12, which is changing its speed and going faster as the wind blows harder. Add force arrows to your drawing for the force of the wind pushing it along, the drag of the water, the weight of the boat and the buoyancy.

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2 A force can change an object's speed.

When a sudden impact causes an imbalance of forces, there can be a change to an object's speed. Consider a golf club hitting a stationary golf ball. There will be an almost immediate change in the speed of the golf ball on impact, and this type of force is thus called an **impact force**. This type of force is present in many sports including tennis, badminton, hockey, baseball and cricket.

Impact forces can also make objects move more slowly. Consider a moving car that crashes into a wall. It will decelerate (lose speed) very quickly on impact.

A more gradual speed change occurs when a car applies its brakes. The brake pads apply friction to the moving wheels with enough force to slow down the moving vehicle. The friction of the brakes is transmitted through the wheels to the road with enough force to eventually stop a car.

impact force
a contact force that sometimes only lasts for a short time; impact forces often change an object's speed

turning force
a force that increases or decreases an object's rate of rotation

3 A force can make an object change its direction or rotate.

As well as changing the speed of an object, unbalanced forces can also make objects change direction or rotate. **Turning forces** are used frequently on everyday objects including a vehicle steering wheel, household taps and door handles, as well as tools such as screwdrivers and drills.

Figure 5.13 (a) The force of the golf club changes the speed of the golf ball from zero to extremely fast in a matter of milliseconds. **(b)** A moving car loses speed very quickly when it crashes.

Figure 5.14 The force of your hand results in the top of the tap rotating.

Figure 5.15 In the workshop, screwdrivers and drills require a force to make them turn.

Figure 5.16 In the kitchen, a food mixer uses turning forces.

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Turning forces can certainly change the direction of an object; however, they are not the only method to change the direction of an object. Consider a soccer ball being kicked at a wall: what would the outcome be?

Figure 5.17 illustrates how a wall will exert an impact force that will change the direction of a ball. There are many sports where you can see a force change the direction of an object like a ball.

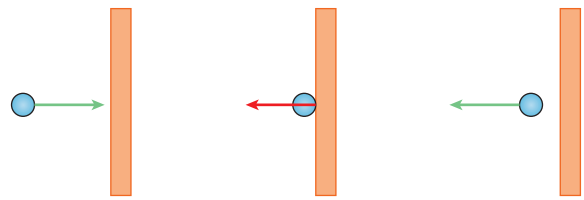

Figure 5.17 When a ball directly hits a wall, the direction of the rebound will be in the opposite direction to the initial direction. The green arrows indicate the direction of the ball, and the red arrow represents the force of the wall on the ball.

Quick check 5.3

1. Name some sports where a force can change the speed of an object or a person.
2. Name some sports where a force can change the direction of an object or a person.
3. Name some sports where a force can change the rotation of an object or a person.
4. Explain if it is possible for an object to speed up or change direction without a net force.
5. Decide whether two forces that act together to speed up, slow down or change the direction of an object must be balanced or unbalanced.

4 A force can change an object's shape by moulding, bending, stretching or breaking it.

When bread or pasta is made by hand, forces are used to mix the ingredients and to mould the dough into a new shape. Similarly, potters use forces to mould clay spinning on a wheel to create bowls. In these examples, the material is soft and is easily moulded into a new shape.

mouldable
soft enough to be shaped

brittle
a material that is likely to break or snap when subject to a big enough force

Another common example of this is plasticine or Play-Doh®, which children use to mould shapes with the force of their hands. A material that can be moulded easily is called **mouldable**.

Not all objects should be considered mouldable, and those that break or shatter instead of bending or stretching are described as **brittle**. If a large enough force is applied to brittle objects such as glass or fired clay, they will break into fragments.

Figure 5.18 Dough is moulded when making pasta or bread.

Figure 5.19 Potters use a wheel to spin the clay as they shape it to form a bowl.

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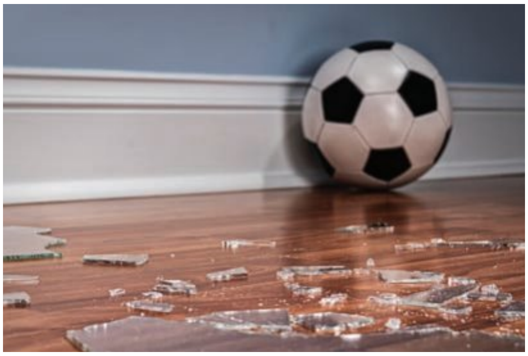

Figure 5.20 Glass can shatter if a large impact is applied.

Figure 5.21 Once the clay has been fired in a kiln, pottery becomes very brittle.

Figure 5.22 The spring on this park ride exerts an elastic force when moved from its original position.

Elastic materials stretch or bend when a force is applied and then return to their original shape when the force is removed. Elastic materials can also exert a force of their own called an elastic force when their shape is changed. Objects that commonly exert an elastic force include metal springs and elastic bands.

elastic
materials that bend, stretch or compress when a force is exerted on them; they exert elastic forces when this happens

Practical skills 5.2

Investigating forces

Aim

To measure some everyday forces.

Materials

- a range of force meters (e.g. 1 N, 5 N, 10 N, 50 N)
- a selection of masses (e.g. 10 g, 20 g, 50 g, 100 g, 1 kg, 2 kg)

Method

1. Copy the results table into your science book.
2. Record the masses you have selected in the first column.
3. Hook each mass onto an appropriately scaled force meter and measure the force required to hang (suspend) it against gravity. Record the measurement in your results table.

continued …

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… continued

4 Place each mass on a bench, attach a force meter near the base and drag each mass along the bench steadily at the same constant speed. Record the force reading when it is moving at a steady rate. Write it in your results table.

Planning

1 Identify the independent variable.
2 Identify the dependent variable.
3 Develop a hypothesis by predicting how a change in the mass will affect the dependent variable.
4 Identify the controlled variables and describe how these will be managed.

Results

Mass (g)	Force required to suspend the mass (N)	Force required to drag mass at constant speed (N)

Data processing

1 Plot a graph showing the relationship between mass and the force required to suspend it. Draw a single straight line so that it best fits through the average line of all the data points.
2 Plot another graph showing the relationship between mass and the force required to drag the mass at a constant speed. Again, draw a line of best fit for the data points you have.

Analysis

1 Identify the relationship between the mass and the force required to suspend it.
2 Identify the trend in your second graph.
3 Identify any **anomalous** results in your second graph.
4 Extrapolate your second graph to find out how much force would be required to drag a 4 kg mass at the same constant speed you used previously.

anomalous
an outlying result that does not fit in with the pattern of the other results

Evaluation

If you had any anomalous results, explain how these may have been caused.

Conclusion

1 Propose a valid conclusion that can be drawn from these results.
2 Justify this conclusion using data from your results.
3 State whether your hypothesis is supported or not.

Quick check 5.4

Match each word to its correct description.

1 Brittle — A Can be stretched but always returns to its original shape when the force is removed
2 Elastic — B Can be made into a new shape
3 Mouldable — C Breaks into pieces when a force is applied

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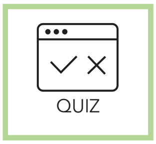
Section 5.1 questions



Retrieval

1 **State** the name given to two forces that cancel each other's effect.
2 **Name** one body component that can exert a force.
3 **Identify** four examples of impact forces.
4 **List** the different things that forces can do to an object.
5 **List** the features of balanced and unbalanced forces. Include an example where possible.
6 **Identify** an everyday example of each of the different results that forces can cause to complete the following table.

Result of the force	Everyday example
No change in motion	
Speeding up of object	
Slowing down of object	
Rotating of object	
Changing direction of object	
Changing shape of object	

7 **Name** an example from everyday life for each of the following types of force.
  a A force that changes the motion of an object
  b A force that changes the shape of something
  c A force that stretches or bends something
8 **Name** examples of materials that are:
  a able to be moulded
  b brittle
  c elastic
9 If a motor boat is travelling at a constant speed in a straight line on the water, what can you **infer** about the drag and the force of the engine?

Comprehension

10 **Explain** whether or not water can exert a force.
11 **Explain** how a force meter can be used to measure force.
12 You push a door and find it is locked and will not open. Apply your knowledge of forces to **decide** if you still exerted a force even though the door did not move.
13 If you hold a glass of water at arm's length in front of you, **explain** if you are still exerting a force on it, given the glass of water is not moving.
14 You are sitting on the couch at home. **Illustrate** a diagram of yourself and draw arrows to represent the forces acting on you. Are the forces balanced?
15 In Figure 5.23, the weight (force of gravity) of the gymnast is balanced by the normal force of the bar. **Illustrate** a sketch of the gymnast and include arrows to represent all forces acting on her.

Figure 5.23 A gymnast training

Analysis

16 Force is measured in newtons. **Describe** how large a force of 30N is.

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17 **Analyse** Figure 5.24 and describe or draw the forces on a cyclist. Assume they are moving at constant speed in a straight line.

Knowledge utilisation

18 Three cycling triplets are identical in every way, including their size, mass and clothing, and they have identical bikes. They start a sprint race side by side at the same time. After 10 seconds, Ahmet has gone 200 m, Barak has gone 160 m and Cinna has gone 120 m. **Discuss** these results. Was the average force each exerted on the pedals the same during the 10 seconds or different? Who exerted the highest force, and who exerted the lowest? Was it a fair comparison? Explain your reasoning.

Figure 5.24 Cyclists in Cairns

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5.2 Contact forces

Learning goal
To be able to describe some contact forces.

WORKSHEET
Friction

VIDEO
Contact forces

Forces are pushes or pulls that affect objects in many different ways, depending on whether the forces are balanced or unbalanced.

These forces can be classified as contact forces, where physical contact is made to exert a force on an object, or non-contact forces, where non-physical contact is made. In this section you will explore four different types of contact forces: friction, elastic, buoyancy and impact.

Friction forces

Friction is occurring everywhere in your everyday life. It is a contact force and is used to describe any contact where surfaces rub together or a liquid or gas flow over a surface. An example is pulling a couch over carpet or even running into a very strong wind. When one object tries to move over or through another, the contact forces act in opposite directions.

While friction can often be considered a hindrance, it can also make our life easier and safer! Walking without it would be difficult because your shoes would have no grip on the floor. Normally you push your foot backwards against the ground and the ground pushes back on you, but if there were no friction, it would feel like everything was covered in a thin film of slippery soap. This type of friction is called traction. Without friction, car brakes would not work and without traction, cars would not be able to move in any direction – backwards, forwards or around corners.

Making thinking visible 5.2

Generate-Sort-Connect-Elaborate: A push or a pull

Create a list of forces (a push or a pull) that you have experienced in the last few days. It might be at school, at home or playing a sport, for example.

Group and connect the forces in your list by placing physical forces in the centre of the page and less or non-physical forces toward the outside of the page.

Connect your different types of forces by drawing lines between forces that have something in common. Write a short sentence to explain how the forces are connected.

Expand on any of the forces you have listed by adding further details that expand, extend or add to your initial list.

The *Generate-Sort-Connect-Elaborate* thinking routine was developed by Project Zero, a research centre at the Harvard Graduate School of Education

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Practical skills 5.3

Surfaces and friction

Aim
To observe the effect of various surface types on the frictional force on a moving object.

Materials
- large block of wood with hook attached
- force meters (10 N, 20 N and 100 N)
- a variety of different surfaces (e.g. vinyl floor, carpet, concrete, polished concrete, sandpaper, grass or bitumen in a safe area)

Method
1. Copy the results table into your science book. Ensure the independent variable is in the left-hand column and the dependent variable trials and mean sit at the right of the table. Don't forget units in the headers.
2. Place the block of wood on the first surface and attach the appropriate force meter. (Hint: Which force meter would be the best for each surface? How would this be determined?)
3. Pull the block of wood at a constant speed across the surface and read the force on the force meter. The force on the force meter will be equal to the force of friction. Record this reading in your results table.
4. Repeat the measurement two more times and record in your table.
5. Repeat steps **1–4** on three other different surfaces.

Results

Surface	Friction force			
	Trial 1 (N)	Trial 2 (N)	Trial 3 (N)	Mean (N)

Analysis
1. Why was it necessary to measure the friction of each surface three times and find the mean?
2. List your surfaces in order of lowest to greatest friction force.
3. Explain why some surfaces create more friction than others.

VIDEO
Friction

Friction between solid surfaces

The strength of the friction force depends on the type of surfaces present. Rough surfaces tend to produce more friction than smooth ones, and heavier objects also have more friction than lighter ones. Consider the example of moving a couch over carpet. If the couch is extremely heavy, there will be more friction opposing the push you are giving.

Friction also depends on the speed at which an object is moving. It increases as the speed increases. This is why is it important to use the same constant speed in an experiment.

Friction between two solid surfaces also has a side effect: it releases energy in the form of heat, increasing the temperature. In some cases, this can be beneficial. For example, you

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might have rubbed your hands together on a cold morning to warm them up, or rubbed sticks together to start fire, or for use in a First Nations Australian smoking ceremony. However, higher temperature is not always welcome because it can represent wasted energy or be dangerous.

Minimising friction between solid surfaces

One way to reduce friction between two solid surfaces is to polish them or to use lubrication such as oil or graphite. This allows the surfaces to move over each other with less friction force and thus generate less wasted energy. In Figure 5.25, clean oil is put into an engine to lower the friction between the moving parts. If there not enough oil, the extra frictional forces will destroy the engine because the metal expands as the temperature increases.

Another way friction can be reduced, especially when moving heavy loads from one place to another, is to use a wheel and axle. This is one of humankind's earliest and most widely used inventions.

By using a wheel and axle, trains, cars, trucks and even aircraft taking off and landing can all move with little friction. One place where wheels are not the preference is on snow and ice, where surfaces already have low friction and it is better to use skis or sledges on runners. Skis and runners do not sink into the snow and get stuck like a wheel would. In fact, in these conditions, a wheel would generate more friction force than skis and runners do. Additionally, being long and thin, skis and runners also tend to run straight where wheels would slide sideways.

Figure 5.26 The wheel and axle allows objects to be moved over a surface with very little friction.

Figure 5.25 Petrol engines need oil to lower the friction inside.

Figure 5.27 Seaplanes use floats instead of wheels to land on water.

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Wheels also do not work well if the ground is very rough, so trains need tracks and cars work best on roads. Furthermore, wheels do not work on water, so seaplanes designed to land on water use long thin hollow floats or pontoons shaped like closed canoes in place of wheels.

streamlined
designed to minimise air resistance or drag

Try this 5.3

Friction in action
Use a force meter to measure the force required to pull a wooden block across your bench. Next, lay out pencils or pens that are perfectly round and about the same thickness next to each other and measure the force required to pull the block on top of them. Can you explain how the force required differs?

Friction in gases and liquids

Friction between a solid surface and a liquid or a gas is also possible, and is called drag. When gases make contact with a solid surface, this type of drag is called air resistance. Friction can also occur between liquids and gases or even within liquids or gases. Friction involving gases or liquids is called fluid friction.

Air resistance acts as an opposing force when an object moves through the air. A skydiver will reach terminal velocity (a constant speed) when falling towards Earth, as the air resistance provides an opposing force on the skydiver. When an arrow is shot from an archery bow, air resistance will act to slow it down, but because arrows are **streamlined**, the force slowing the arrow is small.

Figure 5.28 The friction force on an arrow as it flies through the air is small.

Figure 5.29 Trains have become more streamlined as their speed has increased.

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Fish have a streamlined shape that helps them move through water easily. The same shapes are used by the designers of boats and submarines to reduce drag and to enable them to travel at high speed in water.

In the air, birds have a streamlined shape to fly with as little air resistance as possible. Air resistance is a major consideration for the designers of cars, trains and aircraft. Have a look at the two trains in the images in Figure 5.29; their design has become more streamlined to allow them to go faster.

Figure 5.30 The welcome swallow (*Hirundo neoxena*), native to eastern Australia, has a streamlined shape for fast and sharp movements while flying.

Quick check 5.5

1 Explain how friction can slow down a runner when running into the wind.
2 Describe a feature of a car that is designed to minimise friction for better fuel economy.
3 Describe a feature of a car that is designed to maximise friction for safety.
4 Define the key terms 'air resistance', 'drag' and 'streamlined'.
5 Explain why a dolphin's body is streamlined, whereas a wombat's is not.

Science as a human endeavour 5.1

The Breakthrough Laminar Aircraft Demonstrator in Europe (BLADE) project

Airbus is an international aeroplane manufacturer. It constructs large passenger aircraft for Australian companies such as QANTAS. Aeronautical engineers at Airbus understand the forces acting on aeroplanes very well. They use this knowledge to design heavy machines with wings that fly!

Figure 5.31 The Airbus A340 laminar-flow demonstrator 'BLADE' aircraft in flight for testing

While air travel is commonplace in the modern world, there are still many improvements to make to the design of planes. These improvements could make air travel safer, more comfortable and cost-effective for passengers. They could also improve the environmental impact of aircrafts and reduce carbon emissions. These are important ethical, social and economic considerations.

The Airbus BLADE project launched in 2017, with the aim of reducing the air resistance force (drag) on aeroplane wings by up to 50%. Reducing air friction on an object is achieved by increasing laminar flow on the wings, meaning the air travels past the wings more smoothly. This would reduce the force required of the engines and thus reduce fuel consumption and carbon emissions by up to 5%.

The BLADE demonstrator plane will need many hours of flight to collect data on the increased laminar flow, but in future years, you might travel on an aeroplane using the design developed from the engineers' knowledge of forces in this prototype!

ISBN 978-1-009-40426-6

Science as a human endeavour 5.2

David Ngunaitponi (Unaipon) and the vertical flying machine

Many groups of First Nations Australians have used boomerangs for hunting purposes for thousands of years. The boomerang has a design that allows it to lift in the air when thrown, and return to the thrower in flight. When thrown, the boomerang spins and the lifting arm of the tool provides more lift force than the dingle arm. This difference in lift force causes an imbalance of forces on the tool and it thus turns in flight back towards the thrower.

David Ngunaitponi (Unaipon) was a Ngarrindjeri man from the Coorong region of South Australia, born in 1872. He was an insightful inventor of his time and he had a wealth of traditional and cultural knowledge of the aerodynamic properties of boomerangs. In 1914, he predicted that the physics that allowed the boomerang to hover through the air could be applied to an aeroplane.

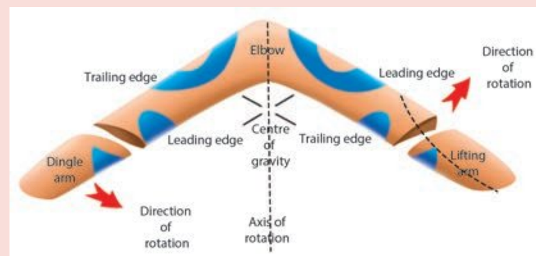

Figure 5.32 Top: David Ngunaitponi (Unaipon) on the Australian $50 note. Bottom: The boomerang uses forces in various ways to make unique movements in the air.

He stated: 'An aeroplane can be manufactured that will rise straight into the air from the ground by the application of the boomerang principle' and 'The boomerang is shaped to rise in the air according to the velocity with which it is propelled, and so can an aeroplane.'

David Unaipon conceptualised this 'vertical lift flying machine' almost 25 years before the first helicopter was constructed. His contribution to science is recognised every day in Australia, with his portrait appearing on the Australian $50 banknote.

Elastic spring force

Springs can be pulled, pushed or bent sideways. In each case they will exert a force in the opposite direction to the force applied and this is called an elastic spring force.

Forces in elastic materials

Solid pieces of elastic or rubber can be pulled, pushed or bent sideways. But a rubber band or strand of elastic cannot be compressed lengthwise, because of its shape.

Rubber and other elastic materials can be compressed when they are formed into a short, fat shape, and they are used in this way to absorb bumps and shocks in vehicles and machines.

Long pieces of wood, plastic or metal can also exert an elastic force when they are bent. They spring back to their original position when the force is removed, as long as the force is not large enough to break or deform them permanently. Tree branches are an example of this as they can bend in the wind. If they become rotten and unable to bend, they will break in a storm.

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Practical skills 5.4

Stretching springs

Aim

To observe the relationship between force and extension for a spring.

Materials

- spring
- retort stand, bosshead and clamp
- set of slotted masses
- ruler

Method

1. Using a retort stand, hang a spring on a bar and place an empty weight holder on the end of the spring.
2. Tape a ruler to the vertical bar of the retort stand. Use the scale of the ruler to record the initial position of the bottom of the weight holder.
3. Add masses to the weight holder. Each time a new mass is added, record the new position of the bottom of the weight holder. Be careful not to overstretch the spring.

Results

Mass (g)	Force (N)	Extension (m)

Data processing

1. Calculate the force applied to the spring by dividing the mass in grams by 1000 and multiplying by 9.8.
2. Draw a graph of how force affects the extension of the spring.

Analysis

1. Identify the trend in your graph.
2. Identify any anomalous results in your graph.
3. Can you use your graph to make predictions about other masses?

Conclusion

Conclude any trends found in your collected data and relate it to the aim of the experiment. State some specific data that justifies your conclusion.

Elastic forces are used by divers on a springboard to gain extra height when they dive. The force exerted by a bow on an arrow is another example of an elastic force. Some of the force comes from the stretching of the string; however, most of the force comes from bending the wood or plastic of the bow.

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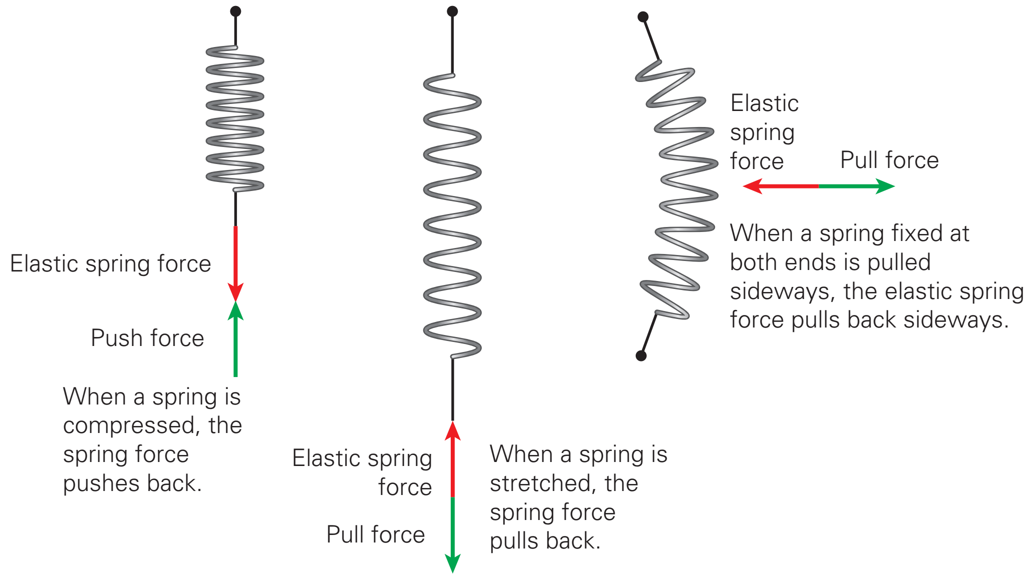

Figure 5.33 Three ways to apply a force to a spring

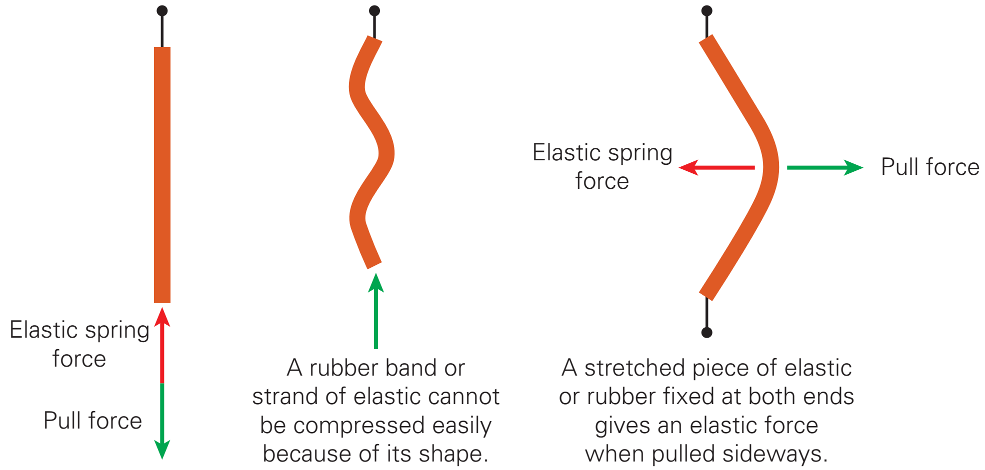

Figure 5.34 Two ways to apply a force to a rubber band

Figure 5.35 The diver makes use of the elastic forces in a springboard.

Figure 5.36 A pole vaulter uses the elastic forces in a pole to reach the top of the vault.

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Quick check 5.6

1 What is an elastic spring force?
2 Can you think of other sports or activities that have not been mentioned that use elastic spring forces?

Buoyancy

The buoyant force is the upward push that occurs when an object is partially or fully submerged in fluid such as water or air. If an object placed in water sinks, the buoyant force acting upwards is smaller than the weight force of the object. If it floats to the surface, the buoyant force is greater than the object's weight.

There is also an upwards buoyant force on an object in a gas, but it is much smaller, and can only be seen in an object that is very light compared to their size, such as a helium balloon. If the air's upward buoyant force on a helium balloon is greater than its weight, it will rise.

When you swim, you will have experienced the buoyant force on your body; it allows you to feel almost weightless in the water. In Figure 5.39, the buoyancy (blue) here is approximately equal to the weight (red).

Figure 5.37 Buoyancy allows heavy container vessels to float.

Figure 5.38 In sparkling water, bubbles of gas rise to the surface due to buoyancy forces.

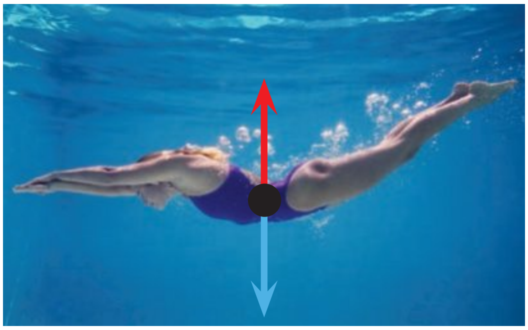

Figure 5.39 The buoyant force on the girl is approximately equal to the girl's weight.

Try this 5.4

Buoyancy in action

Fill a bucket with water and collect a range of different balls such as a table tennis ball, golf ball and tennis ball.

Take each ball and submerge it in the water, releasing it at the bottom of the bucket.

Write down your observations when you let go of each ball. Did the different balls act differently? What forces are acting in this situation? When are the forces balanced and unbalanced?

Did you know? 5.1

Bouyant magma!

Magma is the name of molten rock under Earth's surface. Hot molten magma can be more than 1000°C and is less dense than the surrounding cooler magma. Buoyant forces cause molten magma to rise through the cooler magma towards Earth's surface in a giant convection current. When magma reaches the surface, it is then called lava, which you would likely associate with erupting volcanoes. So while buoyancy force is most commonly thought about in connection with objects floating on water, it is also at work in the magma underground!

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Impact forces

applied force
force that is applied to an object by another object or person

The contact forces you exert or experience in daily life, such as when moving an object or opening a door, are called **applied forces**. When objects collide, they typically exert or experience a force that lasts just a fraction of a second. This is called an impact force and it is a push that fast-moving objects or particles exert for the very short time that they are in contact with another object. When objects are heavier or moving faster, impact forces also increase. Constructive uses of impact forces include using an axe to chop firewood or a hammer to hit a nail.

However, the nature of impact forces can also be very dangerous if not controlled. For example, a car accident might involve a heavy vehicle travelling at a high speed and impact forces can cause severe damage to the vehicle itself, as well as to the passengers.

Given car accidents are always a possibility when driving, safety measures have been implemented to reduce the impact forces felt by passengers in an accident. Seatbelts, air bags and crumple zones are examples that spread the impact force over a larger area or a larger distance to reduce the risk of serious injury.

Quick check 5.7

1. Name the two forces acting on you when you are lying on an inflatable mattress in a swimming pool.
2. Define the term 'impact force' and provide three examples.
3. Explain how a cultural knowledge of the forces acting on a flying boomerang was used when David Unaipon conceptualised the vertical lift flying machine.

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QUIZ

Section 5.2 questions

Retrieval

1 **State** the names of five main types of contact force.

2 **State** the contact force that can be easily used to warm up a small object or surface.

3 **Recall** the common name for friction on an object moving through a liquid or gas.

4 An impact force is a force that acts for a short time. **Provide** three examples of impact forces from sport.

Comprehension

5 The wheels of a car and some bikes are attached with springs. **Explain**, using your knowledge of forces, how the springs help give a smooth ride even on a bumpy road.

Analysis

6 Look at the picture of the two aircraft in Figure 5.40 and **identify** which one is designed to go faster. Give reasons for your answer.

Figure 5.40 Which plane is designed to have a higher top speed?

7 The feet in Figure 5.41 belong to a seagull. Use your knowledge of forces to **analyse** the structure of the foot and how it is adapted to be used in water.

Figure 5.41 The feet of a seagull

Knowledge utilisation

8 Propose whether a glass or a plastic bottle is a better choice for carrying water in a backpack.

9 Earthquakes are dangerous and buildings in earthquake-prone places must be specially designed to withstand their effects. There are three types of building materials that could be used in an earthquake zone. Use your knowledge of forces to **propose** how you would use or modify each material to cope with earthquakes. Give your reasons and sketch examples of what you mean.

- brittle
- elastic
- deformable

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5.3 Non-contact forces

WORKSHEET
Gravity

VIDEO
Non-contact forces

Learning goals

1. To be able to describe the effect of Earth's gravitational force.
2. To be able to describe three non-contact forces.

Non-contact forces do not require physical contact for the force to act; they are forces that act at a distance through space.

There are three key non-contact forces you will explore:

- gravitational
- magnetic
- electrostatic.

Gravitational force

Gravity is the name that we give to a force of attraction that exists between objects that have mass. Your experience with the term gravity might be to simply consider it as the force that pulls you towards the centre of Earth. However, everything that has mass has its own gravitational force. While Earth's gravitational force pulls you towards it, you also pull Earth towards you with a gravitational force.

field
a region in space in which an object is affected by a force

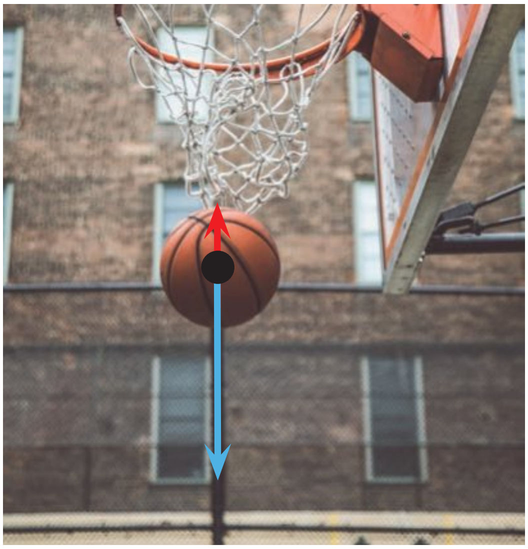

Figure 5.42 A basketball falls due to the force of gravity (blue arrow), which is opposed by the smaller force of air resistance (red arrow). The forces are unbalanced and there is a net force downwards.

The gravitational force increases with increasing mass, so it's no surprise that you feel Earth's gravitational force on you more! This force extends out into the vacuum of space. It is responsible for constantly pulling the Moon towards Earth and causing its orbit. Satellites also orbit Earth due to gravitational force.

The Sun contains 99.86% of all the mass in the solar system and Earth and all the other planets, even Jupiter, are tiny in comparison. All the planets in the solar system, including Earth, orbit the Sun because of its enormous mass.

Although the force of Earth's gravity gets weaker in space, the weight of an object is almost the same everywhere on Earth's surface. Remember, force is measured in newtons, so weight, which is a force, is measured in newtons, not kilograms.

Explore! 5.1

Fields

You may not be able to see gravity but it is always there. Gravity creates a gravitational **field** around Earth; this is a region in space in which any objects with mass feel a force. It extends out to the Moon and beyond.

- Find out and summarise what it means to say that Earth's gravity creates a field around it.
- Search the internet for a diagram of Earth's gravitational field and describe what happens to the strength of this field as you move further away from Earth.

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Different gravitational forces

At the beginning of Section 5.1, you learned that mass and weight are not the same thing, and on Earth's surface an object with a mass of 1 kilogram has a weight of about 9.8 N. This relationship can be summarised by the following equation:

Weight (N) = mass (kg) × force of gravity (m/s^2)

where force of gravity on Earth = 9.80 m/s^2. Table 5.2 shows you how different locations in our universe have different gravitational forces and so a mass of 1 kilogram has different weights in different places.

The Sun has the strongest gravitational force in the solar system, about 28 times the gravity on Earth. Aside from being too hot, an average person would weigh about the equivalent of two cars on the Sun, and it would require a lot of effort just to move, if the person hadn't already been squished by the weight of their own body! Neutron stars are extremely dense objects that are left behind when some stars explode. They are so dense that 1 cm of human hair on a neutron star would weigh more than all the water in an Olympic-size swimming pool on Earth! Black holes have such strong gravity that not even light can escape from them.

Location	Mass (kg)	Weight (N) = mass (kg) × gravitational force (m/s^2)
Surface of Earth	1	9.8
Surface of the Sun	1	275
Surface of the Moon	1	1.6
Surface of Mars	1	3.7
Deep space	1	0
Surface of a neutron star	1	200 000 000 000

Table 5.2 The table shows how a mass of 1 kg has a different weight at different locations in the universe because of the different strengths of gravity.

Try this 5.5

Jumping on planets: Mass versus weight

Use a metre ruler and sticky tape to calculate how high you could jump on different planets.

1 Tape the ruler to a table leg or wall so that it is vertical.
2 Get a partner to kneel down so their eyes are level with the ruler.
3 Jump as high as you can while your partner records the height you achieved.
4 Repeat the jump two more times.
5 Swap roles so you are now recording the jump height of your partner. Repeat steps 2–4.
6 Copy the table below into your book and calculate the mean jump height.

	Jump height (m)			
Student name	Jump 1	Jump 2	Jump 3	Mean

continued …

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... continued

7 Calculate how high you could jump on each planet, plus the Sun and the Moon. Divide your mean height by the surface gravity of each celestial body in the table below. For example, if you jumped a mean height of 0.65 m and wanted to calculate how high you could jump on Venus, you would divide 0.65 by 0.91. This would tell you that you could jump 0.71 m if you were standing on the surface of Venus.

Member of the solar system	Ratio of the surface gravity of each location to Earth's surface gravity	The height I could jump at each location (m)
The Sun	27.9	
Mercury	0.38	
Venus	0.91	
Mars	0.38	
Jupiter	2.36	
Saturn	0.92	
Uranus	0.89	
Neptune	1.12	
Pluto	0.06	
The Moon	0.16	

Quick check 5.8

1 Define these key terms: gravity, mass, weight.
2 Describe the relationship between the force of gravity, mass and weight.
3 A supermarket claims that jumbo size chicken eggs have an average *weight* of 68 g. Compare the meaning of the word 'weight' for the supermarket in this situation versus what it actually means.
4 Use Table 5.2, which shows the pull of gravity at different locations, to decide where you would weigh the most, where you would weigh the least, and where you could jump the highest.

Gravity and air resistance

Do all objects of the same weight fall at the same rate? If they do, then identical pieces of paper, no matter how they are folded or not folded, should fall at the same rate. See whether this is the case or not in the following activity.

The experiment in Practical skills 5.5 demonstrates that the reason different objects hit the ground at different times is due to the interaction of the object with air: the air resistance of the object. When the flat piece of paper is used, the air resistance is much greater because it has to push more air out of the way. This is related to the area of the paper that pushes against the air. The side of the paper is a very big area, so it falls much more slowly than the folded piece of paper where a smaller area pushes the air out of the way.

If these experiments were repeated without air (in a vacuum), then all the objects released from the same height at the same time, regardless of their mass, would hit the ground at the same time.

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Practical skills 5.5

Surface area vs. air resistance

Aim

To determine how surface area and mass affect air resistance.

Materials

- one piece of A4 paper
- one piece of A4 card
- metre ruler
- stopwatch

Method

1. Copy the results table into your science book.
2. Take the A4 paper and measure its length and width to calculate its surface area. Record this in your table.
3. Hold the paper horizontally and release from a height of 1.5 m and record the time it takes to reach the ground. Repeat two more times.
4. Fold the paper in half and then repeat steps **1** and **2**. Continue doing this until you have folded the paper 4 times.
5. Repeat, using the piece of card.

Results

		Time taken to drop paper (s)			
Number of folds	Surface area of paper (cm^2)	Trial 1	Trial 2	Trial 3	Mean
0					
1					
2					
3					
4					

		Time taken to drop card (s)			
Number of folds	Surface area of card (cm^2)	Trial 1	Trial 2	Trial 3	Mean
0					
1					
2					
3					
4					

Data processing

Plot both sets of results onto the same graph to compare them. Plot the surface area of each item against the mean time it takes to drop.

Analysis

Identify any trends, patterns or relationships in your results.

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Did you know? 5.2

Galileo's experiment

Galileo was a scientist who did an interesting series of experiments on gravity. Up until Galileo's experiments it was thought that lighter objects fall at a slower rate than heavy objects. This is our common experience: if a hammer and a feather are dropped together most people would predict that the hammer will hit the ground first because the force of gravity is greater on the hammer. Galileo had another explanation. He found that by dropping objects from towers and by rolling balls down ramps, all objects fall at the same rate, no matter how heavy they are. In other words, when two different stones are dropped, even if one has double the mass of the other, they should hit the ground at the same time. The rate at which an object falls on Earth is called the acceleration of Earth's gravity and is 9.8 m/s^2 near Earth's surface.

