OXFORD

obook pro

SCIENCE

# OXFORD SCIENCE 7

HELEN SILVESTER

SECOND EDITION

AUSTRALIAN CURRICULUM

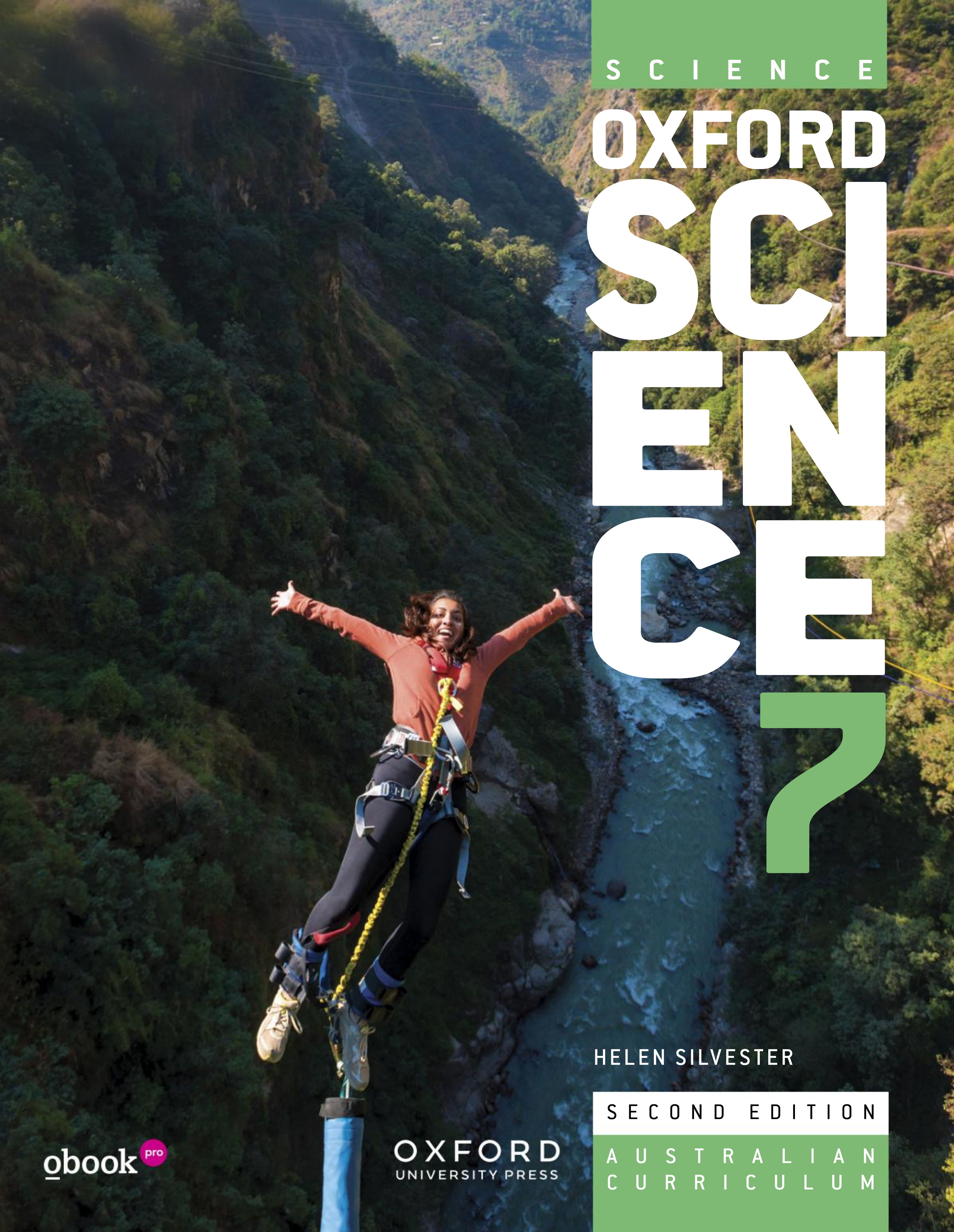
SCIENCE

# OXFORD SCIENCE 7

HELEN SILVESTER

SECOND EDITION

AUSTRALIAN CURRICULUM



obook pro

OXFORD UNIVERSITY PRESS

OXFORD
UNIVERSITY PRESS

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

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



First published 2016
Second edition 2023



ISBN 9780190332372



Typeset by QBS Learning
Proofread by Sarah Endacott
Indexed by Max McMaster
Printed in Singapore by Markono

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

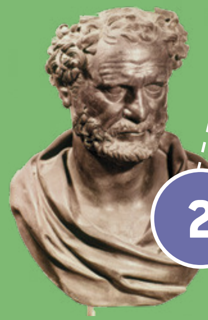


**Acknowledgement of Country**
Oxford University Press acknowledges the Traditional Owners of the many lands on which we create and share our learning resources. We acknowledge the Traditional Owners as the original storytellers, teachers and students of this land we call Australia. We pay our respects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

**Warning to First Nations Australians**
Aboriginal and Torres Strait Islander peoples are advised that this publication may include images or names of people now deceased.

# OXFORD SCIENCE 7

## 1 Science toolkit
Scientists work collaboratively and individually in the laboratory or the field, to plan or conduct investigations safely and ethically. Scientists make predictions, control variables and record their results accurately. Scientists communicate their results using scientific language.



## 2 Particle model
The properties of the different states of matter can be explained using the particle model. Scientists' understanding of matter has developed over thousands of years.

## 3 Mixtures
All things are made of materials. Many materials are mixtures. Some materials are not mixtures – they consist of one pure substance. Mixtures contain a combination of pure substances that can be separated using a range of techniques.

## 4 Forces
A force is a push or pull, arising from the interaction between two objects. Change is caused by unbalanced forces acting on the object. Earth's gravity pulls objects towards the centre of the Earth.

## 5 Classification
Living things are called organisms. There are differences within and between groups of organisms. Classification is a system that helps organise the diversity of life on Earth. The system of classification continues to develop and change.

## 6 Ecosystems
Organisms interact with one another in their environments. Scientists use food webs and food chains to represent these interactions. Humans are part of the food chain, and human activity can affect the interaction of the organisms.

## 7 Earth, Sun and Moon
The position of the Sun, Earth and Moon in the sky causes change on Earth, including seasons, tides and eclipses. Scientists can make predictions based on the relative positions of the Sun, Earth and Moon.

## 8 Experiments

OXFORD UNIVERSITY PRESS


CONTENTS

# INTRODUCING *OXFORD SCIENCE 7–10 AUSTRALIAN CURRICULUM*

*Oxford Science Australian Curriculum* has been developed to meet the requirements of the *Australian Curriculum: Science* across Years 7–10. Taking a concept development approach, each double-page spread of Oxford Science represents **one concept**, **one topic** and **one lesson**. This new edition ensures students build science skills and cross-curriculum capabilities, paving a pathway for science success in the senior secondary years.

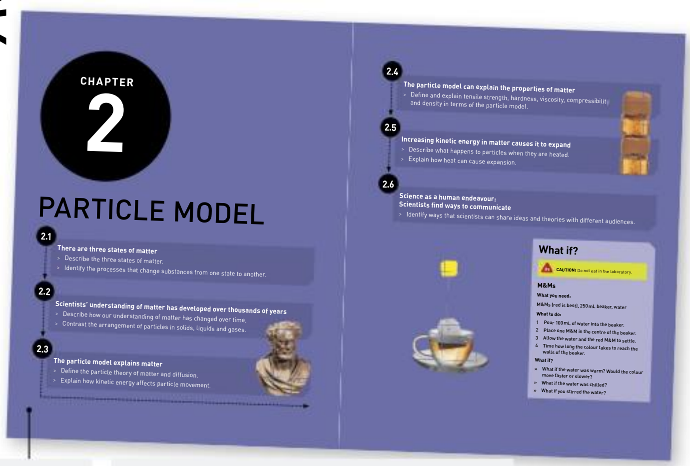
The series offers a completely integrated suite of print and digital resources to meet your needs, including:

- Student Book
- Student obook pro
- Teacher obook pro.

## Key features of this Student Book

- This Student Book combines complete curriculum coverage with clear and engaging design.
- Each print Student Book comes with complete access to all the digital resources available on Student obook pro.

## Focus on concept development





### Reflect

- Students are encouraged to self-assess their learning against a set of success criteria in the Chapter checklist tables at the end of each chapter. If students do not feel confident about their learning, they are directed back to the relevant topic.

### Chapter openers

- Every chapter begins with a clear learning pathway for students.

### Concept statements

- Every topic begins with a concept statement that summarises the key concept of the topic in one sentence.

### Learning intentions

- Learning intentions are clearly stated for every topic.

### Key ideas

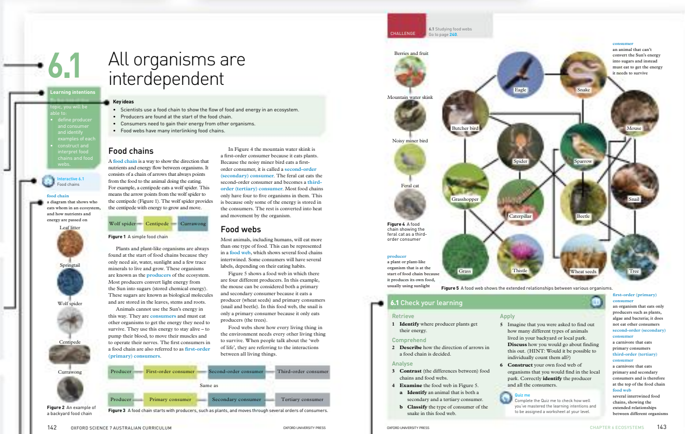
- Key ideas are summarised for each topic in succinct dot points.

### Integrated links to engaging digital resources

- Where relevant, digital icons flag engaging resources that can be accessed via Student obook pro. These resources are directly integrated with the topic being covered.

### Margin glossary terms

- Key terms are bolded in the body in blue text, with a glossary definition provided in the margin.




### Check your learning

- Each topic finishes with a set of 'Check your learning' questions that are aligned to the learning intentions for the topic. Questions are phrased using bolded cognitive verbs, which state what is expected of a student and prepares them for studying senior science subjects.

# Focus on science inquiry skills and capabilities

## Digital hotspots

Icons found in the student book link to digital resources accessible via the obook pro.

- Digital versions of the Check your learning and Chapter review questions
- Videos
- Digital quizzes
- Interactives


## Science toolkit

- The Science toolkit is a standalone chapter that explicitly teaches important science inquiry skills and capabilities.

## Science as a human endeavour

- 'Science as a human endeavour' topics explore real-world examples and case studies, allowing students to apply science understanding.

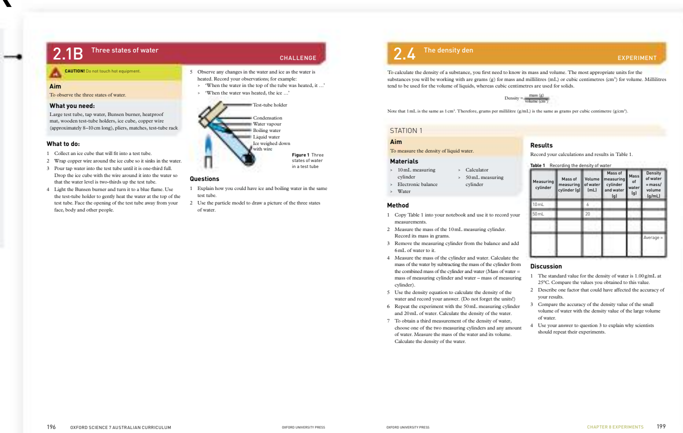
## Test your skills and capabilities

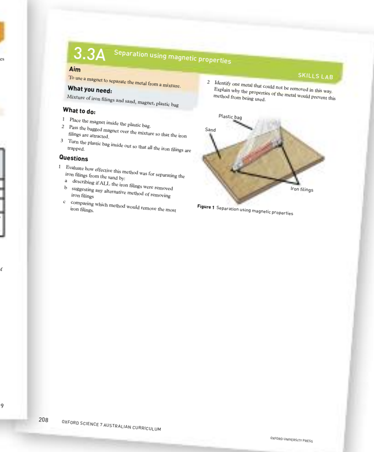
- This section provides scaffolded opportunities for students to apply their science understanding while developing skills and capabilities.

# Focus on practical work

## Practical work appears at the back of the book

- All practical activities are organised in a chapter at the end of the book and signposted at the point of learning throughout each chapter.




## Challenges, Skills labs and Experiments

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

# Focus on STEAM

## Integrated STEAM projects

- Take the hard work out of cross-curricular learning with engaging STEAM projects. Two fully integrated projects are included at the end of each book in the series, and are scaffolded and mapped to the Science, Maths and Humanities curricula. The same projects also feature in the corresponding Oxford Humanities and Oxford Maths series to assist cross-curricular learning.


## Problem solving through design thinking

- Each STEAM project investigates a real-world problem that students are encouraged to problem solve using design thinking.

## Full digital support

- Each STEAM project is supported by a wealth of digital resources, including student booklets (to scaffold students through the design-thinking process of each project), videos to support key concepts and skills, and implementation and assessment advice for teachers.

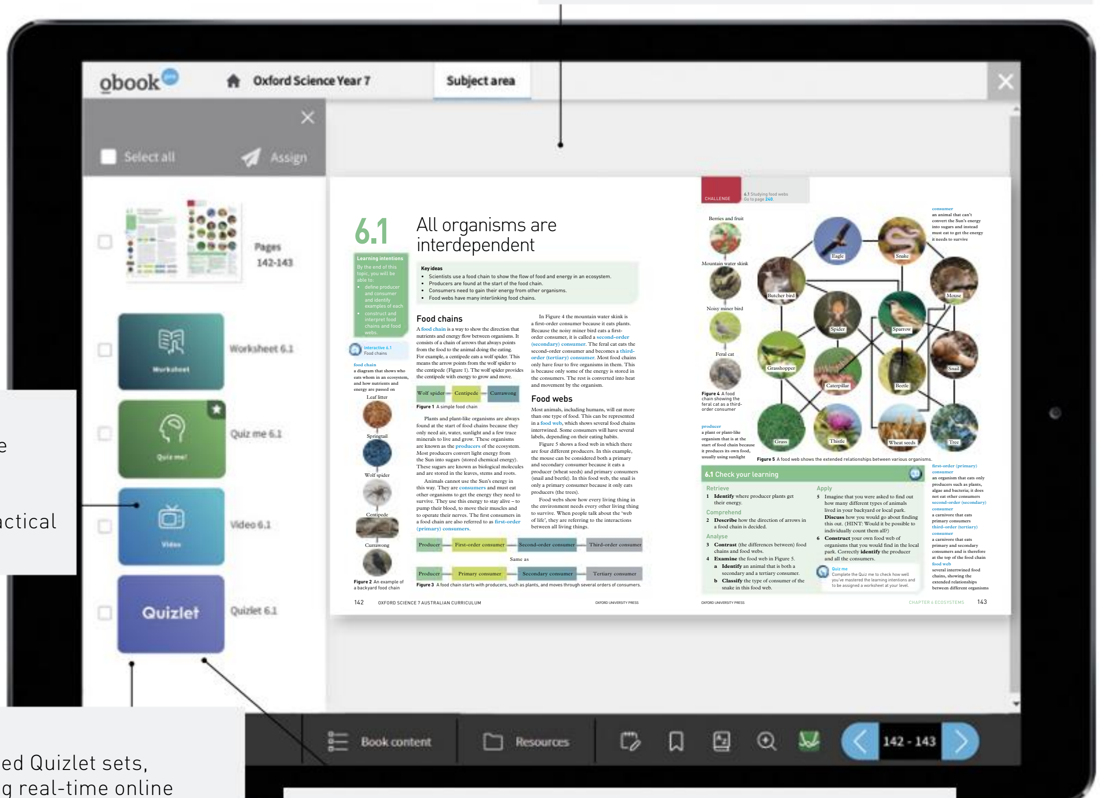
## Key features of Student obook pro

obook pro

- Student obook pro is a completely digital product delivered via Oxford's online learning platform, **Oxford Digital**.
- It offers a complete digital version of the Student Book with interactive note-taking, highlighting and bookmarking functionality, allowing students to revisit points of learning.
- A complete ePDF of the Student Book is also available for download for offline use and read-aloud functionality.

### Focus on eLearning

**Complete digital version of the Student Book**
- This digital version of the Student Book is true to the print version, making it easy to navigate and transition between print and digital.




**Videos**
- Videos are available online to support understanding of concepts or key practical activities.

**Quizlet**
- Integrated Quizlet sets, including real-time online quizzes with live leaderboards, motivate students by providing interactive games that can be played solo or as a class. Quizlet can be used for revision or as a topic is introduced to keep students engaged.

**Interactive quizzes**
- Each topic in the Student Book is accompanied by an interactive assessment that can be used to consolidate concepts and skills.
- These interactive quizzes provide a mix of auto- and teacher-corrected questions, with students receiving instant feedback on achievement and progress. Students can also access all their online assessment results to track their own progress and reflect on their learning.

### Benefits for students

- integrated *Australian Concise Oxford Dictionary* look-up feature
- targeted instructional videos for key concepts, practicals and worked examples
- interactive assessments to consolidate understanding
- integrated Quizlet sets, including real-time online quizzes with live leaderboards
- access to their online assessment results to track their own progress.

oxforddigital

# Key features of Teacher obook pro

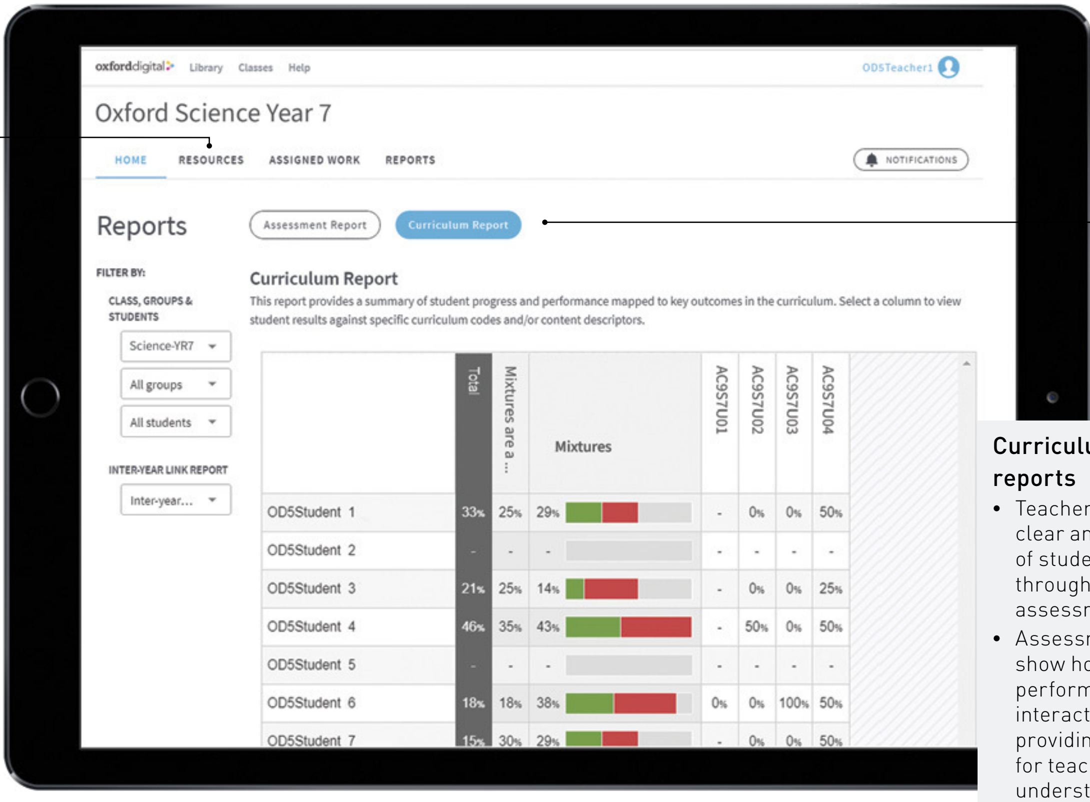
obook pro

- Teacher obook pro is a completely digital product delivered via **Oxford Digital**.
- Each chapter and topic of the Student Book is accompanied by full teaching support. Teaching programs are provided that clearly direct learning pathways throughout each chapter, including ideas for differentiation and practical activities.
- Teachers can use their Teacher obook pro to share notes and easily assign resources or assessments to students, including due dates and email notifications.

## Focus on assessment and reporting

**Complete teaching support**

- Teaching support includes full lesson and assessment planning, ensuring there is more time to focus on students.




**Additional resources**

- Each chapter of the Student Book is accompanied by additional worksheets and learning resources to help students progress.

**Curriculum and assessment reports**

- Teachers are provided with clear and tangible evidence of student learning progress through curriculum and assessment reports.
- Assessment reports directly show how students are performing in each online interactive assessment, providing instant feedback for teachers about areas of understanding.
- Curriculum reports summarise student performance against specific curriculum content descriptions and curriculum codes.

# Benefits for teachers

- In addition to online assessment, teachers have access to editable class tests that are provided at the conclusion of each chapter. These tests can be used as formative or summative assessment and can be edited to suit the class's learning outcomes.
- Teachers are provided with laboratory support through experiment answer guidance, laboratory technician notes and risk assessments to ensure safe learning experiences.

# AUSTRALIAN CURRICULUM: SCIENCE 7 SCOPE AND SEQUENCE

## YEAR 7 DESCRIPTION

In Year 7, students explore the diversity of life on Earth and continue to develop their understanding of the role of classification in ordering and organising information. They use and develop models to represent and analyse the flow of energy and matter through ecosystems and explore the impact of changing components within these systems. They investigate relationships in the Earth-Sun-Moon system and use models to predict and explain events. They extend their understanding of the particulate nature of matter and explore how interactions of matter and energy at the sub-microscopic scale determine macroscopic properties. They consider the effects of multiple forces when explaining changes in an object's motion. Students make accurate measurements and analyse relationships between system components. They construct and use models to test hypotheses about phenomena at scales that are difficult to study directly and use these observations and other evidence to draw conclusions. They begin to understand the relationship between science and society and appreciate the need for ethical and cultural considerations when acquiring data.

| YEAR 7 CONTENT DESCRIPTIONS | |
|---|---|
| SCIENCE UNDERSTANDING | |
| *Biological sciences* | |
| Chapter 5 | 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) |
| Chapter 6 | 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) |
| *Earth and space sciences* | |
| Chapter 7 | 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) |
| *Physical sciences* | |
| Chapter 6 | 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) |
| *Chemical sciences* | |
| Chapter 2 | 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) |
| Chapter 3 | Use a particle model to describe differences between pure substances and mixtures and apply understanding of properties of substances to separate mixtures (AC9S7U06) |
| SCIENCE AS A HUMAN ENDEAVOUR | |
| *Nature and development of science* | |
| All chapters | Explain how new evidence or different perspectives can lead to changes in scientific knowledge (AC9S7H01) |
| All chapters | Investigate how cultural perspectives and world views influence the development of scientific knowledge (AC9S7H02) |
| *Use and influence of science* | |
| All chapters | Examine how proposed scientific responses to contemporary issues may impact on society and explore ethical, environmental, social and economic considerations (AC9S7H03) |
| All chapters | Explore the role of science communication in informing individual viewpoints and community policies and regulations (AC9S7H04) |

| SCIENCE INQUIRY | |
|---|---|
| *Questioning and predicting* | |
| All chapters | Develop investigable questions, reasoned predictions and hypotheses to explore scientific models, identify patterns and test relationships (AC9S7I01) |
| *Planning and conducting* | |
| All chapters | Plan and conduct reproducible investigations to answer questions and test hypotheses, including identifying variables and assumptions and, as appropriate, recognising and managing risks, considering ethical issues and recognising key considerations regarding heritage sites and artefacts on Country/Place (AC9S7I02) |
| All chapters | Select and use equipment to generate and record data with precision, using digital tools as appropriate (AC9S7I03) |
| *Processing, modelling and analysing* | |
| All chapters | Select and construct appropriate representations, including tables, graphs, models and mathematical relationships, to organise and process data and information (AC9S7I04) |
| All chapters | Analyse data and information to describe patterns, trends and relationships and identify anomalies (AC9S7I05) |
| *Evaluating* | |
| All chapters | Analyse methods, conclusions and claims for assumptions, possible sources of error, conflicting evidence and unanswered questions (AC9S7I06) |
| All chapters | Construct evidence-based arguments to support conclusions or evaluate claims and consider any ethical issues and cultural protocols associated with using or citing secondary data or information (AC9S7I07) |
| *Communicating* | |
| All chapters | Write and create texts to communicate ideas, findings and arguments for specific purposes and audiences, including selection of appropriate language and text features, using digital tools as appropriate (AC9S7I08) |
| YEAR 7 ACHIEVEMENT STANDARD | |
| By the end of Year 7, students explain how biological diversity is ordered and organised. They represent flows of matter and energy in ecosystems and predict the effects of environmental changes. They model cycles in the Earth-Sun-Moon system and explain the effects of these cycles on Earth phenomena. They represent and explain the effects of forces acting on objects. They use particle theory to explain the physical properties of substances and develop processes that separate mixtures. Students identify the factors that can influence development of and lead to changes in scientific knowledge. They explain how scientific responses are developed and can impact society. They explain the role of science communication in shaping viewpoints, policies and regulations. Students plan and conduct safe, reproducible investigations to test relationships and aspects of scientific models. They identify potential ethical issues and intercultural considerations required for field locations or use of secondary data. They use equipment to generate and record data with precision. They select and construct appropriate representations to organise data and information. They process data and information and analyse it to describe patterns, trends and relationships. They identify possible sources of error in methods and identify unanswered questions in conclusions and claims. They identify evidence to support their conclusions and construct arguments to support or dispute claims. They select and use language and text features appropriately for their purpose and audience when communicating their ideas and findings. | |

# ACKNOWLEDGEMENTS

The author and the publisher wish to thank the following copyright holders for reproduction of their material.

**Cover:** Alex Treadway/Getty Images.

**Chapter 1:** The Washington Post via Getty Images, p.5 fig 6; imageBROKER / Alamy Stock Photo, p.5 fig 9; Science Photo Library / Alamy Stock Photo, p.9 fig 1a; Nick Dolding / Getty Images, p.14 fig 1; Science Photo Library / Alamy Stock Photo, p.17 fig 3; Science Photo Library / Alamy Stock Photo, p.17 fig 4; Getty/Peter Macdiarmid, p.22 fig 1a; PCN Photography / Alamy Stock Photo, p.22 fig 1b; Donald Hobern/CC BY 2.0, https://creativecommons.org/licenses/by/2.0/, p.30 fig 2; Dani Gawlik / Newspix, p.31 fig 3; Victorian Aboriginal Corporation for Languages, p.32 fig 1; Elizabeth Tibbets, p.27 fig 4; Shutterstock, p.4 fig 1, p.5 fig 3, p.5 fig 4, p.5 fig 5, p.5 fig 7, p.5 fig 8, p.6 fig 1, p.8 Q1a, p.9 fig 1b, p.9 fig 2, p.10 fig 4, p.11 fig 1, p.11 fig 2, p.14 fig 2, p.14 fig 3, p.14 fig 4, p.15 fig 6, p.19 fig 1, p.21 fig 4, p.23 fig 6, p.26 fig 1, p.26 fig 2, p.30 fig 1, p.33 fig 2, p.34 fig 1, p.35 fig 2, p.36 fig 1.

**Chapter 2:** omersukrugoksu/istock, p.42 fig 3; Granger Historical Picture Archive/ Alamy Stock Photo, p.46 fig 1; Granger Historical Picture Archive/Alamy Stock Photo, p.46 fig 2; John Sirlin/Alamy Stock Photo, p.48 fig 1; istock/small frog, p.50 fig 1; Valvoline, p.56 fig 2; istock/prill, p.52 fig 1; istock/Rendery, p.52 fig 2; David R. Frazier Photolibrary, Inc./Alamy Stock Photo, p.53 fig 4; Fairfax Photos/JOE ARMAO, p.53 fig 5; Calum Robertson/ Newspix, p.57 fig 4; Shutterstock, p.42 fig 4, p.42 fig 1, p.42 fig 2, p.43 fig 6, p.43 fig 7, p.43 fig 8, p.44 fig 9, p.43 fig 5, p.45 fig 10, p.49 fig 4, p.49 fig 9, p.56 fig 1, p.54 fig 1, p.55 fig 4, p.55 fig 5, p.50 fig 3, p.50 fig 3, p.58 fig 5, p.58 fig 6, p.59 fig 7.

**Chapter 3:** Stocksy.com/Hugh Sitton, p.64 fig 2; Penny Tweedie / Getty Images, p.66 fig 1; Martin Leigh/Getty Images, p.72 fig 1; Simone Stone/SPL/Alamy, p.72 fig 2; Polimerek via Wikimedia Commons, p.73 fig 4; Avalon/Construction Photography / Alamy Stock Photo, p.76 fig 1; Shutterstock, p.62 fig 1, p.63 fig 3, p.63 fig 4, p.63 fig 5, p.65 fig 4, p.66 fig 3, p.66 fig 2, p.67 fig 4, p.67 fig 5, p.68 fig 1, p.69 fig 4, p.69 fig 5, p.69 fig 6, p.70 fig 1, p.70 fig 2, p.71 fig 4, p.73 fig 5, p.74 fig 1, p.74 fig 2, p.74 fig 3, p.75 fig 4, p.76 bottom right, p.77 fig 4, p.78 fig 3, p.79 fig 6a, p.79 fig 6b, p.79 fig 6c, p.80 fig 7, p.80 fig 78.

**Chapter 4:** Jasper Juinen/Getty, p.84 fig 1; David Crausby/Alamy Stock Photo, p.85 fig 7; Rawpixel Ltd/Alamy Stock Photo, p.87 fig 3; Mark Dadswell /Getty, p.86 fig 2; Anirban Basu/Alamy Stock Photo, p.89 fig 6; PHOTOTAKE Inc./Alamy, p.90 fig 1; G.GLATZMAIER, LOS ALAMOS NATIONAL LABORATORY / P.ROBERTS, UCLA / SCIENCE PHOTO LIBRARY, p.91 fig 4; blickwinkel / Alamy Stock Photo, p.92 fig 1; sciencephotos / Alamy Stock Photo, p.93 fig 3; © Look and Learn / Bridgeman Images, p.98 fig 1; Hemis / Alamy Stock Photo, p.99 fig 3; (b) Steve Gorton/Getty, p.100 fig 5b; Robin Smith/ Getty, p.101 fig 7; Peter Steiner / Alamy Stock Photo, p.101 fig 10; istockphoto, p.103 fig 6 istockphoto/TommL, p.104 fig 1; Dorling Kindersley ltd / Alamy Stock Photo, p.104 fig 2; James Croucher/Newspix, p.108 fig 1; Scott Barbour/Getty Images, p.109 fig 2; 123RF, p.107 fig 3; Shutterstock, p.84 fig 2, p.85 fig 3, p.85 fig 4, p.85 fig 5, p.85 fig 6, p.85 fig 8, p.85 fig 9, p.86 fig 1, p.91 fig 3, p.91 fig 5, p.92 fig 2, p.94 fig 2, p.96 fig 1, p.96 fig 2, p.97 fig 3, p.98 fig 2b, p.100 fig 4b, p.100 fig 6b, p.101 fig 9, p.102 fig 1, p.104 fig 3, p.105 fig 4, p.105 fig 5, p.105 fig 6, p.112 fig 7, p.112 fig 8, p.112 fig 9.

**Chapter 5:** Nick Volpe and Museum Victoria, p.117 fig 5; Science Photo Library/Alamy Stock Photo, p.125 fig 5; blickwinkel/Alamy Stock Photo, p.125 fig 6; Amanda Cotton/lamy Stock Photo, p.126 fig 1; (a) Michael McKelvey & Dr Peggy Rismiller of Pelican Lagoon Research & Wildlife Centre, Kangaroo Island, South Australia (b)Shutterstock (c)Jean-Paul Ferrero/AUSCAPE/Alamy, p.128 fig 1; Ken Griffiths/Alamy Stock Photo, p.129 fig 3; The Natural History Museum/Alamy Stock Photo, p.129 fig 4; The Natural History Museum/Alamy Stock Photo, p.131 fig 4; Anne Saarinen/ Alamy Stock Photo, p.131 fig 5; John W Banagan/Getty, p.132 fig 2; Minden Pictures/Alamy Stock Photo, p.133 fig 5; CSIRO, p.134 fig 3; CSIRO/Martin Ollman, p.134 fig 2; Bryan D. Lessard, p.134 fig 4; Shutterstock, p.116 fig 1, p.117 fig 6, p.118 fig 1, p.118 fig 2, p.118 fig 3, p.118 fig 4, p.119 fig 5, p.119 fig 6, p.119 fig 7, p.119 fig 8, p.122 fig 1, p.122 fig 3, p.122 fig 2, p.124 fig 2, p.125 fig 3, p.125 fig 4, p.127 fig 2, p.127 fig 3, p.128 fig 2, p.129 fig 5, p.129 fig 6, p.130 fig 1, p.130 fig 2, p.130 fig 3, p.132 fig 1, p.133 fig 3, p.133 fig 4, p.135 fig 1.

**Chapter 6:** (b) Springrail: WildPictures/ Alamy Stock Photo all others Shutterstock, p.142 fig 2; Image Professionals GmbH/ Alamy Stock Photo, p.144 fig 1; Kevin Maskell/Alamy Stock Photo, p.145 fig 4; Getty Images/Photo Researchers RM, p.145 fig 5; Getty Images/iStockphoto, p.145 fig 6; mike lane/Alamy, p.146 fig 9; photolibrary.com, p.146 fig 10; Getty Images/iStockphoto, p.146 fig 11; Science Photo Library/Alamy Stock Photo, p.147 fig 13; Ken Griffiths/Alamy Stock Photo, p.142; Paul Glendell/Alamy Stock Photo, p.152 fig 4; Arko Lucieer, University of Tasmania, p.156 fig 4(a) & 4(b); Jason Edwards/Alamy Stock Photo, p.158 fig 1; News Ltd, p.160 fig 5; Auscape International Pty Ltd/Alamy Stock Photo, p.161 fig 8; Darren McNamara/Newspix, p.163 fig 4; CSIRO, p.168 fig 6; Shutterstock, p.142 fig 4, p.144 fig 2, p.146 fig 7, p.146 fig 8, p.148 fig 1, p.149 fig 4, p.149 fig 3, p.143, p.152 fig 5, p.153 fig 6, p.154 fig 1, p.154 fig 2, p.155 fig 3, p.159 fig, p.159 fig 3, p.160 fig 6, p.161 fig 7, p.162 fig 1, p.163 fig 2a, p.163 fig 2b, p.163 fig 3, p.163 fig 5, p.165 fig 7a, p.165 fig 7b, p.167 fig 5, p.168 fig 7, p.147 fig 12.

**Chapter 7:** NASA, p.4 fig 1; Newspix/ File Photo, p.7 fig 2; Science Photo Library/Alamy Stock Photo, p.7 fig 3; ANITA BLAKER/Getty, p.7 fig 4; Rainer Hartmeyer/Alamy Stock Photo, p.10 fig 2; Hubble/European Space Agency/NASA, p.14 fig 2; © Commonwealth of Australia, Bureau of Meteorology. Released under CC BY 3.0 AU, p.16 fig 2; Cairns Charts & Maps, p.12 fig 5 left; NASA / ESA / STSCI / SCIENCE PHOTO LIBRARY, p.115 fig 3a; NASA / ESA / CSA / STSCI / SCIENCE PHOTO LIBRARY, p.115 fig 3b; © The University of Waikato Te Whare Wananga o Waikato | www.sciencelearn.org.nz, p.6 fig 1; Kirsten Banks, p.18 fig 6; NASA / SCIENCE PHOTO LIBRARY, p.18 fig 7; NASA / SCIENCE PHOTO LIBRARY, p.18 fig 8; NASA/JPL-Caltech, p.15 fig 4; Shutterstock, p.4 fig 2, p.17 fig 4, p.5 fig 4, p.14 fig 1, p.8 fig 1, p.18 fig 5.

**Chapter 8:** Brian Jackson/Alamy Stock Photo, p.190; 123RF, Shutterstock & Natural Visions/ Alamy Stock Photo (Platypus), p.207; Tetiana Zhabska/Alamy Stock Vector, p.222; Shutterstock, p.188, p.200, p.201, p.202, p.204, p.210, p.220, p.223, p.226, p.228, p.233, p.238, p.239, p.240, p.241, p.231, p.243, p.246, p.248, p.197, p.198, p.240, p.249.

**STEAM projects:** WILLIAM WEST/ AFP via Getty Images, p.252 fig 1; Shutterstock, p.253 fig 2, p.253 fig 3, p.256 fig 1, p.257 fig 2, p.257 fig 3.

**Contents, glossary and index:** GRANGER - Historical Picture Archive/ Alamy Stock Photo, p.iii; 123RF, p.iii; Ken Griffiths/Alamy Stock Photo, p.iii; Rainer Hartmeyer/Alamy Stock Photo, p.v, p.260, p.266; Shutterstock; p.iii, p.v, p.xii, p.260, p.266.

Every effort has been made to trace the original source of copyright material contained in this book. The publisher will be pleased to hear from copyright holders to rectify any errors or omissions.

CHAPTER

# 1

# SCIENCE TOOLKIT

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

> Describe the questions scientists might ask.

> Describe where and how scientific investigations can occur.

1.2 **Scientists use specialised equipment**

> Describe a variety of different pieces of specialised science equipment.

1.3 **Scientists take safety precautions**

> Describe safe practices within the laboratory.

1.4 **Scientists use observation and inference to answer questions**

> Define observation and inference as scientific terms.

> Explain the difference between qualitative and quantitative data.

1.5 **Science relies on measuring with accuracy**

> Describe how to accurately measure data using a variety of equipment.

**1.6** A Bunsen burner is an essential piece of laboratory equipment
> Use a Bunsen burner safely and accurately.

**1.7** A fair test is a controlled experiment
> Explain the term 'variable' and describe the difference between dependent and independent variables.
> Describe how repetition increases the reliability of results.

**1.8** Graphs and tables are used to show results
> Use graphs and tables appropriately to communicate the data from investigations.

**1.9** Scientists analyse claims and results
> Describe how errors can affect the results of an experiment.
> Describe the evidence a scientist uses when making a claim.

**1.10** Scientific reports communicate findings
> Construct a scientific report that uses data and scientific language.

**1.11** Science as a human endeavour: Science skills are used to solve important problems
> Describe how scientists plan, conduct and communicate their investigative strategies and conclusions.

**1.12** First Nations Australians use science
> Describe how First Nations peoples use science skills.

**1.13** Cognitive verbs identify the tasks in a question
> Recognise the cognitive verb in a question.
> Understand the different tasks involved for different cognitive verbs.

## What if?

### Bubbology

**CAUTION!** Do not suck on the straw.

**What you need:**

Bubble mix, straw, plastic ruler

**What to do:**

1 Put a little bubble mixture onto a clean bench surface.
2 Put the end of the straw in the bubble mix.
3 Blow gently through the straw.

**What if?**

» What if you touch a bubble with a wet finger?
» What if you touch a bubble with a dry finger?
» Why do wet and dry fingers affect bubbles differently?

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

**Learning intentions**

By the end of this topic, you will be able to:

- describe the questions scientists might ask
- describe where and how scientific investigations can occur.

**Key ideas**

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

Video 1.1A
Ask a scientist – Dr Aaron Stewart (entomologist)

Video 1.1B
Ask a scientist – Dr Jo Whittaker (geologist)

Video 1.1C
Ask a scientist – Dr Niraj Lal (physicist)

Video 1.1D
Ask a scientist – Ms Jenny Powell (environmental scientist)

## Curiosity through history

Many scientific discoveries start with one person who is curious about something. Our world would be a very different place without people asking questions, such as 'How does this work?' or 'Why is this so?'

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

**Figure 1** Early scientists were called natural philosophers.

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

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

## Curiosity today

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

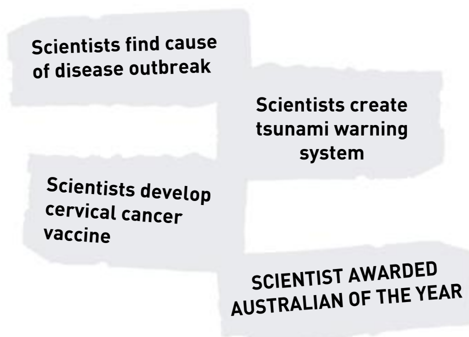



**Figure 2** Curiosity leads scientists to new discoveries.

## Scientists in the world

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

**scientist**
a person who studies the natural and physical world

**philosopher**
a 'lover of knowledge'; someone who studies ideas, theories and questions

**science**
the study of the natural and physical world

CHALLENGE

**1.1:** Sideways ping pong
Go to page **190**.

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

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

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

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

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

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

## 1.1 Check your learning

### Retrieve

1 **Identify** (write) the name that was given to the early scientists.

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

### Comprehend

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

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

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

### Analyse

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

### Apply

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

8 Look carefully at Figure 9. **Propose** a possible question about gorillas that the scientist may be investigating. **Describe** the risk the close contact may have to:

**a** the scientist

**b** the gorillas.

**Figure 9** A scientist observes gorillas

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

**atmosphere**
the envelope of gases surrounding the Earth or another planet

**cell**
(in biology) the building block of living things

# 1.2 Scientists use specialised equipment

**Learning intentions**

By the end of this topic, you will be able to:

- describe a variety of different pieces of specialised science equipment.

Interactive 1.2
Types of equipment used in the laboratory

**Key ideas**

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

## Scientific equipment

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

**equipment**
items used in the laboratory to conduct experiments

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

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

**laboratory**
a specially designed space for conducting research and experiments

**apparatus**
equipment placed together for an experiment


**Figure 1** Types of equipment used in the laboratory

**1.2:** Drawing scientific diagrams
Go to page **191**.

## Brain training: Scientific equipment

1. Your class will divide into two teams and revise Figure 2. Spend 2 minutes reminding yourself of the correct names for the pieces of equipment.
2. Your teacher will uncover a mystery tray containing 16 pieces of equipment. You will be able to view the tray for 60 seconds; it will then be re-covered.
3. Write down the names of all the pieces of equipment you can remember.
4. When you check your answers: score 2 points for each piece remembered and spelt correctly; score 1 point if the spelling was incorrect.
5. Add up the points for each team. The team with the most points wins.

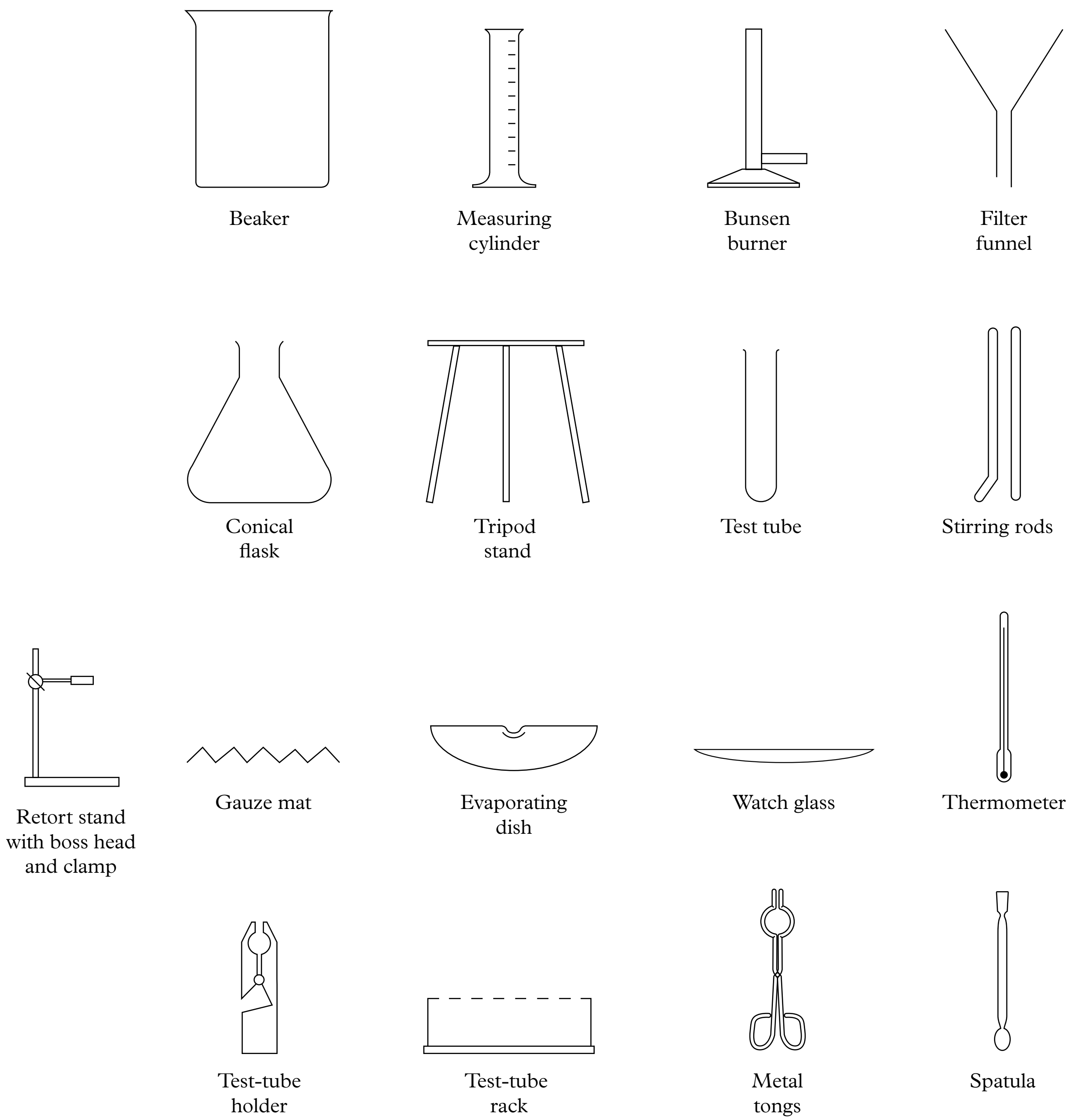



**Figure 2** Scientific drawings of laboratory equipment

## Scientific diagrams

To show others how to set up an experiment, scientists write a list of equipment needed and draw how it should be set up.

Scientists have a quick and simple way to show scientific equipment. They use drawings called **scientific diagrams**. Using scientific diagrams means you do not have to be an artist to be a good scientist and you have more time to do the experiments.

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

The procedure for drawing scientific diagrams is as follows:

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

### 1.2 Check your learning

#### Retrieve

1 **Identify** the name of each scientific diagram.

a

b

**Figure 3** Scientific diagrams

#### Analyse

2 **Contrast** (describe the differences between) a scientific diagram and an artist's drawing.

3 Complete these sentences by writing them in your notes.
   a Laboratory equipment that is put together to do an experiment is called …
   b Experiment beakers, stands and other items used for experiments are called …

#### Apply

4 **Draw** scientific diagrams for:
   a a filter funnel
   b a beaker
   c metal tongs
   d a measuring cylinder.

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.


**Figure 4** Selecting the correct equipment for an investigation can improve the reliability of results.

# 1.3 Scientists take safety precautions

**Key ideas**

- Scientists may be exposed to a variety of hazards in their work in a laboratory or in the field.
- Scientists need to plan experiments so that they can complete them safely.
- Experiments in a laboratory are easier to control.

**Learning intentions**

By the end of this topic, you will be able to:

- describe safe practices within the laboratory.

**Video 1.3A** Test tube skills

**Video 1.3B** The science laboratory

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

## Safety symbols

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

Your laboratory may already have some of these symbols displayed.

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

## Laboratory safety rules

A class laboratory is not like a normal classroom – there are additional rules to follow. The class laboratory is a place where people are learning to be better scientists, but they may not always get it right the first time. You will notice your science skills improving as you do more and more experiments carefully in the laboratory.

### In the laboratory do:

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

### In the laboratory don't:

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


**Figure 1** Have you seen these safety symbols before?

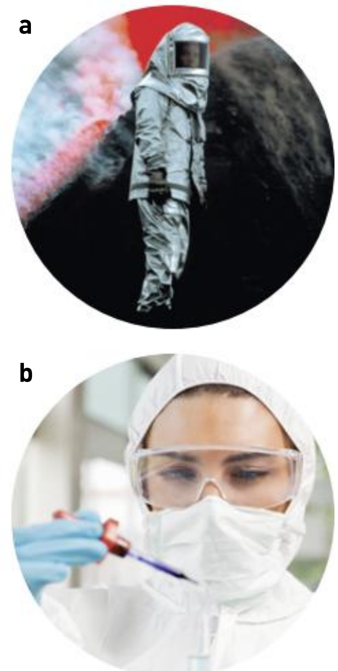



**Figure 2 a** Vulcanologists (scientists who study volcanoes) wear heat-resistant silver suits to protect themselves against heat, ash and molten rock. **b** Microbiologists researching infectious diseases wear protective clothing to ensure they do not get sick.

## Labfab: Notes from the fashion labwalk

Welcome to our fabulous fashion show for the label that is taking the fashion world by storm – *Labfab*.

Olivia is wearing our new designer lab coat, which has three- and four-button options. Note that the buttons are worn done up.

Lab coats are going to be loose this year for stylish comfort during those tricky experiments. And this year, knee length is *the* length to protect yourself from stray chemicals.

Safety glasses are hot and big. Top model and scientist Corey is modelling a pair from the new range, which are hipper than the latest sunglasses. If you already wear glasses, you may not need to wear safety glasses.

This year, laboratory shoes are solid – no tootsies please! Solid and sensible, they scream 'enduring style'.

Finally, you can never have too many accessories. The latest in latex or plastic is our fabulous range of disposable gloves. They are available in a range of colours to suit your every experimental mood.

**Figure 3** Can you see the potentially dangerous activities?

## Creating laboratory safety rules

Look at Figure 3 and then consider the following:

> How many potentially dangerous activities can you identify in this picture?
> What rules might be needed to prevent potential danger?
> Create a list of rules you think might be needed in your science laboratory. Give a possible consequence if the rule is not followed.
> Compare your list of do's and don'ts rules with those listed on the opposite page.
> Type up your list on a computer, print it out and stick it on the inside front cover of your workbook.

## 1.3 Check your learning

### Retrieve

1 **Identify** the three safety symbols shown in Figure 4. Describe the meaning of each symbol.

**Figure 4** Three safety symbols

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

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

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

### Comprehend

5 With a partner, take turns to mime a safety rule for your partner to guess.

6 **Describe** why do you think it is dangerous to drink from laboratory glassware.

### Apply

7 **Evaluate** the effectiveness of the protective equipment being worn by the students in Figure 5 (by identifying the ways the students are using the equipment safely and the ways they are being unsafe). Write a list of suggestions you could offer the students to improve their safety.

**Figure 5** Protective equipment worn by students

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 1.4 Scientists use observation and inference to answer questions

**Key ideas**

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

**Learning intentions**

By the end of this topic, you will be able to:

- define observation and inference as scientific terms
- explain the difference between qualitative and quantitative data.

The skill of observation usually requires you to notice small differences. Figure 1 shows two scenes. There are 10 differences between the two. Can you find them all?

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

## Quantitative or qualitative observations

**Quantitative observations** use measurement – they are 'amounts' or quantities and are normally written using numbers. The numbers are usually accompanied by units that describe the size or what is being measured, such as 2.7 m or 23.4 degrees Celsius (°C). For example, 10 m is a measurement of length, while 10 L is a measurement of volume.

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

**Qualitative observations** use words to describe anything that is not an amount. The five main sense organs of the human body are essential for qualitative observations. What you see, hear, smell, taste or feel are generally qualitative observations. 'Rough', 'sour' and 'yellow' are all words describing qualitative observations.

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

## Testing your senses

The secret to being observant is to use your senses. The activities in this unit will make you more aware of your senses. In some activities you will need a blindfold. It is best to use safety glasses that have been painted black or covered with dark paper. You will not test your fifth sense, taste, because it is not good safety practice to eat in a laboratory.

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

1.4: Observation versus inference
Go to page 192.

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

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

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

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

Based on your responses to Figures 3–5, answer the following questions.

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

## Inferences

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

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

**Table 1** Some sample observations and inferences

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

## 1.4 Check your learning

### Retrieve

1 **Define** (describe the meaning of) the term 'observation'. Use an example to support your definition.

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

### Analyse

3 **Contrast** (describe the differences between) quantitative observations and qualitative observations.

4 **Classify** which of the following are observations and which are inferences.

a You smell a strong odour from a garbage bin.

b Coffee stays hotter if you add the milk before the hot water.

c I measured the temperature today at 37°C.

d It is so hot that the temperature must be 37°C.

e There is a person in a Santa suit. It must be Christmas.

f This soup is so hot that it hurts my teeth.

5 **Identify** one observation from question 4 that is quantitative and one observation that is qualitative.

### Apply

6 **Discuss** why scientists do not use the sense of taste in a laboratory.

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

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 1.5 Science relies on measuring with accuracy

**Key ideas**

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

**Learning intentions**

By the end of this topic, you will be able to:

- describe how to accurately measure data using a variety of equipment.

**Video 1.5** Measurement, errors and accuracy

## What if?

### Human thermometer

**What you need:**

Very warm water, 3 ice-cream containers, room temperature water, cold water, ice cubes, thermometer

**What to do:**

1. Half fill the first container with cold water and add the ice cubes.
2. Half fill the second container with room temperature water.

**CAUTION!** Make sure it is safe to put your hand in the water.

3. Half fill the third container with very warm water.
4. Place one hand in the cold water and the other in the warm water for 2 minutes.
5. Remove both hands and place them both in the room temperature water.
   » What do you notice about how hot/cold the water is?
   » Do both hands tell your brain the water is the same temperature?
6. Use a thermometer to measure the temperature of the water in all three containers.

**What if?**

» What if a foot was put in the water instead of a hand?

As you discovered in the 'Human thermometer' activity, your body picks up changes in the environment, but it cannot tell you the exact temperature of the water or air. Your body will also become used to warmer temperatures in summer and colder temperatures in winter. What might seem like a nice 18 degrees in winter, might feel cold in summer. For this reason scientists rely on accurately measuring all things during their experiments.

## Old ways of measuring

For thousands of years, distances have been measured by comparing them to parts of the human body (see Table 1). The height of a horse, for instance, is still measured in hands. Some countries, such as the United States of America, measure distance in feet. A standard system is now used, instead of human hands and feet.

## Measurement and units

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

**Table 1** Measurements used in ancient civilisations

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

**1.5:** Measuring mass and volume
Go to page **193**.

**units**
standard measurements

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

**matter**
anything that has space and volume; matter is made up of atoms

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

The idea of having standard **units** for measurement soon spread, so all types of measurement were included. The **metric system** is now used by scientists worldwide. A measurement of 2.45 m has to be the same in Cairns, Queensland, as in New York, USA. A temperature of 37°C is just as hot in Kolkata, India, as in Toowoomba, Queensland. Scientists often check each other's work by repeating experiments to see if they get the same results. To do this they need to use measurements that are consistent with the original experiment. By using a standard system of measurement, scientists everywhere can understand and build on each other's work. Five kinds of measurement are important when you are exploring science: volume, mass, temperature, time and length.

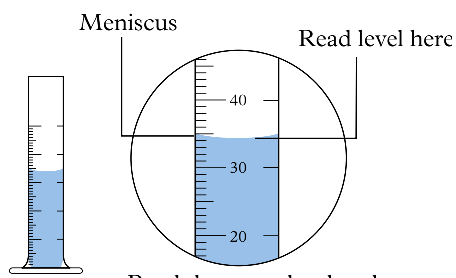
**Figure 1 Length** Measurements of length can be shown using a unit called metres, with the symbol 'm'. For long distances, kilometres (km) are used. For short distances, centimetres (cm) or millimetres (mm) can be used. In school science, the devices we use to measure length and distance are the trundle wheel (pictured), metre rule and tape measure.

**Figure 2 Mass** This measures the amount of **matter** or substance in an object. Mass is measured in units called grams (g), kilograms (kg) and tonnes (t). Smaller masses are measured in milligrams (mg). Mass-measuring devices are called scales or balances. You will use an electronic balance to measure mass.

**Figure 3 Time** A watch or clock set to the correct time tells you the time of day. A stopwatch measures how much time has passed. In your experiments, measurements of time will often have the unit called seconds (s).

**Figure 4 Temperature** This is usually measured using a thermometer. Some thermometers have a digital scale. Measurements of temperature have the unit called degrees Celsius. Its symbol is '°C'.

Place the measuring cylinder on a level surface. Look in line with the top of the water.




Read the water level at the bottom of the meniscus. (Here the correct measurement is 34 mL.)

**Figure 5 Volume** This measures how much space something takes up. Measurements of liquid volumes can be shown with units called litres (L) or millilitres (mL). In science, beakers and measuring cylinders are used to measure the volume of liquids. Some beakers have a measuring scale on them, but measuring cylinders are more accurate than beakers. Scientists usually prefer to use measuring cylinders to measure volume. Liquids cling to the sides of containers, forming a slightly curved surface. This is called a **meniscus**. The diagram shows how to read a meniscus. Measurements of the volume of solid objects have units such as cubic centimetres ($cm^3$).

**meniscus**
the curved upper surface of a liquid in a tube

## Recording measurements

All measurements have two parts: a number and a unit (see Table 2). For example, 5 metres is written as '5 m'. Notice that the unit does not have an 's' after it, even though it stands for 'metres'. This is so that it does not become confused with milliseconds.

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

**Figure 6** Stopwatches are used to measure minutes and seconds.

## Converting units of length

To compare two measurements, their units must be the same. It is difficult to compare 10 000 m with 13 km – which is longer? Comparing 10 km with 13 km is easier. The metric system works in multiples of 10, so we can convert using a formula (see Table 3). Worked examples 1.5A and 1.5B show how to convert between units.

1 kilometre = 1000 metres
1 metre = 100 centimetres
1 centimetre = 10 millimetres

**Table 2** Some metric units of measurement

| Measurement | Unit | Symbol | Instrument used |
|---|---|---|---|
| Distance or length | kilometre | km | trundle wheel |
| | metre | m | metre rule |
| | centimetre | cm | tape measure or ruler |
| | millimetre | mm | tape measure or ruler |
| Volume | litre | L | beaker |
| | millilitre | mL | measuring cylinder |
| Mass | tonne | t | weighbridge |
| | kilogram | kg | beam balance |
| | gram | g | spring balance |
| | milligram | mg | electronic scales |
| Time | hour | h | clock |
| | minute | min | stopwatch |
| | second | s | stopwatch |
| Temperature | degree Celsius | °C | thermometer |

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

**Table 3** Converting units

| Change from | Change to | Conversion |
|---|---|---|
| km | m | × 1000 |
| m | cm | × 100 |
| cm | mm | × 10 |
| m | km | ÷ 1000 |
| cm | m | ÷ 100 |
| mm | cm | ÷ 10 |

### Worked example 1.5A: Converting between units

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

#### Solution

Before you can compare the numbers, they need to be changed so that they have the same units.

1 m = 100 cm (multiply by 100)
150 m = 150 × 100 = 15 000 cm
15 000 cm is longer than 12 000 cm.

Therefore, the 150 m tree is taller than the 12 000 cm tree.

### Worked example 1.5B: Comparing measurements that use different units

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

#### Solution

100 cm = 1.0 m (divide by 100)
295 cm = 2.95 m

Therefore the 2.95 m pipe will fit in the 3.0 m postage cylinder and will be too long for the 2.5 m cylinder.

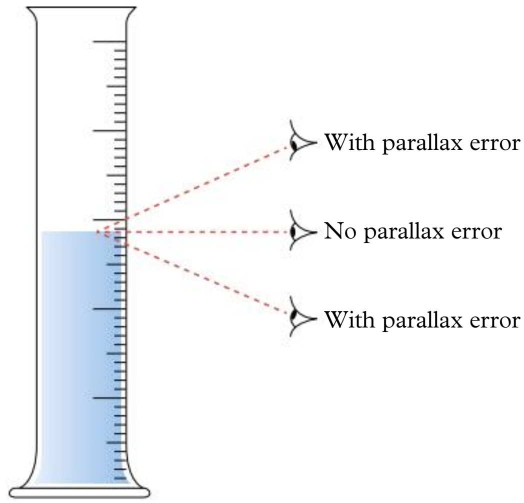



**Figure 7** Parallax error occurs when you read a scale from an angle.

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

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

## Measuring accurately

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

You can do several things to improve your **accuracy** in the science laboratory. Always take your time when measuring and make sure you write down the result straight away. When reading a scale, line up your eye directly in front of the object and the scale. Looking from above or from the side can produce different readings. This is called **parallax error** (Figure 7).

## 1.5 Check your learning

### Retrieve

1 **List** everything you have measured today. Think carefully – you have probably measured more things than you realise. Try to list at least five things.

2 **Identify** the part of the meniscus that you should read when measuring volume.

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

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

### Comprehend

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

5 In the United States of America, people use imperial units of measurement (foot, pound, mile), but scientists use metric units.

- **a** **Explain** why the scientists in the United States need to use metric units.
- **b** **Explain** why problems might arise if scientists in the United States used imperial units.

6 Use a labelled diagram to **describe** a meniscus.

7 **Explain** why you might prefer to walk 14 900 cm instead of 3 km.

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

### Analyse

9 **Identify** which is longer: 10 000 mm or 500 m.

10 **Identify** which is shorter: 3 km or 1000 m.

11 Convert 1 km into metres, centimetres and millimetres.

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

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

**Key ideas**

- A Bunsen burner is used to heat things in the laboratory.
- The yellow flame is called the safety flame because it is easier to see.
- The blue flame produces more heat than the yellow flame (over 1500°C).

**Learning intentions**

By the end of this topic, you will be able to:

- use a Bunsen burner safely and accurately.

## Using a Bunsen burner

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

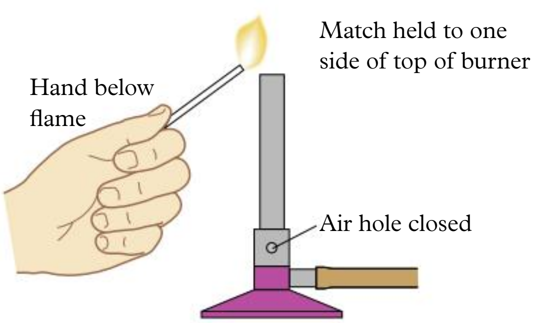



**Figure 1** The right way to light a Bunsen burner

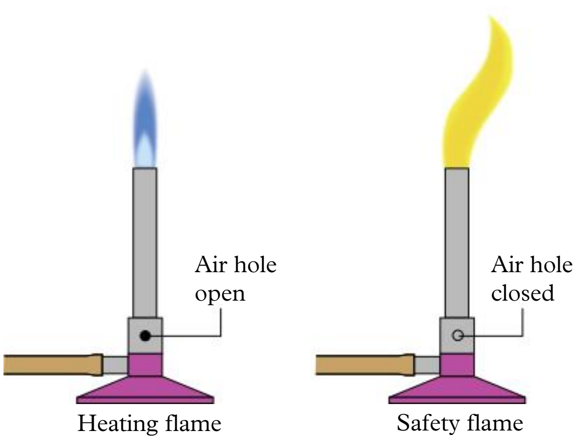



**Figure 2** Blue (heating) and yellow (safety) flames on the Bunsen burner

If the collar hole is open, air mixes with the gas, allowing a hotter blue flame to burn (Figure 2).

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

## What to do if there is a fire in the laboratory

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

## Treating scalds and burns

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

Video 1.6
How to use a Bunsen burner

Interactive 1.6
Lighting a Bunsen burner

**Bunsen burner**
a piece of equipment used as a heat source in the laboratory

**Figure 3** A scalded hand

**Figure 4** A burnt hand

# 1.6 Lighting and using a Bunsen burner

SKILLS LAB

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

## What you need:

Bunsen burner, heatproof mat, matches, notebook, coloured pencils, grey pencil, metal tongs, two pieces of white ceramic or porcelain

**Figure 5** Place the Bunsen burner on a heatproof mat.

**Figure 6** Connect the rubber hosing firmly to the gas tap.

**Figure 7** Close the air hole by turning the collar.

**Figure 8** Light a match and place it above the barrel, with your hand below the flame.

**Figure 9** Open the gas tap fully.

**Figure 10** After you have followed these steps, the Bunsen burner will have a yellow (safety) flame.

## What to do:

1 Follow the steps shown in Figures 5–10 to light your Bunsen burner.
2 Change the flame to blue by opening the air hole on the collar.
3 Write down and draw what happens to the flame when the hole is closed, half open and fully open.
4 Close the collar so that a yellow flame is produced.
5 Using tongs, hold a piece of porcelain in the top of the yellow flame for a minute. Place the hot porcelain on the heatproof mat when you have finished. Describe what happens to the porcelain and draw it.
6 Hold the other piece of porcelain with the tongs. Change the flame to blue and heat the porcelain for 1 minute by holding it in the top part of the flame. Describe what happens to this piece of porcelain and draw it.
   > Describe two reasons why the yellow flame is called the safety flame.
   > Identify which flame is noisier: blue or yellow? Explain why this is useful to know.
   > Identify which flame leaves a sooty carbon black deposit on whatever object it heats.
   > Identify which flame is the 'clean' flame for heating.
   > Describe two reasons why you might use a blue flame for heating in an experiment.

## 1.6 Check your learning

### Comprehend

1 **Describe** the colour of the Bunsen burner's safety flame.
2 **Describe** the colour of the Bunsen burner's heating flame.
3 **Explain** how (what you do) to get a heating flame with your Bunsen burner.
4 **Explain** how you should treat a scald.
5 If you were heating a substance to check for colour change, **describe** the flame that you would use to make it easier to observe.
6 **Explain** why hair should be tied back when using a Bunsen burner.

### Apply

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

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 1.7 A fair test is a controlled experiment

**Key ideas**

- Scientists are reliable sources of information because of the way they test their ideas.
- Pseudoscience is when people use the language of science to promote unscientific information.
- Scientists control the variables and repeat their experiments.
- Reasonable experiments occur when an experiment tests a hypothesis.

**Learning intentions**

By the end of this topic, you will be able to:

- explain the term 'variable' and describe the difference between dependent and independent variables
- describe how repetition increases the reliability of results.