To explain why the feather hits the ground after the hammer, Galileo argued correctly that the reason was not due to gravity at all, but it was because of air resistance. The air resistance for the feather was much greater than for the hammer. Take away the air, Galileo argued, and the two will fall together. This surprising result has now been demonstrated many times, most famously by astronaut David Scott of Apollo 15 on the Moon, where there is no atmosphere.

Figure 5.43 Galileo's experiment: dropping two stones of different mass out of a tower to see which landed first

Galileo had a ruler to measure distance, but clocks had not yet been invented to time the balls rolling down the ramp. Instead, he used his pulse to measure time in his experiments.

Parachutes are a practical application of air resistance. You can fall through the air safely if you have a parachute. When the parachute opens it increases your air resistance so that it greatly exceeds your weight and you slow down. As you float to the ground the air resistance is equal to your weight and you fall at a constant speed.

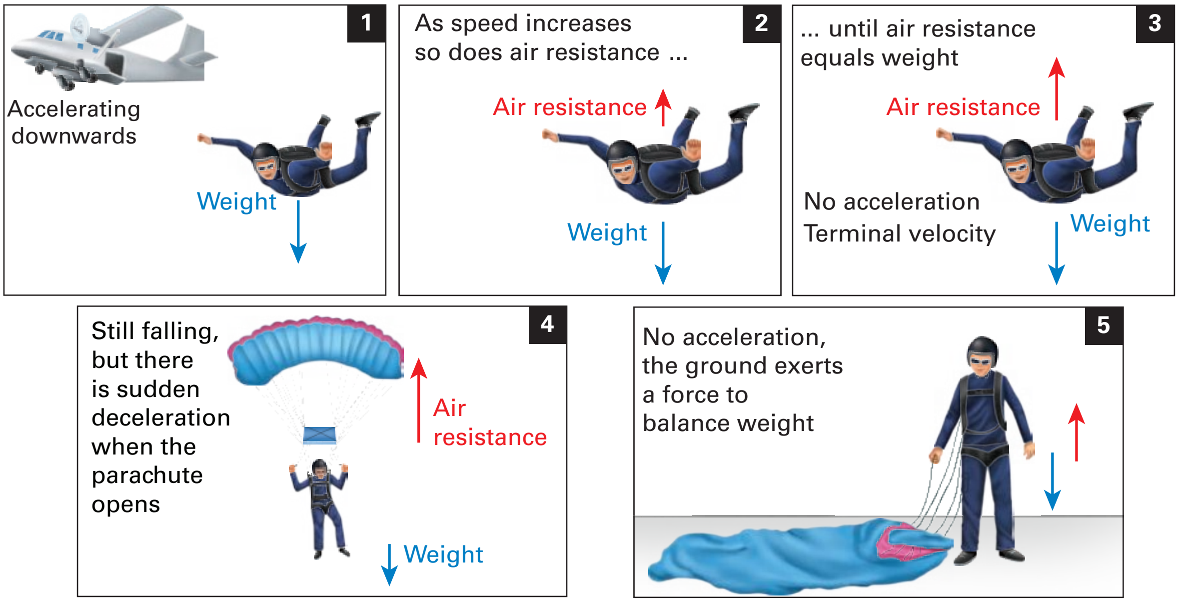

Figure 5.44 The way a parachutist falls depends on the size of the pull of gravity and the air resistance from the parachute.

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Try this 5.6

Drop time of a parachute

Materials
- plastic freezer bags
- scissors
- modelling dough
- stopwatch
- cotton or string
- metre ruler

Use the materials provided to design and build a parachute. Write a hypothesis as an appropriate 'if ... and then ...' statement. In this experiment consider the relationship between the variables: surface area of the parachute and how long it takes the parachute to hit the ground.

Compare your design to other group designs in your class. Did the size of the parachute affect the time taken for the parachute to hit the ground?

Quick check 5.9

1 Explain the meaning of the terms 'air resistance' and 'terminal velocity'.
2 Describe the relationship between the speed an object falls at, the pull of gravity and air resistance.
3 Figure 5.45 shows a paramotorist flying through the air. The propeller on his back provides a forwards thrust force and there is also a parachute attached above him.
   a Identify the forces acting on the paramotorist if he is accelerating moving forwards and not losing or gaining altitude.
   b Describe how these forces change if the paramotorist is moving at a constant speed.

Figure 5.45 A paramotorist uses knowledge of forces to fly through the air.

Magnetic forces

Magnetic force, like gravity, is a non-contact force. You might have seen it in action with the magnets on a refrigerator at home. Magnetic forces are always strongest at the ends of a magnet, which are called poles. There are two types of magnetic poles, north and south, and they always occur as a pair. Even if you break a magnet in half, it will still have a north and south pole at the ends of each of the pieces.

The north and south poles of a magnet experience an attractive force, while two like poles experience a repulsive force (they **repel**). Have you ever tried to push two magnets together and it felt like there was an invisible barrier? That was the magnetic repulsive force.

DOC
WORKSHEET
Electrostatic and magnetic forces

magnetic force
a non-contact force between a magnet and another magnet or magnetic metal

repel
to force back or apart

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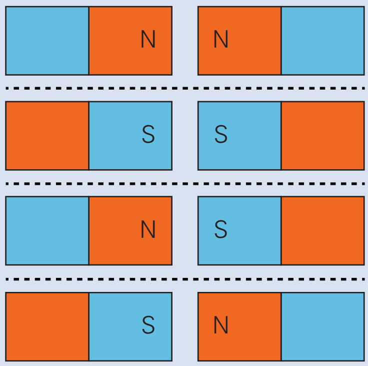
Try this 5.7

Magnetic poles

1 Which of the situations below display interactions between like poles?

2 Which situations display interactions between unlike poles?



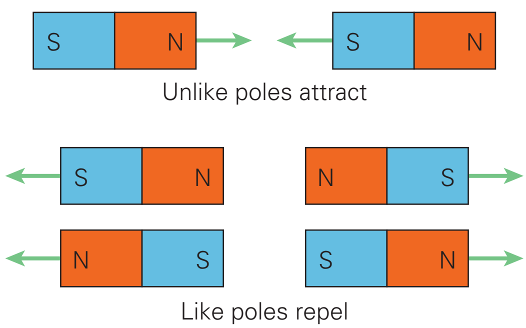


Figure 5.46 Forces between magnets

alloy
a substance composed of two or more elements, usually metals

magnetic field
the space around a magnet where the magnetic force can act

Some magnets always retain their ability to be magnetic and so they are called permanent magnets. An example would be a fridge magnet; they are always magnetic. On the other hand, metals like soft iron become magnets only when they are near a permanent magnet; they can become a temporary or induced magnet. Try hanging a paperclip from a magnet. While it is there, it will behave like a magnet and can be used to attract other paperclips. Even on its own it does not behave as a magnet.

In addition to each other, magnets also attract iron, cobalt, nickel and their **alloys**, such as steel (an alloy of iron and carbon).

The way that magnets exert their force is through **magnetic fields**; that is, the space around a magnet where the magnetic force can act. The magnetic field is a force field, like the gravitational field, although the two fields are different in most other respects. Look at Figure 5.47. You can see the iron filings are strongly attracted to the south pole of the magnet and, amazingly, they are lining up in a certain way. Your job in the following activity is to investigate and explore what the shape of this magnetic field is and how it changes with different shapes of magnets.

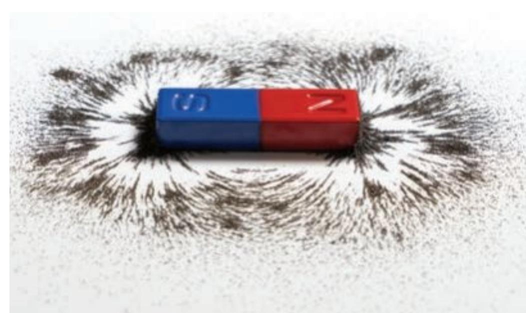


Figure 5.47 Magnetic fields around a magnet form a particular pattern.

Practical skills 5.6

Magnetic field lines

Aim

To visualise the shape of the magnetic field of different magnets.

Materials

- 2 bar magnets
- horseshoe magnet
- iron filings
- piece of A4 paper
- compass

continued …

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... continued

Method

1 Place the bar magnet on a table and cover it with a piece of paper.
2 Sprinkle iron filings on the paper and look at the pattern formed.
3 Hold the compass at different points around the magnet. The direction that the compass points in indicates the direction of the magnetic field lines.
4 Repeat steps **1–3** with the horseshoe magnet.

Results

Draw a sketch of the pattern formed by the iron filings.

Analysis

1 Using your diagram, determine where the magnet's poles are.
2 Identify where the magnetic field appears to be the strongest.
3 Investigate different patterns formed with two or more magnets placed near each other.

Quick check 5.10

1 Explain why magnetism is considered a non-contact force.
2 Complete the following sentence: Opposite poles _________ each other while poles that are the same _________ each other.
3 Explain the difference between a permanent and a temporary magnet.
4 Describe a magnetic field. Draw a picture of the field around a bar magnet and indicate the direction of the magnetic field lines.

Science as a human endeavour 5.3

Nuclear force and the atomic bomb

Another non-contact force occurs within individual particles. The force acting inside particles, holding them together, is called the 'nuclear force'.

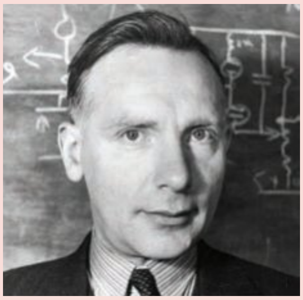

Figure 5.48 Joseph Rotblat in 1956

During World War II, a Polish scientist, Joseph Rotblat, was working first in England and then in the USA on research to develop the atomic bomb as part of the Manhattan Project. Doing this would utilise nuclear forces to release a huge amount of energy. This would later be realised in the creation of the atomic bomb, which was used by the USA on the Japanese cities of Kawasaki and Hiroshima. The devastating outcome continues to be a reminder of the dangers of nuclear weapons in the modern world.

However, at the end of 1944 Rotblat withdrew his participation in the research for ethical reasons, as he was well aware that the research he was undertaking had dire consequences if used in war.

Rotblat was a keen advocate that scientific research should be used for peace, and for his ethical consideration in World War II and peaceful work after the war, he was awarded the Nobel Peace Prize in 1995.

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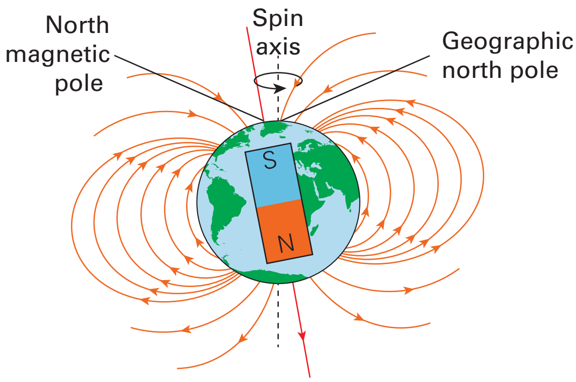

Figure 5.49 The magnetic pole near the North Pole is actually a south magnetic pole. This is known because a compass always points north and opposites attract, so the north of a compass is attracted to the south pole of a magnet.

Earth itself is a giant magnet with magnetic poles near the geographic poles. A suspended magnet will turn until its north pole points geographically north because of its attraction to the south pole of the internal Earth magnet. This is a property of natural magnets or lodestones and has been used by navigators for thousands of years. What is called the North Magnetic Pole by geographers is called the south pole of Earth's magnet by scientists.

Magnetism and electricity are closely related; wires carrying electricity create a magnetic field

Try this 5.8

Making a compass

Use a steel nail, a strong magnet, a piece of cork (or polystyrene foam) and a bucket of water to make a compass. Follow these instructions.

1. Stroke the steel nail with the strong magnet in one direction. After each stroke, be sure to lift the magnet away from the nail before your next stroke. Repeat this process about 50 times.
2. Test your nail to see if it has become magnetised by holding it near some paperclips.
3. Place the cork or polystyrene in the bucket of water. Then place the nail on top.
   Identify which end of the nail is the north pole. How did you know this?

Check the accuracy of the homemade compass with an ordinary compass. Discuss the accuracy of the homemade compass. State one way in which the accuracy of the homemade compass could be improved.

Did you know? 5.3

Sea turtles use Earth's magnetic field to find home

Female sea turtles always return to the beach where they were born to lay their own eggs. Sometimes this means swimming thousands of kilometres, and the way they do this is by relying on Earth's magnetic field. Scientists have hypothesised that turtles have a very sensitive detection of magnetic particles of the surrounding land, and it is possible that tiny magnetic particles in their brains help the turtles navigate.

Figure 5.50 The sea turtle is guided along the coast by Earth's magnetic field.

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around them. Magnets called **electromagnets** are made by coiling a wire. When a battery is connected, the current flows along the wire and a magnetic field is created. When the current stops, the magnetic field ceases. The strength of the field can be increased by wrapping the coil around a piece of magnetic iron.

electromagnet
a magnet made by passing electricity through a coil of wire

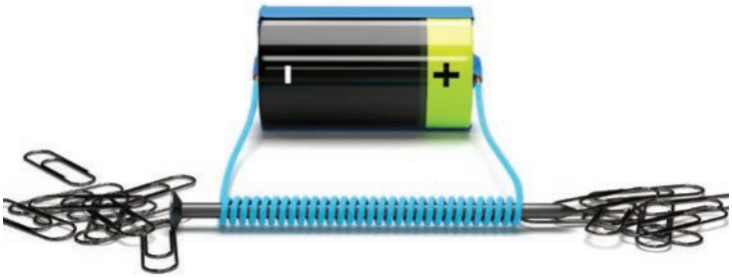


Figure 5.51 An electromagnet can attract anything that a magnet can (in this case, paperclips).

Investigation 5.1

Making a simple electromagnet

Be careful
Make sure you only turn on your electromagnet for a short time. If left on, it will get hot.

Aim

To investigate how changing the number of coils on an electromagnet will affect its strength.

Research question

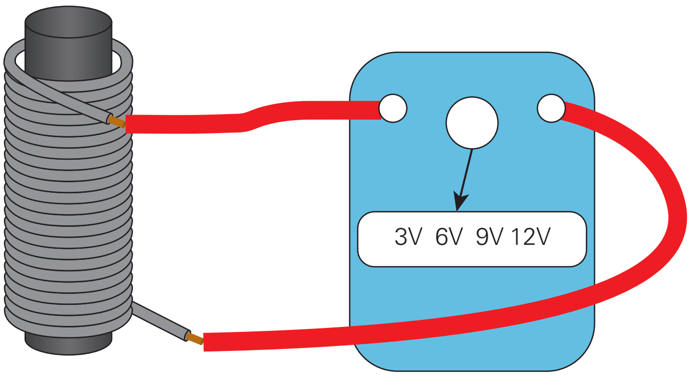
How do the number of coils on an electromagnet affect its strength?

Materials

- 9 V battery or powerpack
- long nail
- compass
- 2 insulated wires with alligator clips (one short, one long)
- switch
- paperclips

Method

1 Draw the table shown in the results section into your science book.
2 Set the DC powerpack to 6 V and make sure the switch is OFF.
3 Carefully wrap the long wire around the nail 10 times, ensuring to only wind in one direction and avoiding any overlap of wires.
4 Connect the powerpack to both ends of the long wire using the insulated wires with alligator clips.



5 Turn the powerpack ON.
6 Test your electromagnet by seeing how many paperclips it picks up. Record this number in the results table.
7 Retest the electromagnet two more times and record.
8 Repeat steps **2–6**, increasing the number of coils each time, according to the results table.

Planning

1 You need to provide some background information to the investigation. Research electromagnets. Write a brief paragraph to explain how electromagnets work and the factors that can affect their strength.
2 Identify the independent variable in this investigation.

continued …

... continued

3 Identify the dependent variable in this investigation.
4 Develop a hypothesis by predicting how the independent variable will affect the dependent variable.
5 Identify the controlled variables in this investigation.
6 Create a risk assessment for this investigation.

Results

Independent variable: Number of coils	Dependent variable: Number of paperclips				
	Trial 1	Trial 2	Trial 3	Mean	Range
10					
20					
30					
40					

Use a spreadsheet to create a digital graph using Excel or Google Sheets displaying the mean for each group. Label each axis appropriately and add an appropriate title.

Peer review

1 Swap graphs with a peer. Give each other feedback on how easily the graph can be used. Feedback should identify if the graph displays only the mean results, has appropriate labels, units and title, and any other features that could be improved to enhance how well the experimental results are communicated, such as scale or formatting.
2 After receiving feedback, make alterations to the graph to address the identified issues.

Analysis

1 Identify the trend in your graph.
2 Identify any anomalous results in your graph.
3 Extrapolate your graph to find out how many paperclips could be picked up if there were 80 coils.

Evaluation

1 If you had any anomalous results (ones that were very different from the others), explain how these may have been caused.
2 Describe how the investigation could be improved if you had the chance to do it again.

Conclusion

1 Propose a valid conclusion that can be drawn from these results.
2 Justify this conclusion using data from your results.
3 State whether your hypothesis is supported or not.

Explore! 5.2

Uses of magnets

You may not realise but electromagnets and permanent magnets are used everywhere and every day. Examples include electric motors, door bells, computer hard drives, MRI machines, phone speakers, microphones, drills, hair dryers and bank cards!

Research any one of these examples and write a short report on each. Include a picture and details of how an electromagnet or permanent magnet is involved in how the object functions.

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Quick check 5.11

1 Describe an observation that is evidence that Earth has its own magnetic field.
2 Explain how an electromagnet is different to a bar magnet.
3 Name some examples of electromagnets used every day.
4 Describe the advantages of an electromagnet over a permanent magnet.

Electrostatic forces

Another non-contact force that you might encounter in your everyday life is the **electrostatic force**. This force is the one responsible for electric shocks after rolling on a trampoline or carpet, and is also the cause of lightning during a storm.

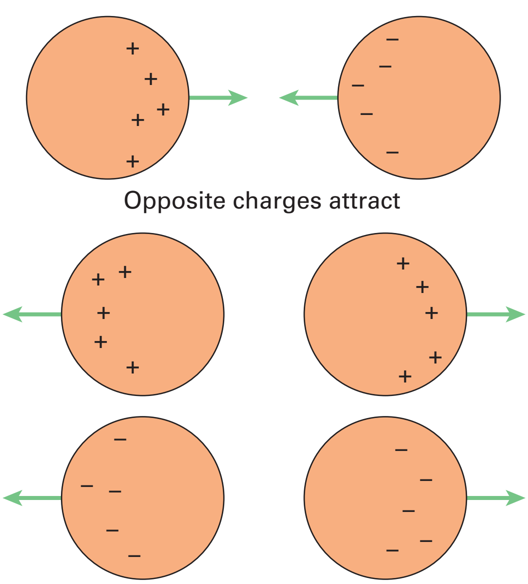

Figure 5.52 Forces between charges

Like magnets, electrical charges attract and repel each other. There are two types of charge: positive (+) and negative (–). Opposite charges attract each other and like charges repel.

Like gravity and magnetism, objects with an electric charge also create a field around them. The electrostatic field is the region in which charged particle will feel the electrostatic force.

Look at Figure 5.53. The machine the girl is touching is called a Van de Graaff generator, and it is a machine that separates positive and negative charges. The negative charges go down to the ground while the positive charges in the metal dome stay in place. Because the girl is touching the dome, the negative charges from her hair flow to the dome, making her hair positively charged. Remember, like charges repel, so with all her hairs turning positively charged, they all try to get away from each other!

electrostatic force
a non-contact force between positive and negative charges; opposite charges attract, like charges repel

static electricity
a build-up of electric charge

A build-up of charge in this way is called **static electricity**. The girl's hair is not going to stay charged forever, and eventually the charges will return to normal. When there is a large build-up of charge, the charge can jump from one area to another and that jump appears like a spark. This is called a static discharge.

Static electricity can be seen and felt when you get an electric shock or when you see lightning strike in a storm. Charges jump from one place to another due to electrostatic forces.

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Figure 5.53 Electrostatic forces can make your hair stand on end.

Quick check 5.12

1. Define the key terms 'electrostatic force' and 'static electricity'.
2. Complete the following sentence: Opposite charges ___________ and like charges ___________.
3. Explain how a Van de Graaff generator works.
4. Explain why you sometimes get a small electric shock even though you have not touched a supply of electricity.

Try this 5.9

Observing static electricity

Materials

- 2 balloons
- string
- a metre ruler
- woollen cloth

Instructions

1. Rub the inflated balloon with the woollen cloth and place it against a wall. Record your observations.
2. Suspend the balloon from the metre ruler using the string.
3. Suspend the second balloon so it is close to, but not touching, the first balloon.
4. Rub both balloons with the woollen cloth on the sides that are facing each other.
5. Record any observations of any movement in the balloons.

Evaluation

Discuss the following questions with your classmates.

1. What is the purpose of rubbing a balloon with a woollen cloth?
2. Did the balloon stick to the wall? Propose reasons as to why or why not.
3. Describe the movement of the two balloons when hung next to each other.
4. Does the movement indicate that the balloons had like or unlike charges? How do you know?

Section 5.3 questions

QUIZ

Retrieval

1 **State** the forces that are acting on a dropped book as it falls to the floor.
2 **Name** the force that a magnet exerts.
3 **Recall** some objects that use electromagnets.
4 **Recall** three magnetic materials.
5 **Define** the term 'magnetic field' and illustrate with a picture.
6 **Name** the two types of electric charge.
7 **State** whether the mass of an object changes as it moves around the universe.
8 A falling object is pulled down by Earth. Earth is pulled up toward the object. **Explain** why the movement of Earth cannot be detected.
9 **Determine** your weight in deep space.
10 **State** which ball will hit the ground first: a wooden ball, a plastic ball or a metal ball, if air resistance is ignored.
11 The north pole of a magnet points north if it is free to move. **Identify** which magnetic pole must be near the North Pole.
12 **State** which types of forces have a field.
13 **Identify** three situations where air resistance is useful and one situation where it is not useful.

Comprehension

14 **Calculate** the weight of a 5 kg cat on Earth (g = 9.8 N/kg) and on Mars (g = 3.7 N/kg).
15 **Describe** which would take longer to fall, a rock dropped from 1 metre on the Moon (gravity is about one-sixth of Earth's) or a rock dropped from 1 m on Mars (gravity is a little over one-third of Earth's). You can ignore air resistance on both planets.
16 **Summarise** how you can visualise the magnetic fields that surround a bar magnet.
17 Two balloons are hanging loosely near each other. One balloon is given a negative charge and the balloons start to move away from each other. **Explain** what is happening and what the charge on the other balloon must be.
18 **Compare** the similarities between charged objects and magnets.
19 **Explain** whether a hammer and a feather would hit the ground together if dropped from the same height at the same time on the planet Mercury where there is no atmosphere.
20 **Analyse** how a compass works and describe why it is useful.
21 A parachute is made of large pieces of material. **Explain** why it has a large surface area and how it makes a falling object slow down.

Analysis

22 The geographic North Pole is located in the middle of the Arctic Ocean, which is covered with sea ice. There is no permanent station or marker of the true North Pole. However, there is a marker that shows the location of the South Pole. **Infer** why the true North Pole does not have a marker, whereas the South Pole does.

Knowledge utilisation

23 **Evaluate** the effects of living in a low-gravity environment for a long time.

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Chapter review

Chapter checklist

You can download this checklist from the Interactive Textbook to complete it.

Success criteria		Linked questions	Check
5.1	I can recall what a force is and how forces are measured.	1, 2, 4	
5.1	I can describe the impact of balanced and unbalanced forces on an object.	5, 6, 7, 10, 11, 12	
5.1	I can draw a force arrow diagram to indicate the forces acting on an object.	9	
5.2	I can describe some contact forces.	3, 14, 15, 16	
5.3	I can describe the effect of Earth's gravitational force.	8	
5.3	I can describe three non-contact forces.	3, 13	

Review questions

SCORCHER

Retrieval

1 **Define** the term 'force'.
2 **State** the units for mass and weight.
3 **List** three contact forces and three non-contact forces.
4 **Define** the term 'net force'.
5 **Recall** the word that is used to describe two forces that are equal in size and act in opposite directions.
6 **State** whether an object can change direction without a force.
7 **State** whether an object always moves when a force acts on it.
8 **Describe**, using your knowledge of forces, why the Moon orbits Earth and why Earth orbits the Sun.
9 **Draw** or describe the pair of equal and opposite forces on each of the koalas in Figure 5.54.

Figure 5.54 Koalas (*Phascolarctos cinereus*) sitting on a tree branch

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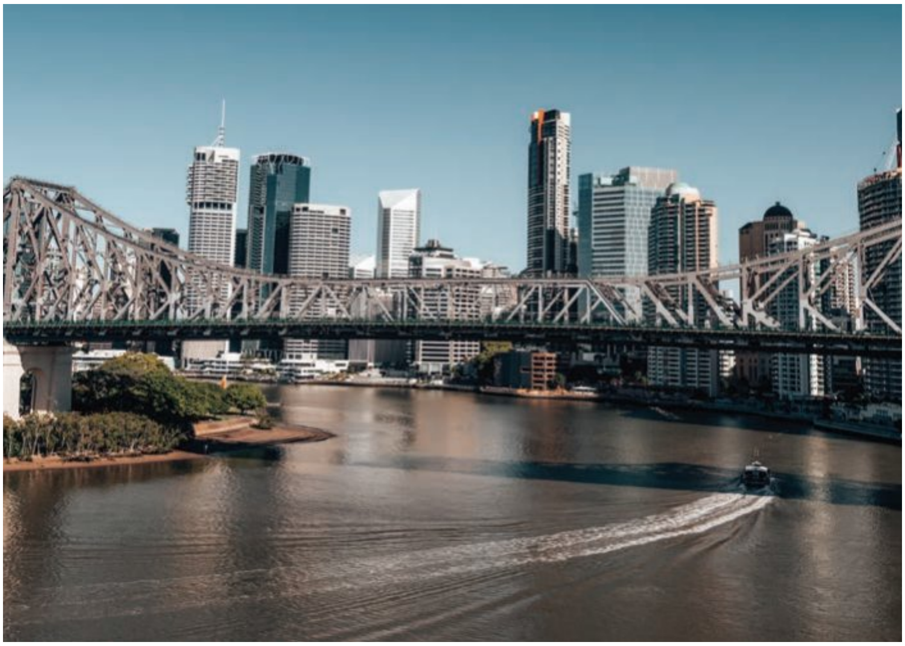

Figure 5.55 Story Bridge, Brisbane

Comprehension

10 **Describe** what happens if the forces on an object are unbalanced.

11 There are many forces between the parts of the Story Bridge in Brisbane. **Explain** whether all the forces between the parts are balanced or unbalanced.

12 **Explain** whether an object that is travelling horizontally in a straight line at a constant speed needs a force to keep moving.

13 Metal recycling takes place in most cities. Aluminium, copper and steel are the most common metals that are recycled. After collection, the first step is to flatten the metal and then cut it into small pieces. The second step is to separate the iron and steel from the aluminium and copper before finally melting the metals ready to be used again. **Describe** a way that could be used to easily carry out the second step.

Analysis

14 On snow and ice, wheels with tyres are often replaced by skis and tracks on vehicles. **Consider** the skis and the tyre below and how their shape and friction forces relate to their use.

Figure 5.56 Skis versus tyres

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Knowledge utilisation

15 Use your answer to the previous question and knowledge of forces to **justify** why a snowmobile is preferred for snow compared to a normal motorcycle.

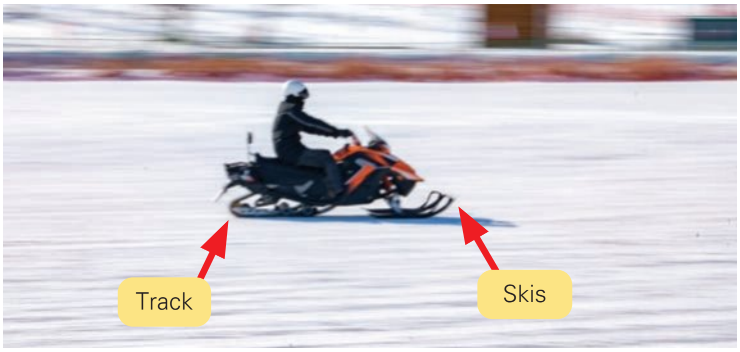

Figure 5.57 Snowmobiles use skis and a track instead of wheels.

16 Figure 5.58 shows a scientist inspecting seagrass in Queensland. Around his waist he is wearing a heavy belt made of metal. Using your knowledge of forces, **propose** the function of this belt.

Figure 5.58 Diver wearing a weight belt

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Data questions

Earth's Moon and the other planets in our solar system have different forces of gravity on their surface from Earth because they have different masses. These forces of gravity on the surface of each are shown with respect to that of Earth in the graph below.

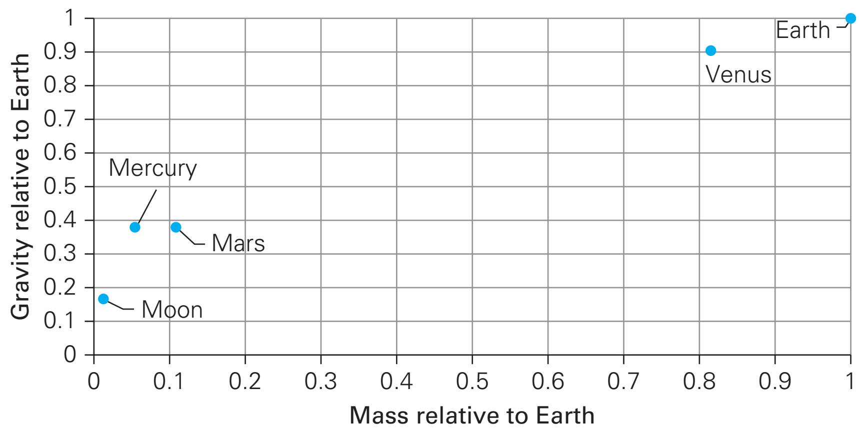

Figure 5.59 Gravity on the Moon and other planets relative to that of Earth given their relative masses

Apply

1 **Identify** which planet (those not including the Moon) in the graph has the lowest mass.
2 **Determine** which planet has a force of gravity closest to that on Earth.
3 If the acceleration of Earth's gravity is 9.8 m/s^2, and the gravity on Mars is 38% of that of Earth, **calculate** the force of gravity on Mars.

Analyse

4 **Identify** the general relationship between the mass of a planet and force of gravity.
5 Use the data presented in the graph to **contrast** the gravitational forces of Earth and Mercury.
6 **Deduce** why the Moon orbits Earth, instead of Earth orbiting the Moon.

Interpret

7 The mass of Jupiter is approximately 318 times that of Earth. **Predict** whether the force of gravity on Jupiter would be greater or less than that of Earth.
8 Among the planets shown, two of them are such that a person standing on their surface would weigh about the same. **Infer** which two planets they are.
9 Pluto has a relative force of gravity of 0.06 of Earth's. Use the relationship identified in Question 4 to **justify** the statement that Pluto will have a mass less than that of Earth's Moon.

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STEM activity: The buoyant ferry prototype

Background information

Ferries are used throughout Australia and worldwide to connect two or more points over water. They carry passengers but can also be used to carry goods or even vehicles and machinery. They are important in many cities around the world as it is often expensive to build bridges across large bodies of water. This is also the case is some remote locations throughout the world where rivers become a main avenue for travel, such as the Amazon rainforest.

Ferries, like boats, ships and canoes, float in water as a result of buoyancy. Generally, if an object is less dense than water (less mass per unit of volume), it will float on the surface of water. That is to say, the less dense an object, the more buoyant it will be. But it is hard to imagine how a large ferry made of steel carrying cars can float on water. How can the ferry possibly have less density than the water it floats on?

That is the question that is answered and prototyped by engineers!

Design brief: Design and construct a ferry boat

Activity instructions

In engineering teams (maximum of 3 people), you will design and construct a ferry for riverside communities that is capable of transporting a payload (goods) and people between two points (return trip) over water.

As an engineer, you should investigate the science and technology of boats.

Figure 5.60 Ferries transport passengers in many Australian cities such as Brisbane, Perth, Sydney and Melbourne.

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Suggested materials

- ruler and tape measure
- scissors
- cardboard
- bubble wrap
- plastic bags
- 5 × 100 g parcels of sugar/salt (payload)
- sticky tape (duct tape or gaffer tape would be good)

Research and feasibility

1 List the features that would make a useful boat.
2 Research the terms 'density' and 'buoyancy' and discuss in your group how these factors are important in boat design.

Design

3 List all the materials that you have available and that you plan to use for your ferry.
4 Design a ferry that is capable of transporting your payload (set mass) between two points and return.
5 Label and include measurements of your ferry.

Create

6 Build your ferry using the materials, checking as you progress that your ferry is capable of floating.

Evaluate and modify

7 Discuss the challenges you have encountered throughout this project with at least three of your peers. List the strategies or actions that allowed you to overcome it.
8 Create a list of improvements to your design that could be applied to this project to refine its performance.

Chapter 6 Simple machines

Chapter introduction

Forces are at work in every machine you see in the world around you. Some tasks require a large amount of force to complete. In this chapter, you will learn how simple machines are able to make tasks easier. They can reduce the force required to move an object or increase its speed. You will learn about three classes of levers and the inclined plane, as well as how pulleys and gears use moving parts to multiply a force or a speed.

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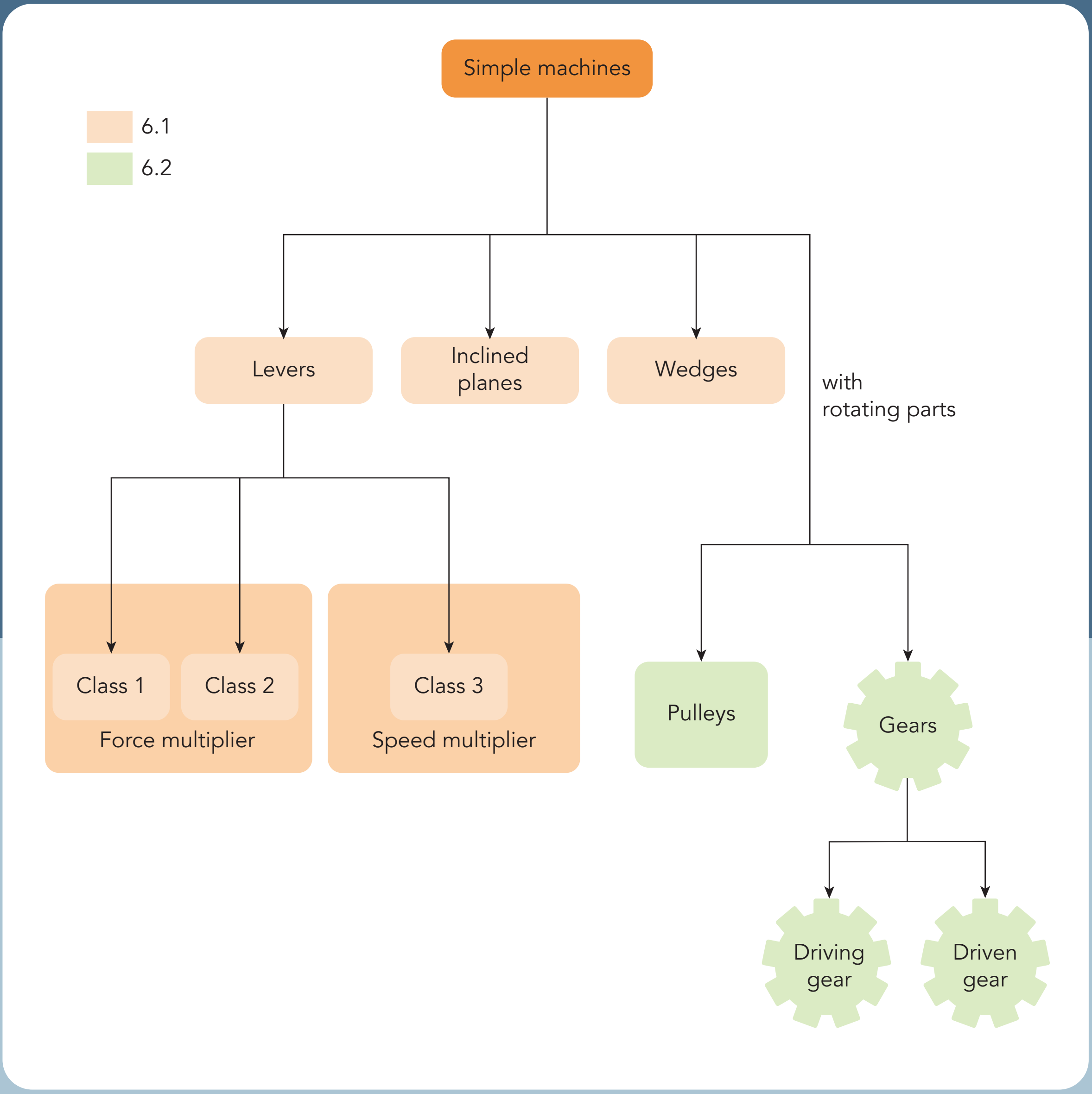
Concept map



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Curriculum

Investigate and represent balanced and unbalanced forces, including gravitational force, acting on objects, and relate changes in an object's motion to its mass and the magnitude and direction of forces acting on it (AC9S7U04)	
investigating how simple machines such as levers and pulleys are used to change the magnitude of force needed to perform a task	6.1, 6.2
analysing the forces acting on boomerangs and how early First Peoples of Australia designed an airfoil profile which allowed for multiple variations and applications	6.2
investigating the effect of forces through the application of simple machines, such as the bow and arrows used by Torres Strait Islander Peoples or the spearthrowers used by First Peoples of Australia	6.1

Glossary terms

Class 1 lever
Class 2 lever
Class 3 lever
Cog
Driven gear
Driving gear
Effort force
Force multiplier
Fulcrum
Gear
Lever
Load
Load force
Mechanical advantage
Pulley
Ramp
Simple machine
Speed multiplier

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6.1 Investigating simple machines

Learning goals

1. To be able to recall some types of simple machines and what they are used for.
2. To be able to describe, and state an equation for, mechanical advantage.
3. To be able to identify and draw diagrams of class 1, class 2 and class 3 levers.

WORKSHEET Levers

simple machine
a basic mechanical device for applying a force and changing either its size or direction

lever
a rigid bar that moves around a fixed point so one end can be pushed or pulled to move the other end with a greater or smaller force

ramp
an inclined surface connecting a higher and a lower level

pulley
equipment consisting of a grooved wheel (or wheels) with a rope or chain attached to an object to be moved

effort force
the input force to a simple machine

load
the object that is to be moved

load force
the output force of a simple machine

mechanical advantage
the ratio of the output force to the input force

In this section, you will learn about how **simple machines**, including **levers**, **ramps** and **pulleys**, can be used to perform tasks using less force than it would take without them. The common principle of a simple machine is to make a task easier to do. This might be by reducing the force required to do the task or increasing the speed of the task.

The force applied to the machine is called the **effort force**. The object being moved is called the **load** and the **load force** is the force applied to the load.

Mechanical advantage

Simple machines give us a **mechanical advantage**. In most cases, simple machines reduce the amount of force required to do a task. They do so because the force acts over a longer distance. The reduced force required means that we have an advantage. The mechanical advantage of a simple machine can be measured by the following equation:

$$\text{mechanical advantage} = \frac{\text{load force (output force applied by machine to object)}}{\text{effort (input applied by you to the machine)}}$$

Generally, the effort force is less than the load force when using a simple machine, and so the mechanical advantage is greater than 1. The higher the mechanical advantage of a simple machine, the more the effort force is magnified, meaning the easier it is for us to move a load.

VIDEO Assistive technology

Worked example 6.1

You need to use a simple machine to move a load. The load force is 120 N and the mechanical advantage of the machine is 4. Calculate the effort required to move the load.

Working	Thinking
Rearranging the formula gives: $\text{effort force} = \frac{\text{load force}}{\text{mechanical advantage}}$ Substituting the numbers into the formula gives: $\text{effort force} = \frac{120\text{ N}}{4} = 30\text{ N}$	To move the load force of 120 N using a simple machine with a mechanical advantage of four, you need to exert a force of 30 N.

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VIDEO
Lever classes

Levers

Levers are very common simple machines. They are used in a variety of ways in our everyday lives to make work easier. A cricket bat, a wheelbarrow, tongs, scissors, a see-saw and a shovel are all examples of levers.

Figure 6.1 A nutcracker is an example of a lever.

A lever usually consists of a rigid arm, which may be bent or straight, made of wood, steel or similar material. Levers are used to exert a force on the load and are classified into three types called **class 1**, **class 2** and **class 3**.

All levers have the following characteristics:

- Levers have a fixed point called the **fulcrum** on which the arm pivots.
- An effort force is applied to the lever.
- The effort force is transferred by the lever to exert a load force that moves or pushes the load.

Class 1 and class 2 levers are called **force multipliers** because they are able to magnify the effort force applied. However, in order to magnify the force, it must be applied over a greater distance.

class 1 lever
a lever in which the fulcrum is between the load and effort

class 2 lever
a lever in which the fulcrum is at one end and the load is between the fulcrum and the effort

class 3 lever
a lever in which the fulcrum is at one end and the effort is between the fulcrum and the load

fulcrum
the point on a lever where the arm pivots

force multiplier
something that increases the size of a force

Class 1 levers

In a class 1 lever, the fulcrum lies between the load force and the effort force. This type of lever magnifies the effort force to generate a larger load force. In a class 1 lever, the distance moved by the effort force will be larger than the distance moved by the load. To increase the mechanical advantage and make the job easier, the lever could be lengthened to increase the distance from the effort to the fulcrum. However, this comes at a cost. The distance you push down on the lever will be much larger than the distance your load moves.

For example, in Figure 6.2, if you tried to pull up a floorboard with your fingers, it would require a lot of effort force, but your fingers only move a short distance. Using a crowbar as a lever allows less effort force to be used to complete the job, but the hand has to move a greater distance.

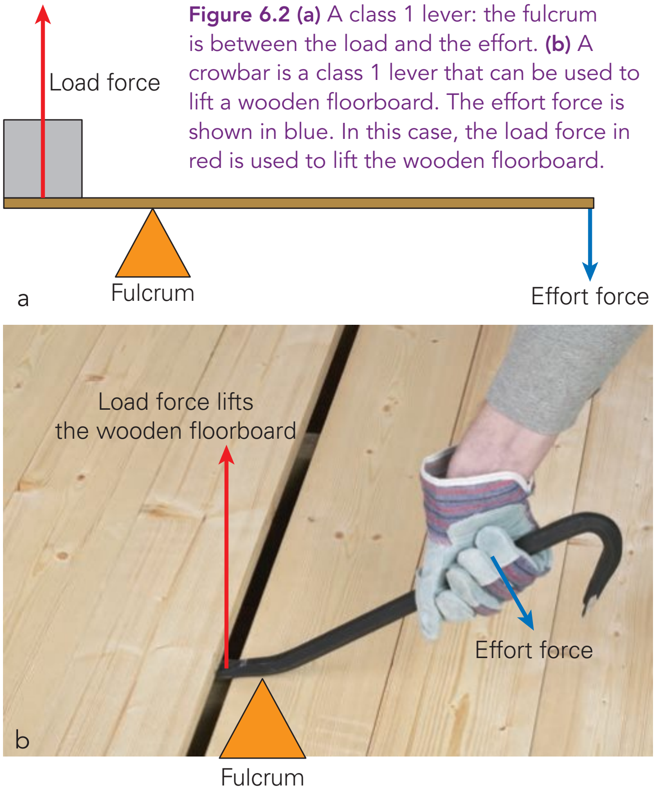

Figure 6.2 (a) A class 1 lever: the fulcrum is between the load and the effort. **(b)** A crowbar is a class 1 lever that can be used to lift a wooden floorboard. The effort force is shown in blue. In this case, the load force in red is used to lift the wooden floorboard.

Figure 6.2 shows the direction and size of the effort force (input) and load force (output) in this example. Note that the effort force arrow is shorter than the load force arrow, indicating the mechanical advantage. In a class 1 lever, the effort force moves in the opposite direction to the load force.

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Class 2 levers

A class 2 lever has a fulcrum at the end and the load in the middle. The effort is applied at the other end. Like a class 1 lever, a class 2 lever can magnify the effort force to generate a large load force. In class 2 levers, the effort force moves in the same direction as the load force.

In the examples shown below, can you think of a way to make this job even easier?

You guessed it! Increasing the length of the handles will increase the mechanical advantage.

Figure 6.3 A bottle opener is a class 2 lever. The fulcrum (shown by the orange triangle) rests on the cap and the effort force is applied to the handle. This results in a large load force on the edge of the cap, which opens the bottle. It would otherwise be difficult to open the bottle with our bare hands.

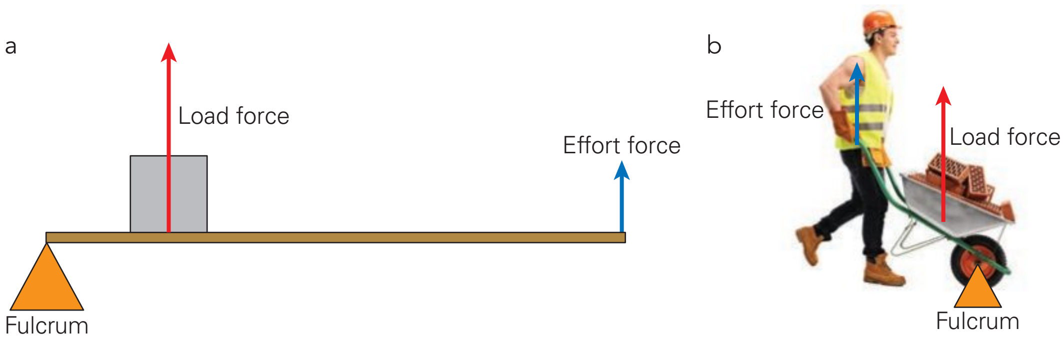

Figure 6.4 (a) A class 2 lever. The fulcrum is at one end and the load is between the fulcrum and the effort. **(b)** A wheelbarrow is an example of a class 2 lever. The workman does not have to apply as much effort force to lift the load. Without this simple machine, it would be nearly impossible to lift that amount of bricks!

Making thinking visible 6.1

Beginning, middle, end: Simple machines in action

The following images show the beginning and middle of a story taking place.

1 What is the person trying to do in the left-hand image and why is it difficult?
2 Identify what type of simple machine is being used in the right-hand image.
3 Describe what the missing third image might look like, using your knowledge of simple machines to explain your answer.

Figure 6.5 The beginning and middle images

The *Beginning, middle, end* thinking routine was developed by Project Zero, a research centre at the Harvard Graduate School of Education

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Investigation 6.1

Effect of changing the distance from the effort to the fulcrum

Aim

To investigate the effect on the effort force when changing the distance from the effort to the fulcrum.

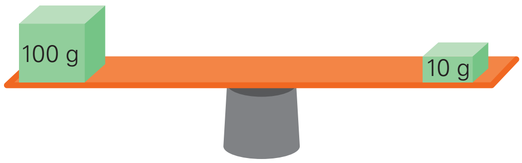
Materials

- 1 metre ruler
- rubber stopper (alternative: eraser)
- 1 × 100 g mass
- 10 × 10 g masses
- 1 × 5 g mass

Planning

1 Write a research question guided by the aim stated above.
2 Identify the independent variable.
3 Identify the dependent variable.
4 List the controlled variables.
5 State a hypothesis based on your research question.
6 Read the method below and draw an appropriate results table.

Method



1 Place the rubber stopper under the 1-metre ruler at the 10 cm mark. The rubber stopper will act as a fulcrum.
2 Place the 100 g mass on top of the ruler at the 0 cm mark.
3 Place a 10 g mass on the 100 cm mark at the other end of the ruler. Observe.
4 Continue to add a 5 g or 10 g mass to the 100 cm mark until the 100 g mass is lifted.
5 Record the mass required to lift the 100 g mass in your results table.
6 Move the rubber stopper to the 20 cm mark and repeat steps **1–5**.
7 Move the rubber stopper to the 30 cm mark and repeat steps **1–5**.
8 Move the rubber stopper to the 40 cm mark and repeat steps **1–5**.
9 Move the rubber stopper to the 50 cm mark and repeat steps **1–5**.

Analysis

1 State which class of lever was used in this experiment.
2 Describe any trends in your results.

Evaluation

Limitations

1 Discuss whether the control variables were managed properly to ensure they did not change and affect the measurements.

Improvements

2 Identify any changes that could be made to the method to improve the quality of the data in future experiments.
3 Describe how the experiment could be extended if it was done again.

Conclusion

Draw a conclusion based on the hypothesis about the relationship between the effort and the distance from the fulcrum.

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Class 3 levers

Unlike class 1 and 2 levers, class 3 levers do not multiply force. The effort force for class 3 levers generates a load force that is smaller than it, but more speed or distance can be obtained. These levers are called **speed multipliers**.

speed multiplier something that increases the speed of an object

They are a special case where the effort force is larger than the load force. (Note that this results in a mechanical advantage of less than 1; see the formula in the Extension section.)

In a class 3 lever, the fulcrum is at one end and the effort force is between the load and fulcrum. Recall that class 1 and 2 levers increase the force applied to an object, but that force must be applied over a larger distance than the load moves. In class 3 levers, the load moves a much greater distance than the effort, but with a smaller force. This type of lever is common in sports such as tennis, cricket, golf and baseball where speed multipliers are beneficial. For example, a tennis racquet can hit a ball with much greater speed than can be achieved with just your arms. In a tennis racquet, the wrist acts as the fulcrum and the effort is applied by the hand to the handle. The load is in the middle of the racquet head. The head of the racquet moves a larger distance than the hand, multiplying its speed.

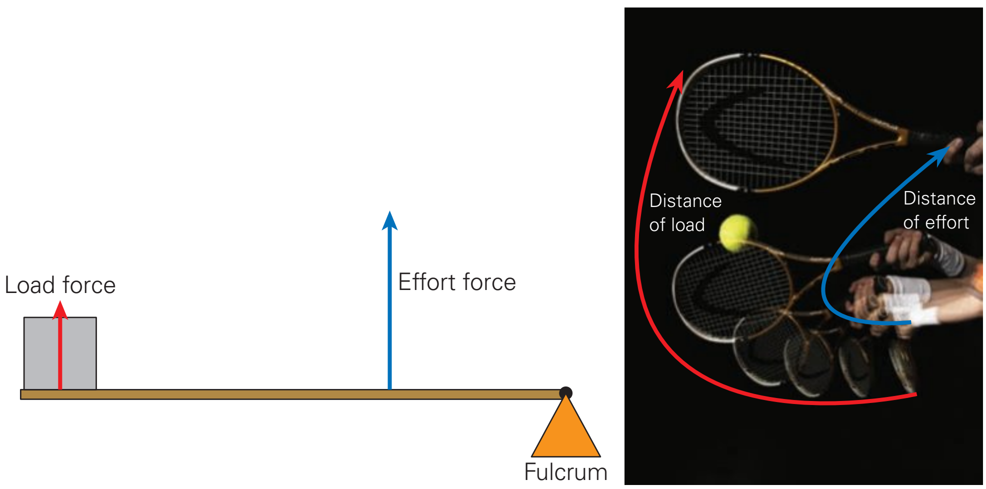

Figure 6.6 (a) In a class 3 lever, the fulcrum is at one end and the effort force is between the load and the fulcrum. **(b)** Sports scientists apply this knowledge of forces to help their clients improve their sporting performance. This knowledge has helped tennis players to now make serves at speeds above 250 km/h!

Try this 6.1

Levers are everywhere!

Look around the room that you are currently in and identify as many levers as possible. Once you identify a lever, classify it as either first, second or third class.

Did you know? 6.1

Biological levers

There are a number of levers in the human body. Raising the forearm, for example, uses a class 3 lever. The elbow is the fulcrum, the bicep muscle provides the effort force to the forearm and the hand holds the load. Other levers in nature include birds' beaks and crabs' claws.

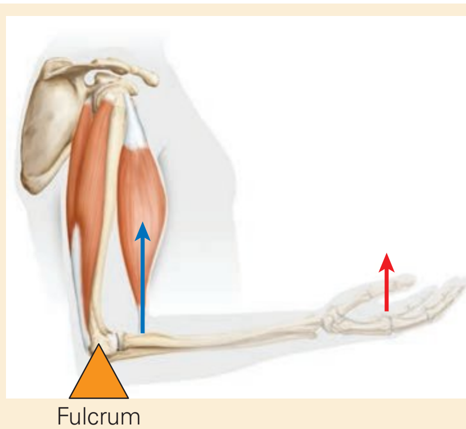

Figure 6.7 The arm is a class 3 lever.

Extension

The mechanical advantage of a lever can also be calculated using the distance of the effort and load from the fulcrum.

$$\text{Mechanical advantage} = \frac{\text{distance of effort from fulcrum}}{\text{distance of load from fulcrum}}$$

You also know that:

$$\text{mechanical advantage} = \frac{\text{load force}}{\text{effort force}}$$

Notice that when calculating the mechanical advantage using forces, the term relating to load is on the top, whereas when calculating the mechanical advantage using distance, the term relating to effort is on the top.

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Worked example 6.2 shows the use of a class 1 lever to move a load. With a short lever, an effort force applied at the end of the lever produces a large force at the other end, but it is not enough to move the load.

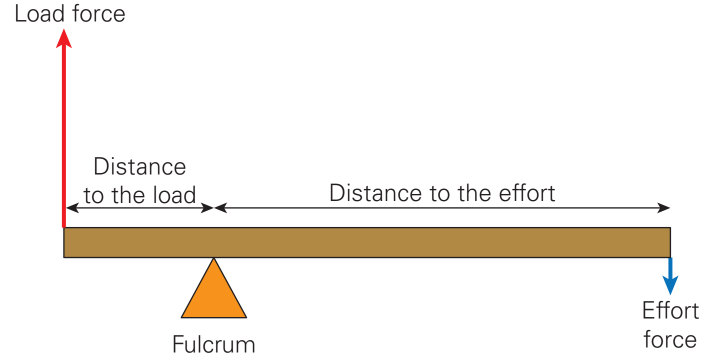

Figure 6.8 How to measure the distances to the fulcrum

Worked example 6.2

Use the information in Figure 6.9 to:

a calculate the mechanical advantage of the lever

b determine whether a load of 300 N can be moved by an effort force of 50 N using the lever.

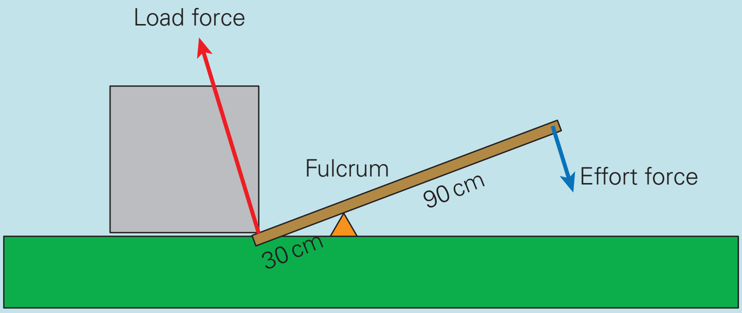

Figure 6.9 An example lever system

Working	Thinking
a Mechanical advantage	
We use the formula $$\text{Mechanical advantage} = \frac{\text{distance of effort from fulcrum}}{\text{distance of load from fulcrum}}$$ Substitute the numbers: $$\text{Mechanical advantage} = \frac{90\text{ cm}}{30\text{ cm}} = 3$$ The mechanical advantage is 3.	This means that the effort can lift a load 3 times its force.
b Effort force required to move 300 N	
We can rearrange the formula so that the effort force required is on the left-hand side: $$\text{Mechanical advantage} = \frac{\text{load force}}{\text{effort force}}$$ Doing this gives: $$\text{Effort force} = \frac{\text{load force}}{\text{mechanical advantage}}$$ Substituting the numbers: $$\text{Effort force} = \frac{300\text{ N}}{3} = 100\text{ N}$$ The load will not move.	The effort force required by this lever system to move a load force of 300 N is 100 N. This is because the mechanical advantage is 3. This means that an effort force of 50 N will not move the load.

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Worked example 6.3 shows the same load is able to be moved by the same effort force if it is applied at the end of a longer rod. The longer lever produces a greater load force.

Worked example 6.3

The lever from the previous example was then replaced with a longer lever. Use the information in the diagram to determine whether an effort of 50 N could now move the same initial load of 300 N.

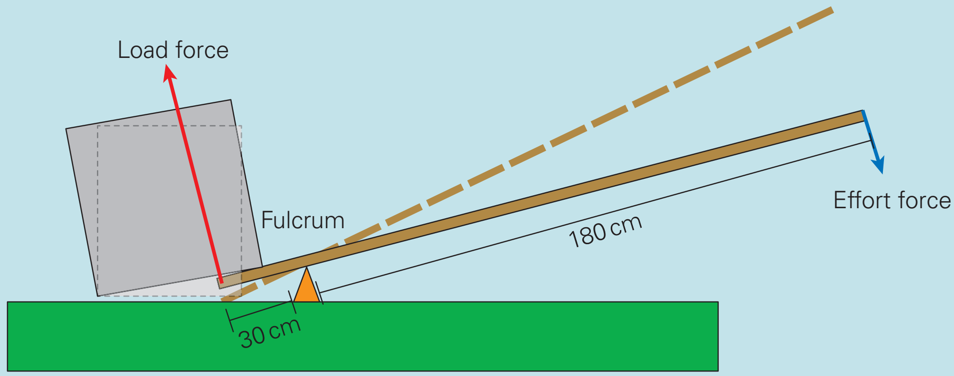

Figure 6.10 An example lever system

Working	Thinking
$\text{mechanical advantage} = \frac{\text{distance of effort from fulcrum}}{\text{distance of load from fulcrum}}$ $= \frac{180\text{ cm}}{30\text{ cm}}$ $= 6$ The mechanical advantage is now 6. The effort required is now: $\text{effort force} = \frac{\text{load force}}{\text{mechanical advantage}}$ $= \frac{300\text{ N}}{6}$ $= 50\text{ N}$ The effort force of 50 N is able to move the load.	The distance between the effort and fulcrum has increased by using a longer lever. Now, an effort force of 50 N is required to move the load force of 300 N.
Alternatively, we can find the maximum load that an effort of 50 N can move with this new lever system. Rearrange the formula so that load force is on the left-hand side: $\text{mechanical advantage} = \frac{\text{load force}}{\text{effort force}}$ $\text{load force} = \text{effort force} \times \text{mechanical advantage}$ $= 50\text{ N} \times 6$ $= 300\text{ N}$ The effort force of 50 N is able to move the load.	The maximum load is 300 N. Therefore, in this case, the effort force of 50 N is able to move a load force of 300 N.

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Explore! 6.1

First Nations use of simple machines

Spear-throwers are simple machines that were developed by First Nations Australians to help with hunting. Indigenous spear-thrower devices are commonly about 50 cm long and made from hardwood timber. At one end, a hand grip is often coated with spinifex resin. At the other end is a peg, made from either wood or a large tooth, which is attached to the spear-thrower using animal sinew and resin to hold the spear in place.

The spear-thrower acts as a lever, multiplying the force that a hunter can apply to the spear, as well as improving its projectile accuracy. It allows spears of up to 3 m in length to be thrown at speeds of up to 150 km/h. The peg helps hold the spear (or dart) in position, and focuses the throwing force.

Figure 6.11 The design of the spear-thrower will depend on where in Australia it was developed. Spear-throwers are refined and altered by the people of each area to suit their own particular needs.

Torres Strait Islander peoples also used another simple machine, the bow and arrow, in hunting. This was not used by First Nations Australians on mainland Australia, likely due to heavier spears being required to hunt larger animals such as kangaroos.

The bow is also a simple machine, multiplying the force acting on an arrow for hunting small animals.

Conduct research and watch videos of the spear-thrower and bow and arrow being used to answer the following questions.

1 Draw a spear-thrower and spear and identify where on the spear-thrower the load, force and fulcrum are located.
2 Draw a bow and arrow and identify where on the bow elastic energy could be stored and released.
3 Deduce what type of lever is being utilised in the spear-thrower.

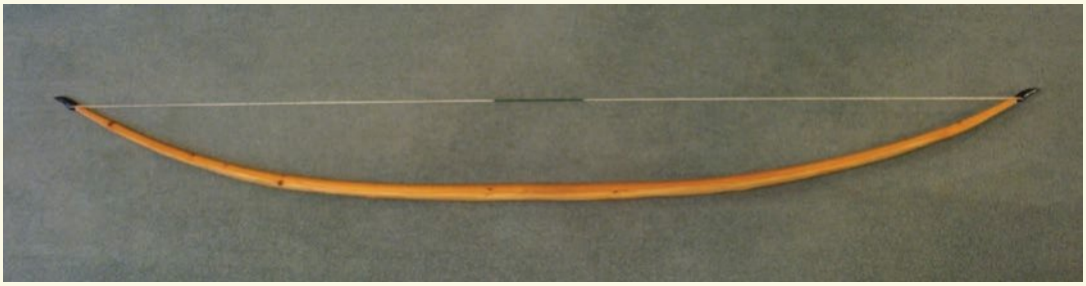

Figure 6.12 An example of a simple bow

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Quick check 6.1

1. Define the terms 'effort force' and 'load force'.
2. Recall an example of a class 1, 2 and 3 lever.
3. Describe the difference between class 1, 2 and 3 levers in terms of where the fulcrum, load and effort are placed relative to each other.
4. Explain the term 'mechanical advantage'.
5. Describe how you could make a class 1 or 2 lever more effective.
6. If a wheelbarrow had a mechanical advantage of 10, and the load weighs 1000 N, calculate how much effort force is required to lift the load.

Inclined planes

The type of inclined plane you would be most familiar with is a ramp. A ramp allows objects to be moved up against the force of gravity, but over a distance. For example, it takes less effort force to push a box up a ramp onto a moving truck than lift it vertically. Therefore, inclined planes provide a mechanical advantage compared to lifting an object vertically. However, once again there is a trade-off. The effort force must be applied over a larger distance. In other words, it is easier to push the object up a ramp, but you have to push it further. Inclined planes are always force multipliers.

Examples of inclined planes include boat ramps that lift boats out of the water, playground slides and inclined roads. The longer the distance of the ramp the greater the load that can be lifted. That means that inclined planes that are longer have a greater mechanical advantage than ramps that are shorter. Heavy vehicles cannot go up inclines of more than about 20°, so mountain roads on land that rises at a greater angle are designed with a series of bends to increase the horizontal length for the same rise. This results in a longer and less steep road.

Figure 6.13 illustrates the example of a ramp and a removalist truck. Like levers, the mechanical advantage of an inclined plane can also be calculated using the *length* of the inclined plane:

Figure 6.13 Ramps are used to lift and move heavy objects.

Figure 6.14 Roads that climb altitude often have hairpin bends to reduce the incline for vehicles.

$$\text{mechanical advantage} = \frac{\text{length of the inclined plane}}{\text{vertical height}}$$

Using a ramp decreases the effort force needed to move an object from one height to another. However, the trade-off is that you must move the load through a greater distance.

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Worked example 6.4

Look at the images below. Using a ramp decreases the amount of effort needed to lift the object into the truck.

a Calculate the mechanical advantage of each ramp.

b If the load force was 120 N, what is the required effort force?

Figure 6.15 Which inclined plane provides a greater mechanical advantage?

Working	Thinking
a Mechanical advantage	
3 m ramp: $\text{Mechanical advantage} = \frac{\text{length of the inclined plane}}{\text{vertical height}}$ $= \frac{3\text{ m}}{1\text{ m}}$ $= 3$ 8 m ramp: $\text{Mechanical advantage} = \frac{8\text{ m}}{1\text{m}} = 8$	A less steep ramp gives a greater mechanical advantage but you have to push the object further.
b Effort force	
$\text{Mechanical advantage} = \frac{\text{load force}}{\text{effort force}}$ 3 m ramp: $\text{Effort force} = \frac{\text{load force}}{\text{mechanical advantage}}$ $= \frac{120\text{ N}}{3}$ $= 40\text{ N}$ 8 m ramp: $\text{Effort force} = \frac{120\text{ N}}{8} = 15\text{ N}$	If the box has a load force of 120 N, the worker needs to apply 40 N of effort force with the 3 m ramp shown on the left, and only 15 N of effort force with the 8 m ramp on the right!

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Investigation 6.2

Inclined plane practical

Aim

Investigating the relationship between the effort force required to pull a mass up a ramp and the height of the ramp.

Materials

- books or wooden blocks
- spring balance (1 N, 10 N)
- 1 kg mass on a trolley
- long wooden plank

Method

1. Set up a ramp using the wooden plank and books/blocks and measure the height and the length of the plank.
2. Place the 1 kg trolley at the bottom of the ramp and attach the appropriate spring balance. (Hint: which spring balance would be the best for each ramp height?)
3. Pull the 1 kg mass up the ramp using the spring balance at a constant speed and record the force required. Record this reading in your results table.
4. Repeat the measurement two more times and record in your table.
5. Repeat steps **1–4** at four different ramp heights.
6. Complete the results table by calculating the average effort force for each ramp height. (To do this, add all the readings you took for a particular ramp angle, then divide the total by the number of readings you took for that ramp angle.)

Data processing

Draw a graph showing the relationship between ramp height and effort force.

Analysis

1. Identify any trends in your results.
2. Use the load force = 10 N to calculate the mechanical advantage of the ramp. Does it agree with the formula?

$$\text{mechanical advantage} = \frac{\text{length of the inclined plane}}{\text{vertical height}}$$

Conclusion

Answer your research question, using evidence to support your statement.

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Did you know? 6.2

Ancient use of ramps

While the ramp appears as a very simple machine, archaeologists believe that it was used extensively to help teams of men move the limestone blocks into position to build the pyramids in Egypt thousands of years ago.

Figure 6.16 Blocks of limestone were moved into position on these pyramids using inclined planes.

The idea of the inclined plane is applied to much more than just ramps. Consider a screw or a bolt, and the inclined plane that wraps around its stem. Screws and bolts are used to penetrate materials such as wood or metal. Using a screwdriver to slowly rotate the inclined plane of the screw into a piece of wood takes less effort force that hammering a nail of the same size! However, again the distance that the screw is rotated is much longer that the hammered nail.

Figure 6.17 Screws and bolts are a special type of inclined plane.

Did you know? 6.3

Archimedes' screw

Archimedes was an ancient Greek scientist who invented a simple machine that could carry water up from a river using a screw shape. The Archimedes' screw is essentially a long inclined plane, and a depiction from 1815 as well as a modern-day photo is shown in Figure 6.18. The Archimedes' screw is still used today to move water to higher levels after being invented over 2000 years ago!

Figure 6.18 Left: Archimedes' screw illustration from 1815. Right: A modern-day Archimedes' screw.

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Wedges

A wedge is a portable inclined plane that can be used to split, lift or hold an object. When splitting an object, the wedge contains two inclined planes that multiply the effort force. In Figure 6.19, the blue force arrows show that the direction of the force is also changed perpendicular to the inclined plane face. Wedges can be used to split firewood (Figure 6.19).

Wedges can also be used to lift heavy objects off the ground by hammering the wedge underneath the object. The wedge acts as an inclined plane, lifting the load force over the distance of the wedge. For very heavy objects, the wedge will be made very thin and long to increase the distance and increase the mechanical advantage.

Other examples of wedges are axe heads, doorstops and the pointed ends of nails and pins.

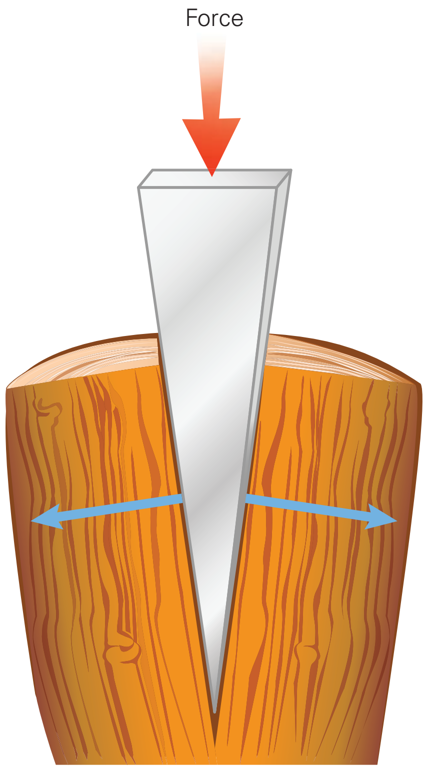

Figure 6.19 A wedge used to split a block of wood. It has been placed with the sharp edge on the end of the block, parallel to the wood grain (its natural layers). It is then tapped with a hammer, driving it into and splitting the wood.

Quick check 6.2

1 Recall three real-world examples of inclined planes.
2 Explain the effect of an inclined plane on the effort force required to complete a task.
3 Explain how inclined planes are used to enable vehicles to drive up mountains.
4 Describe what happens to the mechanical advantage of a ramp as it becomes less steep.
5 Does the effort force increase or decrease as a ramp becomes less steep?

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QUIZ

Section 6.1 questions

Retrieval

1 **Identify** the missing words in the following sentence: To calculate mechanical advantage of an inclined plane, you must divide ________ by ________.

Comprehension

2 If the mechanical advantage is 3, **calculate** the maximum load force if the effort force is 50 N.

3 If the mechanical advantage is 4, **calculate** the minimum effort force required to lift a load force of 120 N.

4 Most schools and public buildings now have ramps designed for wheelchair access. Use your knowledge of ramps and forces to **explain** why the maximum gradient of those ramps is about 5 degrees.

Analysis

5 **Classify** each of the following as a class 1, class 2 or class 3 lever, and justify your response by describing where the fulcrum, load and effort are located for each one.

a Crowbar

b Wheelbarrow

c See-saw

d Barbecue tongs

e A screwdriver used to open a can

6 **Distinguish** between a class 1, 2 and 3 lever, what they magnify and the trade-offs.

Knowledge utilisation

7 Consider whether the lower beaks of birds are examples of levers. Examine the picture of the laughing kookaburra (*Dacelo novaeguineae*) beak in Figure 6.20 and use your knowledge of simple machines to justify your answer by identifying the load force, effort force and fulcrum. Do you think your jaw is also lever? If so, what class of lever is it?

Figure 6.20 The laughing kookaburra (*Dacelo novaeguineae*) holds a meal in its beak.

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6.2 Simple machines with rotating parts

Learning goals
1. To be able to describe how pulleys are useful.
2. To be able to describe how gears are useful.

DOC WORKSHEET Classifying simple machines

The lever and the inclined plane are simple machines that use stationary parts. In this section, we will explore simple machines with rotating parts such as pulleys and gears.

Pulleys

Pulleys can be used to lift heavy objects by changing the direction of the effort force. When a single fixed pulley is used, a rope attached to the load hangs over a pulley wheel, allowing the effort force to pull down on the rope. A common example is a bucket in a well moving up by pulling down on a rope over a single fixed pulley. This is also the type of machine used to open and close household blinds.

While there is no mechanical advantage to using a single fixed pulley, it does allow the work to be done by pulling down on the rope rather than lifting the object directly.

To decrease the effort force needed to lift an object, more pulley wheels need to be added. The more pulley wheels that are added to a pulley system, the higher the mechanical advantage. If a pulley system has a mechanical advantage of 2, that means that it takes half the effort force to lift an object compared to if a single fixed pulley or no pulley was used. However, the trade-off again is that the rope will have to be pulled twice the distance to lift the load.

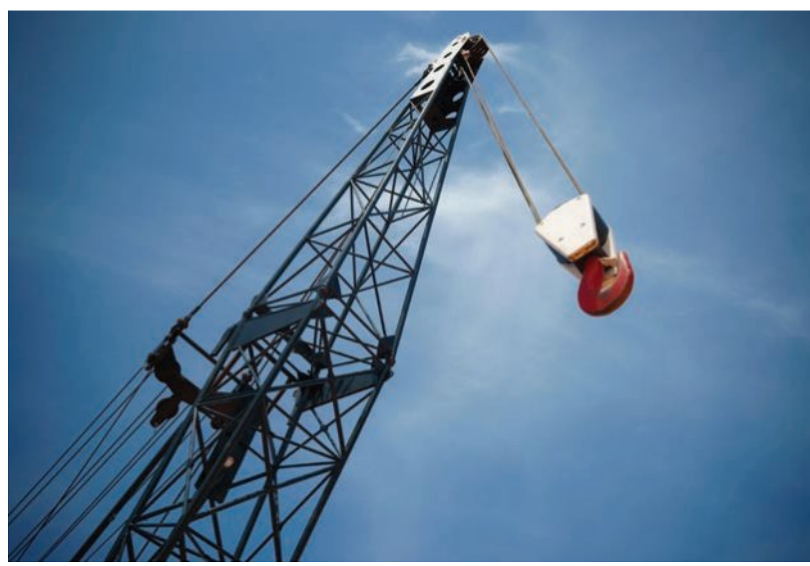

Figure 6.21 A construction crane uses a pulley system to gain a mechanical advantage to lift a load with less effort force.

Practical skills 6.1: Teacher demonstration

Observing the effect on effort force of more pulleys

Aim
To observe the effect on the effort force of adding more pulleys to a pulley system.

Materials
- 2 compound pulleys
- string
- 500 g mass
- ruler
- 500 g spring balance

continued ...

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... continued

Planning

1 You need to provide background information to the investigation. Complete research and write a brief paragraph to explain the key concepts of pulleys. Ensure you reference this appropriately.
2 Create a research question based on information in the aim.

Method

1 Set up the four pulley systems as shown in Figure 6.22 or by the teacher.
2 Draw up a results table in your science book and label it appropriately.
3 Hook a 500 g mass to the load part of the pulley.
4 Attach the spring balance to the effort part of the pulley.
5 Observe the amount of force required to lift the mass at a constant rate by pulling on the spring balance. Record.

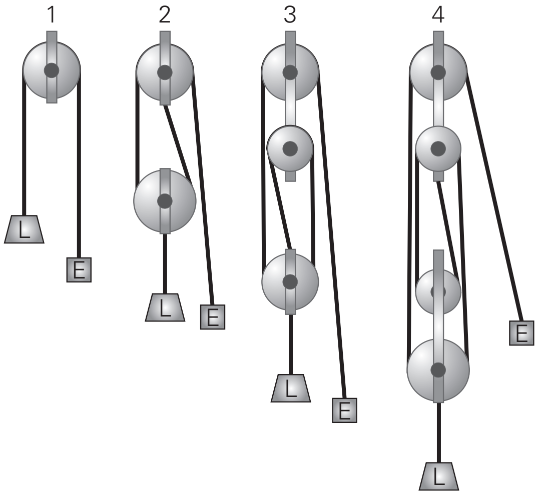

Figure 6.22 L represents the load force (the weight of the mass attached) and E represents the effort force required to lift the mass.

Results

	Dependent variable	
Independent variable	**Load**	**Effort**
Set-up 1		
Set-up 2		
Set-up 3		
Set-up 4		

Discussion

Identify any patterns, trends or relationships in the results.

Conclusion

Answer your research question, using evidence to support your statement.

Pulley systems are used on construction cranes to lift heavy construction materials. This type of load would be impossible to lift by humans without a simple machine.

Extension

The mechanical advantage of a pulley system can be estimated by the number of strings supporting the load.

mechanical advantage = number of strings supporting the load

In Figure 6.24, when the effort force rope (blue) is pulled, each of the two load ropes (red) is shortened. As there are two load ropes and one effort rope, the mechanical advantage of this system is 2.

In Figure 6.25, when the effort force rope (blue) is pulled, the load ropes (red) are shortened. As there are four load ropes and one effort rope, the mechanical advantage is 4.