## Pseudoscience

Have you ever seen advertisements for weight loss or hair growth 'miracles' or 'miraculous' wrinkle treatments? Although some of these products may have been partly developed by scientists, the results are usually less fabulous than they seem. The word 'pseudo' (pronounced 'seoo-doe') means 'false' – **pseudoscience** is false science. Real science is based on asking questions that can be investigated so that the results can be reproduced by other scientists. The Australian Government has regulations about many of the products sold here, but not all types of products are covered (Figure 1).

## Variables

A **variable** is something that can affect the results of an experiment. When the variable is changed, the results of the experiment will change. If the variables are kept the same, they are described as controlled. Controlling variables ensures that an experiment is fair and that the results can be trusted.

Once you can control the test, you can experiment with it. To do this you must choose only one variable to change. This is called the **independent variable** because an independent scientist makes the decision. This can be done in the form of a 'What if' question; for example:

> What if the amount of vinegar was increased?
> What if the amount of bicarbonate soda was decreased?

Once you ask a 'What if' question, you can predict what may happen (Figure 2). A reasoned prediction can be written by removing the 'What' at the start and adding a 'then' at the end of the question.

The first half of the reasoned prediction is the independent variable, and the second half of the prediction is what we are testing for. This is called the **dependent variable** because the measurements may depend on any other changes. All other variables must remain the same; these variables are called **controlled variables**. A **hypothesis** is a suggested explanation for the reasoned prediction. A good hypothesis can be tested to see if it is supported (the prediction is correct) or refuted (the prediction was wrong).

Once the hypothesis has been written, its time to plan how to do the experiment. All methods need to have a controlled test that can be repeated to get the same results. Your hypothesis should then tell you the only variable that needs to be changed.

**Reasonable tests** ensure that experimental results can be used to make the right decisions. When you consider the results of an experiment and try to draw some conclusions, you need to consider the following questions:

> Did you control every factor/variable, except the one you were changing on purpose?
> Were there any variables in the environment you could not control?
> If you did the same experiment again, would you expect the results to be exactly the same?
> Did you estimate or assume any measurements during the experiment?

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

**Figure 1** 'Miracle' products are often the result of pseudoscience.

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

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

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

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

**hypothesis**
a proposed explanation for a prediction that can be tested

**reasonable test**
a test where all variables are controlled except for the one being changed on purpose

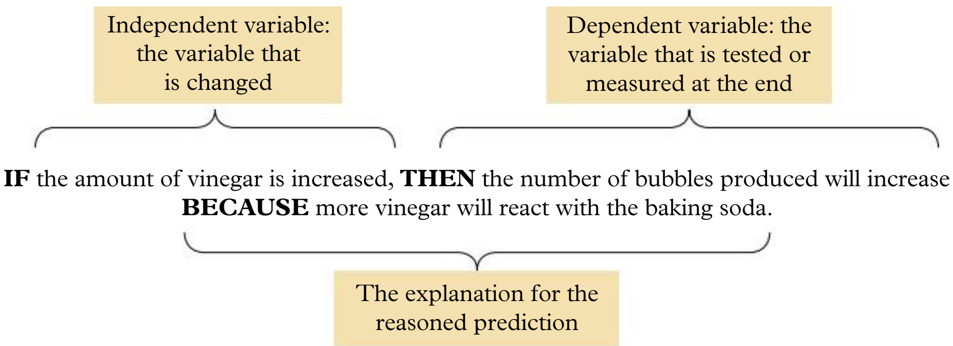



**Figure 2** A hypothesis can be made once you ask your 'What if' question.

## Asking 'What if?'

Choose one of the questions from the 'What if?' activity shown on this page to investigate.

1. Write a reasoned prediction for your inquiry.
2. Identify the independent variable that you will change from the first method.
3. Identify the dependent variable that you will measure and/or observe.
4. Write a hypothesis for your inquiry.
5. List the variables that you will need to control to ensure a fair test.
6. Describe how you will control these variables.
7. Test your hypothesis. Repeat your experiment at least three times to make sure your results are reliable.
8. Record your results in a table.
9. Write a summary of your results.

## What if?

### Controlling an experiment

**What you need:**

A large plastic cup, teaspoon, permanent marker, bicarbonate soda, vinegar, ruler

**What to do:**

1. Add a small amount of vinegar to the plastic cup and then a teaspoon of bicarbonate soda.
2. Describe what happens. Use the permanent marker to mark on the side of the cup how far up the reaction reached.
3. Use the ruler to measure the distance between the table and the mark on the cup.
4. Rinse the cup with water.
5. Repeat steps 1–4 until you can get the reaction to rise to the same mark three times in a row.

**What if?**

» What if you did not add the same amount of vinegar each time?

» What if you did not add the same amount of bicarbonate soda each time?

» What if you used a smaller cup for the reaction?

**Figure 3** If you were testing the effect of sunlight on plant growth you would need to control variables such as watering levels, soil type, fertiliser and pot size.

## Making your results reliable

Repetition of experiments is very important. If you performed an experiment and achieved certain results, you would conclude that the results were reliable. But what if you did the experiment a second time and the results were slightly different? Did you do something slightly different? Were the conditions slightly different? Did you use the same materials from the same source? If you measured the same results the second time, was it a coincidence?

Performing an experiment at least three times will give you greater confidence in your results. If other people repeat your experiment and achieve the same results, then your results are supported even more.

**Figure 4** Repeating an experiment improves the reliability of your results.

### 1.7 Check your learning

#### Retrieve

1 **Define** the term 'variable'.

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

#### Comprehend

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

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

- a **Explain** why you agree or disagree with Justin's conclusion.
- b **Explain** whether Justin conducted a reasonable test (by describing if he controlled all other variables, describing if he would have the same results if he repeated the experiment, and deciding if the test was fair).
- c **Identify** two variables that needed to be controlled. **Explain** how these variables could have affected the results.
- d **Describe** two ways you could improve Justin's experiment so that his results were more reliable.

#### Apply

5 When repeating experiments, a scientist claimed that:
'One set of results was random.
Two sets were a coincidence.
Three sets is evidence.'
**Discuss** what the scientist meant by this saying.

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 1.8 Graphs and tables are used to show results

**Learning intentions**

By the end of this topic, you will be able to:

- use graphs and tables appropriately to communicate the data from investigations.

**Key ideas**

- Scientists need to collect data and present it in an organised manner.
- Tables or graphs allow scientists to identify patterns that may exist in their results.
- Tables should have a heading, column headings with units of measurement, and data in each column.
- Different graphs should be used depending on the type of data (discrete or continuous) being displayed.

## Data tables

When recording the results of experiments, the data collected should be neatly presented in a table or logbook. There are four steps for drawing a table:

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

2 Write a heading that describes the contents of the table; for example, 'The change in water temperature over time' (see Table 1).

3 Give each column a label and units (what the number means), such as 'Temperature (°C)'.

4 Add your data in the correct columns.

**Table 1** Change in water temperature over time

| Time (min) | Temperature (°C) |
|---|---|
| 5 | 43 |
| 10 | 37 |
| 15 | 35 |
| 20 | 24 |

## Graphing data: Discrete and continuous data

There are two main types of data. The first type, **discrete data**, is obtained when the numbers can only be whole numbers, such as the number of people in a class (you cannot have half a person). Discrete data is often represented in a **column graph**.

The second type of data, **continuous data**, is obtained when the numbers can be any value. For example, the fastest time in the world for a 100 m race is currently 9.58 s; the tallest person in the world is 251 cm tall (Figure 1). Continuous data should always be represented in a line or **scatter graph**.

**discrete data**
data where the numbers can only be whole numbers

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

**continuous data**
data that are measured and can be any value

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

a

b


**Figure 1 a** Sultan Kosen is 251 cm tall.
**b** Usain Bolt ran 100 m in 9.58 s. Height and time are examples of continuous data.

SKILLS LAB
**1.8:** Heating water
Go to page **194**.

## Column graph

In a column graph, the height of the columns represents the number that you were measuring. This type of graph is good for showing discrete data. The steps for drawing a column graph are listed below.

For example, when graphing the number of insects caught at each location, the independent scientist changes the independent location variable and the number of insects is counted at each point. Therefore, location is the independent variable and is on the horizontal axis. The number of insects is the dependent variable and is on the vertical axis.

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

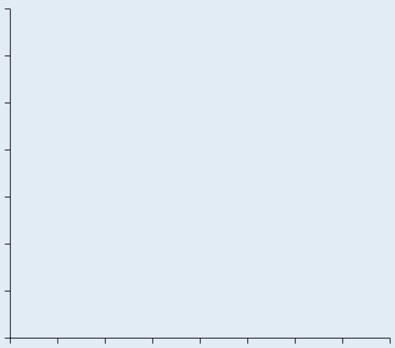


**Figure 2** Drawing a set of axes

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

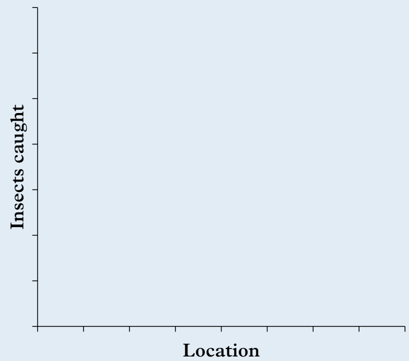



**Figure 3** Labelling each axis

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

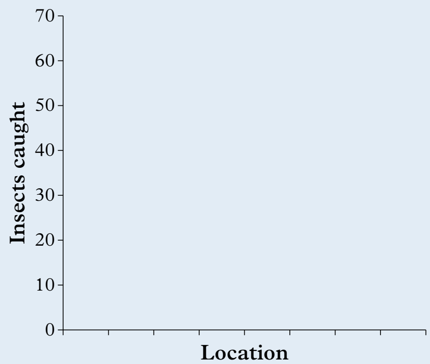



**Figure 4** Adding numbers to the axes at regular intervals

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

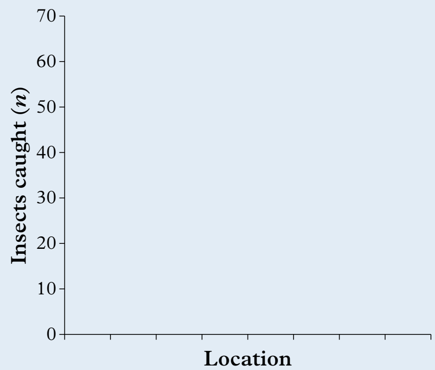



**Figure 5** Adding units to the axes

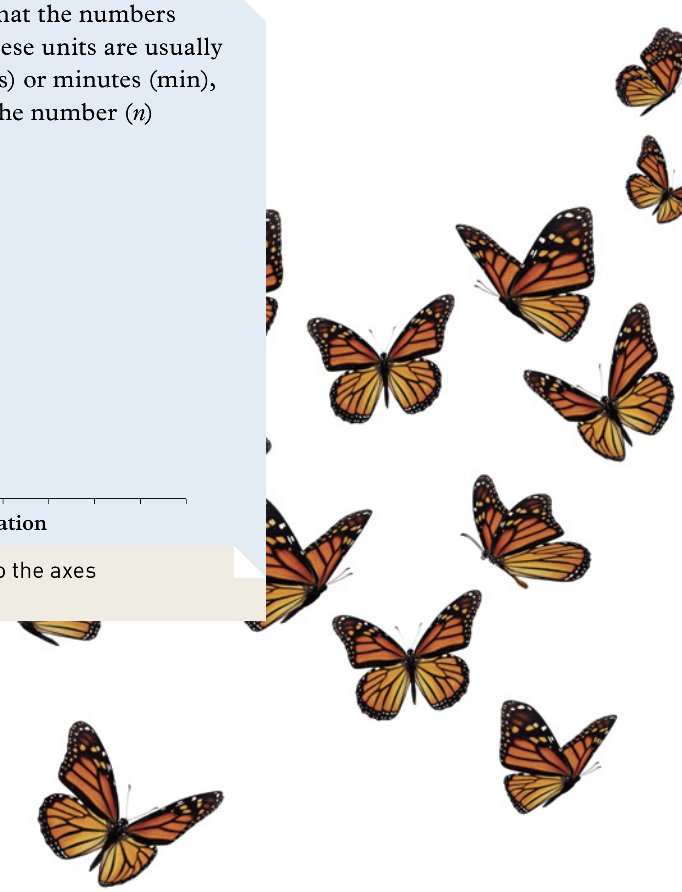


**Figure 6** Make sure to keep a careful record of insects caught at different locations.

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

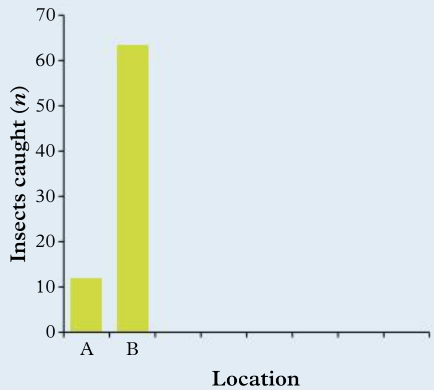



**Figure 7** Plotting data on the column graph

**Step 6:** A completed column graph shows the number of insects caught at different locations.

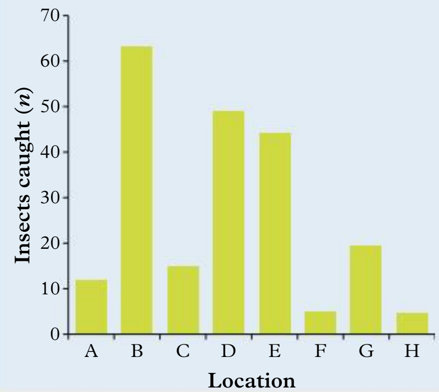



**Figure 8** Finishing the column graph

## Scatter graph

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

**Step 1:** Use a pencil and a ruler to draw a large set of axes (the horizontal and vertical lines of a graph). Label each axis. The horizontal (flat) axis should show the independent variable, and the vertical (up) axis should be the dependent variable.


**Figure 9** Drawing a set of axes

For example, when graphing how temperature changes over time, the independent scientist changes the independent variable (time) and then measures the temperature. Therefore, time is on the horizontal axis and temperature is on the vertical axis.

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

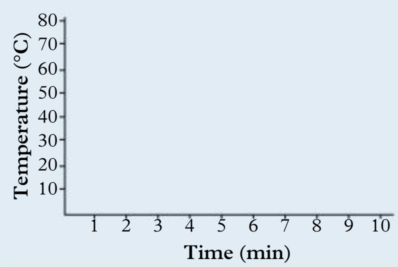



**Figure 10** Adding numbers to axes at regular intervals

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

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

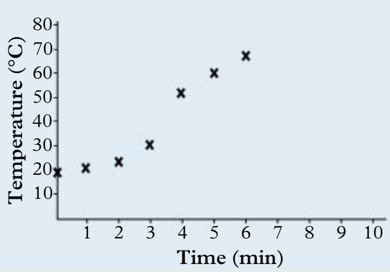



**Figure 11** Potting data on the graph using small crosses

**Step 4:** Draw a **line of best fit** or a smooth curve that passes through or near to as many data points as possible. In this case a line of best fit is shown.

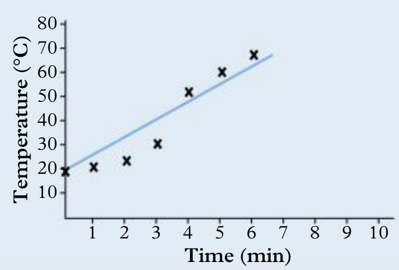



**Figure 12** Drawing a line of best fit

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

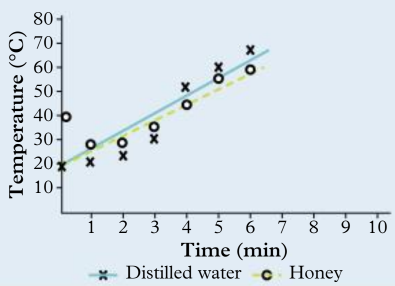



**Figure 13** Using small crosses and circles when plotting more than one set of data

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

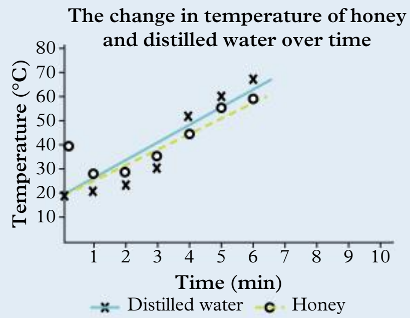



**Figure 14** Writing a descriptive title for the scatter graph

## 1.8 Check your learning

### Retrieve

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

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

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

4 Figure 15 shows a graph drawn by a student. **List** all the things that should be corrected on the graph.

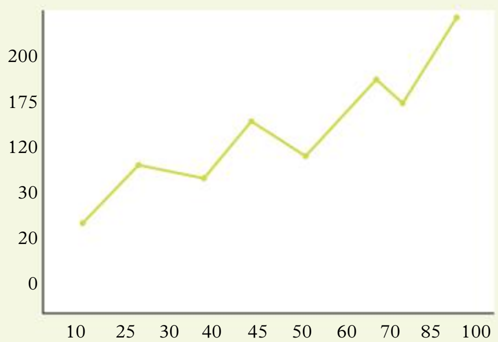



**Figure 15** A graph drawn by a student

### Comprehend

5 For each set of data that follows:

a **describe** the type of graph that should be drawn

b **explain** what has happened during each of the following events:

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

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

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

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

iii how the number of trees in an area affects the amount of birds.

| Number of trees | Number of birds |
|---|---|
| 1 | 2 |
| 2 | 3 |
| 3 | 7 |
| 4 | 10 |
| 5 | 13 |
| 6 | 18 |
| 7 | 20 |

**Quiz me**

Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 1.9 Scientists analyse claims and results

**Learning intentions**

By the end of this topic, you will be able to:

- describe how errors can affect the results of an experiment
- describe the evidence a scientist uses when making a claim.

**Key ideas**

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

## Good science

Earlier in the chapter you learnt about how pseudoscience claims are commonly made on the internet or in the media. These claims will often use scientific words and describe poorly designed experiments that did not have all variables controlled. A good science experiment needs to be carefully planned, and the results will be carefully analysed to make sure that all errors have been minimised.

When you are planning your methods, or analysing the results of your experiment, there are a few hints you can use to help you avoid making pseudoscientific claims.

## Analysing the method

One of the most difficult things to do in an experiment is to control all variables. Sometimes random things, like someone opening a door or window, can cause an **error** in an experiment (Figure 1). An example of this might be when a scientist is testing if salty water takes longer to boil than fresh water. A window opening might cause cold air to change the temperature of the surrounding air.

This is why it is important to check if an experiment was repeated at least three times with the same results. Repeated experiments are more reliable than single experiments.

**error**
an inaccuracy or inconsistency in measurement

**Figure 1** Even something as small as having a window open can impact the results of an experiment.

### Assumptions

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

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

### Errors

Occasionally the scientist can make a mistake in the way they do an experiment. Mistakes should be fixed immediately, or the experiment should be started again. An error is different from a mistake – it can happen for various reasons, no matter how careful you are. Errors can occur if the object you are measuring falls between two markings on a scale; this will mean that you have to estimate the exact measurement. When this occurs, it is important to use a more accurate scale or a digital device. Sometimes scales can be calibrated (set up) incorrectly, which means that no matter what you measure you will get a slightly inaccurate result (Figure 2). You can minimise the effect of this kind of error by always using the same measuring device.


**Figure 2** Scales should always be calibrated to avoid an error.

## Improvements

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

# Analysing the results

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

## Data anomalies

Sometimes when plotting data on a graph, there may be a single dot or number that is unexpected or that does not fit with the rest of the graph (Figure 3). This is called an **anomaly** in the data. It is important not to remove or ignore this value. If you can, try to explain what might have caused this unexpected result.

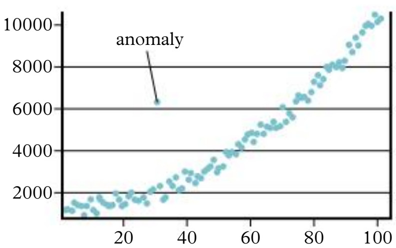



**Figure 3** A data anomaly can be identified by a graphed data point that is away from the other data.

## Making a claim

If the data has no anomalies, and it matches the original reasoned prediction, then the scientist can claim their hypothesis is supported. When making a claim, the scientist will:

> rewrite their hypothesis
> describe the experiment and data that matches it
> explain the science of why the dependent variable was changed by the independent variable
> describe any examples that have not yet been tested (the limitations).

If there is no match between the data and reasoned prediction, or there are several anomalies, the scientist must admit that the hypothesis is refuted (not supported by the evidence). It is always exciting when a hypothesis is shown to be wrong. As stated by famous scientist, Isaac Asimov, 'The most exciting phrase to hear in science, the one that heralds new discoveries, is not "Eureka!" but "That's funny …"'.

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

**Figure 4** Associate Professor Elizabeth Tibbetts discovered that the wasps she was studying had individual markings.

## 1.9 Check your learning

### Retrieve

1 **Define** the term 'anomaly'.

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

### Comprehend

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

### Analyse

4 **Contrast** the terms 'mistake' and 'error'.

### Apply

5 Associate Professor Elizabeth Tibbets had difficulty putting marks on the wasps she was studying. When looking closely at the wasps, she realised that they all had different markings (Figure 4). This encouraged her to test if the wasps could tell one another apart. **Propose** a hypothesis that the associate professor could test based off this idea.

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

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 1.10 Scientific reports communicate findings

**Learning intentions**

By the end of this topic, you will be able to:

- construct a scientific report that uses data and scientific language.

**Key ideas**

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

**conclusion**
a statement that 'answers' the aim of an experiment

**aim**
the purpose of an experiment

**method**
a series of steps explaining how to do an experiment

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

## What is a scientific report?

A report is a written account of an experiment and usually has eight parts:

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

### Writing in the third person

The best type of scientific report lets the results speak for themselves. If an experiment has been controlled to make it a fair test, then it should not matter whether Einstein or your 5-year-old brother conducted the experiment. This is one reason why personal pronouns ('I', 'me', 'our') are usually left out of scientific reports. When you use personal pronouns, it is tempting to put in a lot of information that is not relevant.

## Writing a scientific report

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

> Create an outline of the scientific report, including a table for your results, before you begin.
> Conduct the experiment and fill in the table of results.
> Answer the discussion questions, practising using the third person.
> Check back to the aim to remind you of what your conclusion is answering.
> Write a conclusion by following the instructions in the example on page 29.
> Evaluate the design of this experiment.

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

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

## The number of rubber bands for a bungy-jumping egg

EXPERIMENT

### Aim

To drop an egg close to the ground safely.

### Materials

This is a list of what you need.

> Rubber bands
> Plastic or mesh bag
> Raw egg or small bag of water
> Wire or paper clip
> Retort stand
> Boss head
> Clamp
> Metre ruler

### Method

1 Place the egg in the plastic or mesh bag and seal the bag with the wire or paper clip. Be careful to tie it tightly to prevent the egg from slipping through and spilling on the floor. Make a loop at the top of the wire – this is where the rubber bands will be attached.

2 Connect the rubber band around the wire loop and hook it over the retort stand clamp (as shown in Figure 1). One person will need to hold down the retort stand to ensure that it does not tip.

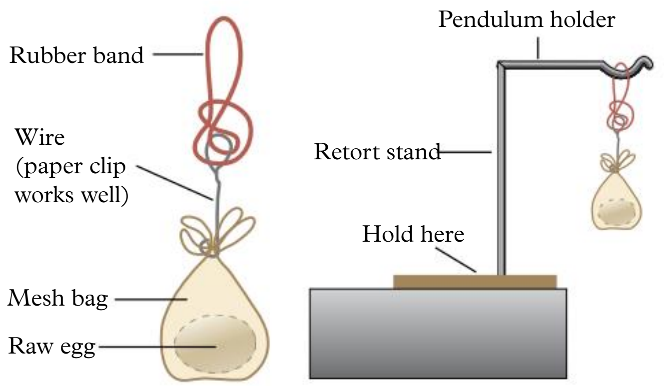



**Figure 1** Connecting the rubber band around the wire loop and then hooking it over the retort stand clamp

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

3 Carefully hold the egg so that it is level with the clamp and let it drop. One member of the group may need to catch the egg on its return back up to ensure that it does not hit the clamp.

4 Measure the distance the egg travelled from the clamp. Be careful to avoid parallax error for this measurement.

5 Repeat steps 2–4 using additional rubber bands connected in a chain.

### Results

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

### Discussion

1 Describe the difficulties you had when measuring the distance that the egg fell.

2 Describe how your results would have been affected if the rubber bands were different sizes.

3 Identify one other variable that could have affected the results. Describe how you tried to control this variable.

4 Extend your graph so that it shows how many rubber bands would be needed for a 2 m drop. From this extrapolation/ extension, calculate how many rubber bands you would need to safely drop the egg as close to the floor as possible.

5 Explain how your results may have changed if extra weight was added to the egg before dropping it.

6 Explain how your results could help people who want to bungy jump off a bridge.

7 Describe two safety recommendations that should be made to anyone trying this experiment.

### Conclusion

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

## 1.10 Check your learning

### Retrieve

1 **Define** the term 'hypothesis'.

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

### Comprehend

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

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

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

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

**Quiz me**

Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

//SCIENCE AS A HUMAN ENDEAVOUR//

# 1.11 Science skills are used to solve important problems

**Learning intentions**

By the end of this topic, you will be able to:

- describe how scientists plan, conduct and communicate their investigative strategies and conclusions.

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

In this chapter you have learnt about asking questions and about doing science safely. You have used your skills of experimentation, observation, inference and measurement. You are now going to apply these skills to a problem facing our country: an invasion of cane toads.

## Cane toads in Australia

Cane toads have been successful in Australia for a number of reasons. They can live in a wide range of environments and can breed in almost any body of water, no matter how small. They produce very large numbers of eggs several times a season, and the adults live for a long time. Also, many of the diseases and parasites that keep cane toad populations under control in their native countries are not found in Australia (Figure 1).

**Figure 1** Cane toads have taken over much of northern and eastern Australia.

**Figure 2** A cane beetle

Cane toads are a threat to native Australian animals. When cane toads feel threatened, they release a poison from poison sacs behind their eyes. This poison can kill almost all animals, including the saltwater crocodile and humans. They eat a very wide range of native animals, including small vertebrates, such as birds, and invertebrates, such as beetles. They will also eat processed food, such as pet food. Because they are toxic to most animals that try to eat them, cane toads have very few predators.

When they arrived, cane toads ate everything in sight except for the cane beetle that they were brought here to eat (Figure 2). Cane beetles lived halfway up the cane plant where the toads could not reach, or in thick fields where the toads had no reason to go. Also, within five years, an insecticide – a chemical that kills insects – became available and the sugar cane farmers no longer needed to rely on the cane toad to destroy the cane beetle.

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

## Kimberley Toad Busters

Australia is now home to more than 200 million cane toads. A group of people called the Kimberley Toad Busters have joined together to get rid of the cane toad and to stop it entering Western Australia (Figure 3). They have organised outings to capture and then humanely (respectfully and without pain) kill the toads.

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

## 1.11 Test your skills and capabilities

### Communicating solutions to problems

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

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

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

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

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

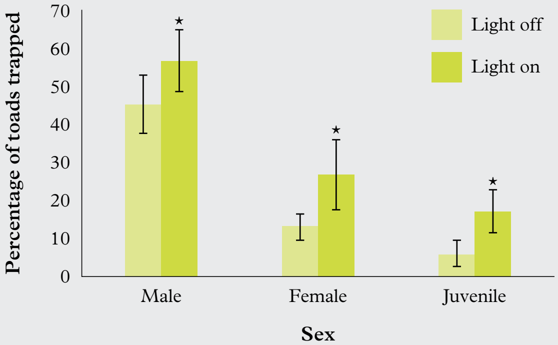



**Figure 4** The percentage of male, female and young juvenile cane toads trapped with and without lights.

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

6 Design an experiment that scientists could have conducted before cane toads were brought to Australia. (Remember how quickly the cane toad breeds in the wild – your experiment must be controlled.)
   a **Describe** the aim of your experiment.
   b Write a list of equipment that you would need.
   c Write a list of questions you would ask yourself during the experiment.
   d Imagine that you have conducted the experiment. Using the information on this page, write the results of your experiment.
   e Write the conclusion. Remember to look back at the aim when you write this.

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

# 1.12 First Nations Australians use science

**Learning intentions**

By the end of this topic, you will be able to:

- describe how First Nations peoples use science skills.

**Key ideas**

- First Nations peoples come from many diverse nations that have their own unique cultures and knowledge.
- First Nations peoples use science skills.

Aboriginal and Torres Strait Islander cultures are some of the oldest continuous cultures in the world and have lived on this land for at least 60 000 years. First Nations peoples have been using scientific skills and methods for thousands of years. They have observed the world around them, carried out experiments and collected data and repeated those experiments with similar results so that they can understand and manage the world around them.

As we will learn throughout Year 7 Science, Indigenous knowledge incorporates a wide variety of ideas and contexts, such as understanding ecosystems, medicine and astronomy.

## Australia is home to many Nations

We say First Nations peoples (not 'people') because there are many diverse language groups across Australia (more than 250 different languages), each of whom have their own unique cultures, laws, practices and languages.

The map in Figure 1 shows how many different social or language groups or Nations there are in modern-day Australia. Language groups refer to First Nations peoples or groups who share the same language.


**Figure 1** The map these people in the Queensland Parliament are looking at shows the many different First Nations Australian language groups.

**Figure 2** A female fruiting cone from the Australian cycad

When you learn about the Dreaming stories or cultural practices of one Nation, it is important to understand that not all Nations have the same cultural practices or knowledge.

## Using science skills

First Nations peoples made many observations of all living things in the land, waters and sky. While Europeans grouped turtles as reptiles, the dugong as mammals and barramundi as fish, First Nations peoples group these animals together because they all live in water and have fins or flippers. This grouping is also used in the separation of the different parts of a mixture. Many of the living things can be culturally significant and, like their **totems**, are not used as a food source.

First Nations peoples use their skills to observe and identify plants that are able to be eaten and those that are poisonous, and to make water safe to drink. For example, First Nations peoples across Far North Queensland developed techniques to detoxify many poisonous plants. One such technique involved roasting the seeds and stems of cycads. After roasting, the cycads are crushed and left to soak for a day before they are roasted again. This process removes the toxin (cycasin) from seeds and stems and provides an edible food source.

These processes are understood as a result of observing the surrounding environment, planning and conducting experiments, and analysing, communicating and repeating the results through oral traditions.

**totem**
a spiritual being, symbol or object that is sacred to a group of people

## 1.12 Check your learning

### Retrieve

1 **Define** the word 'observation'.

2 **Identify** the traditional custodians of your school's land.

### Comprehend

3 **Describe** why it is important to refer to First Nations peoples as 'peoples' and not 'people'.

4 **Describe** one example of First Nations peoples observing the world.

5 **Describe** one example of an experiment that First Nations peoples may have conducted thousands of years ago.

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

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 1.13 Cognitive verbs identify the tasks in a question

**Learning intentions**

By the end of this topic, you will be able to:

- recognise the cognitive verb in a question
- understand the different tasks involved for different cognitive verbs.

**Key ideas**

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

**cognitive verb**
a doing word that requires you to perform a specific thinking task

## Cognitive verbs

A **cognitive verb** is a verb or 'doing word' that requires thinking to perform a set task. For example, the word 'describe' is a cognitive verb because it requires you to remember what you know about something and talk about its features. Cognitive verbs are commonly used in questions which means you will encounter a variety of cognitive verbs in school as you learn new information.

Common cognitive verbs and the task/s associated with them are given in Table 1. Understanding these cognitive verbs and the tasks behind them can help you figure out how to best answer a question.

**Figure 1** Familiarising yourself with different cognitive verbs can help you answer questions and improve your learning.

**Table 1** Common cognitive verbs and their tasks

| Cognitive verb | Task | Category |
|---|---|---|
| Define | give the meaning of a word | **Retrieve** – Recall information from permanent memory. |
| Identify | recognise and state a distinguishing factor or feature | |
| Name | provide the correct term or noun | |
| Recall | present remembered ideas, facts or experiences | |
| Use | operate or put into effect | |
| Select | pick out | |
| Describe | give an account of a situation, event, pattern or process, or of the characteristics or features of something | **Comprehend** – Activate and transfer knowledge from your permanent memory to your working memory. |
| Explain | make an idea or situation plain or clear by describing it in more detail or revealing relevant facts | |
| Summarise | give a brief statement of a general theme or major point/s; present ideas and information in fewer words and in sequence | |
| Categorise | place in or assign to a particular class or group | **Analyse** – Use your reasoning to go beyond what was directly taught. |
| Classify | arrange, distribute or order in classes or categories according to shared qualities or characteristics | |
| Compare | display recognition of similarities and differences and recognise the significance of these similarities and differences | |
| Contrast | give an account of the differences between two or more items or situations | |

| Cognitive verb | Task | Category |
|---|---|---|
| Distinguish | recognise as distinct or different; note points of difference between | |
| Interpret | use knowledge and understanding to recognise trends and draw conclusions from given information | |
| Calculate | determine or find (e.g. a number, answer) by using mathematical processes | |
| Create | reorganise or put elements together into a new pattern or structure | **Apply** – Use your knowledge in specific situations. |
| Discuss | examine by argument; sift the considerations for and against; talk or write about a topic | |
| Evaluate | examine and determine the merit, value or significance of something | |
| Elaborate | investigate, inspect or scrutinise | |
| Justify | give reasons or evidence to support an answer, response or conclusion | |
| Predict | give an expected result of an upcoming action or event | |

Some cognitive verbs require more thinking and understanding than others. For example, if you were asked to *name* the two fruits in Figure 2, you might instantly remember 'apple' and 'orange' and could write the names down without much trouble. However, if you were asked to *compare* the two fruits, you would need to consider the two fruits and identify at least one similarity and one difference between them. In this sense, 'compare' requires a deeper level of thinking than 'name'.

Table 1 shows how the type/s of thought processes behind the task can be used to categorise cognitive verbs. Throughout this book you will notice that you are usually tasked with 'retrieve' type questions before you are asked an 'apply' type questions. This is because working in order from retrieve to comprehend to analyse and finally to apply helps your learning process.

**Figure 2** Two healthy fruits

## 1.13 Check your learning

### Retrieve

1 **Define** the term 'cognitive verb'.

2 **Identify** the cognitive verb that requires you to describe at least one similarity and one difference between two things.

### Comprehend

3 **Describe** what is required to correctly answer:

a a 'classify' question

b a 'distinguish' question

c an 'explain' question.

### Analyse

4 **Distinguish** the different categories of cognitive verbs.

### Apply

5 A student was asked to 'distinguish' between the apple and orange in Figure 2. Their response was 'Both the apple and orange are round in shape'. **Evaluate** whether the student has correctly answered the question.

**Quiz me**

Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

## SCIENCE TOOLKIT

### Retrieve

1 **Identify** which of the following is most accurate when measuring 10 mL of liquid.
- A conical flask
- B beaker
- C measuring cylinder
- D test tube

2 **Identify** which of the following could be used to measure the temperature of the air.
- A balance
- B electronic scales
- C stopwatch
- D thermometer

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

4 **Identify** the metric units used for the following measurements.
- a volume
- b temperature
- c time
- d mass

5 **Define** the term 'mass'.

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

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

### Comprehend

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

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

**Figure 1** A Bunsen burner with a blue flame

10 **Explain** what this safety sign means.

**Figure 2** Identifying safety signs

11 **Describe** a reasonable test.

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

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

14 Answer the following questions about a Bunsen burner.
- a **Provide** an example of when the Bunsen safety flame is important.
- b **Explain** what steps you need to use to achieve a safety flame with your Bunsen burner.
- c **Describe** two reasons why the safety flame is not good for heating.
- d **Identify** which part of the blue flame is best for heating.

15 A student is conducting an experiment and measuring the amount of water they need to use in a measuring cylinder. They look at their measuring cylinder from three angles A, B and C.
- a **Identify** which angle would provide them with the most accurate reading.
- b **Explain** your answer to part a.

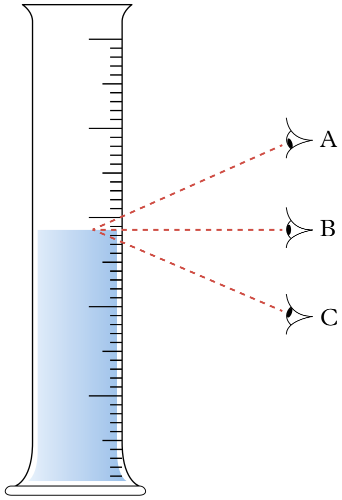



**Figure 3** Which angle provides the most accurate reading?

## Analyse

**16** Write three observations and three inferences about:

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

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

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

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

**19** Measure the length of the palm of your hand. Check the length of your own palm against the suggested value (see Table 1 on page 13) in centimetres.

- **a** **Calculate** the length of 50 standard 'palms'.
- **b** **Calculate** the length of 50 values of the measurement of your palm.
- **c** **Calculate** the difference in the two measurements.

## Apply

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

- **a** What is the temperature inside a furnace?
- **b** What is the thickness of a sheet of paper?
- **c** How fast do your fingernails grow? How could you measure this?

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

- **a** **Evaluate** why a column graph would be the most appropriate graph to use for this data.
- **b** Use the data to draw a column graph.
- **c** **Discuss** why you could not use this data to determine which state has the largest koala population.

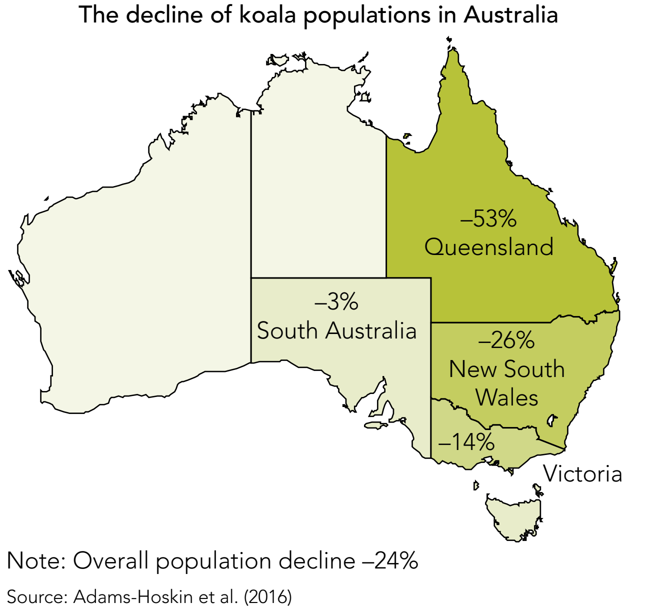



**Figure 4** The decline of koala populations in Australia

**22** Pseudoscience challenge: Your teacher will provide you with a set of last week's horoscopes. They will be randomly numbered, and the dates and star signs removed.

- Decide which horoscope from last week best fits you.
- Collate all the horoscope numbers and class members' names on the board.
- Your teacher will list the corresponding star signs for each number.

Once you have carried out the above tasks:

- **a** **identify** how many horoscopes were correct
- **b** **determine** what this tells you about astrology
- **c** use the evidence from questions a and b to **determine** if astrology is a science or a pseudoscience
- **d** **discuss** two new things you learnt from this activity.

### Social and ethical thinking

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

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

## Critical and creative thinking

24 **Design** one of the following experiments. Write an aim, prediction and method for the experiment. **Identify** the variables and make sure you control all but the independent variable. Make note of any safety issues. Set it out like one of the experiments in this book.
- An experiment to test if three types of material are waterproof.
- An experiment to see how high a rubber 'bouncy-ball' can bounce on different surfaces.

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

## Research

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

### » Famous Australian scientists

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

» Select one of the scientists from this list: Frank Macfarlane Burnet, Douglas Mawson, Gustav Nossal, Mark Oliphant, Helen Caldicott, Nancy Millis, William McBride, Struan Sutherland, Suzanne Corey.

» Describe the area in which they do research.

» Explain any significant discoveries that they may have made.

» Create a list of questions that you would ask them if you had the chance.

### » Depending on variables

Scientific discoveries rely on carefully controlling experiments. This means that the methods must be able to be repeated and all the variables have to be controlled.

» Explain the difference between controlled variables and the independent variable.

» Describe what would happen if the variables in an experiment were not controlled.

» Describe two experiments: one that was controlled and one that was not controlled.

» Explain how the reputation of a scientist may be affected if they made a claim based on an uncontrolled experiment.

### » Intellectual property

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

» Identify what is meant by the term 'biopiracy'.

» Describe the things you would need to consider before you started your research.

## Chapter checklist

Now that you have completed this chapter, reflect on your ability to do the following.

| | I can do this. | I cannot do this yet. |
|---|---|---|
| • Describe the questions scientists might ask.<br>• Describe where and how scientific investigations can occur. | ☐ | ☐ Go back to Topic 1.1 'Science is the study of the natural and physical world'.<br>Page 4 |
| • Describe a variety of different pieces of specialised science equipment. | ☐ | ☐ Go back to Topic 1.2 'Scientists use specialised equipment'.<br>Page 6 |
| • Describe safe practices within the laboratory. | ☐ | ☐ Go back to Topic 1.3 'Scientists take safety precautions'.<br>Page 9 |
| • Define observation and inference as scientific terms.<br>• Explain the difference between qualitative and quantitative data. | ☐ | ☐ Go back to Topic 1.4 'Scientists use observation and inference to answer questions'.<br>Page 11 |
| • Describe how to accurately measure data using a variety of equipment. | ☐ | ☐ Go back to Topic 1.5 'Science relies on measuring with accuracy'.<br>Page 13 |
| • Use a Bunsen burner safely and accurately. | ☐ | ☐ Go back to Topic 1.6 'A Bunsen burner is an essential piece of laboratory equipment'.<br>Page 17 |
| • Explain the term 'variable' and describe the difference between dependent and independent variables.<br>• Describe how repetition increases the reliability of results. | ☐ | ☐ Go back to Topic 1.7 'A fair test is a controlled experiment'.<br>Page 19 |
| • Use graphs and tables appropriately to communicate the data from investigations. | ☐ | ☐ Go back to Topic 1.8 'Graphs and tables are used to show results'.<br>Page 22 |
| • Describe how errors can affect the results of an experiment.<br>• Describe the evidence a scientist uses when making a claim. | ☐ | ☐ Go back to Topic 1.9 'Scientists analyse claims and results'.<br>Page 26 |
| • Construct a scientific report that uses data and scientific language. | ☐ | ☐ Go back to Topic 1.10 'Scientific reports communicate findings'.<br>Page 28 |
| • Describe how scientists plan, conduct and communicate their investigative strategies and conclusions. | ☐ | ☐ Go back to Topic 1.11 'Science as a human endeavour: Science skills are used to solve important problems'.<br>Page 30 |
| • Describe how First Nations peoples use science skills. | ☐ | ☐ Go back to Topic 1.12 'First Nations Australians use science'.<br>Page 32 |
| • Recognise the cognitive verb in a question.<br>• Understand the different tasks involved for different cognitive verbs. | ☐ | ☐ Go back to Topic 1.13 'Cognitive verbs identify the tasks in a question'.<br>Page 34 |

**Check your Student obook pro for these digital resources and more:**

**Quizlet**
Play a Quizlet game to test your knowledge.

**Chapter quiz**
Test your understanding of this chapter with the chapter review quiz.

CHAPTER

2

# PARTICLE MODEL

2.1

**There are three states of matter**

> Describe the three states of matter.
> Identify the processes that change substances from one state to another.

2.2

**Scientists' understanding of matter has developed over thousands of years**

> Describe how our understanding of matter has changed over time.
> Contrast the arrangement of particles in solids, liquids and gases.

2.3

**The particle model explains matter**

> Define the particle theory of matter and diffusion.
> Explain how kinetic energy affects particle movement.

2.4

**The particle model can explain the properties of matter**

> Define and explain tensile strength, hardness, viscosity, compressibility and density in terms of the particle model.

2.5

**Increasing kinetic energy in matter causes it to expand**

> Describe what happens to particles when they are heated.

> Explain how heat can cause expansion.

2.6

**Science as a human endeavour:**
**Scientists find ways to communicate**

> Identify ways that scientists can share ideas and theories with different audiences.

## What if?

**CAUTION!** Do not eat in the laboratory.

### M&Ms

**What you need:**

M&Ms (red is best), 250 mL beaker, water

**What to do:**

1 Pour 100 mL of water into the beaker.
2 Place one M&M in the centre of the beaker.
3 Allow the water and the red M&M to settle.
4 Time how long the colour takes to reach the walls of the beaker.

**What if?**

» What if the water was warm? Would the colour move faster or slower?
» What if the water was chilled?
» What if you stirred the water?

# 2.1 There are three states of matter

**Learning intentions**

By the end of this topic, you will be able to:

- describe the three states of matter
- identify the processes that change substances from one state to another.

**Key ideas**

- All things are made of matter.
- There are three major states of matter – solid, liquid and gas.
- Many substances can be found in more than one state.

## Solids, liquids and gases

Water is a common substance that we experience in different states of matter. Solid water is called ice, we drink and wash with liquid water, and the gas form of water is known as water vapour. Occasionally we see a fog or mist in the air. This steam-like substance is actually very small drops of water mixed with the air.

Although the ocean and iceberg shown in Figure 1 may look and behave very differently, they are both different forms of water. The ocean is liquid water, and the iceberg is solid water. There is also water vapour in the air. Clouds and fog are made of small liquid water droplets. All of these different states of water are made of the same 'building blocks' or water particles.

Often, substances can be described as just one state. However, some substances contain more than one state of matter, like honeycomb (Figure 2). Sometimes we can see all the states in the one mixture – like in the glass of iced soda water in Figure 3 – and sometimes it can be difficult to tell the state of a mixture. For example, would you classify slime or jelly (Figure 4) as a solid, a liquid or a gas?

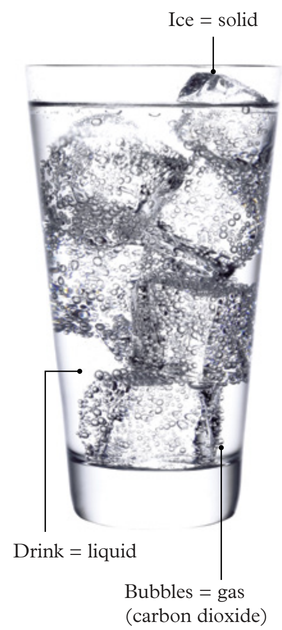



**Figure 3** A glass of iced soda water contains the three states of matter.

**Figure 2** Honeycomb is a combination of solid and gas. Or is it?

**Figure 1** Solid water (ice) floats on liquid water.

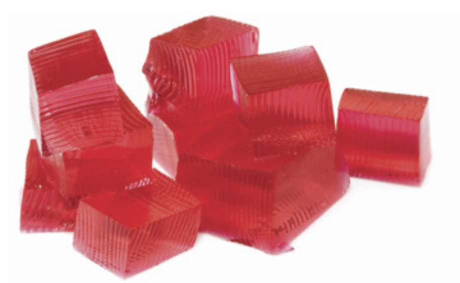


**Figure 4** Is jelly a solid, a liquid or a gas?

EXPERIMENT

**2.1A:** Comparing states of matter
Go to page 195.

CHALLENGE

**2.1B:** Three states of water
Go to page 196.

## Change of state

The minimum temperature required to melt a solid is called its melting point. Any substance above its melting point will be a liquid (or a gas), and any substance below its melting point will be a solid.

The process of water becoming a gas (water vapour) is called **evaporation**. Each substance has a different temperature that causes the gas to form. This temperature is called the **boiling point**. If heat is removed from the water vapour, the gaseous water slows its movement until it once again forms liquid water. This process is called **condensation**. Figure 9 shows how the state of water changes when heat is added and removed.

**Figure 5** A kettle boils liquid water.

**Figure 6 Liquid water** When most of us think of water, we think of the liquid form that comes out of our taps. Liquid water sits at the bottom of cups and flows smoothly over surfaces. Water can fit into containers of all shapes and sizes. It is flexible.

**Figure 7 Solid water** When heat is removed from liquid water, the movement of the water slows. The water has been solidified. This is the solid form of water called ice. Like all solids, ice holds its shape even when it is tipped from a container.

**Figure 8 Gas water** When heat is added to liquid water, the water starts to move faster. Eventually it becomes a gas called water vapour. The gas has much more energy than a liquid or solid. It does not sit at the bottom of a container. Instead, it moves freely around the whole container.

**evaporation**
a change in state from liquid to gas; also a technique used to separate dissolved solids from water

**boiling point**
the temperature at which a liquid boils and becomes a gas

**condensation**
the cooling down of gas into a liquid

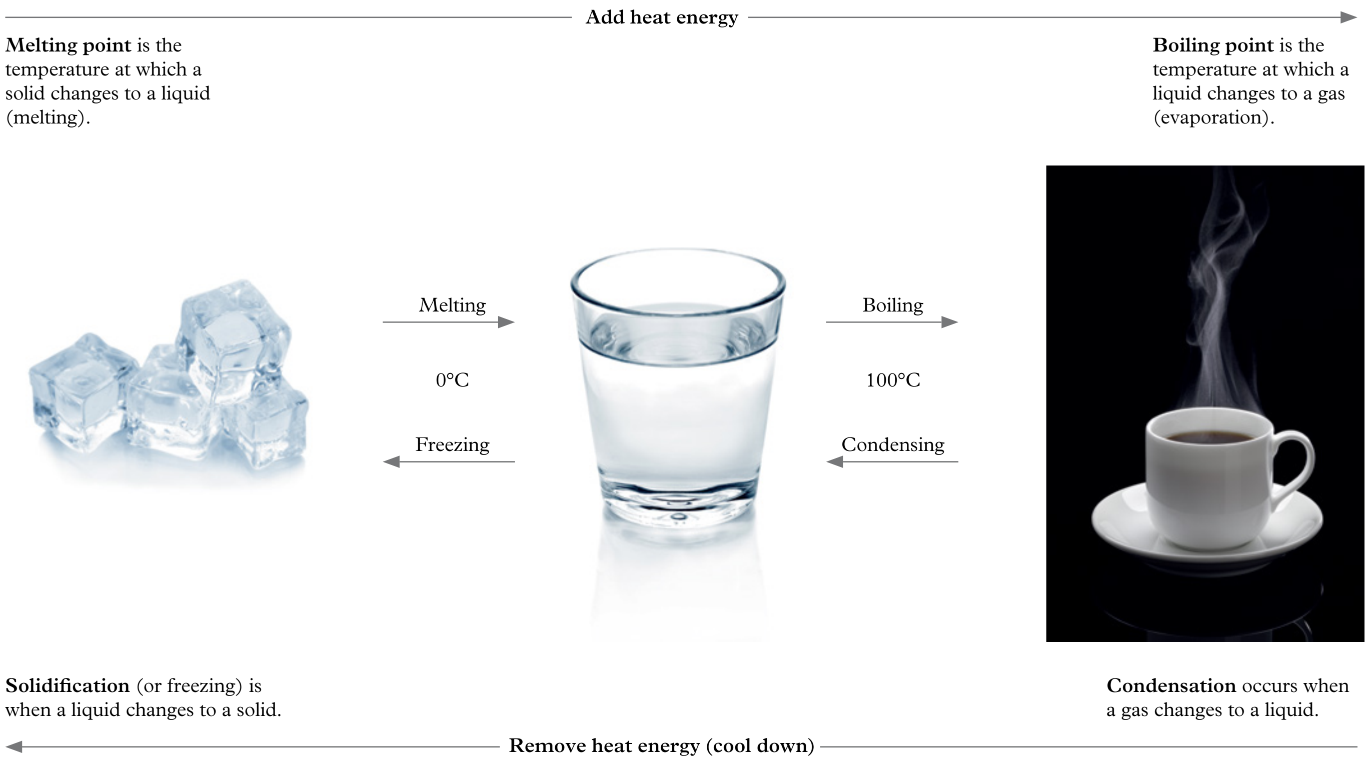



**Figure 9** Adding or removing heat energy can change the state of water.

**physical property**
a property of a substance that can be measured or observed without changing the substance into something else; examples are colour and boiling point

**chemical property**
how a substance behaves in a chemical reaction, such as how it reacts with an acid

**Table 1** Physical properties of water

| Physical property | Value |
|---|---|
| Melting point | 0°C |
| Boiling point | 100°C |
| Colour | Colourless |
| Density | 1.00 g/mL at 25°C |

## Preventing evaporation

Understanding how water evaporates (liquid to gas) becomes very important when you live in a hot and dry climate like in parts of Australia. Bright sunshine, high temperatures and wind will all cause waterholes to quickly dry up. Before Europeans colonised Australia, First Nations peoples would cover the waterholes in rocks to prevent evaporation.

If water was found in clay, First Nations peoples would make the hole deeper but not wider so that more water could be stored without increasing the evaporation from the water surface. The Yankuntjatjara peoples in the Everard Range region of South Australia would also prevent evaporation by adding sand to their local waterholes. The water particles were able to 'hide' between the sand grains, preventing evaporation. When it was time to collect the water, a hole was made in the centre of the sand so that the fresh water could drain into a puddle.

## Describing matter

The properties of a substance are the characteristics that make it unique. Solids, liquids and gases have unique properties. Solids do not change their shape easily and cannot be compressed. Liquids cannot be compressed, but they can change their shape to fit the container holding them. Gases completely fill the container holding them and can be compressed into a smaller space.

Some substances are important to us because of particular properties. For example, one property of water is that it can be used to dissolve (mix with) many other substances. This makes water useful for cleaning clothes, cooking and experiments in a chemistry laboratory.

The properties of substances can be divided into two groups:

1 **Physical properties** are what we can observe and measure without changing the substance into something else. Examples of physical properties are colour, texture, boiling point, reversible state changes, density and how much heat it can store (heat capacity). Table 1 lists the physical properties of water.
2 **Chemical properties** are what a substance does in a chemical reaction. Examples include bubbling, permanent colour change and irreversible change of state.

**Figure 10** You can sometimes see condensation when you breathe out on a cold morning. The water vapour in your breath becomes a fine liquid when it hits the cold air, making what is commonly called 'dragon breath'.

## 2.1 Check your learning

### Retrieve

1 **Identify** the:
  a melting point of water
  b boiling point of water.

2 Use the information in Table 2 below to **identify** which substance has the:
  a lowest melting point
  b highest melting point
  c lowest boiling point
  d highest boiling point.

**Table 2** Melting and boiling points

| Substance | Melting point (°C) | Boiling point (°C) |
|---|---|---|
| Water | 0 | 100 |
| Iron | 1535 | 2750 |
| Lead | 327 | 1750 |
| Mercury | –39 | 357 |
| Table salt | 805 | 1413 |
| Oxygen | –219 | –183 |
| Nitrogen | –210 | –196 |

3 Select a common substance, such as cling wrap or vinegar. **Name** some of the physical properties of this substance.

### Comprehend

4 **Describe** what happens to water when it:
  a evaporates
  b condenses
  c freezes.

5 **Explain** what is meant by a 'property' of a substance.

6 **Explain** why the properties of matter are so important to us.

### Analyse

7 **Compare** (the similarities and differences between) the processes of melting and boiling.

8 **Contrast** (the differences between) the physical and chemical properties of a substance.

9 **Categorise** the following substances as a solid, liquid or a gas (or a combination of states).
ice cream, chocolate bar, clouds, thick smoke, glass, honey, cake or bread, mashed potato, paper, peanut butter (smooth), cling wrap, play dough, sand, steam, slime

10 **Classify** each of the following properties as either a physical or a chemical property: the ability to be hammered into flat sheets (malleability), the ability to explode, the amount of vapour released at different temperatures.

11 **Identify** what would happen to liquid water when heat is applied.

### Apply

12 A student claimed a frozen drink bottle was leaking because condensation had formed on the outside of the container. **Develop** an explanation for the student that describes where the condensed water came from.

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 2.2 Scientists' understanding of matter has developed over thousands of years

**Learning intentions**

By the end of this topic, you will be able to:

- describe how our understanding of matter has changed over time
- contrast the arrangement of particles in solids, liquids and gases.

**Key ideas**

- Science involves developing a hypothesis, testing it with a reproducible experiment and modifying ideas.
- The particle theory of matter has been tested and refined by scientists for more than 2000 years.

Scientists have been investigating and proposing ideas about particles for thousands of years. When an idea becomes supported by the current evidence, it becomes a **theory**.

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

## Democritus

Over 2400 years ago, Democritus (c. 460–370 BCE) (Figure 1), a Greek philosopher, put forward the idea that all matter is made up of particles. He proposed that if you were to cut up these particles into smaller and smaller pieces, you would eventually have tiny particles that could not be divided any more. Democritus called these particles *atomos*, which is Greek for 'indivisible'. This is the origin of the word **atom**.

**atom**
the smallest particle of matter; cannot be created, destroyed or broken down (indivisible)

**Figure 1** Democritus proposed that all matter is made of atoms.

## John Dalton

It was not until more than 2000 years later, in the early 1800s, that Englishman John Dalton (1766–1844) (Figure 2) developed Democritus's idea further. Dalton's ideas were based on the results of experiments performed by many earlier chemists. Dalton studied these results and proposed a model to explain them. His model was that matter is made of particles.

Dalton's ideas are outlined below.

> All matter consists of tiny particles called atoms.
> Atoms cannot be created or destroyed and are indivisible.
> All atoms of the same **element** are identical, but they are different from atoms of other elements.
> When atoms combine to form **compounds**, each atom keeps its identity.
> Atoms combine to form compounds called **molecules** in simple whole-number ratios. For example, hydrogen and oxygen combine in a ratio of 2:1 to form water, which is written as $H_2O$.

**element**
a pure substance made up of only one type of atom

**compound**
a substance made up of two or more types of atoms bonded together

**molecule**
a group of two or more atoms bonded together, such as a water molecule

**Figure 2** John Dalton developed Democritus's ideas about particles.

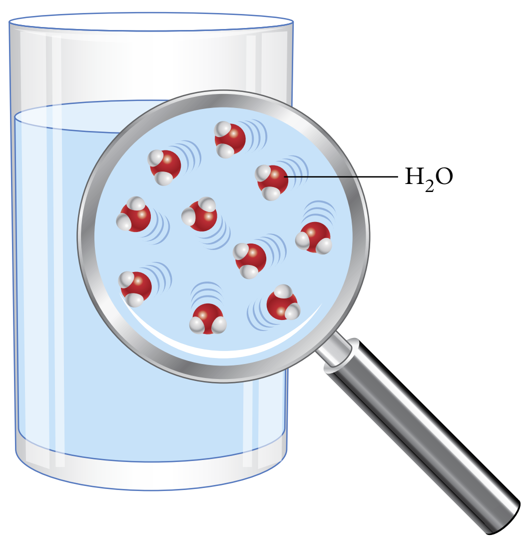



**Figure 3** A glass of water is made of molecules. Each molecule contains two hydrogen atoms and one oxygen atom.

## Modern chemistry

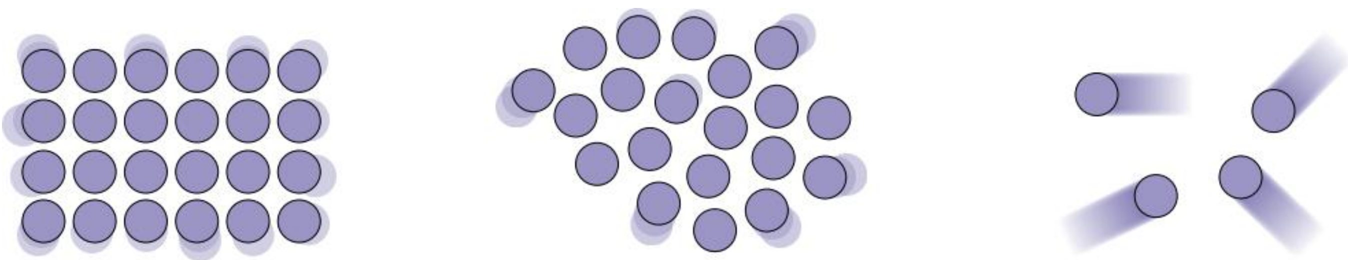
This new understanding encouraged scientists to find out more and more about these tiny particles, eventually leading to the branch of science now called **chemistry**.

We can add some new ideas to Dalton's list to help us explain matter:

- Particles are too small to be seen.
- Particles are always moving. When it is hotter, the particles move faster; when it is cooler, the particles move slower.
- Particles have mass.
- Particles can join to make larger particles. When they combine, their masses add together.
- There are spaces between particles.
- Forces hold particles together to stop them from separating.

All these ideas, or rules, explain how particles act in real substances. The real particles follow these rules in all substances.

**chemistry**
the branch of science that deals with matter and the changes that take place within it



**Solids**
The particles are close together. They are held in a regular arrangement and vibrate around a fixed point.

**Liquids**
The particles are close together, but they can move and slide over one another.

**Gases**
The particles are far apart and move quickly on their own. They spread out to fill the space available to them.

**Figure 4** The particle model explains the differences between solids, liquids and gases.

## 2.2 Check your learning

### Retrieve

1 **Identify** how an 'idea' is different from a 'theory'.

2 Prepare a table (set up like Table 1) that **demonstrates** the ideas of Democritus and Dalton. Add Democritus's ideas in one column and Dalton's ideas in the other column.

**Table 1** Historical ideas on matter

| Democritus's ideas | Dalton's ideas |
|---|---|
| | |
| | |

### Analyse

3 **Contrast** (the differences between) the ideas proposed by Democritus and Dalton.

4 **Consider** a school assembly. Everyone is sitting quietly in their seats in rows. When the assembly finishes, there is a crowd at the doors pushing to go through them to leave. When outside, the students run off in all directions as fast as they can. **Explain** which parts of this analogy represent a solid, a liquid and a gas.

5 Some people use analogies, or models, to compare states of matter. **Identify** which state could be represented by the following situations.

**a** a swarm of bees crawling over one another

**b** a thousand tennis balls tidily arranged in a large cardboard box

**c** eggs in trays in a large egg container

**d** a school of fish darting in all directions as they avoid a predator

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 2.3 The particle model explains matter

**Learning intentions**

By the end of this topic, you will be able to:

- define the particle theory of matter and diffusion
- explain how kinetic energy affects particle movement.

**Key ideas**

- All particles have kinetic (movement) energy.
- Adding heat increases the kinetic (movement) energy of particles.
- Removing heat decreases the kinetic (movement) energy.
- The particle model of matter can be used to explain the properties of matter.

## The kinetic theory of matter

The particle model of matter is always true. Every observation and every experiment can be explained with this model.

In the particle model of matter, the particles are always moving. The word 'kinetic' refers to the energy of anything that is moving. Therefore, particles always have **kinetic energy**. The faster they move, the more kinetic energy they have. For this reason, the particle model can also be called the kinetic theory of matter.

**Figure 1** Some of the energy in storms comes from the condensation of vapour into liquid, which we see as rain.

**kinetic energy**
the energy possessed by moving objects

## Particle energy

The movement of people and particles is related to their kinetic (movement) energy.

- When people are sitting quietly, they have little kinetic energy. This is like a solid, where the particles only vibrate, and people only sit quietly and breathe.
- In a crowd, people are standing and moving around and have more kinetic energy. This is like a liquid, where the particles jostle about. Particles in a liquid have more kinetic energy than particles in a solid.
- When people are running, they have much more kinetic energy. This is like a gas, where the particles move fast and on their own. Particles in a gas have the highest amount of kinetic energy.

## Using the kinetic theory of matter

The kinetic theory of matter can be used to explain many of the observations and measurements that we make about the substances around us.

Mass is the amount of matter in a substance and is measured in kilograms (kg). Mass depends on the number of particles and the mass of each individual particle.

A particular volume of solid or liquid has a greater mass than the same volume of gas because it has more particles in it (Figure 2). For example, imagine two containers that are the same size. One container is filled with liquid nitrogen. The other is filled with nitrogen gas. The container with liquid nitrogen is much heavier because the liquid has more particles in it than the fast-moving gas particles.

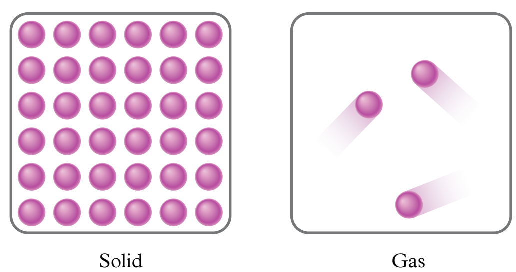



**Figure 2** A container of a solid has more particles than the same container of gas.

A piece of lead has a much greater mass than the same-sized piece of aluminium. Both are metals that are made of atom particles that are packed closely together. The difference is the mass of each atom. Lead atoms are bigger and have a greater mass than aluminium atoms (Figure 3).

CHALLENGE **2.3A:** Modelling matter
Go to page **197**.

CHALLENGE **2.3B:** Making a cuppa
Go to page **198**.

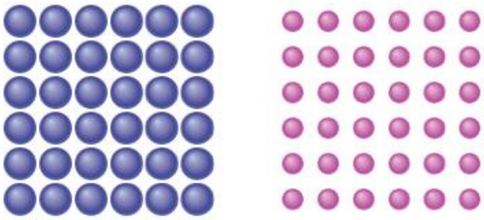



**Figure 3** Lead atoms have a greater mass than aluminium atoms.

## Diffusion

When the lid is taken off a bottle of perfume, the smell of the perfume spreads throughout the room (Figure 4). This occurs without any breeze or wind and is called diffusion. Another example of diffusion is tea spreading out from a tea bag in a cup of hot water (Figure 5). Stirring the cup of tea will mix the particles and speed up the rate of diffusion.

Diffusion occurs fastest in gases. This is because the particles in gases are moving freely and quickly and there is plenty of space between them. The particles in a gas will spread out quickly and take up the space available (Figure 6).

**Figure 4** Perfume diffuses when its bottle is open.

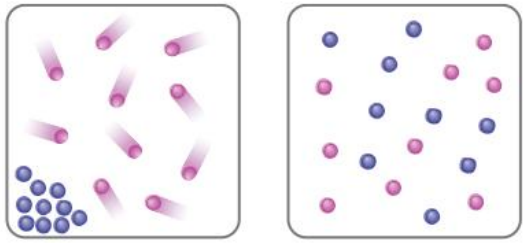


**Figure 6** Before (left) and after (right) diffusion in a gas

In liquids, the particles jostle against one another. They do not move far before colliding with another particle. As a result, particles in a liquid do not move very far or very fast. Diffusion in liquids is slow (Figure 7).

In solids, the particles are locked into position. The particles vibrate, but they cannot move to a new location. So the particles in a solid cannot spread out and diffusion does not occur in solids (Figure 8).