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Figure 6.23 A two-pulley system

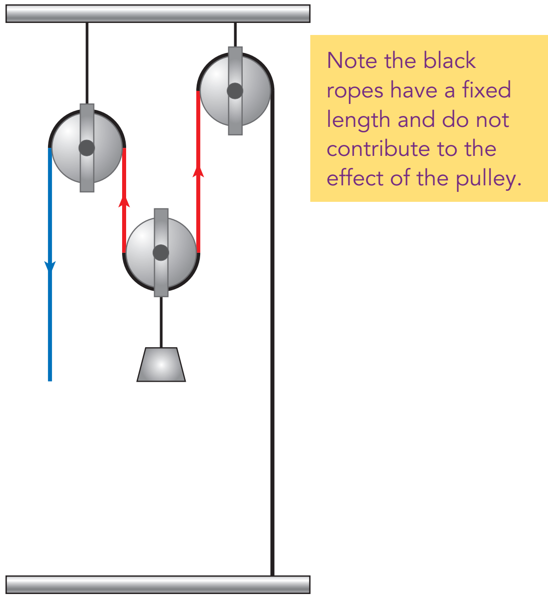

Figure 6.24 A pulley system with a mechanical advantage of 2

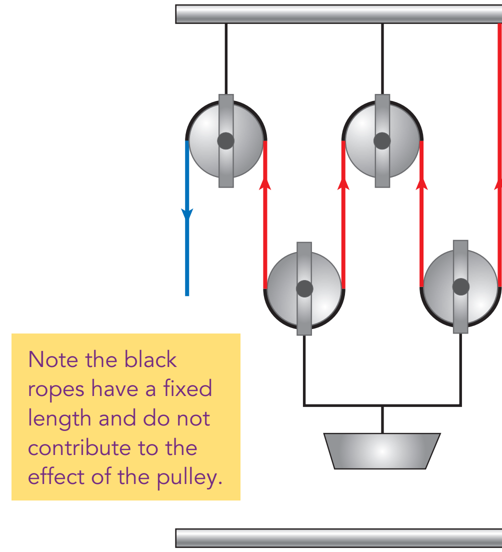

Figure 6.25 A pulley system with a mechanical advantage of 4

Quick check 6.3

1 Identify the mechanical advantage of the pulley system shown.

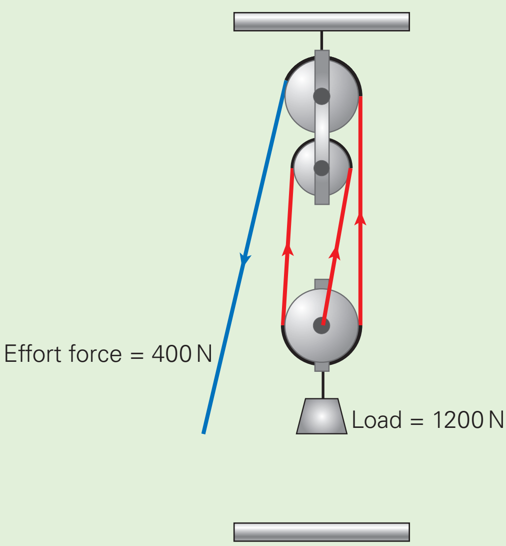

Figure 6.26 A pulley system

2 Calculate the maximum load that could be lifted if an effort force of 40 N was applied to the system in Question **1**.

3 Explain why, in practice, the actual load that can be lifted may be less than the value calculated in Question **2**.

Gears

Another type of simple machine is a special type of wheel called a **gear** or cogwheel. They are essentially wheels with **cogs** (teeth) that transfer force from one wheel to another. Gears are used in bikes and clocks. In a bike, the gears are connected by a chain, whereas in a clock they are called 'meshed' gears because the teeth fit into each other.

gear
a device consisting of connecting sets of wheels with teeth

cog
one of the tooth-like parts around the edge of a wheel

driving gear
the gear connected to the source of the force

driven gear
the gear that rotates due to the rotation of a driving gear

When gears of different sizes can be used, they can be either speed or force multipliers. In a gear system, the **driving gear** (the gear to which the effort is applied) turns the **driven gear**. If the driving gear is the larger of the two, then you have a speed multiplier. This is because for each turn of the large driving gear, the smaller driven gear turns more times. A motor can be attached to the gear to produce a turning force. An old-fashioned egg beater is an example of this sort of gear system in use.

VIDEO
Complex machines

WIDGET
Gear ratios

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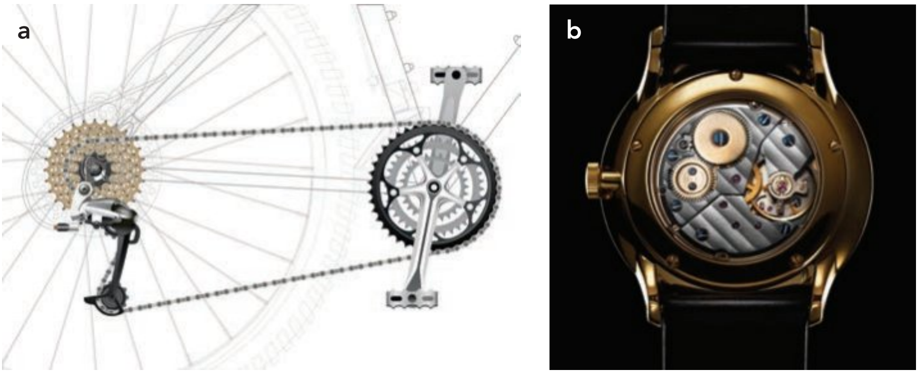

Figure 6.27 (a) Chained gears in a bicycle, **(b)** gears in a wristwatch

Figure 6.28 Every time the larger driving gear turns once, the smaller driven gear turns multiple times, spinning faster.

Figure 6.29 A manual egg beater. The handle turns the large gear, which in turn spins smaller gears that cause the beaters to spin fast.

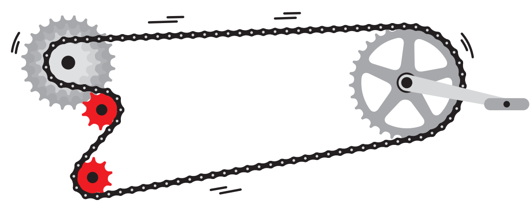

Figure 6.30 By pushing the pedals on a bike, effort force is applied to the larger gear. This transfers a load force to the smaller gear connected by a chain. Selecting a smaller gearwheel allows a cyclist to ride faster, whereas by choosing a larger gearwheel the cyclist moves slower but can climb hills.

In this case, when the larger gear is turned using the handle, the beaters spin faster than the handle is turned.

The other type of gear system is a force multiplier, where the smaller gear is the driving gear. For every turn of the driving gear, the driven gear does not turn as many times, so it turns more slowly, but it turns with more force. This sort of arrangement provides a mechanical advantage and is found on mountain bikes.

Try this 6.2

You will need a hand beater.

1. Count how many small gears and large gears are present in your simple machine.
2. Either measure the diameter of each gear or count the number of teeth.
3. Use the handle to operate your beater. Draw a diagram of the gear set-up to show how the machine works. Be sure to label the driving gear and driven gear.
4. For every full rotation of the driving gear, how many times does the driven gear turn?
5. Explain whether this is a speed or force multiplier.
6. How could you make the machine turn faster? How could you make your machine turn with more force?

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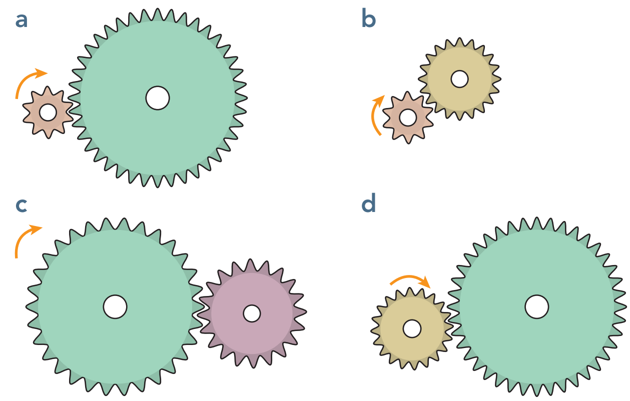
Section 6.2 questions

Retrieval

1 **List** some everyday objects that use gears.

Comprehension

2 **Illustrate** the gear set-up most commonly used in bikes.
3 **Explain** the difference between a speed multiplier and a force multiplier for gears.
4 **Describe** when you would use a speed multiplier and when you would use a force multiplier.
5 **State** whether the gears shown at right are speed or force multipliers. The arrows indicate the driving gear.



Analysis

6 An experiment was done with the pulley system shown in Figure 6.31 and the results are shown in the table. Use the formula given to complete the table and hence **calculate** the average mechanical advantage to 2 decimal places.

$$\text{mechanical advantage} = \frac{\text{load force}}{\text{effort force}}$$

Load (N)	Effort (N)	Mechanical advantage
88	30	
121	40	
147	50	
185	60	
Average		

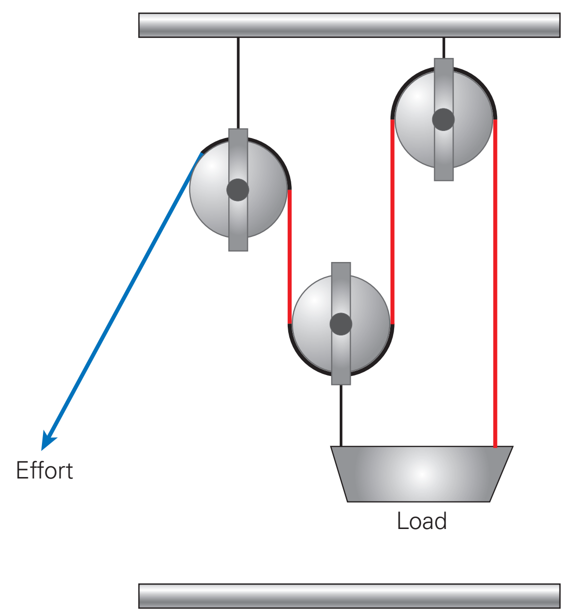


Figure 6.31 A load system

7 **Analyse** the bike gear system in Figure 6.32. Explain why a bike might have a number of different-sized driven gears.
8 **Contrast** a force multiplier and a speed multiplier.

Knowledge utilisation

9 A gear system has a driving gear with 30 teeth and a choice of driven gear with 10, 15, 30, 45 and 50 teeth. If the driving gear spins once per second, **discuss**: how many times would each of the driven gears turn per second?

Figure 6.32 Bike gear system

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Chapter review

Chapter checklist

You can download this checklist from the Interactive Textbook to complete it.

Success criteria		Linked questions	Check
6.1	I can recall some types of simple machines and what they are used for.	3, 8	
6.1	I can describe 'mechanical advantage'.	5	
6.1	I can identify class 1, class 2 and class 3 levers.	1, 7	
6.2	I can describe how pulleys are useful.	4	
6.2	I can describe how gears are useful.	2	
6.1	I can explain the types of simple machines used in First Nations Australians' spear throwers.	9	

Review questions

SCORCHER

Retrieval

1 **Recall** the different classes of lever.

2 **Describe** the two different types of gears in a gear system: driving gear and driven gear.

3 **Explain** how simple machines allow us to do something that would otherwise be difficult.

Comprehension

4 A pulley system has a mechanical advantage of 4 but is less than 100% efficient. If an effort force of 80 N was applied, **explain** whether the maximum load that could be lifted would be less than 320 N or more than 320 N.

5 Extension: The mechanical advantage of a lever is given by:

$$\text{mechanical advantage} = \frac{\text{load}}{\text{effort}} = \frac{\text{fulcrum to effort distance}}{\text{fulcrum to load distance}}$$

Use the formula to analyse the lever in Figure 6.33 and **calculate** the maximum load that can be moved with this lever.

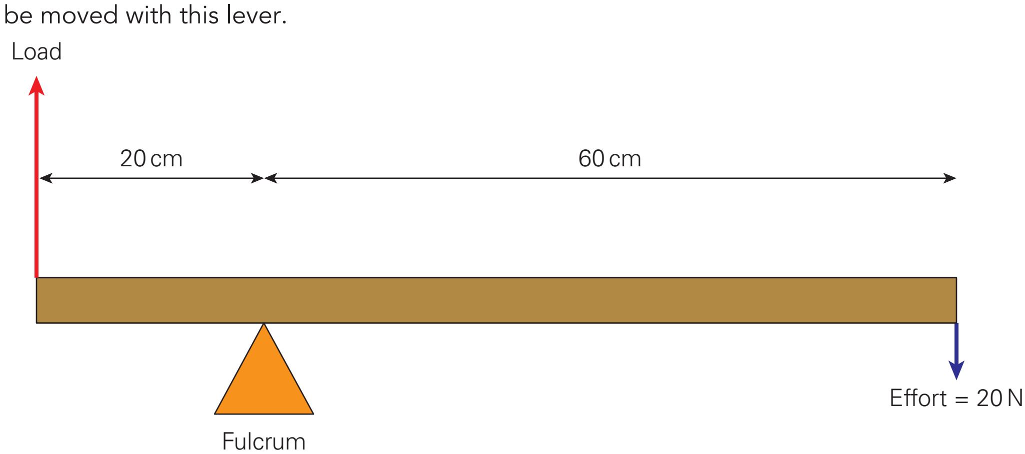

Figure 6.33

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6 Extension: Analyse the pulley system in Figure 6.34 and state the mechanical advantage. Use your result to **calculate** the maximum load that can be lifted by an effort force of 80 N.

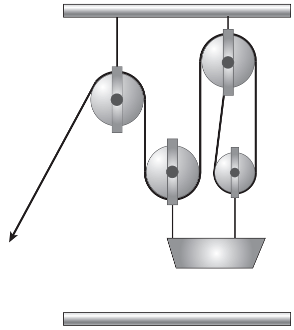

Figure 6.34 A pulley system

Analysis

7 **Analyse** the following and **classify** the objects as either class 1, 2 or 3 levers.

a Screwdriver opening a lid of paint

b Fishing rod

c Scissors

d Wheelbarrow

e Claw hammer

f Nutcracker

g Pliers

h Crowbar

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i Barbecue tongs

j See-saw

k Broom

Knowledge utilisation

8 You have the choice of a ramp that is 6 m high and 10 m long, or a ramp that is 6 m high but is 20 m long. **Explore** the advantages and disadvantages of each situation.

9 **Explain**, with the aid of a diagram, how a spear-thrower is a type of simple machine used by First Nations Australians.

Data questions

The ancient Greek engineer, Archimedes, said, 'Give me a lever long enough and a fulcrum on which to place it, and I shall move the world.' In this activity you will analyse the results of the experiments by a group of Year 7 students. They designed systems to lift a 10 kg bucket of water using a series of pulleys (Table 6.1) and also using a 2-metre class 1 lever with the bucket at one end, the effort force at the other end and the fulcrum moved to different distances from the bucket (Table 6.2).

Number of pulleys	Effort (N)
1	100
2	50
3	33
4	25
5	20
6	17

Table 6.1 Effort force (N) for lifting a 10 kg bucket of water with respect to a number of pulleys used

Distance of bucket from fulcrum (m)	Mechanical advantage
0.4	4.0
0.8	1.5
1.0	1.0
1.2	0.7
1.6	0.3

Table 6.2 Mechanical advantage for lifting a 10 L bucket of water using a 2-metre class 1 lever with the load (bucket) a varying distance from the fulcrum

Apply

1 **Identify** the number of pulleys in Table 6.1 that requires the least effort force to lift a 10 kg bucket of water.
2 **Calculate** the mechanical advantage for using a pulley system with five pulleys.
3 Use the data from Table 6.2 to **determine** which of the distances investigated would require the least effort force to lift the 10 kg bucket.

Analyse

4 **Identify** the trend in Table 6.2 between the distance of the bucket from the fulcrum and the mechanical advantage.
5 Use the data in Table 6.1 to **identify** the relationship between the number of pulleys used and the mechanical advantage.

Interpret

6 **Deduce** how the students could gain a greater mechanical advantage using the class 1 lever.
7 **Compare** the mechanical advantage of a five-pulley system to that using a 2-metre class 1 lever with the bucket 40 cm from the fulcrum, and describe which simple machine would use less effort force.
8 **Examine** the data presented in Table 6.1 to predict the effort force (N) used in a 10-pulley system.
9 **Predict** whether mechanical advantage would increase or decrease in Table 6.2 if a 4-metre lever was used instead.

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STEM activity: The mechanical arm prototype

Background information

Machines have helped humans use force in efficient ways for centuries. Whether it be the invention of the wheel or even the modern-day car, machines are capable of reducing the effort required for us to do work in everyday life. An extreme example of a helpful machine is the tower crane (Figure 6.35). This machine is generally able to move up to 20 tonnes of mass all day long, which is impossible for a human being!

Simple machines such as levers and pulleys spread the required force over a longer distance. Therefore, the effort force is reduced. When two or more simple machines are combined into one machine, a complex machine is formed.

Figure 6.35 A crane is a complex machine using pulleys and levers to move large masses in construction of high-rise buildings.

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Design brief: Design and build a mechanical arm that can lift and move the greatest weight

Activity instructions

Your team of engineers has been assigned a task to construct a complex machine that involves at least two simple machines to lift a load a distance of at least 30 cm vertically and move it a distance of at least 30 cm horizontally. You will provide the force to move the machine and to lift and move the load. The machine must stay in one place while its arm moves around and hooks the load.

Your team of engineers should first explore various types of mechanical arms that could be used without a motor. Once the design prototype is agreed upon in your team, draw the design and start construction using materials provided by your teacher. Record the effort force required to move different load masses.

Suggested materials

- four weights – 50 g, 100 g, 250 g, 500 g
- pulleys
- ruler and tape measure
- scissors
- cardboard
- string
- straws
- icy-pole sticks
- sticky tape
- wire

Research and feasibility

1 Research and list all the ways that mechanical arms are useful.

2 List the construction materials and the components used in cranes. Record the explanation for each. A table has been constructed as an example.

Materials	Components	Explanation
Steel lattice	Mast – upright steel lattice structure	The mast uses triangular steel structures bolted to each other.

3 Explain which simple machine types are involved in a crane and how they contribute to the motion of the arm.

Design

4 List the materials you have available for construction and how they would be useful.

5 Design a mechanical arm that you could build using your available materials. Ensure you have included in your design the capacity to move a load 30 cm both vertically and horizontally.

6 Label the design and include measurements for construction.

Construction

7 Build your mechanical arm. At several points during the construction process, check that the structure continues to meet the design constraints. You may wish to test the mechanical arm's strength and ability to lift the load during construction in case you need to make refinements.

Evaluate and modify

8 Discuss the challenges that you have encountered throughout this activity. List the strategies or actions that enabled you to overcome each one.

9 Propose ways that your prototype could be improved if you had more time and resources available.

10 Predict what would happen if the prototype was used on a heavier load and test if possible.

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Chapter 7
States of matter

Chapter introduction

Welcome to the world of matter. Particles make up matter and matter makes up everything in the universe! In this chapter you will be introduced to three states of matter: solid, liquids and gases. You will then explore their physical properties and the changes of state that occur between them.

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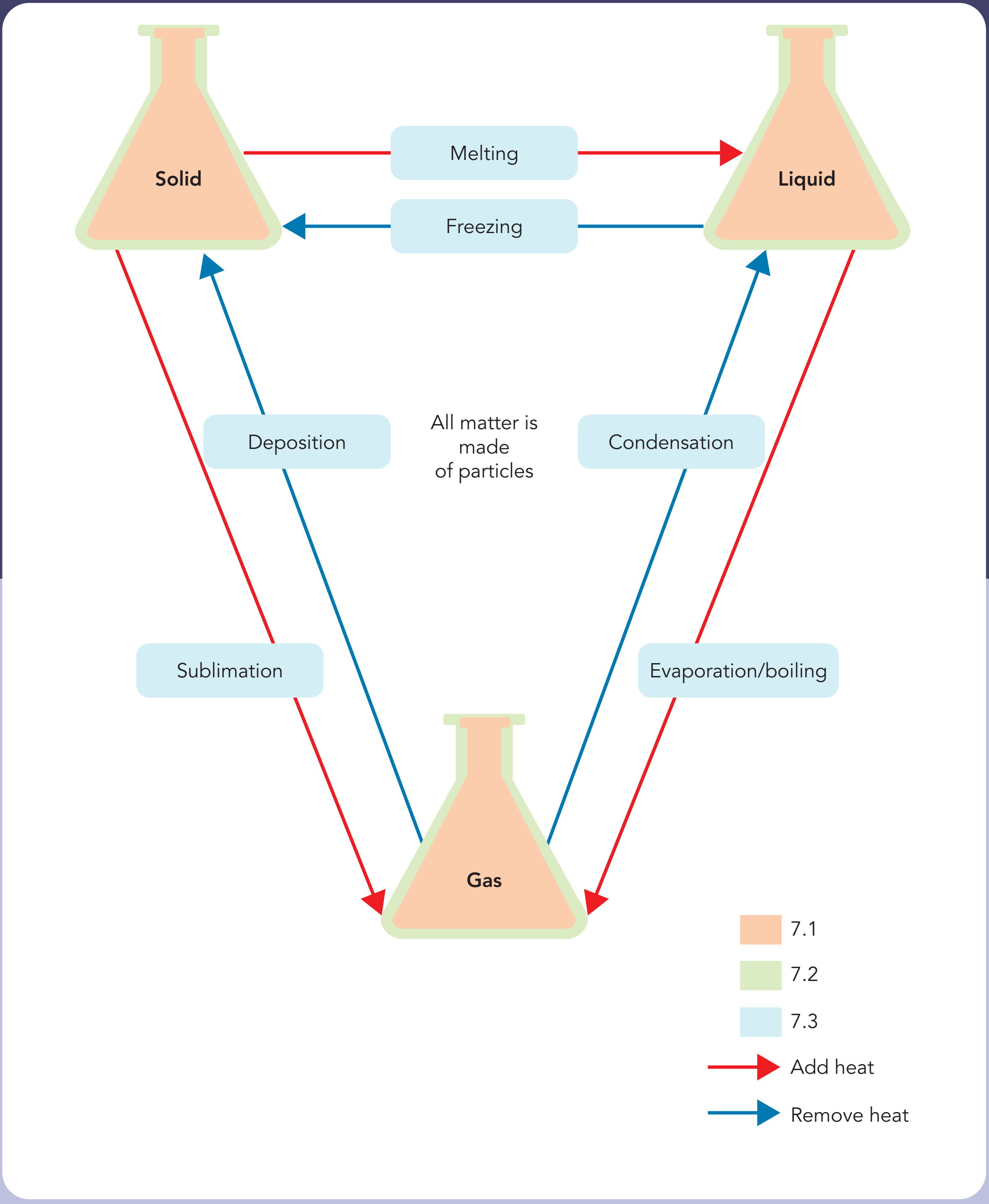
Concept map



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Curriculum

Use particle theory to describe the arrangement of particles in a substance, including the motion of and attraction between particles, and relate this to the properties of the substance (AC9S7U05)	
using and constructing models, diagrams or virtual simulations to represent changes in particle arrangement as substances change state	7.1
relating motion and energy of particles to distances between particles of the same substance in different states	7.1, 7.2
comparing attractive forces in the solid, liquid and gaseous states of the same substance and relating this to relative position and movement of particles	7.1
examining how the changing motion and energy of particles is affected by the amount of heat energy absorbed or released	7.1
comparing the properties of different states of matter and explaining differences using particle theory	7.2, 7.3
investigating properties of materials such as density, melting point and compressibility and explaining these in terms of particle arrangements	7.2, 7.3
explaining the process of diffusion in a liquid and a gas in terms of particles	7.1

Glossary terms

Boiling
Boiling point
Brownian motion
Chemical property
Compress
Concentration
Condensation
Contraction
Density
Deposition
Diffusion
Evaporation
Expansion
Freezing
Gas
Liquid
Mass
Matter
Melting
Melting point
Particle model
Physical property
Pressure
Radiation
Solid
State
Sublimation
Vibrate
Volume

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7.1 Particle model and states of matter

Learning goals

1. To be able to describe the particle model of matter.
2. To be able to distinguish between solids, liquids and gases.
3. To be able to describe the contraction and expansion of substances in response to heat.
4. To be able to define 'diffusion.'

WORKSHEET
Gas pressure

Everything in the universe is made up of matter, whether it be a desk, the ocean, a meteorite or the air you breathe. **Matter** is anything that takes up space and has **mass** and **volume**. Mass is the amount of matter in a substance or object, and volume is the amount of space the substance or object takes up. On Earth, the most common **states** of matter that exist are **solids**, **liquids** and **gases** (see Did you know? 7.1 for an example of another). Figure 7.1 shows a range of examples of matter. Use your current knowledge of the world around you to identify which are the solids, liquids and gases. What is similar and what is different between the three states of matter?

matter
anything that has mass and volume

mass
the amount of substance in an object that never changes, even in space

volume
the space an object occupies

state
a distinct form matter can exist in

solid
a substance that has a fixed shape and constant volume

liquid
a substance that flows freely and takes the shape of its container but has constant volume

gas
a substance that expands freely to fill space

Figure 7.1 States of matter: solids, liquids and gases. What are the similarities and differences between the three states of matter illustrated above?

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Did you know? 7.1

Plasma, a fourth state of matter?

Solids, liquid and gases are the three states of matter that make up almost all matter that you will find on Earth. However, there are rare examples of other states of matter that exist, particularly throughout the universe in stars such as the Sun.

Plasma is a fourth state of matter that can be created on Earth in high-energy circumstances such as lightning strikes. The high amount of energy can create a build-up of particles with a charge which behave differently to a solid, liquid or gas.

It can even be created inside a microwave using a grape, which has been filmed by many YouTubers in recent years. A team of scientists published a study of what makes grapes produce plasma in the microwave in 2019 but they did the experiment in very safe conditions.

Figure 7.2 Plasma, a fourth state of matter, produced from grapes

The particle model

A philospher in ancient Greece named Democritus wondered what would happen if an object was split repeatedly until it could not be split any further. His idea was that all matter was made up of tiny indivisible particles. And thus the **particle model** was born.

particle model
all matter is made of particles that behave differently depending on whether they are solid, liquid or gas

In science, models are used to represent different aspects of real-world objects (like models of trains and cars) and phenomena (like Earth orbiting the Sun). Sometimes though, scientists make models to test out ideas, or to represent what they cannot see to try to explain how it might work. This is the case with the particle model.

Figure 7.3 A model solar system represents the orbit of planets around the Sun, which we cannot see visually ourselves.

So, to better understand what makes up all solids, liquids and gases, we can start by looking at the particle model. This model suggests that all matter is made up of extremely small spherical particles that are invisible to the naked eye. These particles are not only different sizes in different substances, but are also arranged differently in solids, liquids and gases. The closer the particles are to one another, the stronger the attraction between them. This helps us to understand why each state of matter has different properties.

The particles that make up matter are always moving because of their energy. The more energy a particle has the faster it will move. Adding heat can also increase the energy of particles and therefore make them move faster. Particles will always have some energy and so will always move, even if it is just a little bit. In

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solids, the particles **vibrate** in fixed positions, but in liquids and gases, the way particles move is in random straight lines. This type of movement is called **Brownian motion** after the scientist who first observed it, Robert Brown, in 1827.

Brownian motion
the random movement of particles in fluids

vibrate
periodic motion of particles

Explore! 7.1

Brownian motion

Robert Brown and Albert Einstein both contributed to the understanding of Brownian motion. Research the following questions using the internet:

1 Explain how Robert Brown first observed particles moving in random straight line motion.
2 Describe Albert Einstein's contribution to knowledge about Brownian motion.

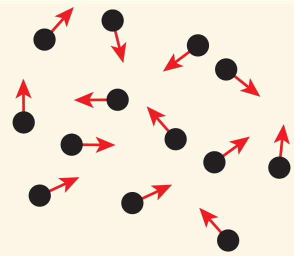

Figure 7.4 A representation of particles moving in random straight lines

Quick check 7.1

1 Define 'matter'.
2 State the three common states of matter.
3 Summarise the key points of the particle model by completing the following sentences.
 a All matter is made up of __________.
 b Particles are __________ moving.
 c Particles move faster if the substance is __________.

Practical skills 7.1

States of chocolate

Aim

To demonstrate the three states of chocolate.

Materials

- chocolate buttons
- small beaker
- large beaker
- boiling water

Method

Heat the chocolate in a small beaker surrounded by boiling water in a large beaker.

Evaluation

1 After a few minutes, some of the chocolate will be partially melted. How many states of matter can you see?
2 What do you think is happening to the particles as they are heated up?
3 How does particle theory help explain your observations about the properties of the chocolate before and after melting?

Be careful

Do not consume chocolate in a laboratory classroom.

Figure 7.5 Chocolate in the solid and liquid states

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Solids

In a solid, the particles are packed tightly together. Due to their close proximity, the forces of attraction between particles are very strong. Because of this, the particles in solids cannot move freely; instead, they vibrate in their places.

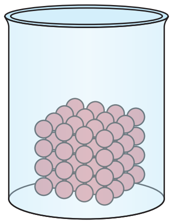

Figure 7.6 Diagram showing the arrangement of particles in a solid. Particles in a solid are very closely packed together and just vibrate in their places.

Liquids

In liquids, particles are held together by forces of attraction, but these are weaker than the attractions in a solid. So, particles in a liquid are not vibrating in fixed positions, but instead 'slide' over each other in free movements, often described as 'flowing'.

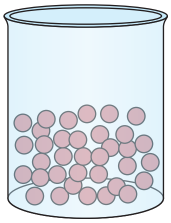

Figure 7.7 Diagram showing the arrangement of particles in a liquid. Particles in a liquid are packed closely together but can still move about and slide over one another. Gravity pulls the liquid into the shape of the container.

VIDEO Animation of water particles

Did you know? 7.2

Non-Newtonian toothpaste

Sir Isaac Newton was a mathematician and physicist born in 1643. He described the behaviour of fluids as having constant viscosity, which means a constant resistance to flow unless temperature or pressure changed. For example, if you were to stir a cup of water, its viscosity would stay the same with each stir. Most fluids behave in this way and they are called Newtonian fluids after Newton's observations.

However, not all fluids behave in a Newtonian way. Toothpaste is a fluid that flows out of its container with a small amount of force. But what happens when a large force is applied to the toothpaste against your teeth? The behaviour of toothpaste changes; it becomes less viscous and it flows much more easily.

Toothpaste is an example of a non-Newtonian fluid that changes its viscosity when a force is applied.

The behaviour of non-Newtonian fluids can be described by particle theory just as Newtonian fluids can be. In this case, the force moves the particles further away from each other.

Figure 7.8 Toothpaste is a non-Newtonian fluid. Left: solid toothpaste on a toothbrush. Right: liquid toothpaste after brushing.

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Gases

The particles in a gas are in constant Brownian motion as they have much more energy than those in solids or liquids. The attraction between the particles in a gas is weak because the particles are so far apart, so the particles spread out to take up any space that is available.

When a gas is added to a space, the particles will quickly move to spread evenly and throughout the entire space. This process of the movement of particles from an area of high **concentration** of particles to low concentration of particles is called **diffusion**.

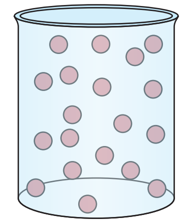

Figure 7.9 Diagram showing the arrangement of particles in a gas. Gas particles are always moving and spread out to fill any space they are in.

concentration
the number of particles present in a given volume

diffusion
the movement of particles from an area of high concentration of particles to low concentration of particles

Try this 7.1

Role playing states of matter

Working with your classmates, role play what a solid, liquid and gas look like. Make sure you can explain what the particles are doing in each state of matter.

Quick check 7.2

Copy and complete the following table.

State of matter	Describe and explain the strength of attraction between particles	Describe and explain the movement of particles	Diagram of particle arrangement
Solid			
Liquid			
Gas			

Try this 7.2

Balloon pressure

Blow up a balloon slowly until it is about half full with air. Inside the balloon there are gas particles moving in straight random lines. Sometimes those particles collide with each other and sometimes they collide with the walls of the balloon. Each collision with the wall of the balloon exerts a force, which we call pressure. The more gas particles in the balloon, the more force on the walls and the more pressure. If there is too much pressure the balloon will pop. What happens when you let go of the inflated balloon? Try to use the words 'gas particles' and **pressure** in your explanation.

pressure
the amount of force exerted on a given area

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Practical skills 7.2: Self-design

Diffusion

Be careful

Make sure that no one suffers from any respiratory issues before using the aerosol deodorant/perfume.

Aim

Firstly, to investigate diffusion, the movement of liquid and gas particles as they spread out in another liquid or gas. Then, to design an investigation into how quickly particles can diffuse through water at different temperatures.

Materials

- aerosol deodorant/perfume
- food colouring
- eye dropper
- 4 × 250 mL beakers
- iced water, cold tap water and hot tap water
- thermometer
- stopwatch

Method

1. Spray some aerosol deodorant/perfume in one corner of the room. Move to the opposite corner of the room and record the time it takes for the scent to reach you.
2. Put one drop of food colouring into a beaker of tap water. Observe how the colour spreads and record the time it takes for the colour to spread evenly in the water.
3. Design an experiment to determine if the diffusion of food colouring occurs faster in warm or cold water. In science experiments, every variable is kept the same except for the one being investigated. What are the dependent, independent and controlled variables in this experiment? Consider what you will need to record and how you can do it.
4. Write a hypothesis about what you think might happen.
5. After checking your design with your teacher, carry out your experiment and record your results.

Results

1. Draw a diagram showing how the deodorant/perfume particles moved through the air.
2. Draw a diagram showing how the food colouring particles moved through the water.
3. Draw up a table that summarises your results from your self-designed experiment.

Analysis

1. How does particle theory explain the observations of spreading that were made about the deodorant and food colouring in this experiment? Use the terms you have learned in class about the particle model and diffusion.
2. Explain why changing the temperature affected how fast diffusion occurred.
3. Many industries use diffusion to dispose of their waste products either as gases into the air or as liquids into rivers and the sea. Explain whether you think this is a suitable method in the long term.

Evaluation

Identify any sources of error and how you might prevent these from occurring again.

Conclusion

Draw a conclusion from this experiment on diffusion, supporting your statement with data.

Did you know? 7.3

Microwave ovens

Microwave ovens heat your food by using **radiation**. Radiation is energy in the form of light or heat. In a microwave oven, the radiation released is light called 'microwaves'. The microwaves are absorbed by the water in food and cause those particles to vibrate with higher energy and so they have more heat. This heat cooks the food by heating the surrounding particles.

radiation the emission of energy in the form of light or heat

Figure 7.10 Microwave ovens work by causing the water particles in food to vibrate and heat up.

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Heating and cooling

The particle model suggests that if a substance is heated, the particles will gain more energy and so they will begin to move more rapidly. As the particles start to move more rapidly, the distance between the particles increases and they begin to take up more space. As the particles are further apart, the attraction between the particles decreases. This process of getting larger is called **expansion**. When heat is applied, gases can usually expand more than solids and liquids because the particles are not held together by strong attractive forces and so are free to spread out.

When a substance is cooled, the particles lose energy, their movements slow down, and the distances between the particles gets smaller. As the particles are closer, they become more strongly attracted to one another, except in a gas, in which they are still relatively far apart. This process of the material (and not the particles) getting smaller is called **contraction**.

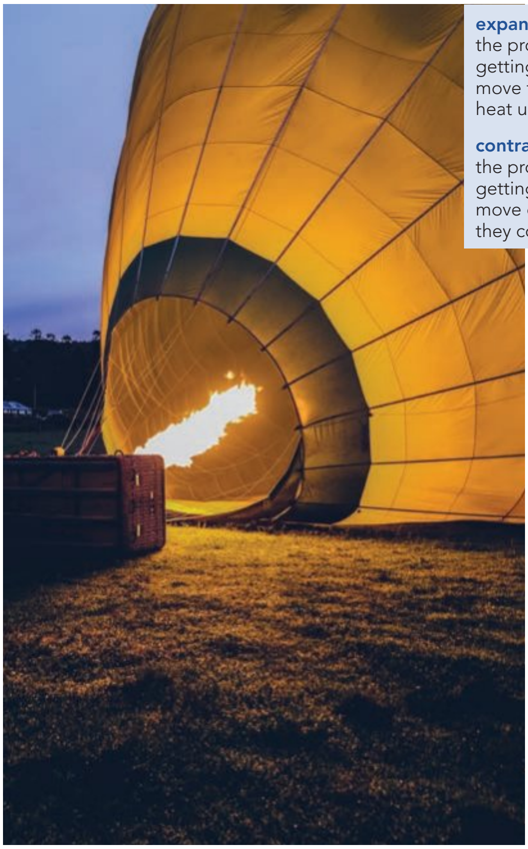

Figure 7.11 In a hot air balloon, the heated air expands and becomes lighter than the air outside the balloon, so the balloon rises.

expansion
the process of substances getting larger: particles move further apart as they heat up

contraction
the process of substances getting smaller: particles move closer together as they cool

Try this 7.3

How does the volume of a balloon change as it is heated and cooled?
Blow up a balloon to a size that will fit inside your fridge or freezer and tie a knot to close it. The research question that you will investigate here is how the size of a balloon will change when heated and cooled. Take a tape measure and measure around the widest part of the balloon.

Place the balloon in the fridge or freezer for 10 minutes. Retrieve the balloon and measure as you did previously. What was the result? Can you describe the result using the particle model?

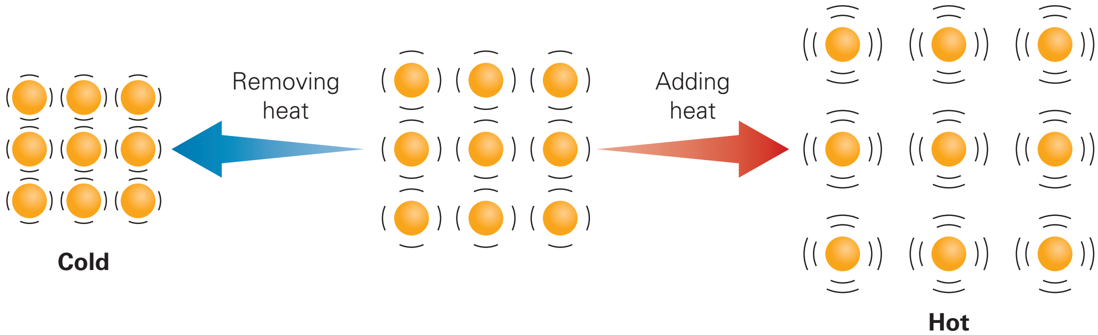

Figure 7.12 Diagram showing the changes in movement experienced by particles with heating and cooling

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Science as a human endeavour 7.1

Graphene

Graphene – a two-dimensional arrangement of the particle carbon – was discovered in 2004. It has the physical properties of being extremely strong and an excellent conductor of electricity. Since then, scientists found a way to turn this amazing material into three-dimensional structures. This may not seem very exciting, but these 3D structures are 10 times stronger than steel yet only 5% as dense! The breakthrough material can therefore help reduce the amount of steel used for infrastructure, but also excites scientists because of its applications in space programs.