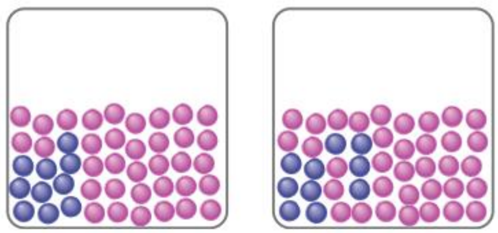


**Figure 7** Diffusion is slow in liquids.

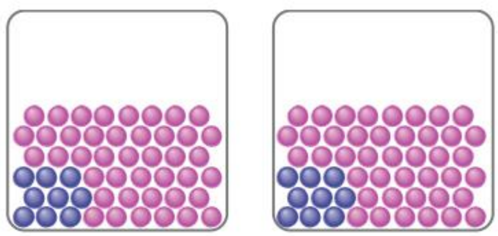


**Figure 8** Solids do not diffuse.

**Figure 5** Tea diffuses in hot water.

## 2.3 Check your learning

### Retrieve

1 **Name** the states solid, liquid and gas from having the most to the least energy content.

2 **Define** the term 'mass'.

### Comprehend

3 **Explain** the meaning of 'kinetic' in the kinetic theory of matter.

4 **Explain** the similarity between the particle model of matter and the kinetic theory of matter.

5 **Describe** how the kinetic molecular theory (or particle model) of matter explains the mass of different substances.

6 **Explain** why a 2 $cm^3$ block of lead will have a greater mass than a 2 $cm^3$ block of wood.

7 **Describe** how the kinetic molecular theory of matter explains diffusion in:

**a** liquids **b** gases.

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 2.4 The particle model can explain the properties of matter

**Learning intentions**

By the end of this topic, you will be able to:

- define and explain tensile strength, hardness, viscosity, compressibility and density in terms of the particle model.

**Key ideas**

- Strong bonds between particles can make the material stronger (able to withstand force), harder and more viscous.
- Tightly packed particles make the material dense and less able to be compressed.

Video 2.4
Calculating density

**tensile strength**
a measure of the flexibility of the bonds between particles in a substance

**compressional strength**
the ability of a substance to withstand large forces

**viscosity**
a measure of how slowly a liquid changes its shape; the thickness of a liquid

**hardness**
how easily a mineral can be scratched

**Figure 1** Reinforced concrete combines the tensile strength of steel with the compressional strength of concrete.

**compressibility**
the extent to which a substance can be compressed (squashed); gases can be compressed but solids and liquids cannot

## Strength

The idea of strength can be considered in different ways. A rubber band is easily stretched, but what about a piece of wire? Different wires made of different metals will break if stretched. **Tensile strength** is a measure of the flexibility of the links or bonds between the particles. The bonds between the particles in steel are stronger than those between tin particles. Another type of strength is **compressional strength**. Substances that can withstand large forces without being crushed have a high compression strength.

## Hardness

**Hardness** is the ability of a substance to scratch another substance. An iron nail will scratch a plastic ruler because the iron is harder than plastic (Figure 2). However, the iron nail will not scratch glass because the iron is softer than glass. For these substances, the order of hardness is glass, next iron and then plastic.

Hardness is not the same as strength. A very hard substance may shatter easily. If this happens, the material is described as 'brittle'. The particle model of matter explains hardness in terms of the forces that hold the particles together. The particles in hard substances are held together very strongly and it is difficult to separate them. In plastic, the particles are not held together as strongly and can be removed or scraped off. Therefore, plastic is not a hard substance.

There is a connection between hardness and melting. Substances that are hard have strong forces (bonds) between their particles. These strong forces mean that for hard substances to melt, a lot of heat energy is needed. These substances usually have a high melting temperature.

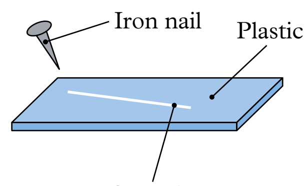



**Figure 2** An iron nail will scratch plastic because iron is harder than plastic.

## Viscosity

**Viscosity** is the thickness, or 'gooiness', of a liquid. It describes how easily the particles move around one another. Viscous liquids are hard to pour out of a container. Water has a low viscosity, cooking oil is more viscous and honey is very viscous (Figure 3). Engine oils used in engines have different viscosities.

**Figure 3** Honey has a higher viscosity than water and so can't be poured as easily as water.

## Compressibility

**Compressibility** refers to the ability of a substance to be squashed or compressed. You can test for compressibility when substances are in a plastic syringe.

If you put your finger over the end of a syringe, you can compress the air inside it.

EXPERIMENT

**2.4:** The density den
Go to page **199**.

However, if you replace the air with a liquid such as water, you cannot compress the water. Similarly, if you filled the syringe with a solid such as sand, you would not be able to compress it.

In solids and liquids, there are no empty spaces between the particles, so it is not possible to compress the particles closer together. Solids and liquids are said to be **incompressible**. Gases, like air, can be compressed. This is because the particles are spread out and there is space between them (Figure 4).

## Density

One way of comparing the 'heaviness' of two substances is to compare their densities. **Density** describes the number of particles and how tightly packed they are. The density of a substance will affect its properties, such as its ability to float.

Objects with lower density float on liquid if the liquid has a higher density. For example, a piece of cork will float on water. This is because the water has a higher density than the cork. On the other hand, coins will sink to the bottom of water. This is because the coins have a higher density than the water.

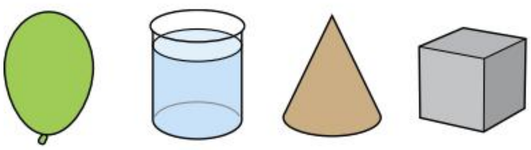



**Figure 5** Density compares the mass of objects of the same volume.

In Figure 5, we see that 1 L of water is heavier than 1 L of air. We say that water has a greater density than air. Sand has a greater density than water or air, but it has a lower density than lead.

The particle model of matter explains density in terms of both the mass and the closeness of the particles. Gases always have low densities because there is a lot of empty space between the particles. Solids normally have high densities because there is no space between the particles.

The densities of some common substances are given in Table 1.

**Table 1** Densities of some common substances

| Substance | Density (g/cm³) |
|---|---|
| Air | 0.001 |
| Foam rubber | 0.05 |
| Wood | 0.3 |
| Oil | 0.75 |
| Water | 1.0 |
| Glass | 2.6 |
| Steel | 7.8 |
| Iron | 7.8 |
| Copper | 8.9 |
| Lead | 11.3 |
| Mercury | 13.6 |
| Gold | 19.3 |

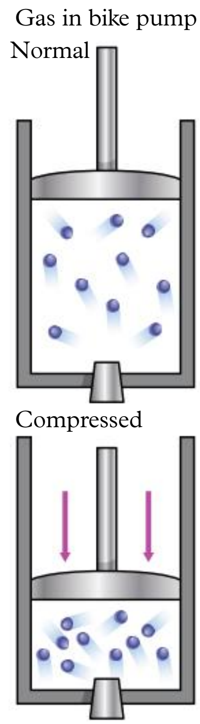



**Figure 4** Compression reduces the space between particles.

**incompressible**
unable to be compressed; solids and liquids are incompressible

**density**
a measure of mass per unit of volume

## 2.4 Check your learning

### Retrieve

1 **Identify** the most and least dense material in Table 1.

2 **Name** the following in order of compressibility from least to most: solid, liquid, gas.

### Comprehend

3 Prepare a table (set up like Table 2) that **summarises** the following physical properties: strength, hardness, viscosity, compressibility and density.

**Table 2** Physical properties and their meanings

| Physical property | Meaning |
|---|---|
| | |
| | |

4 Use the particle model of matter to **explain** why steel is stronger than tin.

5 **Describe** what would happen if you placed a highly viscous liquid, such as oil, into a water pistol. **Explain** your reasoning (by comparing the properties of water and oil and how this will affect how the oil will behave in the water pistol).

### Apply

6 Use Table 1 to **predict** which of the following would sink or float in water: oil, an iron nail, a balloon filled with air, a glass marble.

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 2.5 Increasing kinetic energy in matter causes it to expand

**Learning intentions**

By the end of this topic, you will be able to:

- describe what happens to particles when they are heated
- explain how heat can cause expansion.

**Key ideas**

- Heating matter increases the kinetic energy of the particles.
- The particles in warm materials move faster than particles in cool materials.
- Melting point is the temperature at which the particles in a solid behave like a liquid.
- Boiling point is the temperature at which the particles in a liquid behave like a gas.

## Heating particles

Gold is usually a solid at room temperature (20°C). Like all solids, the particles in gold are packed tightly together. When solid gold is given heat energy, the gold particles start vibrating faster and faster. When the gold reaches its melting point (1064°C), the particles have enough kinetic energy to move around one another, just like the particles in a liquid. The gold has melted.

If you continue heating the gold, the particles continue to gain kinetic energy, move faster and take up more space. Eventually, when the gold reaches its boiling point (2807°C), the gold particles have enough kinetic energy to break free from the other gold particles and move off on their own as a gas.

This process can also happen in reverse. If a gas is cooled down, the particles will move more slowly. The attraction to other particles will now keep the particles close together and the gas will condense into a liquid.

If the particles in a liquid are cooled even further, their movement will slow down even more. Eventually, they are held in place by other particles and do not have enough energy to move on their own – they become particles locked into a solid. The liquid has solidified or frozen.

Remember that the main difference between a hot and a cold substance is the amount of kinetic energy in the particles. The differences in the movement of hot and cold particles can be seen in a beaker of water. As the particles move around, they cause diffusion. If the particles move faster, diffusion should occur faster.

**Figure 1** Vaporisation explains steam rising from soup.

**Figure 2** Solidification occurs when a substance cools.

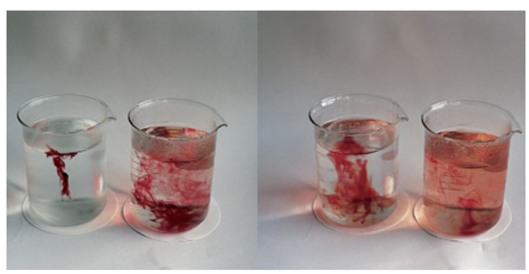


**Figure 3** Diffusion occurs faster in hot water (right beaker) than in cold water (left beaker).

## Heat causes expansion

All objects and substances expand (increase in size or volume) as their temperature increases. These objects contract (shrink) back to their original size when they are cooled back to their original temperature.

EXPERIMENT
**2.5A:** Effect of heat
Go to page **201**.

EXPERIMENT
**2.5B:** From ice to steam
Go to page **203**.

The expansion is only small – roughly 10 mm in a 30 m bridge – but it is very important for the strength of the object. Expansion effects are seen in bridges, railway tracks and large buildings (Figures 4 and 5).

Applying heat energy causes the particles in the liquid or gas to gain more energy. The particles jostle more and speed up. As they move around faster, they take up more space and push the other particles further apart.

Expansion and contraction have many important applications, such as liquid-in-glass thermometers. When an alcohol thermometer is placed in your mouth, the heat from your body passes to the liquid inside the thermometer, causing it to expand and move up the tube. Thermometers are filled with red- or green-coloured alcohol, but not the type of alcohol in alcoholic drinks.

**Figure 4** An expansion joint in a suspension bridge

**Figure 5** Train tracks would buckle in the heat without tiny gaps between them.

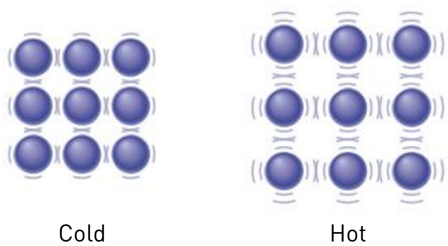



**Figure 6** In a hot solid, the particles vibrate harder, faster and wider than in a cold solid.

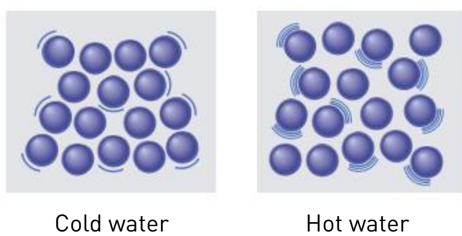



**Figure 7** In a hot liquid, the particles jostle around faster and take up more space than in a cold liquid.

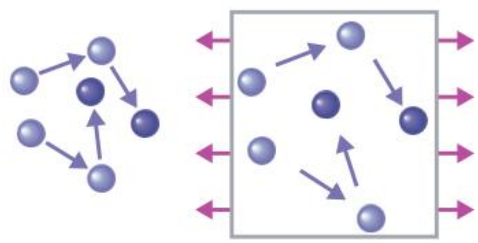


**Figure 8** In a hot gas, the particles move faster, and collide with one another harder, than in a cold gas.

## 2.5 Check your learning

### Retrieve

1 **Recall** what precautions are taken with railway tracks and bridges to make sure that they do not buckle and bend when they expand on a hot day.

### Comprehend

2 **Explain** how the movement of particles changes when a substance gains heat.

3 **Explain** why objects return to their original size when their temperature returns to normal.

4 When a solid is heated, it expands. **Explain** why.

### Analyse

5 **Contrast** (the differences between) the terms ‘expand’ and ‘contract’.

6 Draw a diagram similar to that shown in Figure 9. Add labels to **identify** the energy changes between states.

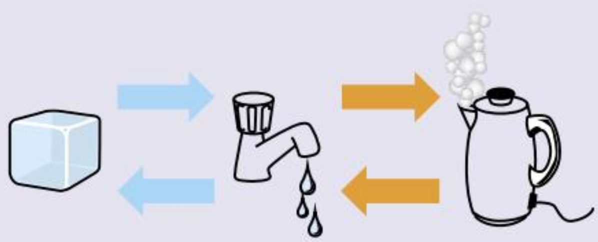


**Figure 9** Energy changes between states

**Quiz me**
Complete the Quiz me to check how well you’ve mastered the learning intentions and to be assigned a worksheet at your level.

//SCIENCE AS A HUMAN ENDEAVOUR//

# 2.6 Scientists find ways to communicate

**Learning intentions**

By the end of this topic, you will be able to:

- identify ways that scientists can share ideas and theories with different audiences.

**scientific model**
a physical, mathematical or conceptual representation of an object, system, event or process that is used to explain or predict the behaviour of a scientific process or phenomenon

Scientists can research many exciting and different things in the world around them. This research needs to be explained to those people who do not have an understanding of science. To do this, they need to be able to communicate their ideas clearly and in a number of different ways.

The ability to describe scientific ideas is an essential skill for all scientists so that the non-scientists do not become confused or scared of the scientific ideas or information. There are many different ways a scientist can describe their research.

## Scientific models


**Figure 1** The particle model helps us to understand different states of matter, even though we cannot observe particles.

Scientists use **scientific models** to explain and predict how things work. Scientific models are ideas or representations that we can use to explain phenomena that are difficult to observe. For example, the particle model helps us to explain matter, which we would not normally be able to see (Figure 1).

Other examples of scientific models include models of the solar system or DNA. We cannot view either of these things, but you might have an idea in your head of what they look like.

## Scientific papers

Many scientists use formally written scientific reports or papers to describe how they did research and the data they measured, and to explain how it affects the world around them (Figure 2). These reports are usually used to provide information to other scientists who are specialists in the same field. Because these reports are meant to be read by other scientists, they often use a lot of complex terminology that can be difficult for the average person to read. Each report is also peer reviewed. This means other scientists who work on the same research will read the report and check that it was a fair experiment before it is published in a scientific journal.

## Scientific posters

Before a scientist writes a paper for a scientific journal, they will often present it to other scientists as a poster (Figure 3). Posters are a shorter summary of the experimental method and results that can be put on a wall for other scientists to see at a conference (a meeting for scientists). This allows the scientist to discuss their ideas and research with other scientists walking past so that they can offer suggestions on how the research could be improved.

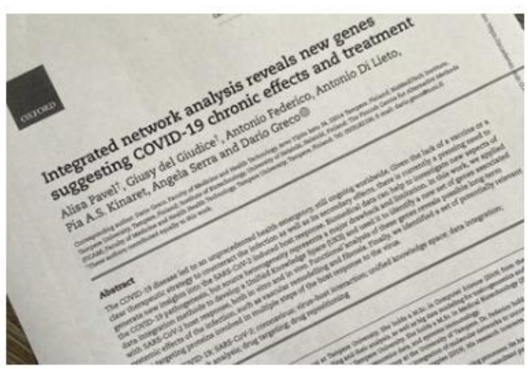



**Figure 2** Scientific papers are reports published to share ideas or findings with other scientists.

| Title of experiment | | |
|---|---|---|
| Introduction<br><br>Method and materials<br><br>Results | Communication statement reporting the key finding of the investigation as a one-sentence summary | Discussion<br><br>Conclusion |

**Figure 3** Scientific posters include a short summary of an experiment's hypothesis, method, results, discussion and conclusion.

## Conferences

Scientists will often travel to other states or countries to share their research with other scientists. A conference occurs when a large number of scientists who are interested in the same research travel to the same place to discuss their ideas (Figure 4). The chance to share ideas and to see their research from another person's perspective can cause good ideas to become great ideas.

## Social media

Scientists are not the only people who are interested in learning about science. Many people are interested in learning about discoveries on the Moon, new treatments for cancer and new forms of renewable energy. This means that scientists need to be able to share their ideas with non-scientists through newspapers, magazines, television or social media (for example, online blogs, YouTube and Twitter) (Figure 5).

**Figure 4** Scientists often present their findings at science conferences.


**Figure 5** Many scientists and science organisations have a presence on social media.

## 2.6 Test your skills and capabilities

### Identifying your audience

Before a scientist can communicate effectively, they need to answer a few questions. Use the hints below to **create** an animation or other form of communication that explains how you could reduce the amount of water evaporating from a waterhole in central Australia. You should use your knowledge of particle theory to explain why your idea will work.

1. Who is the audience?
   Knowing who will be reading or listening to the information is the most important thing a scientist needs to know. Do the people in the audience know the meaning of the scientific words? Will you communicate your science to your classmates, an older or younger class, or a teacher? How much science do they know? What words might you have to change?
2. How can the scientist make science relevant?
   There are many different types of scientific research on many different topics. While some people will be very interested in the topic, others may not be as interested. You will need to consider how your experiment is similar to something in their life. They may have slower train trips on hot days because of the train tracks bending or buckling, or they may wonder why they get condensation on the outside of their glass. A scientist needs to make the science interesting to their audience.
3. What is the most effective way to communicate science?
   Different people use different forms of communication. If a scientist wanted to share their research with the general public, they would not use a scientific paper or a poster. Instead, they might use an oral (talking) report, television report or a blog. Which method would be the best way to present to your audience?
4. How much information should be passed on?
   A single tweet is limited to 280 characters, while an online blog can be much longer. Reports on television are often limited to three minutes while a scientific paper can be several pages of information. What information do you need to pass on to your audience? Will they want to hear how you did your research and see the data in graphs or tables? How will you convince them that the experiment was a fair test and that your results are accurate?
5. Pictures or words?
   The type of communication you use will often determine if you can use pictures or words. Using a lot of words in a small space in a report or on a poster means that the audience needs to stop and concentrate. Do you need to describe the method, or will a single, well-labelled diagram be more useful? If you are presenting an oral report, a pause after saying a word will make it more important and more likely to be remembered.
6. What are the two things that you want the people in the audience to remember?
   Most people in an audience will only remember two things after a communication. What two things are the most important for your audience to remember? How will you make sure that they remember these things? Will you repeat the important information or have a summary at the end?

Good luck with your communication.

# PARTICLE MODEL

## Retrieve

1 **Recall** where the word 'atom' came from.

2 **Identify** what happens to water during condensation.
  A The solid melts into a liquid.
  B The liquid heats to become a gas.
  C The liquid loses heat to become a solid.
  D The gas loses heat to become a liquid.

3 **Identify** what would happen to the particles in a beaker of water as it is heated.
  A The particles start moving faster.
  B The particles start moving slower.
  C The particles stop moving.
  D The particles start to disappear.

4 **Identify** the best description for 'density'.
  A the ability of a substance to scratch another substance
  B the ability of a substance to be compressed
  C the mass of a certain volume of a substance
  D the thickness of a liquid substance

5 **Define** the term 'volume'.

6 **Define** kinetic energy in your own words.

7 **Identify** the three common states of matter.

8 **Recall** one word to replace each phrase.
  a the spreading out of a substance such as a dye or smell
  b the ability of one substance to scratch another substance
  c the ratio of the mass divided by the volume

9 Use the information in Table 1 to **identify** which substance has the:
  a lowest melting point
  b highest melting point
  c lowest boiling point
  d highest boiling point.

**Table 1** Melting and boiling points

| Substance | Melting point (°C) | Boiling point (°C) |
|---|---|---|
| Water | 0 | 100 |
| Iron | 1535 | 2750 |
| Lead | 327 | 1750 |
| Mercury | –39 | 357 |
| Table salt | 805 | 1413 |
| Oxygen | –219 | –183 |
| Nitrogen | –210 | –196 |

## Comprehend

10 **Identify** which state of matter has particles with the most kinetic energy. **Explain** your reasoning (by describing the amount of kinetic energy in solids, liquids and gases).

11 Use the particle model to **explain** the following properties.
  a strength
  b hardness
  c viscosity
  d compressibility
  e density

**Figure 1** Glass is a hard, but brittle, substance.

**Figure 2** Engine oils are labelled with viscosities.

12 In your own words, **explain** the five key ideas identified by Dalton.

13 **Explain** why perfume sprayed on one side of a room will eventually be smelled by someone sitting on the other side of the room.

14 Use the kinetic theory of matter to **explain** why metal will expand when it is heated.

15 When you are boiling water, the volume of the water is reduced as it evaporates. Use the particle model to **explain** what happened.

16 Use the kinetic theory of matter to **explain** why the pressure inside car tyres will increase on a hot day.

17 **Explain** how a thermometer determines a difference in temperature.

18 **Explain** what will happen when the air in a balloon is heated.

19 **Explain** why the train tracks can buckle on very hot days.

## Analyse

20 **Classify** each of the following substances as a solid, liquid or gas.
  a milkshake
  b cheesecake
  c chewing gum
  d sandcastle

21 **Contrast** physical and chemical properties.

22 **Contrast** mass and matter.

23 **Identify** which of the following substances will have particles with the most kinetic energy: ice, milk or the air in a balloon.

24 **Identify** each of the following in Figure 3 as a solid, liquid or gas.

The particles are close together. They are held in a regular arrangement and vibrate around a fixed point.

The particles are close together, but they can move and slide over one another.

The particles are far apart and move quickly on their own. They spread out to fill the space available to them.

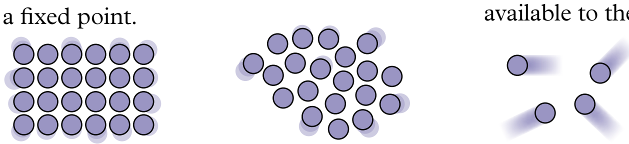


**Figure 3** Solid, liquid or gas?

25 **Contrast** solidification and freezing.

26 **Compare** the processes of melting and boiling.

**Figure 4** The metal train tracks buckle on hot days.

## Apply

27 Use Table 2 to **decide** which of the following items would have a greater density.

a 1 L of water or 1 L of oil

b a gold necklace or a crystal necklace

c 10 planks of wood or 10 steel bars (assume they are all equal in size)

**Table 2** Density of various substances

| Substance | Density (g/cm$^3$) |
|---|---|
| Air | 0.001 |
| Foam rubber | 0.05 |
| Wood | 0.3 |
| Oil | 0.75 |
| Water | 1.0 |
| Glass | 2.6 |
| Steel | 7.8 |
| Iron | 7.8 |
| Copper | 8.9 |
| Lead | 11.3 |
| Mercury | 13.6 |
| Gold | 19.3 |

28 Many people have ideas they think will explain observations and events in science. For an idea to become a theory, it must be able to explain a range of different observations. The idea must also be supported by evidence and/or observations.

a **Propose** what evidence would have been required to support the idea that all substances are made of atoms.

b It is found that a substance cannot be broken down into a more simple substance. Use the particle model to **explain** this observation.

29 **Explain** the following observations of solids, liquids and gases by describing the arrangement and/or the movement of particles within the substance. **Create** labelled diagrams to help your explanations.

a Water left in an open bottle will gradually evaporate and, if the temperature of the water increases, the water will evaporate more quickly.

b Mercury is a unique substance because it is the only metal that is liquid at room temperature, and it even gives off a vapour (which makes it very dangerous because this vapour can be breathed into our lungs and cause damage).

c Polythene plastic can be produced in two different forms: high-density polythene (HDPE) or low-density polythene (LDPE). If the particles in HDPE and LDPE are the same, suggest how the structure of the two substances would be different.

d When a piece of polythene is heated, it will melt. While it is changing state from a solid to a liquid, it can be formed into a different shape. When it cools, the polythene will stay in this new shape.

30 **Create** a way to draw or model the following.

a the melting point of a material

b the boiling point of a material

c the density of a material

d the kinetic energy of a particle as it heats up

e diffusion

## Social and ethical thinking

31 Science is communicated in many different ways, including scientific journals and posters, television reports, newspapers and social media, such as blogs, YouTube and Twitter. **Identify** which of these forms of communication are most trustworthy. **Justify** your answer (by describing why the communication you chose is better than the other forms of communication).

## Critical and creative thinking

32 Democritus identified that all substances were made of tiny particles called *atomos*, while Dalton suggested how these particles were combined and how they moved. **Propose** an argument to support the particle theory of matter being called either the Democritus Model or the Dalton Model.

33 The kinetic theory of matter is supported by data from many different experiments completed by many different scientists across multiple countries. **Discuss** why a single experiment carried out by a single scientist is not a theory.

34 **Discuss** how Democritus's ideas of an atom were expanded by Dalton to produce the current particle model of atoms.

## Research

35 Choose one of the following topics for a research project. Present your research in a format of your own choosing, giving careful consideration to the information you are presenting.

### » Hot air balloons

Most of our understanding of how gases move and change is a result of the first hot air balloonists.

- » Identify the first person who made an unmanned balloon.
- » Describe how the balloon was made.
- » Use your understanding of density to explain why a hot air balloon flies and how the pilots control the descent and landing safely.
- » Identify what is meant by the 'flight ceiling' and why it is important to stay beneath it when flying.

### » People matter

The discovery of air pressure is a long and interesting story.

- » Research the background of Evangelista Torricelli, Blaise Pascal and Otto von Guericke.
- » Describe where they lived, the research that they did, and how they communicated the outcomes of their work.

For example, Otto von Guericke built a large water thermometer in the front of his house and made the Magdeburg Hemispheres. Two opposing teams of eight horses, working like a tug-of-war, could not pull the hemispheres apart.

**Figure 5** The Magdeburg Hemispheres are represented by a statue in Magdeburg, Germany.

### » Gas warfare

Gas was first used in a battle in 1914 by French soldiers, but it was so unsuccessful that it was only noticed in the records after the battle. It wasn't until 31 January 1915 that a German soldier witnessed 18,000 gas shells containing xylyl bromide land on the Russian lines. The cold weather prevented the gas from diffusing across the battleground. In April the same year, German chemists started testing chlorine gas as a weapon.

- » Compare the different gases that were used in warfare and their effects on the soldiers.
- » Explain why the use of chemical and biological weapons in war was banned in 1925.
- » Compare this ban to the Chemical Weapons Convention signed in 1997.

## Chapter checklist

Now that you have completed this chapter, reflect on your ability to do the following.

| | I can do this. | I cannot do this yet. |
|---|---|---|
| • Describe the three states of matter.<br>• Identify the processes that change substances from one state to another. | ☐ | ☐ Go back to Topic 2.1 'There are three states of matter'.<br>Page 42 |
| • Describe how our understanding of matter has changed over time.<br>• Contrast the arrangement of particles in solids, liquids and gases. | ☐ | ☐ Go back to Topic 2.2 'Scientists' understanding of matter has developed over thousands of years'.<br>Page 46 |
| • Define the particle theory of matter and diffusion.<br>• Explain how kinetic energy affects particle movement. | ☐ | ☐ Go back to Topic 2.3 'The particle model explains matter'.<br>Page 48 |
| • Define and explain tensile strength, hardness, viscosity, compressibility and density in terms of the particle model. | ☐ | ☐ Go back to Topic 2.4 'The particle model can explain the properties of matter'.<br>Page 50 |
| • Describe what happens to particles when they are heated.<br>• Explain how heat can cause expansion. | ☐ | ☐ Go back to Topic 2.5 'Increasing kinetic energy in matter causes it to expand'.<br>Page 52 |
| • Identify ways that scientists can share ideas and theories with different audiences. | ☐ | ☐ Go back to Topic 2.6 'Science as a human endeavour: Scientists find ways to communicate'.<br>Page 54 |

**Check your Student obook pro for these digital resources and more:**

**Quizlet**
Play a Quizlet game to test your knowledge.

**Chapter quiz**
Test your understanding of this chapter with the chapter review quiz.

CHAPTER

# 3

# MIXTURES

## 3.1

**Mixtures are a combination of two or more substances**

> Describe the properties of various mixtures, including solutions, suspensions, colloids and emulsions.

## 3.2

**A solution is a solute dissolved in a solvent**

> Contrast the terms 'soluble' and 'insoluble', 'solute' and 'solvent', and 'concentrated' and 'dilute'.

> Describe the properties of a saturated solution.

> Explain the importance of water as a solvent.

## 3.3

**Mixtures can be separated according to their properties**

> Describe the processes of decanting, sedimentation, flotation and magnetic separation.

> Define sediment, magnetism and flocculant.

> Explain how the properties of a substance can be used to separate them from a mixture.

**3.4**

### Mixtures can be separated according to their size and mass

> Describe the processes of filtration, sieving and centrifuging.
> Explain how the size and mass of molecules of a substance relate to methods used to separate them from mixtures.

**3.5**

### The boiling points of liquids can be used to separate mixtures

> Describe the processes of evaporation, distillation and crystallisation.
> Explain how different boiling points can be used to separate mixtures.

**3.6**

### Solubility can be used to separate mixtures

> Describe the process of chromatography.
> Explain how the solubility of a substance can be used to separate it from a mixture.

**3.7**

### Science as a human endeavour: Wastewater is a mixture that can be separated

> Describe the separation processes involved in water treatment.

**3.8**

### Science as a human endeavour: Materials recovery facilities separate mixtures

> Describe the separation processes involved in recycling at a materials recovery facility.

## What if?

### Case mix

**What you need:**

A variety of different pencil cases (size, shape, colour)

**What to do:**

1 Place all the pencil cases in one pile.
2 List your pencil case's properties that will allow it to be identified easily, such as colour, weight, shape and size.
3 Give the list to another student. Can they identify your case by using the list?

**What if?**

» What if you were blindfolded? Could you still find your pencil case?
» What if the pencil cases were too small to feel? How could you identify yours?
» What if all the pencil cases were exactly the same? Would it still be a mixture?

# 3.1 Mixtures are a combination of two or more substances

**Learning intentions**

By the end of this topic, you will be able to:

- describe the properties of various mixtures, including solutions, suspensions, colloids and emulsions.

**Key ideas**

- A pure substance is one where all the particles are identical.
- The different substances in a mixture can have different properties.
- The different properties of substances can determine the type of mixture.

**mixture**
a substance made up of two or more pure substances mixed together

**solution**
a mixture of a solute dissolved in a solvent

**pure substance**
something that contains only one type of substance (e.g. a single element or a single compound)

**suspension**
a cloudy liquid containing insoluble particles

**sediment**
substance or matter that settles to the bottom in a mixture

**colloid**
a type of mixture that always looks cloudy, because clumps of insoluble particles remain suspended throughout it rather than settling as sediment

**emulsion**
a type of colloid in which two or more liquids are mixed together, with one suspended in the other as tiny droplets

In the previous chapter, you learnt about the particle model of matter. The particles in a pure sample of ice, water and water vapour are all identical ($H_2O$). This is different from water found in the sea, which is a **mixture** of salt, water and many other types of particles.

## Properties of mixtures

There are many different types of mixtures, each with different characteristics. For this reason, scientists group mixtures according to their properties: what they are made of and how they behave. Knowing the type of mixture and the properties of each particle help us to work out ways to separate the different particles into **pure substances**.

Figure 1 Most of the things we use every day are mixtures. What mixtures can you see in this photograph? Can you see any pure substances?

## Solutions

When you mix salt into water, it seems to disappear. But we know the salt is still there because we can taste it. The particles of salt become so small that they spread evenly throughout the water. This clear mixture of salt and water will not separate by itself. It is a **solution**. A solution is a mixture of one substance dissolved evenly throughout another (Figure 2). Solutions are usually transparent (see-through).

## Suspensions

Dirty water is an example of a **suspension**. A suspension is a mixture of two substances, in which a solid is mixed through (dispersed), undissolved, in a liquid (Figure 3). The result is a cloudy liquid where the dirt is suspended or 'hanging around' in the middle of the water. Sand in water is also a suspension. If you shake a container of sand and water, the sand spreads through the water, forming a cloudy liquid. The sand will then settle to the bottom of the container as a **sediment**. Suspensions often need to be shaken or stirred before use to spread the sediment through the liquid.

## Colloids

When two types of particles are mixed, they do not always separate out with time. Suspensions that do not separate easily are referred to as **colloids**. These can be formed when a solid is suspended in a liquid, such as hot chocolate in milk. Occasionally, different particles are suspended in a gas. Fog is an example of this: small drops of water suspended in the air (Figure 4).

CHALLENGE
**3.1:** Comparing different types of mixtures
Go to page **204**.

The word 'colloid' comes from the Greek word *kolla*, which means 'glue'. You can think of a colloid as a substance being 'stuck' – suspended – in another substance. The benefit of colloids is that there is no need to mix them before using them. Hair gel and hand cream are examples of colloids.

## Emulsions

An **emulsion** is a colloid of two or more liquids. Usually, one liquid is the 'base' and the other is broken into tiny droplets spread throughout the base. Milk is an emulsion, with tiny droplets of fats and oils spread throughout the base, which is water (Figure 5).

In some cases, when mixtures like this are left to settle, the tiny droplets float above the base liquid. (This is different from what happens in a suspension, where the solid particles tend to fall to the bottom.) A substance called an emulsifier can be added to these mixtures to allow the liquids to remain completely mixed.

The most common emulsions we use are mixtures of different types of oil mixed with water and an emulsifier. Examples include food and drinks, and 'emulsion' paints.

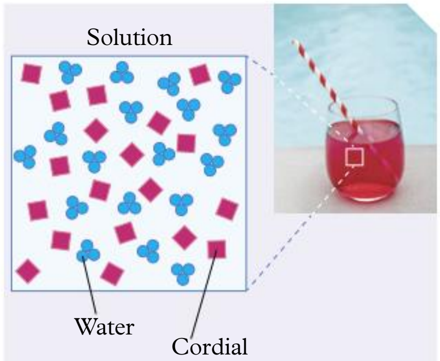



**Figure 2** This glass of cordial is an example of a solution. The small cordial particles are dissolved evenly throughout the water.

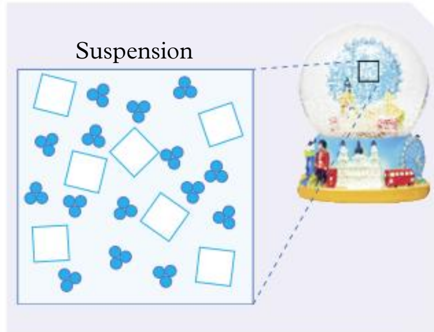



**Figure 3** A snow dome can be described as a suspension, with the larger 'snow' particles being suspended in the water for a short time before they fall to the bottom of the dome to form a sediment.

**Figure 4** Fog is a colloid because it is made up of suspended liquid particles in air.

**Figure 5** Milk is an emulsion because it contains many substances suspended in what is mainly water.

## 3.1 Check your learning

### Retrieve

1 **Define** the term 'pure substance'.

### Comprehend

2 Complete Table 1 below to **summarise** different types of mixtures.

**Table 1** Different types of mixtures

| Type of mixture | Substances involved | Appearance when light shines through | Separates on standing? | Example |
|---|---|---|---|---|
| **Suspension** | Solid + liquid | Cloudy | Yes, slowly | Milo in milk |
| **Emulsion** | | | | |
| **Colloid** | | | | |
| **Solution** | | | | |

### Analyse

3 **Compare** (the similarities and differences between) a pure substance and a mixture.

4 **Contrast** (the differences between) the type of substances found in sea water and pure water.

5 **Classify** the following substances as pure substances or a mixture.

a cup of tea
b soft drink
c table salt
d soap
e olive oil

### Apply

6 **Predict** the types of particles you think the mixtures in question 5 might contain.

7 **Predict** the type of mixture(s) that would form a sediment.

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 3.2 A solution is a solute dissolved in a solvent

**Learning intentions**

By the end of this topic, you will be able to:

- contrast the terms 'soluble' and 'insoluble', 'solute' and 'solvent', and 'concentrated' and 'dilute'
- describe the properties of a saturated solution
- explain the importance of water as a solvent.

**Key ideas**

- A solvent can be used to dissolve a soluble solute.
- A dilute solution has very little solute in the solvent.
- The more solute that is dissolved in the solvent, the more concentrated the solution.
- A solution is saturated when no more solute will dissolve.

## Solubility and insolubility

In some places in Australia, the water from the local water supply has an unpleasant taste, or washing with soap is difficult because the water forms a scum instead of a foamy lather. In these cases, the water contains metal salts that affect its taste and behaviour. Because they are so small, these metal salts do not fall to the bottom or float on the top; instead, they remain evenly spread through the liquid. The resulting mixture (a solution) is clear – light will shine through it. We say that the metal salts have dissolved in the water.

A substance that is able to dissolve in a liquid is considered to be **soluble**, whereas a solid that cannot dissolve is described as insoluble. The substance dissolving is called the **solute**, and the liquid into which it dissolves is called the **solvent**. An example of this is salty water. The salt is the solute, and the water is the solvent. Sometimes it is necessary to help a solute such as salt to dissolve. Warming the solvent (water) is the most common way of making a solute dissolve faster.

## Working with solutions

You have seen that a solution is a solute dissolved in a solvent (Figure 1). Solutions can be compared in terms of their concentration: how much solute is in the solvent. If just a little solute is dissolved, the solution is described as **dilute** (low concentration). If a lot of a solute is dissolved, the solution is described as **concentrated** (high concentration). This is shown in Figures 2 and 3.

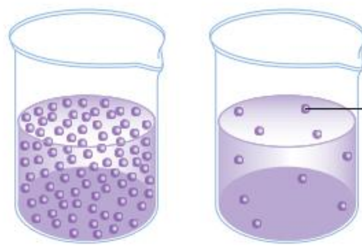



**Figure 3** A concentrated solution contains more solute particles in a given volume than a dilute solution.

**soluble**
can be dissolved in a liquid

**solute**
a substance that dissolves in a liquid (solvent)

**solvent**
a liquid in which other substances dissolve

**dilute**
containing a small number of solute particles in the volume of solution

**concentrated**
containing a large number of solute particles in the volume of solution

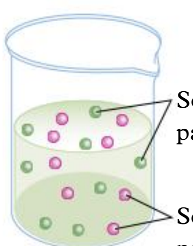



**Figure 1** A solute dissolves in a solvent to create a solution.

**Figure 2** The concentration of salt in the Dead Sea is so high that when people try to swim in it, they float instead because their body is less dense than all that salt!

EXPERIMENT

**3.2A:** What if salt was dissolved in water?
Go to page **206**.

EXPERIMENT

**3.2B:** What if the solvent was heated when making a mixture?
Go to page **207**.

It is only possible to dissolve a certain amount of a particular solute in a solvent. If no more solute can dissolve into a solution, the solution is described as **saturated**. What sort of cordial drink do you prefer: dilute, concentrated or saturated?

We often work with solutions in our everyday lives. By adding solutes to pure liquids, the properties of the pure liquids may change. An example is adding bath crystals to a bath to give the water a pleasant smell.

## Water as a solvent

Water is a good solvent. This is one of its most important properties. Our digestive system uses water to dissolve our solid and liquid food, and to break up the food into nutrients that our body needs to build new cells, grow and repair.

Our bodies are more than 60 per cent water. Our blood, which is mainly water, transports oxygen to every cell and carries away dissolved carbon dioxide gas (a waste product).

Humans are not the only living things that depend on water as a solvent. Without water's ability to dissolve gases, there would be no underwater life in our oceans and lakes and no fish in the rivers. These creatures all live by extracting dissolved oxygen gas from the water (Figure 4).

Imagine that you found a colourless and see-through liquid and were really thirsty. Is it water? There are many other colourless and clear liquids, and you do not know what substances might be dissolved in them. Tasting may be dangerous. There are more scientific ways of working out whether a liquid is pure. This is explored further in Topic 3.3.

**saturated**
describes a solution in which no more solute can be dissolved

**Figure 4** Oxygen dissolved in water is essential for aquatic organisms.

## 3.2 Check your learning

### Retrieve

1 **Define** the following 's' words used in this section: solute, solvent, solution, soluble and saturated.

2 Someone asks for a dilute glass of cordial. **Identify** if you would add a lot of cordial or only a little.

### Comprehend

3 **Describe** how you could increase the amount of a solute that will dissolve in a solvent.

4 **Explain** if you can see the particles of a solute in a solution.

5 **Explain** why water cannot be a solvent for all substances.

6 **Explain** what happens to sugar particles when they dissolve in water.

### Analyse

7 **Compare** (the similarities and differences between) the solubility of particles in suspensions, colloids, emulsions and solutions.

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 3.3 Mixtures can be separated according to their properties

**Learning intentions**

By the end of this topic, you will be able to:

- describe the processes of decanting, sedimentation, flotation and magnetic separation
- define sediment, magnetism and flocculant
- explain how the properties of a substance can be used to separate them from a mixture.

**Key ideas**

- Properties are how a substance looks (size, mass, texture, shape, volume) and how it behaves around other substances (magnetic, soluble).
- A magnet can be used to separate particular metals.
- Decanting can be used to separate sediment from a liquid.

## Simple separation

Some mixtures are quite simple to separate. Sometimes we can simply pick out the bits we need to separate. The Alyawarre, Anmatyerre, Warlpiri and Pitjantjatjara peoples in the desert parts of the Northern Territory use their fingers to individually separate the good desert raisins (*Solanum centrale*) from the stalks and rotten fruit (Figure 1). This leaves the ripe fruit that is good for eating. This works well if there is a small number of raisins that are big enough to see. But what if the raisins were too small to see? You may need another way of separating out your favourite fruit.

**Figure 1** First Nations peoples use different techniques to separate mixtures.

## Magnetic separation

Do you separate recyclables from your rubbish? Have you ever wondered how the different recyclable materials are separated once they are out of your house? **Magnetic separation** uses magnets to attract and separate particular objects. Some metals are magnetic. Magnetic substances are attracted to a magnet. They are made of iron or a mixture containing iron.

Magnetism will only separate substances containing iron, so magnetic materials such as iron nails can be separated from other non-magnetic materials such as glass, aluminium and paper.

Tin cans are magnetic, whereas aluminium cans are not. Sometimes large magnets are used to separate tin cans in the rubbish from aluminium cans (Figure 2). This means both types of cans can be recycled in different ways.

**magnetic separation**
the process of using magnets to separate magnetic materials from non-magnetic materials

**decanting**
a technique used to separate sediment from the liquid it is in by carefully pouring the liquid away

**Figure 2** Magnets can be used to separate tin cans (left), which are magnetic, from aluminium cans (right), which are not.

## Decanting

Have you ever had a piece of food in the bottom of your drink? Did you use a spoon to remove it? Or maybe you carefully poured your drink into another glass, leaving the food behind? The careful pouring of liquid, or **decanting**, is often done to remove high density sediment from wine (Figure 3).

The objects or liquids that sink are denser than the liquid on the top. The particles in dense objects are packed together more tightly than those in less dense objects. Oil floats on top of water because the particles in the oil are packed very loosely. The water particles pack together more tightly, so they sink to the bottom below the oil.

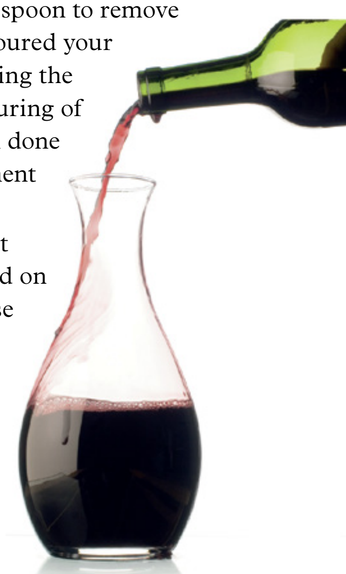


**Figure 3** Decanting wine separates the undrinkable sediment.

SKILLS LAB
**3.3A:** Separation using magnetic properties
Go to page **208**.

SKILLS LAB
**3.3B:** Separating mixtures using sedimentation and flotation
Go to page **209**.

EXPERIMENT
**3.3C:** What if a flocculant was added to muddy water?
Go to page **210**.

The particles in a grain of sand are packed together very tightly. The sand is more dense than water. Therefore, the sand settles to the bottom of a glass of water. The sand forms a sediment in the glass.

## Sedimentation and flotation

**Sedimentation** and **flotation** are used in sewage treatment to separate the mixture of substances (Figure 4). Sewage is left in settling ponds to allow the sediment to settle to the bottom. Fats and oils that float to the top of the ponds can be scooped off for digestion by bacteria.

Oil spills can be cleaned up using the fact that oil floats on the surface of water (Figure 5). Cork and other substances can be sprinkled on top of the oil to soak it up, and these substances are then scooped off and squeezed out.

In certain situations, sedimentation is more difficult. Chemicals called **flocculants** can be added to a mixture to make suspended particles clump together. This makes them heavy enough to settle to the bottom. Flocculation is regularly used to separate substances from water.

## First Nations peoples separate mixtures

Some mixtures can be separated by their ability to be blown or floated away. The Alyawarre people of the Sandover River in the Northern Territory separate mixtures using these properties. In one technique, a variety of local seeds are collected before being beaten with sticks to remove the seeds from their pods. Blowing air gently under the mixture blows away the light pods, leaving the heavier seeds to be used for food.

The Yindjibarndi people in Western Australia separate sand and dirt from seeds in a process called yandying. This technique involves placing the mixture in a shallow wooden dish, called a yandy or a coolamon in other places in Australia, which is gently shaken back and forth. The dense sand sinks to the bottom and the less dense dirt and larger seeds float on the surface, allowing them to be collected for food or growing. This process is very similar to gold panning.

**Figure 4** Sewage treatment involves sedimentation and flotation.

**Figure 5** Oil floats on the surface of water.

**sedimentation**
the process of a substance settling to the bottom in a mixture

**flotation**
the action of floating in a liquid or gas

**flocculant**
a chemical added to a mixture to make suspended particles clump together

## 3.3 Check your learning

### Retrieve

1 **Define** the following terms.
  a sediment
  b flocculation
  c decant
  d density

### Comprehend

2 **Describe** the property that allows the separation of tin cans from aluminium cans.

3 **Explain** why flotation allows oil spills to be cleaned up more easily.

4 Use an example to **describe** what can be done to encourage sedimentation if a suspension does not separate.

5 Use an example to **describe** a situation where people need to separate a mixture by hand.

### Apply

6 **Discuss** a situation where magnetism cannot be used to separate a mixture. **Evaluate** how the properties of the materials cause this problem.

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 3.4 Mixtures can be separated according to their size and mass

**Learning intentions**

By the end of this topic, you will be able to:

- describe the processes of filtration, sieving and centrifuging
- explain how the size and mass of molecules of a substance relate to methods used to separate them from mixtures.

**Key ideas**

- Large particles (residue) can be separated from liquids (filtrate) by filtering.
- Heavy particles can be separated from light particles by using a centrifuge.

Video 3.4
Separation techniques (filter paper)

**filtering**
a technique used to separate different-sized particles in a mixture depending on the size of the holes in the filter used

**sieving**
a separation technique based on the difference in particle size

## Filtering and sieving

Anyone who has cooked pasta will probably have used a colander to separate the boiling water from the cooked pasta. The holes in the colander are designed to let the water through but not the cooked pasta.

Filters have a series of holes in them that let through small things but trap larger particles. A grate on a stormwater drain is an example of a filter. The grate lets the water through while filtering out the leaf matter and rubbish. Flyscreens on windows and doors filter bugs and some dust from the air, and tea bags filter the leaves from the liquid (Figure 1).

**Filtering** separates solids from liquids (or solutions) as the particles of the solution or liquid are smaller than the size of the holes in the filter paper (Figure 2). The filtrate passes through the filter and the residue is left behind in the filter.

**Sieving**, on the other hand, separates solids according to the size of their particles (Figure 3). When you use a sieve, anything that is smaller than the hole can pass through and the larger solids are left behind in the sieve. Sieves can separate solids of different sizes.

**Figure 1** Tea bags are a common household filter.

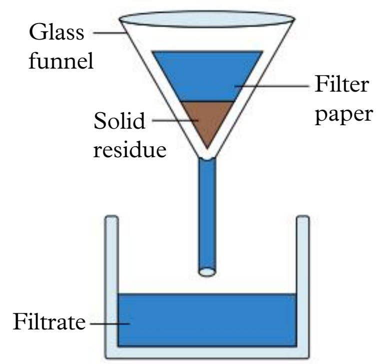



**Figure 2** Filters are used in science to separate substances. Particles that pass through the filter are called the filtrate. The filter paper traps the residue.

Filter paper has holes that are too small to see. Solutions can flow through the filter paper because the particles in the solution are small enough to fit through the holes; however, most solid particles in suspensions are not. Different filter papers come with different-sized holes. Coffee filters and the filters found in vacuum cleaner bags are both made of paper filters. High-efficiency particle arrestance (HEPA) filters are used in vacuum cleaners, air conditioners and face masks to remove even tiny dust particles.

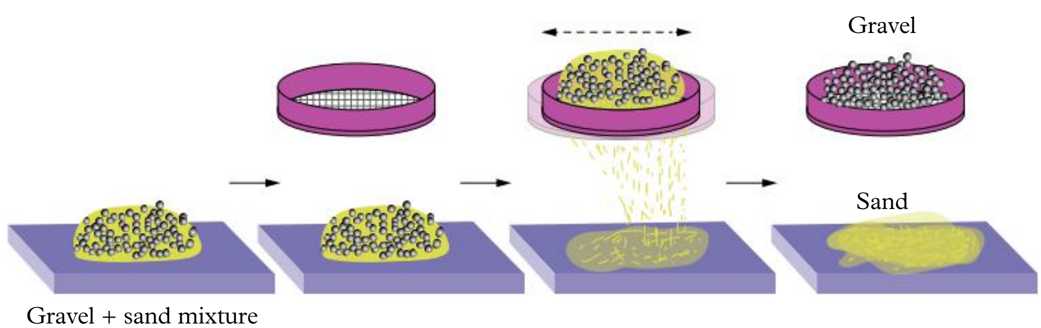



**Figure 3** Sieves can be used to separate solids of different sizes, such as gravel and sand.

SKILLS LAB

3.4A: Filtering a mixture of sand and water
Go to page 211.

EXPERIMENT

3.4B: What if you centrifuge tomato sauce?
Go to page 212.

Sometimes filters remove substances using chemicals rather than by physically stopping them. Gas masks often contain a special type of charcoal that attracts and holds onto some poisonous gases (Figure 4).

**Figure 4** A gas mask uses activated charcoal to filter poisonous gases.

## Centrifuging

Sometimes mixtures do not separate well using sedimentation because the particles are not dense enough. Sometimes things need to be separated using their weight.

Some playgrounds have equipment that spins around very fast. When you spin very fast on this equipment, you can feel a force pulling you towards the outside of the spin. Heavy objects feel the pull more than light objects.

**Centrifuging** separates light and heavy particles by spinning a mixture. A centrifuge is a machine that spins very quickly. In a laboratory, small test tubes of mixtures are fixed to the inside of the bowl of the centrifuge. The spinning motion causes the heavier particles to move to the bottom of the tubes.

Centrifuges are used in medical research and at blood banks. When blood is spun in a centrifuge, the red blood cells, which are heavier, sink to the bottom of the test tube, leaving the yellowish liquid part of blood (plasma and platelets) at the top (Figure 5). Medical professionals use different parts of blood depending on the medical need.

Centrifuges are used in dairy processing factories to separate cream from milk. Salad spinners and washing machines also use this principle (Figure 6).

**Figure 6** A spinning washing machine is a centrifuge, separating water from the clothes.

**centrifuging**
a technique used to separate light and heavy particles by rapidly spinning the mixture

**Figure 5** When blood (right) is separated by a centrifuge, the red blood cells collect at the bottom of the tube and the less dense liquid, the plasma and platelets, collects at the top (left).

## 3.4 Check your learning

### Retrieve

1 **Recall** the missing words and use them to complete the sentences below.
Filtering is like using a _____________. The _____________ lumps are caught in the sieve, and the _____________ goes through the _____________ paper. The substance caught in the _____________ paper is called the _____________. The substance that passes through is called the _____________.

2 **Name** two places where centrifuges are used.

### Analyse

3 **Identify** the filters used around your home and school. **Identify** the substances that these filters allow to pass through them and the substances they collect.

4 **Contrast** (the differences between) each of the following pairs.
 a mixture – pure substance
 b sedimentation – flotation
 c residue – filtrate

### Apply

5 **Discuss** why a forensic scientist, who was investigating a crime, would want to compare a mixture of different types of sand found in a suspect's car with a similar mixture found at the crime scene.

6 In traditional times, the Gunditjmara people of Southwest Victoria used honeysuckle cones from banksia trees as filtration straws. The straws allowed them to separate clean water from muddy pools. **Justify** why this is an example of a filter. (HINT: Compare how a filter works with how the honeysuckle cones work.)

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 3.5 The boiling points of liquids can be used to separate mixtures

**Learning intentions**

By the end of this topic, you will be able to:
- describe the processes of evaporation, distillation and crystallisation
- explain how different boiling points can be used to separate mixtures.

**Key ideas**
- The different particles in a mixture will often have different boiling points.
- The substance with the lowest boiling point will evaporate first.
- When a solvent evaporates, it will leave behind crystallised solute.
- If the evaporated solvent is cooled it will condense into a liquid in a process called distillation.

**Figure 1** Water will evaporate from a mixture of salt and water, leaving behind salt crystals.

## Evaporation and crystallisation

When water in a saucepan is heated, it will quickly start to boil. This means the liquid evaporates: it becomes a gas. Every substance has a different volatility. This means they evaporate at different temperatures. Table 1 shows the boiling points of some common liquids.

The different boiling points of liquids can be used to separate them in a mixture. A mixture of water and turpentine can be easily separated because the water will evaporate first. This means the water will become a gas (water vapour) and move away from the turpentine. Eventually only turpentine will be left behind.

Evaporation can also be used to separate the parts of a solution. Salt evaporates at 1414°C. When a mixture of salt and water is heated, the water evaporates first, leaving behind the salt crystals (Figure 1). This process of evaporating the solvent (the water) and leaving behind the solute (salt) is called **crystallisation**.

**crystallisation**
a separation technique used with evaporation to remove a dissolved solid from a liquid; after the liquid has been evaporated the solid remains, often in the form of small crystals

**distillation**
a technique that uses evaporation and condensation to separate a solid from the solvent in which it has dissolved

**Table 1** Boiling points of common liquids

| Liquid | Boiling point (°C) |
|---|---|
| Water | 100 |
| Alcohol | 78 |
| Petrol | 95 |
| Olive oil | 300 |
| Tar | 30 |
| Turpentine | 160 |

## Distillation

What if we want to keep the substance that has the lowest boiling point? Collecting drinkable water from sea water is difficult if all the water evaporates into the air. **Distillation** is a way of collecting the gas that evaporates from a mixture and cooling it down so that it becomes a liquid again (Figures 2 and 3). This cooling down of a gas into a liquid is called condensation.

**Figure 2** Whisky production uses distillation.

EXPERIMENT

**3.5A:** Crystallisation of salt water
Go to page **213**.

CHALLENGE

**3.5B:** Design a way to purify water from sea water
Go to page **214**.

Distillation was a process used by many First Nations Australians to separate the medicinal oils from eucalyptus plants (Figure 4). When the leaves are placed over a fire, the heat causes the leaves to break apart and the water and eucalyptus oil to be released into the air. If someone is sick, they might lean over the steam to breathe in the oil. This could ease their breathing. If the steam is collected, it will contain a mixture of oil and water which can be separated in a slower distillation process that uses the different boiling points of the two liquids.

**Figure 4** Eucalyptus oil was distilled from eucalyptus leaves by First Nations Australians to use as a medicine.

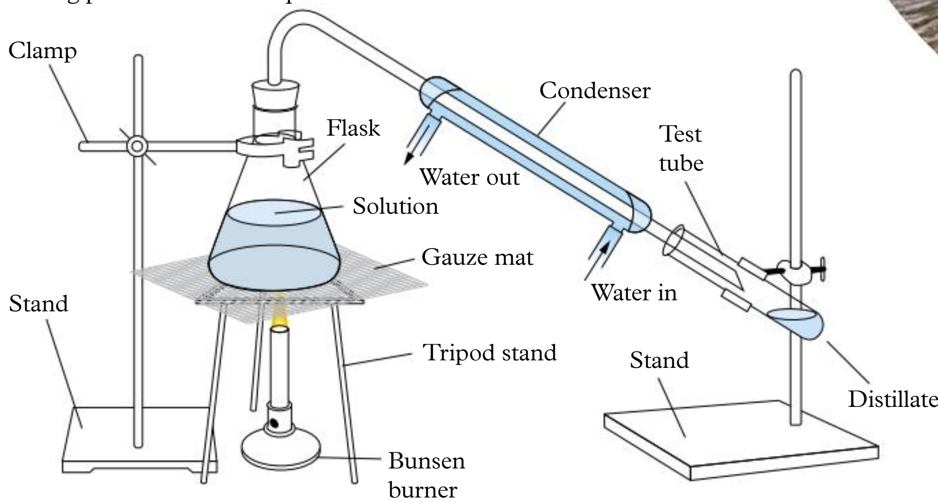



**Figure 3** Equipment set-up for distillation

## 3.5 Check your learning

### Retrieve

1 **Recall** the difference between evaporation and crystallisation.

### Comprehend

2 **Identify** an example of a mixture that could be separated by evaporation and crystallisation. **Explain** why distillation may not be appropriate.

3 Alcohol boils at 78°C, while water boils at 100°C. In a mixture of alcohol and water, **explain** which liquid would be the first collected through distillation. (HINT: The word 'explain' means you need to provide a reason why.)

4 **Identify** the separation technique that is being conducted in Figure 5.

### Apply

5 **Create** a scientific diagram of the equipment set-up that could be used to produce pure water from sea water by distillation.

6 **Propose** how you would answer question 5 without using the science equipment found in a laboratory.

**Figure 5** Conducting a separation technique

**Quiz me**

Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 3.6 Solubility can be used to separate mixtures

**Learning intentions**

By the end of this topic, you will be able to:

- describe the process of chromatography
- explain how the solubility of a substance can be used to separate it from a mixture.

**Key ideas**

- Some substances are able to dissolve more easily in solvents than others.
- Chromatography can be used to separate mixtures of substances that have different solubilities.

Video 3.6
Separating mixtures

**solubility**
how easily a substance dissolves in a solvent

**chromatography**
a technique used to separate substances according to their differing solubilities

## Solubility

Another property that can differ between substances is **solubility**. Solubility describes how easily a substance dissolves in a solvent. Some dyes have a higher solubility than others. This can be used to separate them from one another. Many dyes are small particles that are suspended in a solvent. They are usually made from plants or minerals. The Ancient Greeks made a mixture of soot and vegetable gum that could be used for writing. One thousand years later, the Chinese made red ink from mercury sulfide and black ink from iron sulfate mixed with sumac tree sap. Today, many of the inks in textas are made of a mixture of these dyes. We can separate these dye mixtures because the dyes have different solubilities.

## Chromatography

Paper **chromatography** is a common way to separate a mixture. Chromatography works when the end of an absorbent paper is dipped in water, allowing the water to slowly move up the paper. As the water moves past the dye mixture, the most soluble dye dissolves first and starts to move with the water. The other dyes in the mixture take longer to dissolve. Eventually the next dye forms a solution and starts moving towards the top of the paper. Finally, the paper has a series of smudged dye colours running up to the top (Figure 1). The coloured dye that is the most soluble is at the top, whereas the dye that is least soluble is at the bottom.

More complex and sensitive chromatography instruments are used to separate mixtures, such as drinks and polluted air. Science laboratories often have chromatography equipment that can be used to detect 1 g of a substance in thousands of litres of solution even if it is mixed with many other substances. Scientists use chromatography to find out what substances are in a mixture. Chromatography works because different substances move through the chromatography equipment at

**Figure 1** Chromatography is used to separate samples, such as inks and dyes.

**Figure 2** Performing gas chromatography

CHALLENGE

**3.6A:** Separation challenge
Go to page **215**.

EXPERIMENT

**3.6B:** Who wrote the nasty note?
Go to page **216**.

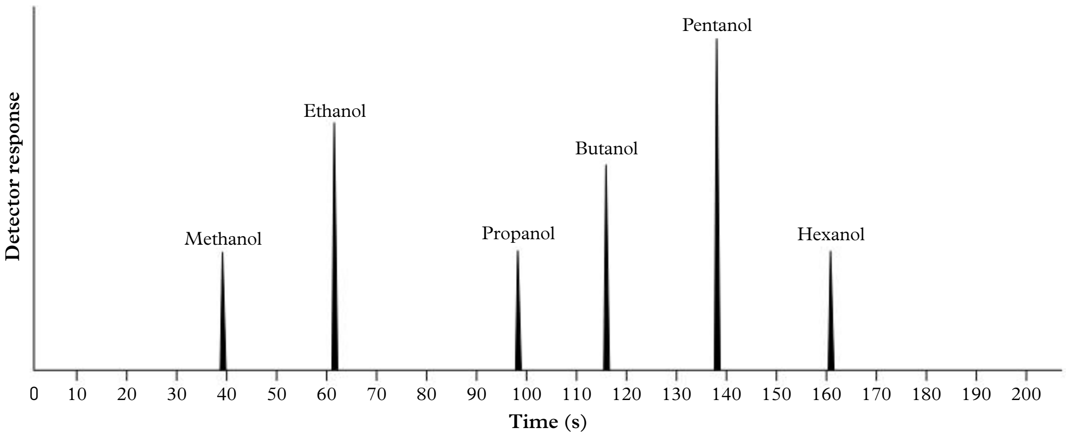



**Figure 3** A gas chromatogram obtained from performing chromatography shows what is in an alcohol mixture. The higher the peak, the more a substance is present.

different times, and produce a graph like the one shown in Figure 3. The height of each peak tells the scientist how much of a particular substance is in the mixture.

One of the uses of chromatography today is to identify athletes who use banned substances when they compete by testing their urine. A chromatography machine separates all the substances in the urine, including any illegal drugs that leave the body.

Airport security also tests for illegal drugs. A piece of chromatography paper is wiped over a person or their bag and then inserted into a machine (Figure 4). A gas is pushed through the paper. If the drug is soluble in the gas, it will dissolve and be detected by the sensors.


**Figure 4** Airport security uses chromatography to test for illegal drugs.

## 3.6 Check your learning

### Retrieve

1 **Name** the substances that were used to make the first inks.

2 **Recall** the solvent that is used in the chromatography for drugs at airports.

3 **Define** the term 'solubility'.

### Comprehend

4 **Explain** how chromatography can be used to separate inks and dyes.

5 **Describe** an example of chromatography being used in real life to separate a substance.

### Apply

6 Some people think they can disguise drugs at airports by putting them in a strong-smelling substance, such as coffee beans. **Discuss** why this will not work with airport security that uses chromatography.

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

**Figure 5** Some people try to use strong-smelling coffee beans to disguise drugs at airports.

//SCIENCE AS A HUMAN ENDEAVOUR//

# 3.7 Wastewater is a mixture that can be separated

**Learning intentions**

By the end of this topic, you will be able to:

- describe the separation processes involved in water treatment.

Washing dishes or using the bathroom produces wastewater containing a mixture of vegetable matter, paper, cloth and plastics. This cannot be released directly into waterways without harming the environment. Scientists use their knowledge of separating mixtures to make the water safe.

**Figure 1** A water treatment plant

Many unusual things have been found at wastewater treatment plants, including BMX bikes, toys, false teeth and even money. One of the biggest problems currently is caused by the small stickers found on fruit. If eaten accidentally, the small plastic stickers pass through the digestive system and end up at the water treatment plants.

**Figure 2** Flocculation clumps together the suspended particles in wastewater.

## Primary treatment

Initially, the wastewater is filtered to remove any large products.

Aluminium sulfate is added to the wastewater to encourage any remaining suspended particles to coagulate (or clump together). This process is called flocculation (Figure 2).

The small clumps are then left to sit in sediment ponds to allow the clumps to form a sediment on the bottom of the pond. This sediment is called sludge, and can be removed and disinfected. Many industries use the sludge as fertiliser or to manufacture biofuels.

## Secondary treatment

The remaining wastewater often contains levels of nutrients, such as nitrogen and phosphorus, that would be harmful to rivers or the ocean. When these nutrients enter waterways in large amounts, algae feed off them and grow into large blooms (Figure 3). The large numbers of algae use all the oxygen and nutrients in the water, leaving other aquatic life to starve. Secondary waste treatment pumps the wastewater through a series of tanks where bacteria remove the excess nutrients from the water.

## Tertiary treatment

Sometimes the water will be treated at a tertiary treatment plant, as shown in Figure 4. Once again, the water is filtered to remove any particles that may be left in the water. Chlorine can be added (just as in a swimming pool) to kill any bacteria that may still be in the water.