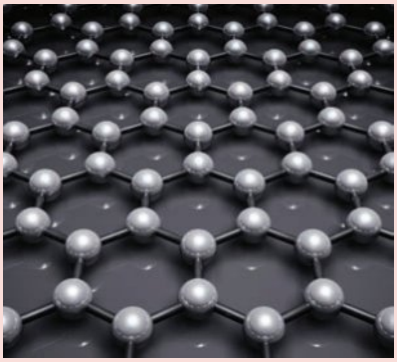

Figure 7.13 Model of the hexagonal lattice of a graphene layer

Explore! 7.2

Skyscrapers

Modern skyscrapers are built using a variety of materials, but metal and concrete continue to be very common when constructing the foundations of towers. Particles in these materials will expand and contract with the changing temperature of the surroundings. Engineers must consider the expansion and contraction of materials in their design and construction of towers.

1 Explain what is done to allow for the expansion and contraction of materials in skyscrapers.
2 Discuss why it is important for engineers to carefully select the materials they choose for building skyscrapers.

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Quick check 7.3

1 Compare the distances between particles in a gas, a liquid and a solid.
2 Use the particle model to explain what happens when a substance gains heat.
3 The particles of a substance in a sealed container are investigated at two different temperatures.
   - At temperature A, the particles are very close together but move freely at moderate speed in the bottom of the container.
   - At temperature B, the particles are distant from one another and move freely at high speeds in all parts of the container.

   What is the state of the substance at temperature A and at temperature B?

Practical skills 7.3

Expansion and contraction

Aim

To observe and explain the expansion and contraction of solids and gases.

Materials

- ball and ring apparatus
- tongs
- Bunsen burner
- bimetallic strip
- 2 metal bars of same size but different material
- wax candle
- stopwatch
- 1 balloon
- felt-tip pen
- ruler or tape measure
- coin
- bucket of ice water
- bucket of warm water

Figure 7.14 A ball and ring apparatus

Method

1 Examine the ball and ring apparatus. Does the ball fit through the ring when it is cold? What do you predict will happen when you heat the ball? Heat the ball using the Bunsen burner and see if it still fits through the ring. What happens if you heat the ring and not the ball?
2 Look at the bimetallic strip – predict or hypothesise what will happen when you heat it. Now, heat the bimetallic strip. Describe and explain what happens.
3 Attach a coin to one end of the metal bar with the wax from a candle. Hold the metal bar using tongs and heat the other end of the metal bar with a blue Bunsen flame. Time how long it takes before the coin falls off.
4 Hypothesise what might happen if you used another metal bar of the same length and size but made of a different material. Test this hypothesis by repeating step **3** with the new metal bar.
5 Inflate a balloon. Draw two felt-tip pen lines exactly 10 cm apart on the balloon. Place the balloon in the bucket of ice water. What happens to the lines? Place the balloon in the bucket of warm water. What happens to the lines?

Results

Record all observations and descriptions from **each** step of the method.

Analysis

1 Write a sentence explaining your observations from **each** step of the method, referring to the particles, their energy, their movement and the strength of their attraction.
2 Do you think a balloon can be used as a thermometer to measure temperature? Investigate how gas thermometers are made and used by completing some research.

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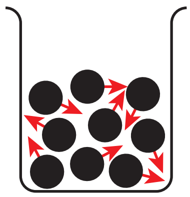
Section 7.1 questions

QUIZ

Retrieval

1 **Recall** four key points of the particle model.
2 **Recall** the state where particles are only able to vibrate in a fixed position.
3 **Identify** which state is shown in the diagram below.



4 **Name** the state that cannot flow from place to place.
5 **Name** the state where particles have the weakest forces of attraction between them.
6 **Define** 'diffusion'.
7 **Recall** the word that describes the change you expect to see when a metal is heated.

Comprehension

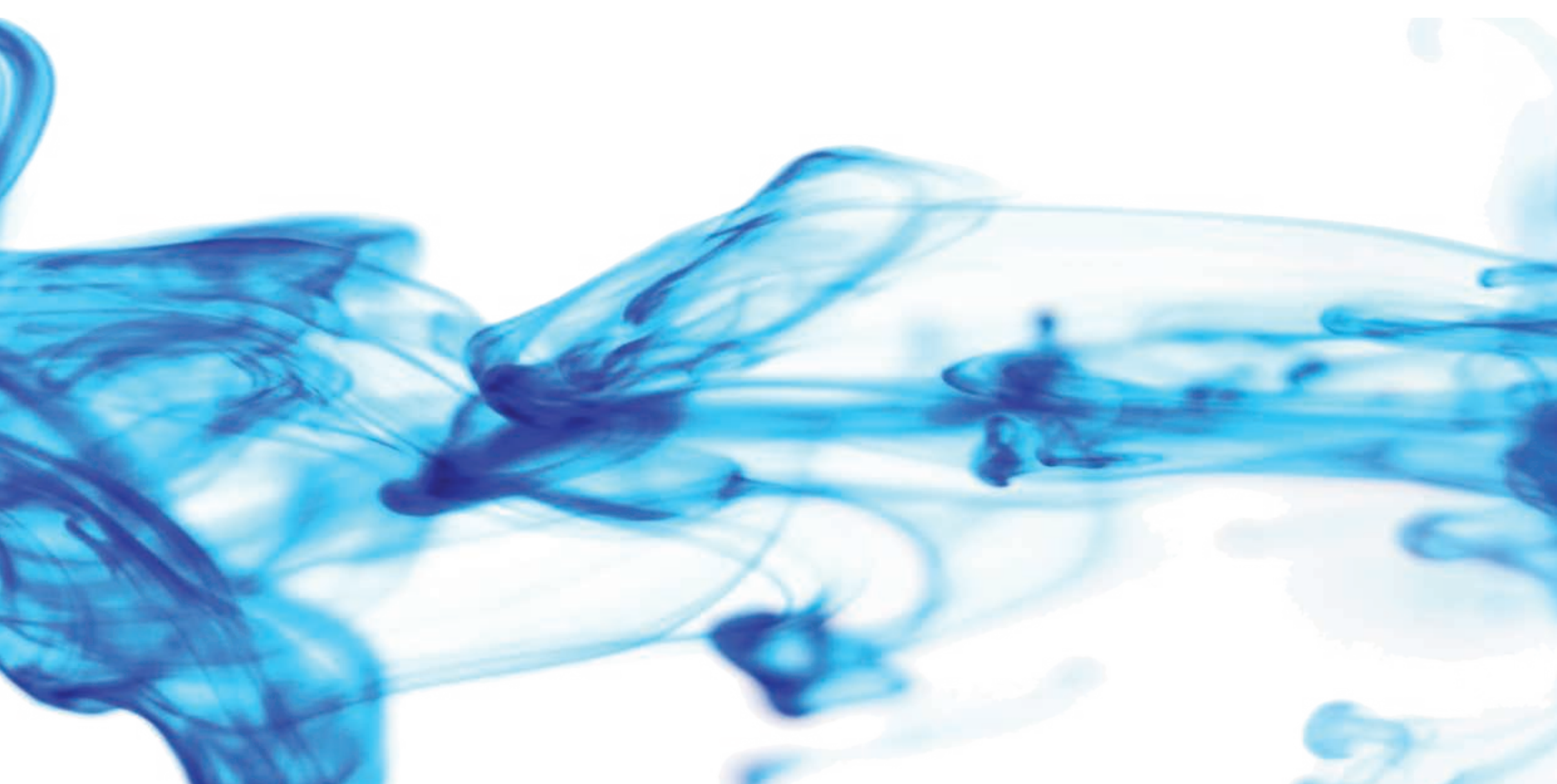
8 **Describe** what happens when you heat up particles.
9 Use the particle model to **explain** why food colouring and water mix together but food colouring and ice do not.

Analysis

10 **Compare** the closeness of the particles and the speed at which they move at different states, and list some examples for each.

Knowledge utilisation

11 **Discuss** how a mercury thermometer can provide a reading of temperature.



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7.2 Properties of solids, liquids and gases

Learning goal
To be able to list the different properties of solids, liquids and gases.

WORKSHEET
Density

When scientists talk about the different states of matter, they refer to two types of properties: **physical properties** and **chemical properties** (Table 7.1).

physical property
the way a substance looks and acts; a characteristic of a substance that can be observed and/or measured without changing it chemically

chemical property
the behaviour of a substance when it reacts with another substance

	Property	
	Physical	**Chemical**
Definition	A characteristic of a substance that can be observed and/or measured without changing it chemically	The behaviour of a substance when it reacts with another substance
Examples	Colour, size, solubility, melting point, hardness, boiling point, conductivity, shape and density	Burns or explodes in oxygen, rusts or corrodes, acidity, biodegradability
Picture		

Table 7.1 The two types of properties investigated when looking at matter

Science as a human endeavour 7.2

Superhydrophobic substances

Superhydrophobic substances have a remarkable ability to repel water. Developed by Australian researchers, they are useful for a number of purposes, such as coating fabrics or car windshields in order to improve driving visibility. They also have the potential to be used to waterproof mobile phones, prevent ice from forming on aircrafts and protect boat hulls from corroding. They are highly antimicrobial, so they could be heavily used in the protection of surgical instruments and medical equipment. Unfortunately, these coatings are very delicate and easily damaged by cleaning or any minor wear, leading to the loss of superhydrophobic properties. However, in 2020, scientists developed a new armour-plated coating that can withstand wear and still repel water effectively.

Figure 7.15 The properties of substances are used by scientists to design new materials with specific purposes.

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While working through the last section, you might have identified a number of the key properties of solids, liquids and gases. Here we will discuss these properties, using the particle model.

density
how much matter (mass) is contained in a certain volume of a substance

compress
squeeze to make smaller

Solids

The particle model describes solid particles being packed very tightly with strong forces of attraction.

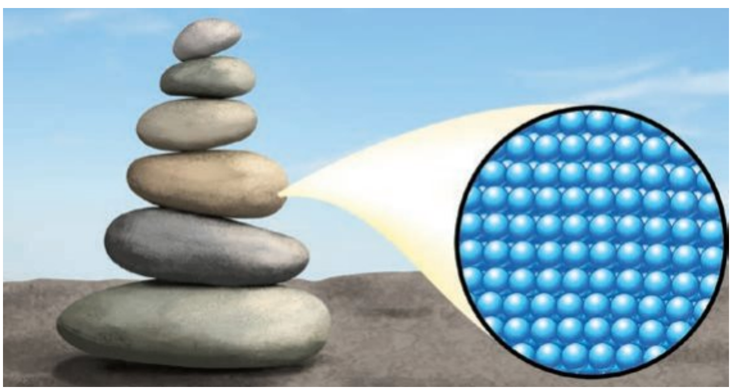

Figure 7.16 Consider these rocks and the arrangement of their particles shown in the diagram. Are their shapes fixed? Can they be compressed or poured?

These particles vibrate in their fixed positions. This is why solids usually have a fixed shape and a volume that cannot be changed. This also explains why solids cannot easily be **compressed** (squashed) or poured.

Density

Table 7.1 mentioned the property of **density**. Density describes how heavy or light something is for its size, but it is not the same as its weight or mass. For example, 1 kg of bricks will always weigh the same as 1 kg of feathers (they are both 1 kg), but the space they take up is very different. Density can be defined as the measurement of how much matter (or mass) fits in a certain amount of space (or volume). So, a denser substance (e.g. a brick) has more mass in a particular volume than a less dense substance (e.g. feathers). The relationship between density, mass and volume is written in this way:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

Practical skills 7.4: Self-design

Calculating density

Aim

To design and conduct an investigation to measure the mass and volume of different objects. Then use this information to calculate the density of the objects and determine whether they would float or sink in water.

Materials

- ruler
- large measuring cylinder
- 8 small random objects

Method

When you design your experiment, consider the following questions.

- What measurements do you need to be able to work out the density of an object?
- How will you measure the mass of the random objects you have access to?
- How will you measure the volume of the random objects you have access to? What will you do with objects of regular and irregular shape?
- How will you record your data? Perhaps a table would help.
- How will you calculate density?
- What is your prediction for the results? Which items do you expect will float and which will sink?

continued …

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… continued

Before beginning, your teacher will show you how to determine volume using the water displacement method. You will then write up your intended method step by step, as though it was going to be published in a textbook. Then check with your teacher that you can begin your investigation.

Results

1 Record your prediction.
2 Write your method step by step.
3 Record your measurements in a table using the headers below:

Object	Mass (g)	Volume (cm^3)	Float or sink?	Density (g/cm^3)

4 Using the equation for density, calculate the density of the objects you had access to.

Analysis

1 The density of water is 1.00 g/mL. If an object has a density of less than 1.00 g/mL, it should float in water. If an object has a density of greater than 1.00 g/mL, then the object should sink when placed in water. Did your results show these statements to be true?
2 Were your predictions correct?

Evaluation

1 Identify the advantages and disadvantages of using the water displacement method for determining volume.
2 Would your results be different if you used a different liquid to water? Explain your reasoning.
3 Were there any steps of the practical that you would do differently if you were to repeat the task? How would you improve the experiment next time?

Making thinking visible 7.1

Compass points: Dangerous science

The scientific knowledge of particles and states of matter has grown over the past 300 years. It has provided a foundation for much of the fantastic chemical technology we have in the modern world, which includes smart phones, solar panels and computers. However, this knowledge has also provided the opportunity for less ethical and even dangerous technology to be advanced as well.

For example, in World War I, knowledge of the compressibility of particles in the gas state for transport gave rise to a boom in poison gas warfare. This is often referred to as 'chemical warfare' and, in 1925, the Geneva Protocol was signed to prohibit the use of poisonous gases in war. In 1993, the Chemical Weapons Convention international arms control treaty was signed to ban the creation of chemical weapons and required their destruction within certain periods of time.

Figure 7.17 Chemical warfare was a dangerous consequence of advances in particle theory.

Complete the Compass points activity about chemical warfare:

1 What **excites** you about future developments in chemical technology?
2 What do you find **worrisome** about future developments in chemical technology?
3 What else do you **need to know** or find out in order to evaluate this idea?
4 What is your current **stance** or proposal on the idea? How can you continue to assess this concept in the future?

The *Compass points* thinking routine was developed by Project Zero, a research centre at the Harvard Graduate School of Education

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Quick check 7.4

1 Copy and complete the table below.

Properties of a solid according to particle model	Behaviour of a solid as a result of property
Packed tightly together	
	Hard to break apart
Particles in solids cannot move freely; they vibrate in one spot, which is called a fixed position.	

2 A substance like sand can be poured and does not have a fixed shape. Explain whether it is a solid.

3 a Explain the relationship between mass and density.

b Explain the relationship between volume and density.

Did you know? 7.4

Meteorite diamonds!

A pure diamond is known as the hardest material on Earth. This is because diamonds are able to scratch all other materials but not be scratched themselves. However, in 1967, a strange new form of diamond was discovered on a meteorite that had hit Earth. It was called lonsdaleite. In 2020, Australian researchers at the Australian National University provided evidence that they had created lonsdaleite at room temperature on Earth as a result of a separate experiment that they were conducting.

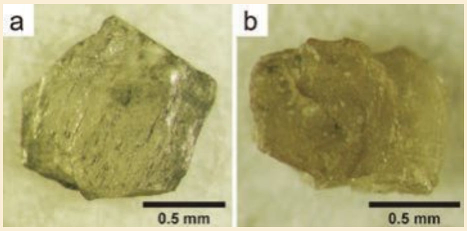

Figure 7.18 (a) A diamond. **(b)** Lonsdaleite is a type of diamond formed when meteorites hit Earth!

In 2021, researchers at Washington State University were able to record the stiffness of pure lonsdaleite, and it was greater than that recorded of pure diamonds! Is lonsdaleite the hardest material in the universe?

Liquids

Liquids are held together by the forces of attraction between particles, but these forces are not as strong as those in solids. The particles of a liquid can move more freely and flow (be poured) and therefore take on the shape of the container they are inside. Because of gravity, a liquid always sits at the bottom of the container. Although their shape can change, liquids have a fixed volume and mass. Like solids, they cannot be compressed into 'much' smaller spaces. The particles can actually be pushed a tiny bit closer together, but it takes a massive effort, and so we generally say that the particles in a liquid are so closely packed that they cannot be compressed.

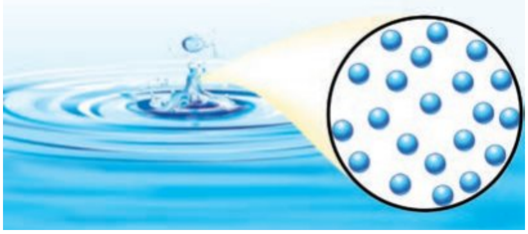

Figure 7.19 Consider the tap water and the arrangement of its particles shown in the diagram. Is its shape fixed? Can it be compressed or poured?

Density is also a physical property of liquids. Unlike solids, the density of liquids changes when heated. The particles of a liquid are able to move more rapidly when heated and thus take up more space. Therefore, the density of a liquid decreases as heat increases. The same occurs in gases, as the particles are moving freely.

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Try this 7.4

Make your own lava lamp!

You will need:

- 1 cup water in a clear glass or container (at least 600 mL capacity)
- 1 cup oil (any type)
- 1 effervescent tablet (e.g. AsproClear tablet)
- Food colouring

Figure 7.20 A lava lamp demonstrates density, one of the physical properties of liquids.

Begin by measuring the mass of the oil and water. Which one is heavier? So, which one is more dense? How can you explain this using the particle model and your understanding of density?

Add a few drops of food colouring to the water and mix to combine. Slowly pour the oil onto the coloured water (note: make sure your water container is big enough to hold both!). Drop an effervescent tablet in and watch what happens!

Think about how an effervescent tablet was used to power your lava lamp. What is used in a real lava lamp? Explain how temperature affects the density of substances.

Gases

The force of attraction between gas particles is weak and therefore the particles freely move to take up as much space as possible. Gas particles have no fixed shape or volume, and can diffuse into new unoccupied spaces. Due to the large spaces between gas particles, there is plenty of space for the particles of a gas to be squashed together or compressed.

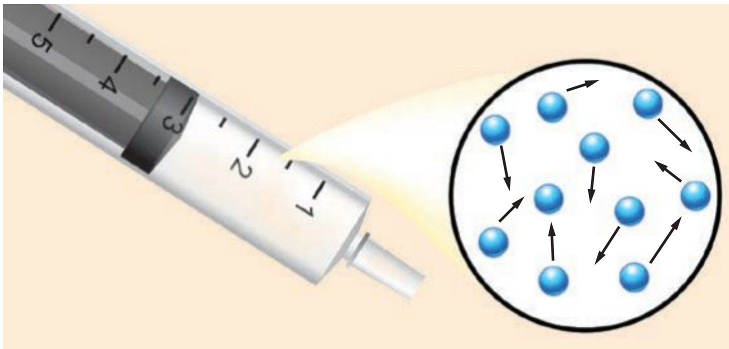

Figure 7.21 Consider the air in the first 3 cm of this syringe and the arrangement of the air particles shown in the diagram. Is its shape fixed? Can it be compressed or poured?

Explore! 7.3

Compressed gas

Gases are compressible due to the large spaces between the particles. This property is important when transporting gases for a variety of uses. For example, deodorant cans and fire extinguishers carry compressed gases in containers that are able to be carried easily and stored safely. Butane gas is carried in a canister and is commonly used as a source of fuel for barbecues or outdoor stoves.

Figure 7.22 Gases can be compressed and stored in canisters.

1 Why is carbon dioxide a good choice for extinguishing fires?
2 Use the particle model to explain why the gases in a can of deodorant can be compressed.
3 Explain why butane in a canister is under a lot of pressure.

VIDEO Aerosol cans and heat packs

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Quick check 7.5

1 Define the terms 'volume' and 'mass'.
2 Contrast the shape and volume of solids, liquids and gases.
3 Copy and complete the following table to describe the particle structure and properties of solids, liquids and gases.

State	Examples	Diagram of particle arrangement	Properties
Solid			
Liquid			
Gas			

Section 7.2 questions

QUIZ

Retrieval

1 **Recall** how a liquid behaves in a container and what happens if it is put in a different container.
2 **Recall** how a gas behaves in a container and what happens if it is put in a different container.
3 **Recall** how particles in a solid behave. Use these terms in your answer: fixed, vibrate, shape, compressed, attraction.

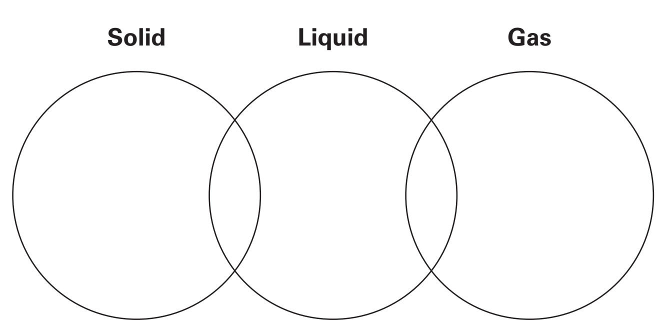
Comprehension

4 **Summarise** the properties of a gas.
5 **Explain** why steam can be compressed but ice cannot.
6 **Explain** two ways you could identify if a material is a solid.
7 The metal lid of a glass jar is stuck and cannot be undone. Kim runs the lid under hot water, and now the lid can be unscrewed. Using your understanding of the particle model and the properties of matter, **explain** why Kim used the hot tap.

Analysis

8 Copy the Venn diagram and **organise** the following statements into the correct place to describe solids, liquids and gases.

Strong attraction between particles that are not as close	Particles that are free to move, no strong attraction	Strong attraction between close particles
Easy to compress	Definite shape	Can be poured
Expand to fill a container	Particles in a fixed position	Difficult to compress
Fixed volume	Not a fixed shape	Particles vibrate in a fixed position



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9 A plastic toy animal floats in liquid X but sinks in liquid Y. **Infer** what this tells us about the densities of the toy animal, liquid X and liquid Y.

Knowledge utilisation

10 The table below lists the densities of several materials. **Deduce** which material will float in water, which has a density of 1.00 g/mL. Explain your answer referring to the materials in the table as evidence.

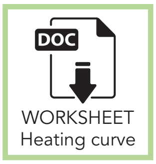
Material	Density (g/mL)
Plastic	0.90
Sulfur	2.07
Steel	7.80
Rubber	1.20

11 **Discuss** how and why the properties of a liquid are different from the properties of a gas.

12 Office chairs, like the one shown below, usually have a lever on the side for adjusting their height. The stand contains a cylinder and a piston that can move up and down inside it and, consequently, the chairs often feel quite springy when you sit on them. **Decide** if the cylinder contains a solid, a liquid or a gas. Give reasons for your answer.

Figure 7.23 An office chair

7.3 Changing states



Learning goals

1. To be able to describe the changes in physical state during heating, including melting, boiling, evaporation and sublimation.
2. To be able to describe the changes in physical state during cooling, including freezing, condensation and deposition.

All states of matter can change from one to another under certain temperature and pressure conditions. These conditions could be naturally occurring or caused by human intervention.

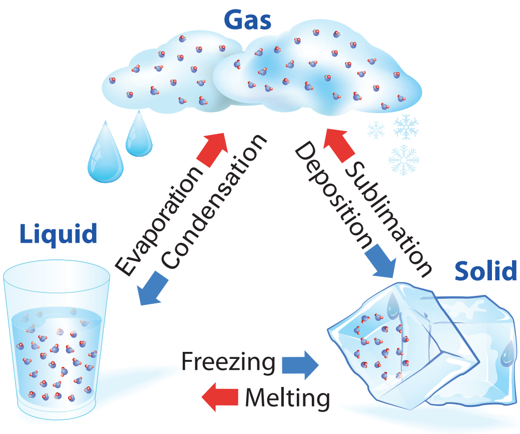


Figure 7.24 Changes in the state of water

Adding heat

Heating a substance causes an increase in temperature and, if enough heat is added, the substance can change its state.

Melting occurs when heat causes a solid to become a liquid. When solid particles are heated, they gain energy and vibrate more rapidly. When enough heat is added to the particles, the edge of the solid will eventually vibrate so quickly that the forces of attraction between the solid particles will be reduced and some of them will move into the liquid state. The temperature at which this occurs is called the **melting point** of the substance. Different substances respond to heat differently and therefore have different melting points. When a substance changes from a solid to a liquid its properties also change; however, the actual substance remains the same. For example, melting ice involves solid water forming a liquid form of water and the properties are very different (hardness, ability to be poured, shape) but they are both water.

melting
when heat causes a solid to become a liquid

melting point
the temperature at which a specific solid becomes a liquid

Figure 7.25 Melting butter on toast involves a solid forming a liquid. The properties may change but it is still butter.

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Evaporation (or vaporisation) occurs when heat causes a liquid to become a gas. Heating a liquid gives its particles more energy to move more rapidly. These particles then spread out more. When a particle at the surface of a liquid has enough energy, it will overcome the attraction to other liquid particles and move into the gas state. For example, at a natural hot spring, water changes state from liquid to gas, and some of it changes back to liquid droplets, forming clouds. Evaporation can, however, occur at a range of temperatures. Consider the clothes you hang on the line to dry. They will dry by the water evaporating from the surface of the clothes. Drying is faster when it is sunny and hot, but they still do dry on cooler cloudy days.

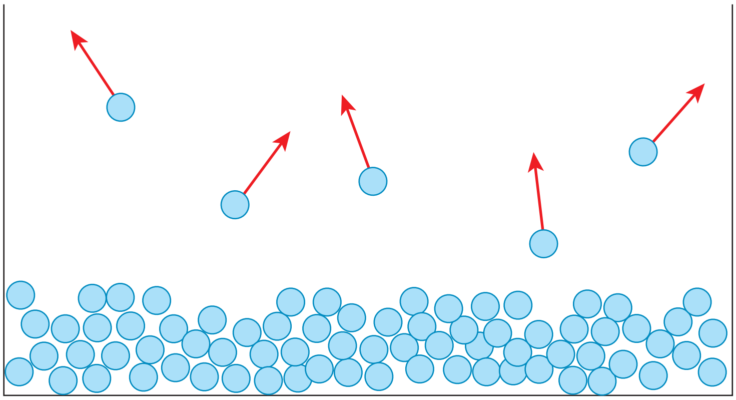

Figure 7.26 When heated, particles gain energy and spread out, allowing them to break free from the liquid and form a gas.

evaporation
when heat causes liquid to become gas

boiling
the rapid vaporisation of a liquid which occurs when it is heated to a certain temperature

boiling point
the temperature at which a specific liquid becomes a gas

Boiling is the rapid vaporisation of a liquid that occurs when it is heated to a temperature called the **boiling point**. Vaporisation starts at various points throughout the liquid where bubbles of vapour form. For example, when water boils at 100°C in a transparent kettle, you can see bubbles containing water vapour begin to form low down in the water. The bubbles expand, rise and break at the surface (Figure 7.27).

Figure 7.27 The bubbles in boiling in water form low down in the liquid, then expand and rise to the surface.

Explore! 7.4

Researching melting and boiling points

Different substances have different boiling and melting points.

1. Find out the melting and boiling points of some different substances.
2. Draw up a table to record the melting point and boiling point of each of the substances you researched.

Did you know? 7.5

Melting and boiling points can change!

Melting and boiling points depend not only on temperature, but also on the pressure. Atmospheric pressure changes depending on the altitude above sea level. In Toowoomba, which is about 598 metres above sea level, the boiling point of water is around 98°C. Can you think of why this is the case?

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Sublimation is when a solid changes state to become a gas without becoming a liquid first. Most solid substances can go through the processes of melting to a liquid and boiling or evaporating to a gas. However, there are some examples of solid substances that can skip the liquid state altogether and can change from a solid directly to a gas. Dry ice (solid carbon dioxide) is an example of a substance that sublimes.

sublimation
where heat causes a solid to become a gas, without passing through the liquid state

freezing
where heat is lost and a liquid becomes a solid

Removing heat

Cooling a substance causes a decrease in temperature. If enough heat is lost, the substance can change its state.

Freezing (or solidification) occurs when heat is lost, causing a liquid to become a solid. The process of freezing is the opposite of melting. As liquid cools, the particles lose energy and move or vibrate more slowly. When enough energy has been removed, the particles will vibrate in fixed positions in close proximity to other particles and form very strong attractions. And so the solid state will be formed. The point at which this occurs is called the freezing point and different substances have different freezing points. For example, the freezing (and melting) point of water is 0°C, while the freezing (and melting) point of oxygen is –218.8°C.

Figure 7.28 Snowflakes form when the liquid water turns into the solid ice.

Did you know? 7.6

Ice, the exception!

Solids usually take up a smaller volume than liquids because the particles are held closer together. However, solid water (ice) is an exception to this rule as it actually takes up more space! That is why icebergs float on the ocean, rather than sink to the bottom. A bottle of water put into the freezer will expand and sometimes break because the frozen ice takes up more space than the water. This is because particles occupy different positions in solid ice and liquid water.

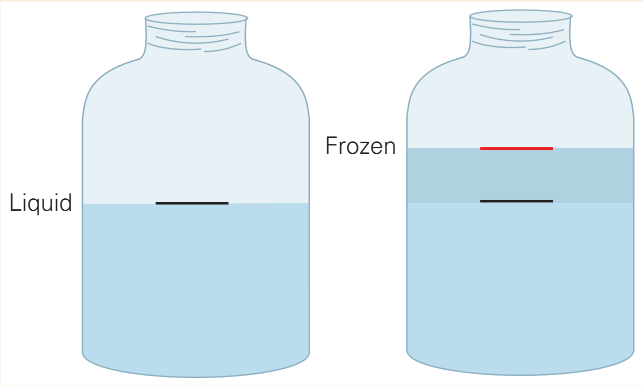

Figure 7.29 When water is frozen, its volume increases.

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Condensation is when heat is lost, causing a gas to become a liquid. As a gas cools, the particles of gas lose energy and slow down. When they have slowed down enough, the particles become close enough together that they begin to attract one another, and consequently form a liquid. An example you may see every day is when the steam from your shower condenses on the mirror of your bathroom as the water vapour (gas) hits the cool mirror and forms a liquid.

Deposition is also known as reverse sublimation or desublimation. Deposition occurs when cooling causes a gas to become a solid, without passing through the liquid state. It is the opposite of sublimation. An example occurs in sub-freezing air, when water vapour changes directly to ice without first becoming a liquid.

condensation
where heat is lost and a gas becomes a liquid

deposition
where a reduction in heat causes a gas to become a solid, without passing through the liquid state

Figure 7.30 Condensation forms on a window overnight as the air cools.

Try this 7.5

Simulating particle theory

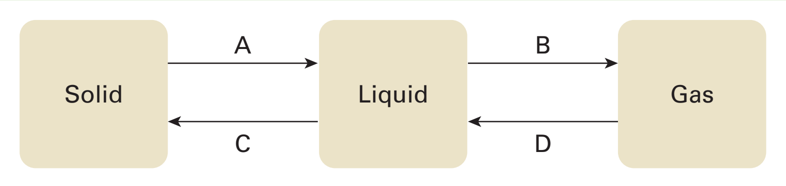
Using your preferred software (e.g. Microsoft PowerPoint), create an animation or simulation that shows one of the following:

- **a** solid particles melting to liquid particles
- **b** liquid particles boiling to gaseous particles
- **c** gaseous particles condensing to liquid particles
- **d** liquid particles freezing to solid particles.

When your animation or simulation is complete, present it to one of your peers in the class.

Quick check 7.6

1. In your own words, define the processes of: melting, evaporation, boiling, sublimation, freezing, condensation and deposition. Add these terms to your glossary.
2. Solids, liquids and gases can change their state. In the diagram below, each arrow represents a change in state. Answer the questions below.



   - **a** Which letter represents melting?
   - **b** What is the name of process B?
   - **c** Which letter represents condensation?
   - **d** What is the name of process C?
3. Use particle theory to answer these questions.
   - **a** What happens when you increase the temperature of a cube of frozen juice?
   - **b** What happens when you increase the temperature of liquid water?

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Investigation 7.1

Heating and cooling curves

Be careful

Take care when using the Bunsen burner, heatproof mat, tripod and glass thermometer. Be aware of the boiling water.

Aim

To investigate and construct the heating and cooling curves for stearic acid.

Planning

1 Complete some research and write a rationale about particle theory, energy and changes of state.
2 Write a risk assessment for this investigation.

Materials

- boiling tube
- 250 mL beaker
- Bunsen burner
- stearic acid (octadecanoic acid): There should be enough to fill approximately a quarter of a boiling tube. Solidified stearic acid can be stored in the boiling tubes and reused again.
- tripod
- gauze mat
- heatproof mat
- thermometer/temperature probe
- retort stand and clamp
- stopwatch
- matches
- safety glasses

Method

1 Wearing your safety glasses, set up the equipment as shown in Figure 7.31.
2 Fill the beaker with 150 mL of water.
3 Heat the beaker on a tripod and gauze until the water just starts to boil. Maintain this at a gentle boil, pulling the Bunsen burner aside if it becomes too vigorous.
4 Record the temperature of the stearic acid every 30 seconds until it reaches 70°C. Make a note on your results table when the stearic acid starts to melt.
5 Carefully remove the boiling tube from the beaker using the clamp and record the temperature of the stearic acid every 30 seconds as it starts to cool.
6 Continue until it reaches 30°C. Make a note on your results table when the stearic acid starts to solidify.

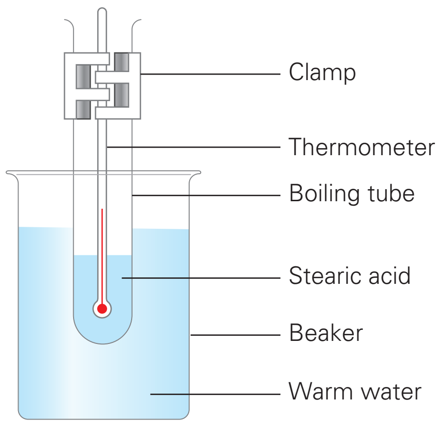

Figure 7.31 The equipment set-up you will need

Results

Draw suitable results tables for this investigation.

Draw a line graph to show how the temperature of the stearic acid changed over the total time you took measurements. You should plot both sets of results on the one graph. Use a blue pencil to plot your cooling data and a red pencil to plot your heating data.

Analysis

1 Analyse your graph to deduce the freezing point of stearic acid.
2 Compare this temperature with the melting point temperature indicated on the graph.
3 Explain what is happening to the particles in the solid stearic acid as they are melting.
4 Explain why parts of the graph are horizontal lines. Think about what is happening. Shouldn't the temperature be increasing if the Bunsen burner is still on? Where is the energy going?

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… *continued*

Evaluation

Limitations

1 Identify any potential sources of error in this experiment.

Improvements

2 Suggest any changes that could be made to the method to improve the quality of the data in future experiments. Justify your suggestions by explaining how each change will improve the data quality.

Conclusion

Draw a conclusion from this investigation regarding particle theory and energy. Justify your answer with data.

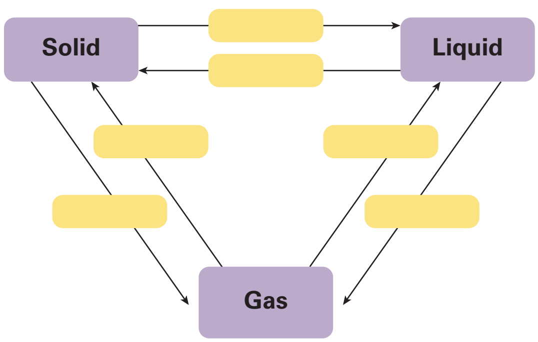
Section 7.3 questions

QUIZ

Retrieval

1 **Recall** what happens to the closeness and energy of particles when you heat a substance. What happens when you cool a substance instead?

2 **Recall** the name of the process in each yellow box (e.g. melting, evaporation). Indicate whether you add heat or take away heat to achieve that change of state. You may do so by redrawing the diagram shown and using different colours for the arrows depending on whether heat is added or taken away.



3 For each of the following processes, **state** whether energy is added or removed.
- a sublimation
- b evaporation
- c freezing
- d condensation
- e deposition
- f melting

Comprehension

4 Use the following terms to describe the processes of:
- a ice melting
- b water boiling

boil	boiling point	decrease
evaporate	gas	heat
increase	liquid	melt
melting point	particle	solid
space	speed	temperature

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Analysis

5 Answer the following questions using the information in Figure 7.32.

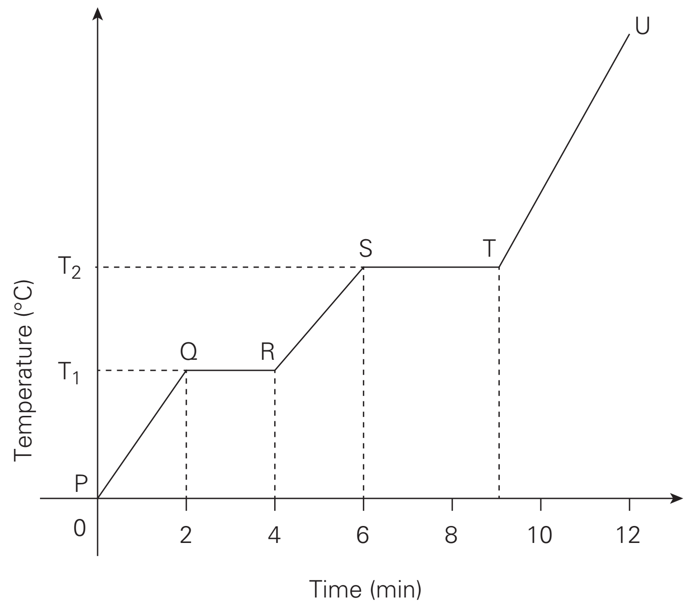

Figure 7.32 The heating curve of a substance that exists as a solid at time 0 minutes

- a **Identify** the process that is occuring between 2 and 4 minutes.
- b **Identify** the state of matter that is present at U.
- c **Identify** the temperature of the boiling point.
- d **Identify** the time period when the substance is all in liquid form.