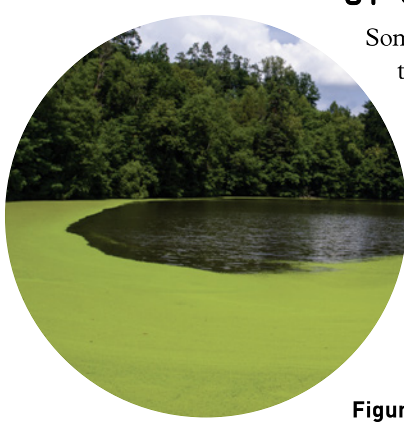


**Figure 3** An algal bloom

**Figure 4** Chlorine and wastewater tanks in a tertiary water treatment plant

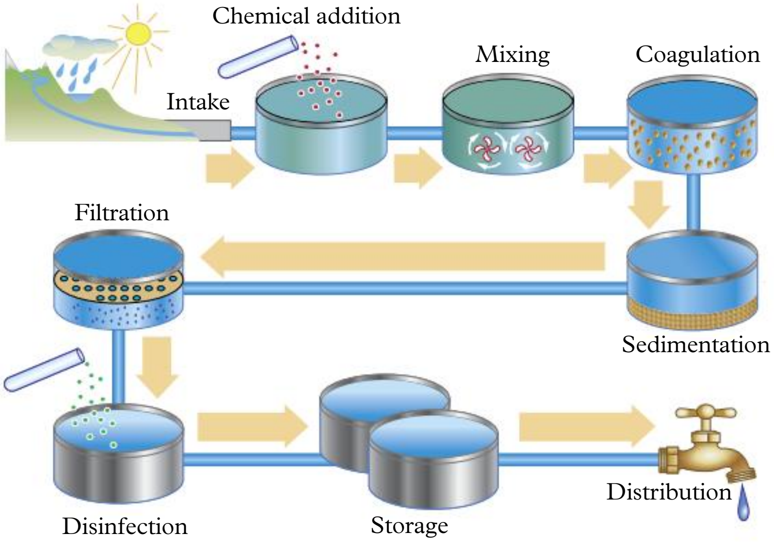



**Figure 5** Summary of the water treatment process

## 3.7 Test your skills and capabilities

### Analysing data in graphs

Scientists often gather data from the water treatment plants to help them understand how water is used, as well as the health of the population. Recording, processing and analysing data are essential skills in science.

1 Water use is often an indication of the amount of wastewater produced per person every year. A graph of the annual water consumption per person in Australian cities is shown in Figure 6.

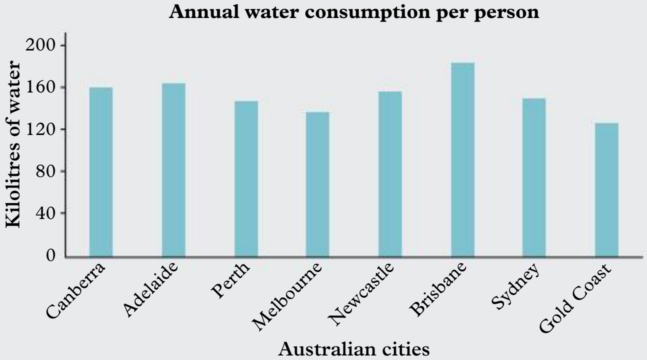



**Figure 6** Annual water consumption per person

a **Identify** the city that uses the highest amount of water per person each year.

b **Identify** the city that uses the lowest amount of water per person each year.

c **Identify** the amount of water that the average person in Canberra uses in a year.

d **Describe** one reason why a person living in Brisbane might use more water than a person living in Melbourne.

2 Seqwater, the water supply authority in South East Queensland, encourages locals to try to save 3 L of water per day.

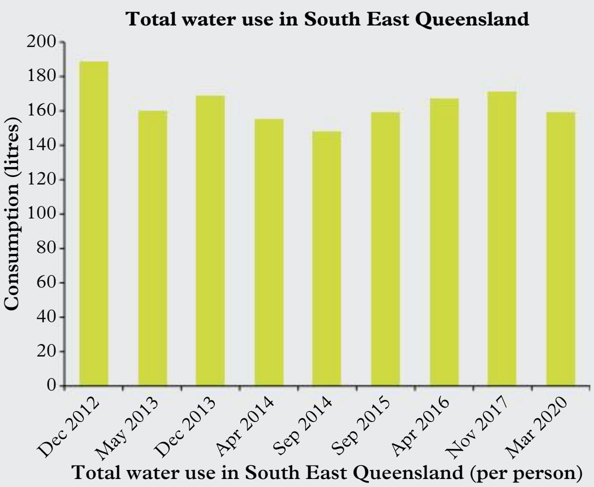



**Figure 7** Total water use in South East Queensland

a Use Figure 7 to **identify** the month that residents in South East Queensland used the most water.

b **Identify** the month that residents in South East Queensland used the least water.

c The number of people (population) of South East Queensland has continued to increase for each of the years shown on the graph in Figure 7. Use this information to **decide** whether South East Queenslanders have become more or less efficient with their water usage between December 2012 and March 2020.

3 The more water that is used by people living in Brisbane, the greater the amount of sewage that needs to be treated. **Create** a poster that encourages the people in your house to use less water in their everyday activities. (HINT: Use the communication skills you learnt in Chapter 1.)

//SCIENCE AS A HUMAN ENDEAVOUR//

# 3.8 Materials recovery facilities separate mixtures

**Learning intentions**

By the end of this topic, you will be able to:

- describe the separation processes involved in recycling at a materials recovery facility.

A materials recovery facility uses the properties of the items in a recycling bin to separate them so that they can be reused. The items are separated by mass, colour and magnetic properties. Recycling of rubbish saves electricity and water, and reduces the amount of greenhouse gases that would be released by landfill.

## Household recyclables

Have you ever wondered what happens to the rubbish in the recycling bins collected by your local council? Most households put their paper, cardboard, glass bottles, cans and recyclable plastics into a separate rubbish bin. These items are collected by a different truck from the general rubbish trucks. Instead of going to landfill, these different trucks take the recyclable rubbish to a materials recovery facility (MRF). As the name suggests, this facility separates the mixture of rubbish before sending it off to be recycled.

## The materials recovery facility

At the materials recovery facility, the truck unloads the recycled rubbish onto a conveyer belt. The conveyer belt carries the rubbish into the facility before allowing the rubbish to drop onto a slight incline belt. Paper, cardboard and other light rubbish stay on the incline belt and are carried up and along to where they are sorted by hand (Figure 1). People separate the paper from the plastic bags, placing each into their special bins for recycling.

Heavier objects, such as larger plastic containers, aluminium and tin cans, fall backwards off the incline conveyer belt onto another moving belt. This conveyer belt uses a large magnet to separate the steel and tin cans into a large bin. Aluminium cans are not attracted to the magnet and remain mixed with the larger glass and plastic containers.

The aluminium cans, glass and plastics are exposed to a special eddy current separator. This separator pushes the aluminium cans away so that the cans fall further than the glass and plastic bottles (Figure 2).

**Figure 1** A materials recovery facility

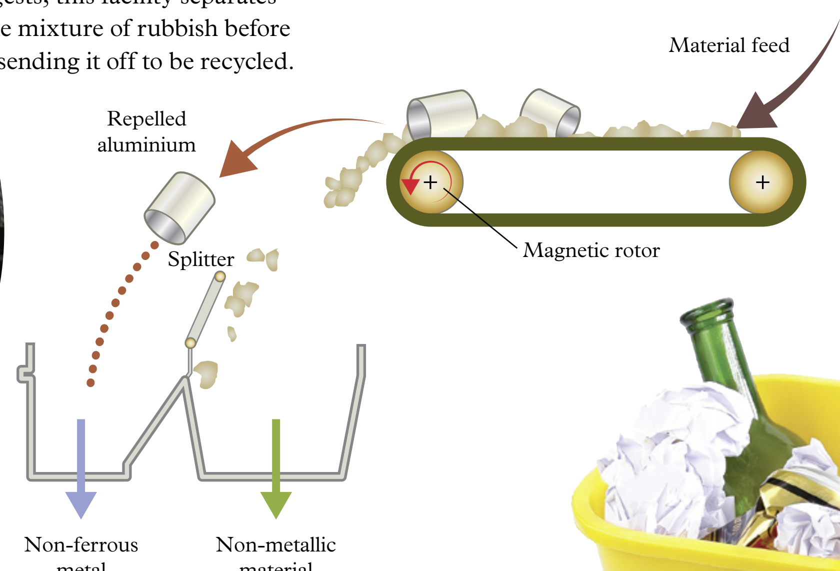



**Figure 2** How an eddy current separator works

The conveyer belt carries the remaining glass and plastic bottles forward over a pit. The heavier glass containers fall faster and are collected in a bin. The lighter plastic containers are caught by the last conveyer belt and are separated on the basis of colour. A light scans each plastic container for the type of plastic. Each type of recycled plastic is a different colour. Each colour plastic receives a different blast of air that projects it into the correct bin.

## Why recycle?

The recycled glass is crushed into a ‘cullet’ and heated to 1500°C until it is liquid/molten. The molten glass is then poured into a mould to form new bottles. The energy saved from recycling one glass bottle will run a 100 watt light globe for four hours. Aluminium cans are recycled in a similar manner. Each aluminium can that is recycled will create enough electricity to run a television for three hours. Recycling 1 t of paper and cardboard will save 13 trees.

**Figure 4** Aluminium cans can be almost endlessly recycled.

## 3.8 Test your skills and capabilities

### Discussing ethical issues

Ethics is the study of making decisions based on what is thought to be right and what is thought to be wrong. Each person will often make different ethical decisions based on what they consider is the right thing to do. Their opinions are often affected by the information (or science communication) provided by local councils or discussions with their neighbours. For example, many people think throwing rubbish away to be buried in a landfill site is wrong. They may be able to communicate their opinion effectively to their neighbour, encouraging their neighbour to recycle their rubbish.

1 **Describe** a possible reason why some people see burying rubbish in landfill as wrong.

2 **Suggest** why someone might place an aluminium drink can in a rubbish bin that is taken to landfill.

3 Is it better to place the aluminium can in the rubbish bin or drop the aluminium can on the ground? **Explain** why you made this decision.

4 **Suggest** an alternative decision that could be made by the person so that the aluminium can did not go to landfill. Would you make this decision? **Explain** why or why not.

5 Someone places a non-recyclable wrapper in the recycling bin. **Discuss** whether it is better or worse to do this or drop the wrapper on the ground.

6 Split your class into five groups. Each group should work together to try to:

a **describe** what is happening at one of the labelled stages of the recycling plant in Figure 5

b **describe** how this process may be impacted based on your answers to questions 2 and 5.

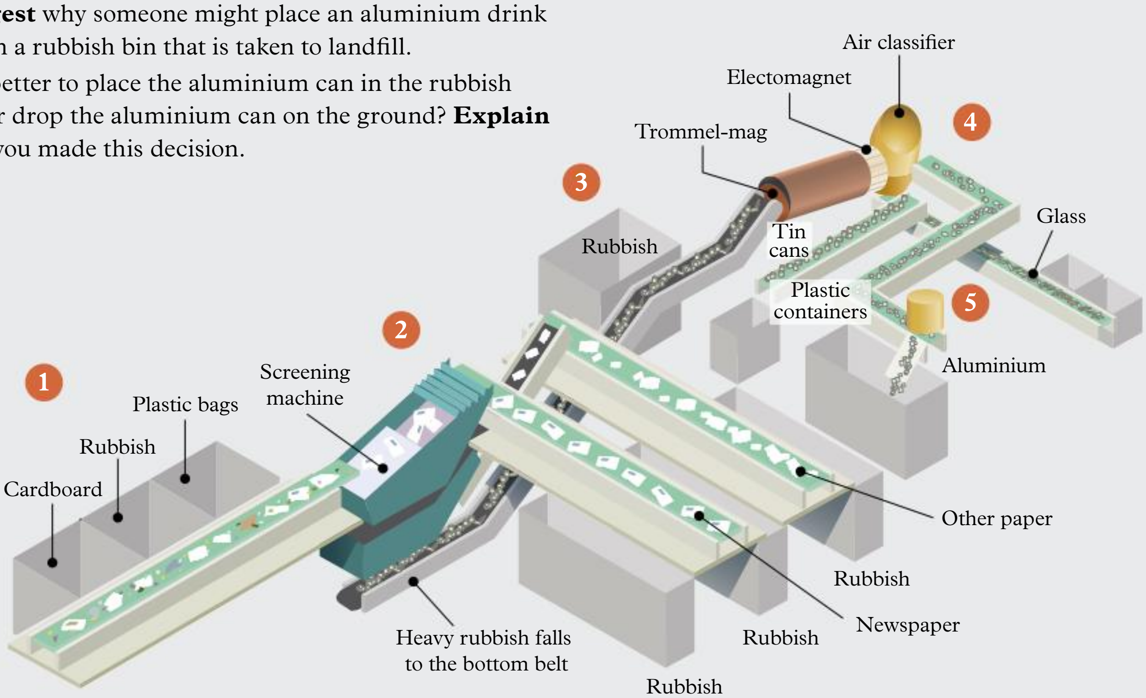



**Figure 5** An illustration of a materials recovery facility

**Figure 3** Household recyclables

# CHAPTER 3 REVIEW

## MIXTURES

### Retrieve

1 A tablet is dissolved in a glass of water. **Identify** the solvent in the scenario.
  A the tablet
  B the water
  C the glass
  D the tablet and water combined

2 **Identify** the physical property that allows mixtures to be separated by decanting or sedimentation.
  A boiling point
  B magnetism
  C density
  D compressibility

3 **Identify** the separation technique that can be used to separate materials with different solubilities.
  A evaporation
  B distillation
  C magnetic separation
  D chromatography

4 a **Recall** the separation technique that is used to separate the parts of blood.
  b **Identify** the physical property that is being used to separate this mixture.

5 **Identify** the property used to separate substances through centrifuging.

6 **Define** the term 'flocculation'.

7 Nail polish remover and paint stripper are both useful solvents.
  a **Define** the term 'solvent'.
  b **Identify** the solute for nail polish remover and paint stripper.

### Comprehend

8 **Describe** an example of a mixture that could be separated into its parts by filtration.

9 **Explain** two safety recommendations that you would give to someone using evaporation and crystallisation.

10 Imagine dropping salt in sawdust. **Explain** how you would separate the parts of this mixture, using the particle model.

11 A criminal buries an aluminium drink can containing DNA evidence in the sand. **Explain** whether the aluminium could be separated from the sand using a magnet.

12 **Describe** each of the processes involved in the primary, secondary and tertiary treatment of wastewater.

13 Daniel was measuring the solubility of two chemicals (A and B) in water. He placed a spatula full of each substance in separate test tubes of water. Figure 1 shows what he saw.

Use the terms 'dissolve', 'solvent', 'solute' and 'suspension' to **explain** what has happened.

**Figure 1** Test tube A (left) and test tube B (right)

14 Imagine that you have just bought a large factory. Due to flood damage, it is filled with tonnes of matchsticks mixed with tonnes of iron scraps.
  a **Describe** how you would separate this mixture.
  b **List** the equipment you would need to make this happen on such a large scale.

15 A particular coloured dye is being created for Fashion Week.
  a Look at the chromatogram of the dye mixture in Figure 2. **Identify** how many pure dyes were mixed to create the colour.
  b **Identify** the colour of the pure dye that is the most soluble.

**Figure 2** Chromatogram of a dye mixture

16 The Alyawarre, Anmatyerre, Warlpiri and Pitjantjatjara peoples in the desert parts of the Northern Territory use their fingers to separate desert raisins from rotten fruit. **Describe** a situation where you would use the same separation technique.

**Figure 3** First Nations peoples in the Northern Territory use their fingers to separate desert raisins from rotten fruit.

## Analyse

17 Examine Figure 4 and **identify** the suspension, the solution and the colloid.

**Figure 4** Identifying mixtures

18 **Contrast** evaporation and distillation.

19 **Compare** the use of decanting and filtration to separate mixtures. **Identify** examples of situations where you would use one over the other.

20 **Compare** a solution of salt dissolved in water, a suspension of muddy water, and a colloid mixture of milk in water.

**Figure 5** **a** Salty water, **b** muddy water and **c** milk in water

## Apply

21 Examine the chromatograms in Figure 6, taken from blue pens belonging to suspects (A–D). **Compare** these with the one taken from the original forged cheque (X). **Decide** whether any of the suspects is likely to be the culprit.

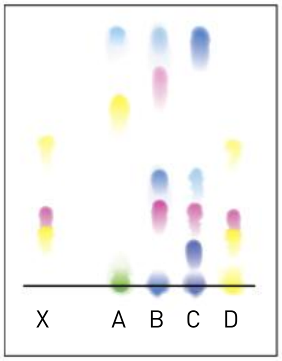



**Figure 6** Which suspect is the likely culprit?

### Social and ethical thinking

22 Do you think that performance-enhancing drugs are spoiling the image of sports? Pair up with a partner and make a list of all the advantages and disadvantages of athletes using these drugs to compete. Use your list to **create** and **justify** an argument for or against drug testing competing athletes.

### Critical and creative thinking

23 **List** the techniques in the order that you could use them to separate a mixture of iron fillings, sand, marbles and salt. **Create** a flow chart to present your answer.

24 People sometimes need to enter environments containing poisonous gases. In these situations, they will wear gas masks. Use the internet or other research tools to find out how gas masks interact with poisonous gases and how they change the air before it is inhaled by the person wearing the mask. **Create** a poster to show how the gas masks make the air safe to breathe.

25 Until recently, Australia would ship all their plastic waste to other countries to be processed. This is no longer possible, because most countries are refusing to accept the waste. **Discuss** and suggest reasons why Australia did not previously process their own plastic waste.

## Research

26 Choose one of the following topics to research working with mixtures.

### » How do we work with mixtures?

Research a separation technique that is used in a different industry or in nature.

- » Prepare a 'SWOT' analysis as part of your report, listing the strengths, weaknesses, opportunities and threats of the separation technique that you choose to research.
- » You could present your report with a series of photographs of the technique.

### » Filters of the sea

Certain types of whales, known as baleen whales, have a filter in their mouth made of a bone-like substance called baleen.

- » Identify what these whales eat.
- » Describe the balleen and how it filters the food.
- » Describe the bubble-net feeding behaviour used by the whales.
- » Investigate how these whales are different from other filter-feeders, such as barnacles, sponges and flamingos.

**Figure 7** The humpback whale is one of the baleen whale types.

### » Distillation for survival

Imagine that you were hiking in central Australia, became separated from your group and then ran out of drinking water.

- » Describe the way First Nations peoples might obtain drinking water in the desert environment.
- » Describe how you could turn stagnant or polluted water from a waterhole into drinkable water.
- » Describe how you could use your knowledge of separating mixtures to obtain drinkable water if you were isolated near the sea coast.

### » Filtration in the human body

The human body needs to control what goes into it and what comes out. In particular, the filtering system of the kidneys prevents us from being poisoned by our own wastes, and tiny hairs in our noses filter dust and germs as we breathe.

- » Select one of these filtration systems.
- » Describe the structure of the system that does the filtering.
- » Describe what the system filters.
- » Explain why it is important to use the filtering system to remove the particles.
- » Describe what would happen if these body filtering systems did not work.

**Figure 8** Hairs in our noses filter dust and germs.

### » Self-cleaning suburbs

As our population grows, new suburbs are being built on the outskirts of cities. In some of these new suburbs, several features have been included to keep the water and air clean.

- » Find out about strategies that are used to purify water and the air in housing estates.

## Chapter checklist

Now that you have completed this chapter, reflect on your ability to do the following.

| | I can do this. | I cannot do this yet. |
|---|---|---|
| • Describe the properties of various mixtures, including solutions, suspensions, colloids and emulsions. | ☐ | ☐ Go back to Topic 3.1 'Mixtures are a combination of two or more substances'. Page 62 |
| • Contrast the terms 'soluble' and 'insoluble', 'solute' and 'solvent', and 'concentrated' and 'dilute'.<br>• Describe the properties of a saturated solution.<br>• Explain the importance of water as a solvent. | ☐ | ☐ Go back to Topic 3.2 'A solution is a solute dissolved in a solvent'. Page 64 |
| • Describe the processes of decanting, sedimentation, flotation and magnetic separation.<br>• Define sediment, magnetism and flocculant.<br>• Explain how the properties of a substance can be used to separate them from a mixture. | ☐ | ☐ Go back to Topic 3.3 'Mixtures can be separated according to their properties'. Page 66 |
| • Describe the processes of filtration, sieving and centrifuging.<br>• Explain how the size and mass of molecules of a substance relate to methods used to separate them from mixtures. | ☐ | ☐ Go back to Topic 3.4 'Mixtures can be separated according to their size and mass'. Page 68 |
| • Describe the processes of evaporation, distillation and crystallisation.<br>• Explain how different boiling points can be used to separate mixtures. | ☐ | ☐ Go back to Topic 3.5 'The boiling points of liquids can be used to separate mixtures'. Page 70 |
| • Describe the process of chromatography.<br>• Explain how the solubility of a substance can be used to separate it from a mixture. | ☐ | ☐ Go back to Topic 3.6 'Solubility can be used to separate mixtures'. Page 72 |
| • Describe the separation processes involved in water treatment. | ☐ | ☐ Go back to Topic 3.7 'Science as a human endeavour: Wastewater is a mixture that can be separated'. Page 74 |
| • Describe the separation processes involved in recycling at a materials recovery facility. | ☐ | ☐ Go back to Topic 3.8 'Science as a human endeavour: Materials recovery facilities separate mixtures'. Page 76 |

**Check your Student obook pro for these digital resources and more:**

**Quizlet**
Play a Quizlet game to test your knowledge.

**Chapter quiz**
Test your understanding of this chapter with the chapter review quiz.

CHAPTER

# 4

# FORCES

## 4.1 A force is a push, a pull or a twist

- Explain why a measuring device must be calibrated.
- Provide examples of forces in real-life situations.

## 4.2 An unbalanced force causes change

- Identify balanced and unbalanced forces.
- Describe how force diagrams can represent forces in a situation.
- Calculate net force.

## 4.3 Forces can be contact or non-contact

- Define and provide examples of contact forces and non-contact forces.

## 4.4 Magnetic fields can apply a force from a distance

- Describe the natural magnetic field of the Earth.
- Provide examples of how magnetism is used in real-life situations.

## 4.5 Electrostatic forces are non-contact forces

- Define electrostatic forces and charge.
- Provide examples of electrostatic forces in real-life situations.

**4.6**

### Earth's gravity pulls objects to the centre of the Earth

- Calculate weight when given the mass of an object and gravitational force.
- Explain why the weight of an object does not affect the rate that it falls.

**4.7**

### Friction slows down moving objects

- Define and provide examples of friction, lubrication, air resistance, drag and streamlining.

**4.8**

### Simple machines decrease the amount of effort needed to do work

- Compare and contrast distance magnifiers and force magnifiers.
- Provide examples of first-, second- and third-class levers.
- Calculate mechanical advantage and effort.

**4.9**

### A pulley changes the size or direction of a force

- Explain how a pulley makes it easier to lift a load.
- Calculate effort in a pulley system.

**4.10**

### There are different types of machines

- Define and provide examples of ramps, wedges, screws and wheels.

**4.11**

### Science as a human endeavour: The forces in flight

- Identify and describe the four main forces involved in flying: lift, thrust, drag and weight.
- Use an infographic to communicate with an audience.

**4.12**

### Science as a human endeavour: Forces are involved in sport

- Explain how understanding of forces has improved sporting abilities and technologies.

## What if?

### Rolling jars

**What you need:**

Ramp, jar with a lid

**What to do:**

1 Roll the empty jar down the ramp.
2 How far did it roll?
3 What made it roll that far?
4 How could you make the jar roll further without changing the ramp?

**What if?**

» What if the ramp was covered with another material?
» What if the jar was full or half full of water?
» What if the jar was bigger or smaller?

# 4.1 A force is a push, a pull or a twist

**Learning intentions**

By the end of this topic, you will be able to:

- explain why a measuring device must be calibrated
- provide examples of forces in real-life situations.

**Key ideas**

- A force is a push or pull that happens when two objects interact.
- The effect of a force can be measured.
- Gravity affects the movement of objects on Earth.

## Forces in action

Forces act on everything around us all the time. Usually, more than one force is acting on an object at one time, but often we do not notice them. You have many forces acting on you at the moment. **Gravity** is pulling you towards the centre of the Earth. The chair you are sitting on is pushing back against you, changing the shape of your leg muscles. Because the forces acting on you are in balance (the same strength), you do not move. You sit still on the chair.

When you kick or throw a ball, you use energy to generate a push force. This force causes the ball to move (Figure 1). When you catch a ball, you still give it a push. This time, the push force causes the ball to stop moving.

Forces act on everything around us all the time. Forces cause objects to:

> begin to move
> speed up
> slow down or stop moving
> change direction
> change shape
> spin
> remain still.

Examples of these forces are shown in Figures 3–9.

## Measuring forces

One way to 'see' a force at work is to measure it. In the kitchen, cooks use scales to measure how much the Earth's gravity pulls on the ingredients. Twenty grams of flour is pulled to the centre of the Earth, causing the flour to push down on the scales. In the laboratory, force is measured using a **spring balance** (Figure 2). A stiff spring in the balance stretches when an object pulls on it. This moves the marker so that the amount of force can be measured. A rubber band can measure the size of forces in a similar way to a spring balance.

**Figure 1** The force of Ronaldo kicking the ball is easy to identify and describe, but what is pulling him towards the centre of the Earth?

**gravity**
the force of attraction between objects due to their masses

**Figure 2** Spring balances are used to measure force.

**spring balance**
a device consisting of a spring and a scale, used to measure forces

**calibrate**
check the accuracy of a meter or measuring device against known measurements

**newton**
the unit used to measure force; symbol N

EXPERIMENT

**4.1:** Measuring forces
Go to page **218**.

Before we can use a rubber band to measure a force, it must be **calibrated**. This means matching the stretch of the rubber band to the force pulling on it. The unit used to measure forces is called the **newton** after English physicist Sir Isaac Newton (1642–1727), who first described the force used to pull an apple from a tree. Spring balances are also sometimes known as newton meters. Scientists around the world have agreed to this standard measurement so that they can communicate with one another. In every country, the force of 100 g being pulled to the centre of the Earth is about 1 newton (N). This is about the same as one large chocolate bar sitting on your hand.

**Figure 3 Begins to move** The golf club pushes the ball. The club exerts a force on the ball, causing it to begin to move. If the club misses the ball, there is no new force on the ball from the club and the ball stays still.

**Figure 4 Speeds up** When skateboarders want to move faster, they use their feet to exert a force on the ground.

**Figure 5 Slows down** The brakes on this bicycle wheel push down on the rotor of the wheel, causing the wheel to slow down. This in turn brings the bicycle to a stop.

**Figure 9 Remains still** The gravity pulling down on the pot plant and the weight of air above it are in balance with the force of the ground pushing up on the pot.

**Figure 6 Changes direction** The tennis racquet pushes the ball in a different direction.

**Figure 7 Changes shape** The hands push the plasticine into a different shape. When the hands stop pushing, the plasticine no longer changes.

**Figure 8 Spins** The hand turns the knob to open the door.

## 4.1 Check your learning

### Retrieve

1 **Define** the term ‘force’.

2 **Recall** seven things that forces can do.

3 **State** the unit used when measuring a force.

4 **Name** the person whom the unit of force is named after.

### Comprehend

5 **Describe** how force can be measured.

6 Use an example to **describe** how you can see the effects of a force, but not see the force.

7 Many measuring instruments have to be calibrated. Use an example to **explain** why calibration of equipment is important. (HINT: Describe the consequences of not calibrating the equipment and how this would affect the results of an experiment.)

### Analyse

8 **Rank** these forces from biggest to smallest.

- **a** a truck hitting a pole
- **b** a rocket being launched
- **c** typing one letter on a computer keyboard
- **d** kicking a soccer ball
- **e** pushing a car along the street

### Apply

9 A student was using the force measurer in Experiment 4.1 when the rubber band broke. **Predict** how using a different rubber band would affect the results.

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 4.2 An unbalanced force causes change

**Learning intentions**

By the end of this topic, you will be able to:
- identify balanced and unbalanced forces
- describe how force diagrams can represent forces in a situation
- calculate net force.

**Key ideas**
- Forces are balanced when they are pushing or pulling equally in opposite directions.
- If the forces on an object are unbalanced, then the object will change its speed, direction or shape.

## Balanced forces

**Balanced forces** are very important. Pushing on a brick wall does not usually cause the brick wall to move. This does not mean your push force did not exist. This is because the forces are balanced. If the forces of the two people in Figure 1 balance each other, then there is no movement. The people are pushing or pulling with equal and opposite forces.

## Unbalanced forces

**Unbalanced forces** are also very important. Consider the forces acting on the barbell in Figure 2. The barbell stays up in the air at a particular height because the forces acting on it are in balance. The weightlifter is pushing the barbell up with exactly the same amount of force as the Earth is pulling down due to gravity. To move the barbell up, the weightlifter must use a force stronger than the Earth's pull. This will make the forces on the barbell unbalanced.

**Figure 1** Forces can balance each other.

**balanced forces**
two forces equal in size and opposite in direction

**unbalanced forces**
describes two or more forces that are unequal in size and direction and therefore change an object's speed, direction or shape

**Figure 2** A weightlifter applies a force to lift the barbell.

## Evidence of an unbalanced force

There are three ways you can tell if a force is unbalanced. Forces are unbalanced if there is a change in the speed, direction or shape of an object. If a ball is resting on the ground, then all the forces acting on it are balanced. If two people are pushing equally in opposite directions on a stationary object, then the forces are balanced and the object does not move. If one person starts pushing harder, then the object will start to move. There is a change in motion because the forces are unbalanced.

Consider a soccer ball rolling towards the goal. If the goalkeeper kicks it away, then the ball will change direction because the goalkeeper's kick unbalanced the forces.

## Representing forces

Force diagrams can be represented using an arrow. A short arrow shows a weak force and a long arrow shows a strong force. The direction of the arrow shows the direction of the force. Figure 3 shows a tug-of-war between two teams. The arrows show the pull force they are exerting on the rope. One team is much stronger than the other team. Which team will win? What evidence will you see in real life that this team is stronger?

CHALLENGE

**4.2:** Design a ball whacker
Go to page **219**.

## Forces can be added together

If you tried to lift a heavy object such as a piano, you would not succeed because the upward force you exert on the piano would be too weak. But if a few of your friends helped you by also adding their force to yours, the combined upward forces would be stronger than the downward pull of the Earth. The **net force** is the combination of all the forces acting on the piano. If the piano is lifted up, the forces are unbalanced and the net force on the piano is upward.

If an object is stationary (not moving) or moving at a constant speed in the same direction, then the net force acting on that object is zero. All the forces are balanced. If an object changes its speed (by speeding up or slowing down), shape or direction, then a net unbalanced force must be acting on it. Worked example 4.2 shows how to calculate net force.

### Worked example 4.2: Calculating net force

Khan and Kim were moving a table tennis table for their parents. Khan pushed the table with a force of 200 newtons, while Kim pushed with a force of 150 newtons.

**a** Calculate the net force if both Khan and Kim pushed in the same direction (left).

**b** Calculate the net force if Khan pushed to the left and Kim pushed to the right.

#### Solution

**a** If both forces are in the same direction (left), they will add together.

Net force = 200 N + 150 N = 350 N

The net force is 350 newtons to the left.

Note: Always mention the direction of the net force.

**b** If both forces are in opposite directions, then they will be subtracted from one another.

Net force = 200 N (left) – 150 N (right) = 50 N (left)

The net force is 50 newtons to the left.

### 4.2 Check your learning

#### Comprehend

1 **Describe** the evidence that shows the forces acting on the objects are unbalanced in the following situations.
  - **a** pushing down the lever on a toaster
  - **b** jumping on a trampoline
  - **c** a car starts moving

2 **Explain** why a brick wall does not fall over when you push against it. **Explain** why a bulldozer could push the wall over.

3 **Explain** why weightlifters get tired when they hold heavy masses in the air.

4 Draw two people having a tug-of-war. Give them names and draw arrows to show the different forces they are exerting on the rope. **Explain** who will win.

#### Analyse

5 **Identify** one example for each of the following.
  - **a** Forces that are balanced (net force = 0)
  - **b** Forces that add together to make an object fall

6 Sally pushes with a force of 150 newtons and Marilla pushes with a force of 200 newtons.
  - **a** **Calculate** the net force if both forces are in the same direction.
  - **b** **Calculate** the net force if they push in opposite directions. Identify who will win.

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

**net force**
the vector sum of all the forces acting on an object; also known as resultant force

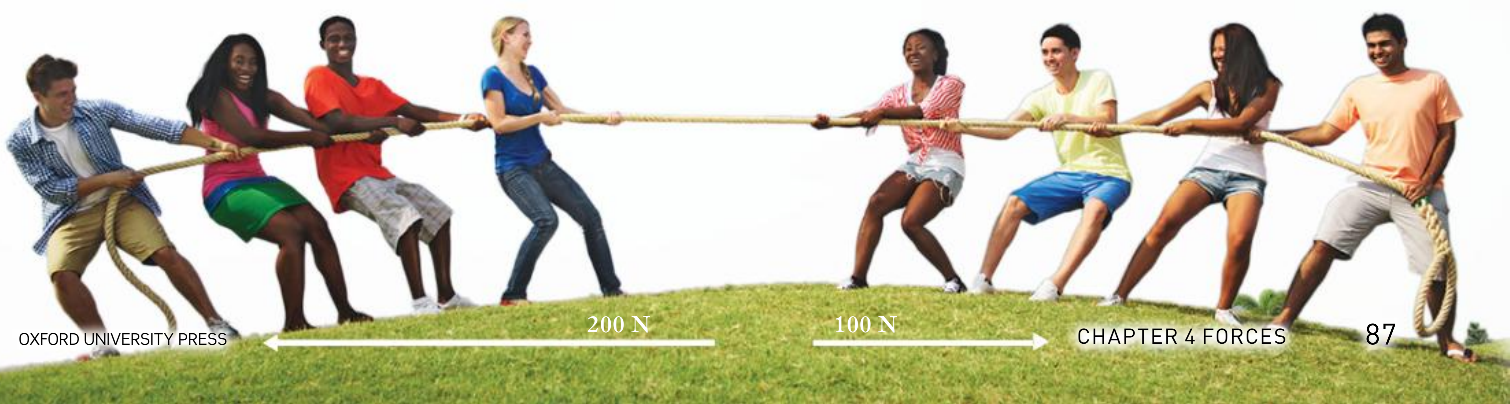



**Figure 3** When forces are unbalanced, a change in motion will occur, with the greatest force 'winning'. In a game of tug-of-war, if one team pulls with a force of 200 N to the left and the other team pulls with a force of 100 N to the right, the net force is 100 N to the left. The team on the left will win the game because both teams will move that way. Unbalanced forces lead to a movement in the direction of the greater force.

# 4.3 Forces can be contact or non-contact

**Learning intentions**

By the end of this topic, you will be able to:

- define and provide examples of contact forces and non-contact forces.

**Key ideas**

- Contact forces involve two objects touching each other.
- Non-contact forces occur when one object is able to push or pull another without touching the other.
- Magnetism is an example of a non-contact force.

All forces occur between two or more objects. These objects can be living or non-living.

## Contact forces

Some forces make objects move because of a direct push or pull. For example, if you push a pencil with your finger the pencil moves. Your finger has to touch the pencil or be in contact before the pencil will move. This is called a **contact force**.

## Non-contact forces

Some forces cause movement without touching. These are called **non-contact forces**. An example of this is the force of attraction between a magnet and a metal paperclip (Figure 1). When a magnet is held near a metal paperclip, the paperclip is pulled towards the magnet. There is no touching, or contact.

## How magnets push and pull

Magnets are made of an alloy (a mixture of metals) that is mostly iron. The bar magnets used most commonly in schools are usually made of the alloy alnico, which is iron mixed with aluminium, nickel and cobalt. New, strong magnets are made from metals known as 'rare earth' metals. These are much stronger than normal magnets and do not lose their magnetism.

One end of a magnet is labelled 'N' for north and the other end 'S' for south. If you hang a bar magnet from its centre by a piece of string, the north end will swing to point north. The magnet is said to have two **magnetic poles** – north and south.

When the north pole of one magnet is placed near the south pole of another magnet, the two magnets are pulled to each other. This is called an **attraction force** (Figure 2). The two **unlike poles** (a north and a south) attract each other. Magicians use this attraction force to slide something along a table. You can do this too. Place one magnet on top of a thin table and a second magnet under the table. Can you make the top magnet move? Can you see the pull force? Are the two magnets contacting each other?

When two **like poles** (two north poles or two south poles) are placed together, they push each other apart. You can use one magnet to push another magnet along a table. This is called a **repulsion force** (Figure 3). The two magnets do not need to touch to be affected by the repulsion force. It is a non-contact force.

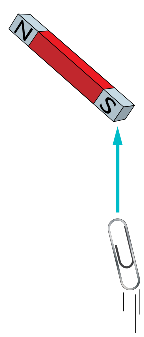



**Figure 1** The attraction between the paperclip and the magnet is a non-contact force.

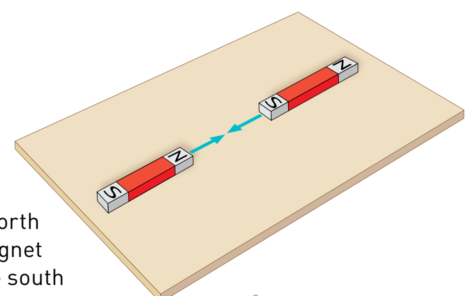



**Figure 2** The north pole of one magnet is pulled by the south pole of another magnet.

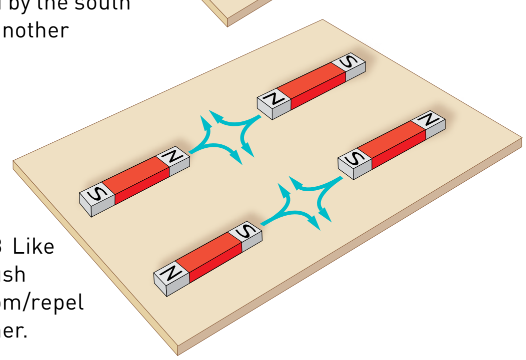



**Figure 3** Like poles push away from/repel each other.

**attraction force**
the force that attracts one object to another

**unlike poles**
the north and south poles of a magnet

**contact force**
a force acting between two bodies in direct contact

**non-contact force**
a force acting between two bodies that are not in direct contact

**like poles**
two north poles or two south poles of a magnet

**repulsion force**
a force that pushes one object away from another

**magnetic poles**
(here) the north and south ends of a magnet

CHALLENGE

**4.3:** Can you use the push and pull of a magnet? Go to page **220**.

## What causes a magnetic force?

An iron needle can be made into a magnet by sliding a strong magnet along one side of it (in one direction only). The strong magnet pulls tiny groups of particles so that they all line up in one direction. Each time you stroke the needle, these particles line up. This causes larger sections of the magnet called **domains** to point in the same direction. When most of the domains are pointing the same way, they can pull or attract a metal pin. Dropping the needle can cause the domains to become mixed up again.

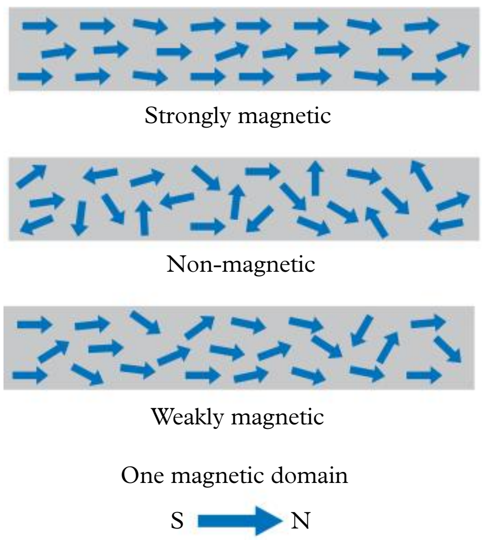



**Figure 4** The magnetic domain theory

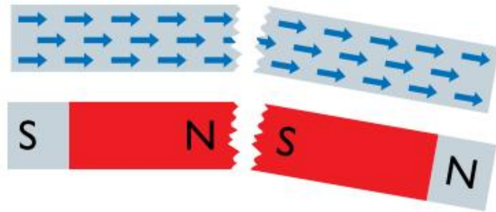



**Figure 5** When a magnet is broken, it forms two magnets.

Some magnets never lose their magnetic force. These magnets are called permanent magnets. The domains in these magnets are often arranged while the metal is still buried deep under the ground. Breaking these magnets in half does not change the arrangement of the domains. The two halves become smaller magnets with the same pull or push forces as the larger magnet (Figure 5).

The push forces of magnets are used in the design of Maglev (magnetic levitation) trains (Figure 6). A series of electronic magnets on the train and track suspend the train above the tracks. The magnets on the train and the track have like poles, causing them to push away from each other and for the train to sit above the track. There is no contact between the train and the metal track. To make the train move, the driver changes the pole of the train magnet, and the track magnet pushes the train magnet forward.

**domain**
a small section of a magnet where the magnetic field of all the atoms is aligned in the same direction

**Figure 6** Repulsive magnetic forces cause this Maglev train to move.

## 4.3 Check your learning

### Retrieve

1 **Name** three places where you might find a magnet.

### Comprehend

2 **Identify** a magnetic force as either a contact or a non-contact force. **Explain** your answer.

3 **Explain** why one part of a magnet is called the north.

4 **Describe** what will happen when the following poles of two magnets are pushed close together.

- **a** N and S
- **b** N and N
- **c** S and S
- **d** S and N

### Apply

5 Draw how you might arrange bar magnets to **create** the letters of your name. Label the north and south poles of the magnets.


**Figure 7** Spelling out your name using magnets

6 **Propose** how you might levitate a magnetic skateboard above a large magnet on the ground. Mention the arrangement of the poles of the magnet in your description.

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 4.4 Magnetic fields can apply a force from a distance

**Learning intentions**

By the end of this topic, you will be able to:

- describe the natural magnetic field of the Earth
- provide examples of how magnetism is used in real-life situations.

**Key ideas**

- A magnetic field is the area around a magnet where a magnetic force is experienced.
- A magnetic field cannot be seen, but we can see the way it interacts with other objects.
- The further away an object moves from the magnet, the weaker the field.

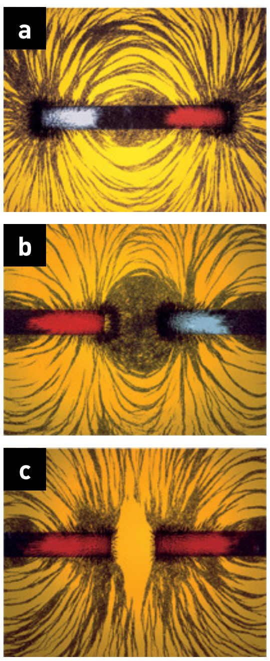



**Figure 1** Magnetic fields: **a** around a single bar magnet; **b** between two attracting bar magnets; **c** between two repelling magnets

**magnetic pole**
the north and south ends of a magnet; (here) each of the points near the extremities of the axis of rotation of the Earth or another body where a magnetic needle dips vertically

## How compasses work

A compass needle is a weak magnet. When a compass is placed near a strong magnet, the compass needle points in the direction of the field. You can see this by moving a compass around the sides and ends of a bar magnet. The north pole of a compass always points to the south pole of a magnet.

Iron filings and iron powder are tiny bits of iron. If you put them near a strong magnet, they become temporary magnets. They line up like tiny compass needles around the strong magnet. You can draw this pattern and make a map of the magnetic field. Figure 1 shows the magnetic fields around one and two bar magnets.

There is a large magnetic field around the Earth. A compass needle will line up with the Earth's magnetic field. The part of the compass needle with the 'N' on it points to the north **magnetic pole** of the Earth. It is important to note that the 'geographic' North Pole of the Earth is not the same as the magnetic north pole. They are both in the Arctic Circle but hundreds of kilometres apart.

The North Pole, also known as the geographic North or true North Pole, is the northernmost point of Earth. If you tunnelled through the Earth from the North Pole in a straight line, you would come out the other side at the South Pole. The magnetic north pole is quite different. The magnetic north pole is not a fixed point – it moves about according to the magnetic field of the Earth and has done so for hundreds of years. This movement is caused by the Earth's magnetic field.

The magnetic south pole does not always line up with the magnetic north pole. Figure 2 shows the different locations of the geographic North and South Poles and the magnetic north and south poles.

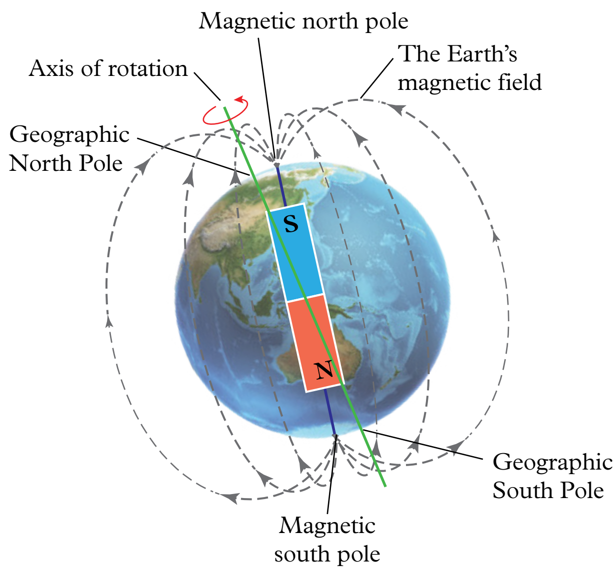



**Figure 2** The Earth's geographic poles are not in the same place as its magnetic poles.

## How turtles use the Earth's magnetic field

When a turtle hatches, it crawls down the beach to the water and swims out to the brightest light on the horizon, which is usually the Moon. For the next 30 years, it will swim in the fast-flowing sea currents around the world. When it is ready, the turtle is able to detect the magnetic field around the Earth. It can measure the direction of the magnetic field (just like a compass) and how strong it is. All it needs to do is follow the magnetic field back to exactly the same beach where it hatched (Figure 3). Once there, it will mate and lay eggs, completing the cycle of life once again.

**Figure 3** What do magnets and turtles have in common? Magnets create a magnetic field, and turtles use the magnetic field to find their way back to the same beach where they hatched.

## Flipping the magnetic poles

Throughout history, the magnetic north and south poles have flipped upside down every now and then. The last flip happened 780 000 years ago. The flip can take a few thousand years to complete. While this happens, the poles become very disordered and a magnetic north or south pole can appear anywhere (Figure 4). How will this affect the turtles being able to find their beach?

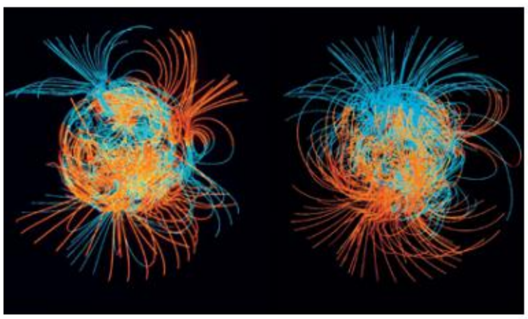


**Figure 4** The Earth's magnetic poles between reversals and during a reversal

## Bankcards and magnets

You use magnetic fields in your own life. The black strip on the back of a bankcard has a series of small, magnetised zones separated by demagnetised zones (Figure 5). You can see these zones if you sprinkle fine iron filings on them. The iron filings arrange themselves according to the magnetic field surrounding the magnetic zones, which look a bit like a bar code. When the card is swiped through a card reader, the magnetic bar code is read and the person's name, bank and account number are decoded.

The information on the black strip on a bankcard can be changed if it is put next to a strong magnet. This includes the magnetic clasps on a purse, or wallet. Some stores also attach magnetic security devices to their stock to protect against theft. They remove these using a demagnetiser near the cash register. Leaving a bankcard on a store demagnetiser will also change the magnetic strips on the card.

**Figure 5** The magnetic strip on a bankcard contains zones of magnetised and demagnetised areas.

## 4.4 Check your learning

### Comprehend

1 **Describe** a magnetic field.
2 **Explain** how you could map the magnetic field around a magnetic nail.
3 **Describe** in words the shape of the magnetic field when two magnets are:
  a attracting b repelling.
4 **Describe** how you could decide which magnet was stronger by looking at the magnetic fields made by different magnets.
5 **Explain** how a compass works.
6 **Explain** why you should never leave a library card on the demagnetising panel of a shop.

### Apply

7 **Create** a drawing of the magnetic field around a broken magnet:
  a that has been re-joined
  b with the two pieces 10 cm apart
  c with the two pieces 1 cm apart.

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 4.5 Electrostatic forces are non-contact forces

**Learning intentions**

By the end of this topic, you will be able to:
- define electrostatic forces and charge
- provide examples of electrostatic forces in real-life situations.

**Key ideas**
- Rubbing two objects together can cause an electrostatic force.
- Like (two positive or two negative) charges repel.
- Unlike charges attract.
- Charged objects attract uncharged objects.

**electrostatic force**
the force between two objects caused by a build-up of negative charges

**Figure 1** When the negatively charged balloon moves away, the positively charged hair is still attracted to it.

## What causes electrostatic force?

Have you ever rubbed a balloon on your hair and seen the hair cling to the balloon? This is a result of a force called an **electrostatic force**. When two objects rub against each other, a small electrical charge builds up. One object becomes positively (+) charged and the other becomes negatively (–) charged. These two charges act like the north and south poles of a magnet. The positively charged objects are pulled, or attracted, to the negatively charged objects. The unlike charges attract each other. Because the objects do not need to touch each other to attract, electrostatic forces are a non-contact force. Rubbing a balloon on hair causes the hair to become positively charged and the balloon to become negatively charged. When the (negatively charged) balloon moves away, the (positively charged) hair is still attracted to it. The hair lifts up and tries to cling to the balloon (Figure 1).

## Van de Graaff generators

A Van de Graaff generator works in the same way as rubbing a balloon on hair. In the long shaft of the machine, two long belts rub against each other, making the rounded dome of the machine positively charged. Negative charges are attracted to the dome. If anything comes close enough to the dome, the negative charges are attracted and jump through the air. You might see this as a spark (Figure 2).

As well as negatively charged objects, uncharged objects (neither positively nor negatively charged) are also attracted to the positively charged dome. If you stand too

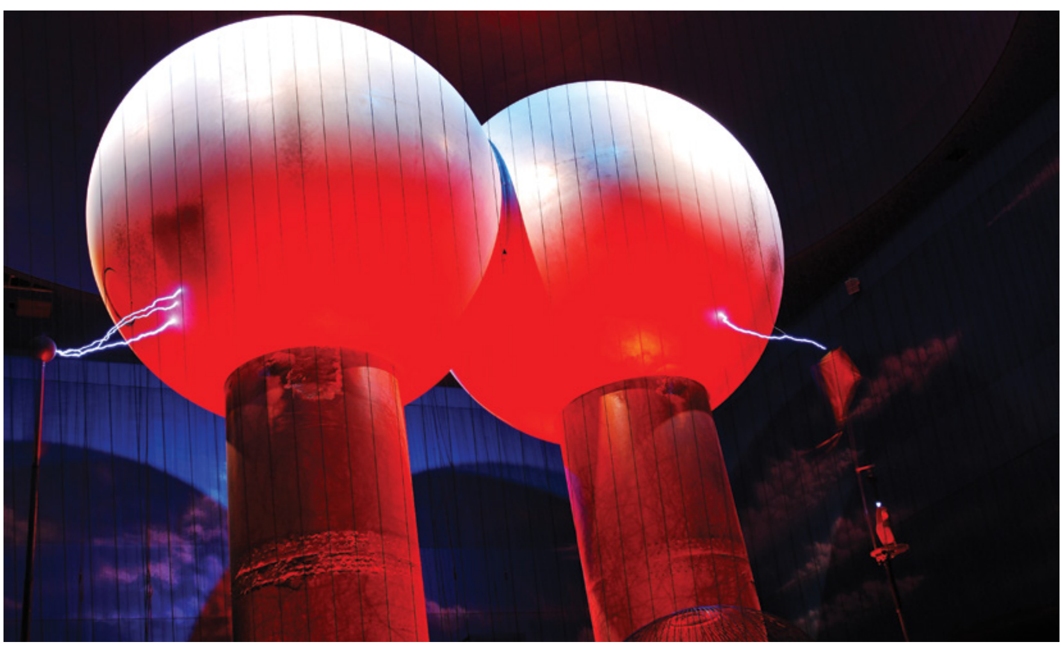


**Figure 2** Sparks jump across to a Van de Graaff generator when negative charges come close enough.

EXPERIMENT

**4.5:** What if a balloon was electrostatically charged? Go to page **221**.

close to the Van de Graaff generator, your uncharged hair might be attracted to the dome.

Anything touching the dome also becomes positively charged. The girl in Figure 3 is standing on a rubber mat so that the negative charges cannot move from the ground into the dome. This means that she becomes positively charged like the dome. Every part of her body becomes positively charged, including all her hair. Just like the forces in a magnet, the like charges in the hair repel each other. This makes the strands of the girl's hair try to push away from one another.

The rules of electrostatic forces are:

> unlike charges attract
> charged objects attract uncharged objects
> like charges repel.

## 4.5 Check your learning

### Retrieve

1 **Recall** if electrostatic charges are contact or non-contact forces.

2 **Recall** the terms that complete these statements.

- **a** Unlike charges ____________.
- **b** ____________ charges repel.
- **c** Charged objects ____________ uncharged objects.

### Comprehend

3 **Describe** how electrostatic forces can be created.

4 **Explain** why the hair of a person touching a Van de Graaff machine may be standing up.

### Apply

5 Isaac was leaving the carpeted library to go home. When he touched the door handle, he received an electric shock. **Discuss** why this happened.

6 When it is about to rain, the water particles in the clouds rub against one another and electrostatic charges form. **Discuss** how this may cause lightning.

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

## Electrostatic forces in everyday life

You may have experienced electrostatic forces when you were jumping on a trampoline. Every time you jump, your feet rub against the trampoline mat. This causes a charge to build up in your body. Sometimes this causes your hair to stand up because the strands are pushing away from each other. When you touch someone else, or the framework of the trampoline, you may feel the spark as the negative charges are attracted.

Electrostatic charge can build up on cars as they drive along the road. It is this charge that can cause explosions when filling up at a petrol station. If the driver gets out of the car without touching the metal of the car, then the car can still have the positive charges built up. It is usually safe to start filling up the car, but if the driver gets in and out of the car when the petrol fumes are in the air, the negative charges can be pulled between the car and the driver. This causes a spark and in rare cases could result in an explosion.

**Figure 3** This girl has become positively charged, like the dome of the Van de Graaff generator that she is touching. The strands of her hair are repelling each other.

# 4.6 Earth's gravity pulls objects to the centre of the Earth

**Learning intentions**

By the end of this topic, you will be able to:

- calculate weight when given the mass of an object and gravitational force
- explain why the weight of an object does not affect the rate that it falls.

**Video 4.6**
Geomagnetism

**weight**
a measure of the gravitational pull on an object

**mass**
the amount of matter in a substance, usually measured in kilograms; the mass of an object never changes, even in space

**Figure 1** The large mass of the Earth can pull objects to its centre.

**Key ideas**

- Earth's gravity can cause a non-contact force.
- Large objects (such as planets, moons and stars) pull objects towards their centre.

## Gravity

One day in 1665, a young student named Isaac Newton was sitting under an apple tree when an apple fell to the ground. 'Why did it fall?' he wondered. There was nothing he could see that could push it or pull it. He realised that there must be a force that pulled the apple towards the Earth. This is how Newton claimed he first had the idea of gravity.

Gravity is the effect of a large object (such as a planet) warping space and time. This results in the large object (Earth) attracting everything nearby to its centre. This means people, animals and apples are pulled to the centre of the Earth. Consider Figure 1. If everyone in the picture dropped an object, those objects would fall towards the centre of the Earth.

Every object that is made of matter (small particles called atoms) is able to pull other things towards it. The Earth is made up of enormous amounts of matter, allowing it to exert a relatively strong non-contact force on objects around it. Even you have weak gravity surrounding you. The Earth has much more matter than you do, and therefore the Earth's pull force is much stronger than yours (Figure 2). The more matter an object has, the stronger its pull force. Stars like our Sun have much more matter than the Earth. This means that the gravitational pull of the Sun is much stronger. It can even keep the planets from travelling off into space.

## The difference between weight and mass

The Moon is made of less matter than the Earth. This means that the Moon's ability to pull objects is much less than the Earth's. An astronaut jumping on the Moon will be able to jump much higher than on Earth. This is because the Moon does not have as strong a pull force as the Earth. **Weight** is a measure of the pull force on an object. Your weight on the Moon would be less than that on Earth. This does not mean you are smaller. It just means the Moon is pulling you down less. Because weight is a measure of pull force, it is measured in newtons.

If weight is a measure of the pull force, then how do scientists describe the amount of matter of an object? **Mass** (measured in kilograms) is the term used to describe how many particles or atoms make up an object. The mass of an object does not change, no matter where in the universe it is. If a brick has a mass of 1 kg on Earth, it has this mass everywhere. However, the weight of

**Figure 2** The Earth pulls base jumpers towards its centre, 6371 km below.

SKILLS LAB
**4.6A:** Calculate weights in the solar system
Go to page **222**.

CHALLENGE
**4.6B:** Modelling gravity in the solar system
Go to page **223**.

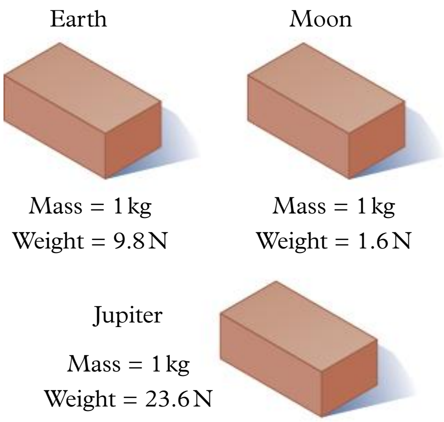



**Figure 3** The mass of a brick does not change, but its weight is affected by gravity.

the brick will change. On Earth, the brick may weigh 9.8 newtons, but on a large planet such as Jupiter it would weigh 23.6 newtons. On the Moon, the brick would weigh approximately 1.6 newtons because the Moon is small and has less pull force (Figure 3).

## Gravity changes

As you move away from the Earth, the pull force slowly decreases. This means that if you stand on a chair your weight will have decreased slightly. Most scales will not be sensitive enough to measure this small change. However, if you stood on the top of Mount Everest, you would be several kilometres further away from the centre of the Earth. As a result, your weight (the amount of pull force the Earth exerts on you) is 0.25 per cent less than if you were at sea level.

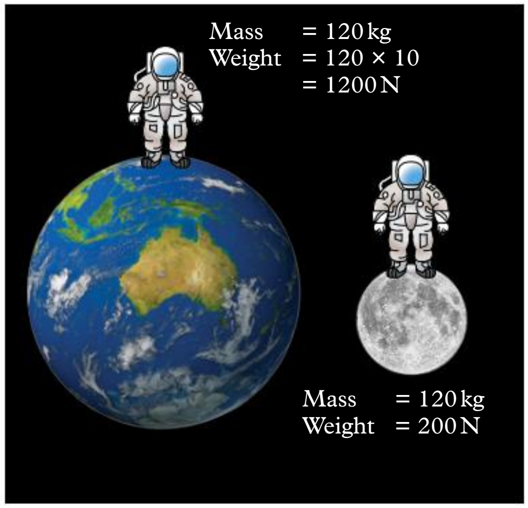



**Figure 4** A person who wants to lose weight could go to the Moon. A person who wants to lose mass could take their shoes off.

Gravity is not the same for every object. Objects with a larger mass experience a greater pull than objects with less mass. This means a 3 kg bowling ball feels a stronger pull force than a basketball that is lighter does. Does this mean that the bowling ball will fall faster than the basketball?

If you do this experiment, you will find that both balls hit the ground at exactly the same time. This is not what most people expect to happen. Logic might suggest that heavier things fall faster. You may need to do the experiment a few times until you believe it. The heavy bowling ball needs more force to start it moving than the basketball. This offsets the larger pull, so both balls fall at the same rate and hit the ground at the same time (Figure 5).

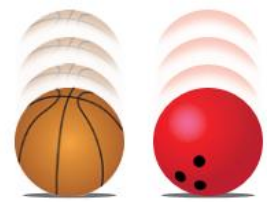


**Figure 5** A bowling ball has more mass than a basketball and therefore takes more force to start it moving. The Earth pulls more on the bowling ball, causing both balls to fall at the same speed.

## 4.6 Check your learning

### Retrieve

1 **Name** the person who first described gravity.

### Comprehend

2 If a half-full water bottle was dropped from the top of a flight of stairs at the same time as a full bottle of water, **explain** which bottle would hit the ground first.

### Analyse

3 **Identify** whether the following statement is true or false.
The pull of the Earth is stronger on an elephant than on a feather.

4 **Contrast** mass and weight.

### Apply

5 An astronaut on the Moon dropped a feather and a hammer at the same time. There is very little atmosphere on the Moon to slow down objects. **Discuss** why the feather and hammer hit the ground at the same time.

6 Building a settlement on the Moon has been suggested several times since Neil Armstrong first walked on the Moon. **Discuss** the advantages and disadvantages of building such a structure in a low-gravity environment.

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 4.7 Friction slows down moving objects

**Learning intentions**

By the end of this topic, you will be able to:

- define and provide examples of friction, lubrication, air resistance, drag and streamlining.

**friction**
a force that acts to oppose the motion between two surfaces as they move over each other

**Key ideas**

- Friction is a contact force.
- Friction (such as air resistance) slows down moving objects.
- Friction can be reduced by streamlining, lubricants or ball bearings.

It is much easier to slide along ice than along a gravel road. This is because the **friction** of the gravel road acts to slow the forward motion. Friction is the force that resists movement between two objects in contact. In other words, friction generally slows down moving objects.

## Friction

When buying sports shoes, many people look for shoes with good grip. This grip prevents the shoe from sliding when they run and helps to avoid sliding when they stop. The grip provides friction between the ground and the wearer (Figure 1). Friction slows everything down that is moving. It acts in the opposite direction to the movement. The greater the friction, the more the movement slows down and eventually stops. Friction happens because objects rub together. When you start walking, you rely on the shoe rubbing against the ground and gripping so that you can push forward. When you try to stop, you rely on the friction between the shoe and the ground to stop your movement. Without friction, your feet would just slip over the ground. It would be like trying to walk on ice.

**Figure 1** Friction between the shoe and the ground stops you from sliding around.

## Evidence of friction

We can see evidence of friction in many parts of our lives. Any time a movement is slowed down, it is because of friction. Without friction, a bike would keep rolling along a road without the need to pedal. A pen or pencil would slide over a page without leaving a mark. Friction is very useful to us, but it can create problems and we often try to reduce it.

## How to decrease friction

Rollers or balls are one way to reduce friction. Because the balls roll across the ground, it is much easier than being dragged along. Tiny balls are often used as bearings to allow two surfaces to slide over one another easily (Figure 2).

**Figure 2** These ball bearings allow the two metal circles to move past each other with very little friction.

Hovercrafts and air pucks have low friction because they use a layer of air to glide over a surface. There is no contact between the surfaces and, as a result, almost no friction. The same idea is used in magnetic levitation (Maglev) trains, where the train carriages are held above the tracks by strong magnetic forces.

EXPERIMENT

**4.7:** What if the amount of friction was changed?
Go to page **224**.

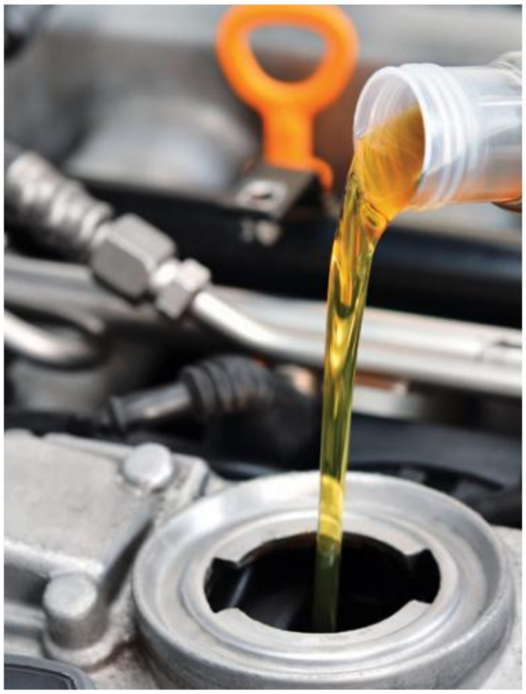


**Figure 3** Oil is added to a car engine to reduce friction between engine parts.

Lubricants, such as oils and grease, also reduce friction (Figure 3). This is called **lubrication**. If a kitchen drawer sticks, you can use candle wax or soap as a lubricant. Lubricants work by coating the surface with an oily or greasy substance, which makes them slippery. Putting oil on bicycle chains and grease on the wheel axles makes the wheels spin more easily, with less friction.

**Air resistance**, or drag, is the friction between a moving object and the air it is moving through. As the object moves, it needs to push the air particles out of the way, limiting the speed of the object. Parachutes use air resistance to slow the movement of the falling people. While this is an advantage if you are sky diving, it can be a problem for cars and trucks. The greater the air resistance, the more fuel the car will use. **Streamlining** (making the surface smooth and rounded) helps to overcome air resistance (Figure 4).

Fish and sharks have streamlined bodies. This allows them to move through the water with the least amount of friction.

**lubrication**
the action of applying a substance such as oil or grease to an engine or component so as to reduce friction

**air resistance**
friction between a moving object and the air it is moving through

**streamlining**
giving an object a form that presents the least resistance to motion

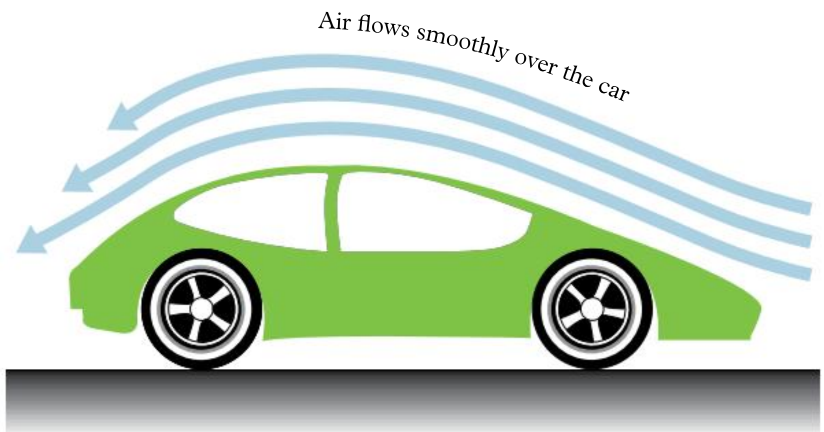



**Figure 4** Streamlining reduces friction.

## 4.7 Check your learning

### Retrieve

1 **Identify** three examples where friction is useful and three examples where friction is a problem.

### Comprehend

2 **Explain** why a penguin is streamlined, but a sea anemone is not.

3 Soft wax can have a high level of friction. **Explain** why surfers wax their surfboards.

4 The tread on the tyres of your bike wears down with a lot of use. **Explain** this in terms of force.

5 A hovercraft moves across water on a cushion of air. **Describe** this in terms of friction.

### Analyse

6 In a world without friction, **identify** what would happen if you tried to:

- **a** go down a slide in a playground
- **b** play tenpin bowling
- **c** tie your shoelaces.

### Apply

7 Use your knowledge of friction and air resistance to complete the hypothesis below.

If the surface area of a parachute is decreased, the parachute will ______ because ______.

8 **Identify** the surface (sand, wood, or metal coated in oil) that would allow you to move fastest with the same pushing force. **Justify** your answer (by describing the friction of each surface and deciding which surface will allow for the fastest movement).

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 4.8 Simple machines decrease the amount of effort needed to do work

**Learning intentions**

By the end of this topic, you will be able to:

- compare and contrast distance magnifiers and force magnifiers
- provide examples of first-, second- and third-class levers
- calculate mechanical advantage and effort.

Interactive 4.8A
Simple machines

Interactive 4.8B
Types of levers

**lever**
a simple machine that reduces the effort needed to do work

**fulcrum**
the turning point of a lever

**effort**
the force used to operate a lever

**load**
(in physics) resisting force

**Key ideas**

- A lever is a solid rod with a turning point.
- Levers provide a mechanical advantage of force or distance.
- All levers need an effort (force used), fulcrum (turning point) and a load (the section being moved).
- Levers can be divided into first-class, second-class or third-class levers.

The ancient Egyptians, Romans and Greeks understood forces very well. They made simple machines that helped them to build the pyramids, fight wars and build cities (Figure 1). The simplest machine they used was a lever. A lever can be used to decrease the amount of effort needed to do work. You use levers every day. Scissors, pliers, brooms, shovels, wheelbarrows and can openers are all levers.

**Figure 1** Ancient Egyptians used round logs and rope to haul large blocks of stone when they built the pyramids.

## Levers

A **lever** is a solid rod or bar that is supported at a turning point called a **fulcrum**. Figure 2 shows the main features of a simple lever – a see-saw. The force used to operate a lever is called the **effort**, and the resisting force it overcomes is called the **load**.

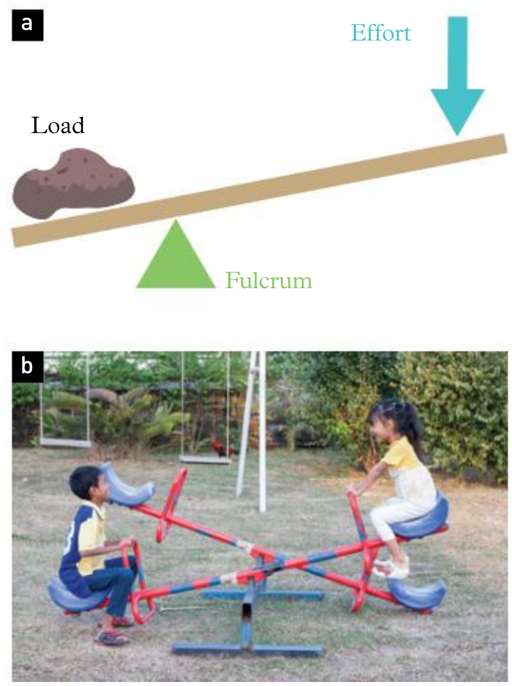



**Figure 2** **a** A lever has three features: the fulcrum, effort and load. **b** A see-saw is an example of a lever.

EXPERIMENT

**4.8A:** Using a first-class lever to lift weights
Go to page **225**.

EXPERIMENT

**4.8B:** Using a second-class lever to lift weights
Go to page **226**.

When one person on a see-saw is pulled down by the Earth, the other person is pushed up. The weight of the two people does not need to be equal for this see-saw lever to work. One person can lift a heavier weight by moving further away from the fulcrum in the middle. In fact, a single person 2 m away from the fulcrum can lift two people who are 1 m on the other side of the fulcrum.

## Mechanical advantage

The lever gives you a mechanical advantage. The size of the advantage can be calculated by dividing the size of the load by the size of the effort:

$$\text{Mechanical advantage} = \frac{\text{size of the load}}{\text{size of the effort}}$$

The magnification of the force comes with a disadvantage. For this type of lever, the distance the effort must move is greater than that moved by the load. Worked example 4.8A shows how to calculate mechanical advantage. Worked example 4.8B shows how to calculate effort.

These levers are called **force magnifiers**. They can change a weak force into a stronger force. A crowbar can be used to lift a heavy rock even though the rock is heavier than the effort used. There is a disadvantage to force magnifiers. The effort section of the lever must move a greater distance to move the rock a short distance.

Other levers are **distance magnifiers**. They magnify the distance the effort moves. This means that when the effort moves a short distance, the load will move a long distance. The disadvantage is that the effort force required will need to be larger than the load. An example of this is a tennis racquet. The end of the tennis racquet moves a greater distance (and faster) than the hand holding the racquet.

**Figure 3** A crowbar is a force magnifier.

### Worked example 4.8A: Calculating mechanical advantage

Calculate the mechanical advantage of a lever that allows an effort of 4 newtons to lift a load of 12 newtons.

#### Solution

Effort = 4 N, load = 12 N

$$\text{Mechanical advantage} = \frac{\text{size of the load}}{\text{size of the effort}} = \frac{12}{4} = 3$$

The mechanical advantage is 3.

### Worked example 4.8B: Calculating effort

Calculate the effort required to lift a box of books (6 newtons) with a lever with a mechanical advantage 2.

#### Solution

Load = box of books = 6 N, mechanical advantage = 2

$$\text{Mechanical advantage} = \frac{\text{size of the load}}{\text{size of the effort}}$$

$$2 = \frac{6\text{ N}}{\text{effort}}$$

$$\text{Effort} = \frac{6\text{ N}}{2} = 3\text{ N}$$

The effort needed is 3 newtons.

**Figure 4** The trebuchet was a powerful machine used to fling objects such as rocks against enemy defences.

**force magnifier**
a device that can increase the amount of force available (for example, to shift something); an example is a lever

**distance magnifier**
a lever that changes a strong force that acts over a short distance into a weak force that acts over a longer distance

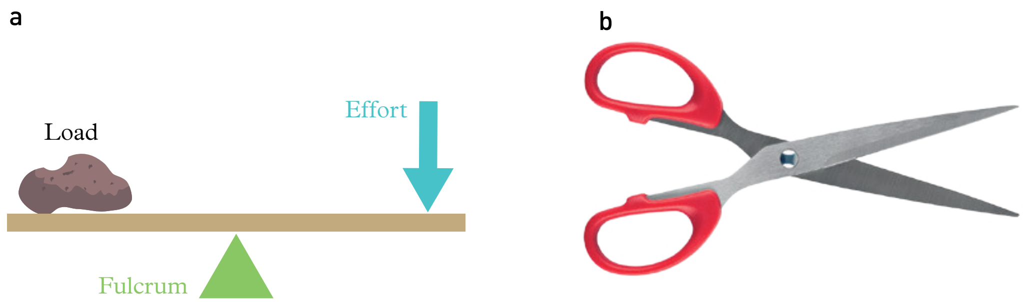



**Figure 5** **a** In a first-class lever, the fulcrum is between the load and the effort. **b** Scissors are an example of a first-class lever.

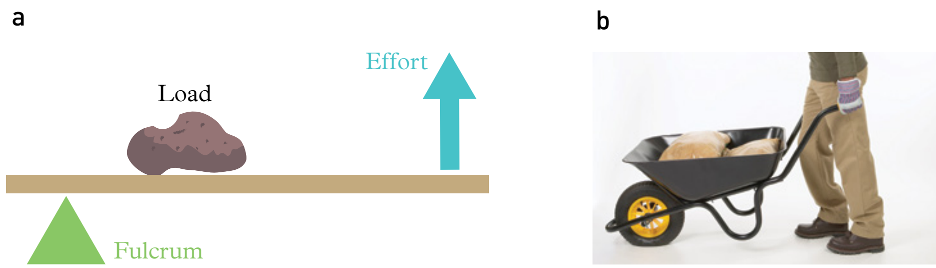



**Figure 6** **a** In a second-class lever, the load is between the effort and the fulcrum. **b** A wheelbarrow is an example of a second-class lever.

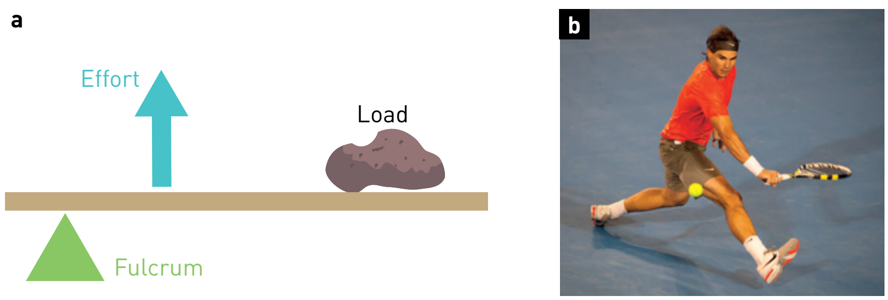



**Figure 7** **a** In a third-class lever, the effort is between the load and the fulcrum. **b** A tennis racquet is an example of a third-class lever. When a person uses a tennis racquet to hit a ball, the muscles exerting the effort are between the shoulder fulcrum and the ball load.

## Types of levers

There are three types of levers and they are classified according to the position of the fulcrum (turning point):

> **First-class lever**: the fulcrum is between the effort and the load (EFL) (Figure 5).
> **Second-class lever**: the load is between the effort and the fulcrum (ELF) (Figure 6).
> **Third-class lever**: the effort is between the load and the fulcrum (LEF) (Figure 7).

Use FLEE to remember the middle position for each type of lever.

**F** (Fulcrum) – first-class lever
**L** (Load) – second-class lever
**E** (Effort) – third-class lever
**E** (Easy to remember!)

**first-class lever**
a lever that has its fulcrum between the point of effort and the load

**second-class lever**
a lever that has its load between the point of effort and the fulcrum

**third-class lever**
a lever that has its point of effort between the fulcrum and the load

## First Nations levers

Many First Nations peoples understand the advantage of levers in hunting. The word 'woomera' comes from the Dharag language and refers to a spear thrower that can launch a spear further and with more force and with more acceleration. A spear is fitted into the 50–100 cm long lever and held in place with a short peg that connects to the end. The person throwing the spear could then hold the woomera and swing it over their head, similar to a catapult action. This makes the lever arm longer, moving the spear faster, increasing the speed that the spear left the thrower and making the spear more accurate.

The type of lever depends on the position of the fulcrum. If the wrist is used to flick the spear, then this becomes the fulcrum. If the arm and wrist remain straight, and the motion is like a bowler (in cricket), the fulcrum is located between the thrower's shoulder blades.

Once the spear has left the spear thrower, the unbalanced forces of air resistance cause the spear to slow down and the force from the Earth's gravity causes the spear to fall.

Different First Nations groups developed different styles and shapes of spear throwers. Longer spear throwers are able to increase the speed more than shorter spear throwers. This increase in speed means that the spears used need to be lighter.

**Figure 8** A woomera is a lever.

## 4.8 Check your learning

### Retrieve

1 **Define** the term 'lever'.

### Comprehend

2 **Describe** how you would identify a first-class lever.

### Analyse

3 **Compare** (the similarities and differences between) a second-class lever and a third-class lever.

4 Examine Figure 9.

a **Identify** the type of lever that is shown.

b **Calculate** whether a mass of less than 200 kg would lift the load.

c **Describe** how you would reposition the fulcrum so that a mass much less than 200 kg could lift the load.


**Figure 9** A lever

### Apply

5 A crowbar can be used to move a load (Figure 10).

a **Identify** the class of lever used.

b **Identify** whether this class of lever is a force magnifier or a distance magnifier. **Justify** your answer.

**Figure 10** A crowbar moving a load

6 Modern cranes use leverage to lift heavy objects (Figure 11).

a **Identify** where the load for this lever is located.

b **Identify** where the effort is located.

c **Identify** where the fulcrum is located.

d **Identify** the class of lever being used.

e **Identify** whether this class of lever is a force magnifier or a distance magnifier. **Justify** your answer.


**Figure 11** A modern crane

**Quiz me**

Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 4.9 A pulley changes the size or direction of a force

**Learning intentions**

By the end of this topic, you will be able to:

- explain how a pulley makes it easier to lift a load
- calculate effort in a pulley system.

**Key ideas**

- A pulley is a simple machine that makes it easier to lift an object.
- Pulleys are wheels with a groove along their edge.
- The wheel is used to change the size or direction of the force used.

**Figure 1** Sailing ships have pulley systems for lifting heavy sails and cargo.

## History of the pulley

Between the fifteenth and seventeenth centuries, a period known as the Age of Discovery, the people of Europe were desperate for spices, gold and silver. Sailors navigated the seas looking for these treasures. They returned with large amounts of bounty that included food, weapons and slaves. All this cargo needed to be loaded on and off the ships as quickly as possible. To help the sailors do this work, they used a simple machine invented by Archimedes many centuries before.

## Types of pulley

The simplest pulley system is made of one pulley. This system only changes the direction of the applied force, not the size of the force. As a person pulls *down* on the rope, the weight on the other end moves *up* (Figure 2). This does not change the amount of effort needed, but it makes lifting easier. This is because the person can use their weight to help in the lifting. You have probably used this type of pulley when you pull the cord to open a window blind at home (Figure 3). The mechanical advantage is calculated by the number of ropes between the upper and lower pulleys; in the roller blind system, it is one.

**Figure 3** The simplest pulley system is made of one pulley.

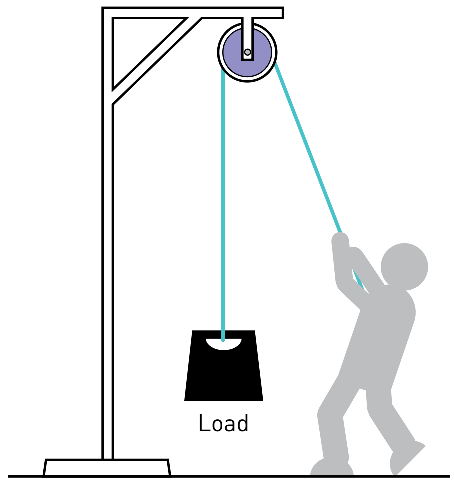



**Figure 2** A single-pulley system – rope is guided through the groove of a rotating wheel.

The more pulleys that are used, the easier it is to lift a load because its mechanical advantage is increased. For example, if two pulleys are used, the system can lift twice the load of a single-pulley system. The mechanical advantage of this system is 2 (Figure 4).

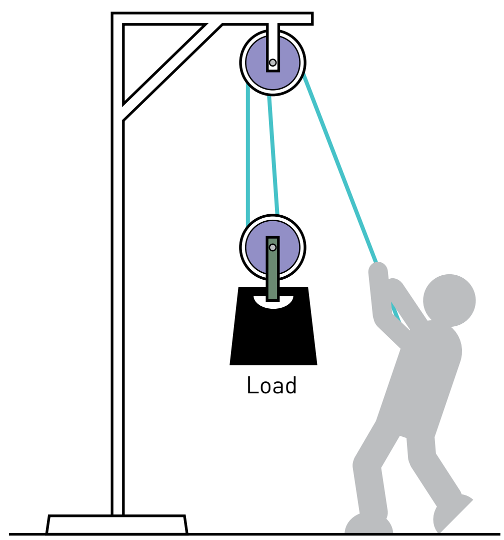



**Figure 4** A two-pulley system doubles the mechanical advantage.

EXPERIMENT

**4.9:** Calculating mechanical advantage
Go to page **227**.

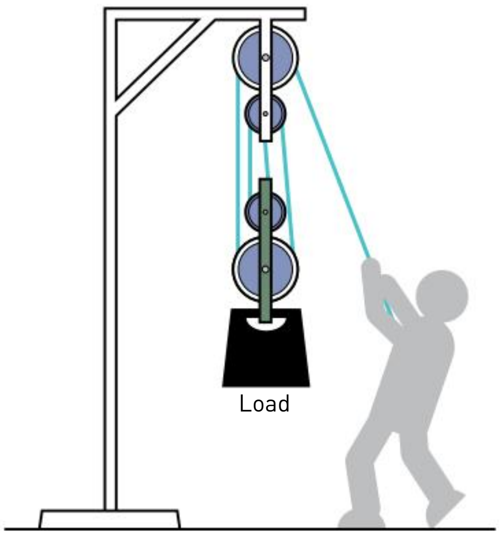



**Figure 5** A four-pulley system increases the mechanical advantage by a factor of four.

A four-pulley system can magnify the effect of the effort four times. For example, a 25 kg effort can lift a 100 kg load in a frictionless pulley system. The simple system shown in Figure 5 not only changes the direction of the applied force, but it also multiplies it by four. This system has a mechanical advantage of 4. Worked example 4.9 shows how to calculate effort in a pulley system.

Groups of pulleys are often mounted together in a frame or 'block'. This device is called a **block and tackle**. A small effort pulling through a long distance lifts a large load through a much smaller distance.

### Worked example 4.9: Calculating effort

Calculate the effort needed to lift a load of 150 newtons with a frictionless block and tackle with five pulleys.

#### Solution

Mechanical advantage = 5 (5 pulleys)

Load = 150 newtons

$$\text{Mechanical advantage} = \frac{\text{size of the load}}{\text{size of the effort}}$$

$$5 = \frac{150\,\text{N}}{\text{effort}}$$

$$\text{Effort} = \frac{150\,\text{N}}{5} = 30\,\text{N}$$

The effort needed is 30 newtons.

**Figure 6** A block and tackle

**block and tackle**
a group of pulleys mounted together in a frame or block, which provides significant mechanical advantage

## 4.9 Check your learning

### Comprehend

1 **Explain** why two pulleys are better than one.

2 **Describe** three examples where single pulleys or pulley systems are used.

3 **Describe** how pulleys have made loading and sailing huge cargo vessels possible.

### Analyse

4 A block and tackle provides a mechanical advantage because it can lift heavy loads. **Infer** the disadvantages of this system.

5 **Identify** the correct option. A pulley system can:
 a increase force and distance at the same time
 b decrease distance while increasing force
 c decrease force and distance at the same time.

6 A 100 kg mass is used to lift an 800 kg mass.
 a **Calculate** how many pulleys are needed to make this possible.
 b **Calculate** the mechanical advantage of this machine.

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 4.10 There are different types of machines

**Learning intentions**

By the end of this topic, you will be able to:

- define and provide examples of ramps, wedges, screws and wheels.

**Key ideas**

- Inclined planes such as ramps can provide a mechanical advantage.
- A wedge or screw can reduce the effort needed to split or enter an object.
- A wheel and axle is a special lever that turns about a fulcrum.

Many different machines have been developed through the centuries that make less work for us. Ancient Greek mathematician Archimedes (c. 287–212 BCE) developed a screw that carried water to the top of a house. The screw was just a hollow pipe with an inclined plane (a simple machine) wound around the inside.

As well as pulleys and levers, other simple machines are ramps, wedges, screws and wheels and axles.

**ramp**
a sloping surface joining two different levels

**wedge**
a piece of wood, metal or other substance that tapers to a thin edge and is driven between two objects or parts of an object to secure or separate them

**screw**
a sharp-pointed metal object with a spiral thread running along its length and a slotted head

**thread**
the spiral ridge of a screw

**Figure 1** An escalator is an example of a ramp.

## Ramps

Ramps are the simplest types of inclined planes. A **ramp** is used to lift heavy objects (the load) up to a higher level. For example, a piano mover might use a ramp to get a piano from the ground onto a truck. Ramps are used to bridge gaps between uneven surfaces. Escalators are moving ramps with steps (Figure 1). A ramp is called a simple machine because it makes moving a load easier. Going up the ramp might take longer than a single step up, but it requires a lot less force from your legs.

## Wedges

A **wedge** is an inclined plane that moves through another object and changes the direction of a downward force to a sideways force. An axe is a wedge. When an axe hits a log, the downward force is changed to a sideways force, which splits the log (Figure 2).

Humans discovered the benefits of wedges when they used the jagged edges of rocks to cut animal flesh and skin. It is more than likely that you have used a wedge today: a knife is a wedge and so are your teeth. Each tooth in a zipper is a tiny wedge that fits tightly with the adjacent teeth.

**Figure 2** An axe is an example of a wedge.

**Figure 3** Corkscrews are used to pull the cork out of a bottle.

## Screws

You might be surprised to know that a **screw**, like the wedge and the ramp, is also an inclined plane. The indent that spirals around a screw, called the **thread**, looks almost like a road (a ramp) spiralling up the side of a mountain. Screws penetrate materials such as wood or cork by using the turning effect of a force (Figure 3). The effort needed to turn a screw into an object is much less than that required to hammer the screw into the same object.

EXPERIMENT

**4.10:** Comparing different machines
Go to page **228**.

## Wheels and axles

If you have used a circular door handle or travelled in a car, bus or train today, you have used a wheel-and-axle simple machine. A wheel is a type of lever that turns in circles about its centre – the fulcrum or pivot point. An axle usually links the lever and the wheel.
For example, when you turn a doorknob, you apply an effort force to the door handle and the axle exerts a force on the load (the latch), which opens the door.

**Figure 4** A Ferris wheel is an example of a wheel and axle.

A **wheel and axle** is sometimes a force magnifier. For example, you apply a small effort to a doorknob to move a larger load, the latch. This is because the outside edge of the wheel, or doorknob, moves a larger distance than the axle, or latch. A Ferris wheel is an example of a wheel and axle (Figure 4).

Wheel-and-axle machines can also act as distance magnifiers. When you pedal a bike, you apply a force to the pedals (Figure 5). This force causes the larger wheels to turn. The distance the wheel travels is much further than the distance the pedal travels. The distance has been magnified.

**Figure 5** A bike wheel is an example of a distance magnifier.

**wheel and axle**
a type of lever that can rotate about its centre, magnifying force or distance

## 4.10 Check your learning

### Retrieve

1 **Name** the six types of simple machines.

2 **Identify** a circular doorknob as either a force magnifier or a distance magnifier.

### Analyse

3 **Identify** which of the following is not an inclined plane.
  a knife used to cut bread
  b screwdriver used to turn a screw
  c nail driven into a piece of wood
  d spear thrust into a tree

4 **Identify** the part of a circular doorknob that is a wheel and the part that is an axle. Draw a labelled diagram to support your answer.

5 **Compare** (the similarities and differences between) a wedge and a ramp.

### Apply

6 **Discuss** how the can opener shown in Figure 6 is acting as a wheel and axle by identifying the effort, load, fulcrum, wheel and axle.

**Figure 6** A can opener is a lever.

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

//SCIENCE AS A HUMAN ENDEAVOUR//

# 4.11 The forces in flight

**Learning intentions**

By the end of this topic, you will be able to:

- identify and describe the four main forces in flying: lift, thrust, drag and weight
- use an infographic to communicate with an audience.

Have you even seen or flown in an airplane? When you consider that it is a large metal tube weighing several tonnes, moving through the air, you realise that there must be some amazing forces involved. You can apply the forces you have learnt about in this chapter, to understand how the wings of a plane keeps the plane and people in the air.

There are four main forces involved in flying: lift, thrust, drag and weight (Figure 1). The thrust is the force produced by the engines of the plane. They may be a propeller, a jet engine or a rocket. All of these engines pull in air and push it out the other end. This propels the plane forward.

The drag is the force caused by the friction of air moving out of the way of the plane. It acts in the opposite direction of the thrust force and tends to slow the plane down.

The weight is the force caused by gravity pulling the plane to the centre of the earth. The greater the mass of the plane, the greater the force caused by gravity.

Lift is the force that holds the wings of the plane in the air. The lift force is generated when the plane moves forward and the air moves over the wings. The shape of the wings encourages the air to move up. This decreases the pressure of the air above the wing and reduces the forces pushing down. This makes it easier for the wing to move upwards. The air under the wing pushes up against the surface of the wing generating a lift force (Figure 2).

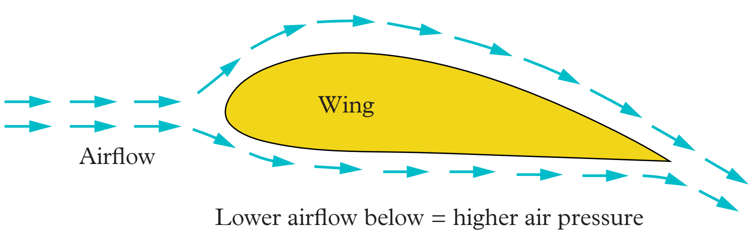



**Figure 2** The shape of the wing generates high pressure under the wing and low pressure above the wing.

When the lift and weight forces are balanced, the plane is able to stay in the air. When the forward thrust from the engine decreases, the air flow will slow down and reduce the lift on the wings. The weight of the plane does not change so there will be unbalanced forces between the larger weight force and the smaller lift force. This means the plane will start moving down towards the Earth.

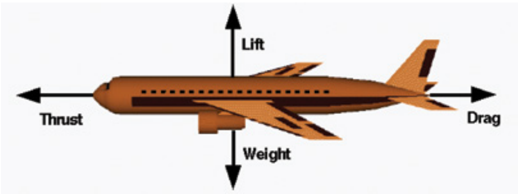



**Figure 1** The four forces involve in flying a plane are thrust, drag, weight and lift.

## Boomerang flight

One of the unique tools of First Nations peoples is the boomerang. Its unique way of flying was researched by David Unaipon, a Ngarrindjeri man from Coorong region in South Australia. You may recognise him from the Australian $50 note. As well as being the inventor of the modern method for shearing sheep, he was the first person to describe the forces involved in the movement of a boomerang and in 1914 he developed the idea of a 'vertical lift flying machine' based on his understanding of boomerang flight.

Its shape is similar to two plane wings joined together at an angle (Figure 3). The top surface of the boomerang generates low pressure, while the bottom surface of the boomerang generates high pressure. These combine to generate lift that keeps the boomerang in the air.

EXPERIMENT
**4.11:** Comparing the forces in flight
Go to page **230**.

When the return boomerang is thrown correctly, it will fly vertically. As it rotates, one end of the wing-shaped boomerang will be moving forward, while the other wing-shaped end will be rotating backwards. This means there are different air pressures generating lift and causing the the boomerang to gradually turn and fly back to its original position. The boomerang flies vertical or upright with this balance of changing air pressures.

Understanding how and why a boomerang flies meant that First Nations peoples have been able to develop many types of boomerangs that fulfill different functions. Not all boomerangs are designed to return. Some were designed for hunting animals, while others were designed to generate noise to scare birds into flying into the air where they could be caught with a net or spear.

**Figure 3** A boomerang has a unique shape similar to the wings of an airplane.

## 4.11 Test your skills and capabilities

### Using infographics

Presenting data to an audience can take many forms. An increasingly common way to present important information is an infographic. Infographics are visual ways to present data so that the viewer can easily see the patterns. This can be through the use of graphs, pictures and important figures.

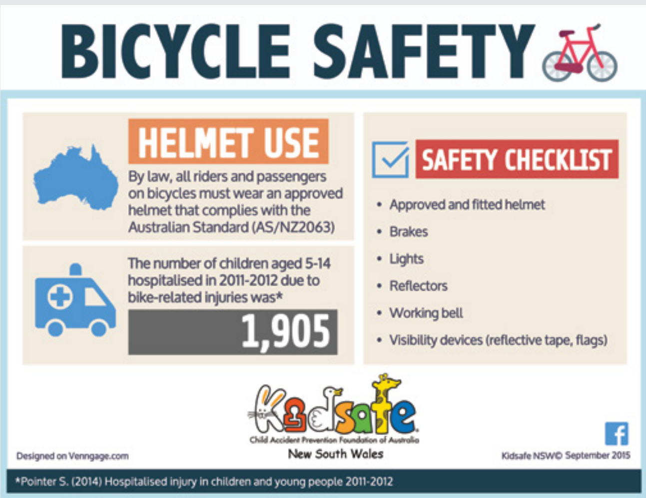



**Figure 4** Bicycle safety infographic

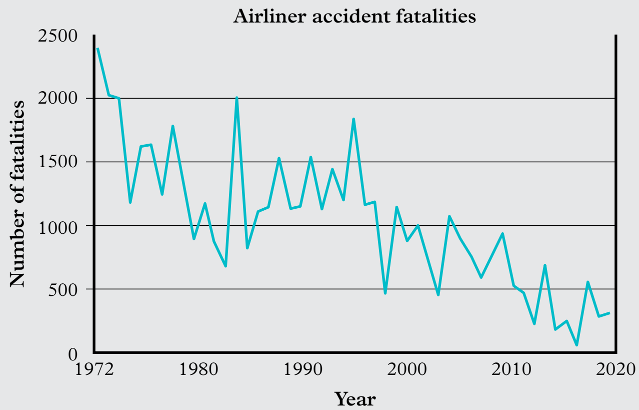
Select two of the sets of data in Figure 5 and Table 1 and develop an infographic that convinces your peers that flying in airplanes has become safer in the last 50 years.

1 **Identify** the key information in the set of data. For example, how many airplane crashes were there in 1972? How many crashes were there in 2020? When is the most dangerous part of the flight? Can you explain why?

2 **Propose** one possible reason why fewer accidents occur now.

3 Draw a picture that represents an airplane accident. Draw three different variations of the picture to represent more or fewer accidents.

4 Infographics use short phrases or sentences to pass on the key information. **Decide** the important information that you want people to remember and write it in a short phrase or sentence.




*Fatal accidents/incidents involving aircraft certified to carry 14 passengers or more.

**Figure 5** Airliner accident fatalities by year from 1972–2020

Source: Aviation Safety Network

**Table 1** Fatal accidents and onboard fatalities by phase of flight (2008–2017)

| Phase of flight | Fatal accidents | Onboard fatalities |
|---|---|---|
| Parked (taxi), load/unload | 5 | 0 |
| takeoff | 4 | 160 |
| Initial climb | 4 | 18 |
| Climb (flaps up) | 3 | 92 |
| Cruise | 6 | 515 |
| Descent | 2 | 74 |
| Initial approach | 4 | 399 |
| Final approach | 15 | 730 |
| Landing | 12 | 273 |

//SCIENCE AS A HUMAN ENDEAVOUR//

# 4.12 Forces are involved in sport

**Learning intentions**

By the end of this topic, you will be able to:

- explain how understanding of forces has improved sporting abilities and technologies.

Many athletes dream of winning Olympic gold medals. They train for long periods, control what they eat and make sure they have the best equipment available. Having a good understanding of the forces involved in their sport can give athletes an advantage over their competitors.

## Forces in swimming

Swimmers must have a good understanding of how the water moves around them to maximise their speed. First, they must control how they dive into the water. Breaking the water's surface creates friction and can slow them down. So they must make sure that their whole body enters the water at the place where their hands originally broke the surface.

Many swimmers shave all their body hair before a big competition. A smooth surface allows the water to move along their body with less friction.

The swimmer's position in the water is important. If the body is straight, the water moves along without interruption. If the legs hang down, the moving water must change direction. This creates more friction and slows the swimmer down.

In 2012 Fédération Internationale de Natation (FINA), the international governing body of swimming, banned the use of full-body smart suits (Figure 1). These suits were designed by scientists to reduce the friction between the swimmer and the water. The suits were made of a material that mimicked the small scales on a shark. This material repelled the water rather than absorbing it, making it lighter for the swimmer to wear. It also reduced the friction between the swimmer and the water. The suits were also designed to be very tight with smooth seams. This helped the swimmer to be more streamlined in the water.

Many world records were broken when this smart suit was first used, but FINA decided that it gave an unfair advantage to the countries that could afford this expensive technology. New rules were made that limited the type of swimming costumes that could be worn in high-level swimming competitions.

**Figure 1** Smart suits provide an advantage to the swimmer by reducing friction. They have been banned at major swimming competitions.

# Forces in tennis

The human arm acts as a third-class lever for which the shoulder is the fulcrum, the muscle attached to the middle of the upper arm provides the effort and the load is usually near the hand. A tennis racquet acts as an extension of the player's arm. This increases the distance between the load (where the tennis ball hits) and the fulcrum (Figure 2). Third-class levers are speed multipliers as well as distance multipliers. When a player hits the tennis ball with a racquet, the speed of the ball is increased. If the tennis player's arm is bent, the end of the racquet is travelling more slowly, and therefore the ball will rebound more slowly.

Tennis players will often have longer tennis racquets, not to increase their ability to reach for the ball, but to increase the speed at which they can hit the ball.

**Figure 2** Tennis racquets increase the distance between the load and the fulcrum.

# Forces in golf

The benefit of a dimpled surface on a golf ball is now widely known. However, golf balls originally had smooth surfaces. When golfers noticed that their old and battered golf balls flew further than the newer, smoother balls, a group of scientists investigated why this occurred.

The dents and bumps in an old golf ball cause the layer of air next to the ball to stay close to the ball, moving in an organised way over the surface (Figure 3). This decreases the overall air resistance of the ball moving through the air, making it fly further. As a result, a golf manufacturer started making the 'pre-dented' golf balls that you see today.

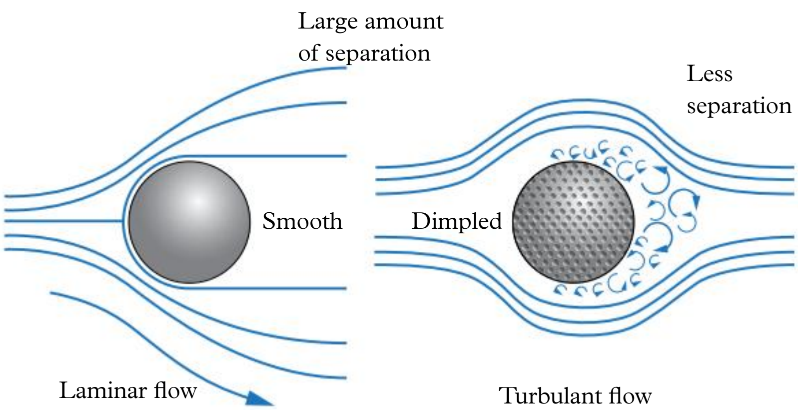



**Figure 3** Air flows over a smooth ball differently from how it flows over a dented ball so that air resistance is decreased over the dented ball and it flies further.

## 4.12 Test your skills and capabilities

### Ethics in sport

You may have heard the saying 'Winning isn't everything'. This is an example of the ethics in sport, otherwise known as 'fair play'. The main goal in an ethical sports competition is fairness, responsibility and respect:

> Fairness: All participants follow the same rules, and no one is discriminated against on the basis of race, gender or financial capability.
> Responsibility: All participants take responsibility for knowing the rules and regulations, and the way they behave (including their performance and emotions).
> Respect: All participants show respect for other participants.

Choose one of the examples of sports technology and **discuss** how an inappropriate use of technology could affect the 'fair play' of the sport.

1 **Describe** the ethical problem.
2 **Identify** the facts for the use of the technology.
3 **Identify** the facts against the use of the technology.
4 **Describe** who would be affected if the technology was used.
5 **Identify** your own bias (an opinion you might already have due to your past experiences).
6 **Identify** if using the technology could lead to other changes in the future that would be unethical.
7 **Describe** all the possible decisions that you could make.
8 Make a decision and **describe** why you made your decision.

# CHAPTER 4 REVIEW

## FORCES

### Retrieve

1 **Identify** which of the following is an example of a pull force.
 A kicking a soccer ball
 B diving into a swimming pool
 C dragging a box towards you
 D pushing a shopping trolley

2 **Identify** the scenario that demonstrates balanced forces.
 A a ball flying through the air after it was thrown
 B a book sitting on a table, not moving
 C a piece of modelling clay being moulded into a different shape
 D a car slowing down for a stop sign

3 **Recall** what will happen if the north poles of two magnets are pushed together.
 A They will repel.
 B They will attract.
 C They will remain where they are.
 D They will move sideways.

4 **Recall** why a person jumping on a trampoline may have their hair standing out from their head.

### Comprehend

5 Think back to the start of your day. **Describe** the forces that you experienced from the time you got up to the time you arrived at school.

6 Copy and complete the following sentences.
 a A force is a ________ or a ________ between ________ objects.
 b To measure a force, you can use a ________ ________.
 c The unit used to measure forces is called a ________. Its symbol is ________. The weight force of 50 g is about ________ newtons.
 d When an object is not moving, its forces are said to be ________. Evidence of an unbalanced force is a change in ________, ________ or ________.

7 **Identify** which of the following examples involve forces. **Explain** the forces involved.
 a opening a window
 b turning a screw with a screwdriver
 c smelling food cooking
 d modelling clay
 e standing on a diving board
 f watching a candle burn

8 **Explain** how mechanical advantage is calculated.

9 Your mass at a given time remains the same, regardless of gravity. Your weight, however, changes as a result of gravity.
 a **Explain** why the mass of any object is not changed by gravity.
 b **Explain** why the weight of an object sometimes changes.

10 **Describe** what happens to the magnetic properties of a magnet when it is broken into two.

11 **Explain** the following in terms of friction.
 a Gymnasts put chalk on their hands.
 b People driving cars on ice or snow put chains on their tyres.
 c A car uses more petrol when it has a load on the roof.
 d It is hard for a person to run on ice.

12 **Explain** what a first-class lever is and provide an example of one.

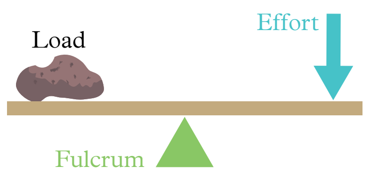



**Figure 1** A first-class lever

13 **Explain** what a second-class lever is and provide an example of one.

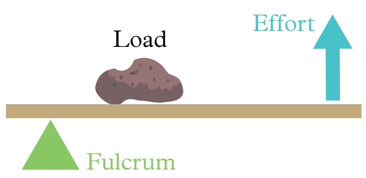



**Figure 2** A second-class lever

14 **Explain** what a third-class lever is and provide an example of one.

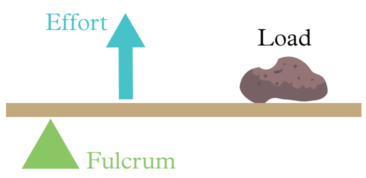



**Figure 3** A third-class lever

15 **Describe** the four main forces involved in flying.

16 When skydivers step out of an airplane, they begin to fall towards the Earth. **Describe** the forces acting on the skydivers.

## Analyse

17 Consider the pulley system in Figure 4. **Calculate** how far the 100 kg load will rise if 2 m of rope is pulled through the pulleys.

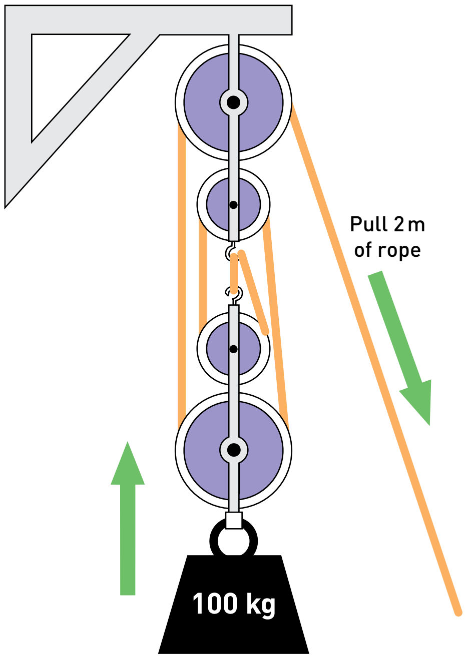



**Figure 4** A pulley system

18 **Compare** a contact force and a non-contact force.

19 **Compare** a lever and a pulley.

## Apply

20 Figure 5 shows what happens when you stand on your toes.
 a **Identify** the type of lever that is formed by the foot when you do this.
 b **Discuss** why this lever is a force magnifier.

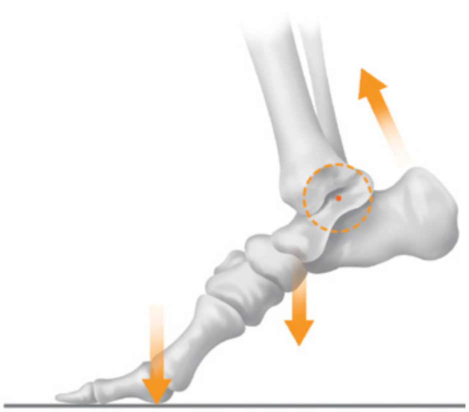


**Figure 5** Standing on your toes

21 **Investigate** the kicking action of a soccer player.
 a Draw a picture of a leg kicking a ball. On your diagram, **identify** which of the muscles are involved in moving the foot.
 b **Identify** the class of lever that is formed by the muscle and bone attachments.
 c **Identify** the lever as a force magnifier or a distance magnifier.

22 Think about how far a toy car and a marble would roll along a flat bench. **Determine** which has the least friction and which rolls the furthest. **Discuss** how friction can be minimised.

23 **Investigate** the action of an Olympic shot-putter.
 a **Explain** why the athlete bends backward just before releasing the shot.
 b **Identify** the class of lever that is formed by the upper torso.
 c **Identify** as many levers acting as possible. Label each lever as first, second or third class.

24 **Discuss** how the motion of an airplane will change (rise, fall, slow or accelerate) when:
 a lift becomes greater than weight
 b drag becomes greater than thrust
 c weight becomes greater than lift
 d thrust becomes greater than drag.

## Social and ethical thinking

25 Understanding the forces involved in a flying airplane means that we can modify the design of the airplane to make it more efficient.
 a **Describe** how streamlining will affect the amount of fuel used to generate thrust force.
 b Use the information in question a to **infer** how the environment could benefit from understanding the forces involved in flight.
 c **Describe** how using less fuel could affect the cost (the economics) of people flying in an airplane.
 d Use the information in question c to **discuss** how using less fuel could affect people's ability to maintain contact with their friends and family (social factors).

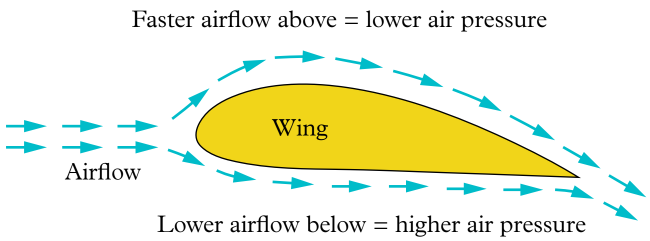



**Figure 6** Streamlining makes airplanes more efficient.

## Critical and creative thinking

**26** Suppose Matilda fills her car with petrol and drives 100 km along a freeway. She then turns off the freeway and travels 100 km along country roads.

- **a** **Determine** which part of the trip would use more petrol.
- **b** **Justify** your answer using your knowledge of forces and friction.

**27** **Design** an infographic poster that encourages people to wear their seatbelt when in a car. Use your knowledge of forces to illustrate the dangers of not wearing a seatbelt when in an accident.

## Research

**28** Choose one of the following topics on which to conduct further research. Present your findings in a format that best fits the information you have found and the understandings you have formed.

### » Musical instruments

Musical instruments often use simple machines to make it easier for the musician to play. Different types of machines are used in a piano, drum kits, the keys of a string instrument and brass instruments. Select one of these instruments and consider the following questions.

- » Describe the machine you have identified.
- » Describe how the musician uses the machine.
- » Describe how the machine makes it easier for the musician playing the instrument.

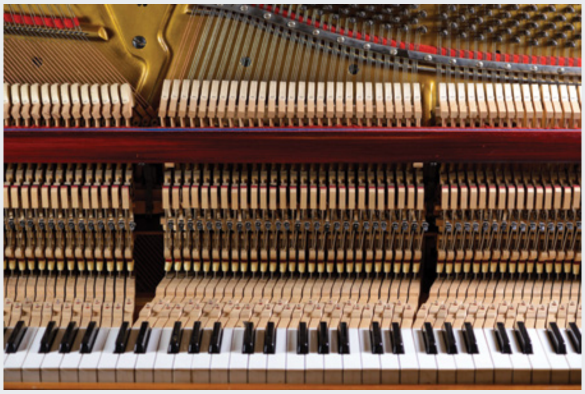


**Figure 7** Levers are part of piano keys.

### » Careers with space

Astronauts are people who work outside the Earth's atmosphere. Not all astronauts are pilots. Some are flight specialists, flight engineers, botanists, computer specialists or payload specialists.

- » Research one of the careers involved in space programs around the world.
- » Describe the types of qualifications you need to work in this area.
- » Describe the types of things you would do in an average day.
- » Describe the most challenging part of your job.

**Figure 8** Becoming an astronaut is only one career available in the space industry.

### » Seatbelts

The wearing of seatbelts in cars was made law in Australia in the early 1970s.

- » Describe what happens when a car hits a tree.
- » Describe how you know that an unbalanced force is involved.
- » Describe what happens to the car and the tree.
- » Describe what would happen if you were not wearing a seatbelt.
- » Describe how a seatbelt is made and the materials that are used.
- » Explain how a seatbelt could save your life if your car hit a tree.

**Figure 9** In Australia, it is against the law not to wear a seatbelt in a car.

## Chapter checklist

Now that you have completed this chapter, reflect on your ability to do the following.

| | I can do this. | I cannot do this yet. |
|---|---|---|
| • Explain why a measuring device must be calibrated.<br>• Provide examples of forces in real-life situations. | ☐ | ☐ Go back to Topic 4.1 'A force is a push, a pull or a twist'. Page 84 |
| • Identify balanced and unbalanced forces.<br>• Describe how force diagrams can represent forces in a situation.<br>• Calculate net force. | ☐ | ☐ Go back to Topic 4.2 'An unbalanced force causes change'. Page 86 |
| • Define and provide examples of contact forces and non-contact forces. | ☐ | ☐ Go back to Topic 4.3 'Forces can be contact or non-contact'. Page 88 |
| • Describe the natural magnetic field of the Earth.<br>• Provide examples of how magnetism is used in real-life situations. | ☐ | ☐ Go back to Topic 4.4 'Magnetic fields can apply a force from a distance'. Page 90 |
| • Define electrostatic forces and charge.<br>• Provide examples of electrostatic forces in real-life situations. | ☐ | ☐ Go back to Topic 4.5 'Electrostatic forces are non-contact forces'. Page 92 |
| • Calculate weight when given the mass of an object and gravitational force.<br>• Explain why the weight of an object does not affect the rate that it falls. | ☐ | ☐ Go back to Topic 4.6 'Earth's gravity pulls objects to the centre of the Earth'. Page 94 |
| • Define and provide examples of friction, lubrication, air resistance, drag and streamlining. | ☐ | ☐ Go back to Topic 4.7 'Friction slows down moving objects'. Page 96 |
| • Compare and contrast distance magnifiers and force magnifiers.<br>• Provide examples of first-, second- and third-class levers.<br>• Calculate mechanical advantage and effort. | ☐ | ☐ Go back to Topic 4.8 'Simple machines decrease the amount of effort needed to do work'. Page 98 |
| • Explain how a pulley makes it easier to lift a load.<br>• Calculate effort in a pulley system. | ☐ | ☐ Go back to Topic 4.9 'A pulley changes the size or direction of a force'. Page 102 |
| • Define and provide examples of ramps, wedges, screws and wheels. | ☐ | ☐ Go back to Topic 4.10 'There are different types of machines'. Page 104 |
| • Identify and describe the four main forces involved in flying: lift, thrust, drag and weight.<br>• Use an infographic to communicate with an audience. | ☐ | ☐ Go back to Topic 4.11 'Science as a human endeavour: The forces in flight'. Page 106 |
| • Explain how understanding of forces has improved sporting abilities and technologies. | ☐ | ☐ Go back to Topic 4.12 'Science as a human endeavour: Forces are involved in sport'. Page 108 |

**Check your Student obook pro for these digital resources and more:**

**Quizlet**
Play a Quizlet game to test your knowledge.

**Chapter quiz**
Test your understanding of this chapter with the chapter review quiz.

Chapter

# 5

# CLASSIFICATION

5.1

**Classification organises our world**

> Explain the purpose of classification systems and how they are used by scientists.

5.2

**Living organisms have characteristics in common**

> Describe the eight characteristics shared by all living things using the acronym MR N GREWW.

5.3

**Classification keys are visual tools**

> Construct and use tabular and dichotomous keys for classification.

5.4

**The classification system continues to change**

> Describe the two-part naming system devised by Linnaeus.

> Identify the genus and species of an organism from its two-part name.

**5.5**

### Kingdoms can be used to classify organisms

> Explain how living things have been classified into different kingdoms.
> Describe how classification of organisms changes as new information becomes available.

**5.6**

### Animals that have no skeleton are called invertebrates

> Explain that invertebrates have either an exoskeleton or no skeleton.
> Identify the six main phyla of invertebrates.

**5.7**

### Vertebrates can be organised into five classes

> Distinguish between vertebrates and invertebrates.
> Identify the five classes of vertebrates and use the terms 'endotherm' and 'ectotherm' to group them.

**5.8**

### Plants can be classified according to their characteristics

> Explain that plants are generally classified according to how they transport nutrients or how they reproduce.
> Categorise plants using a key.

**5.9**

### The first Australian scientists classified their environment

> Describe some of the ways in which First Nations peoples classified and communicated their understanding of local flora and fauna.

**5.10**

### Science as a human endeavour: Taxonomists classify new species

> Describe the role of taxonomists in identifying and naming new species.
> Evaluate the reliability of primary and secondary data.

## What if?

### Identifying animals

**What you need:**

Paper, pencil

**What to do:**

1 Work in pairs. Describe an animal to your partner without using the animal's name. Can your partner draw the animal you describe?

2 Now draw an animal while your partner tries to guess what it is. How quickly did they guess your animal?

**What if?**

» What if you had code words that described several features of an animal at once? For example, 'mammal' could mean four limbs, covered in fur and feeds their baby with milk. How would this affect the way you communicate?

# 5.1 Classification organises our world

**Learning intentions**

By the end of this topic, you will be able to:

- explain the purpose of classification systems and how they are used by scientists.

**Key ideas**

- Classification systems help scientists to communicate.
- Scientists identify all living things through scientific names.
- Carolus Linnaeus developed the modern Linnaean classification system.

## Early classification methods

Early humans first classified plants by learning which plants were edible and which were poisonous. A new plant or animal discovered by humans was (and still is) studied and put into a group. Some plants were found to help sick people and others were poisonous. Some animals could produce food, such as milk and eggs. Each generation of scientists worked to improve how these groups were classified.

## Common names or scientific names

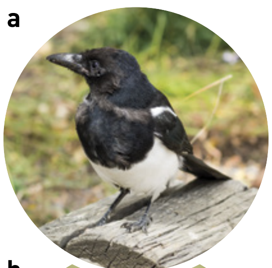
Scientists try to communicate with each other regularly to help with their research. Before the existence of photographs or computers, scientists would have to draw creatures, such as birds, by hand and describe them in as much detail as they could. This was difficult, and it was easy to make mistakes, as the photographs of the American magpie and the Australian magpie show in Figure 1.

Both birds looked so similar that they were given the same common name, 'magpie'. However, their scientific names are different. The name *Cracticus tibicen* for the Australian magpie means the same to scientists in every country around the world.

## The Linnaean classification system

Greek philosopher Aristotle (384–322 BCE) was the first scientist to start using systems to describe plants and animals. By the seventeenth century the early classification systems used a hierarchy list of names, starting with large general groups (such as plants and animals) and then dividing

a



b

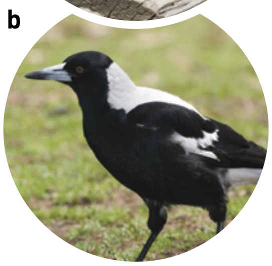
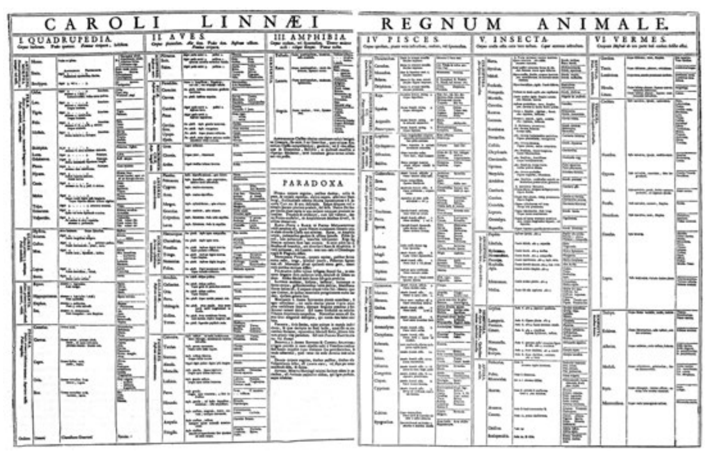


**Figure 1 a** The American magpie *Pica hudsonia* and **b** the Australian magpie *Cracticus tibicen*


CAROLI LINNÆI REGNUM ANIMALE.

I. QUADRUPEDIA | II. AVES | III. AMPHIBIA | IV. PISCES | V. INSECTA | VI. VERMES

PARADOXA

**Figure 3** Part of Linnaeus's classification system

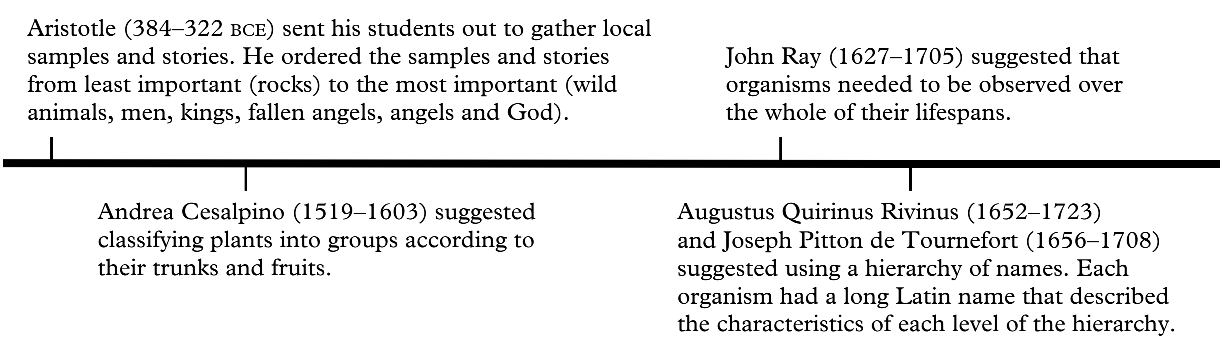



**Figure 2** A timeline of classification

CHALLENGE
**5.1:** Department store classification
Go to page **232**.

each group into smaller and smaller groups based on their characteristics. Each organism ended up with a long Latin name that described the characteristics of each level of the hierarchy. Swedish botanist Carolus Linnaeus (1707–1778) tried these classification systems but found their descriptions to be too long. He decided that a simpler system was needed. He changed the descriptions to single words and reduced the number of classification groups to seven.

## Finding new species

There are many living things that are still to be discovered or named. In 2020, seven new species of peacock spiders were identified in Australia. These spiders are the same size as a grain of rice. During their courtship dance, they wave their brightly coloured abdomens.

**Figure 5** Peacock spiders are unique to Australia.

Small groups of scientists are trying to find undiscovered plants in Brazilian rainforests before they are destroyed by logging and farming. Often the scientists are supported by large pharmaceutical companies from other countries in the hope that it may lead to the discovery of new medications. The antibiotic penicillin was discovered from a type of mould; aspirin comes from a substance in the bark of willow trees. The next painkiller could come from a small fungus in the rainforest or an insect that relies on the fungus for food. Without a name, the new discoveries would be lost and forgotten.

**Figure 6** The rainforests of Brazil contain many undiscovered plant species.

**Figure 4** Carolus Linnaeus

## 5.1 Check your learning

### Comprehend

1 **Explain** why Linnaeus simplified the classification system used by previous scientists.

2 **Explain** why it would be difficult to classify frogs and tadpoles using the early methods of classification.

### Apply

3 **Propose** two reasons why scientists still classify organisms today.

4 The earliest scientists did not have pens or paper. **Describe** how they would have passed on the information they discovered. **Discuss** the accuracy of this approach (by describing the advantages and disadvantages of using this method).

5 Aristotle was one of the first scientists to gather information from wide regions. **Propose** the method he might have used to tell the differences between a horse and a fly.

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

Carolus Linnaeus (1707–1778) introduced the Linnaean classification system.

Carl Woese (1928–2012) suggested that the bacterial kingdom Monera be split into two domains, and the third domain contain all other organisms.

Thomas Cavalier-Smith (1942–2021) suggested the kingdom Plantae be split into two kingdoms because of differences in their cells.

# 5.2 Living organisms have characteristics in common

**Learning intentions**

By the end of this topic, you will be able to:

- describe the eight characteristics shared by all living things using the acronym MR N GREWW.

**Key ideas**

- Biology is the study of living organisms and what it means to be alive.
- Living things move, reproduce, need nutrition, grow, respond, exchange gases, produce waste and need water.
- Dead organisms were once living.

**Figure 1** Living things move.

**Figure 2** Living things reproduce.

**reproduction**
the production of offspring by a sexual or asexual process

**autotroph**
an organism that makes its own food

**heterotroph**
an organism that absorbs nutrients from other living things

## Characteristics of living things

It has taken many years of observation and discussion for scientists to develop eight characteristics that all living things – plants, animals and even microorganisms such as bacteria – have in common. To remember all eight characteristics, just remember: MR N GREWW.

### Living things can MOVE by themselves

Animal movements are easy to see. But do plants move? Look at the leaves on an indoor plant – they usually face the window (a source of light). Turn the plant around so that the leaves face into a darker part of the room. In a few days, the leaves will again be facing the window. The leaves have moved by themselves. Sunflowers turn their heads to follow the Sun as it moves across the sky each day.

### Living things can REPRODUCE

Living things can make new individuals that grow up to look like them. Animals mate and produce offspring, plants produce seeds that grow into new plants, and bacteria divide to produce more bacteria. **Reproduction** is the process by which living things make new life.

### Living things need NUTRITION

All living things need nutrients to survive. Animals obtain most of their nutrients by eating food and drinking. Plants absorb nutrients through their roots and fungi feed on decaying organisms. Plants are **autotrophs**, which means they make their own food. Animals and fungi are **heterotrophs**, which means they rely on other living things for food or nutrients.

### Living things GROW as they get older

All living things grow during their lives. Mushrooms start off as tiny spores. Humans are born as babies and develop into children, teenagers and then adults. Insects hatch from eggs as larvae and then metamorphose into adult insects (Figure 4). In every case, living things, when fully grown, resemble their parents.

**Figure 3** Living things need nutrients to survive.

**Figure 4** Living things grow during their lives.

### Living things RESPOND to change

When an animal realises it is being chased, like the springbok in Figure 5, it runs. It is responding to stimuli (the sight and sound of a charging predator) or to changes in its

**Figure 5** Living things respond to change.

environment (the sudden brush of leaves or movement of shadows). The sunflowers shown in Figure 1 are responding to the changing stimuli of light and warmth.

## Living things EXCHANGE GASES with their environment

Plants and animals have organs and structures that allow them to exchange oxygen and other gases. Some animals, such as humans, use their lungs to inhale and then exhale. Other animals, such as fish and the axolotl (Figure 6), have gills.

**Figure 6** The axolotl has gills to exchange gases with its environment.

Some animals, such as worms, breathe through their skin. Even plants need to exchange gases with their environment.

## Living things produce WASTES

We, like other animals, take in food, water and air to fuel our bodies. Chemical reactions occur in our bodies and wastes are produced as a result. We get rid of these wastes by exhaling, sweating, urinating and defecating (emptying our bowels). Plants get rid of their wastes through their leaves.

## Living things require WATER

All living things need water; it is required for many jobs. For example, it transports substances in our bodies to where they are needed, and it is involved in many essential chemical reactions. In animals such as humans, water helps maintain body temperature. No wonder a large proportion of our body is water!

# Non-living or dead?

Something classified as living needs nutrition and water, and is able to move by itself, reproduce, exchange gases, grow, respond to stimuli and produce wastes.

If something does not have these characteristics, it would seem logical to assume that the thing is non-living. But what about something that is dead? Something dead, such as a dried flower or an Egyptian mummy, was once living; when it was alive it *did* have the characteristics of a living thing. Something that is non-living, such as a computer or your watch, has *never* had these characteristics.

**Figure 7** Sweating is one way humans get rid of waste products from their bodies.

**Figure 8** The human body uses water for many jobs, including maintaining body temperature.

## 5.2 Check your learning

### Retrieve

1 The system scientists use to classify things divides the things first into two groups. **Name** the two groups.

2 **Identify** what the letters of MR N GREWW represent when discussing the characteristics of living things.

### Analyse

3 Consider the following things: eucalyptus tree, water, paper, robot, leather belt, wombat, roast chicken, plastic chair.
With a partner or by yourself, **classify** each thing as living, non-living or dead.

4 **Contrast** non-living and dead things.

### Apply

5 **Identify** the items listed in question 3 that are dead. **Justify** your answer (by defining the term ‘dead’ and comparing the definition to the item).

6 **Identify** a bushfire as either living, non-living or dead. **Justify** your answer (by describing the characteristics of a living thing and comparing it with the properties of a fire).

**Quiz me**
Complete the Quiz me to check how well you’ve mastered the learning intentions and to be assigned a worksheet at your level.

# 5.3 Classification keys are visual tools

**Learning intentions**

By the end of this topic, you will be able to:

- construct and use tabular and dichotomous keys for classification.

**Key ideas**

- A key is a visual tool used in the classification of organisms.
- A branched key can show the relationship between different organisms.
- Scientists use keys to identify the scientific name of an organism.

Interactive 5.3
Using a dichotomous key

When you visit an outdoor market, you might wander around for some time before you find what you want. A department store is more organised, with similar items grouped together. Scientists use a system similar to this to sort things into groups or **classify** them. A visual tool called a **key** helps scientists identify the names and descriptions of organisms.

## Using dichotomous keys

One common type of key is called the **dichotomous key** (pronounced 'dye-COT-o-muss') because the branches always split into two (*di* meaning 'two'). Scientists use this type of key to make simple 'Yes' or 'No' decisions at each branch. For example, does the animal have fur (Yes/No)? Does it have scales (Yes/No)? Each answer leads to another branch and another question. This key only works if the animal has already been identified by someone else. A newly discovered organism would need to be studied first and then new branches added to an existing key.

## Dr Redback's family

Dr Redback loved to send out Christmas cards with a family photo on the front. One year, just for fun, he included two dichotomous keys to help everyone identify all his family and pets.

Use the picture of Dr Redback's family (Figure 1) and one of the dichotomous keys provided (Figures 2 and 3) to work out who is who.

## Tabular keys

If a scientist is going out into the bush to study plants and animals, a large drawing like the one in Figure 2 may not be useful. Instead, a field guide or tabular key, such as that shown in Figure 3, can be used. This is used in the same way as the diagram version (Figure 4). Two choices are offered at each stage. When a decision is made, the scientist is led to the next characteristic choice.

**classify**
arrange in classes or categories

**key**
(in biology) a visual tool used to classify organisms

**dichotomous key**
a diagram used in classification; each `arm' of the key contains two choices

**Figure 1** Dr Redback's family

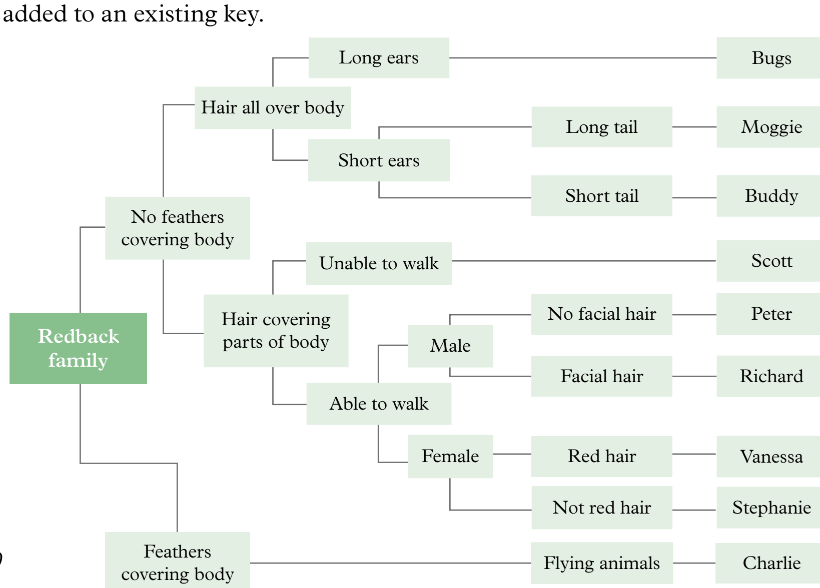



**Figure 2** A dichotomous key for Dr Redback's family

CHALLENGE
**5.3:** Dichotomous key
Go to page **233**.

| | | |
|---|---|---|
| 1 | No feathers covering body | Go to 2 |
| | Feathers covering body | Go to 9 |
| 2 | Hair all over body | Go to 3 |
| | Hair covering parts of body | Go to 4 |
| 3 | Short ears | Go to 5 |
| | Long ears | Bugs |
| 4 | Unable to walk | Scott |
| | Able to walk | Go to 6 |
| 5 | Long tail | Moggie |
| | Short tail | Buddy |
| 6 | Male | Go to 8 |
| | Female | Go to 7 |
| 7 | Red hair | Vanessa |
| | Not red hair | Stephanie |
| 8 | No facial hair | Peter |
| | Facial hair | Richard |
| 9 | Flying animals | Charlie |

**Figure 3** Tabular key for Dr Redback's family

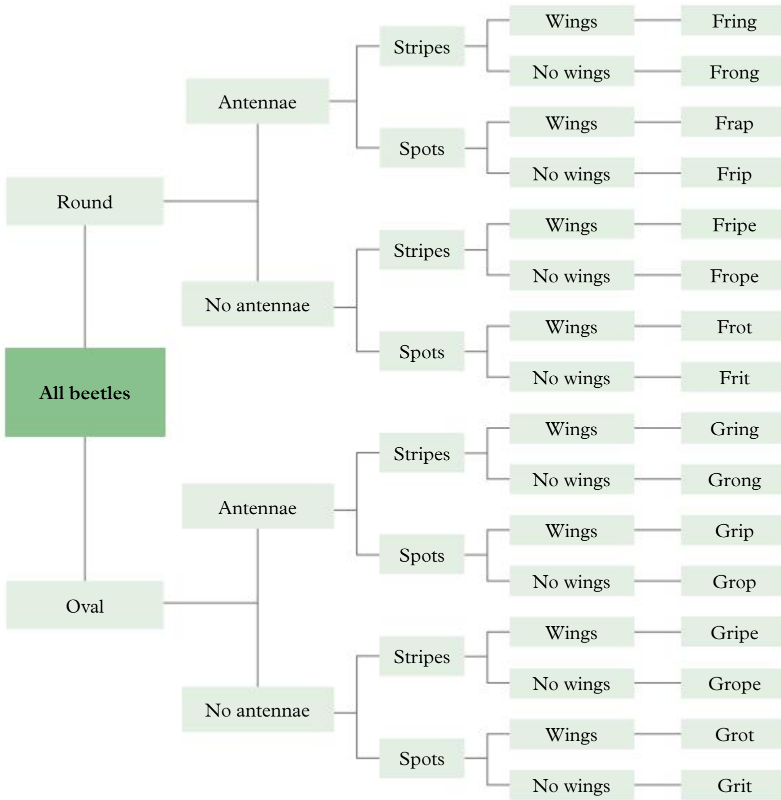



**Figure 4** A dichotomous key to help identify 16 different types of beetles

## 5.3 Check your learning

### Remember and understand

1 **Define** the term 'dichotomous key'.