6 Use the information in the table below to answer the following questions.

Substance	Melting/freezing point (°C)	Boiling point (°C)
Water	0	100
Aluminium	660	2467
Iron	961	2212
Ethanol	–130	78
Helium	–272	–268

- a **Identify** the substance that has the highest melting point.
- b **Identify** the substance that has the lowest melting point.
- c **Sequence** the substances from lowest boiling point to highest boiling point.
- d **Identify** one substance that is a gas at 20°C.
- e **Identify** one substance that is a liquid at 20°C.
- f **Identify** one substance that is a solid at 20°C.

Knowledge utilisation

7 In cold countries, rock faces can sometimes have pockets of water trapped inside cracks after it rains. **Decide** what might happen if the trapped water freezes when the temperature drops.

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Chapter review

Chapter checklist

You can download this checklist from the Interactive Textbook to complete it.

Success criteria		Linked questions	Check
7.1	I can recall the particle model.	11	
7.1	I can describe the three states of matter.	7, 17	
7.1	I can describe how heat influences contraction or expansion of particles.	1, 8, 9	
7.1	I can define the term ‘diffusion’.	6	
7.2	I can list the properties of solids, liquids and gases.	2, 5	
7.3	I can describe how matter can change state.	1, 10, 13	

Review questions

SCORCHER

Retrieval

1 **Identify** the correct words or terms to answer the questions or fill in the blanks below.
  - **a** Something you can do if you want a metal to contract.
  - **b** Hot air ________ because it expands and gets less dense.
  - **c** This metal is a liquid at normal temperatures and, because of the way it contracts and expands, can be used to measure temperature.
  - **d** A word that means the same as evaporation.
  - **e** The process of turning a solid into a liquid by heating it.
  - **f** When the water vapour in the air cools down overnight, it will often ________ and form dew.
  - **g** Hot air balloons rise because the ________ of the air inside them increases.

2 **Recall** the correct properties of solids, liquids and gases to complete the following table.

	Solids	Liquids	Gases
Shape			
Volume			
Density			
Ability to flow			
Ability to be compressed			
Closeness of particles			

3 **Recall** the two measurements that you need to make to calculate the density of an object.

4 **State** if each of the following statements is true or false. Rewrite the false statements so that they are true.
  - **a** Toothpaste behaves only like a solid.
  - **b** Oxygen can be compressed.
  - **c** A wooden toy has a fixed shape.
  - **d** Melting points are different depending on the substance.

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e Steam changes back to a liquid at the boiling point.
f Liquid particles have the highest speed of movement.
g The particles in water are closer together than the particles in steam.
h Solids and liquids have a fixed mass, while gases do not.

5 **Select** the property (A–D) that matches with the correct behaviour of the particles (1–4).

Property
A Take the shape of the container
B Are very difficult to be compressed
C Cannot be poured
D Can spread out in all directions

Behaviour of particles
1 Because their particles are very close already
2 Because their particles are not held together at all
3 Because their particles are free to move
4 Because their particles are not free to move

6 **Define** 'diffusion' with respect to particle theory.

Comprehension

7 **Explain** why a solid is very difficult to compress when force is applied.

8 **Explain** why temperature influences the state of a substance.

9 **Describe** the likely outcome of heat being absorbed by particles.

10 Use your knowledge of the particle model to **explain** what happens in the following situations.
a The temperature of steam (gas) is decreased
b The temperature of liquid water is decreased

11 **Describe** the gas pressure in a full balloon in terms of the particle theory.

12 Imagine a single grain of sand. It is hard and has a definite shape. If you scoop up a handful of dry sand, you can pour it out of your hand, which sounds like the behaviour of a liquid, not a solid. It is very difficult to build a sand castle with dry sand. However, if you wet the sand, you can shape it into a sand castle. **Explain** why you might classify sand as a solid.

Figure 7.33 Sand seems to have different properties when it is wet and when it is dry.

13 A can of soft drink is taken out of the fridge and left on the bench. After a few minutes the can has beads of water on the outside. **Explain** where the water came from and what change of state occurred.

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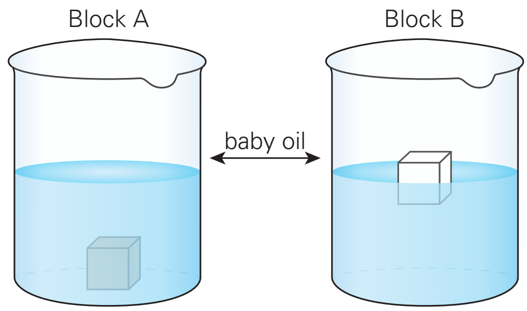
14 Block A and block B are made of different materials. Each block is in a beaker with baby oil, as shown below.



a **Explain** why block A sinks and block B floats. The density of baby oil is 0.82 g/mL.

b **Decide** whether warming up the baby oil in the beaker containing block B would give the same or different results.

15 **Describe** how one gas diffuses through another.

16 The diagram below shows the process of diffusion occurring; that is, the movement of gases or liquids spreading out in another gas or liquid.

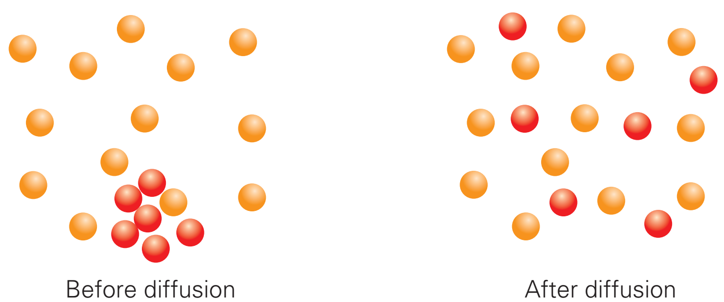


Figure 7.34 The process of diffusion illustrated as particle diagrams. The particles are constantly moving and, over time, will spread out.

a **Explain** what is happening to the red particles as they diffuse through the orange particles.

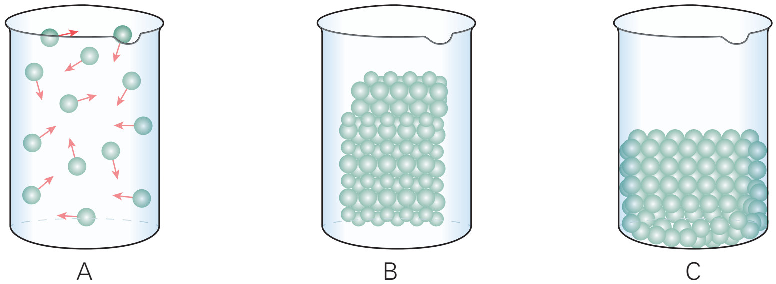
b Factors like heat can affect how fast diffusion occurs. Would the red particles diffuse faster or slower if moved from a room temperature beaker into warm water? **Explain**, making mention of the particle model.

c The state of the substances diffusing can also affect how fast diffusion occurs. **Decide** which one you think would diffuse faster – particles of perfume in the air or ink in water, giving reasons for your answer.

d An effervescent tablet put into water bubbles away until it dissolves and is an example of diffusion. **Decide** if this is an example of a solid moving through a liquid, liquid moving through a liquid or a gas moving through a liquid, giving reasons for your answer.

Analysis

17 **Classify** the following diagrams as a solid, liquid or gas. What it is about substance **B** that enabled you to identify it?



Knowledge utilisation

18 The particle theory of matter states that there are attractive forces and spaces between particles. **Decide** whether the forces of attraction are greater or lesser for particles that are further apart from one another.

19 Burning a fuel produces a lot of heat and the particles formed are usually in the gaseous state. **Discuss** why, when solid or liquid fuels burn, the product is usually a gas.

20 When you are walking home from school, have a look at the concrete footpath. You may notice that it is not one long path but rather a series of large sections all in a row. **Propose** why you think concrete paths are constructed this way.

21 Dry ice is used in film-making to set the mood for scenes (e.g. in horror, fantasy and mystery films) (Figure 7.35). **Determine** how dry ice is useful in this case.

Figure 7.35 What process is involved in dry ice such that it can create this effect?

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Data questions

Water exists naturally on Earth in three states: solid (ice), liquid (water) and gas (water vapour). Figure 7.36 shows the point at which water changes between these states at different temperatures and pressures.

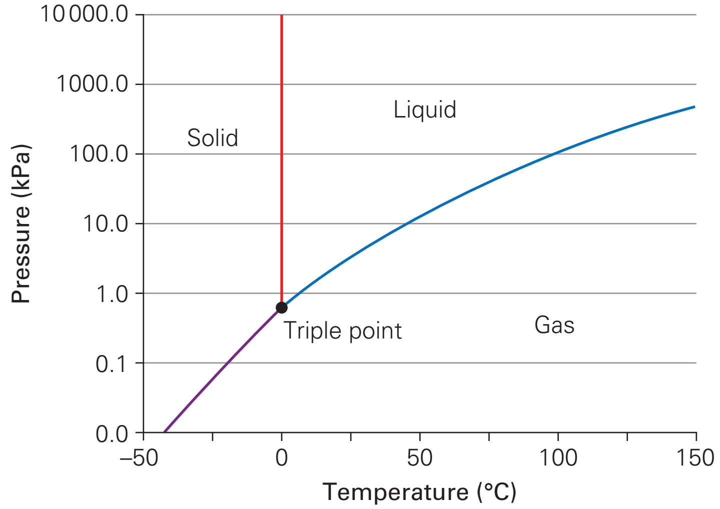

Figure 7.36 State changes of water at different temperatures and pressures. The purple line illustrates sublimation, the red line melting and the blue line the evaporation.

Apply

1 **Identify** the state of water at 50°C and 100 kPa.

2 **Identify** the temperature at which water will freeze at 1000 kPa.

Analyse

3 **Contrast** the boiling point of liquid water at 10 kPa pressure and 100 kPa pressure.

Interpret

4 **Infer** what is meant by the 'triple point'.

5 Given that atmospheric pressure (the pressure at sea level) is approximately 101 kPa, **explain** why we tend to encounter water in its liquid state in our daily lives (puddles, rain, rivers, lakes, coming out of taps, etc.).

6 **Predict** at what temperature liquid water will freeze at 20 000 kPa pressure.

7 **Justify** why, at atmospheric pressure (101 kPa), snow should melt, and not sublime.

8 Starting at atmospheric pressure (101 kPa), **deduce** whether the pressure needs to be increased or decreased at 0°C for ice to sublime.

9 **Deduce** whether it is possible for water to exist as a liquid above 100°C.

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STEM activity: Reduce, reuse, repurpose, recycle

Background information

Waste is a huge issue for the whole world. Queensland has banned retailers from supplying plastic bags and now has a container refund scheme to raise awareness and decrease waste, with the hope that Queensland will become a zero waste society.

Being a zero waste society involves rethinking how we use our resources to eliminate all waste products. Queensland councils, in a meeting of the Local Government Association of Queensland, voted to have zero waste going to landfill by 2028. With this important goal, society needs to be educated about having a zero waste philosophy.

Design brief: Design an educational poster for the Queensland Government to distribute through schools about zero waste and the science behind making a zero waste society.

Activity instructions

Your group has been employed by the Queensland Government to produce an educational poster about zero waste for primary school children. It should include the science behind how different waste products are made, and how different items can be reused, repurposed and recycled, as well as including the reasons why certain products must be avoided.

Figure 7.37 Return. Reuse. Recycle. Reusable cups reduce the impact on waste generated by takeaway hot chocolates.

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Suggested materials

- pens/pencils
- butcher's paper
- PowerPoint/poster-making software
- computers

Research and feasibility

1. Research, discuss in your group and list different types of waste produced by society.
2. Discuss in your group which types of waste you think should be the focus of your poster and research how they are made, used and then re-used/repurposed/recycled.
3. Create a table like the one shown below to help determine which types of waste are easiest or most difficult to make zero waste.

Waste	Household/society quantity	Can this product be made zero waste?	How? Level of difficulty
E.g. cling wrap	Varies depending on household	Yes	It can be recycled, but it is more difficult, and should be avoided as a product.

Design and sustainability

4. Decide, as a group, five key ideas you want to have on your poster, and discuss if you have enough important research to help convince students of their importance.
5. Sketch, as a group, different poster designs and annotate the locations of the most important information. Discuss as a group if the poster is effective visually.

Create

6. Use butcher's paper or a computer to create your information poster. Remember, this is a poster designed for primary school children.

Evaluate and modify

7. Present your poster to your class as a group, and encourage questions and feedback from your class.
8. Evaluate the effectiveness in transforming the message of zero waste to your class.
9. Discuss modifications you would make to your poster based on feedback from the class.

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Chapter 8
Mixtures

Chapter introduction

Water, seawater and freshly squeezed orange juice are all made of matter and could all be considered liquids. However, they also have some differences. Water will always be water, no matter if it is frozen or boiled. It is a pure substance. But if you boil seawater, the water evaporates and leaves salt behind. If you strain the orange juice, you will be left with bits of orange pulp. The seawater and orange juice are mixtures. In this chapter, you will explore how to separate mixtures using a variety of separation techniques. This will include techniques you might already use at home, as well as industrial applications.

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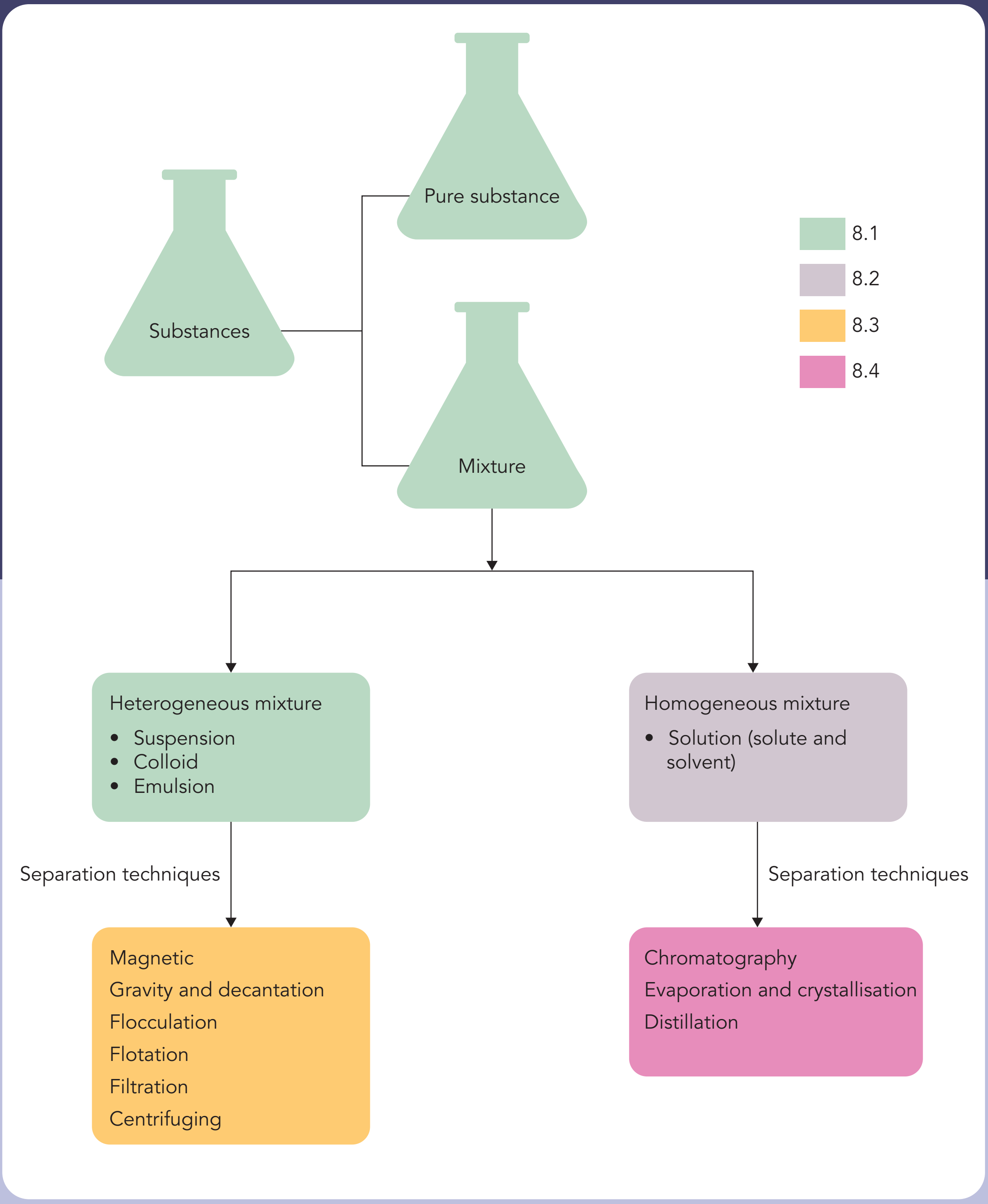
Concept map



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Curriculum

Use a particle model to describe differences between pure substances and mixtures and apply understanding of properties of substances to separate mixtures (AC9S7U06)	
using representations of particles to show the difference between samples of pure substances and mixtures, and identifying examples of each	8.1
examining different solutions and identifying the solvent and solute	8.1, 8.2
investigating and using a range of physical separation techniques such as filtration, decantation, evaporation, crystallisation, chromatography and distillation	8.3, 8.4
exploring and comparing separation methods used in a variety of situations such as in the home, recycling industries and purifying water	8.3, 8.4
analysing how the physical properties of substances in mixtures, such as particle size, density or volatility, determine the separation technique used	8.3, 8.4
investigating separation techniques used by First Nations Australians, such as hand-picking, sieving, winnowing, yandying, filtering, cold-pressing and steam distilling	8.3

Glossary terms

Aqueous solution
Centrifuge
Chemical substance
Chromatography
Colloid
Concentrated
Crystallisation
Decantation
Dilute
Dissolve
Distillate
Distillation
Emulsion
Evaporation
Filtrate
Filtration
Flocculant
Flotation
Heterogeneous mixture
Homogeneous mixture
Insoluble
Mixture
Physical property
Pure substance
Residue
Saturated
Sieving
Smog
Soluble
Solute
Solution
Solvent
Suspension

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8.1 Pure substances and mixtures

Learning goals
1. To be able to identify the difference between pure substances and mixtures.
2. To be able to distinguish between homogeneous and heterogeneous mixtures.

DOC
WORKSHEET
Mixtures

Everything in the world around you, whether you can see it or not, is made up of matter. In the last chapter, matter was described as anything that has mass and occupies space. Matter can be made up of one type of **chemical substance**, which has only one type of particle present and constant chemical properties. Or it can be a mixture of different chemical substances. That is, it can have two or more different types of particles present and inconsistent properties throughout.

Pure substances

A **pure substance** is made up of only one type of chemical substance. Examples of pure substances include pure gold, pure water or pure oxygen gas. Every pure substance has a unique set of physical properties such as density, size, magnetism, colour, mass, melting points and texture. An understanding of the unique **physical properties** of a pure substance allows scientists to distinguish it from a mixture.

Figure 8.1 Pumpkin soup is a tasty mixture.

Mixtures

Mixtures are materials made from two or more different chemical substances mixed together and can be physically separated. Mixtures can be separated because they are not combined chemically in a chemical reaction. Some examples of mixtures that you may be familiar with include soft drinks (a mixture of sugar, water, carbon dioxide, flavours and colouring), a cup of tea (a mixture of tea leaves and water), tap water (a mixture of water, fluoride salts, salts **dissolved** from ground water and chlorine), pumpkin soup (a mixture of pumpkin, water, milk and spices) and healthy fruit salad (a mixture of kiwi fruit, apples, bananas and raspberries).

chemical substance
matter that contains only one type of particle

pure substance
material that is made up of just one type of chemical substance

physical property
the way a substance looks and acts; a characteristic of a substance that can be observed and/or measured without changing it chemically

mixture
material that is made up of two or more different types of chemical substances that are not chemically bonded together

dissolve
to become mixed in a substance so that it cannot be seen

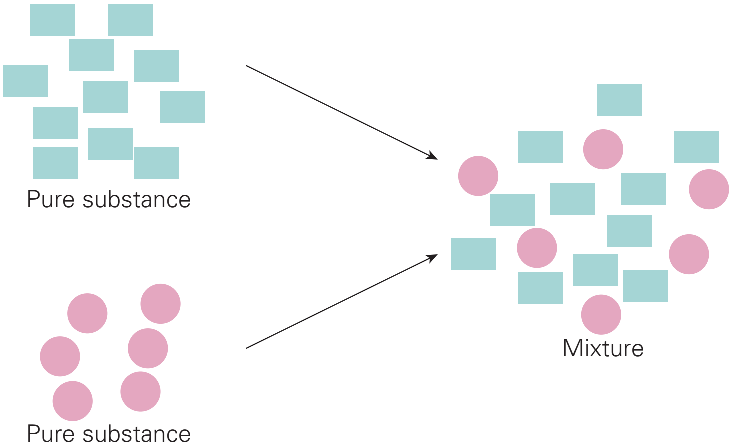

Figure 8.2 A mixture is made of two or more chemical substances.

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Making thinking visible 8.1

Thinking with images: Pure or mixture?

The four images below show two pure substances and two mixtures of substances.

a

b

c

d

1 How is image **a** like image **d**?
2 How is image **b** like image **c**?
3 How is image **a** not like image **b**?
4 How is image **c** not like image **d**?
5 Make a prediction of which two substances could be classified as pure and which two images could be classified as mixtures.

The *Thinking with images* thinking routine was developed by Project Zero, a research centre at the Harvard Graduate School of Education

Quick check 8.1

1 Define the terms 'pure substances' and 'mixtures'.
2 Draw up a table with the headings 'pure substances' and 'mixtures' and classify the names of the following substances by writing them into the correct column.

smoke	pen ink	iron
soft drink	aluminium foil	cough medicine
trail mix	margarine	filtered water
hand cream	chocolate milk	jelly
salt water	ice cream	cheese
oxygen	carbon dioxide	blood

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Types of mixtures

Mixtures can be classified as four different types based on their observable physical properties.

Table 8.1 introduces these types of mixtures: **solutions**, **suspensions**, **colloids** and **emulsions**.

Type of mixture	Definition	Examples
Solution	A type of mixture that is formed when one chemical substance (**solute**) dissolves uniformly in another chemical substance (**solvent**). A solution is typically transparent.	Vinegar (a mixture of water and ethanoic acid) Lemonade Seawater
Suspension	A type of mixture that is formed when a chemical substance does not dissolve in a liquid and separates and settles to the bottom if left to stand. They are usually cloudy only after mixing.	Muddy water Orange juice with pulp Dust in the air
Colloid	A type of mixture that is formed when a suspension does not separate or settle. The larger particles of one chemical substance stay distributed through the other chemical substance.	Whipped cream (the gaseous air is distributed throughout the liquid cream) Wet paint (a solid pigment distributed in liquid) Toothpaste (solid particles distributed in a viscous liquid)
Emulsion	A type of mixture that is formed when a colloid of two or more liquids spread evenly through one another	Salad dressing when shaken together (the liquid oil is spread out throughout the liquid vinegar) Milk (an emulsion of fat droplets and oils in water)

Table 8.1 Types of mixtures

solution
a mixture where one chemical substance is evenly dissolved in another

suspension
a mixture where one chemical substance will eventually settle out of the solvent

colloid
a mixture where particles of one chemical substance will not dissolve but remain distributed through another chemical substance

emulsion
a colloid of two or more liquids

solute
the component of a solution being dissolved

solvent
the component in a solution capable of dissolving another chemical substance

VIDEO Types of mixtures

Try this 8.1

Observing mixtures

Take a sample of tap water, muddy water, toothpaste and milk. Make a list of key physical properties that distinguish these four mixtures. For example, the tap water is a solution and should be the only mixture that is transparent. These observations can make part of your definition of these four types of mixtures.

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Quick check 8.2

Copy and complete the following table and select the correct mixtures from Figure 8.3 for the 'Examples' column.

Type of mixture	Transparent or cloudy?	Separates/settles when left to stand?	Examples
Solution			
Suspension			
Colloid			
Emulsion			

Figure 8.3 Can you identify the type of mixture present in each image?

Did you know? 8.1

The first vinaigrette

A tasty emulsion that has been used to dress salads for centuries is French dressing. It is an emulsified mixture of vinegar and oil that can also be seasoned with herbs and spices. The modern English word to describe this emulsion is 'French dressing'; however, the French word 'vinaigrette' was used to describe this type of salad dressing in the late 1600s. While the vinaigrette might have been flavouring salads across Europe prior to this word use, it is certain that the knowledge of emulsifying liquids for a flavoursome benefit has been used in cuisine for centuries!

Figure 8.4 A tasty emulsion

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Separating mixtures

As the chemical substances in mixtures are not chemically combined, it is possible to separate a mixture back into its pure components. This is typically done by taking advantage of the unique physical properties of the pure substances in the mixture. Physical properties such as density, size, colour, magnetism and boiling point can be used to separate components of mixtures.

Recycling sorting

To use a real-world example of separating a mixture, consider your weekly household recycling. Once the recycling truck delivers recycling waste to the collection centre, a range of separation techniques are applied to separate plastics, paper, glass and metal cans. This can be done using manual sorting, sieves, magnets and machines that sort by size or weight. The separated elements are then taken to their respective recycling companies.

Figure 8.5 The different properties of recycling materials such as size and type of material allows sorting of your weekly recycling.

Classifying mixtures

Mixtures can be more broadly classified into two categories: **homogeneous mixtures** and **heterogeneous mixtures**. These categories are important as they give an indication of the type of properties the mixture will have and therefore the method to separate the components. Homogeneous mixtures are mixtures where you cannot tell that two or more substances have been mixed as they don't settle or separate out when left to stand. The components of the mixture are all evenly distributed, and the entire mixture has the same properties. For example, air, tap water and soft drinks are all homogeneous mixtures because wherever you take a sample of these mixtures, the properties of the samples will be the same. A solution is an example of a homogeneous mixture.

homogeneous mixture a mixture where components are evenly distributed

heterogeneous mixture a mixture where components are not evenly distributed

smog a mixture of smoke, gases and chemicals, especially in cities

Heterogeneous mixtures are mixtures where components are not evenly distributed and do not have consistent physical properties throughout. These mixtures can be more easily separated into their parts, and those parts retain their original properties. Examples of heterogenous mixtures include trail mix, fruit salad, pizza, choc chip cookies, **smog** and salad dressing. Suspensions, colloids and emulsions are generally considered to be heterogeneous, although, to the naked eye, some may appear to have some of the same qualities of homogeneous mixtures.

Try this 8.2

Separate your recycling

At home, take a look at the items currently in your recycling bin. In what ways could you separate the items based on physical properties? For example, you might separate based on size of the item. Come up with at least three different characteristics to sort.

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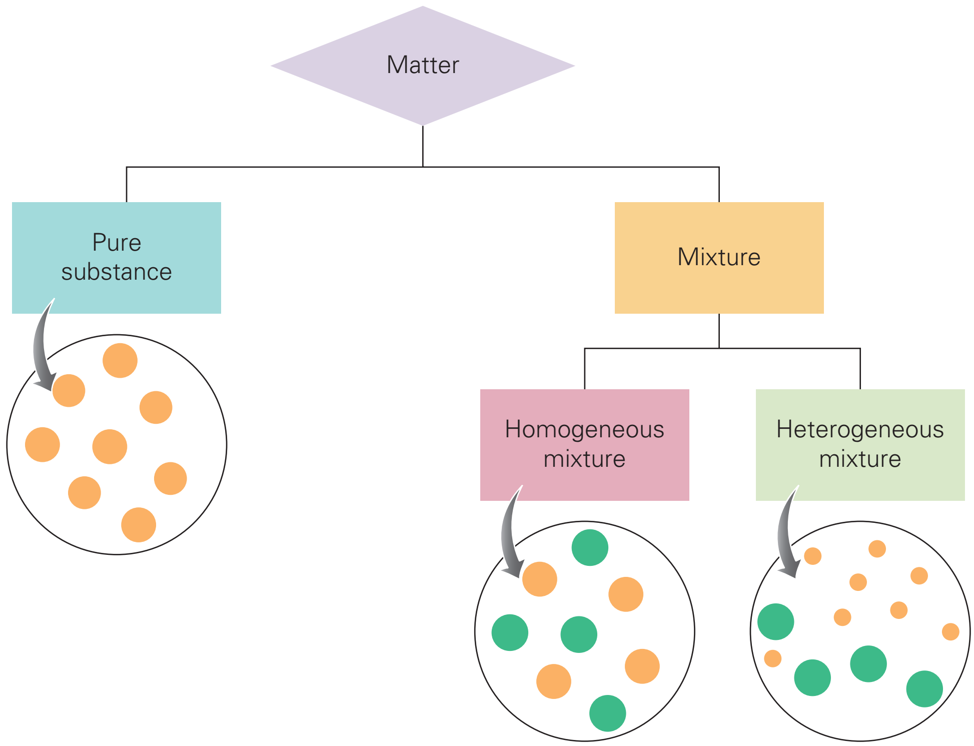

Figure 8.6 Particles in matter may be arranged in a pure form or as a homogenous or heterogenous mixture.

Try this 8.3

Homogenous mixtures

There are many mixtures that look like they could be a pure substance because they have a homogenous colour or transparency, or relatively consistent properties throughout. Make a list of ten household substances that, when observed, could be considered pure substances but are actually homogenous mixtures.

Quick check 8.3

1. Define the term 'heterogeneous'.
2. Recall the characteristics that allow you to identify if a mixture is heterogeneous.
3. Define the term 'homogeneous'.
4. Recall the characteristics that allow you to identify if a mixture is homogenous.
5. Classify the following substances as either a homogenous mixture, a heterogenous mixture or a pure substance. Substances: pure water, cola, iron nails, green paint, chunky salsa, silver ring, chocolate chip cookies, concrete, orange juice with pulp, table salt.
6. Research online to investigate your local recycling processes and use this information to describe the properties of the items being recycled that allow for the parts to be separated.

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Section 8.1 questions

QUIZ

Retrieval

1 **Identify** which of the following would not be described as a colloid: smoke, foam, salt water, hair gel.

Comprehension

2 **Summarise** the differences between pure substances and mixtures and provide two examples of each.

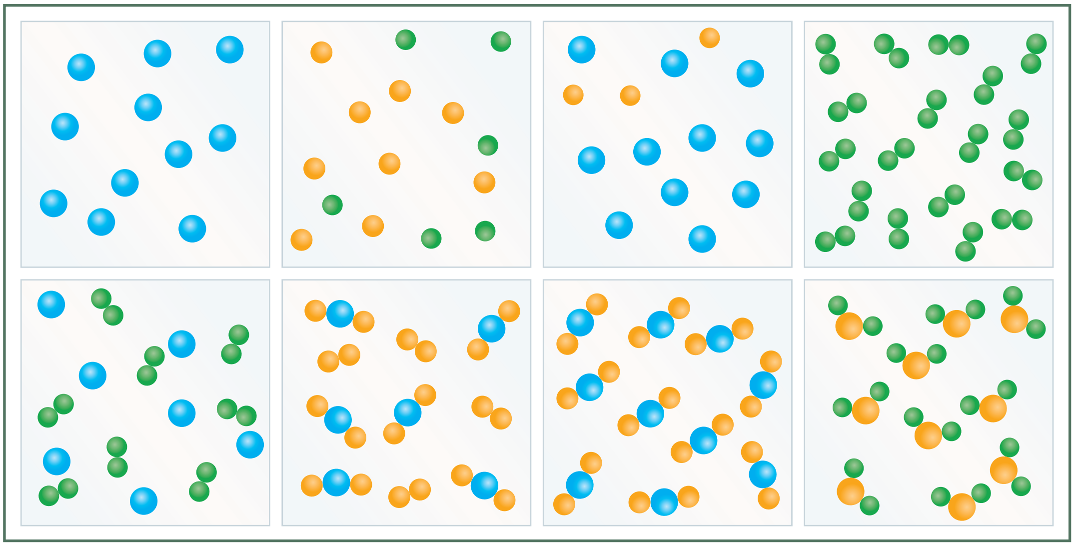
3 **Outline** the differences between heterogeneous mixtures and homogeneous mixtures and provide two examples of each.

4 Is 100% pure carrot juice a pure substance? **Explain**, using the definitions you have learned.

5 You are looking at a beaker with a substance in it. **Describe** how you can tell if it is a solution, suspension, colloid or emulsion. Show your knowledge of the characteristics of the four types of mixtures in your answer.

Analysis

6 **Categorise** the following particle diagrams using the terms: pure substance, heterogeneous mixture, homogeneous mixture.



Knowledge utilisation

7 **Justify** that all solutions are mixtures, but not all mixtures are solutions.

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8.2 Homogenous mixtures

WORKSHEET
Solutions, solutes and solvents

VIDEO
Dissolving solutes in a solvent

Learning goals
1. To be able to define an aqueous solution including the terms 'solute' and 'solvent'.
2. To be able to compare a dilute, concentrated and saturated solution.

Solutions are a type of homogenous mixture in which a solute is dissolved and evenly distributed in a solvent. In this section, you will learn about everyday aqueous solutions as well as their concentrations and saturation.

Figure 8.7 Fresh drinking water is a solution as various trace elements from ground water are dissolved evenly in pure water.

Solutions

A solution is a type of mixture that is formed when the particles of one substance separate and spread out evenly into another substance, that is, dissolve. Typically, solutions appear transparent due to the even distribution of the dissolved particles. Recall that the solute is the name given to the substance that dissolves and the solvent is the name given to the substance it dissolves into. A solution is therefore the name given to a mixture of a solute dissolved in a solvent.

Try this 8.4

Particle theory

Figure 8.8 shows a solute being added to a solvent. If the solute is made up of salt particles and the solvent is made up of water particles:

1 Describe what is occurring in the sequence of images.
2 What type of mixture is present at the end?

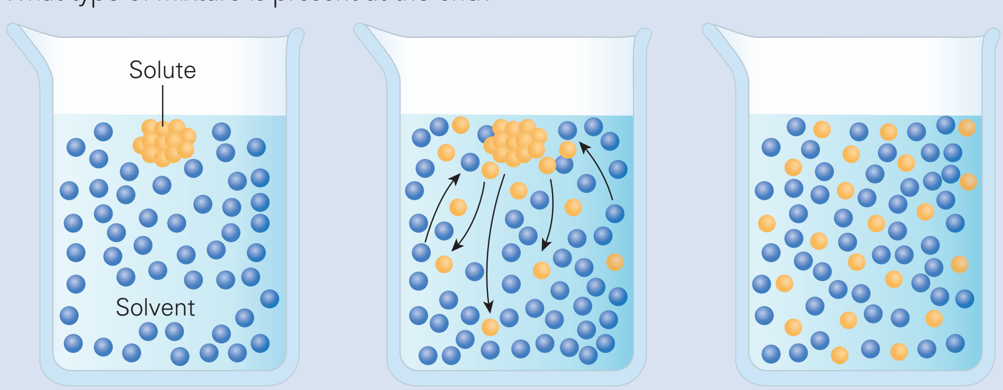

Figure 8.8 Particle diagram of a solute being added to a solvent

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Examples of solutions

An everyday example of a solution is the oxygen dissolved in fish tank water, where the oxygen is the solute and the water is the solvent. Other examples include cordial (solute) dissolved in a glass of water (solvent) and the carbon dioxide (solute) dissolved in fizzy drink (solvent). You will notice that many of the solutions mentioned so far are made of solutes dissolved in the solvent water. Water is sometimes called the 'universal solvent' due to its versatility to dissolve a wide variety of different solutes. Solutions using water as a solvent are called **aqueous solutions**.

Chemical substances that can dissolve in a particular solvent are called **soluble** and those that cannot dissolve in a particular solvent are called **insoluble**. Chemical substances that are insoluble have very strong forces of attraction between their particles and the solvent cannot break them apart to help them dissolve.

Solution concentrations

Solutes can dissolve in solvents to different extents depending on how much is added to the solvent. When a solution has a relatively small amount of solute dissolved in the solvent, the solution is said to be **dilute**. It is also described as a solution with a low concentration of solute. For example, a friend might ask you to make a 'weak' glass of cordial. You would add only a small amount of the cordial (solute) and a lot of water (solvent) to make a weak or dilute solution. A solution that has a relatively large amount of solute dissolved in a solvent is called **concentrated**. It is also described as a solution with a high concentration of solute. How would you make your friend's cordial drink in this case?

DOC
WORKSHEET
Dissolving solutes

aqueous solution
solutions where the solvent is water

insoluble
chemical substances that cannot dissolve in a particular solvent

soluble
chemical substances that can dissolve in a particular solvent

dilute
a solution with a relatively small amount solute

concentrated
a solution with a relatively large amount of solute

Figure 8.9 Fish and coral in the Great Barrier Reef can breathe oxygen, which is a solute dissolved in the ocean water.

Figure 8.10 The more concentrated solutions are on the right, while the more dilute solutions are on the left.

Quick check 8.4

1 Identify the solute and solvent in the following solutions: ocean water, vinegar, tap water, lemonade.
2 Define these terms: soluble, solution, solvent, solute, aqueous solution.

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Try this 8.5

Investigating solubility

Investigate the solubility of household substances in water.

1. Collect five containers of the same size.
2. Add a teaspoon of one of five common household substances to each container and label the container. Typical substances are sugar, salt, flour, coffee and sand.
3. Add two tablespoons of cold tap water and mix the substances together using a spoon or by carefully swirling the container.
4. Record your observations of each substance as soluble, partly soluble or insoluble.
5. Add another teaspoon of each solute to each container. Did the solubility change?