2 **State** why it is called 'dichotomous'.

3 **Define** the term 'classify'.

### Apply

4 A scientist needs to carefully select the characteristics that are used to classify organisms in a dichotomous key. For each of the characteristics listed below, **consider** if it is appropriate for use in a dichotomous key of birds. **Justify** your answer (by explaining how it can or cannot be used to identify a bird).

a eating bird seed

b a blue stripe above the eye

c a broken leg

d sitting on the ground

5 **Create** a key that could be used to **identify** laboratory equipment. Include these items: tripod stand, Bunsen burner, gauze mat, 50 mL beaker, 150 mL beaker, 100 mL measuring cylinder, 10 mL measuring cylinder, 500 mL beaker, 500 mL measuring cylinder, retort stand, clamp.

6 Use the dichotomous key in Figure 4 to help with the following tasks.

a **Identify** the four beetles in Figure 5.

b **Create** a simple sketch of the following:

i frope beetle

ii gring beetle

iii gripe beetle

iv frong beetle.

**Figure 5** Four types of beetles

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 5.4 The classification system continues to change

**Learning intentions**

By the end of this topic, you will be able to:
- describe the two-part naming system devised by Linnaeus
- identify the genus and species of an organism from its two-part name.

**Key ideas**
- Carolus Linnaeus was the first scientist to use a dichotomous key to classify every living thing.
- Scientific names are binomial (two names), the genus and the species.
- The Linnaean taxonomy system is still used today.

## Giving organisms a precise name

When trying find your house on Google Earth, you first find Australia and then the state you live in. Each time you narrow your search closer to your town, your suburb, your street until you finally find your house.

**Figure 1** How do you find your house on Google Earth?

The **Linnaean taxonomy** for classifying living things works in a similar way. It starts with large groups called **kingdoms** and then divides into smaller groups called phyla. Each phylum has several classes. The classes have orders and so on. There are seven different levels to get to the final name of each organism: kingdom, phylum, class, order, family, genus and species. (Tip: Some people use the following mnemonic to remember the Linnaean system: '**K**ing **P**hillip **C**rawled **O**ver **F**our **G**ooey **S**nails'.)

**Linnaean taxonomy**
a hierarchical system of classification developed by Linnaeus in which all organisms are grouped into kingdom, phylum, class, order, genus and species, with each individual organism known by its genus and species names

**kingdom**
the highest category in taxonomic classification

## Linnaeus's double-name system

Have you eaten a *Musa sapientum* lately or have they been too expensive to buy? And did you pat your *Canis familiaris* this morning? These double names are given to every living thing using the Linnaean classification system.

Our homes can easily be found by using only the two smallest groups in an address – the street and the suburb. The information about the bigger groups, such as the Earth and the country, is not really necessary.

**Figure 2** *Musa sapientum* is the Linnaean name for a banana.

**KINGDOM: Animalia**
e.g. insect, fish, bird, lizard, kangaroo, fox, lion, jungle cat, domestic cat

**PHYLUM: Chordata**
e.g. fish, bird, lizard, kangaroo, fox, lion, jungle cat, domestic cat

**CLASS: Mammalia**
e.g. kangaroo, fox, lion, jungle cat, domestic cat

**ORDER: Carnivora**
e.g. fox, lion, jungle cat, domestic cat

**FAMILY: Felidae**
e.g. lion, jungle cat, domestic cat

**GENUS: *Felis***
e.g. jungle cat, domestic cat

**SPECIES: *catus***
domestic cat

**Figure 3** The Linnaean classification system uses seven different levels. It is used to give names to living things such as the domestic cat, *Felis catus*.

CHALLENGE

**5.4:** Can you understand scientific names?
Go to page **234**.

In much the same way, an organism can also be named from the two last groupings on the Linnaean dichotomous key – the genus and the species.

In the double-name (or **binomial**) system, the **genus** group name always starts with a capital letter. The second word is the species name and it does not have a capital letter. The double name is always written using italics (sloping letters).

A **species** is a group of organisms that look similar to one another. When they breed in natural conditions, their offspring are fertile (in other words, they can also breed and have babies). Domestic cats belong to the one species because they can breed together and have living kittens.

## The changing face of science

After 250 years, scientists are still testing and modifying the Linnaean classification system. The development of microscopes led to the discovery of single-celled organisms (bacteria). This led to the number of kingdoms increasing from three – plants, animals and minerals – to the current five – Plantae, Animalia, Fungi, Protista and Monera. In the 1970s, a group of organisms previously thought to be bacteria was discovered to be something else: single-celled organisms that could live in extreme conditions, such as very salty or hot waters. The genetic material (DNA) of these organisms was different from that of other bacteria. This led to the suggestion that a sixth kingdom, Archaea, was needed. Scientists have been discussing this approach of six kingdoms and comparing it with a whole new level that comes before kingdoms.

The 'three-domain system' was first suggested in 1990. This system suggests one super domain, Eukaryota, for plants, animals, protists and fungi. The single-celled organisms in Kingdom Monera would then be split into two domains according to their genetic material.

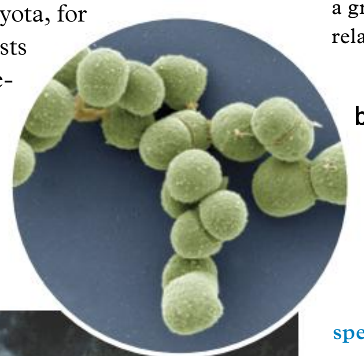




**Figure 4 a** A biologist collecting Archaea samples in the hot springs of the Obsidian Pool in Yellowstone National Park, USA; **b** a magnified view of a clump of Archaean organisms

**binomial**
the double-name system created by Linnaeus to name organisms; the first name is the genus and the second name is the species

**genus**
a group of closely related species

**species**
a group of organisms that look similar to one another, and can breed in natural conditions and produce fertile young

## 5.4 Check your learning

### Retrieve

1 **Identify** the person responsible for the naming system that is still used today to name living things.

2 **Recall** the seven levels or groups that are used to divide all living things. Write them in order from the largest group or level to the smallest level of organisation.

### Comprehend

3 **Explain** how you would know whether two organisms are the same species.

4 Select three species of animal. For each animal:

- a **describe** its appearance
- b **identify** its common and scientific names.

### Analyse

5 **Identify** which two organisms would be most alike: *Felis catus, Canis familiaris* and *Felis bieti*.

### Apply

6 **Discuss** how an understanding of genetic material changed the classification of bacteria.

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 5.5 Kingdoms can be used to classify organisms

**Learning intentions**

By the end of this topic, you will be able to:

- explain how living things have been classified into different kingdoms
- describe how classification of organisms changes as new information becomes available.

**Key ideas**

- Taxonomists are scientists that classify living things.
- New information that compares genetic material may change the five kingdoms.
- The nature of science is to change and develop as new evidence becomes available.

Interactive 5.5
Kingdoms

**multicellular**
consisting of two or more cells

**unicellular**
consisting of only one cell; an example is bacteria

**taxonomist**
a scientist who classifies living things into groups

**nucleus**
a membrane-bound structure in cells that contains most of the cell's genetic material

**cell wall**
a structure that provides support around the cell in some organisms, such as plants and fungi

## Building blocks of life

Cells are often called the building blocks of life. Think of the way bricks are used to build a house. Cells build living things in a similar way. However, there are usually many more cells in living things than bricks in a house. Any living thing with more than one cell is **multicellular** (Figures 1a and 1b). Many living things, such as bacteria, consist of only one cell. These are single-celled or **unicellular** organisms (Figure 1c).

## Parts of a cell

**Taxonomists** ask three questions when they are trying to classify the cells of an organism:

1. Does the cell keep all of its genetic material (called DNA) inside a **nucleus**? The nucleus protects the DNA that carries all the instructions for living and reproducing.
2. Does the cell have a **cell wall** around it for extra support?
3. Does the cell use sunlight to make its own nutrients (autotroph)? Plant cells can do this, but fungi (like mushrooms) need to absorb their nutrients from other living things (heterotrophs).

These three features are used to divide all living things into big groups called kingdoms.

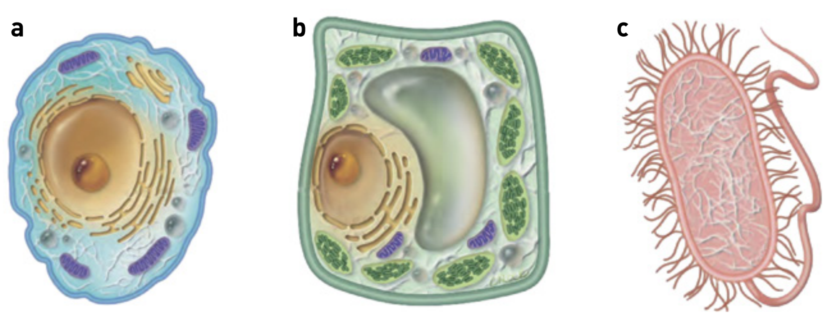



**Figure 1 a** Simple animal cell, **b** plant cell, and **c** bacterial cell

## Kingdom Animalia

All organisms in this kingdom are multicellular. Each cell stores its genetic material in a nucleus but does not have a cell wall. Animals gain energy from other living things. We belong in this kingdom. Zoologists are the scientists who study animals.

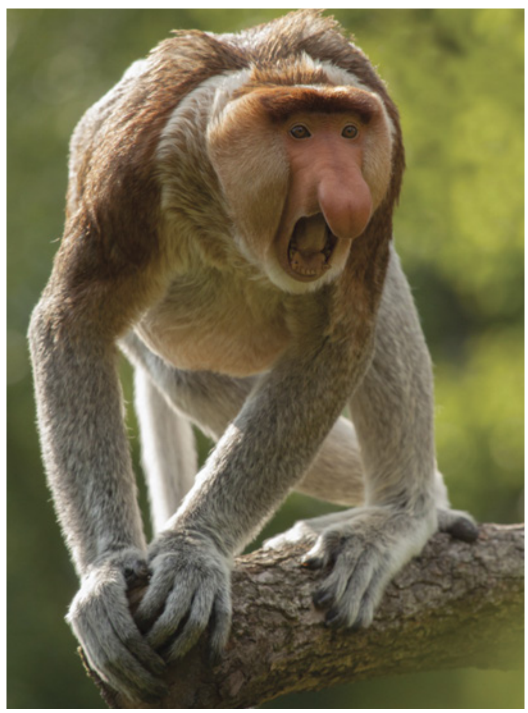


**Figure 2** Kingdom Animalia: the proboscis monkey (*Nasalis larvatus*)

## Kingdom Plantae

Plants include trees, vines, bushes, ferns, mosses, weeds and grasses (Figure 3). They all gain energy by converting the energy from sunlight into food (autotrophs). They are multicellular and their cells are surrounded by a cell wall. There is a nucleus inside each cell. Botanists are the scientists who study the plant kingdom.

CHALLENGE
**5.5:** Classifying living things
Go to page **235**.

**Figure 3** Kingdom Plantae: the smelliest plant, the *Rafflesia*, is found in South-East Asia (its flower can measure up to 90 cm across and weigh about 11 kg, and it gives off a rotten meat odour when it blossoms to attract insects).

## Kingdom Fungi

Kingdom Fungi includes mushrooms, toadstools, yeasts, puffballs, moulds and truffles (Figure 4). Some fungi grow in wood and soil, and develop from tiny spores. Fungi store their genetic material in a nucleus and do not make their own food. Instead, they feed on the remains of dead animals and plants. Some fungi can cause diseases, such as tinea (athlete's foot). Mycologists are the scientists who study Kingdom Fungi.

## Kingdom Monera

Kingdom Monera is made up of the simplest and smallest living things. There are approximately 75 000 different organisms in Kingdom Monera, and they are all unicellular and have a cell wall but no nucleus. **Bacteria** are the most common in this kingdom. Many people think of bacteria as harmful to humans, but this is not always true.

**Figure 4** Kingdom Fungi: mushrooms

Bacteria in the soil break down rubbish and wastes produced by animals (especially humans). Without bacteria, we would be surrounded by mountains of smelly rubbish. Bacteria have been put to use by humans to make food, such as cheese and yoghurt (Figure 5). Microbiologists are the scientists who study microorganisms in Kingdoms Monera and Protista.

## Kingdom Protista

There are approximately 55 000 species of protists. Their cell structure is more complex than that of the Monera. Often, organisms that do not fit into any other kingdom will belong in Protista. Protists may range in size from single-celled organisms to much larger ones, such as kelp (seaweed). They all have one feature in common: they store their genetic material in a nucleus. **Plankton**, the tiny sea creatures eaten in their millions by whales, are part of this kingdom. **Amoeba**, microscopic organisms that change their shape to trap their food, also belong to this group (Figure 6).

**bacteria**
unicellular organisms that have a cell wall but no nucleus

**plankton**
microscopic organisms that float in fresh or salt water

**amoeba**
a type of single-celled organism belonging to the Protista kingdom

**Figure 5** Kingdom Monera, as seen under a microscope: *Lactobacillus casei*, a helpful bacteria used to make some dairy foods

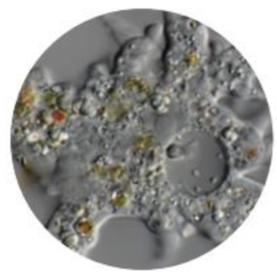


**Figure 6** Kingdom Protista, as seen under a microscope: amoeba

## 5.5 Check your learning

### Retrieve

1 **Identify** where a plant cell stores its genetic material (DNA).
2 **Name** four features of Kingdom Fungi.
3 **Define** the term 'multicellular'.
4 **Name** an organism made up of just one cell.

### Analyse

5 **Contrast** (the differences between) a protist and a bacterium.
6 **Compare** (the similarities and differences between) the cells in Kingdom Plantae and those in Kingdom Fungi.

### Apply

7 **Discuss** why the invention of the microscope was important to our understanding of living things.

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 5.6 Animals that have no skeleton are called invertebrates

**Learning intentions**

By the end of this topic, you will be able to:

- explain that invertebrates have either an exoskeleton or no skeleton
- identify the six main phyla of invertebrates.

**Key ideas**

- Kingdom Animalia contains approximately 35 phyla.
- The two main groups in Kingdom Animalia are vertebrates and invertebrates.
- Endoskeletons are skeletons that are found inside the animal.
- Exoskeletons are hard skeletons or shells that are found on the outside of the animal.

Video 5.6A
Squid dissection

Video 5.6B
Classification confusion

**endoskeleton**
an internal skeleton

**vertebrate**
an organism that has an endoskeleton

**exoskeleton**
an external skeleton

**invertebrate**
an organism that has an exoskeleton or no skeleton

**Figure 1** The giant squid is an invertebrate.

## Internal or external skeleton?

In the same way as using a dichotomous key, dividing the animal kingdom into groups first requires a question. The system scientists use to divide animals into groups is based on their structure. The question is: 'Does this animal have an internal or external skeleton?'

Animals such as cats, humans and birds with an internal skeleton (called an **endoskeleton**) are known as **vertebrates**. Because these animals often have a spinal cord that threads its way along the vertebrate bones, the phylum is called Chordata. Animals with an external skeleton (**exoskeleton**), such as beetles and crabs, and those with no skeleton at all, such as slugs, are known as **invertebrates**. Invertebrates dominate the animal kingdom.

## Invertebrates

There are many more invertebrates on the Earth than there are vertebrates: 96 per cent of all animals are invertebrates. Invertebrates have either an external skeleton (exoskeleton) or no skeleton at all. As well as enormous animals such as the giant squid (Figure 1), thousands of tiny insects and other creatures belong to the invertebrate group.

## Identifying invertebrates

In the same way that vertebrates are classified, invertebrates are grouped into six main groups of phyla on the basis of their characteristics.

Characteristics used to classify invertebrates include the presence of a shell or hard cover, tentacles or spiny skin. Organisms with similar features are placed in the same group. The dichotomous tabular key in Table 1 can be used to place an organism in a particular phylum.

**Table 1** Tabular key for identifying invertebrates

| | | |
|---|---|---|
| 1 | Body spongy, with many holes | Poriferan |
| | Body not spongy | Go to 2 |
| 2 | Soft body, no shell | Go to 3 |
| | Outside shell or hard cover | Go to 6 |
| 3 | Many tentacles or arms | Go to 4 |
| | Long body without tentacles | Go to 5 |
| 4 | Tentacles around the mouth of a sac-like body | Cnidarian |
| | Arms with suction discs | Mollusc |
| 5 | Soft body, large foot | Mollusc |
| | Worm-like or leaf-like | Nematode, platyhelminth or annelid |
| 6 | Proper shell or smooth, hard covering | Go to 7 |
| | Spiny skin with rough covering | Echinoderm |
| 7 | Limbs in pairs | Arthropod |
| | Shell, no segments, large foot | Mollusc |

EXPERIMENT
**5.6A:** Dissecting skeletons
Go to page **236**.

CHALLENGE
**5.6B:** Identifying invertebrates
Go to page **237**.

## Arthropods

Arthropods have segmented bodies, paired and jointed legs and an exoskeleton. Examples include insects, spiders, centipedes and scorpions (Figure 2a).

## Poriferans

Poriferans have spongy bodies with holes and are found in water, attached to rocks. Examples include breadcrumb sponges (Figure 2b) and glass sponges.

## Cnidarians

Cnidarians have soft, hollow bodies with tentacles and live in water. Examples include coral, sea jellies (Figure 2c) and anemones.

## Nematodes, platyhelminths and annelids

Nematodes, platyhelminths and annelids have soft, long bodies and can be segmented, flat or round. Examples include leeches (Figure 2d), tapeworms and flatworms.

## Echinoderms

Echinoderms have rough, spiny skin, their arms radiate from the centre of the body, and they are found in the sea. Examples include sea urchins, sea cucumbers and brittle star (Figure 2e).

## Molluscs

Molluscs have soft bodies and usually have a protective shell. Examples include snails (Figure 2f), octopuses and oysters.

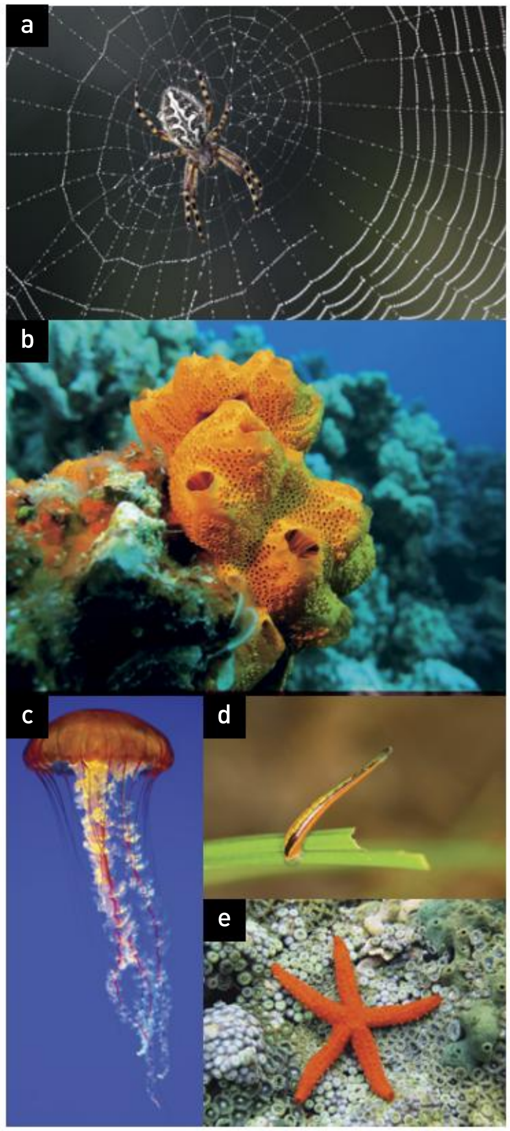




**Figure 2** Some commonly found invertebrate phyla: **a** spider, **b** breadcrumb sponge, **c** sea jelly, **d** leech, **e** brittle star and **f** snail

## 5.6 Check your learning

### Retrieve

1 Animals are divided into two main groups.
   a **Identify** the names of the groups.
   b **Name** the main characteristic of each group.
2 **State** the percentage of animals that are invertebrates.
3 **Recall** two examples of animals with an exoskeleton.
4 **Recall** two examples of animals with no skeleton at all.

### Analyse

5 Beetles have segmented bodies and jointed legs. **Identify** the phylum that contains the beetles.
6 Use Table 1 to **identify** the group that a scientist would place the following animal in: a non-spongy soft body, with many tentacles around the mouth.

### Apply

7 Eighty per cent of animals on the Earth are arthropods.
   a **Discuss** what characteristic the name arthropod suggests. (HINT: Consider 'arthritis' and 'podiatrist'.)
   b Draw three different arthropods and **label** the features that make them part of this phylum.

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 5.7 Vertebrates can be organised into five classes

**Learning intentions**

By the end of this topic, you will be able to:

- distinguish between vertebrates and invertebrates
- identify the five classes of vertebrates and use the terms 'endotherm' and 'ectotherm' to group them.

**Key ideas**

- Vertebrates are animals with a spine or backbone.
- Vertebrates can be broken down into classes based on their body covering, how their young are born, and their body temperature.
- Endotherms have a constant body temperature.
- Ectotherms have a body temperature that changes with the environment.

Interactive 5.7
Classes of vertebrates

**endotherm**
an organism that has a constant body temperature regardless of the temperature of its environment

**ectotherm**
an organism with a body temperature that changes with the environment

## Class Mammalia

Mammalia is a class of vertebrates well known to many people. Many of our pets belong to this class: horses, dogs, cats, rabbits, guinea pigs and mice. We belong to this class too.

Mammals are animals with hair or fur and they can keep their body temperature constant (**endotherms**). This means their body temperature remains the same despite the environment being hot or cold. Female mammals give birth to live young and feed their young with their own milk.

Class Mammalia can be further broken down into three subgroups, as shown in Figure 1. The main feature used to separate mammals is the way in which their young develop.

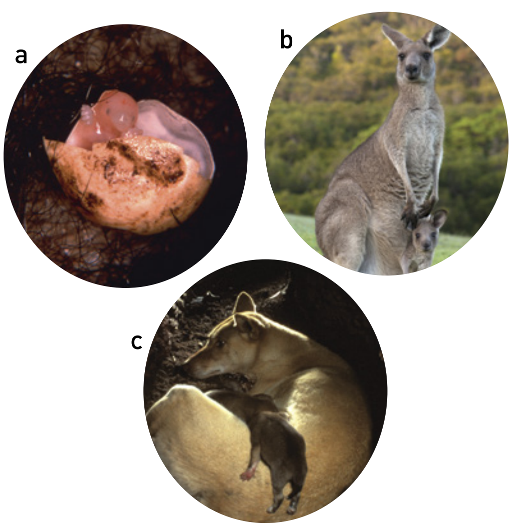



**Figure 1** The three subgroups of mammals: **a** monotremes lay soft-shelled eggs; **b** marsupials are born immature and need to spend the first few months in their mother's pouch; **c** placentals are born with the general shape of the adult animal.

## Class Aves

All birds in phylum Chordata belong in this class. Like mammals, they are endotherms (having a constant body temperature). Two of their main distinguishing characteristics (the way they differ from the other classes) are their covering of feathers and their scaly legs (Figure 2). All animals in this class lay eggs with a hard shell.

**Figure 2** A cockatoo is part of Class Aves.

## Class Reptilia

The skin of reptiles, such as snakes (Figure 3) and lizards, is usually covered in a layer of fine scales. Reptiles use lungs to breathe, even if they live under water (sea snakes). These animals are **ectotherms** because their body temperature is always very similar to the environment. We do not use the term 'cold-blooded' to describe these animals because a lizard that has been lying in the Sun has very warm blood, even though at night its blood is cool.

CHALLENGE
**5.7:** Who are the vertebrates?
Go to page **238**.

Turtles also belong to this class. Many people become confused by the hard outer shell of turtles and tortoises, thinking it is an exoskeleton. Underneath the shell there is a hard backbone with a nerve cord running through it (Figure 4).

**Figure 3** Class Reptilia: a king brown snake

**Figure 4** Despite having a hard outer shell, turtles and tortoises have a hard backbone with a nerve cord running through it.

## Class Amphibia

Like reptiles, amphibians are ectotherms; however, the skin of amphibians is usually soft and slimy to touch. They lay their eggs, without hard shells, in water. For the first part of their life, amphibians have gills and live in the water. As they get older, lungs develop and they become able to live on land. The only remaining group of native amphibians in Australia is frogs. In other parts of the world, caecilians and salamanders may be found.

**Figure 5** Class Amphibia: a growling grass frog

## Class Pisces

Most fish are ectotherms. They are covered in a layer of scales and most have fins. They spend all their life in water and so need gills to breathe. Fish are further grouped according to their skeleton. Sharks, rays and skates have a skeleton made entirely of cartilage, whereas all other fish have bony skeletons.

**Figure 6** Class Pisces: a tuna

## 5.7 Check your learning

### Retrieve

1 The vertebrates have five classes: Mammalia, Reptilia, Amphibia, Aves and Pisces. **Identify** the common names for each of these classes.

### Comprehend

2 **Describe** the main characteristics of mammals.

### Analyse

3 **Contrast** the appearance of a placental mammal when it is born with that of monotremes and marsupials.

### Apply

4 A dolphin lives in the ocean and has fins. It breathes air, gives birth to live young and feeds them milk. **Identify** the class that the dolphin belongs in. **Justify** your answer (by comparing the characteristics of the class with the characteristics of the dolphin).

5 A flying fox can glide through the air like a bird but is covered in fur. **Identify** the class that the flying fox belongs in. **Justify** your answer.

6 Seals have fins like fish and live on the land and in the water like amphibians.

a **Investigate** how a seal's young are born.

b Given that the seal has long whiskers, is endothermic and breathes air, **identify** the class of vertebrate in which a seal belongs.

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 5.8 Plants can be classified according to their characteristics

**Learning intentions**

By the end of this topic, you will be able to:

- explain that plants are generally classified according to how they transport nutrients or how they reproduce
- categorise plants using a key.

**Key ideas**

- Plants belong in one of the five kingdoms of living things.
- All plants are multicellular organisms that use sunlight to produce their own energy.
- Plants have a variety of different characteristics that allow us to classify them into different phyla.

**spore**
a tiny reproductive structure that, unlike a gamete, does not need to fuse with another cell to form a new organism

**vascular tissue**
in a plant, tube-like structures that transport water from the roots to the leaves

**pollination**
the transfer of pollen to a stigma, ovule, flower or plant to allow fertilisation

## Seeds or spores?

Planting a seed and watching it grow is something many people do. But not all plants have seeds. Some plants, such as ferns, produce **spores**. Spores are much smaller than seeds and only contain half the genetic material needed to make a fern. They can be found clinging to the underside of a fern frond (Figure 1).

**Figure 1** Not all plants germinate from seeds. Ferns produce spores instead.

**Figure 2** Mosses and liverworts can absorb water through all parts of their structure.

## Vascular tissue

Plants, like all living things, need water to survive. Many plants use their roots to absorb water and transport it through tube-like structures to the leaves. This system of tubes is called the **vascular tissue** of the plant. Not all plants are so organised. Many plants, such as mosses and liverworts, need to live in damp places where they can absorb water through all parts of their structure (Figure 2).

## The importance of flowers

Most plants in your school or home garden produce flowers. Flowers are the way plants attract birds and insects to encourage **pollination** and therefore enable them to produce seeds. Not all plants have true flowers. Conifers have needle-like leaves and produce cones instead of flowers (Figure 3). Pollen from one cone is often transferred to another cone (pollination) so that a seed can be produced.

## Monocots and dicots

Flowering plants can be divided into two main groups. Monocotyledons (monocots) have a single leaf that grows from the seed. They can usually be recognised by the parallel veins in the leaves and by counting the number of petals in the flowers. Monocot flowers always have petals that are multiples of three (Figure 4).

Dicotyledons (dicots) grow two leaves from the seed. Their leaves have veins that are reticulated (spread out from a central vein), and they tend to have four or five petals on each flower (Figure 5).

**Figure 3** Some plants use flowers or cones to produce seeds.

CHALLENGE

**5.8:** Identifying plants
Go to page **239**.

**Figure 4** The number of petals on a monocot flower is always a multiple of three.

**Figure 5** A dicot flower

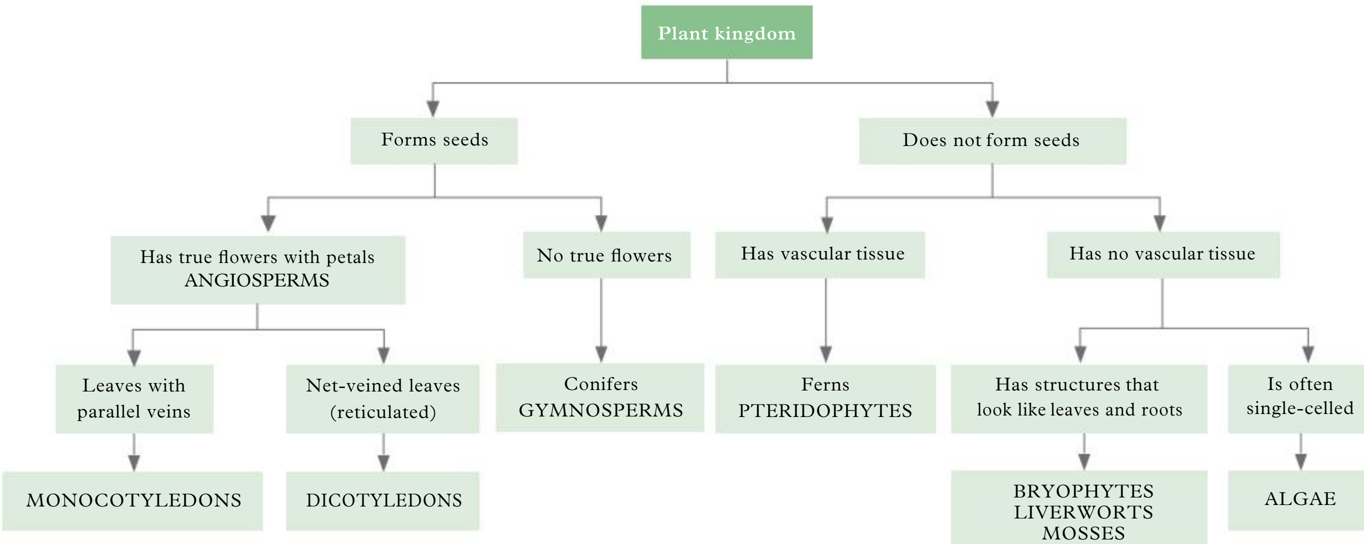



**Figure 6** A sample plant key

## 5.8 Check your learning

### Comprehend

1 **Describe** how mosses, ferns and conifers reproduce.

### Analyse

2 Use the key in Figure 6 to **identify** the features of the plants below.
  a ferns
  b mosses

3 Use the key in Figure 6 to **identify** the kinds of plants below.
  a fruit tree
  b palm tree
  c green weed in a fish tank
  d maidenhair fern
  e bird nest fern
  f moss on the path
  g rose bush
  h vegetables
  i pine tree
  j grass and lawn

4 **Contrast** (the differences between) vascular and non-vascular plants.

5 Who am I? I am large and green. I use sunlight to make my own food. I smell nice and like to come inside at Christmas. Some people do not like me because my leaves can be prickly and needle-like. I use a cone to help me reproduce. **Categorise** me into the plant phylum I belong to.

### Apply

6 Locate a plant in your garden.
  a **Create** a labelled diagram of the plant.
  b **Identify** the features that could be used to categorise your plant.
  c **Propose** at least one feature that is not currently present that would help you to categorise your plant.

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 5.9 The first Australian scientists classified their environment

**Learning intentions**

By the end of this topic, you will be able to:

- describe some of the ways in which First Nations peoples classified and communicated their understanding of local flora and fauna.

**Key ideas**

- Australia is the second driest continent in the world and the driest inhabited continent.
- Despite the harsh climate, Australia is home to hundreds of different organisms.
- First Nations peoples were the first to identify and access the organisms that are unique to Australia.

## The Australian environment

When Europeans first visited Uluru and Kata Tjuta (the Olgas) in the 1870s, they were confronted with a harsh landscape. Their initial aim was to find a route for the overland telegraph line from Adelaide to the Top End and to set up pastures for sheep and cattle grazing. They soon decided that the region was unsuitable and left.

However, the Traditional Owners of the land, the Anangu people, had lived on this land for thousands of years and understood it well.

The Anangu people classified their environment to help them navigate and manage Country. They use the following names:

> *Puli*: rocky areas, gorges, stony slopes; animals come to this area to find shelter and water

> *Puti*: open woodland; after the rains, this area has an abundance of grass, which the kangaroos eat, and honey ants build their nests in this area

> *Pila*: spinifex plains, low areas between dunes; this is the best place to gather seeds to eat.

The Yanyuwa people in the Northern Territory classified all organisms according to where they were located. Their classification system was first divided into two broad categories: coastal/marine or inland. This was then further divided according to the characteristics of the organism. For example, *walya* can refer to all dugong but this is divided into 16 further names according to the dugong's age, size and gender, and even the dugong's status in its herd. This is much more detailed than the descriptions in the Linnaean system.

Early European visitors to Australia often depended on the First Nations peoples to identify and describe the plants and animals in the unique environment. This can be seen with the names that were used when these animals were 'discovered' by European scientists.

**Figure 1** *Puti* habitat

**Figure 2** *Pila* habitat

**Figure 3** *Puli* habitat

Uniquely Australian mammals such as the *wulaba* (wallaby), *buduru* (potoroo), *wularu* (wallaroo), *wumbat* (wombat) and *dingu* (dingo) were all first classified by the Dharawal people of New South Wales.

Mammals are rarely seen during the day in Uluru–Kata Tjuta National Park. Most are nocturnal and come out in the evening, avoiding the heat of the daytime desert. The most abundant groups of mammals are the placentals and the marsupials.

Marsupials, such as the bilby (*Tjalku*, a very important animal for the Anangu people), give birth to underdeveloped young but protect them by having a pouch in which further development can occur. The pouch is similar to that of a kangaroo; however, it is a backward-opening pouch. When the young are fully developed, they can leave the pouch and survive the harsh climate.

**Figure 4** Another example of *Puli* habitat

## 5.9 Check your learning

### Retrieve

1 One of the classes of vertebrate is Amphibia. **Identify** the characteristic of amphibians that would make it difficult for them to live in arid environments. **Identify** the other animal classes that would struggle to survive in arid environments.

2 **Identify** one reason why the bilby's pouch is rear facing.

### Comprehend

3 **Explain** why the Anangu people devised a system of classification for the natural habitats around them.

### Analyse

4 **Infer** why monotremes would find it difficult to breed in arid environments.

### Apply

5 **Investigate** the mammals, reptiles, birds and invertebrates found in the Uluru–Kata Tjuta National Park. Make a list of five for each category. **Classify** each one into its correct group.

6 **Investigate** the kind of environment that the Anangu people lived in and the foods they ate to survive. List at least five animals and five plants they ate.

7 Early Europeans left this environment because they could not survive. **Propose** why they struggled to find food and water here.

8 In a group of four, use a large sheet of paper to **create** two collages about things you would expect to find in Uluru–Kata Tjuta National Park. The first collage should show living things; and the second, non-living things. One pair should create the 'living' collage and the other should create the 'non-living' collage.

9 **Investigate** which mammals can be found in Australia's arid environments. **Classify** each of these mammals as placentals, monotremes or marsupials. List any specific Latin double names (genus and species) given for each animal.

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

**Figure 5** A bilby

//SCIENCE AS A HUMAN ENDEAVOUR//

# 5.10 Taxonomists classify new species

**Learning intentions**

By the end of this topic, you will be able to:

- describe the role of taxonomists in identifying and naming new species
- evaluate the reliability of primary and secondary data.

Taxonomists are scientists who research the classification of new species. There are many organisms in Australia that are yet to be identified. This requires the identification and analysis of primary and secondary data to classify and name the new organism.

## Unique specimens

When a new organism is discovered, it must first be compared with other known organisms to determine if it is different and unique. This is not as simple as it might first seem. For example, in 2012, a new species of horse fly was identified in Queensland by Australian entomologist Bryan Lessard. Like many insects, flies have different stages in their life cycle (Figure 1).

**type specimen**
the specimen used for naming and describing a new species

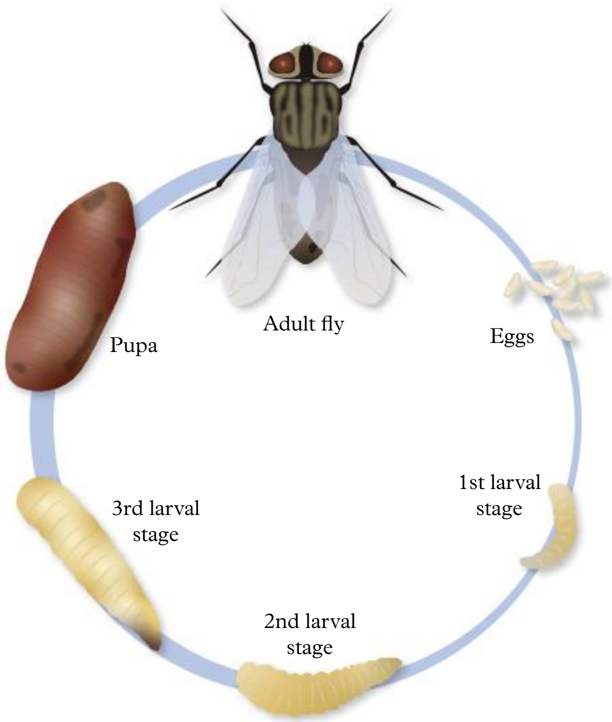



**Figure 1** The fly has many different stages.

**Figure 2** Bryan Lessard (AKA Bry the Fly Guy) digitising the type specimen flies

When a specimen is collected, it is not always known if it is a fully mature organism. The specimen needs to be compared with other **type specimens**. A type specimen is usually one of the first organisms that were collected of each species. It could be a dried plant, a preserved animal or a fossil. These specimens are usually stored in a museum or herbarium.

In 2018, the Australian National Insect Collection was digitised to preserve their almost 15 million biological specimens (Figures 2 and 3). Each specimen was photographed under a microscope and the details recorded. Citizen scientists (members of the public who collect and record data) then recorded the information from the individual labels, allowing the taxonomists to use this information to create an online key that can be used to identify new specimens.

## Naming specimens

There are many rules that must be followed when a new organism is identified. Before it can be named, the organism must be accurately described, drawn and a type specimen preserved. The phylum, class, order and genus must be identified before the species can be named. One of the rules is that the organism cannot be named after the scientist who discovered it. This means if you did find a new species and sent through the taxonomy process, you could not use your own name.

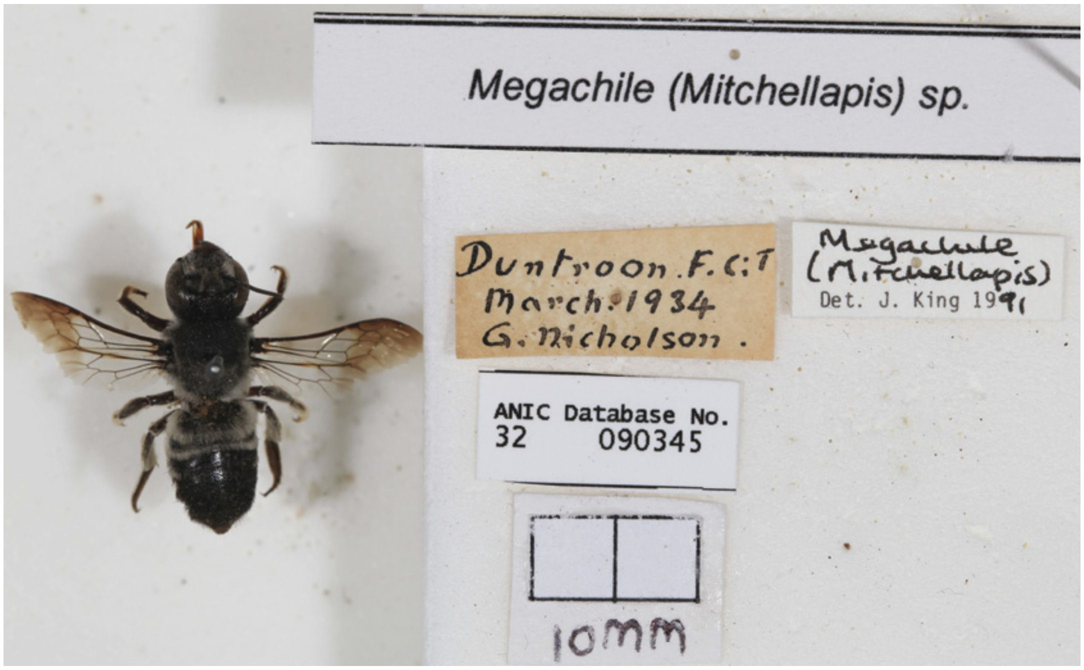



**Figure 3** This leafcutter bee was collected in Canberra in 1934 and is stored in the Australian National Insect Collection.

This does not mean you cannot name it after someone else. Many famous people have animals named after them. After naming almost 50 different species of flies, Lessard named the horse fly with a golden back *Scaptia beyonceae*, after the singer Beyoncé (Figure 4).

Other taxonomists used names to indicate their sense of humour, including beetles named 'not another one' (*Cyclocephala nodanotherwon*) and flies named 'piece of cake' (*Pieza kake*).

**Figure 4** *Scaptia beyonceae* was named after the singer Beyoncé.

## **5.10** Test your skills and capabilities

### Primary and secondary data

There are two sources of data that can be used in scientific research such as taxonomy. Primary data is data collected by the scientist. Secondary data is the data that has already been collected by other scientists. When naming a new organism, the primary data includes the drawings and descriptions of newly discovered organisms. This is then compared with the secondary data of other samples that is stored by the CSIRO in the National Research Collections Australia.

Not all secondary sources of information are as trustworthy as the CSIRO.

**Identify** a source of information located on a website and answer the following questions.

1 Identify who wrote the information or gathered the data. Did they make their observations or measurements in a fair manner, or were they biased (had already decided what they wanted to observe)?
2 Is the source of information a primary source (did the authors make the measurements themselves) or a secondary source (reporting on other people's observations)?
3 When was the information generated? How old is the data? Is it still relevant to your needs?
4 Why did the author write the information or gather the data? Did they want to convince the reader of their view of the world? Does the author gain anything from publishing the data?

# CHAPTER 5 REVIEW

## CLASSIFICATION

### Retrieve

1 **Identify** a reason for classifying living things.
- A Classification helps scientists invent more ways of discussing organisms.
- B Classification helps scientists to communicate new discoveries.
- C Classification helps scientists to keep new information to themselves.
- D Classification helps scientists to shelter living things.

2 **Identify** which of the following is an example of a micro-organism.
- A bacterium
- B chicken
- C kelp
- D sand

3 **Identify** an example of plants moving by themselves.

4 **Name** the five main classes of vertebrates and give an example of each.

5 **Name** two phyla of invertebrates and give an example of each.

### Comprehend

6 **Describe** the advantages of using a dichotomous key.

7 **Explain** why it is important for scientists to use a common system to group all living things on the Earth.

8 **Describe** an example of a plant that has the following characteristic:
- a spores
- b seeds
- c vascular tissues.

9 **Identify** an example of a plant that does not have flowers with petals. **Describe** the alternative structure that allows the plant to produce seeds.

10 'Biodiversity' is the word used by scientists to describe a variety of different organisms in the same region. **Explain** why it is important to preserve a large biodiversity of plants and animals in the world.

11 Imagine that an unknown organism was discovered during a space mission and brought back to Earth. Briefly **describe** two different methods that scientists could use to decide whether it was living or non-living.

### Analyse

12 **Contrast** a monocotyledon leaf and a dicotyledon leaf.

13 **Contrast** vertebrates and invertebrates by writing a definition for each.

14 **Categorise** the items from the following list into the correct columns in Table 1: stewed apple, iPod, daffodil bulb, DVD, hairs in your brush, your teacher, shark's tooth, germs, soft drink bottle, your pet, silver chain, dinosaur skeleton.

**Table 1** Living or non-living?

| Living | | Non-living |
|---|---|---|
| Currently living | Dead | |
| | | |
| | | |
| | | |
| | | |

**Figure 1** Is this dinosaur skeleton living, non-living or dead?

15 Use Table 2 to help you **identify** which phylum the following invertebrates belong to:
- a centipedes
- b octopuses
- c coral
- d leeches.

**Table 2** Tabular key for identifying invertebrates

| | | |
|---|---|---|
| 1 | Body spongy, with many holes | Poriferan |
| | Body not spongy | Go to 2 |
| 2 | Soft body, no shell | Go to 3 |
| | Outside shell or hard cover | Go to 6 |
| 3 | Many tentacles or arms | Go to 4 |
| | Long body without tentacles | Go to 5 |
| 4 | Tentacles around the mouth of a sac-like body | Cnidarian |
| | Arms with suction discs | Mollusc |
| 5 | Soft body, large foot | Mollusc |
| | Worm-like or leaf-like | Nematode, platyhelminth or annelid |
| 6 | Proper shell or smooth, hard covering | Go to 7 |
| | Spiny skin with rough covering | Echinoderm |
| 7 | Limbs in pairs | Arthropod |
| | Shell, no segments, large foot | Mollusc |

16 Look at Figure 2 and Figure 3 and **identify** which class each vertebrate belongs to.

**Figure 2** A cockatoo

**Figure 3** A frog

## Apply

17 Refer to Figure 1 in Topic 5.3 showing Dr Redback's family. **Propose** how the dichotomous keys in Figures 2 and 3 could be modified if his 'family' included his sister, Melinda; his mother, Frances; he had two daughters, Stef and Gemma (Stef wears glasses); and he had a pet lizard named Stealth but not a bird named Charlie.

18 One of the main contributors to the *Encyclopedia of Life* is the *Atlas of Living Australia*. Do an internet search for the *Atlas of Living Australia* and click on 'Explore'. From this page, you can **create** a species list and map for the area in which you live.

a **Identify** the most frequently seen animal in your area.

b **Identify** the most frequently seen plant in your area.

19 Look at Table 3, showing the number of living things on the Earth.

a **Determine** the number of plant species that were estimated to be on the Earth in 2009.

b **Contrast** the number of *known* plant species with the total number of *known* animal species (add animals without a backbone and animals with a backbone together).

**Table 3** Types and numbers of living things on the Earth

| Group | Number of species described | Number of species estimated to exist | Percentage of total estimated number of living things (%) |
|---|---|---|---|
| Animals with internal backbones (vertebrates) | 64 788 | 80 500 | 0.7 |
| Animals without a backbone (invertebrates) | 1 359 365 | 6 755 830 | 61.8 |
| Plants | 297 857 | 390 800 | 3.6 |
| Fungi | 98 998 | 1 500 000 | 13.7 |
| Bacteria (Monera) | 35 351 | >1 200 500 | 11 |
| Algae and protozoa (Protista) | 28 871 | >1 000 000 | 9.2 |
| Total number of species | 1 885 230 | >10 927 630 | 100 |

Source: Chapman, A. D. 2009, *Numbers of Living Species in Australia and the World*, 2nd edn.

## Social and ethical thinking

20 There is often conflict between the rights of animals and those of humans. Animal rights supporters believe it is wrong to use animals in any way. In contrast, animal welfare supporters believe it is acceptable for humans to use animals (such as testing vaccines) as long as the animals do not suffer. Write two reasons that support the view of each group. **Discuss** the reasons with others in your class.

## Critical and creative thinking

21 Download and print a copy of Figure 4 from your obook.

a Cut out the pictures of the insects.

b On your own, sort the insects into groups based on appearance. **Justify** your system of classification (by explaining why you made each decision).

c **Compare** your groupings with those of a partner. Together, **identify** a third way to classify the insects.

d With your partner, **create** a dichotomous key.

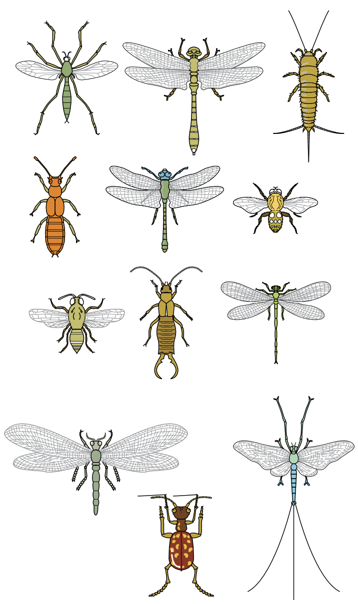


**Figure 4** Collection of insects

22 Design an experiment to show that plants are living things that respond to stimuli. Choose one stimulus (such as reaction to light or a lack of water) to **investigate**. This stimulus is the experimental variable, so you will need to change the variable in some way and control the rest of the variables. Make a list of the equipment you would need.

23 **Discuss** why the invention of the microscope was important to the development of the classification system.

## Research

24 Choose one of the topics to present a report in a format of your choice. Some ideas have been included to get you started. Your report must include a classification key.

### » A newspaper article

Write a newspaper article about how life on Earth is organised. It needs to be about two pages long (no more than 500 words). You should explain how living things are classified for an audience unfamiliar with science. Make a list of the living things whose images you would like to use to illustrate the article. Try to find their scientific and common names. Your article must contain a key of some description.

### » A trip to the Kimberley region

You have just returned from a trip to a remote mountain area of the Kimberley, in Western Australia. While there, you took your portable microscope and examined water from a previously unknown lake. To your surprise, you found some new creatures in the water that look a bit like bacteria. They are single-celled and are either square or oval; some are hairy (have hairs either on the end of the cell or along the edge of the whole cell).

- Draw six different versions of these organisms.
- Create a dichotomous key for these six new organisms so that you can describe them to other scientists.
- Name each of the groups at the bottom of your key.
- Assuming they are a type of bacterium, identify the kingdom to which they would belong.

### » Classifying fossils

Living organisms are not the only things that can be classified. The remains or impression of prehistoric plants or animals that are found in rock can also be classified according to their unique characteristics.

- Identify a photo of a fossil.
- Describe the characteristics that could be used to classify it.
- Identify the group it could belong to in the Linnaean classification system.
- Justify your decision by comparing it to another organisms in the same group.

# Chapter checklist

Now that you have completed this chapter, reflect on your ability to do the following.

| | I can do this. | I cannot do this yet. |
|---|---|---|
| • Explain the purpose of classification systems and how they are used by scientists. | ☐ | ☐ Go back to Topic 5.1 'Classification organises our world'. Page 116 |
| • Describe the eight characteristics shared by all living things using the acronym MR N GREWW. | ☐ | ☐ Go back to Topic 5.2 'Living organisms have characteristics in common'. Page 118 |
| • Construct and use tabular and dichotomous keys for classification. | ☐ | ☐ Go back to Topic 5.3 'Classification keys are visual tools'. Page 120 |
| • Describe the two-part naming system devised by Linnaeus.<br>• Identify the genus and species of an organism from its two-part name. | ☐ | ☐ Go back to Topic 5.4 'The classification system continues to change'. Page 122 |
| • Explain how living things have been classified into different kingdoms.<br>• Describe how classification of organisms changes as new information becomes available. | ☐ | ☐ Go back to Topic 5.5 'Kingdoms can be used to classify organisms'. Page 124 |
| • Explain that invertebrates have either an exoskeleton or no skeleton.<br>• Identify the six main phyla of invertebrates. | ☐ | ☐ Go back to Topic 5.6 'Animals that have no skeleton are called invertebrates'. Page 126 |
| • Distinguish between vertebrates and invertebrates.<br>• Identify the five classes of vertebrates and use the terms 'endotherm' and 'ectotherm' to group them. | ☐ | ☐ Go back to Topic 5.7 'Vertebrates can be organised into five classes'. Page 128 |
| • Explain that plants are generally classified according to how they transport nutrients or how they reproduce.<br>• Categorise plants using a key. | ☐ | ☐ Go back to Topic 5.8 'Plants can be classified according to their characteristics'. Page 130 |
| • Describe some of the ways in which First Nations peoples classified and communicated their understanding of local flora and fauna. | ☐ | ☐ Go back to Topic 5.9 'The first Australian scientists classified their environment'. Page 132 |
| • Describe the role of taxonomists in identifying and naming new species.<br>• Evaluate the reliability of primary and secondary data. | ☐ | ☐ Go back to Topic 5.10 ' Science as a human endeavour: Taxonomists classify new species'. Page 134 |

**Check your Student obook pro for these digital resources and more:**

pro

**Quizlet**
Play a Quizlet game to test your knowledge.

**Chapter quiz**
Test your understanding of this chapter with the chapter review quiz.

CHAPTER

# 6

# ECOSYSTEMS

**6.1**

**All organisms are interdependent**

> Define producer and consumer and identify examples of each.
> Construct and interpret food chains and food webs.

**6.2**

**All organisms have a role in an ecosystem**

> Define the term 'ecosystem'.
> Explain the different types of relationships that can exist within ecosystems.

**6.3**

**Energy flows through an ecosystem**

> Define the terms 'herbivore', 'carnivore' and 'omnivore'.
> Describe how energy flows through an ecosystem.

6.4

**Population size depends on abiotic and biotic factors**

> Distinguish between abiotic and biotic factors.

> Explain how different factors can cause a population to increase or decrease.

6.5

**Introducing a new species may disrupt a food web**

> Define introduced species.

> Explain how an introduced species can impact an ecosystem.

6.6

**Ecosystems can be disrupted**

> Describe how natural disasters can impact ecosystems.

> Describe how human activity can impact ecosystems.

6.7

**Science as a human endeavour: Human management of ecosystems continues to change**

> Describe how First Nations peoples have used different practices to manage ecosystems.

# What if?

## Food webs for humans

**What you need:**

Whiteboard, whiteboard marker, index cards, Blu-Tack

**What to do:**

1. Draw a circle at the bottom of the whiteboard to represent the Sun.
2. Write the following on separate cards and distribute among the class: grass, kangaroo, turtle, human, corn, chicken, duck, pig, hay, grasshopper, cow, trout, shark, seal, plants, twigs, rabbit, berries, carrot, mosquito, worm.
3. Read the statements below and attach corresponding index cards to the whiteboard with Blu-Tack.
   - 'Plants obtain their energy from the Sun.'
   - 'Your organism eats plants.'
   - 'Your organism eats any of those already displayed.'
4. Repeat the third statement in step 3 until all cards are used.

**What if?**

» What if pesticides killed all the insects?

# 6.1 All organisms are interdependent

**Learning intentions**

By the end of this topic, you will be able to:

- define producer and consumer and identify examples of each
- construct and interpret food chains and food webs.

Interactive 6.1
Food chains

**food chain**
a diagram that shows who eats whom in an ecosystem, and how nutrients and energy are passed on


**Figure 2** An example of a backyard food chain

**Key ideas**

- Scientists use a food chain to show the flow of food and energy in an ecosystem.
- Producers are found at the start of the food chain.
- Consumers need to gain their energy from other organisms.
- Food webs have many interlinking food chains.

## Food chains

A **food chain** is a way to show the direction that nutrients and energy flow between organisms. It consists of a chain of arrows that always points from the food to the animal doing the eating. For example, a centipede eats a wolf spider. This means the arrow points from the wolf spider to the centipede (Figure 1). The wolf spider provides the centipede with energy to grow and move.

Wolf spider → Centipede → Currawong

**Figure 1** A simple food chain

Plants and plant-like organisms are always found at the start of food chains because they only need air, water, sunlight and a few trace minerals to live and grow. These organisms are known as the **producers** of the ecosystem. Most producers convert light energy from the Sun into sugars (stored chemical energy). These sugars are known as biological molecules and are stored in the leaves, stems and roots.

Animals cannot use the Sun's energy in this way. They are **consumers** and must eat other organisms to get the energy they need to survive. They use this energy to stay alive – to pump their blood, to move their muscles and to operate their nerves. The first consumers in a food chain are also referred to as **first-order (primary) consumers**.

In Figure 4 the mountain water skink is a first-order consumer because it eats plants. Because the noisy miner bird eats a first-order consumer, it is called a **second-order (secondary) consumer**. The feral cat eats the second-order consumer and becomes a **third-order (tertiary) consumer**. Most food chains only have four to five organisms in them. This is because only some of the energy is stored in the consumers. The rest is converted into heat and movement by the organism.

## Food webs

Most animals, including humans, will eat more than one type of food. This can be represented in a **food web**, which shows several food chains intertwined. Some consumers will have several labels, depending on their eating habits.

Figure 5 shows a food web in which there are four different producers. In this example, the mouse can be considered both a primary and secondary consumer because it eats a producer (wheat seeds) and primary consumers (snail and beetle). In this food web, the snail is only a primary consumer because it only eats producers (the trees).

Food webs show how every living thing in the environment needs every other living thing to survive. When people talk about the 'web of life', they are referring to the interactions between all living things.

Producer → First-order consumer → Second-order consumer → Third-order consumer

Same as

Producer → Primary consumer → Secondary consumer → Tertiary consumer

**Figure 3** A food chain starts with producers, such as plants, and moves through several orders of consumers.

CHALLENGE

6.1 Studying food webs
Go to page 240.

**consumer**
an animal that can't convert the Sun's energy into sugars and instead must eat to get the energy it needs to survive

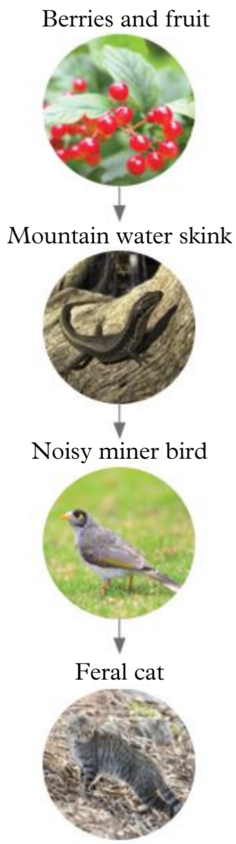



**Figure 4** A food chain showing the feral cat as a third-order consumer

**producer**
a plant or plant-like organism that is at the start of food chain because it produces its own food, usually using sunlight

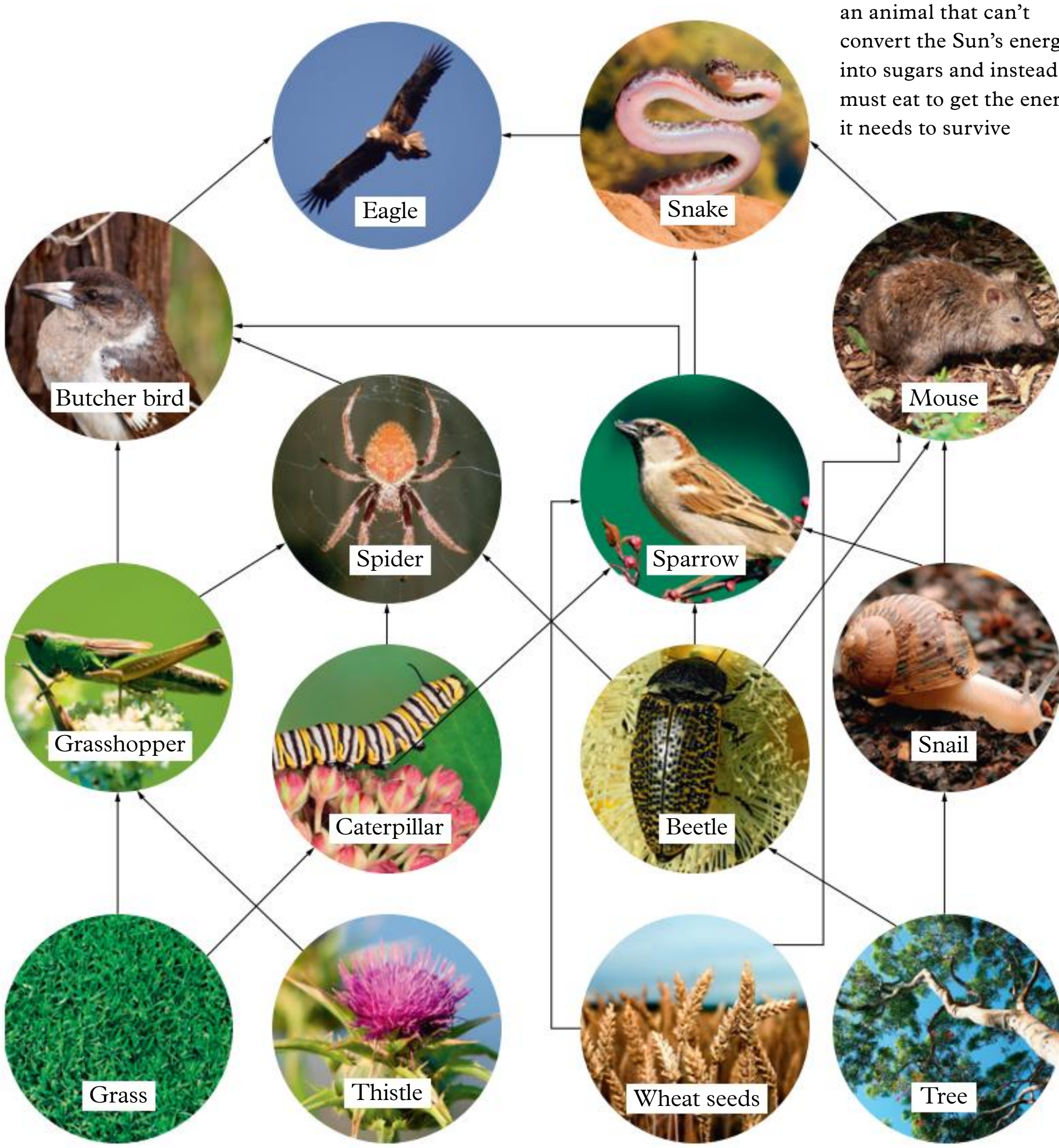



**Figure 5** A food web shows the extended relationships between various organisms.

## 6.1 Check your learning

### Retrieve

1 **Identify** where producer plants get their energy.

### Comprehend

2 **Describe** how the direction of arrows in a food chain is decided.

### Analyse

3 **Contrast** (the differences between) food chains and food webs.

4 **Examine** the food web in Figure 5.

a **Identify** an animal that is both a secondary and a tertiary consumer.

b **Classify** the type of consumer of the snake in this food web.

### Apply

5 Imagine that you were asked to find out how many different types of animals lived in your backyard or local park. **Discuss** how you would go about finding this out. (HINT: Would it be possible to individually count them all?)

6 **Construct** your own food web of organisms that you would find in the local park. Correctly **identify** the producer and all the consumers.

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

**first-order (primary) consumer**
an organism that eats only producers such as plants, algae and bacteria; it does not eat other consumers

**second-order (secondary) consumer**
a carnivore that eats primary consumers

**third-order (tertiary) consumer**
a carnivore that eats primary and secondary consumers and is therefore at the top of the food chain

**food web**
several intertwined food chains, showing the extended relationships between different organisms

# 6.2 All organisms have a role in an ecosystem

**Learning intentions**

By the end of this topic, you will be able to:

- define the term 'ecosystem'
- explain the different types of relationships that can exist within ecosystems.

**Key ideas**

- An ecosystem is a community of living organisms and their surroundings.
- Predators eat prey.
- Symbiotic relationships are long term relationships.

**ecosystem**
a community of living organisms and their non-living surroundings

**population**
a group of individuals of the same species living in the same location at the same time

**community**
different populations living in the same location at the same time

**predator**
an animal that hunts and feeds on another (prey) for food

**prey**
an animal that is hunted and killed by another (predator) for food

## Ecosystems

When studying the environment, we can look at a small part such as the organisms living in or on a log, or we can study a whole forest. When we study a large area with a lot of living organisms and non-living things (such as hot temperatures, little light or water), we say that we are studying an **ecosystem**.

Ecosystems vary in size. They can be as small as a puddle or as large as the Earth itself. Ecosystems are made up of **populations**. A population is a group of living organisms that are the same species, living in the same place at the same time. When different populations interact with one another, they are called a **community**. For example, a population of humans can live in a town together. When all the plants in their gardens and their pets are included, then it becomes a community.

An ecosystem must supply all the needs of the organisms, such as food, water, warm temperatures, oxygen and minerals. These make up the non-living parts of the ecosystem. If these conditions are wrong for a population, then the individuals in that population will move to a better ecosystem or they will die out.

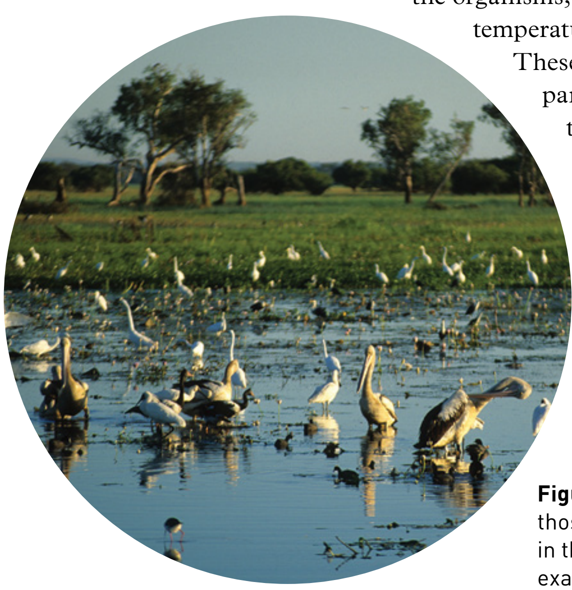


**Figure 1** Wetlands, such as those in Kakadu National Park in the Northern Territory, are an example of an ecosystem.

## Relationships between different species

### Predator–prey

In a predator–prey relationship, one organism (the **predator**) eats another (the **prey**). This relationship only lasts for a short time (until the prey is eaten), and it only happens when a predator is hungry. An example of this is the relationship between a fox and a rabbit (Figure 2). The two species only meet when the fox is hungry and starts hunting the rabbit (the prey). When the rabbit is caught, the relationship ends.

**Figure 2** A fox is the predator of a rabbit (the prey).

Predator species and their prey species have a balanced relationship. If all the prey are eaten, then the predators will starve. As the number of predators decreases (shown by the graph going down in Figure 3), the number of prey will increase again because they are not being hunted as often. This makes the prey numbers in a graph go up. When the number of prey goes up, the predators can hunt more food. This means a predator–prey graph will always show the predator line following the prey line. Figure 3 shows this pattern.

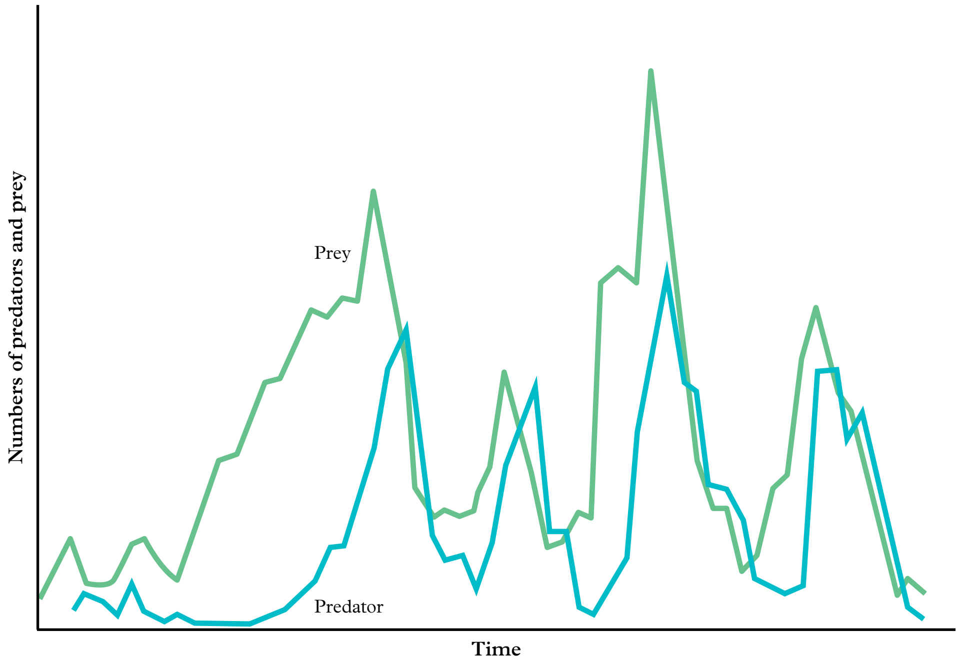



**Figure 3** A predator–prey graph – the scales aren't shown but the prey numbers are mostly greater than those of the predators. Notice that the increase and decrease in prey numbers usually comes before the increase and decrease in predator numbers.

## Competition

**Competition** may also exist between members of different species that need the same food (Figure 4) or shelter. If one species grows quicker, then any species trying to compete may 'lose' and die. Usually, competing species will balance their numbers so that neither one dominates.

Sometimes inhibition competition occurs when one organism produces a chemical that directly inhibits or blocks the survival or growth of another organism (Figures 5 and 6).

**competition**
contest between organisms that require or seek similar resources such as shelter and food

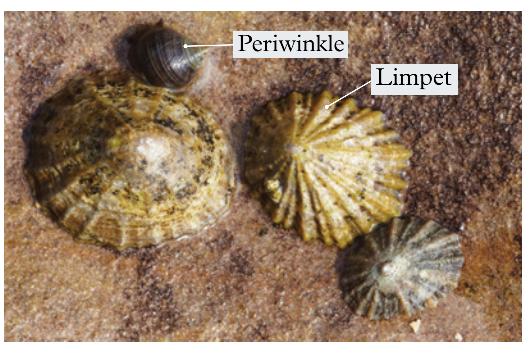



**Figure 4** A black periwinkle (*Nerita*) competes for food with the limpet (*Cellana*) on a rock platform – both species feed on algae growing on the rocks. The periwinkle moves faster but does not eat all the algae in its path. This means there is some food left for the limpet. Both species can survive because the periwinkles usually leave some algae behind for the limpets. However, when the periwinkles are removed, the limpet population increases.

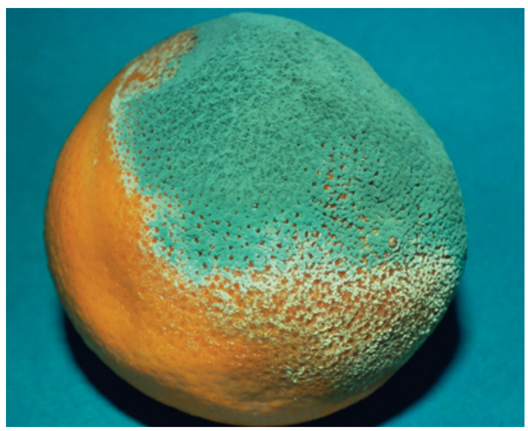


**Figure 5** *Penicillium* fungus mould (seen here growing on an orange) produces an antibiotic called penicillin that inhibits or blocks the growth of many bacteria.

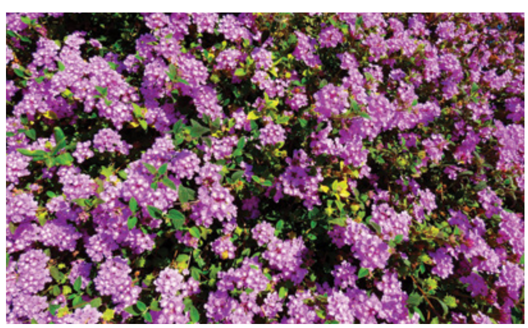


**Figure 6** The *Lantana* plant was introduced into Australia and has become a weed. It releases a chemical into the soil that inhibits or blocks the growth of native plant species.

**symbiosis**
a close physical relationship between two organisms of different species

**mutualism**
a type of relationship between two organisms of different species, in which both organisms benefit

**commensalism**
a type of relationship between two organisms of different species, in which one organism benefits and the other is not affected

**parasitism**
a relationship in which one organism (parasite) lives in or on the body of another organism (host) and benefits while the host is harmed

## Symbiosis

**Symbiosis** happens when two organisms of different species live physically close to each other for a long time. Mutualism, commensalism and parasitism are all examples of symbiosis.

**Mutualism** is a relationship between two organisms in which both organisms are able to help each other to survive. They both benefit.

**Commensalism** is a relationship in which one organism benefits and survives while the other organism does not notice and is not affected. Commensalism does not happen very often in an ecosystem because it is unlikely that an organism does not notice another organism is living so closely to it.

**Parasitism** is a relationship in which one organism (the parasite) lives in or on the body of another (the host). The parasite benefits by taking some of the food and nutrients from the host. This means the host often struggles to survive with less food. Sometimes that parasite can even kill the host.

**Figure 7 Mutualism** A lichen is an alga and a fungus, although you cannot see the two organisms separately (except under a microscope). The alga produces energy from the sun for both organisms, and the fungus provides support and other nutrients.

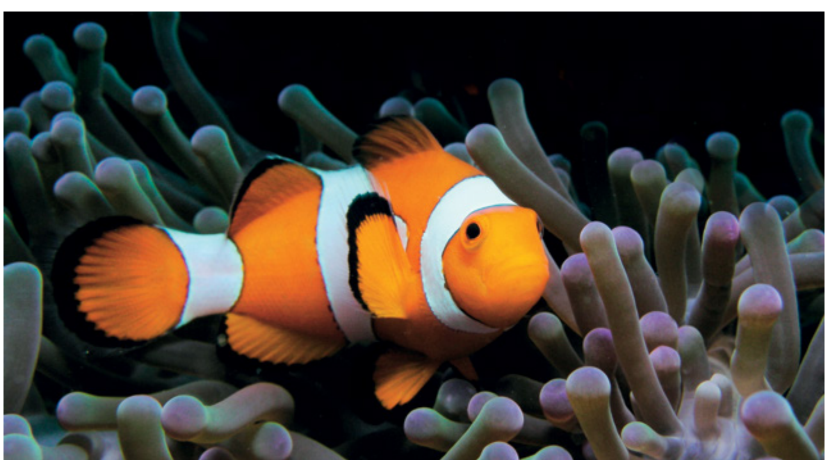


**Figure 8 Mutualism** The anemone fish hides within the tentacles of the sea anemone, where it is camouflaged from its predators. The fish cleans all the algae from the sea anemone.

**Figure 9 Commensalism** Some animals such as cattle and water buffalo make insects fly up as they walk through the grass. Birds such as cattle egrets benefit by feeding on the insects.

**Figure 10 Commensalism** Certain plants have seeds with tiny hooks. These seeds stick to animal fur and are carried away from the parent plant. This means the parent plant will be able to keep all the sunlight and nutrients for themselves.

**Figure 11 Parasitism** Ticks attach to the skin of animals and slowly drink their blood. Although the amount of blood is small, the tick can infect the animal with bacteria, causing it to die.

EXPERIMENT

**6.2:** What if more seeds were planted in a pot?
Go to page **241**.

**Figure 12 Parasitism** Hookworms attach to the inside of a human or animal intestine, feeding on passing nutrients. If the host doesn't eat enough, the worm has been known to burrow out of the intestines and travel to other organs, where they can cause damage to the host.

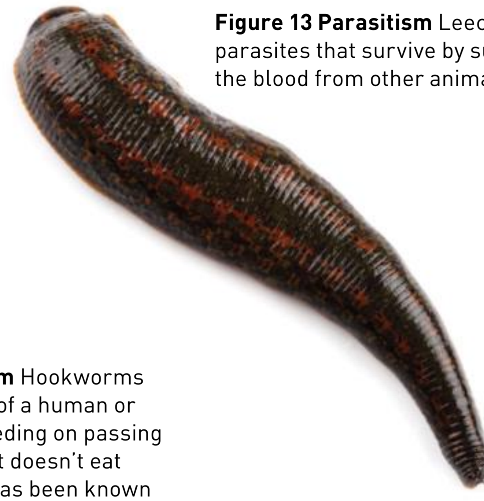


**Figure 13 Parasitism** Leeches are parasites that survive by sucking the blood from other animals.

## 6.2 Check your learning

### Retrieve

1 **Define** symbiosis.

### Comprehend

2 **Describe** an example of the following relationships.
  a predator–prey
  b mutualism
  c commensalism
  d parasite–host

3 **Explain** why a large plant that produces a lot of shade prevents smaller plants from growing.

### Analyse

4 **Contrast** (the differences between) a predator–prey relationship and parasitism.

### Apply

5 Some eucalyptus trees have mistletoe plants living on them. Mistletoe has very similar leaves to eucalyptus leaves. Mistletoe can make its own food, but the stems send suckers into the eucalypt to obtain water and minerals. If too much water and minerals are removed, the eucalypt can die. **Identify** the type of relationship that exists between the eucalypt and the mistletoe. **Justify** your answer (by defining the relationship and matching it to this example).

6 Epiphytes are plants, such as ferns and some orchids, that grow high in the branches of other trees, especially rainforest trees. The epiphytes obtain sufficient light to make their own food, collect water from the moist air and obtain minerals from the decaying leaf litter that they catch at their leaf bases. The tree is not affected by these plants. **Identify** the type of relationship that is described. **Justify** your answer (by describing how each species benefits from, doesn't notice or is harmed by the relationship).

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 6.3 Energy flows through an ecosystem

**Learning intentions**

By the end of this topic, you will be able to:

- define the terms 'herbivore', 'carnivore' and 'omnivore'
- describe how energy flows through an ecosystem.

**Key ideas**

- Animals that only eat plants are called herbivores.
- Animals that only eat other animals are called carnivores.
- Animals that eat both plants and animals, like humans, are called omnivores.
- Microorganisms obtain energy by breaking down dead organisms.

## Energy transfer

All food chains show the transfer of energy from the organism that is eaten to the consumer. This transfer of energy is shown by the direction of the arrow in the food chain or web. The source of energy in most food webs is light energy from the Sun. Even in caves, where there is no sunlight, there may be energy from dead plants and animals, which originally obtained their energy from the Sun. An exception is chemosynthetic bacteria on the ocean floor and in the craters of volcanoes – these bacteria trap the energy from chemicals and chemical reactions occurring under the Earth's crust.

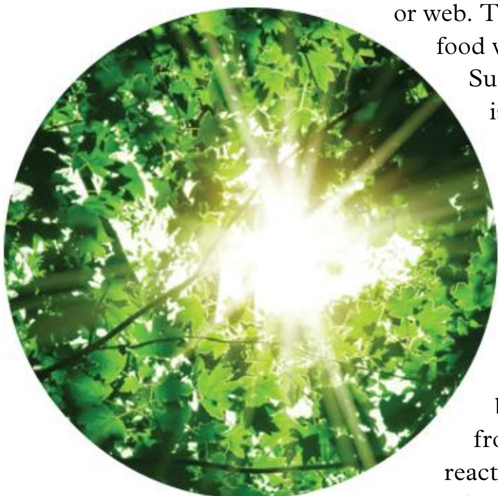


**Figure 1** Plants use energy from the Sun to grow and repair.

## What is photosynthesis?

Living things need energy to grow and repair, to defend themselves, and to move around. Plants, some algae and some bacteria are able to transform the light energy from the sun into chemical energy through a process called **photosynthesis**. In this process, the plant takes in water from the roots and carbon dioxide through their leaves. The water is transported to the leaves, where it is combined with the carbon dioxide to make glucose (a sugar) and oxygen. This can be shown by a word equation for photosynthesis:

carbon dioxide + water → glucose + oxygen

Sugars like glucose provide chemical energy that plants can use to make new leaves and stems. Animals that eat plants are called first-order consumers or **herbivores**. The chemical energy in the plant is used by the animal to move and grow. Some of the energy is stored in the muscles and fat of the animal. When a second-order consumer or **carnivore** such as a dog eats the herbivore, it is able to use the energy in the fat and muscle to keep hunting. Humans eat both meat and plants, making them **omnivores**. Every time the plants and animals grow and move, the chemical energy is transferred to movement energy.

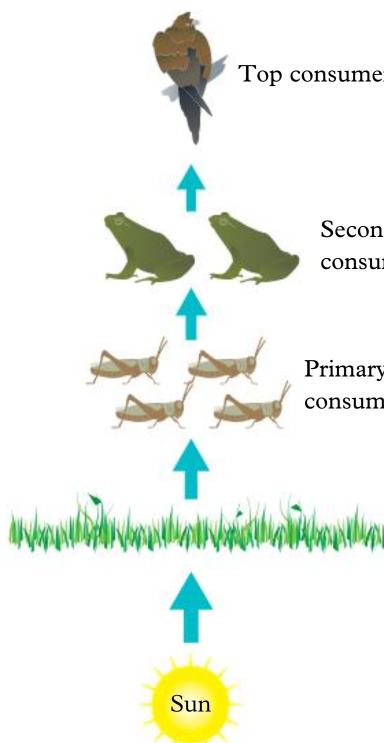



**Figure 2** An example of the movement of energy through an ecosystem, where each green arrow represents the transfer of energy

**photosynthesis**
a chemical process used by plants to make glucose and oxygen from carbon dioxide, sunlight and water

**herbivore**
an animal that eats only plants

**carnivore**
an animal that eats other animals

**omnivore**
an animal that eats both plants and animals

CHALLENGE

**6.3:** Exploring leaf litter
Go to page **242**.

## Some microorganisms decompose organic matter

As well as energy, locked inside all organisms is an enormous amount of nutrients. All organisms in a food web end up passing these nutrients and energy on to **decomposers**. Decomposers – such as bacteria, fungi and invertebrates (slugs and worms) – get the food they need by feeding on dead things. This breaks down the dead organisms and prevents them from piling up. Instead, the chemical energy in the dead organism's muscle and fat are used for energy by the decomposers. When another organism eats a decomposer, the particles (atoms) that make up the nutrients once again become part of the food chain. The nutrients that pass through the decomposers as waste end up in the soil as simpler particles. Plant roots can then absorb the nutrients and the cycle starts again. Imagine what life would be like without decomposers!

**Figure 3** Decomposers recycle important nutrients in an ecosystem.

**Figure 4** Mushrooms (fungi) are decomposers. They get the nutrients they need by feeding on dead things, such as rotting logs.

**decomposer**
an organism that gains nutrients by breaking down dead organisms into simpler nutrients

## Wetlands and forests help clean water

If you poured dirty water through a filter, you would expect cleaner water to come out. A similar thing happens in nature when water passes through a forest or wetland ecosystem. By slowing the flow of water, the plants and bacteria trap some of the pollutants and sediments. But plants are not the only living things that clean water. Aquatic animals, such as freshwater clams, pump water through their bodies to filter out food for themselves and, in so doing, clean the water they live in.

**Figure 5** Forested water catchment areas are vital for keeping Queensland's water supplies clean.

## 6.3 Check your learning

### Retrieve

1 **Identify** the term used to describe animals that eat both meat and plants.

2 **Identify** the following as either an input or an output of photosynthesis.
- **a** carbon dioxide
- **b** glucose
- **c** water

### Comprehend

3 **Describe** one consequence that may occur if decomposers did not exist.

### Analyse

4 **Compare** (the similarities and differences between) the following terms: producer, first-order consumer, second-order consumer, herbivore, carnivore, photosynthesising organism.

### Apply

5 We get the energy we need by eating other living organisms. **Determine** the source of energy for the following organisms.
- **a** Plants
- **b** Herbivores
- **c** Decomposers

6 'Photosynthesis is the most important metabolic process on Earth.'
**Evaluate** the above statement by:
- **a** **describing** why photosynthesis is important in an ecosystem
- **b** **describing** what would happen if photosynthesis was not able to occur
- **c** **deciding** whether the statement is correct.

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 6.4 Population size depends on abiotic and biotic factors

**Learning intentions**

By the end of this topic, you will be able to:

- distinguish between abiotic and biotic factors
- explain how different factors can cause a population to increase or decrease.

**Key ideas**

- All populations are in a constantly changing equilibrium.
- Deaths and emigration can decrease a population.
- Births and immigration can increase a population.

**abiotic factors**
non-living factors that influence an ecosystem, such as wind, water, salinity and temperature

**biotic factors**
living factors that influence an ecosystem, such as animals, plants and bacteria

**immigrate**
when an animal enters a new ecosystem

**emigrate**
when an animal leaves an ecosystem

## Populations

Like a population of humans in a city, the population of living organisms in an ecosystem is constantly changing. In a drought there are high temperatures and little rain. This can make it hard for plant and animal populations to survive. The amount of water or temperature are non-living factors (called **abiotic factors**) that can affect the size of a population. Other abiotic factors that can affect the number of organisms in a population include the amount of sunlight, salt in the water, soil, available nutrients or places for the organism to hide.

Sometimes it is the number of other organisms competing for food or hunting them which can affect the number of organisms in a population. These 'living' factors that affect the survival of organisms are called **biotic factors**.

## A dynamic balance

All organisms live in a complex web of interdependent relationships – with each other and with their environment. In an ecosystem, there needs to be a balance so that all species can survive. The more types of organisms in an ecosystem, the healthier the community of organisms in the ecosystem.

Many things can cause a population of organisms to increase in number. A population of birds will increase when new chicks are born, or when new birds fly into the ecosystem (**immigrate**). In contrast, the number of birds in the population will decrease if some birds die because of hunger or because they are hunted. Sometimes the birds will leave to fly to another ecosystem (**emigrate**) (Figure 2).

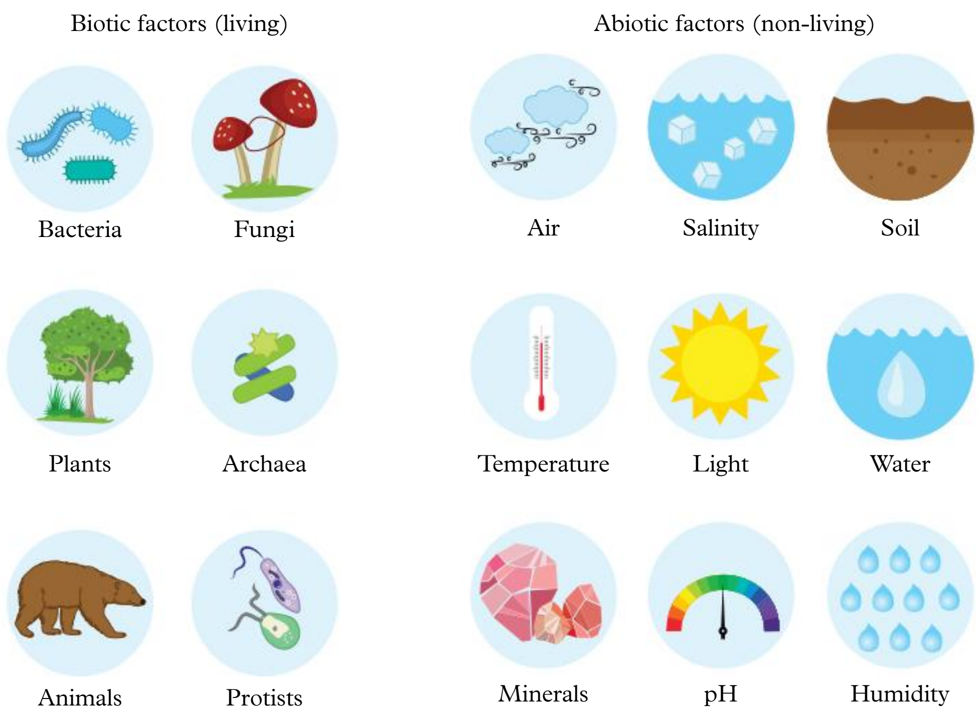



**Figure 1** A comparison of biotic and abiotic factors

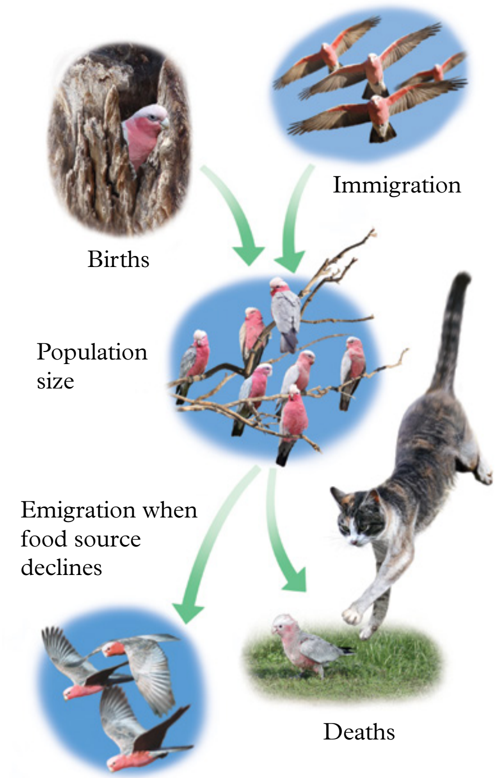



**Figure 2** The size of a galah population in a particular area depends on the food available and the number of births and deaths.

Whenever the size of a population changes, it can affect other organisms in the ecosystem's food web.

Consider the food web for an ecosystem shown in Figure 3. If the number of frogs decreased in this ecosystem, the effects could include:

> an increase in grasshopper numbers, causing the amount of grass to decrease
> an initial increase in praying mantis numbers because of more grasshoppers
> a decrease in lizard numbers
> more birds eating praying mantises rather than frogs and lizards
> a decrease in praying mantis numbers because they are being eaten by birds
> further increase in grasshopper numbers who then start eating the grass. If this was severe enough, the ecosystem would be at risk, because all food webs depend on a good supply of producers.

The most likely outcome is that the bird population would decrease, so all species would return to balance with smaller population sizes. A positive effect is that decreased bird numbers might enable the frog population to recover.

Ecosystem balance constantly changes before returning to a new stable balance. This is called a dynamic equilibrium. Changes may upset the equilibrium, but another new equilibrium arises. Often, the change is only a small one. Changes in ecosystems occur naturally but they may be intensified by external abiotic factors such as floods and bushfires. Reproduction, death, migration, natural events (such as seasonal changes), disasters (floods, droughts, earthquakes) and human intervention occur regularly. Biotic factors, such as the loss of a species or the introduction of a new species, can also change a population.

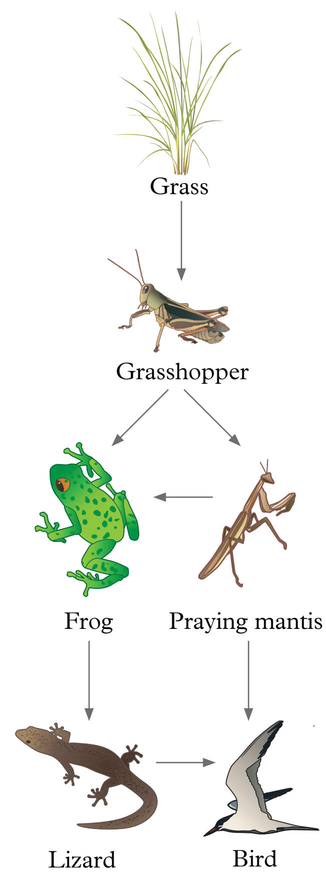



**Figure 3** A food web for an ecosystem

## Population dynamics

**Population dynamics** is the study of changes in population numbers within ecosystems. If scientists can measure how many of each species are in a certain location, they can make predictions and try to prevent a species becoming extinct.

Regular sampling provides information about increases and decreases in population numbers, and causes can be identified.

**population dynamics** the study of changes in species population numbers and the factors that may contribute to these changes

## Counting organisms

There are many ways to measure the size of a population. The simplest way would be to count all the organisms, but in practice this is very difficult. It is easier to estimate the total population by counting a sample from a helicopter, or by using **quadrats** or **capture–recapture** methods. For human populations, a census is the usual method.

**quadrat**
a randomly selected square plot used to estimate the number of organisms

**capture–recapture**
a method of estimating the number of organisms by capturing, marking and releasing a sample of the organisms

For plants and stationary animals, quadrats (randomly selected square plots) are marked in an ecosystem (Figure 4). The organisms in each plot are counted and used to calculate the average number of organisms in each square plot. The total number of organisms in the whole ecosystem can then be calculated by multiplying the average number of organisms by the area of the ecosystem. This method works well if a large number of quadrats are used and the organisms are evenly spread throughout the ecosystem.

For animals that are moving, capture–recapture is a popular method. Animals are captured in traps and marked with tags, correction fluid or permanent marker on their tails.

The number counted on the first capture are called tagged animals (Figure 5). The animals are then released and it is assumed that they move evenly throughout the population. Another capture (recapture) is made one or two days (or nights) later. Some of these recaptured animals will have tags. An estimate of the population is then obtained using these three numbers:

Total number of animals = number of tagged animals × number of recaptured animals ÷ number of tagged animals recaptured

Capture–recapture is a good way to estimate the population size of small Australian mammals, such as the marsupial *Antechinus* (the common bush rat). Because most native Australian mammals are nocturnal, the traps may be set at night and checked the next morning.

## Modern counting methods

When tags or quadrats are used to count organisms, it can disrupt their environment and affect the way the animals behave. Modern counting methods can avoid this disturbance by using remote sensors that detect movement and turn on unmanned cameras (Figure 6). These images allow scientists to count the number of animals moving in an area and to study how animals behave when humans are not around. Other ways to identify animals is to record the calls they make to one another. This recording can then be used to identify the species of animal and the number of them making and replying to the calls.

**Figure 4** Using a quadrat

**Figure 5** A scientist tagging a bird

CHALLENGE

**6.4:** Bead counting
Go to page **243**.

## Worked example 6.4: Calculating population size

Scientists wanted to determine the size of a bilby population in a small reserve. They used the capture–recapture method to estimate the size of the population.

They captured and marked 9 bilbies on the first night and 8 bilbies (4 marked) one week later.

Calculate the size of the bilby population.

### Solution

Number of tagged/marked animals = 9
Number of recaptured animals = 8
Number of tagged animals recaptured = 4

Estimated number of bilbies = number of tagged animals × number of recaptured animals ÷ number of tagged animals recaptured

$= 9 \times 8 \div 4$

$= 18$

**Figure 6** Remote sensors can be used to record and identify animals without disturbing their normal behaviour.

## 6.4 Check your learning

### Retrieve

1 **Identify** two examples of abiotic factors and two examples of biotic factors.

### Comprehend

2 **Describe** two ways a population can:
 a increase
 b decrease.

3 **Describe** suitable methods for estimating the size of populations of:
 a plants and stationary animals
 b other animals.

4 **Explain** how predator–prey relationships achieve a state of balance by **describing** what happens to the number of predators or prey when:
 a prey numbers increase
 b prey numbers decrease
 c predator numbers increase
 d predators numbers decrease.

### Analyse

5 Students on a field trip with a national park ranger set traps for a small nocturnal marsupial, *Antechinus stuartii*, in a heathland ecosystem. They captured 8 animals on the first night and marked white dots on their tails. Then they released them. On the second night, they captured 10 animals, of which 4 were marked.
 a **Calculate** the estimated population size of *A. stuartii* in this ecosystem.
 b **Describe** one way the students could check if their estimated population size was correct.

### Apply

6 Desalination plants take the salt out from sea water to produce fresh water for us to drink. The remaining sea water with high levels of salt is returned to the ocean through a fast flow pipe. A study of the desalination plant in Sydney found that the population of the mobile sponges decreased near the returning pipe, while populations of barnacles sticking to the rocks increased. **Compare** (the similarities and differences between) the two populations and **propose** a hypothesis that might explain the difference between the survival of the two populations.

7 **Investigate** the rules that regulate the type, number and size of fish that can be caught in your local area. Write a letter to a local paper explaining why these rules are needed.

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 6.5 Introducing a new species may disrupt a food web

**Learning intentions**

By the end of this topic, you will be able to:

- define introduced species
- explain how an introduced species can impact an ecosystem.

**Key ideas**

- Introduced species can change the amount of food for other organisms.
- New species can cause a new equilibrium in an ecosystem.
- Biological control is the deliberate introduction of a new species to control a non-native plant or animal.

**introduced species**
an organism that has been brought to and has established itself in an area it is not native to

## Balanced populations

There is a balance between all organisms in a food web. If more grass grows, the number of animals that eat the grass will also grow. In time, the amount of grass available will decrease, which will be balanced by a decrease in the animals who eat the grass. This increase–decrease population cycle is a balance that can be disrupted by **introduced species** or the removal of predators.

## Cane toads

Scarab beetles are a family of beetles that can range in size from 2–70 millimeters in length. One species from this family, *Dermolepida albohirtum* can cause a lot of damage to the sugar cane crops in Queensland. The female of this species lay eggs in the soil of the sugar cane. When the larvae hatch, they eat the roots of the cane plant, causing it to die. Cane toads (*Rhinella marina*) were introduced to Queensland in 1935 in an attempt to control the beetle population (Figure 1). While the cane toads did eat the scarab beetles, they preferred other insects. Cane toads also lacked many natural predators in Australia. When larger animals such as quolls tried to eat the toad, they were killed by the poisonous toxin on the toads' backs. This meant the cane

**Figure 1** Cane toads were introduced to Australia to control scarab beetles in 1935.

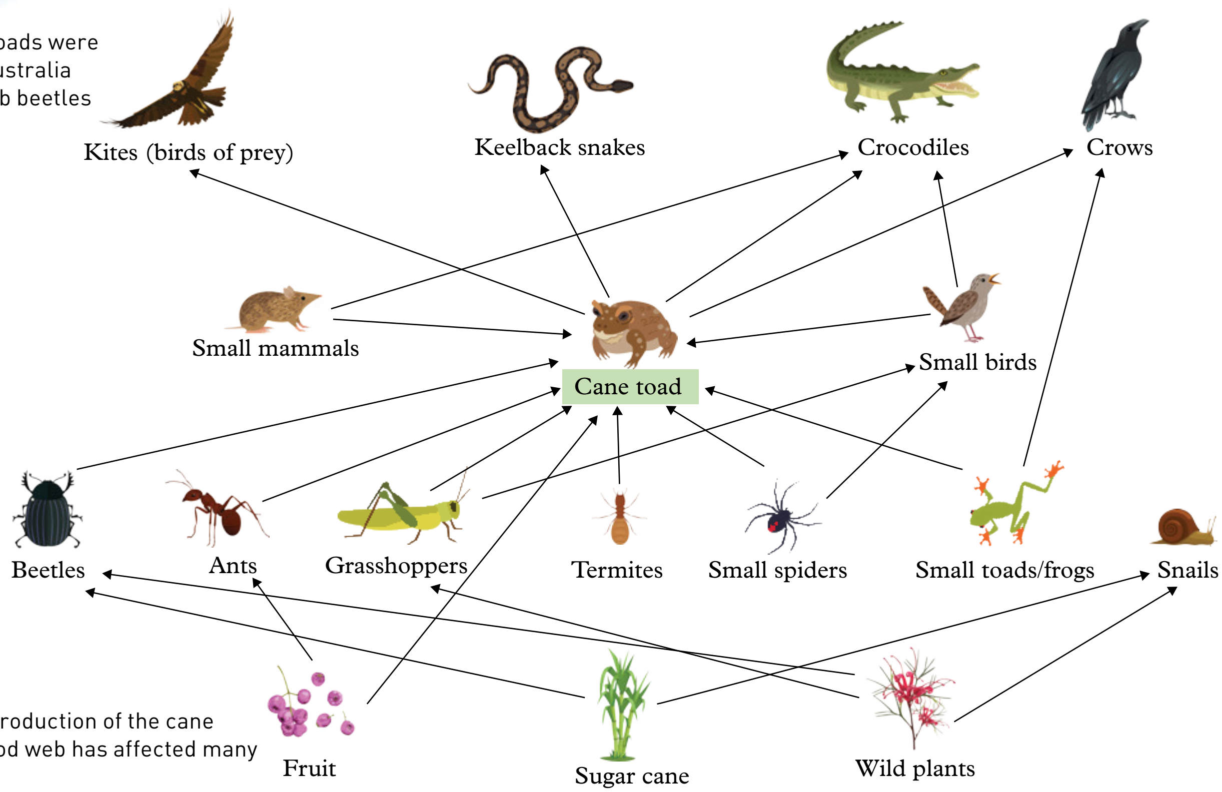



**Figure 2** The introduction of the cane toad into this food web has affected many other animals.

CHALLENGE

**6.5A:** Rabbit and fox chasey
Go to page **244**.

EXPERIMENT

**6.5B:** What if the effectiveness of pollinators was reduced?
Go to page **245**.

toad population (with a lot of food and few predators) could continue to increase.

The introduction of cane toads has also had negative social effects on First Nations peoples who rely on the local ecosystem for food. The yellow-spotted monitor goanna is an important meat source for some First Nations peoples who live in remote communities. Many of these goannas are killed when they try to eat cane toads. This decreases the availability of meat in areas where there is already limited supply of meat and protein.

The Yugul Mangi Aboriginal Ranger group work with government departments to help manage the population and spread of cane toads in Queensland.

## Gamba grass

In the 1930s, farmers concerned about the lack of grass in the dry parts of Australia brought gamba grass from the tropical savannas of Africa (Figure 3). This grass grows very quickly, taking over land that would usually grow native Australian grasses. Because gamba grass grows so quickly, it produces a lot of vegetation that burns in a bushfire.

It also has the potential to prevent small tree seedlings from growing, changing woodlands to a grassland. While cattle farmers might like the increase in grass for their cattle to eat, it has an environmental impact on the plant and animal life in Kakadu National Park. This means it also has an impact on important food sources and medicines for First Nations peoples who live in that area.

## Macquarie Island rabbits

Not all relationships in a food web are easily predicted. In 1985, scientists on Macquarie Island (halfway between Australia and Antarctica) devised a plan to eradicate the cats that had been introduced to the island since the early nineteenth century. The scientists thought that if the cat population decreased, there would be an increase in the native burrowing bird populations on the island. However, the cats were also predators of rabbits. When the cats were gone, the rabbits were no longer hunted. This allowed the rabbits to survive, destroying native plants and affecting many other organisms that were native to the island (Figure 4). Scientists needed to find a way to control the rabbits.

**Figure 3** Gamba grass

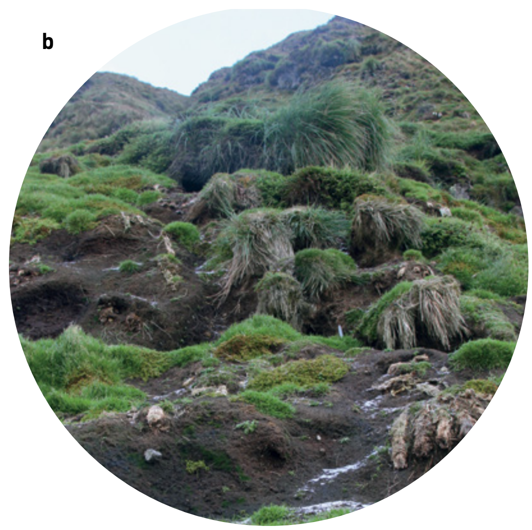


**Figure 4 a** Before: This slope on Macquarie Island had vegetation as recently as 2007.
**b** After: The same slope a few years later – it has been ravaged by rabbits since cats were eradicated.

## Biological control

All efforts to control the rabbit population by physical means were unsuccessful. In 1938, CSIRO scientists studied a way to control the population using a living organism (**biological control**). They tested a virus called *Myxoma* for its ability to cause **disease** in rabbits. This virus causes a disease with symptoms including fever and swelling around the head of the rabbit. Death occurs within 14 days. *Myxoma* was eventually released in the wild and quickly killed almost all the rabbits that caught the infection. This increased Australia's wool and meat production within two years. A small percentage of rabbits were unaffected by the disease. These rabbits survived and bred a new population of rabbits that were **immune** to the disease. New viruses, such as the rabbit calicivirus, have been tried, with similar results.

**biological control**
a method of controlling a population by releasing a living organism into an ecosystem

**disease**
a disorder or condition that interrupts the normal functioning of an organism

**immune**
able to fight an infection as a result of prior exposure

Before a species is introduced as part of biological control of pests, scientists must model the possible effects on populations that compete for the same food source or the predators that may prey on them. Scientist must effectively map the food web of the ecosystem and how the balance between all organisms in the community will be affected by the introduction of the biological control organism.

## Loss of organisms

The removal or loss of organisms from an ecosystem can have dramatic effects. Amphibians, such as frogs, are an important part of the biosphere: they may be warning us of unsafe environmental conditions that could eventually seriously affect our health. The thin skin of amphibians helps them drink and breathe, but it also makes them vulnerable to environmental contaminants, especially agricultural, industrial and pharmaceutical chemicals. Consequently, they are commonly referred to as **indicator species** – indicators of environmental health, as well as protectors of human health.

Amphibians watched the dinosaurs come and go, but today almost one-third of them, representing 1896 species, are threatened with extinction. As many as 165 amphibian species may already be extinct and the population numbers of at least 43 per cent of all species are declining. This means that there will be even fewer frogs and other amphibians in the future.

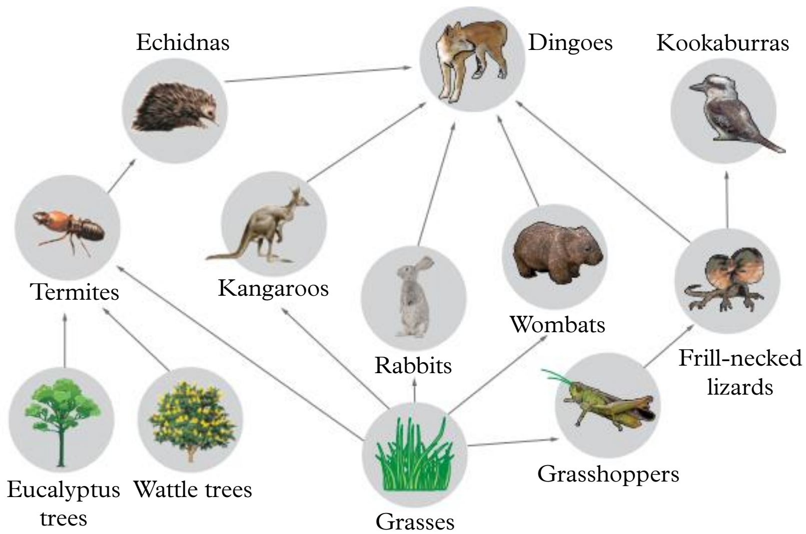



**Figure 5** Rabbits compete with grasshoppers, wombats and kangaroos for grass.

**indicator species**
an organism that can be used to measure the environmental condition of an area

### 6.5 Check your learning

#### Retrieve

1 **Identify** two reasons why the cane toad population was able to increase so quickly when introduced to Australia.

2 **Define** the term 'biological control'.

#### Comprehend

3 **Describe** why cane toads are referred to as an introduced animal in Australia.

4 Use the food web in Figure 5 to **suggest** two populations that would increase as a result of the introduction of rabbits.

5 **Explain** why some cattle farmers would have supported the introduction of gamba grass to Australia.

6 **Explain** why local First Nations peoples should have been consulted before the gamba grass was introduced.

#### Apply

7 **Evaluate** the ethics of using biological control of rabbits, by:

a **describing** how *Myxoma* infection affects the health of a rabbit

b **describing** the effect a large rabbit population has on a native environment, including the native plants and animals

c **describing** how a large rabbit population affects our ability to grow food

d **deciding** whether the life (and *Myxoma*-related death) of a rabbit is more or less important than the effects you described above. (Does the end justify the means?)

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 6.6 Ecosystems can be disrupted

**Learning intentions**

By the end of this topic, you will be able to:

- describe how natural disasters can impact ecosystems
- describe how human activity can impact ecosystems.

**Key ideas**

- Humans compete with other organisms for resources.
- New species can have environmental, social and economic impacts.
- Understanding the impacts allow ecosystems to be maintained.

## Limited resources

Animals use resources such as food and water and, in turn, become food for other organisms. The number of resources in an ecosystem is always limited. As the size of a population reaches its maximum **carrying capacity** (ability of the environment to support it), some of its resources, such as food, space and shelter, will become more limited. This means some organisms will either die or need to emigrate (leave). Once the population decreases, there will be enough resources for those remaining. When this occurs, the population will stabilise (reach its maximum size). The population will find a new balance, or equilibrium.

Natural events, such as the change in seasons, or natural disasters, can disrupt the balance between the biotic (living) and abiotic (non-living) factors in an ecosystem.

**carrying capacity**
the maximum number of organisms in a population that can be sustained by an ecosystem

## Seasonal changes

When the weather becomes colder, many animals migrate to warmer areas (Figure 1). As a result, their populations decrease in one environment and increase in another. During the breeding season, usually spring, the numbers of animals will increase. Flowering plants are pollinated and form seeds that spread throughout the environment, and later germinate into seedlings. As the population increases, so does competition for resources. As a result of this competition, some members of the population survive and others die, allowing the population to maintain its balance.

**Figure 1** Short-tailed shearwaters leave their burrows on Montague Island on the southern coast of New South Wales and fly to feeding grounds in the area of the Bering Sea (between Russia and Alaska) during the northern hemisphere summer. They return to breed in late September.

## Natural disasters

Australia has a widely fluctuating environment. Years of drought can be followed by flooding rains. When extreme natural change affects humans, we call these changes **natural disasters**.

**natural disasters**
natural events, such as floods, volcanic eruptions, tsunamis and earthquakes, that can cause severe damage and fatalities

**flood**
the overflow of a large body of water

### Impacts of floods and droughts

**Floods** are an overflow of water onto dry land, which has an immediate effect on the growth of plants and the germination of seeds. Marine ecosystems do not benefit from floods on land. When the water runs off the land, it brings sediment, pesticides and fertilisers into the marine ecosystem, causing some algal species to dominate the environment. Algal blooms are often deadly to other animals living in the ocean environment.

CHALLENGE
**6.6A:** Natural disasters in Australia
Go to page **246**.

**Figure 2** Flooding in Queensland in 2022

Floods can be a hazard for some animal life. Small mammals often escape to higher ground. Snakes are flushed out of their cover, as witnessed in the 2022 Queensland floods (Figure 2), and became a potential danger to humans. Aquatic animals benefit enormously from floods. Fish can breed in waters, such as a lake. The increase in fish, insects and waterweeds are a food source for water birds. The extra food encourages the water birds to breed in great numbers, temporarily changing the balance in populations.

**Droughts** pose an even greater challenge than floods (Figure 3). During a drought, animals migrate to find water. Some animal populations 'hang on' during drought, but many populations will decrease until the land looks almost bare. Wind can blow the dry topsoil away from the drought affected area, removing many of the nutrients in the ecosystem.

**Figure 3** Drought poses a great threat to life.

## Human impacts

In an ecosystem with limited resources, humans must compete with other organisms for food and shelter. The human population has grown quickly over the last 200 years. This means we have needed to change the environment so that we can grow food, build homes and find resources so that more and more people can live and work. Many of these changes can affect the local environment (environmental impacts), how people live (social impacts) and how we can work or earn money (economic impacts). Understanding the causes of these impacts will allow us to prevent further damage in the future.

### Deforestation

Our landscape was once covered by patches of different types of landscapes, such as swamp, grassland, forest and heath. This variety of vegetation supported many species of animals that moved, reproduced and spread throughout their territories and beyond.

**Figure 4** Only one specimen of the Hastings River mouse has ever been found. It is considered extinct due to changes brought about by European settlement.

Today, over 44 per cent of Australia's original bushland has been cleared since European settlement. Much of that land is used for housing, to grow food or to manufacture products. The food webs that existed in these areas have been changed as new predators (such as dogs and cats) move in and the number of producers decreases.

**drought**
a period in which an area experiences water shortage

## Land degradation

Human activities have led to a degradation of the physical environment. Soil erosion is a major problem caused by the clearing of land for agriculture. In ecosystems with many trees, the soil is stabilised by a dense mat of plant roots. Its surface is covered by a layer of leaf litter, which protects the soil surface from erosion by wind and water. Water from rainfall is quickly absorbed through the top layers of soil.

**urban sprawl**
the spreading and expansion of cities and houses into undeveloped land

**Figure 5** In 1983, large amounts of topsoil were carried across Melbourne and into the Southern Ocean as a result of wind erosion.

Once land is cleared of trees for agriculture, there is little to protect the soil from the action of wind and water. Grazing by animals with hard hooves, such as cattle, compacts the soil. This slows the absorption of water into the soil and increases the amount of water run-off. This, in turn, erodes the soil. Wind also contributes to the removal of the nutrient-rich topsoil (Figure 5).

## Urban sprawl

More than half of the world's population lives in cities. The population in the world's urban areas has grown by more than one billion people since the 1970s. Much of this growth has contributed to a phenomenon or process known as **urban sprawl**.

Urban sprawl means the spread of urban areas into rural areas, such as farmland, forests and coastal lands that lie on the outer edges of cities. Urban sprawl increases the distance between the city centre and its outer edge (Figure 6).

Urban sprawl is common in rapidly developing cities or those with large populations. Some of Australia's cities rate among the world's worst in terms of their sprawling nature, particularly because everyone wants their own garden and local parks.

**Figure 6** Urban sprawl around many of Australia's capital cities is on the rise.

CHALLENGE

**6.6B:** Calculating your ecological footprint
Go to page **247**.

## A changing climate

Human activities are contributing to more significant changes to weather and climate. These changes can have a huge impact on ecosystems.

In alpine areas, changing rainfall and temperature patterns alter the amount of suitable wet alpine habitat. This has made it difficult for animals that need the cool environments to survive.

**Figure 7** Alpine areas are reducing as the climate changes.

## 6.6 Check your learning

### Retrieve

1 **Define** the term 'carrying capacity'.

### Comprehend

2 **Describe** two things you can do to reduce your personal environmental impact (your ecological footprint).

3 **Describe** a possible economic impact of a drought.

4 **Describe** a possible social impact that would occur if the environment surrounding a city was protected so that no new houses could be built.

5 Each winter the cold weather causes the mountain pygmy possum to hibernate (deep sleep). This allows the possum to save energy when the food supplies are low during the winter. **Describe** how a warming climate could affect the mountain pygmy possum's ability to hibernate and survive each winter.

**Figure 8** Mountain pygmy possum

### Apply

6 **Create** a two-column table with the headings 'Problems' and 'Solutions'. In the 'Problems' column, list the types of things that people do that affect wildlife, such as building homes and roads, and cutting down trees. In the 'Solutions' column, **propose** solutions to each problem.

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

//SCIENCE AS A HUMAN ENDEAVOUR//

# 6.7 Human management of ecosystems continues to change

**Learning intentions**

By the end of this topic, you will be able to:

- describe how First Nations peoples have used different practices to manage ecosystems.

Different communities have different views on how to manage their local ecosystems. The growing population needs food to support it. Maximising food production while maintaining resources, such as soil and nutrients, can be difficult. The ability to see an ecosystem from another's perspective can be useful.

## Historical use of ecosystems

Humans first came to Australia over 60 000 years ago. They travelled out of Africa, through South-East Asia, before arriving at northern Australia.

These First Nations peoples were hunter–gatherers and early farmers who respected the land because it provided them with the resources for life – food, water, shelter and medicine.

As original inhabitants of the land, First Nations peoples are aware of the balance that exists in an ecosystem. For thousands of years, the Kaurareg people of the lower Western Islands of the Torres Strait worked with the traditional owners of the surrounding islands so that the harvesting of the local turtles and dugongs was sustained for future generations. Small or pregnant dugongs, and dugong mothers and calves are not hunted so that the population can continue to reproduce in the future (Figure 1). Experienced First Nations ecologists can even determine if a dugong has had calves in the past. The Western Islanders keep the skull bones to check that they have not exceeded their quota.

First Nations peoples are aware of the seasonal nature of plant and animal life in the surrounding ecosystems. Turtles only lays eggs for a few months each year. If all the eggs are collected and eaten, then there will be no turtles to lay eggs in the future. First Nations peoples use oral stories to explain the importance of keeping this balance and to identify the right time to collect the number of eggs that is allowed (Figure 2). These traditions continue today through the collaboration and shared responsibility for marine conservation.

Instead of considering the land to be owned by a person or group of people, to be cleared and used according to their needs, First Nations peoples consider land management to be based on shared ownership and a deep respect for the land. As Indigenous Person of the Year 1999, Bob Randall, said, 'We do not own the land. The land owns us.'

**Figure 1** Dugongs are sea mammals that can live for over 70 years.

**Figure 2 a** First Nations peoples use oral traditions to teach the importance of balance in an ecosystem including restricting the number of turtle eggs to collect. **b** The green sea turtle

## Cool burning

There is increasing recognition of the First Nations peoples' use of 'cool burning' to control bushfires and reduce the emission of greenhouse gases (Figure 4). Early in spring, the grasses are not as dry. Any fires lit burn slowly and are put out by the heavy night-time dew. This means small fires can be lit to reduce the grasses that form the undergrowth under treetops or canopies. If small patches of undergrowth are burnt, the nutrient matter is cycled back into the soil without destroying all the food available. The trees that form shelter for the animals in the area are also protected. Within a short time, new green growth can occur, providing a new source of food for the young animals that are born during this time.

This cool burning process has been used by First Nations peoples for thousands of years and many plants, such as the grass tree (*Xanthorrhoea*), have evolved to only flower when the base of the tree has been burnt by fire. Other plants, such as *Eucalyptus* species have evolved epicormic buds with the ability to regrow branches from deep under thick bark, and lignotubers that can grow new shoots from roots protected from fire under the ground (Figure 5).

**Figure 3** A patch of bush after controlled burning in Ipswich, Queensland

**Figure 4** Modern land managers have been practising traditional methods of regenerating bushland.

**Figure 5** Grass tree and eucalyptus growth after a fire

CHALLENGE
**6.7:** Eucalypt adaptations
Go to page **248**.

First Nations peoples are also careful to not waste the resources in their environment. A good example is the way they use the different parts of the grass tree. They use:

> the shaft as a spear
> resin from the plant for sticking things together
> nectar from the flowers for food
> leaf bases for food
> insects that feed on the flowers for food.

If cool burning is repeated each year, the slow limited burning reduces the release of greenhouse gases (especially methane and nitrous oxide) and the carbon remains trapped in the unburnt large trees and bushes.

## Modern needs

As the population of Australia has increased, so too has the need for food. This need for food must be balanced with keeping the variety of unique plants and animals (the biodiversity) of the unique Australian ecosystem.

In Australia, we currently have plenty of food, thanks to a strong agricultural community. Irrigation of large areas allows the crops to survive. As shown in Figure 6, Australian farmers have become more effective in their use of water, protecting this important resource for future generations.

In 2018, tropical Cyclone Debbie hit the coast of Queensland, causing major property damage, power outages and millions of dollars of damage to Australia's sugar cane industry. Global warming is expected to cause storms of this magnitude to become more frequent and spread over larger areas. Some scientists predict that droughts may also become increasingly frequent in all areas of Australia. This will have an impact on the types of crops that can grow in many areas.

In 2010, Australia's Chief Scientist made some recommendations to enable us to maintain the food production needed to feed Australia and the rest of the world while minimising the impact on the ecosystem.

> Coordinate programs that maintain current food production levels.
> Research methods and crops that would be able to cope with drought conditions.
> Develop methods that allow more efficient use of water and nutrients in agricultural areas.
> Encourage more scientists and engineers to work in agriculture.

This means that agriculture is looking to science and technology to help maintain a balance between food production and biodiversity of the environment (Figure 7).

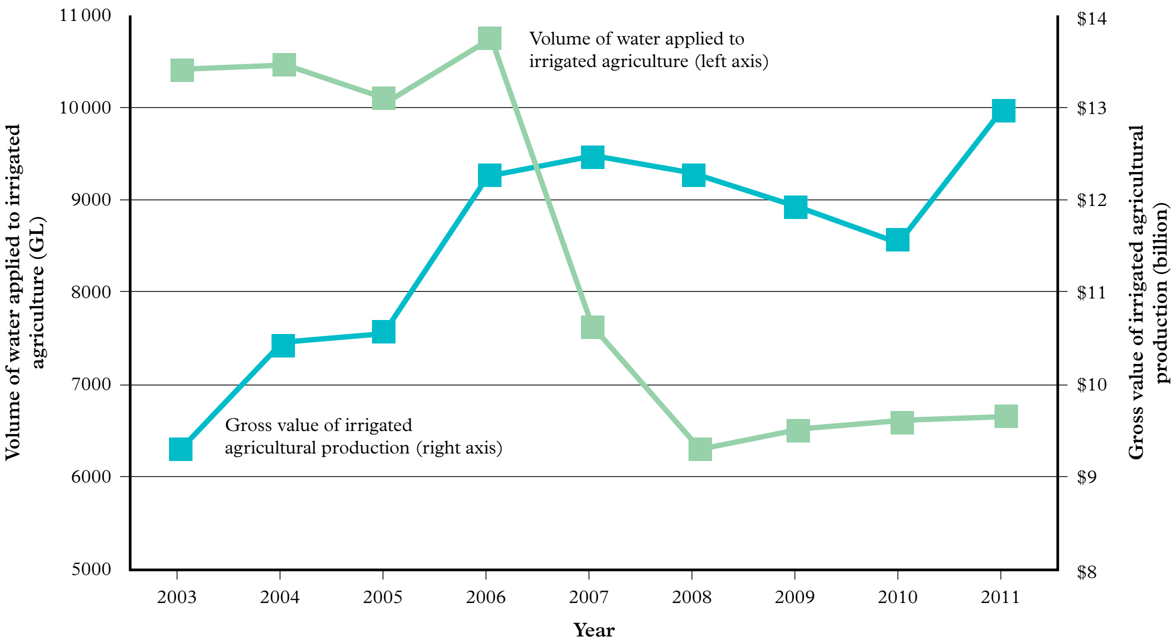



**Figure 6** Modern farming involves using water more wisely.

**Figure 7** Scientists are developing ways to use water more efficiently. **a** Traditional irrigation **b** Modern micro-irrigation system

## 6.7 Test your skills and capabilities

### Conducting interviews

First Nations peoples have traditions of using oral stories to pass on their history and culture. These stories have passed on important environmental information. For example, elders of the Bidjara people of southern Queensland have shared the knowledge for generations about the journey of the Mundagudda or 'rainbow serpent'. The journey of the Mundagudda on land is said to have created rivers, waterways and gorges. These stories provide guidance to navigating the environmental landscape and its different features.

The ability to learn from listening to members of the community is a valuable skill. Interviewing the older people in your life, such as your parent, guardian or grandparent, can allow you to gain an understanding of the environment in your area and how it may have changed over time.

A good interview that gathers qualitative data requires planning. **Consider** each of the following points and use them to **plan** and **conduct** your own interview.

1 Find a good location: people are often more comfortable in a familiar place and will therefore tell better stories.
2 Write down your questions: consider what you want to know before you start the interview. Is there background knowledge that you should know before the interview?
3 Be prepared to wait: your interviewee might need time to think before answering your questions. Despite the awkwardness of silence, it is worth waiting for the answer.
4 Listen to the answers: one of the most difficult things to do in an interview is to listen to what is said instead of planning what questions to ask next. If you listen to the answer, you will be able to ask follow-up questions that turn the interview into a conversation.
5 Record the answers: this can be as simple as a voice or video recording on your phone. But make sure you ask for permission first. Alternatively, you could write down the answers; however, this can interrupt the flow of conversation.
6 Check the stories against other records to confirm when the events might have occurred: sometimes memories can change, or the dates can become difficult to remember. It can also help to fill in the details when you record the qualitative oral data for future generations.

# ECOSYSTEMS

## Retrieve

1 **Identify** the organism in Figure 1 that is the producer in the food chain.

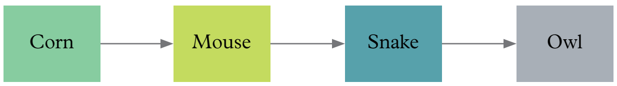



**Figure 1** A food chain

- A corn
- B mouse
- C snake
- D owl

2 **Identify** the organism that is the second-order consumer in Figure 1.

- A corn
- B mouse
- C snake
- D owl

3 **Identify** the organism that is the herbivore in Figure 1.

- A corn
- B mouse
- C snake
- D owl

4 **Define** the term 'ecological footprint'.

5 **Define** the term 'urban sprawl'.

## Comprehend

6 **Describe** one practice First Nations peoples have used to make sure they do not disrupt the environment too much.

7 **Describe** one example of how humans, especially after European settlement, have changed ecosystems because of an introduced species in Australia.

8 **Describe** an example of an abiotic condition in an Australian ecosystem that could limit the populations of a living organism.

9 **Explain** the term 'cool fires'.

10 **Explain** why it is important to have biodiversity in an environment.

11 With a growing population, humans are requiring more from the land around them. **Summarise** three ways in which humans are changing the environment.

## Analyse

12 **Compare** mutualism, parasitism and commensalism.

13 **Classify** the following as either abiotic or biotic factors.

- a Salinity
- b Bacteria present
- c Temperature
- d Plant species present
- e Water availability

14 **Contrast** a producer and a consumer.

15 **Compare** a herbivore and a carnivore.

16 **Analyse** the marine Antarctic food web in Figure 2 below.

- a Describe the relationship between:
  - i orca whales and fur seals
  - ii emperor penguins and fur seals.

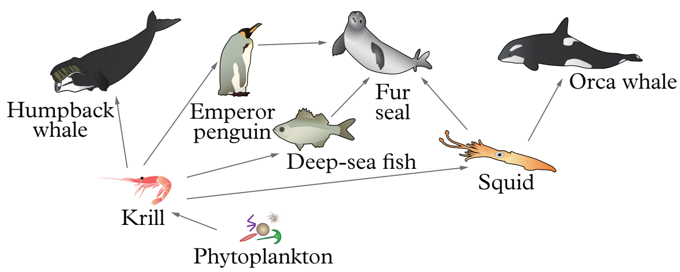



**Figure 2** A marine Antarctic food web

## Apply

17 **Consider** the food web in Figure 5 of Topic 6.1 (page 143). If the mouse were to become locally extinct, **list** the possible changes that might occur to the other organisms in the food web.

18 **Discuss** what happened when the cane toad was introduced into Australian ecosystems. **Explain** how this impact might have been different if the cane toad had more successful predators.

**Figure 3** *Bufo marinus*, the cane toad

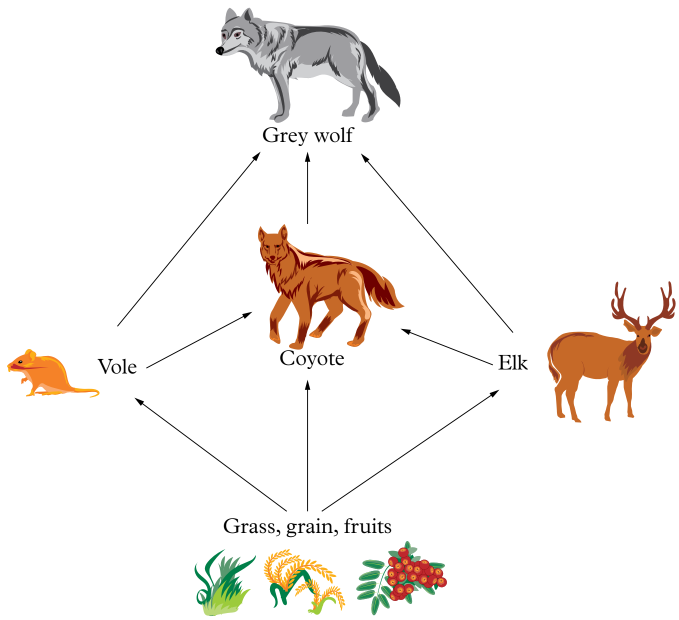



**Figure 4** A Yellowstone National Park food web

19 **Analyse** the following food web shown in Figure 4 that shows organisms from the Yellowstone National Park ecosystem in America. While coyotes can eat larger elk, this usually only occurs when an elk is injured or sick.

a **Identify** one example of a producer and one example of a consumer in this food web.

b **Predict** what would happen to the population of elk in this ecosystem if the grey wolf was removed.

c Use your answer from question b to **describe** what would happen to the populations of grasses, grains and fruits in the park.

20 **Draw** up a table of advantages and disadvantages of cool fire burning of bushland. **Evaluate** the points you raise in the table by judging which points are more important, and deciding if the cool fire burning advantages are better or worse than the disadvantages.

## Critical thinking

21 Imagine a world without spiders. **Discuss** what the world would be like. In your answer, consider what spiders eat and which organisms eat spiders.

22 In some cases, introduced animals fail and never become established. In other cases, they are spectacular 'successes', such as the rabbits and foxes across much of southern Australia. In terms of the environment in which these animals live and their interactions with other animals, **explain** why some animals succeed and others do not.

23 A simple change to your daily habits, such as reusing and recycling paper at school, can make a difference to ecosystems. Use this example, or another, to **discuss** how your actions impact on biodiversity.

**Figure 5** Reduce, reuse, recycle

24 The balance of nature is very delicate, and changes to the environment or any member of a food web bring about changes throughout the whole system. Food webs are graphical ways of showing eating relationships inside ecosystems. If the food web is changing, so is the ecosystem. **Decide** which would be more resistant to change:

> big, complicated ecosystems with numerous species interacting

> simple ecosystems with relatively few species interacting.

This can be done by:

a describing an example of how both environments could be disrupted by the same event

b deciding which environment would be most disrupted and least likely to recover.

25 In this chapter you have learnt about the Earth's growing population. **Create** a visual representation (sketch, drawing, poster or similar) to represent the Earth's changing population 50 years ago, now and 50 years into the future.

## Social and ethical thinking

26 Prior to 1950, most scientists thought that the size and make-up of a population never changed. There were two parts to this. In human population, the poor people in society would stay poor, and the rich would stay rich. In the animal world, some animals would survive, and some would die, but the population would stay the same. In the 1960s, ecologist Richard Levin started researching ecology and populations. He thought that all populations could change if there was enough change in the environment.

a **Decide** if you agree or disagree with Richard Levin.

b **Describe** two arguments from the paragraph above that support your argument.

27 Humans have tried a number of methods to reduce rabbit numbers in Australia, including the introduction of a virus that caused serious deformities and led to a slow and painful death. **Discuss** if the result (reducing the number of introduced rabbits so that other native wildlife survive) justifies how it was achieved (the painful death of the rabbits).

**Figure 6** The introduction of rabbits to Australia has resulted in considerable environmental damage.

## Research

28 Choose one of the following topics on which to conduct further research. Present your findings in a format that best fits the information you have found and understandings you have formed.

### » Science communication causing change

Dame Jane Goodall first travelled from England to Tanzania to study chimpanzees at the age of 26. Although she was not a trained ecologist at the time, she was gradually accepted by the chimpanzees. This allowed her to experience the way they behave and how they were affected by changes in their environment. Her regular communication with other groups around the work increased our understanding of the balance between the needs of humans and chimpanzees.

- Research how she was able to change people's view of chimpanzees by describing people's views before and after Dame Jane Goodall's communications.

### » Laboratory-grown meat

In Australia and many other countries, land is still being cleared so that sheep and cows can be farmed for meat. To prevent this, some laboratories are attempting to grow meat in a petri dish.

- Explain how the lab-grown meat could reduce the impact on the environment.
- Describe how the lives of the sheep and cattle farmers could be affected.
- Decide if you would eat lab-produced meat in the future.

### » Mars biosphere

Earth is particularly special because, as far as we know, it is the only planet that sustains life – our biosphere. The biosphere concept has been looked at as a means of long-distance space travel and as a way to colonise planets such as Mars. As a class project, undertake the mission to Mars project to set up a biosphere on Mars.

This means we will need to identify the abiotic conditions that exist on Mars and consider the biotic factors that we will need to survive.