Saturation

While some chemical substances are soluble in a solvent, there will always be a limit to the solubility. For example, when salt is added to water, it readily dissolves to form a solution. But if too much salt is added to water, eventually there will be no more space left for the salt to dissolve in the water. The solution is now called a **saturated** solution. This is like having a towel saturated with water after you drop it in the pool – the towel cannot take in any more water. A saturated solution is so concentrated that no more solute will dissolve into the solvent.

saturated
a solution with the maximum amount of solute dissolved in the solvent

Explore! 8.1

Safe drinking water

Seqwater is a company responsible for managing Queensland's water assets on behalf of the community. They supply drinking water, catch and store water, recycle water, protect the waterways and maintain drainage systems. Research and find out what is added to our drinking water to make sure it is safe to drink. What is the role of each of the additives?

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Section 8.2 questions

QUIZ

Retrieval

1 **Define** the following terms: saturated solution, aqueous solution, dilute solution, concentrated solution.

2 Each of the following statements are incorrect. Rewrite each statement and **select** the appropriate word(s) to make the statement correct.
  a Soluble is when a substance cannot be dissolved in a solvent.
  b The solvent dissolves in a solute to form a solution.
  c A mixture is when different substances are chemically combined.
  d A saturated solution is a solution in which the minimum amount of solute has been dissolved.
  e In a solution, it is the solute that is unable to dissolve into the solvent.
  f Concentrated solutions have a lot of solvent compared to the amount of solute.
  g A suspension is a mixture in which a solute is dissolved in a solvent to form a transparent liquid.

3 **State** the solvent, solute and solution in the following situations:
  a fizzy water
  b vinegar
  c syrup

Comprehension

4 **Explain** why it is possible to see solid salt crystals in water but not possible to see the dissolved salt particles.

5 You were given a mug of diluted cordial and a mug of concentrated cordial. You were then asked to work out which was which without tasting it. **Describe** how you could do this and what results you would expect.

Analysis

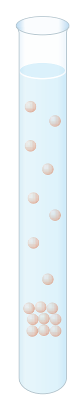
6 **Compare** solutions and mixtures. You may choose to use a Venn diagram.

7 **Justify** whether all solutions are mixtures or all mixtures are solutions. Give some reasons for your choice.

Knowledge utilisation

8 Look at this diagram of a test tube containing a liquid and a soluble solid. **Create** as many new diagrams as needed to show the following key terms. You may be able to include several terms on one diagram

dilute solution	concentrated solution
dissolve	aqueous solution
insoluble	soluble
solution	saturated solution



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8.3 Separation of heterogenous mixtures

WORKSHEET
Separation

Learning goals

1. To be able to describe how magnetism can be used to separate a mixture.
2. To distinguish between techniques used in the separation of mixtures such as decantation, flocculation, flotation and filtration.
3. To recognise the use of centrifugation in the separation of mixtures.
4. To investigate separation techniques used by First Nations Australians.

The chemical substances in mixtures can be separated into their pure parts by using the unique physical properties of the components. This is easier in heterogenous mixtures as the components are not well mixed and can usually be easily observed with the naked eye. For example, a separation technique called hand-picking involves picking out the different components by hand. Imagine a bowl of red and green lollies that could be sorted by picking out the red lollies by hand. This is not always the most effective separation technique, though. This section will explore other techniques commonly used with heterogenous mixtures.

Figure 8.11 A magnet can be used to separate magnetic substances from non-magnetic substances.

Magnetic separation

VIDEO
Oil spills

Magnetic separation is a type of hand-picking where the components picked are magnetic and the hand is a magnet! Imagine you are carefully constructing a shelf in a woodwork class and you drop some iron nails in the sawdust-covered floor. A magnet would pick up only the magnetic nails and leave all the sawdust remaining on the floor. Not all metals are magnetic, so magnetic separation can even be used to separate some metals. This is how steel and aluminium cans are separated in a materials recovery facility.

decantation
the process of separating by using density

Decantation

If you have accidentally dropped a marble in your drink at a birthday party, the marble will sink to the bottom of your glass. The process of **decantation** can help you separate your drink from the marble using the different densities of the components of the mixture. Decantation is a technique where you carefully pour the liquid off the top of a solid–liquid mixture or a liquid–liquid mixture, to separate the two components. You may have done this when pouring water off the top of your vegetables once they have been boiled for dinner.

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Flocculation

Sometimes decantation is tricky if the solid particles in the liquid are very small or fine. A **flocculant** is a chemical substance that can be added to a solid-liquid mixture to help the solid particles clump together. Once the solid has clumped together, it can be more easily hand-picked or decanted. Flocculants are used in swimming pools to aid in the cleaning of small solid particles.

Figure 8.12 Samples of water with flocculant added (left) and the resulting water after treatment (right)

Figure 8.13 The soap froth on this bathtub could be separated from the underlying water due to its ability to float.

Flotation

Flotation is another separation technique but, in this case, the components of a mixture are separated based on their buoyancy or capacity to float. For example, oil floats on water so this allows for the clean-up of ocean oil spills. Firstly, booms (floating barriers) are placed around the oil to help contain it. Skimmers (boats with vacuum machines, sponges or oil-absorbent ropes) then soak up the spilled oil from the surface within the booms.

Filtration

Filtration is a technique used to separate the components of a mixture based on their state of matter or their solubility in a solvent by passing them through a filter. Filters are used for many applications including coffee makers, vacuum cleaners and pool filters. The holes in the filter are sized according to what is being filtered. For example, a filter basket in a pool has holes that you can see, as leaves are not microscopic; however, the holes in a coffee filter are much smaller as the coffee granules are smaller.

flocculant
a chemical substance that causes particles to clump together

flotation
separating a mixture based on the capacity to float

filtration
separating a mixture with different states of matter by passing through a filter

sieving
separating solids based on the size of particles

Sieving is another type of filtration where the filter is a sieve that generally separates solids based on their size. You might have seen sieving in action with the use of flour sifters or salt and pepper shakers. These sieves have particular sized holes that allow similarly sized particles to move through.

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Figure 8.14 Pasta and water are separated by sieving using a colander.

Explore! 8.2

Traditional separation techniques

First Nations Australians have been separating heterogenous mixtures for centuries. Separation techniques are essential to purify food and water sources. Research how each of the following methods might be used by different groups of First Nations Australians to prepare a meal:

1. hand-picking
2. sieving
3. winnowing
4. yandying
5. cold-pressing
6. steam distilling.

Figure 8.15 Boab pods in a koolamon (a carrying vessel) used by First Nations Australians. A koolamon is often used to separate seeds from their outer shells. The word koolamon originally came from the language of the Kamilaroi people of northern New South Wales and southern Queensland.

Quick check 8.5

1. Recall what you should use to separate a mixture of sand and iron.
2. Explain what might prevent a magnet being useful to separate the components of a mixture.
3. Identify a situation when hand-picking would be the most appropriate way to separate a mixture.
4. Explain the separation technique of decantation.
5. Explain the relationship between density and the separation technique of flotation.

Did you know? 8.2

Filters in the home

Filters are used in the home for more than just cooking. For example, there are air filters attached to air conditioning units to separate solid particles in the air before the cool breeze is blown in your direction. A tumble dryer also has a type of filter that catches lint from clothes and ensures it doesn't mix back in with all the other clothes!

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Filtrate and residue

After filtration, there will be a substance remaining on the filter that was too large to pass through and another substance in the underlying container that has passed through the filter. The substance on the filter is called the **residue**, while the substance that passes through the filter is called the **filtrate**.

residue
the substance that is left in the filter

filtrate
the substance that passes through the filter

Did you know? 8.3

The filter-feeding system

Toothless whales, such as the humpback whale (*Megaptera novaeangliae*), contain a very fine filter in their mouth called baleen. This allows the whales to take a large mouthful of ocean water and filter out small animals such as fish and krill to be consumed. This is called the filter-feeding system.

Figure 8.16 The mouth of a humpback whale (*Megaptera novaeangliae*) contains baleen, which allows them to filter the ocean water for krill.

Investigation 8.1

Separating heterogeneous mixtures

Be careful
Do not test water by consuming it.

Aim

To compare the effectiveness of *different* separation techniques for cleaning contaminated water.

Prior understanding

Separation of heterogeneous mixtures relies on each different substance having a unique set of physical or chemical properties. Each difference in property (e.g. one substance is magnetic and the others are not) is used to simultaneously remove one substance from a mixture while the other substances are left behind.

An excellent application of this can be seen by researching the winner of the 2019 Google Science Fair, who was a school student who discovered a way to remove microplastics from seawater safely using a ferrofluid.

Materials

- alum (potassium aluminium sulfate) or equivalent
- contaminated creek water (simulated) – water from a fish tank (water left over from cleaning the filter is ideal), sand, clay, mud
- 3 glass beakers
- metal spoon
- 2 glass cylinders
- stirring rod or spoon
- funnel
- filter paper
- retort stand and clamp
- *optional: microscope with dropper, slide and coverslip to observe water*

Method

Use each of the following methods separately to identify which substances are removed by the process and the physical or chemical property that was used to isolate one substance from another.

1 Draw the table shown in the results section in your science book.
2 Test each of the following methods and record the results in the table for comparison.

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… continued

Decantation

3 Measure 100 mL of water into a cylinder.
4 Stir the water until it appears cloudy.
5 Leave the mixture undisturbed for 5–10 minutes so that solid substances can settle on the bottom.
6 Very carefully, pour the liquid off the top of the solid substances into a beaker so that they remain in the cylinder.
7 Record observations in the table.

Flocculation

8 Measure 100 mL of water into a cylinder.
9 Transfer into a beaker.
10 Stir the water until it appears cloudy.
11 Measure 3 mL of alum solution and stir the mixture for 2 minutes.
12 Leave the mixture undisturbed for 15 minutes.
13 Record observations in the table.

Filtration

14 Fold your filter paper as shown in Figure 8.17.
15 Set up your equipment as shown in Figure 8.18.
16 Measure 100 mL of water into a cylinder.
17 Stir the water until it appears cloudy.
18 Pour the mixture through the funnel and let it filter through the paper.
19 Record observations in the table.

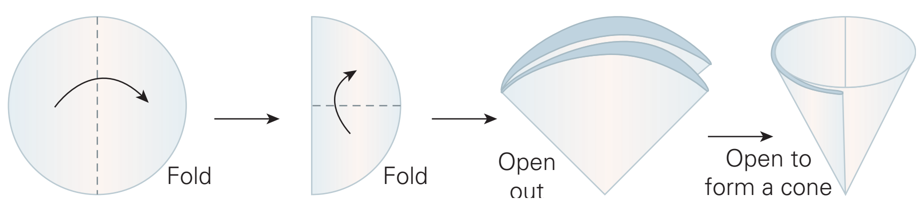

Figure 8.17 How to fold your filter paper

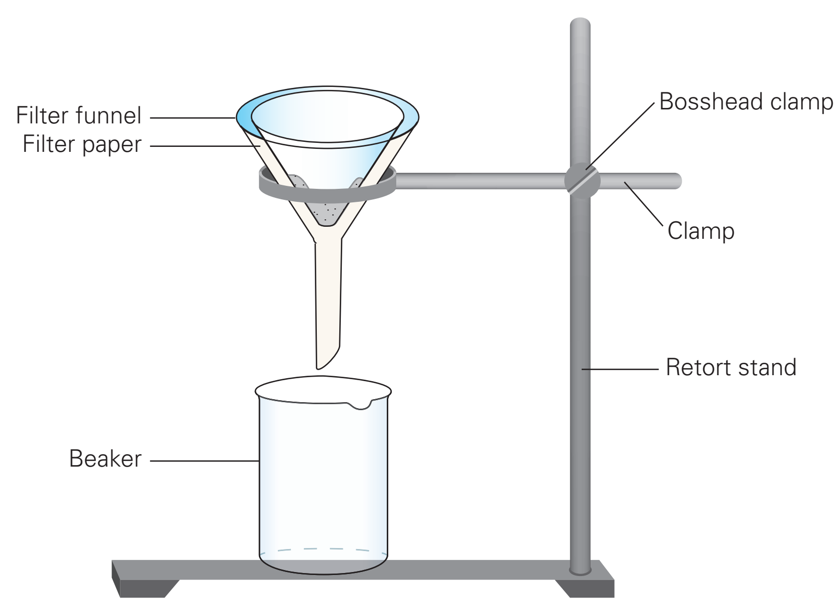

Figure 8.18 Practical set-up

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… continued

Results

Independent variable: Separation technique	Dependent variable: Water quality		
	Describe the initial condition of the water	Number of contaminants removed	Issues that may have affected the results, e.g. speed, incomplete removal of substance
Decantation			
Flocculation			
Filtration			

Analysis

1 Critique the effectiveness of each method by considering the number of contaminants removed and any issues that were found when testing it.
2 Describe how you could use these three methods in combination to remove contaminants from water.

Evaluation

Reliability

1 Compare the results with other class groups. Determine how much variation was found in the results.
2 Identify the method that was the most reliable for separating out a contaminant based on the response in the previous question.

Limitations

3 Discuss whether these three methods effectively clean the water so that it could be consumed by humans.
4 *Optional: place a drop of the contaminated water under a microscope and observe. Review the answer to Question 3 above.*

Improvements

5 Propose any changes that could be made to the method to improve the quality of the data in future experiments.

Did you know? 8.4

Filters in the human body

After eating and drinking, your body does a very good job of absorbing all the nutrients it needs to continue to live and grow. But there are always some waste products left over that your body doesn't need. This could be excess water or too much salt, sugar or protein. This is where the kidneys' job starts! The kidneys are made up of thousands of microscopic filters called nephrons, and these nephrons filter all waste products out of the blood and send them on their way to the bladder. These waste products are then excreted from the body as urine.

Figure 8.19 Kidneys filter waste products from your blood to produce urine.

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Quick check 8.6

Identify the correct words from the following sentences to answer the questions. Copy and complete the sentences by selecting the correct terms for each.

A small amount of sand is mixed with ocean water. This heterogenous mixture was passed through a filter paper and the filtrate and residue were collected.

1 What will remain in the filter paper?
2 What will pass through the filter paper?
3 The filtrate is the ___________.
4 The residue is the ___________.
5 The residue is found in the ___________.
6 A filter funnel can separate two substances in a mixture when those two substances have different ___________.

Science as a human endeavour 8.1

The Gold Coast Desalination Plant

The Gold Coast Desalination Plant, in Tugun, annually provides relief to the water supply of Brisbane and the Gold Coast. The plant provides a source of water that is unaffected in times of drought or flooding and has been filtered over several steps of purification. After seawater has been drawn in through an underground pipe, the water is first filtered to remove any sand and other solid substances. The second filtration technique, called reverse osmosis, then starts. This is where the filtered seawater is forced through an ultra-fine membrane that contains extremely small pores, which only let water particles through. The salt particles are too large to pass through and so are returned to the ocean as a concentrate, and fresh water continues in the process to be treated and then distributed.

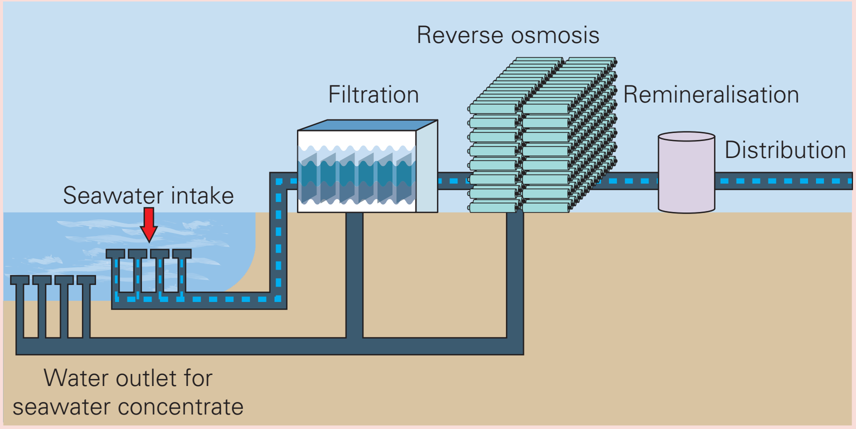

Figure 8.20 Desalination process

Unfortunately, the salt concentrate (brine) from desalination plants that is released into the ocean can cause serious environmental consequences to marine ecosystems as it reduces oxygen content in returned water. In addition, the process has high energy costs and marine organisms can get trapped in pump systems that draw in the water.

Investigate how the following can reduce impacts to marine ecosystems:

- slanted intake wells
- commingling.

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Centrifuging

A **centrifuge** is a device that can separate chemical substances based on their mass (how heavy they are) by spinning them very fast. During spinning, the heavier chemical substances move towards the outside of the centrifuge. An example of this is a blood sample that can be separated into its components of red blood cells, white blood cells, platelets and plasma. After centrifugation, the heaviest component (red blood cells) are at the bottom of the vial, white blood cells and platelets are in the middle of the separated sample and the lightest component (plasma) is at the top of the vial (Figure 8.21).

centrifuge
a device that uses speed to separate substances based on mass

VIDEO Centrifuging blood

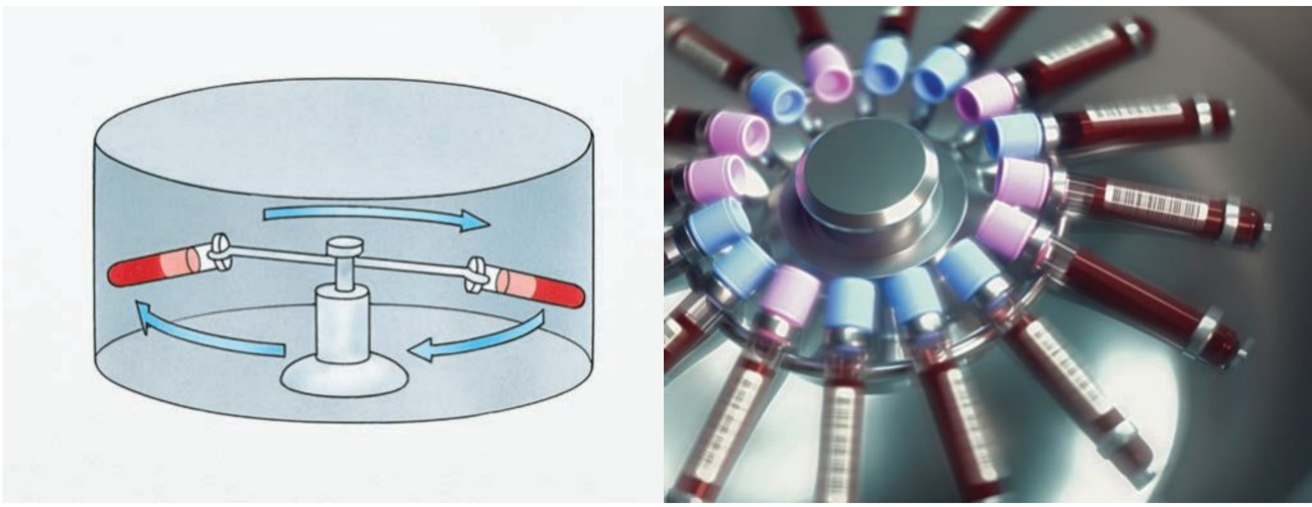

Figure 8.21 Left: an illustration of a blood sample spinning in a centrifuge, showing the separation of different components. Right: blood samples ready for separation in a centrifuge.

Did you know? 8.5

Skimming milk

Full-cream milk is a mixture that contains milk and cream. At the supermarket, you might have recognised milk with a red cap, commonly called 'skim milk'. This type of milk is one that has had the milk content separated from the cream and fat globules using a centrifuge! The full-cream milk enters the spinning centrifuge and the heavier milk component moves towards the edge of the centrifuge while the lighter cream remains in the middle. The separated milk is then collected as 'skim milk' with a lower fat content for consumption.

Figure 8.22 Centrifugation of full cream milk results in 'skim milk'.

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Section 8.3 questions

QUIZ

Retrieval

1 **Identify** which of the following cannot be separated using a centrifuge: components of blood, water on lettuce leaves, cream from milk, salt from seawater.

Comprehension

2 **Describe** how centrifugation separates the substances in a mixture.

3 **Explain** why filtering does not always separate a mixture.

4 **Explain** why dissolved sugar cannot be filtered from water. Use the terms you have learned earlier in this chapter in your response.

Analysis

5 **Describe** the separation technique of hand-picking used by First Nations Australians to sort various food items. Comment on whether this technique could be used to separate a bin full of recycling material.

6 **Explain** why filtering water does not guarantee that the water is pure.

Knowledge utilisation

7 Face masks have become more frequently worn in the community since the start of the COVID-19 pandemic. Suggest why the N95 face mask shown in Figure 8.23 is recommended in preference to cloth masks for protecting against viruses.

Figure 8.23 An N95 face mask

8 All of the filters in Figure 8.24 are used in the home.

a For each, **determine** the:
- components of the mixture
- residue
- filtrate

b Each of the filters has a different mixture to separate. **Discuss** how the different-sized and different-shaped holes of the filters can affect the separation of the mixtures.

Figure 8.24 Filters used for a variety of purposes. Can you think of any other common filters used in your daily life?

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8.4 Separation of homogeneous mixtures

Learning goals

1. To be able to recall the use of chromatography for industrial applications.
2. To distinguish between evaporation and crystallisation as techniques to separate a dissolved solid from a liquid.
3. To be able to identify distillation as a method to separate a mixture of soluble liquids.

WORKSHEET Chromatography

VIDEO Paper chromatography of inks

VIDEO Paper chromatography of food colourings

Homogenous mixtures are generally more challenging to separate given the physical properties of the mixture appear much more uniform than in heterogenous mixtures. However, separation methods such as chromatography, crystallisation and distillation can separate the components of some of these mixtures.

Chromatography

Chromatography is a technique used to separate the substances in a mixture based on their solubility, which is their ability to dissolve in a solvent (and also their attraction to a solid material such as paper). Look at Figure 8.25. This is the common set-up for carrying out paper chromatography. In this example, the coloured components that make up a vegetable stock are being separated. The mixture (vegetable stock) is made to move by a solvent (such as water) through another substance that stays still, such as paper, until the components separate. The more soluble the components of the vegetable stock are in the solvent, the more quickly they will move up the filter paper with the solvent. The 'mobile phase' is the name given to the solvent moving with the soluble parts of the mixture in it. The substance that stays still is called the 'stationary phase'. Chromatography is often used in industry, although it is probably not something you commonly hear about. These are some examples:

- In forensics, chromatography allows you to analyse and separate the components of ink in pens to catch the forger or the writer of a ransom note.
- In toxicology, gas chromatography is used to separate the components of a poison so that it can be identified and neutralised.
- In pharmacology, chromatography allows for the testing of the purity of medicines and drugs.
- In fashion, chromatography helps break down the different components of the dyes in clothing.
- In athletics and other sports, gas chromatography is used to check if the sportsperson has been using any prohibited substances.

chromatography
a technique to separate substances based on different solubilities in a solvent

Figure 8.25 Paper chromatography can be used to separate vegetable pigments, where the yellow component is most soluble and the orange is the least soluble in the solvent.

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Practical skills 8.1

Separating the pigments in water-soluble colour marker pens

Aim

To separate the pigments from water-soluble marker pen ink using chromatography.

Materials

- water
- large beaker
- long strips of filter paper
- icy-pole sticks
- paperclips
- ruler
- water-soluble colour marker pens

Method

1. Use a pencil to draw a line across each filter paper strip 1.5 cm from the bottom. Label the icy-pole sticks A, B and C – one position for each of three strips of filter paper.
2. Add enough water to the beaker so that the pencil lines will sit above the water line.
3. Using the water-soluble colour marker pen, draw a small dot on the filter paper in the middle of your pencil line.

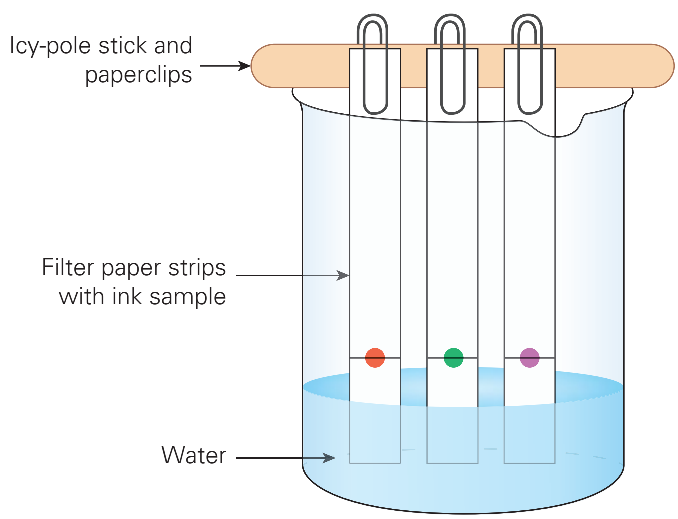

Figure 8.26 Experimental set-up

4. Fold the paper strips over the icy-pole stick, as shown, and clip them on using the paperclips.
5. Repeat steps **1–4**, this time using different coloured marker pens.
6. Lower the three samples into the water in the beaker, making sure the ink spot is above the water and the end of the paper stays in the water.
7. Leave the strips for about 10 to 20 minutes after placing them into the water.
8. Remove the paper strips (called chromatograms) from the beaker when the water has reached approximately 2 cm from the top of the paper and leave them to dry somewhere safe.

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Results

Stick your dried chromatograms into your science book (or take a photo and upload it to your practical report file).

Analysis

1 The chromatogram formed is unique for each type of pigment. Discuss what you found out about the different pigments in the ink of the different coloured pens.
2 Identify possible sources of error when using this separation technique.
3 Discuss how you could minimise the impact of these sources of error in the future.

Conclusion

Copy and complete this statement in your science book. From this activity it can be claimed that pen ink ______________. This is supported through observations that ______________. Therefore, it can be concluded that ______________.

Did you know? 8.6

High performance liquid chromatography (HPLC)

The pharmaceutical industry is responsible for creating and producing novel medicines that contain useful drugs to combat disease. When creating new chemical substances, by-products and impurities are common, meaning that HPLC is commonly used. It uses the same principle of separation based on solubility of components as is used in paper chromatography. However, instead of paper, the stationary phase is a densely packed column under a high pressure of liquid. HPLC allows pharmaceutical scientists to purify important chemical substances to be used in new medicines.

Figure 8.27 A densely packed HPLC column

Evaporation and crystallisation

Evaporation is a change in state from a liquid to a gas, but it can also be used as a separation technique. Evaporation can be used to separate a dissolved substance (solute) from its solvent in a solution by heating the mixture up so the liquid part turns into gas. For example, the water in salt water will evaporate when heated, leaving behind salt crystals – the water and the salt are separated by evaporation. Another example is drying wet washing in the sun on the clothesline or dehydrating baby peas in the pantry.

evaporation
when heat causes liquid to become gas

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Did you know? 8.7

Watercolour painting

Figure 8.28 A watercolour painting

You might remember using 'watercolour paints' at some stage in your schooling during art class. These paints are mixtures containing a water-soluble colour pigment and binding agent as well as a water-based solvent. While painting with watercolour paints, the artwork can become quite wet with water. However, the water is soon separated from the painting mixture by evaporation, leaving behind a dried piece of art. This is a separation technique you might already be familiar with!

Crystallisation

When evaporation of a solvent occurs slowly, the solute can often form a crystalline solid in the evaporating solution. This is called **crystallisation** and, once formed, the solid crystals can be filtered or hand-picked from the remaining solvent. The crystal begins to form as the concentration of solute increases while the solvent is slowly evaporating. Eventually the solution becomes saturated and, as the solvent continues to evaporate, the solute can no longer remain dissolved. Every chemical substance has a unique shape, colour and size, and these can be stunning to look at!

crystallisation
the process through which certain solutes can form into a crystalline solid when a solvent evaporates slowly

You may have noticed salt crystals form on your skin after leaving the salty ocean water. To make the biggest crystals, the evaporation of solvent should be as slow as possible. How could you set up an experiment to grow large salt crystals?

Figure 8.29 Salt crystals can form by the slow evaporation of water from a crystallisation pond.

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Quick check 8.7

1 Select the correct term from the list to copy and complete the sentences: filter, pigments, solvent, water.
Chromatography is a technique that can separate different components of a mixture, such as different ___________ in ink or in a leaf. Samples of different mixtures are put on a piece of ___________ paper, and the paper is put into a solvent. If the mixture dissolves in water, then ___________ can be used for the solvent. If the mixture does not dissolve in water, then a different ___________ such as methylated spirits, must be used.

2 Organise the following statements by numbering them to indicate the order they occur in the process of paper chromatography.
- ______ Place your sample in the centre of the pencil line.
- ______ Place a small volume of water into a beaker (about 1 cm deep).
- ______ Make sure the sample dot does not go below the surface of the liquid in your beaker.
- ______ Leave for 20 minutes until the solvent reaches the top of the filter paper.
- ______ Draw a line using a pencil across a filter strip 1 cm from the bottom.
- ______ Fold the paper strips over the icy-pole stick, clip them and lower them into the water in the beaker.

3 Define the key terms 'evaporation' and 'crystallisation'.

4 Develop a method that would allow you to separate salt and ground pepper (which can float) when they are all mixed up together. Include the concepts of 'evaporation' and 'crystallisation' in your explanation.

Practical skills 8.2

Using evaporation to separate mixtures

Be careful
Observe general fire safety.
Wear safety equipment.

Aim
To analyse the mass of salt contained in a concentrated salt solution.

Prior understanding
Homogenous mixtures contain particles too small to be seen with the naked eye. Solutions are mixtures where one substance is dissolved into another. Separation of substances in a solution relies on each substance having a unique set of physical or chemical properties. One unique property of substances is their boiling point. When a mixture is heated, each substance will evaporate at different temperatures, leaving the other substances behind.

Materials
- concentrated salt water
- measuring cylinder
- 250 mL beaker
- Bunsen burner
- tripod
- matches
- heatproof mat
- gauze
- safety goggles
- scales

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Method

1 Copy the results table into your science book.
2 Weigh the mass of the beaker using the scales. Record in the table.
3 Measure 100 mL of concentrated salt water into the beaker.
4 Set up the tripod and gauze over the Bunsen burner.
5 Place the beaker on the gauze.
6 Light the Bunsen burner as described in Practical Skills 1.2 in Chapter 1.
7 Allow the mixture to boil until there is 25 mL of water left in the beaker.
8 Turn off the gas.
9 Leave the beaker on the tripod to cool.
10 When cool, pack up the equipment and leave the beaker in a warm place to allow the remainder of the liquid to evaporate for a few days.

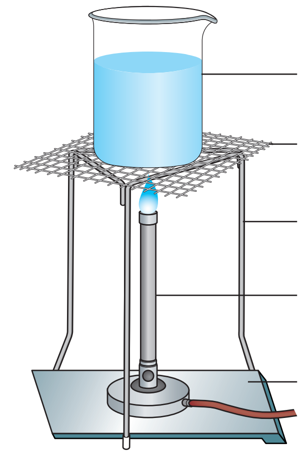

Figure 8.30 Experimental set-up

Next lesson

11 Weigh the beaker and record the mass.
12 Calculate the change in mass.

Results

Mass (grams)	Group result	Class mean
Empty beaker		
Beaker + salt		
Mass of salt		

Analysis

Draw a labelled diagram that clearly shows how to set up the equipment for this separation method.

- Follow the rules for drawing scientifically.
- Use a sharp pencil.

Peer review

1 Swap experimental diagrams with another group and give each other feedback on how clearly the diagram communicates how to set up the separation method. Your feedback should discuss the following:
   - how well the diagram follows the rules for scientific drawing
   - any other suggestions to improve the quality of communication.
2 After receiving feedback, make alterations to the diagram to address the identified issues and write up a final copy to present to the class.

Evaluate

Reliability

1 Compare your result with the actual mass of salt that was dissolved in the water (your teacher has this information).
2 Compare your result with those of other groups. How much variation was observed between the final results for the mass of the salt?
3 Calculate a class mean for the mass of salt that was dissolved in 100 mL of water.
4 Determine if a reliable conclusion could have been drawn about the mass of salt per 100 mL based on the mean class results.

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Limitations

Most natural water sources contain a variety of dissolved salts.

5 Discuss how this would affect the validity of the conclusion drawn about the mass of salt that was dissolved into the water to make the test solution.

Improvements

6 Propose changes to the method to improve the quality of the data in future experiments.

Distillation

During the evaporation method to separate a mixture, what if you want to collect the evaporating solvent? This can be done with the **distillation** method. In distillation, a solution of two soluble liquids or a solution containing a solid solute is heated in a flask (Figure 8.32). The solution is heated to the boiling point of the solvent so the solvent boils and becomes a gas. The gas is then collected in a Liebig condenser, which is cooled by surrounding cold water, and the gas condenses back to the liquid state. The solute remains in the flask while the solvent evaporates and is caught in a beaker as it condenses at the end. This is called the **distillate**. All components of the mixture have been separated and retained.

distillation
a technique to separate substances in a liquid using evaporation through boiling and condensation

distillate
the condensed liquid product from distillation

Figure 8.31 Essential oils can be distilled from plant matter, such as rose oil from rose petals.

VIDEO
Distillation

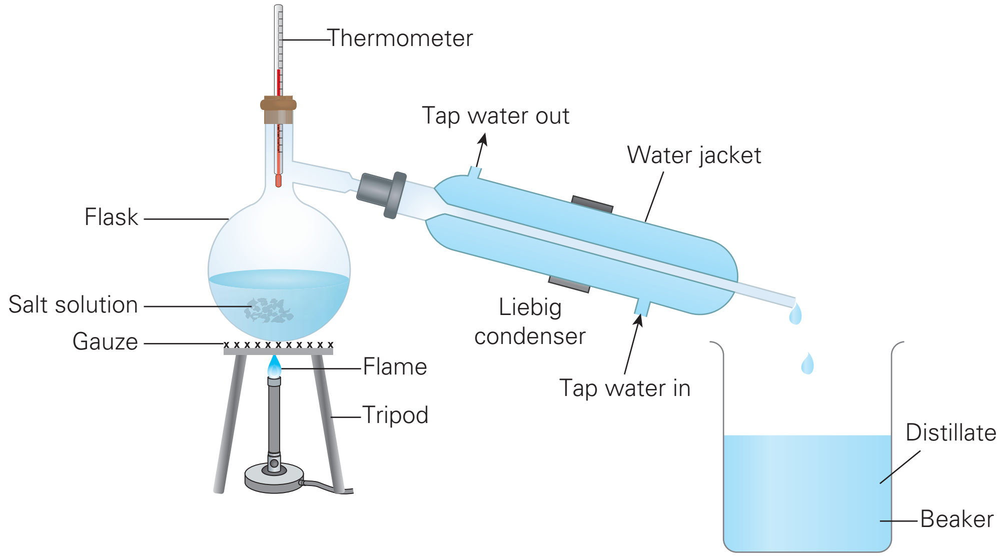

Figure 8.32 A Liebig condenser is used for the process of simple distillation.

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Practical skills 8.3 Teacher demonstration

Distillation

Be careful

Apparatus can become extremely hot during the experiment. Ensure water pressure is slowly increased so that internal stress is not introduced to the condenser.

Aim

To observe the process of distillation.

Materials

- water
- table salt
- 2 × 250 mL beakers
- Bunsen burner
- distillation apparatus
- spatula
- tripod
- safety goggles

Method

1. Set up the equipment for distillation as shown in Figure 8.32.
2. Wear safety goggles.
3. Put 100 mL of water into one of the beakers. (The other one will collect the distilled water.)
4. Use the spatula to add salt and stir.
5. Continue adding salt until the solution is very concentrated but not saturated. Pour the concentrated salt solution into the round-bottomed flask of the distillation apparatus.
6. Turn on the water that circulates in the condenser.
7. Heat the salt solution.

Results

Describe your observations of this process. How did the original solution look? What substance was left behind in the round-bottomed flask?

Analysis

1. Why was it necessary to heat the salty water solution?
2. Explain how the condenser works.
3. Which part is the distillate?

Evaluation

1. What were possible sources of error when using the different separation techniques?
2. How could you minimise the impact of these sources of error in the future?

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Science as a human endeavour 8.2

Purifying mixtures without using heat

Scientists and engineers are trying to find ways of purifying mixtures without using heat. If they could achieve this, it would lower energy use across the world and, consequently, lower dangerous emissions and pollution. Distillation and other separation techniques that use heat account for 10% to 15% of the world's energy consumption. Alternatives such as the separation techniques covered in this chapter are very expensive to do on such a large scale.

Currently, crude oil is removed from the ground and its components are separated by fractional distillation. When crude oil is heated, petrol is one of the first gases that forms as it has a low boiling point compared to other liquids in the mixture. Engineers in industry are looking to develop other ways to separate the components of crude oil when there are many groups of particles in the mixture.

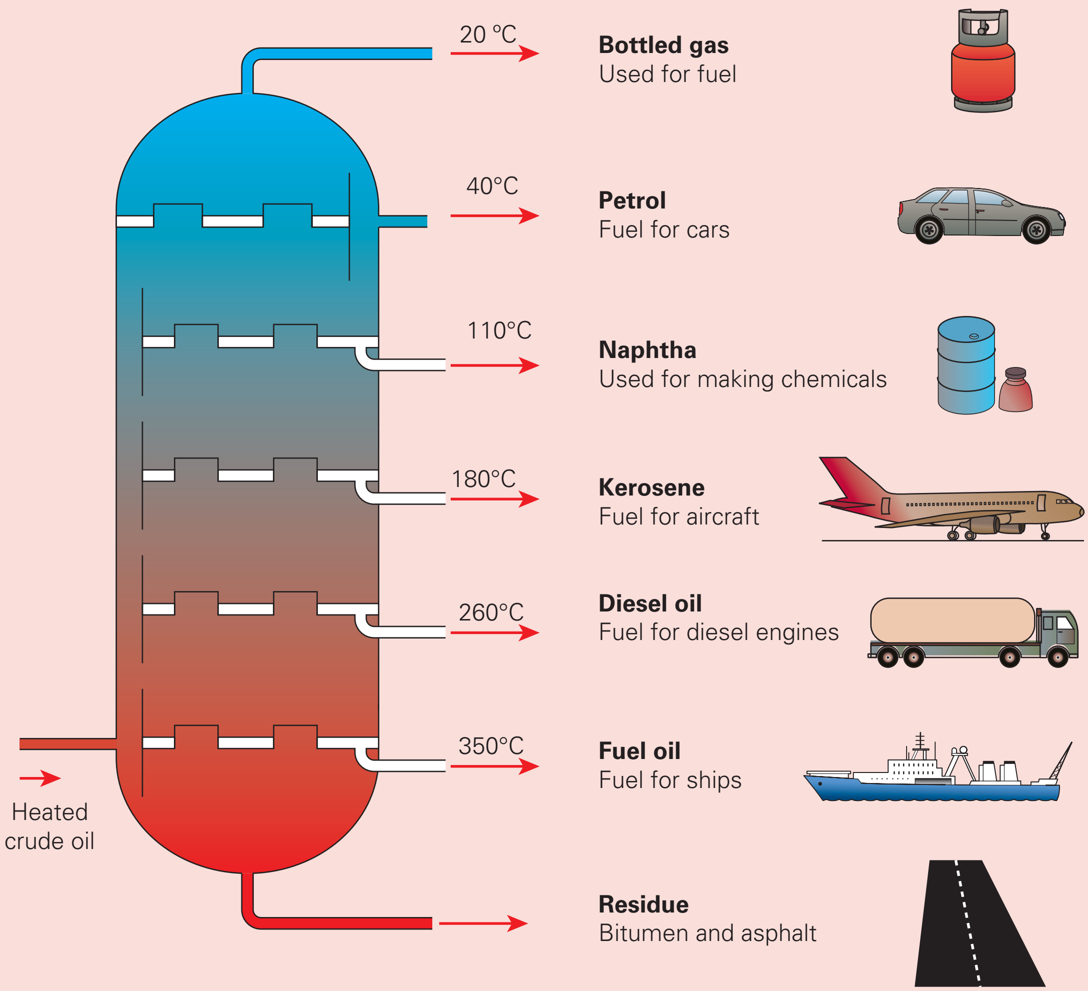

Figure 8.33 Fractional distillation of crude oil

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Explore! 8.3

Essential oils

The formation of essential oils and perfume relies on the separation technique of distillation.

1. Investigate the role of distillation in the creation of essential oils and perfume.
2. Compare the distillation process used to make essential oils and perfume to the one used in your classroom.
3. Summarise how and why three other industries use distillation.

Figure 8.34 To bottle lavender essential oil, it must first be distilled from the lavender plant.

Think about your future

Whichever career you may be interested in, separation techniques will be a part of your world! Consider some of the careers that you have come across in this chapter alone.

WIDGET
Separation methods

Toxicology	Doctors/medical	Pharmaceuticals	Forensics
Fashion industry	Geologists	Water treatment	Engineers
Pathologists	Refineries	Farmers	Chefs
Archaeologists	Mining	Beverage industry	Sports industry
Recycling	Desalination plants	Crude oil processing	Environmental work
Dairy industry	Dentistry	Perfume industry	Botany

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Section 8.4 questions

QUIZ

Retrieval

1 **Label** the parts (A–G) of the Liebig condenser and other equipment indicated in Figure 8.35.

2 **Define** the terms 'distillation' and 'evaporation'.

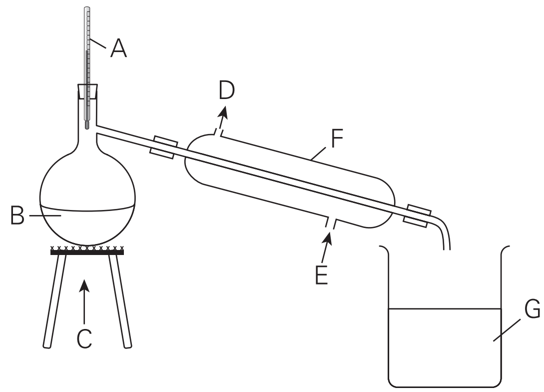

Figure 8.35 Liebig condenser and other equipment

Comprehension

3 **Describe** the similarities and differences between distillation and evaporation.

4 **Explain** what happens to particles during the process of evaporation and the process of condensation. Draw pictures of the particles to help in your explanation.

Analysis

5 **Compare** the separation techniques of evaporation and crystallisation.

Knowledge utilisation

6 a **Label** the diagram in Figure 8.36 (A–C).

b **Explain** what is meant by 'mobile phase' and 'stationary phase'.

c **List** the colours in order from least to most soluble in the solvent.

d **Describe** why the bottom line should be drawn in pencil and not in pen.

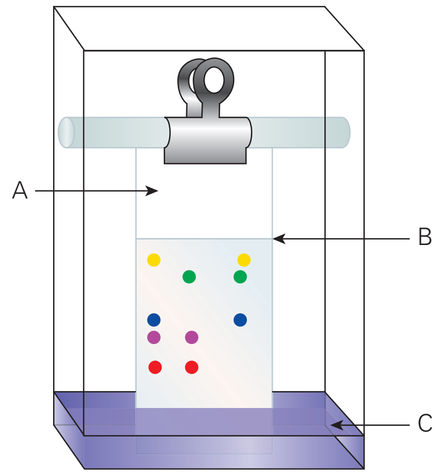

Figure 8.36 Chromatograph

7 Substances X, Y, Z, W and sugar were mixed in water. The properties of each substance are listed below.

Substance	Solubility in water	State at room temperature	Boiling temperature (°C)
Sugar	Soluble	Solid	>110
X	Soluble	Liquid	86
Y	Soluble	Liquid	68
Z	insoluble	Solid	>800
W	insoluble	Solid	86

Determine the steps for how you would separate the mixtures.

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Chapter review

Chapter checklist

You can download this checklist from the Interactive Textbook to complete it.

Success criteria		Linked questions	Check
8.1	I can identify the difference between pure substances and mixtures.	9	
8.1	I can contrast homogenous and heterogenous mixtures.	2, 22	
8.2	I can identify solvents, solutes and solutions.	1	
8.3	I can describe a range of separation techniques to separate heterogenous mixtures.	10, 15, 21, 28	
8.3	I can describe a range of separation techniques that are used by First Nations Australians.	12, 26	
8.4	I can describe a range of separation techniques to separate components of homogenous mixtures.	10, 15, 21, 27	

Review questions

Retrieval

SCORCHER

1 **Define** the following key words:
 a Solvent
 b Solute
 c Solution
2 **Recall** a real-world example of a homogeneous mixture and a heterogeneous mixture.
3 **Recall** the name of the piece of paper at the end of a chromatography experiment.
4 **Select** words from this list to complete the following paragraph.

boiling temperatures   condensed   distillate   evaporated   liquids

Distillation is a method used to separate _______ according to their ______. The liquid is ______ at a certain temperature, the vapour collected and then _______ to form a liquid again. The liquid collected during this process is called the ________. The residue is the mixture that remains in the original container.

5 **Select** words from the list to complete the following paragraph (some words may be used more than once):

filter   filtrate   funnel   large   residue   small

The apparatus used to separate the sand from the salt solution consists of ______ paper inserted in a glass ______. The mixture of the salt solution and sand is poured into the ______. The _______ paper acts as a sieve, separating the particles by size. ______ particles flow through the tiny holes of the filter paper and go into the beaker. These particles are called the ______. The ______ particles become trapped in the filter paper and are called the _______.

6 **Identify** industries that use the following separation techniques:
 a Distillation
 b Filtration
 c Centrifugation
 d Evaporation

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7 **Identify** which method of separation **(1–5)** you would use to perform the separations **(A–E):**

1	Evaporation	A	Separation based on magnetic properties
2	Filtration	B	Separation based on heating liquid
3	Chromatography	C	Separation based on evaporation and condensation
4	Distillation	D	Separation based on size
5	Magnetism	E	Separation based on solubility

8 a You decide to make toffee by dissolving sugar in water. **State** which would be faster: using big sugar cubes or using regular sugar crystals.

b **Recall** what else you can do to make the sugar dissolve faster.

9 **Identify** which of the following substances is a mixture: smog; distilled water; oxygen gas; pure gold.

10 **Determine** whether the following separation techniques are of a solid, liquid or a gas, and describe the property that this separation is based on. Give an example from home. You may choose to do so in table format as shown.

Method of separation	Description of how it works	Example from home
Decanting		
Flocculation		
Evaporation		
Filtration		
Crystallisation		

11 Provide an example of a mixture you would separate using evaporation. **Explain** why no other method would work better.

12 **List** three techniques used by First Nations Australians to separate mixtures.

Comprehension

13 **Describe** the correct order of the steps needed to obtain salt from a mixture of salt and pepper.

14 **Distinguish** between:

a a colloid and a suspension

b a suspension and a solution

15 **Describe** how the following mixtures could be separated into their components:

a How could you get the copper sulfate from copper sulfate solution?

b How could you get the water from clothes?

c How could you get the peas out of a mixture of peas and water?

d How could you get the oil out of a mixture of water and oil?

e How could you get sand from a mixture of sand and iron filings?

f How could you get the red dye from the blue dye?

16 a An emulsion is a type of mixture that is formed when a colloid of two or more liquids spread evenly through one another. Provide an example of an emulsion and **explain** how it is different from a suspension.

b Mayonnaise and salad dressing often contain similar substances. A bottle of salad dressing is usually shaken before it is added to a salad. **Provide** an inference for this.

Analysis

17 **Organise** the colloid name **(A–E)** to the states of matter that make up the colloid **(1–5)**.

A	Hair gel	1	A gas in a liquid
B	Mist	2	A liquid in a solid
C	Smoke	3	A liquid in a gas
D	Foam	4	A solid in a gas
E	Emulsion	5	A liquid in a liquid

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18 Lottie was testing the solubility of some different household substances. Some details of what she found out are shown below.

Substance	Quantity (in grams) that dissolved in a 100 mL glass of water
Baking powder	15
Salt	45
Sugar	223
Flour	1

a **Determine** which substance Lottie found the most soluble.

b **Identify** which substance was the least soluble.

19 Lottie then looked at two glasses of salt solution she had on the bench at home. She thought one was a saturated solution and one was not but could not remember which was which. She put a crystal of salt in each glass and then left it overnight. What she saw in the morning is shown in Figure 8.37.

a **Determine** which glass contained the saturated solution.

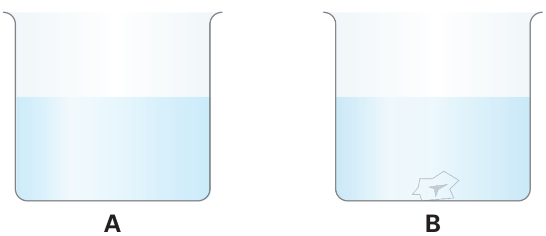

Figure 8.37 The crystal in glass A has disappeared, while the crystal in glass B has grown.

b **Justify** your response to part **a**.

20 Some liquid antibiotics suggest that you shake the bottle before you use them. **Explain** why this may be required, using terms you have learned in this chapter.

Knowledge utilisation

21 **Describe** the state of the substances being separated and their properties, for each separation technique. You may choose to do so in a table as shown.

Separation technique	Separation of solid/liquid/gas?	Property separation is based on
Distillation		
Magnetism		
Filtration		
Centrifuge		
Chromatography		

22 a **Draw** and label a diagram of a heterogeneous mixture showing how the particles are distributed.

b **Draw** and label a diagram of a homogeneous mixture showing how the particles are distributed.

23 **Explain** why soluble nutrients can be absorbed by the roots of plants through microscopic holes, but insoluble nutrients cannot.

24 **Explore** how you could separate:

a a liquid from a liquid

b a solid from a liquid

c a solid from a solid

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25 You have been doing a graphic design course and have created an awesome poster. However, you have forgotten which ink pen you used to create the main heading. Figure 8.38 shows the results of a chromatography experiment you carried out to identify the ink. Five inks were compared: A, B, C, D and E.

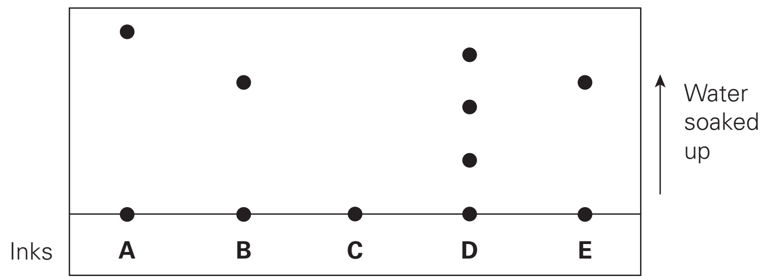

Figure 8.38 Chromatogram of your results

- **a** You know your ink is just one colour. **Identify** which ink sample is a mixture of different colours.
- **b** **Determine** which two inks are the same.
- **c** Given your ink is not soluble in water, **identify** which ink sample is yours.

26 Sieving is a useful separation technique for varying sized solid particles. **Describe** how sieving could be used in a recycling centre as well as how First Nations Australians use sieving to purify food sources.

27 A mixture of pure water and ethanol were accidentally mixed with an unknown substance X. X is highly soluble in water and proved very difficult to separate.
Describe how the mixture can be separated to give pure water, ethanol and substance X. Below are the boiling points of the three liquids.

Substance dissolved in the mixture	Boiling temperature (°C)
Substance X	120
Ethanol	78
Water	100

28 **Propose** the separation processes you would use to separate a mixture of pebbles, sand, salt and water. You may do so in a flow chart. Clearly show what was separated at each step.

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Data questions

Recycling centres in Queensland separate mixtures of recyclable material on a very large scale. The relative mass of paper and packaging components of the recyclable material sent for processing in Queensland in 2019–20 is shown in Figure 8.39.

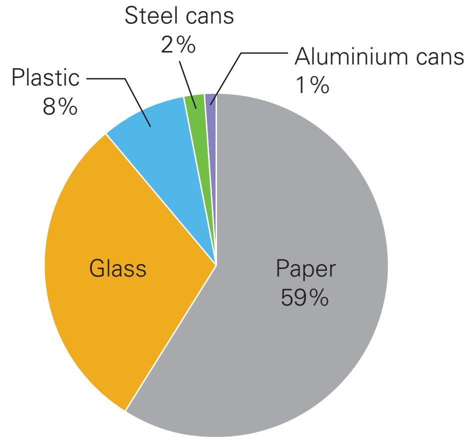

Figure 8.39 Relative mass of paper and packaging materials collected for recycling in Queensland, 2019–20

The mass of glass materials collected for recycling in Queensland from 2004–2020 is shown in Figure 8.40.

Apply

Questions 1–4 refer to Figure 8.39

1 At a Queensland recycling plant, a mixture containing each of the materials listed is sorted using separation techniques such as hand-picking and magnetic separation. **Identify** whether the mixture of recyclable materials is a homogenous or heterogenous mixture.

2 **Determine** which component of the paper and packaging mixture accounts for the smallest mass.

3 **Calculate** the percentage of mass that is made up of glass.

Analyse

4 **Sequence** the components of the paper and packaging mixture in order of the decreasing relative mass.

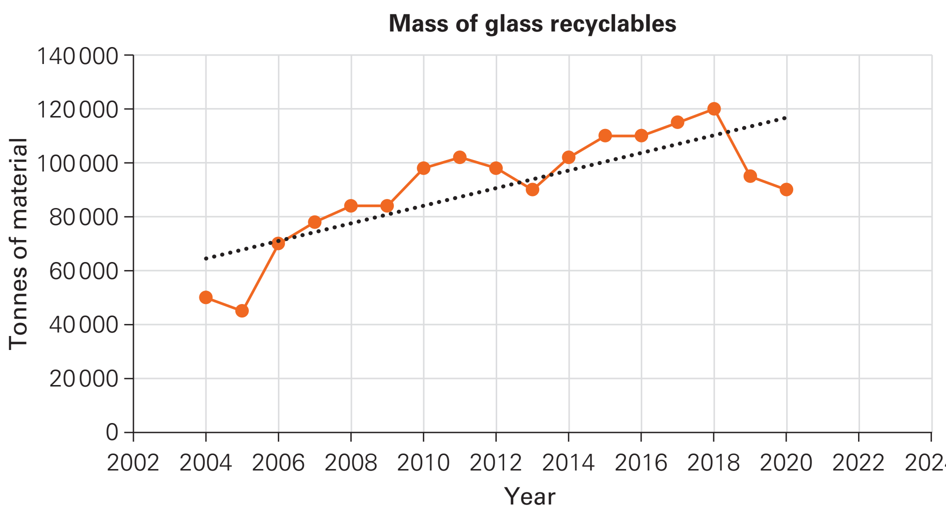

Figure 8.40 Approximate mass of glass collected (solid orange) for recycling in Queensland from 2004 to 2020 (trendline dotted black).

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Questions 5–9 refer to Figure 8.40

5 **Identify the trend** in the mass of glass collected for recycling over the period 2004–2020.

6 **Distinguish** between the information provided by the orange line and the information provided by the black dotted line.

Interpret

7 **Predict** how the trend in mass of glass collected for recycling will progress over the next ten years.

8 **Justify** why the trend would progress in the way you have predicted in question 7.

9 **Extrapolate** the trendline to the year 2024. What mass of glass do you estimate will be collected for recycling in that year?

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STEM activity: Responding to an oil spill

Background information

The Great Barrier Reef is one of the Seven Natural Wonders of the World. It is home to thousands of different types of fish, soft and hard coral, sharks, rays, turtles and marine mammals. This vulnerable ecosystem located off the Queensland coastline is threatened by many external factors, one being oil spills from boats and tankers carrying oil.

Oil has a lower density than water and because of this it floats on the surface of ocean water during an oil spill. This is a useful property as an oil spill can then be contained on the surface water. Unfortunately, oil sticks readily to marine life such as birds, turtles and fish, as well as land such as sand on beaches. Due to their serious impact on the environment, oil spills need to be responded to very quickly. Common clean-up methods employed by engineers include:

- using booms (inflatable containment barriers)
- skimming (vacuuming the oil spill from the surface water)
- absorbing (using sponge-like material to absorb and collect the oil)
- dispersing the oil (breaking up the oil into smaller particles).

In 2010, a cargo ship struck the reef, which caused large damage to the reef itself but also caused the release of approximately 3–4 tonnes of oil into the ocean. The oil slicked on the surface water and although there was a rapid response to disperse the oil, large amounts of tar washed up on the beaches of islands nearby. Booms and skimmers could not be used to collect the oil as the weather had caused large waves.

Figure 8.41 Oil slick on the surface of the water from an oil spill

Design brief: Determine the most effective response to an oil spill on the Great Barrier Reef

Activity instructions

In this task you will play the role of environmental engineer and work together in your group to determine the most effective way to respond to an oil spill on the Great Barrier Reef. You will carry out a simulation of an oil spill and direct how it can be cleaned up. You will collect data about the oil removal and consider the effectiveness and cost of each method.

You will present your findings of the effectiveness and cost of cleaning methods in either a report or a presentation for the local government as a representative environmental engineer.

Figure 8.42 A boom is an inflatable barrier used to contain an oil spill.

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Research and feasibility

1 Complete the table by listing all the possible ways of cleaning up an oil spill and what materials you have access to that could do the job. For each material, consider whether they are a skimmer, absorber or dispersant. Then record how expensive you think each might be.

Material	Effect on oil spill	Skimmer, absorber or dispersant (and cost)
Detergent		
Cotton balls		
Plastic spoon		
Small sponge		
Paper towel		

2 Consider how you will record your data on effectiveness of oil removal and cost.

3 Write a hypothesis for the experiment including a prediction of which material will be most effective at removing oil from water.

Design

4 Design a method in your group for the three different techniques of oil spill clean-up

- **a** using a skimmer
- **b** using an absorber
- **c** using a dispersant.

Note: You may want to pour your oil from a beaker into the tray and then, as you collect the oil, place it back into the beaker to help you measure before and after amounts to compare how effective the removal was. You should try to collect all the oil before it reaches the coastline.

Create

5 Using your set-up reef, place the ship in an agreed location (group consensus), and pour your oil mixture onto the water slowly. Try to completely remove the oil mixture using the skimmer technique. Spill the oil back into the water, then repeat for the absorber, and then the dispersant. Record your results in the table you designed in step 2.

Evaluate and modify

6 Construct a bar graph showing the effectiveness of each clean-up method and another showing the cost of each clean-up method.

7 Discuss with your colleagues whether the experimental data supports your hypothesis. Describe any sources of error in your experiment and how to prevent these errors from occurring in the future.

8 Consider the impact that ocean waves might have on the effectiveness of the skimming method for clean-up. Would it be cost-effective to have boats with specialised equipment for the task?

9 Consider the disposal method for absorbers that have soaked up the oil after the clean-up. Discuss with your colleagues how effective the absorber was as a clean-up technique, and where these absorbers should be disposed after use.

10 Discuss with your colleagues three possible impacts on the marine ecosystem of adding chemical dispersants to clean an oil spill.

11 Compare the measured volume of crude oil spilt into your ocean with the volume of crude oil you removed. What percentage of crude oil did you successfully remove from the ocean? Did one technique prove to be more effective? Explain the possible causes of any differences between the two volumes.

12 Using the information gained from your evaluation of the experiment, prepare a report for the local government that summarises your simulation findings. Include:

- **a** the different methods, their effectiveness and their costs
- **b** which method(s) you think should be utilised by environmental engineers in the future when cleaning up an oil spill in a local waterway.

Glossary

10% rule when energy is passed from one trophic level to another, only 10% of the energy will be passed on

Abiotic relating to the non-living things in an ecosystem

Abundance the number of individuals of a species within a community or ecosystem

Accuracy how close a measurement is to the true value

Adaptation a characteristic that helps an organism survive in its environment

Air resistance the frictional force of the air

Alloy a substance composed of two or more elements, usually metals

Analyse examine something to find meaning, what it is made of or a relationship with other things

Annular eclipse an event when the Moon blocks the Sun but the Moon is further away and the outer edge of the Sun is still visible

Anomalous an outlying result that does not fit in with the pattern of the other results

Apex predator a predator at the top of a food chain

Apogee the point in the Moon's orbit when it is furthest from Earth

Applied force force that is applied to an object by another object or person

Aqueous solution solutions where the solvent is water

Balanced forces forces of the same size but which act in opposite directions

Bar graph a type of graph used to display the frequency of a qualitative variable (category)

Bias when a source of information is influenced by personal opinion or judgement

Bilateral symmetry a form of symmetry where an organism's body can be divided into two identical halves

Binomial nomenclature a system of naming in which two names are used to identify an individual species of organism

Biodiversity the variety of life that exists in an area

Biological control the practice of introducing an organism into an ecosystem with the intention of limiting the spread of another organism

Biologist a person who works in the science field of biology

Biology the study of living organisms and their interactions with their environment.

Biome a large environment that is classified based on various abiotic factors and the organisms that are found there

Biopiracy when naturally occurring biological material is commercially exploited

Biotic relating to the living things in an ecosystem

Blood moon a name given to the Moon during an eclipse while it is completely in Earth's shadow

Boiling the rapid vaporisation of a liquid which occurs when it is heated to a certain temperature

Boiling point the temperature at which a specific liquid becomes a gas

Botanist a scientist who studies plants

Brittle a material that is likely to break or snap when subject to a big enough force

Brownian motion the random movement of particles in fluids

Buoyancy force the force experienced by an object that is partially or fully submerged in a fluid e.g. water or air

Calicivirus a virus that damages a rabbit's internal organs and can cause bleeding

Carnivore an organism that eats only meat

Cell the smallest unit of life that makes up all living things

Cellular respiration the chemical process by which cells release energy from food

Centrifuge a device that uses speed to separate substances based on mass

Characteristic a feature or quality of something

Chemical property the behaviour of a substance when it reacts with another substance

Chemical substance matter that contains only one type of particle

Chemist a person who works in the science field of chemistry

Chemistry the study of matter, its properties, and the interactions between different substances.

Chemotroph an organism that obtains energy through chemical processes in its environment

Chromatography a technique to separate substances based on different solubilities in a solvent

Citizen scientist a member of the public that assists a professional scientist by voluntarily collecting data relating to the natural world

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Claim a statement or assertion that something is true or factual, which may require further investigation or evaluation to determine its validity

Class the taxonomic ranking below phylum and above order

Class 1 lever a lever in which the fulcrum is between the load and effort

Class 2 lever a lever in which the fulcrum is at one end and the load is between the fulcrum and the effort

Class 3 lever a lever in which the fulcrum is at one end and the effort is between the fulcrum and the load

Classification the grouping of similar objects or organisms together

Cog one of the tooth-like parts around the edge of a wheel

Colloid a mixture where particles of one chemical substance will not dissolve but remain distributed through another chemical substance

Commensalism a symbiotic relationship where one organism benefits and the other neither benefits nor is harmed

Community a group of animals or plants that live or grow together

Compress squeeze to make smaller

Concave a surface that curves inwards

Concentrated a solution with a relatively large amount of solute

Concentration the number of particles present in a given volume

Condensation where heat is lost, and a gas becomes a liquid

Condition the different levels of the independent variable

Consumer an organism that obtains food from consuming other organic material

Continuous data quantitative data points that have a value within a range; this type of data is usually measured

Contraction the process of substances getting smaller: particles move closer together as they cool

Controlled variable the variable or variables that are kept the same during an experiment

Convex a surface that curves outwards

Crystallisation the process through which certain solutes can form into a crystalline solid when a solvent evaporates slowly

Data information in the form of facts or statistics gathered to answer a question or for further analysis

Dawn the time of day when the Sun rises over the horizon and night turns into day

Decantation the process of separating by using density

Deciduous a tree that loses its leaves in autumn and grows new ones in spring

Decomposer an organism such as a bacterium or fungus that breaks down organic material

Density how much matter (mass) is contained in a certain volume of a substance

Dependent variable the variable that is measured during an experiment (as it responds to the independent variable)

Deposition where a reduction in heat causes a gas to become a solid, without passing through the liquid state

Detritivore an organism that feeds on dead or decaying organic matter

Detritus dead organic waste or debris

Dichotomous key a tool used to identify organisms, where there are a series of questions with only two alternatives

Diffusion the movement of particles from an area of high concentration of particles to an area of low concentration of particles

Dilute a solution with a relatively small amount of solute

Discrete data quantitative data points that have whole numbers; this type of data is usually counted

Dissolve to become mixed in a substance so that it cannot be seen

Distillate the condensed liquid product from distillation

Distillation a technique to separate substances in a liquid using evaporation through boiling and condensation

DNA stands for deoxyribonucleic acid, a chemical present in cells of living things that carries genetic information

Domain the highest taxonomic rank above kingdom and even more broad

Drag the frictional force of a liquid or gas

Driven gear the gear that rotates due to the rotation of a driving gear

Driving gear the gear connected to the source of the force

Dusk the time of day when the Sun drops below the horizon and day turns into night

Earth and space science the study of natural processes and phenomena occurring on Earth and in the universe beyond

ISBN 978-1-009-40426-6

Ecological niche the role and space that an organism fills in an ecosystem, including all its interactions with the biotic and abiotic factors of its environment

Ecosystem the interrelationship between living and non-living components of a specific area

Ectothermic a cold-blooded organism that cannot regulate its internal temperature

Effort force the input of force to a simple machine

Egestion the process of removing undigested waste material from the body in faeces

Elastic materials that bend, stretch or compress when a force is exerted on them; they exert elastic forces when this happens

Electromagnet a magnet made by passing electricity through a coil of wire

Electrostatic force a non-contact force between positive and negative charges; opposite charges attract, like charges repel

Elliptical oval-shaped

Emulsion a colloid of two or more liquids

Endothermic a warm-blooded organism that can regulate its body temperature

Energy the ability to do work

Environment the physical conditions in which an organism lives

Equator an imaginary line drawn around the middle of Earth equidistant (halfway) between the North and South poles

Eukaryote an organism that contains a nucleus

Evaporation when heat causes liquid to become gas

Excretion the process of removing metabolic waste from the body

Expansion the process of substances getting larger: particles move further apart as they heat up

Experiment a controlled situation where data is gathered to answer a question

Extremophile an organism that thrives in conditions of extreme temperature, pH or chemical concentration

Family the taxonomic ranking below order and above genus

Far side the face of the Moon that is always turned away from Earth; also called the dark side

Fair test an experiment where all variables are kept constant except for the independent variable being tested

Field a region in space in which an object is affected by a force

Filtrate the substance that passes through the filter

Filtration separating a mixture with different states of matter by passing through a filter

Firestick farming the cool burning of areas of bush in stages, by the application of firesticks, to encourage new growth

Flocculant a chemical substance that causes particles to clump together

Flotation separating a mixture based on the capacity to float

Food chain a sequence of living things that shows their feeding relationship and the flow of energy between them

Food web a group of interconnected food chains

Force a push, pull or twist in a specific direction

Force arrow diagram a drawing showing the direction and size of forces acting on an object using arrows

Force meter a piece of equipment that measures force in newtons (N)

Force multiplier something that increases the size of a force

Freezing where heat is lost and a liquid becomes a solid

Friction a contact force opposing motion due to the interaction between two surfaces

Fulcrum the point on a lever where the arm pivots

Gas a substance that expands freely to fill a space

Gear a device consisting of connecting sets of wheels with teeth

Genre a category used to group media such as music, art or books

Genus the taxonomic ranking below family and above species

Geocentric model a cosmological model where Earth was the centre of the universe

Geologist a person who works in the field of earth and space science

Gravitational field the region around a large object where another object can experience its gravity or pull

Gravity a non-contact force describing the pull of any object with mass

Greenhouse gas a gas that traps heat in the atmosphere, leading to global warming

Habitat the place where an organism lives

Heliocentric model a model with the Sun as the centre of the solar system

Herbivore an organism that eats only plants

Herbivory the consumption of plants

Heterogeneous mixture a mixture where components are not evenly distributed

Hierarchical where smaller groups are placed within larger groups, with no overlap between groups

Homogeneous mixture a mixture where components are evenly distributed

Horizon the point where the sky appears to meet the land or the sea

Hypothesis a proposed explanation or an educated guess that can be tested through further experimentation

Impact force a contact force that sometimes only lasts for a short time; impact forces often change an object's speed

Independent variable the variable that is deliberately changed during an experiment

Inference to link an observation with past knowledge and assign meaning to the observation

Insoluble chemical substances that cannot dissolve in a particular solvent

Interdependence the dependence between different species in a community

Interspecific occurring between members of different species

Intraspecific occurring between members of the same species

Invasive species an organism that is not native to an environment and causes harm to native organisms

Invertebrate an animal that does not have a backbone

Investigable question a research question that can be answered through completing an experiment

Kingdom the highest and broadest classification on the Linnaean taxonomic rankings

Knowledge the understanding of information

Leap year a year that happens every four years and has an extra day on 29 February

Lever a rigid bar that moves around a fixed point so one end can be pushed or pulled to move the other end with a greater or smaller force

Line graph a type of graph used to display continuous data

Liquid a substance that flows freely and takes the shape of its container but has a constant volume

Load the object that is to be moved

Load force the output force of a simple machine

Lunar eclipse a full Moon becomes dark as it enters Earth's shadow

Magnetic field the space around a magnet where the magnetic force can act

Magnetic force a non-contact force between a magnet and another magnet or magnetic metal

Mass the amount of substance in an object that never changes, even in space

Matter anything that has mass and volume

Mechanical advantage the ratio of the output force to the input force

Melting when heat causes a solid to become a liquid

Melting point the temperature at which a specific solid becomes a liquid

Meniscus the surface of a liquid in a container

Mesopredator a predator in a mid-ranking trophic level that usually hunts smaller animals

Metamorphosis the process of transformation from an immature form to an adult form

Microbiologist a scientist who studies very small living things like bacteria

Microorganism an organism that can only be seen through a microscope

Misnomer a wrong or inaccurate name

Mixture material that is made up of two or more different types of chemical substances that are not chemically bonded together

Morphology the form and structure of organisms

Mouldable soft enough to be shaped

Mutualism a symbiotic relationship where both organisms benefit

Net force the sum of all forces acting on an object

Newton the unit of force; one newton is roughly equal to the force you need to keep an apple from falling

Non-vascular not containing veins or specialised fluid vessels

Normal force the force that prevents solid objects from passing through each other, sometimes called the support force

Northern Hemisphere the half of Earth north of the equator

Observe use senses and tools to gather information/data

Omnivore an organism that is naturally able to eat both plants and meat

Orbit the curved path of a celestial object or spacecraft around a star, planet or moon

Order the taxonomic ranking below class and above family

Organism a living thing

Outlier an extreme data value that is very different from the other data and could be the result of faulty procedure

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Parallax error an error caused by not reading liquid measurements at eye level, which leads to measurements being too high or too low

Parasite an organism that lives in or on another organism and takes its food from its body

Parasitism a symbiotic relationship where a parasite benefits from living on or in a host (which is harmed)

Partial eclipse an event where the Sun is partially blocked by the Moon

Particle model all matter is made of particles that behave differently depending on whether they are solid, liquid or gas

Pathogen an organism that can cause illness

Peer review to read, check and give an opinion about something that has been written by another scientist or expert working in the same subject area

Penumbra the region in a shadow where the light is partially blocked

Perigee the point in the Moon's orbit when the Moon is closest to Earth

Photosynthesis the process by which a plant uses the energy from the light of the Sun to produce its own food

Phylum the taxonomic ranking below kingdom and above class

Physical property the way a substance looks and acts; a characteristic of a substance that can be observed and/or measured without changing it chemically

Physicist a person who works in the science field of physics

Physics the study of matter, energy, and their interactions with each other and the universe

Pollinator an organism that moves pollen from one plant, or part of a plant, to another

Population all organisms of a particular species or group who live in one area

Precision how close measurements are to each other

Predator an organism that obtains food by killing and consuming other organisms

Predict to make an estimate about a possible future event or outcome

Pressure the amount of force exerted on a given area

Prey an organism hunted and killed by another organism for food

Primary consumer an organism that eats plants

Producer an organism capable of producing food from photosynthesis

Prokaryote a unicellular organism that lacks a nucleus

Pull to exert a force away from something

Pulley equipment consisting of a grooved wheel (or wheels) with a rope or chain attached to an object to be moved

Pure substance material that is made up of just one type of chemical substance

Push to exert a force towards something

Qualitative a form of data that is a descriptive measurement

Quantitative a form of data that is a numerical measurement

Radial symmetry a form of symmetry where an organism's body can be divided into identical parts around a central axis

Radiation the emission of energy in the form or light or heat

Ramp an inclined surface connecting a higher and a lower level

Random error an error that is caused by factors that cannot be easily controlled by the experimenter

Relevant connected to the topic being investigated

Repel to force back or apart

Reproducible able to be reproduced or copied

Research question a question that can be answered practically through scientific investigation or through research

Residue the substance that is left in the filter

Revolution one complete orbit

Rewilding the process of protecting an environment and returning it to its natural state, for example by bringing back wild animals that used to live there

Rotate to turn or spin on an axis

Saturated a solution with the maximum amount of solute dissolved in the solvent

Scavenger an organism that feeds on dead animals that it has not killed itself

Secondary consumer an organism that eats primary consumers

Sessile fixed in one place and not able to move

Sieving separating solids based on the size of particles

Simple machine a basic mechanical device for applying a force and changing either its size or direction

Smog a mixture of smoke, gases and chemicals, especially in cities

Solar eclipse an event when the Sun partly or completely disappears from view, while the Moon moves between it and Earth

Solid a substance that has a fixed shape and constant volume

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Soluble chemical substances that can dissolve in a particular solvent

Solute the component of a solution being dissolved

Solution a mixture where one chemical substance is evenly dissolved in another

Solvent the component in a solution capable of dissolving another chemical substance

Southern Hemisphere the half of Earth south of the equator

Species the most specific taxonomic ranking below genus

Specific clearly defined or identified

Speed multiplier something that increases the speed of an object

State a distinct form matter can exist in

Static electricity a build-up of electric charge

Streamlined designed to minimise air resistance or drag

Sublimation where heat causes a solid to become a gas, without passing through the liquid state

Sunspot feature on the Sun's surface that moves slowly across the surface

Suspension a mixture where one chemical substance will eventually settle out of the solvent

Symbiosis a long-term close interaction between two organisms of different species

Synchronous rotation occurs when the rotation of an orbiting body is the same length of time as its revolution around a larger body

Systematic error an error that causes measurements to differ from the true result by a consistent amount, often due to faulty or uncalibrated equipment

Syzygy the occurrence in astronomy of three or more objects moving in a straight line

Taxonomy a branch of science that groups and names organisms based on their relationships

Telescope an optical instrument for making distant objects appear nearer and larger, or an instrument that detects electromagnetic radiation from space

Tension the force in a wire, cable or string when being stretched

Tertiary consumer an organism that eats secondary consumers

Time zone Earth is divided into 24 time zones, each about 15° of longitude and each one representing a time difference of 1 hour

Total eclipse an event when the Sun is completely blocked by the Moon

Trend a pattern in data that shows the general direction/shape of the relationship between the independent and dependent variables

Trendline/line of best fit a line drawn to show an average of plotted points

Trial a run-through of an experimental method that is usually repeated several times, to obtain data than can averaged, to reduce any effect of variables not being completely controlled

Trophic level refers to an organism's level or position in a food web. It is based on an organism's feeding habits, where producers occupy the first trophic level

Turning force a force that increases or decreases an object's rate of rotation

Umbra the region in a shadow where the light is completely blocked

Unbalanced forces a combination of one or more forces that has an overall effect, and which changes an object's motion

Unicellular consisting of one cell

Variable a factor or condition that can be controlled, changed or measured in an experiment

Vascular containing veins or specialised fluid vessels

Vertebrate an animal that has a backbone

Vibrate periodic motion of particles

Volume the space an object occupies

Waning the period of about two weeks where the illuminated part of the Moon is decreasing from a full moon to a new moon

Waxing the period of about two weeks where the illuminated part of the Moon is increasing from a new moon to a full moon

Weight the force of gravity on an object; it is measured in newtons and changes in space

ISBN 978-1-009-40426-6 Dale et al. 2023

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ISBN 978-1-009-40426-6 Dale et al. 2023

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ISBN 978-1-009-40426-6 Dale et al. 2023

ISBN 978-1-009-40426-6

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ISBN 978-1-009-40426-6 Dale et al. 2023

ISBN 978-1-009-40426-6 Dale et al. 2023

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Text: NSSDCA/NASA, p.196.

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