- Research the abiotic conditions that exist on Mars.
- Explain whether these conditions are suitable for human habitation. If not, describe how we could survive in these conditions (what would we need to take with us).
- Describe the most basic food web that we would need to survive on Mars.
- Describe the abiotic conditions that each of these organisms would need to survive.
- Use the information you have gathered to evaluate the chances of success for a colony to exist on the surface of Mars.

**Figure 7** Dame Jane Goodall studied the behaviour of chimpanzees.

## Chapter checklist

Now that you have completed this chapter, reflect on your ability to do the following.

| | I can do this. | | I cannot do this yet. |
|---|---|---|---|
| • Define producer and consumer and identify examples of each.<br>• Construct and interpret food chains and food webs. | ☐ | ☐ | Go back to Topic 6.1 'All organisms are interdependent'.<br>Page 142 |
| • Define the term 'ecosystem'.<br>• Explain the different types of relationships that can exist within ecosystems. | ☐ | ☐ | Go back to Topic 6.2 'All organisms have a role in an ecosystem'.<br>Page 144 |
| • Define the terms 'herbivore', 'carnivore' and 'omnivore'.<br>• Describe how energy flows through an ecosystem. | ☐ | ☐ | Go back to Topic 6.3 'Energy flows through an ecosystem'.<br>Page 148 |
| • Distinguish between abiotic and biotic factors.<br>• Explain how different factors can cause a population to increase or decrease. | ☐ | ☐ | Go back to Topic 6.4 'Population size depends on abiotic and biotic factors'.<br>Page 150 |
| • Define introduced species.<br>• Explain how an introduced species can impact an ecosystem. | ☐ | ☐ | Go back to Topic 6.5 'Introducing a new species may disrupt a food web'.<br>Page 154 |
| • Describe how natural disasters can impact ecosystems.<br>• Describe how human activity can impact ecosystems. | ☐ | ☐ | Go back to Topic 6.6 'Ecosystems can be disrupted'.<br>Page 158 |
| • Describe how First Nations peoples have used different practices to manage ecosystems. | ☐ | ☐ | Go back to Topic 6.7 'Science as a human endeavour: Human management of ecosystems continues to change'.<br>Page 162 |

**Check your Student obook pro for these digital resources and more:**

**Quizlet**
Play a Quizlet game to test your knowledge.

**Chapter quiz**
Test your understanding of this chapter with the chapter review quiz.

CHAPTER

# 7

# EARTH, SUN AND MOON

7.1

**The Earth, Sun and Moon interact with one another**

> Explain how the length of a day and a year relate to the movements of the Earth.
> Describe the differences between a total and partial solar eclipse.

7.2

**The Moon reflects the Sun's light**

> Identify and describe the phases of the Moon and lunar eclipse.
> Contrast a solar and a lunar eclipse.

**7.3**

## The Moon's gravity causes tidal movements

> Explain how the Moon's gravity causes tidal movements.
> Describe the relationship between the Moon and tides that was recognised by early First Nations Australians.

**7.4**

## Seasons are caused by the tilt of the Earth

> Define the terms 'solstice' and 'equinox'.
> Explain how seasons are related to the position of the Sun and Earth.
> Describe the importance of seasons and seasonal calendars to First Nations Australians.

**7.5**

## Science as a human endeavour: Astronomers explore space

> Identify examples that show how advances in technology and scientific knowledge have improved our understanding of the solar system.

# What if?

### Modelling the Earth and Moon

**What you need:**

Ruler, 2 balloons

**What to do:**

1 Blow up one balloon until it is 20 cm in diameter. This balloon represents the Earth.

2 Blow up the other balloon to 5 cm in diameter. This balloon represents the Moon.

3 Move the two balloons until they are 5 m apart. This represents approximately how far the Earth is from the Moon.

4 With your partner, discuss what effect the Moon has on the Earth. Does the Moon always appear to be the same size when viewed from Earth?

**What if?**

» What if the Moon was closer to the Earth? Would we notice any differences?

# 7.1 The Earth, Sun and Moon interact with one another

**Learning intentions**

By the end of this topic, you will be able to:

- explain how the length of a day and a year relate to the movements of the Earth
- describe the differences between a total and partial solar eclipse.

**Key ideas**

- The solar system is the collection of planets, their moons and smaller bodies (asteroids, meteors and comets) that orbit the Sun.
- The Moon orbits the Earth every 27.3 days.
- The Earth orbits the Sun every 365.25 days.

## Our solar system

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

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

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

## A year

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

## Night and day

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

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

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

**Figure 2** The half of the Earth facing the Sun experiences day and the half in shadow experiences night.

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

**star**
a celestial body appearing as a luminous point in the night sky

**solar energy**
energy made by atoms colliding with each other in the centre of the Sun

**solar system**
the Sun and all the planets, dwarf planets, moons and asteroids that travel around it and one another

**orbit**
the path a planet follows around the Sun or a star; the path a moon follows around a planet

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

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

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

## Solar eclipse

One of the first scientists and mathematicians who investigated the time it took for the Moon to travel around the Earth was al-Battani (whose full name was Abu Abdallah Muhammad ibn Jabir ibn Sinan al-Raqqi al-Harrani al-Sabi al-Battani) in the tenth century. Although he was not the first astronomer to build a model of how the Moon travelled around the Earth, his was one of the most accurate. He was able to correctly calculate the cause for a solar eclipse.

This occurs when the Moon passes between the Sun and the Earth once every 27.3 days. Occasionally, the Moon will be in a position where it blocks some of the light from the Sun. This is known as a **solar eclipse** (Figure 3). During a **total solar eclipse**, the Moon blocks the maximum amount of light from the Sun and the sky goes dark for a short time during the day. The last total eclipse of the Sun visible from northern Australia was on 13 November 2012; the next one is due on 20 April 2023 in Western Australia.

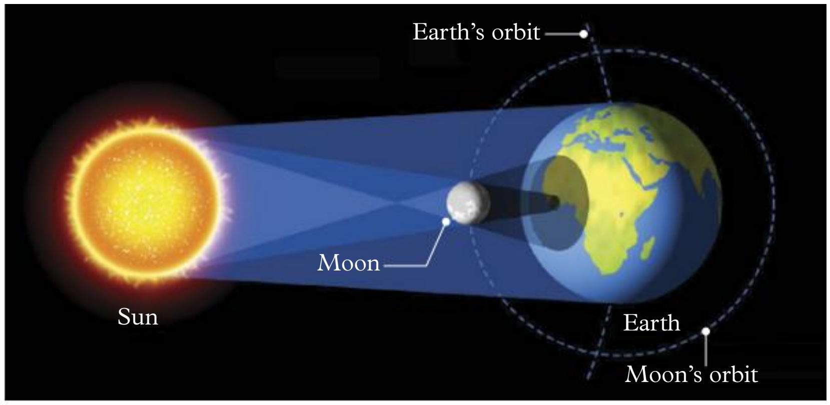



**Figure 3** When the Moon is positioned between the Sun and the Earth, it is called a solar eclipse.

**Figure 4** The phases of a solar eclipse

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

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

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

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

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

## 7.1 Check your learning

### Retrieve

1 **Define** the terms 'rotation' and 'orbit'.

### Comprehend

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

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

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

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

### Analyse

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

7 **Connect** the terms 'day', 'night' and 'year' with the listed explanations:

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

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

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

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 7.2 The Moon reflects the Sun's light

**Learning intentions**

By the end of this topic, you will be able to:

- identify and describe the phases of the Moon and lunar eclipse
- contrast a solar and a lunar eclipse.

**Key ideas**

- The Moon rotates as it orbits the Earth.
- The same face of the Moon always faces towards the Earth.
- The phases of the Moon are caused by the light from the Sun shining on different parts of the Moon.

Many scientists believe that a giant collision between two planetary bodies resulted in the formation of Earth and the Moon. Early astronauts collected samples from the surface of the Moon and compared them with the surface of Earth; they are almost identical.

The first scientific description of the Moon was made in 1609 by Italian astronomer and physicist Galileo Galilei (1564–1642), based on his observations through a telescope. At the time it was believed that the Moon had a smooth surface, which explained its ability to reflect light from the Sun. Galileo knew differently. He saw the rough, mountainous terrain and vast craters that we know cover the surface of the Moon. He even described large flat plains that we call 'maria' (pronounced 'MAHR-ee-ah'; Latin for 'seas') because they look like dark oceans. We now know these plains to be solidified lava.

In 2020, NASA's special SOFIA telescope mounted in an airplane (the Stratospheric Observatory for Infrared Astronomy) identified small molecules of water on the surface of the Moon for the first time. The amount of water found was very small (100 times less than the Sahara Desert). This will not be enough to supply all the needs of the NASA astronauts that will be landing on the Moon by 2024.

**phases of the Moon**
changes in the shape of the Moon as seen from Earth

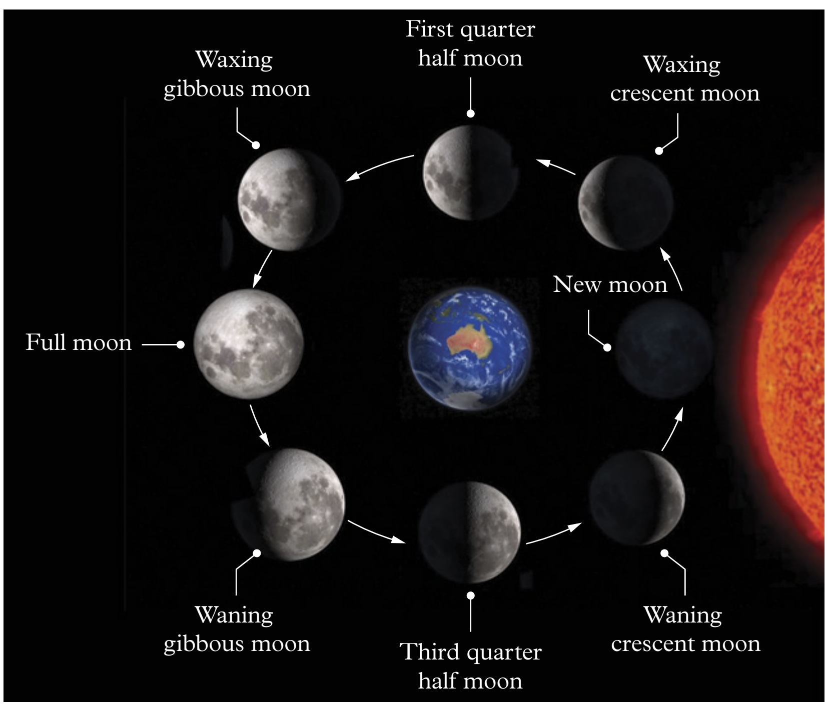



**Figure 1** The phases of the Moon as they appear from Australia (the Southern Hemisphere)

## Moonlight

Unlike the Sun, the Moon does not create its own light. Instead, it reflects sunlight. The amount of light reflected varies with the different phases of the Moon, but even the full Moon only provides a faint light that appears bluish to the human eye. We always see the same side of the Moon from Earth because the Moon rotates at the same speed as it orbits. This is just like walking around a person, making sure you always face toward them. The Moon takes 27.3 days to completely orbit the Earth.

Sometimes, only a part of the Moon is visible. You might see half a Moon, a crescent or a fully round Moon. Sometimes the Moon cannot be seen at all, even though it is in the sky. These changes in the shape of the Moon are called the **phases of the Moon** (Figure 1). Of course, the Moon does not change shape – it is always round. What changes is the amount of the Moon that is lit by the Sun, which makes it possible for us to see the Moon from Earth. We are really looking at the 'day' and 'night' parts of the Moon. The Moon rises and sets, just like the Sun. The Moon rises approximately 50 minutes later from one day to the next. The Moon is always in the sky; however, during the day, the sky is usually so light that the Moon is hard to see.

CHALLENGE

**7.2:** Modelling the phases of the Moon
Go to page **249**.

## Exploring the Moon

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

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


THEIR DAY ON THE MOON

SOUVENIR ISSUE

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

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

The Sun NEWS–PICTORIAL 5c

**Figure 2** The first Moon landing was televised around the world and was front-page news on 21 July 1969.

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

It was possible to beam images of the Moon landing around the world because of the satellite dishes located at Honeysuckle Creek in Canberra and Parkes in New South Wales (Figure 3).

**Figure 3** Australian scientists at the Parkes Observatory played a critical role in the Moon landing.

## Lunar eclipse

In eighteenth-century China, a young scientist called Wang Zhenyi developed a way to model a lunar eclipse. This eclipse occurs when the Earth moves between the Moon and the Sun. The Moon passes into the Earth's shadow and appears dark (Figure 4). Wang modelled this by hanging a lamp from the roof as a Sun, above a circular table that acted like the Earth. She then used a circular mirror that acted like the Moon. By moving the Moon mirror under the Earth table, she was able to model the lunar eclipse.

**Figure 4** A time-lapse photograph of a lunar eclipse

## 7.2 Check your learning

### Retrieve

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

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

### Comprehend

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

### Analyse

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

### Apply

5 **Investigate** an alternative explanation for the phases of the Moon as told by early First Nations Australians. **Explain** how they saw the variation in the appearance of the Moon.

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 7.3 The Moon's gravity causes tidal movements

**Learning intentions**

By the end of this topic, you will be able to:

- explain how the Moon's gravity causes tidal movements
- describe the relationship between the Moon and tides that was recognised by early First Nations Australians.

**Key ideas**

- The Earth's pull force holds the Moon in orbit.
- The relationship between the Moon and the tides was recognised by early First Nations Australians.
- The pull force of gravity causes high and low tides.

The relationship between the Moon and the tides was recognised by early First Nations peoples in Australia. In Yolngu traditions of Arnhem Land, stories describe water filling the Moon-man (Ngalindi) as he rises. When the Moon is full in the sky, the tidal waters are full. As the tide falls, the Moon is left empty for three days before filling once more.

## What causes tidal movements?

The Earth's pull force holds the Moon in orbit. The Moon has its own pull force, even though it is far less than the Earth's. The Moon is approximately one-quarter the size and one-eightieth the mass of the Earth, so its pull force is much weaker.

This does not mean the Moon's pull force does not affect the Earth. The pull of the Moon causes the Earth's oceans to bulge toward the Moon. This causes the oceans to cover slightly more land, which we see on the Earth as a **high tide**. The Earth is also being pulled toward the Moon (and away from the water on the opposite side), so another high tide occurs on the opposite side of the Earth. As the Moon travels around the Earth and as both bodies travel around the Sun, the combined pull force from gravity causes the world's oceans to rise to high tides and fall to **low tides**. Because the Earth is rotating while this is happening, two high tides occur each day, approximately 11 hours apart.

**Figure 1** The Moon

**high tide**
when the ocean covers slightly more land; the highest level that the tide reaches on the shore

**low tide**
when the ocean covers slightly less land; the lowest level on the shore that the tide recedes to

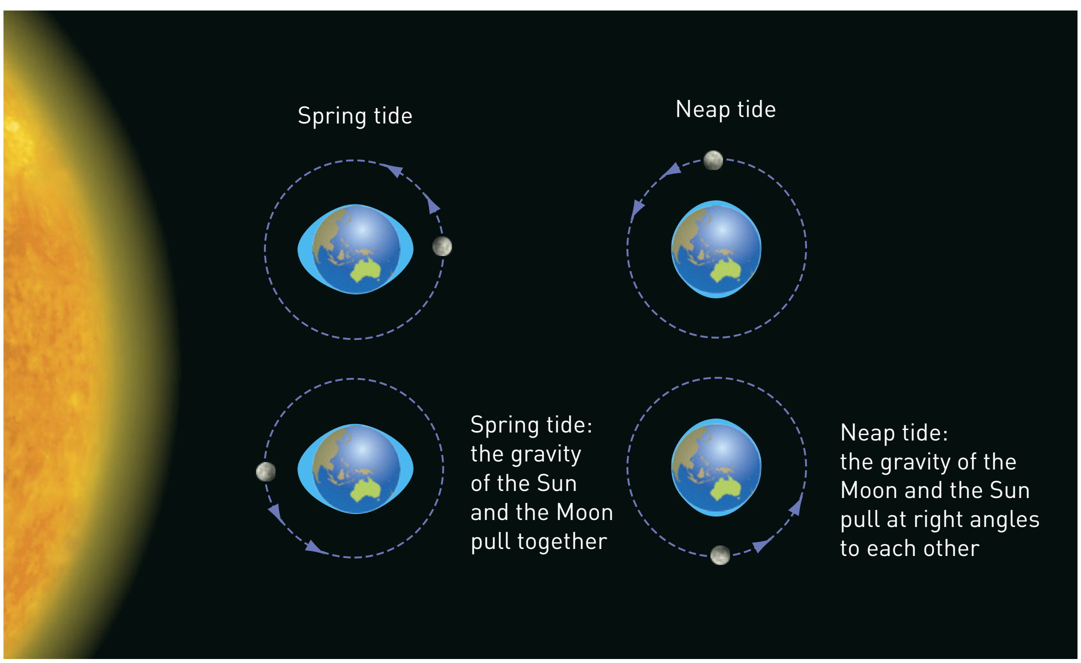



**Figure 2** The Moon's pull on the oceans creates spring and neap tides. (The bulges shown here have been exaggerated so that they are easier to see.)

High tides happen when the land is rotated toward the water being pulled in by the Moon or Sun. Low tides happen when the land rotates away from the water bulge.

When the Sun, Moon and Earth are aligned, the combined pull of the Moon and the Sun causes very high tides in some parts of the Earth.

These are known as **spring tides**. Smaller **neap tides** occur during the Moon's quarter phases. At these times, the Sun and Moon are at right angles to the Earth, causing the sea tides to be pulled in both directions at once. Spring and neap tides are shown in Figure 2.

Worked example 7.3 shows how to calculate the difference in height between low and high tide.

**spring tide**
when there is maximum difference between high and low tides; caused by the combined pull of the Moon and the Sun

**neap tide**
when the difference between high and low tides is smallest; occurs during the Moon's quarter phase, when the Sun and the Moon pull in different directions

## Worked example 7.3: Calculating tides

Table 1 shows the times of high and low tides at Surfers Paradise, in Gold Coast, Queensland, over three days in June 2022. Calculate the difference in height between the two high tides on the Friday.

### Solution

One high tide is 1.01 m at 10.17 am and the other high tide is 1.59 m at 10.38 pm.

Subtract the smaller tide from the larger tide:
1.59 – 1.01 = 0.58 m

**Table 1** High tides at Surfers Paradise, Gold Coast, in June 2022

| Thursday, 2 June 2022 | | Friday, 3 June 2022 | | Saturday, 4 June 2022 | |
|---|---|---|---|---|---|
| Time | Height (m) | Time | Height (m) | Time | Height (m) |
| 4.01 am | 0.35 | 4.42 am | 0.38 | 5.26 am | 0.42 |
| 9.36 am | 1.05 | 10.17 am | 1.01 | 11.02 am | 0.98 |
| 3.12 pm | 0.33 | 3.49 pm | 0.38 | 4.31 pm | 0.44 |
| 9.58 pm | 1.64 | 10.38 pm | 1.59 | 11.21 pm | 1.53 |

## 7.3 Check your learning

### Comprehend

1 **Explain** why the Moon has a greater effect on the tide levels than the Sun.

### Analyse

2 Referring to Table 1, **identify** the difference between:

a the last high tide on Friday and the first one on Saturday

b the first high tide and the following low tide on Saturday.

### Apply

3 Use the data in Table 1 to **predict** the times and heights of the tides for Sunday.

4 For 1 week, graph the high and low tide levels of a beach in your state. **Compare** (the similarities and differences between) this and the times of the Moon rise and set. **Discuss** the relationship between the Moon's position and tide levels.

5 Gravity is not considered a force. Instead, gravity is the distortion of space and time caused by a large object. This allows the large object to have a pull force. **Evaluate** the following sentence and rewrite it so that it is correct.

'The force of the Moon's gravity pulls the water on Earth to cause high tides.'

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

# 7.4 Seasons are caused by the tilt of the Earth

**Learning intentions**

By the end of this topic, you will be able to:
- define the terms 'solstice' and 'equinox'
- explain how seasons are related to the position of the Sun and Earth
- describe the importance of seasons and seasonal calendars to First Nations Australians.

**Key ideas**
- The Sun travels different paths across the sky at different times of the year.
- During summer, the days are longer and the Sun warms the ground and air.
- During winter, the days are shorter and the ground and air are cooler.
- The equinox occurs when the length of day is equal to the length of night.
- First Nations Australians use regional seasonal calendars which describe the weather, plants and animals that are common in that area at that time of the year.

Interactive 7.4
The path of the Sun

The Wurdi Youang egg-shaped arrangement of stones shown in Figure 1 was found at Little River, Victoria, by European settlers nearly 200 years ago. The layout of 100 large boulders is thought to have been set out by the Wathaurong people, the Traditional Owners of the area. It is only recently that archaeologists have discovered that the 1 m high rocks at the two ends of the egg shape mark the points where the Sun sets during the middle of winter (the winter **solstice**) and the middle of summer (the summer solstice).

**solstice**
either of the times when the Sun is furthest from the equator

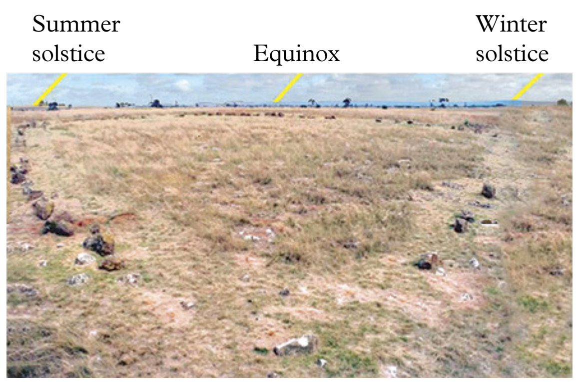



**Figure 1** The Wathaurong people who lived between Melbourne and Geelong marked the movement of the Sun with waist-high stones.

**Figure 2** Deciduous plants change with the seasons described by Europeans.

CHALLENGE
**7.4:** Modelling the seasons
Go to page **250**.

## Summer

The Earth does not rotate evenly. Rather, the Earth rotates around an imaginary line (the axis) that is on an angle of 23.5 degrees. This means that, for part of the year, the southern hemisphere (including Australia) is tilted towards the Sun (Figure 3). The days are longer and the nights are shorter. The Sun is higher in the sky. This allows more time for the Sun's rays to hit the ground and therefore warm up the air. We experience summer. The Wathaurong people in Victoria knew this, and placed stones that marked the place where the Sun set during the longest day (21 December). This is called the summer solstice.

## Equinox

After 21 December, the Earth continues its orbit of the Sun, slowly angling the southern hemisphere away from the Sun. Twice a year (in autumn on 20 March and in spring on 22 September), the position of the Earth allows an equal length of day and night. This is called the **equinox**. The Wathaurong people marked the sunset of these events with the equinox stone.

## Winter

In winter, the southern hemisphere is angled away from the Sun. This means the Sun shines lower in our skies and for less time. As a result, there is less time for the Sun to warm up the ground and therefore the air is cooler. We experience winter. The shortest day (21 June), the winter solstice, was also marked by the Wathaurong people.

The Wathaurong people found a way to mark the movement of the Sun, and hence the seasons, without using telescopes or undertaking long sailing trips around the world.

The northern hemisphere's seasons are the opposite of ours in Australia, so during a northern summer there is a southern winter.

The tilt of the Earth is more noticeable in the Antarctic. In the summer, the tilt of the Earth causes the Sun to remain in the sky for five months. The Sun does not set; instead, it sits just above the horizon for the whole time.

The reverse is true for winter in the Antarctic. The angle of the southern hemisphere away from Sun means the Sun sets in May and does not rise again until July.

## Seasons for First Nations Australians

First Nations Australians have lived in all parts of the Australian landscape for more than 60 000 years. There are over 700 groups and most recognise the different seasons that are unique to their area. First Nations peoples in the Darwin area have seven main seasons in their Gulumoerrgin (Larrakia) year. These seasons are divided according to the weather and the plants and animals that are common at that time of the year. The rainy season (Balnba) from November to December is when the first rains occur. Gulppula (green tree fog) is said to bring the rain. It is also the time to collect shellfish and the black plum. The monsoon season (Dalay: January–April) is when the saltwater crocodiles are laying their eggs and the barramundi are breeding.

**equinox**
a day when day and night are the same length; occurs twice each year

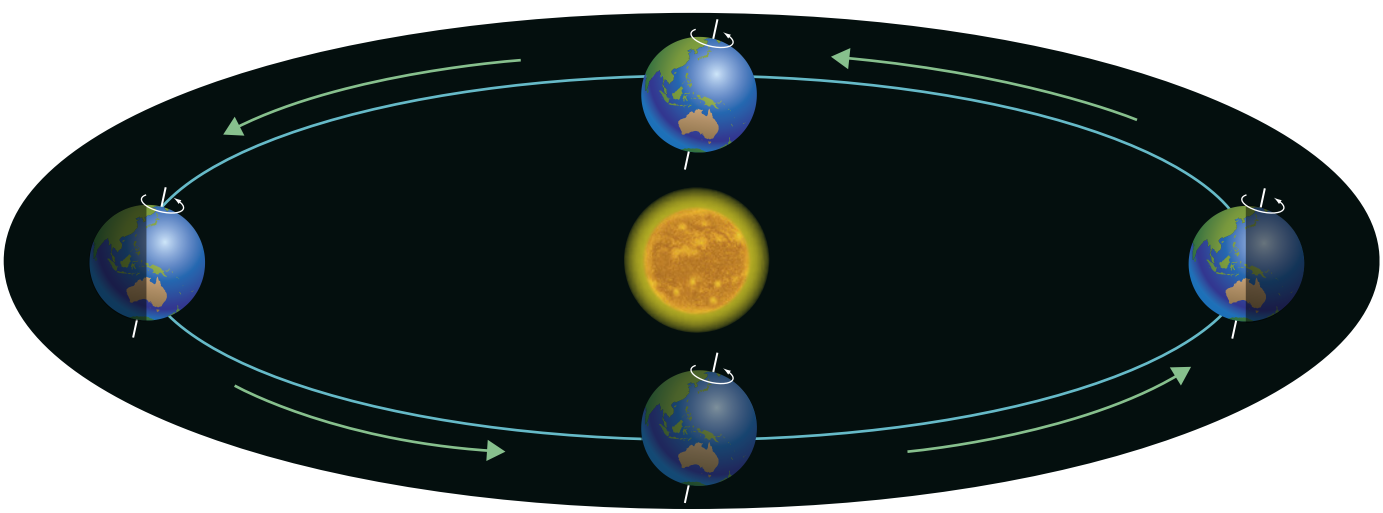


**Figure 3** The Earth's rotation and orbit cause day and night, as well as the seasons.

Mayilema season (March–April) overlaps the monsoon season and is when the speargrass flowers appear and the magpie goose eggs can be collected. Damibila (April–June) is the time to collect the barramundi and bush fruit, while heavy dews are on the ground in the Dinidjanggama season (June–August). During Gurrulwa (July–September) there are often big winds that appear to come from all directions at once, while Dalirrgang (September–October) is very hot and humid as the weather slowly builds up to the next rainy season. Figures 4, 5 and 6 show the seaonal calendars unique to Larrakia Country in the Northern Territory, Yirrganydji Country in Far North Queensland and Gariwerd Country in Victoria.

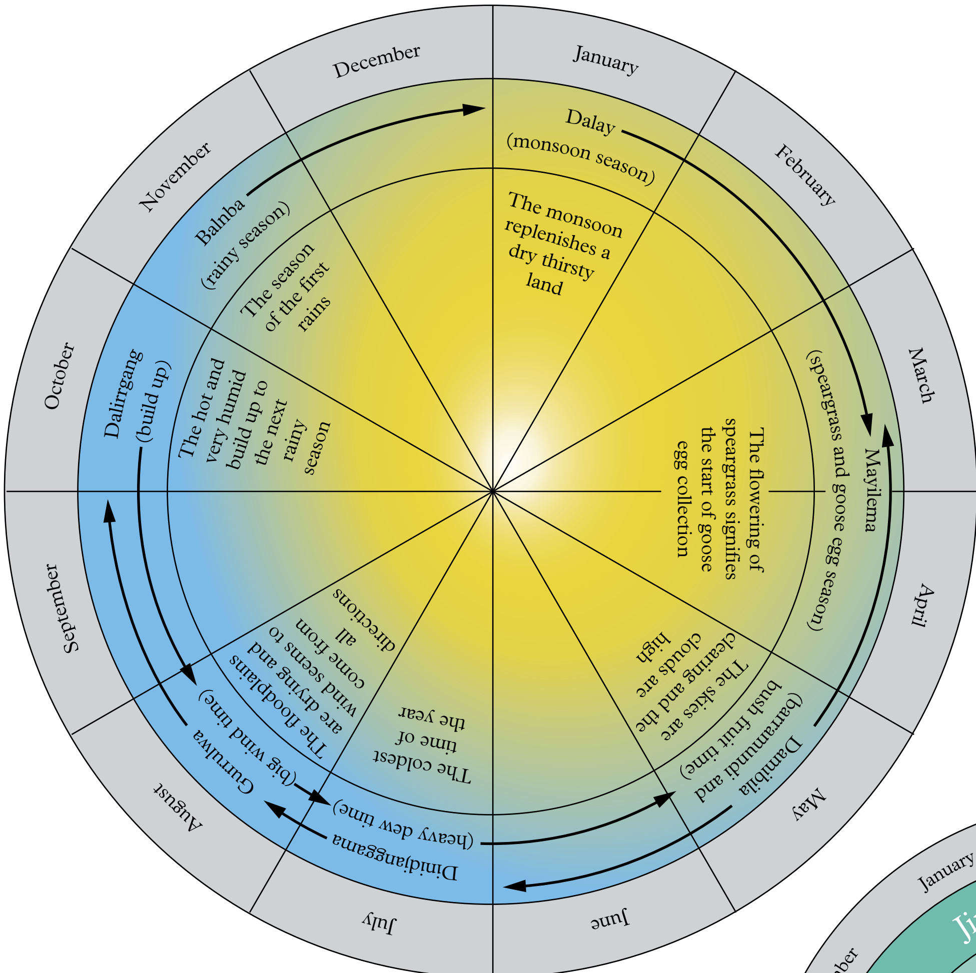
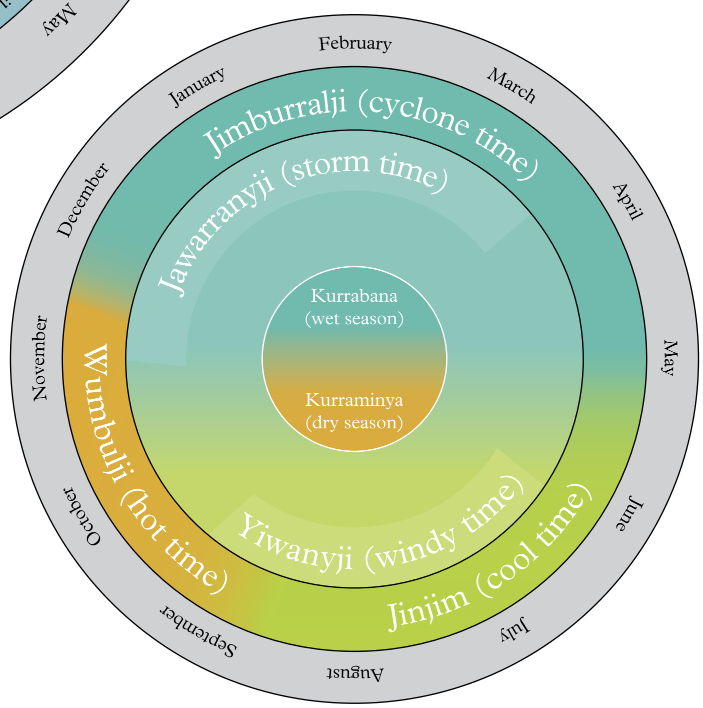




**Figure 4** The Gulumoerrgin (Larrakia) calendar is used by First Nations peoples in Darwin.



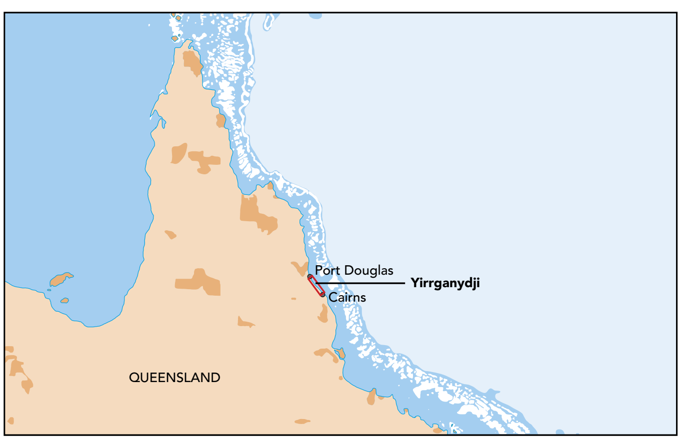
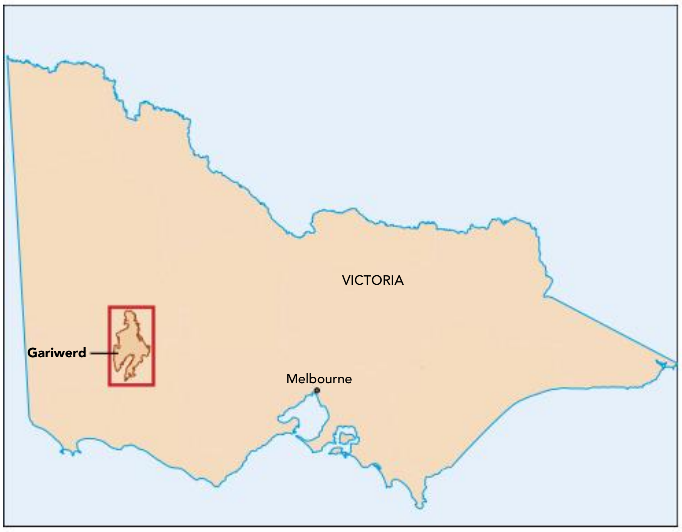




**Figure 5** The Yirrganydji calendar is used by First Nations peoples along the coast of Far North Queensland.

The traditional lands and waters of the Yirrganydji people covers the Queensland coast from Cairns to Port Douglas. Their seasonal calendar shows two major seasons: Kurrabana (wet season) and Kurraminya (dry season). The Kurrabana wet season is divided into a time of storms (Jawarranyji) and a time of cyclones (Jimburralji). The dry season is divided into the cool time (Jinjim), the windy time (Yiwanyji) and the hot time (Wumbulji).

Each of the First Nations communities used their observations of the local environment to create a unique calendar. This is different from the European approach that recognises the same four seasons in all parts of the world from the Antarctic to the tropics, despite the very different climate and conditions.



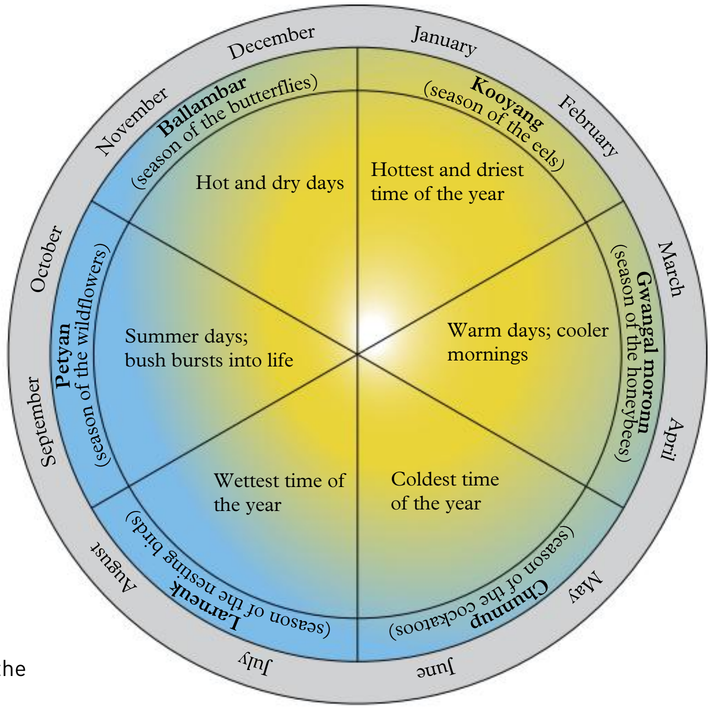




**Figure 6** The Gariwerd calendar is used by First Nations peoples in the Gariwerd (Grampians) region in Victoria.

## 7.4 Check your learning

### Retrieve

1 **Identify** the four seasons experienced in Australia, marked with the letters a, b, c and d on Figure 7.

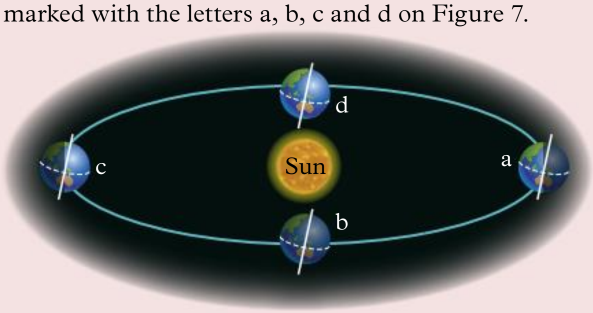



**Figure 7** Four seasons in Australia

2 **Recall** the angle of the Earth's rotational tilt away from the Sun.

### Comprehend

3 **Represent** the seasons in a table. Draw a table with three columns. In the first column, write the months of the year. In the second column, write the names of the four European seasons next to the appropriate months. In the third column, write the names of the seven Gulumoerrgin (Larrakia) seasons.

### Analyse

4 **Compare** (the similarities and differences between) the winter solstice and the summer solstice.

5 Use the motion of the Earth around the Sun to **consider** why January is hotter than July in Australia.

6 **Compare** (the similarities and differences between) the Gulumoerrgin (Larrakia), Yirrganydji and Gariwerd calendars.

### Apply

7 **Create** a paragraph for year five students that discusses how the Wathaurong people gathered and recorded data over many years before placing stones to represent the solstice and equinox.

**Quiz me**
Complete the Quiz me to check how well you've mastered the learning intentions and to be assigned a worksheet at your level.

//SCIENCE AS A HUMAN ENDEAVOUR//

# 7.5 Astronomers explore space

**Learning intentions**

By the end of this topic, you will be able to:

- identify examples that show how advances in technology and scientific knowledge have improved our understanding of the solar system.

It can take many years of travel for a rocket to land on another planet. Scientists therefore need to rely on other methods to learn about space.

## Astronomy

Astronomy is one of the oldest sciences. Ancient astronomers believed that stars were permanently fixed to a heavenly sphere and never changed. Both First Nations and European astronomers tracked the movement of the planets against these heavenly lights, which they grouped into constellations, and used these observations to calculate time and develop calendars. From this they determined the seasons and calculated the best time to plant their crops or gather their foods. They observed solar and lunar eclipses and used the positions of the stars and planets to navigate the oceans.

**Figure 1** Emu in the sky, a constellation seen by First Nations Australians in the dark areas of the Milky Way. Depending on its position in the night sky, it informs people about the different behaviours of the bird.

## Telescopes

**Telescopes** have been used since the seventeenth century to view distant objects. The most common type of telescope used in astronomy is the optical telescope. This works by collecting more light than the human eye can collect and then focusing this light using lenses or mirrors. A distant object viewed through an optical telescope becomes brighter and magnified (Figure 2).

**Figure 2** The Antennae galaxies are about 45 million light-years away from the Milky Way.

### THE HUBBLE AND JAMES WEBB SPACE TELESCOPES

In 1990, NASA launched the Hubble Space Telescope which orbits the Earth at 569 km above our atmosphere. This has given scientists a view of our universe far beyond that of any ground-based telescope because different forms of electromagnetic radiation, such as gamma rays, X-rays and **ultraviolet radiation**, are available for observation.

From the images beamed back to Earth from the Hubble Space Telescope, astronomers have been able to make an enormous number of new observations and have estimated the age of the universe more accurately at around 13–14 billion years. NASA launched the more advanced James Webb Space Telescope on 25 December 2021. It orbits the Earth at 1.5 million km above Earth's atmosphere!

The Webb looks primarily at **infrared radiation**, allowing it to see a greater variety of things than the Hubble. The Webb can see things more clearly than the Hubble because it has a bigger mirror that reflects more light than the Hubble. The newer space telescope will help astronomers build on the knowledge about the universe that they gained from images taken by the Hubble. The first images from the Webb were released to the public in July 2022. Figure 3 shows the difference in the images taken by the Hubble and the Webb.

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

**ultraviolet radiation**
invisible rays that are part of the energy that comes from the Sun

**infrared radiation**
invisible light that has longer wavelengths than visible light

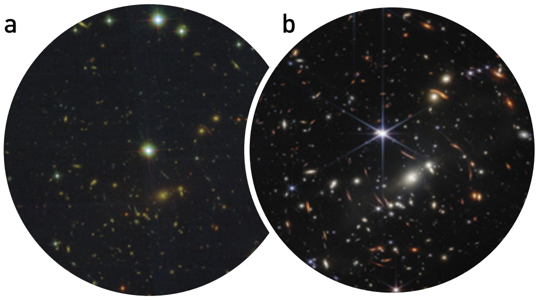



**Figure 3** Images of the same galaxy cluster taken by **a** the Hubble Space Telescope and **b** the James Webb Space Telescope

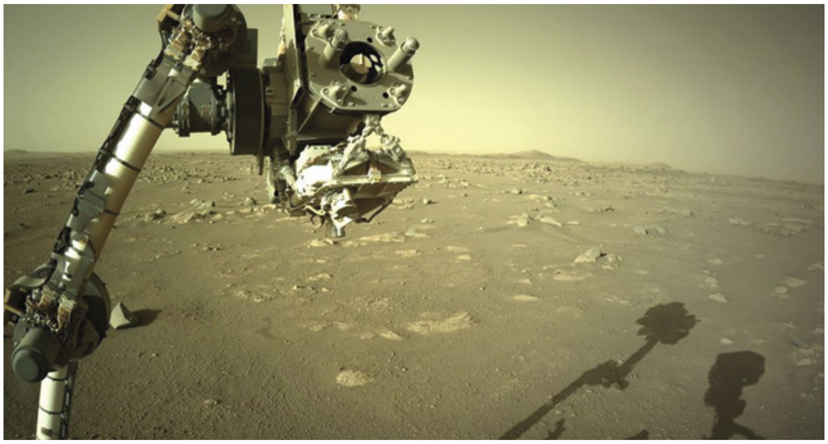


**Figure 4** NASA's Mars *Perseverance* rover took this photo using one of its onboard cameras.

## Mars mission

NASA is already planning a crewed mission to Mars. But could humans live on Mars? The Mars exploration rovers *Spirit* and *Opportunity* were launched in 2003 and landed on Mars in 2004 to find out more about the 'red planet'.

In 2008, the *Phoenix* Mars lander touched down on an ice sheet on the Martian surface. Operated from Earth, its instruments took photographs of ice that was melting. The lander's robotic arm scooped up soil samples and analysis from the lander's instruments revealed traces of magnesium, sodium, potassium and, importantly, water. NASA scientists described this discovery as a 'huge step forward'.

In 2021, NASA's Mars 2020 *Perseverance* rover landed on Mars. The rover's mission is to seek signs of ancient life on Mars and to collect rock samples for scientists to study.

The *Perseverance* rover is taking photos of the surface of Mars (Figure 4) and has even sent back the first audio recordings of Mars.

## Space probes

Humans are also able to gather new information about space by using space probes. Typically, space probes are controlled remotely and can be launched into space to measure properties of Earth, the solar system or the universe around us.

The space probe *New Horizons* was launched by NASA in 2006. After a gravity boost from Jupiter in 2007, its six-month flyby of Pluto in 2015 produced an enormous amount of data on the dwarf planet's surface properties, geology and atmosphere, which was still being analysed one year later.

## 7.5 Test your skills and capabilities

### Understanding the impact of science

In 1967 an Outer Space Treaty that offered a series of guidelines for how countries should explore space was signed by countries in the United Nations. After many more years of negotiations, the Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (also called the Moon Treaty) was created by a group of different nations. It sets out a list of rules for all celestial bodies that countries must follow, including ownership and mining. It is yet to be signed by the countries who are currently exploring space.

Science is not just about experiments and making discoveries. Scientists must also develop an understanding of the consequences of their discoveries. Australia is currently building its capacity for space research. **Develop** a set of guidelines for these scientists to follow.

**Consider** the following to help.

1 **Identify** whether you would own the section of the Moon you land on or explore.

2 **Explain** what you would do if you discovered a valuable metal or mineral on the Moon. (Note: If you do not mine it, how would you pay for the research?)

3 **Describe** what you would do if another country claimed the same section of the Moon.

4 **Describe** the consequences you would face if your rocket crashed into a city in another country.

5 **Compare** your opinions with others in your class.

# CHAPTER 7 REVIEW

## EARTH, SUN AND MOON

### Retrieve

1 **Identify** which of the following best describes the equinox.
  - A the longest day of the year
  - B a day and night of equal length
  - C a lunar eclipse that occurs every year
  - D the shortest day of the year

2 **Recall** that a total solar eclipse occurs when:
  - A the Moon blocks out the maximum amount of light from the Sun
  - B the Earth blocks out the light on the Moon from the Sun
  - C the Sun blocks out the view of the Earth from the Moon
  - D a comet blocks out light from the Sun.

3 **Identify** which of the following statements is true.
  - A The Earth orbits the Sun.
  - B The planets orbit the Moon.
  - C The Sun orbits the planets.
  - D The Earth orbits the Moon.

4 **State** the name for one revolution of the Earth around the Sun.

5 **Identify** the season in Norway when it is summer in Australia.

6 **Recall** the name of the event that occurs when the Moon totally blocks the light from the Sun.

### Comprehend

7 **Explain** what causes day and night.

8 **Describe** how the Sun affects day and night and seasons at the Antarctic.

9 **Describe** the seven seasons identified by the Gulumoerrgin (Larrakia) people.

10 **Describe** the phases of the Moon.

11 **Explain** why 29 February only occurs every four years.

12 A student claims that the Moon is a mini Sun that shines at night. **Explain** why they are incorrect.

13 **Explain** the purpose of the Hubble and James Webb Space Telescopes.

### Analyse

14 **Compare** a solar eclipse and a lunar eclipse.

15 **Compare** astronomy and astrology.

16 Figure 1 shows how the seasons occur. Answer ‘A’ or ‘B’ to each question.
  - a **Identify** the drawing that represents summer.
  - b If the piece of card was the Earth, **identify** which drawing would represent winter.
  - c If the piece of card was the Earth, **identify** which drawing would represent the warmest day.

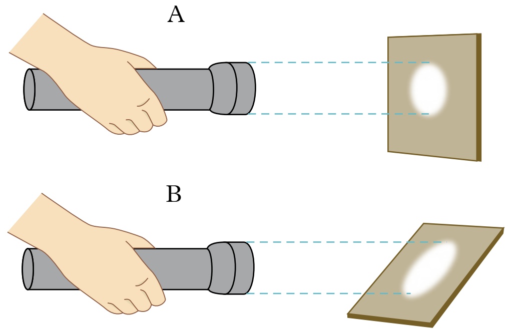



**Figure 1** How the seasons occur

17 Figure 2 shows the average number of sunlight hours across Australia in January and June. **Analyse** the two maps and use the data to explain why Australian summers have higher temperatures than Australian winters.

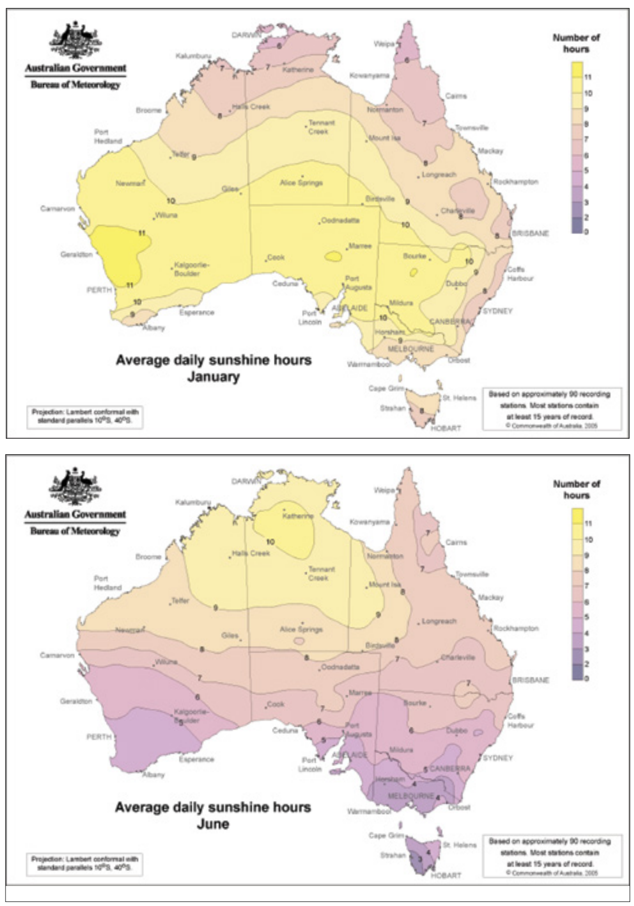



**Figure 2** The average amount of sunlight in January and June

18 Study Figure 3 and answer the following questions.

- **a** **Identify** the season that has the longest shadows.
- **b** **Identify** the season that gives the least opportunity for solar heating.
- **c** **Identify** the season where the Sun travels furthest across the sky.
- **d** **Identify** which side of the house is best to grow plants that like sunlight.
- **e** If a plant is growing on the eastern side of a house, **describe** the amount of sunlight it receives in the morning.

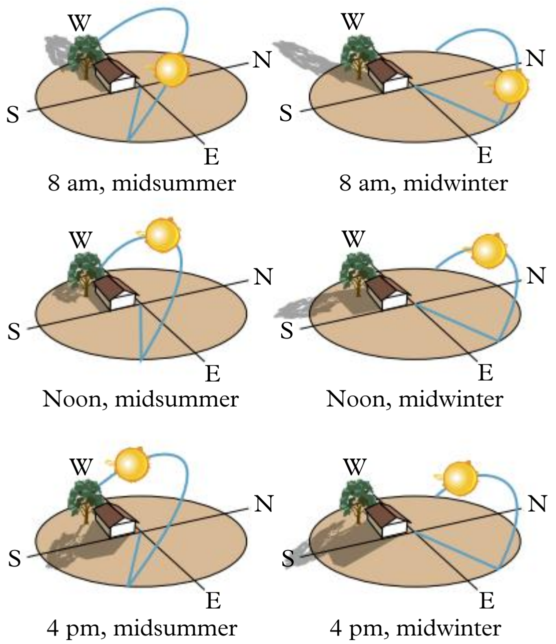



**Figure 3** The path of the Sun across the sky in winter and summer

## Apply

19 Look at Figure 4, which shows a total eclipse of the Sun as it would be seen in the middle of the day from Earth. **Create** and label a diagram to illustrate a:

- **a** solar eclipse
- **b** lunar eclipse.

**Figure 4** Total eclipse of the Sun

20 The Persian calendar celebrates the New Year at the moment the Sun crosses the celestial equator on approximately 21 March each year. In 2014 it was celebrated at 4 am on the east coast of Australia. In 2015 it was celebrated at 10 am. **Discuss** why the exact time of the New Year changes from one year to the next.

21 Visit NASA's website for the 2020 *Perseverance* rover mission (the link is on your obook pro). Navigate to the gallery of 'Raw images' showing recent pictures taken by the rover. Select one image and make five scientific observations about what you can see in the image. **Discuss** what you know about Mars from looking at this image.

22 Gravity is not considered a force. Instead, gravity is the distortion of space and time caused by a large object. This allows the large object to have a pull force. **Evaluate** the following sentence and rewrite it so that it is correct.

'The force of the Moon's gravity pulls the water on Earth to cause high tides.'

### Social and ethical thinking

23 Some nations are planning to develop human settlements on the Moon. **Discuss** an argument for and against this decision. **Decide** if you do or do not support this plan. **Justify** your decision (by comparing the arguments for and against this decision and describing why one argument is more important).

24 Many early European settlers claimed that First Nations Australians did not use any of the sciences. **Provide** evidence that refutes this claim.

25 Scientists are continuously exploring space, including Mars. **Discuss** the ethical implications of finding life on one of these planets.

### Critical and creative thinking

26 Find data for the sunrise and sunset times over seven days in summer and winter. From this information, **calculate** the length of the day and the length of the night. Present your findings in a table. **Discuss** what you notice about the lengths of the days and nights for each season. **Explain** why this difference occurs.

27 In May 2021 there was a lunar eclipse visible in Australia. The Moon was referred to as a 'supermoon'. **Investigate** what the criteria for a supermoon are, and **explain** why a lunar eclipse may be a supermoon.

### Research

28 Choose one of the following topics on which to conduct further research. Present your findings in a format that best fits the information you have found and understandings you have formed.

## » Search for extraterrestrial intelligence

Astronomers are involved in a Search for Extraterrestrial Intelligence (SETI).

- Find out what instruments the astronomers are using in this search.
- Describe how these instruments will help them to find extraterrestrial intelligence.
- Describe what they may expect to find.

You, too, can use your computer to become a part of this search.

**Figure 5** The Search for Extraterrestrial Intelligence (SETI) Institute is America's only organisation entirely dedicated to searching for life in the universe.

## » Science communication

Investigate what it means to be a science communicator.

- Research the work of Wiradjuri astrophysicist and science communicator, Kirsten Banks.
- Describe how she combines First Nations astronomy knowledge with her current work.

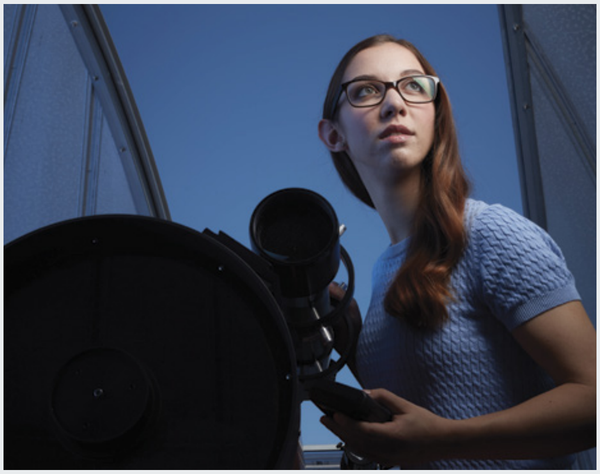


**Figure 6** Kirsten Banks

## » Mission to the Moon

The huge *Saturn* rocket that took *Apollo 11* to the Moon was an extremely powerful system in its day. The rocket had three 'stages'; each carried its own fuel and dropped off as the rocket went higher into the sky. The rocket carried the 'lunar lander', which was itself a very complicated piece of technology.

- Build a model of the *Saturn* rocket and explain the role of each stage and how it performed.

**Figure 7** The launch of the *Saturn* rocket

## » The far side of the Moon

The Moon rotates at the same rate as the Earth, so we never see the far side of the Moon from Earth. So what is it like? Is it the same as the near side of the Moon? Some astronauts have flown over the surface of the far side, but only one has landed a ship.

- Identify how many people have seen the far side of the Moon.
- Identify which country landed a probe on the far side and brought back material from the Moon's surface.
- Compare the far side of the Moon to the side that faces Earth.
- Describe the complexities of living on the surface of the Moon.

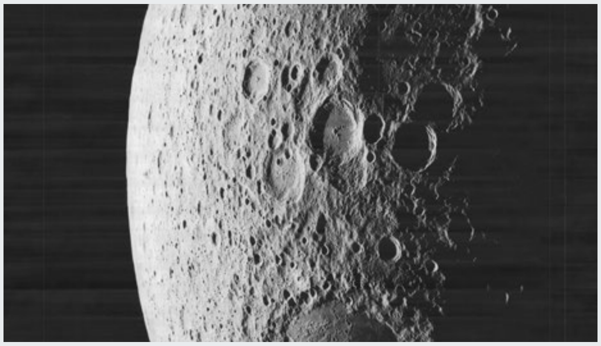


**Figure 8** A section of the far side of the Moon

# Chapter checklist

Now that you have completed this chapter, reflect on your ability to do the following.

| | I can do this. | I cannot do this yet. |
|---|---|---|
| • Explain how the length of a day and a year relate to the movements of the Earth.<br>• Describe the differences between a total and partial solar eclipse. | ☐ | ☐ Go back to Topic 7.1 'The Earth, Sun and Moon interact with one another'.<br>Page 172 |
| • Identify and describe the phases of the Moon and lunar eclipse.<br>• Contrast a solar and a lunar eclipse. | ☐ | ☐ Go back to Topic 7.2 'The Moon reflects the Sun's light'.<br>Page 174 |
| • Explain how the Moon's gravity causes tidal movements.<br>• Describe the relationship between the Moon and tides that was recognised by early First Nations Australians. | ☐ | ☐ Go back to Topic 7.3 'The Moon's gravity causes tidal movements'.<br>Page 176 |
| • Define the terms 'solstice' and 'equinox'.<br>• Explain how seasons are related to the position of the Sun and Earth.<br>• Describe the importance of seasons and seasonal calendars to First Nations Australians. | ☐ | ☐ Go back to Topic 7.4 'Seasons are caused by the tilt of the Earth'.<br>Page 178 |
| • Identify examples that show how advances in technology and scientific knowledge have improved our understanding of the solar system. | ☐ | ☐ Go back to Topic 7.5 'Science as a human endeavour: Astronomers explore space'.<br>Page 182 |

**Check your Student obook pro for these digital resources and more:**

**Quizlet**
Play a Quizlet game to test your knowledge.

**Chapter quiz**
Test your understanding of this chapter with the chapter review quiz.

CHAPTER

# 8

# EXPERIMENTS

# SCIENCE LAB RULES

Being safe in the lab is essential to prevent you and others from getting hurt. Whenever you are in the lab, you must always follow the rules below.

## DO:

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

## DON'T:

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

# 1.1 Sideways ping pong

CHALLENGE

## Aim

To identify the factors that affect the horizontal movement of a ping pong ball.

## What you need:

Ping pong ball, measuring tape or ruler, cardboard cylinder, retort stand, boss head and clamp

## What to do:

1 Working in pairs, use the retort stand to hold the cardboard cylinder 30 cm above the desk or table (Figure 1).


**Figure 1** Making a ping pong ball bounce sideways

2 Place the ping pong ball at the top end of the cylinder and let it roll through the tube to the floor. Do not throw or flick it.

3 Measure how far the ball travels horizontally from the end of the tube to the floor. Record your result in a table.

4 Repeat steps 2 and 3 twice. This is your baseline to compare a potential change.

5 Select one of the questions below to test if it causes a change in the horizontal distance travelled by the ping pong ball. Record your results in a table.

6 Write a sentence that describes the change you made and how the movement of the ball changed.

## What if?

> What if you change the colour of the ball?
> What if you change the type of floor covering?
> What if you drill holes in the ball?
> What if you change the angle of the tube?
> What if you push the ball down the tube?
> What if you vary the height from which the ping pong ball is dropped?

**Figure 2** Ping pong bats and ball

# 1.2 Drawing scientific diagrams

SKILLS LAB

## Aim

To correctly identify and draw scientific diagrams of science equipment.

## STATION 1

### What you need:

Five boxes from your teacher (each containing five different pieces of equipment), grey pencil, ruler, piece of plain A4 paper

### What to do:

1 Share a box with a partner. Write down the name of each piece of equipment in the box and draw a scientific diagram of the equipment in pencil.
2 When finished, return the box to the teacher and collect a different box. Repeat step 1 until you have named and drawn the equipment in all five boxes.
3 Check the names and diagrams (and spelling) for the pieces of equipment from Figures 1 and 2 on pages 6–7 of Chapter 1. Correct any mistakes you may have made.
4 Look at your list of equipment. Decide how you could divide the equipment into two groups. For example, you might group all pouring equipment, all heating equipment or all safety equipment together. In your notebook, write down the names of the group and the equipment that belongs in that group.

**Figure 1** Drawing scientific equipment

## STATION 2

### What you need:

Large flask, retort stand, boss head, clamp, funnel, small beaker (100 mL)

### What to do:

1 Set up the stand with the boss head and clamp, placing the boss head approximately two-thirds of the way up the stand, as shown in Figure 1.
2 Carefully place the flask neck into the clamp and tighten the clamp so that the flask is secure. (The flask should be approximately 10 cm above the bench, not resting on it.)
3 Predict how many beakers of water you think it will take to fill the flask. In your notebook write: 'Step 2 Prediction = __ beakers of water to fill the flask'.
4 Fill the beaker with water. Use the funnel to transfer the water into the flask until it is full. Write the answer in your notebook: 'Number of beakers of water needed to fill the flask = __'.
5 Draw a scientific diagram of the equipment that was set up. Label the equipment.
6 Take the apparatus apart and place each piece of equipment in its appropriate cupboard.

### Questions

1 Name the piece of equipment that was the most difficult to draw.
2 Name the piece of equipment that was the easiest to draw.
3 Name up to five pieces of equipment that you had not seen before and list their uses in a laboratory.
4 Name two pieces of equipment that can be used for:
   a holding things
   b mixing chemicals
   c pouring.
5 Describe where in your laboratory you could find:
   a test tubes
   b Bunsen burners
   c tongs
   d retort stands
   e test-tube racks
   f heatproof mats
   g a rubbish bin
   h beakers.

# 1.4 Observation versus inference

SKILLS LAB

## Aim

To identify the difference between observations and inferences.

How good are you at making observations? Do you confuse observations with inferences? There are many things you can observe.

### What to do:

1. Draw up a table with two columns: one for observations and the other for inferences.
2. Examine Figure 1, which is a drawing of a crime scene. Write six observations from the crime scene in the observation column.
3. Write down three inferences you can make from your observations in the inference column.
4. Use your inferences to describe what could have happened before you started observing the scene.

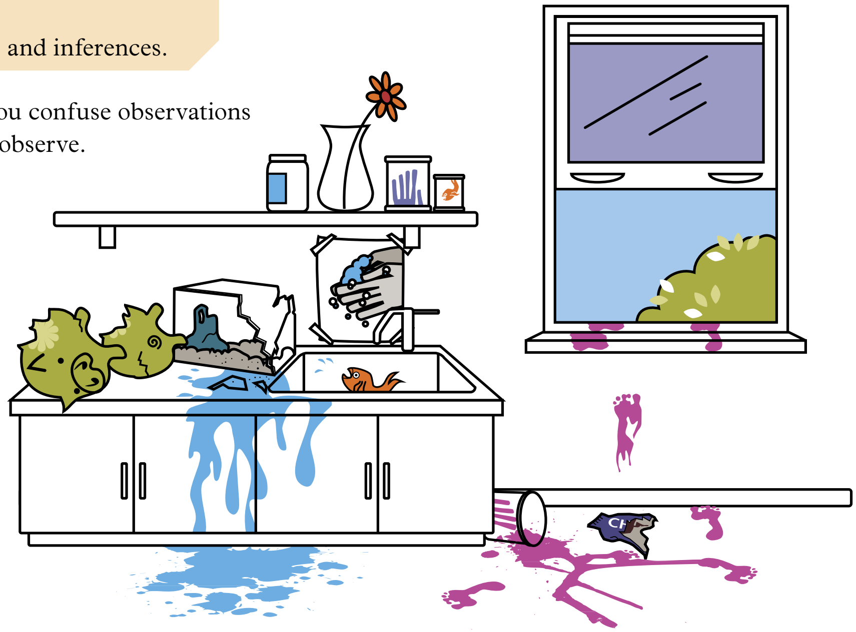


**Figure 1** Drawing of a crime scene

# 1.5 Measuring mass and volume

SKILLS LAB

## Aim

To accurately weigh the sugar mass and liquid volume in a variety of drinks.

## What you need:

A variety of soft drinks, flavoured milk, fruit juices, bottled water, sugar, scales, measuring cylinder, beakers, small spoon

## What to do:

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


**Figure 1** A nutrition panel

2. Place a beaker on the scales and press the 'TARE' button that returns the numbers to zero.
3. Add sugar to each beaker until it reaches the mass of sugar in one serve of drink (as shown by the nutrition panel).
4. Add water to another beaker to carefully measure the volume of a single serve of the drink.
5. Create a table to record the name of each drink, the sugar content per serve for each serve, the volume of each serve and the number of serves of drink that were in each container.

## Questions

1. Identify the drink that had the most sugar in a single serve.
2. Identify the drink that had the most serves in a single container.
3. Identify the drink that has the most sugar in a whole container.
4. Identify a type of drink that had an unexpected amount of sugar content, and explain why you were surprised.

# 1.8 Heating water

SKILLS LAB

**CAUTION!** Wear safety glasses and lab coat, and tie long hair back when using a Bunsen burner. Do not touch hot equipment.

## Aim

To identify how adding sugar or salt to water affects the boiling point of water.

## What you need:

Beaker (250 mL), water, thermometer, retort stand, boss head, clamp, tripod, gauze mat, heatproof mat, stopwatch, Bunsen burner, matches, glass stirring rod, salt (optional), sugar (optional), teaspoon

## What to do:

1 Set up the equipment as shown in Figure 1. Add 150 mL of water to the 250 mL beaker.

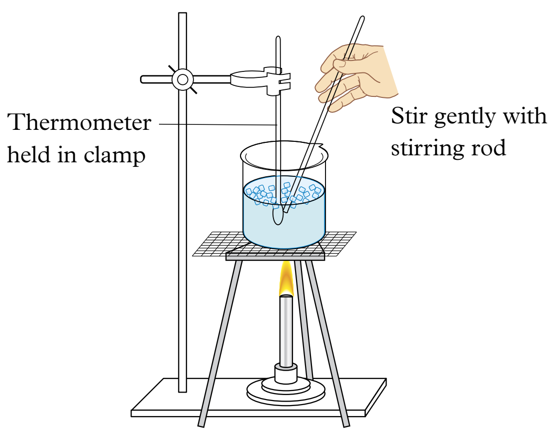



**Figure 1** Equipment set-up

2 Draw a labelled scientific diagram of the equipment in your notebook.

3 Draw a table with two columns: one for time (in minutes) and the other for temperature (in degrees Celsius), as in the example below.

| Time (min) | Temperature (°C) |
|---|---|
| | |
| | |
| | |

4 Measure the starting temperature of the water and write it in the table. This is the temperature at 0 minutes.

5 Safely light the Bunsen burner and then open the collar to get a blue flame.

6 Heat the water over the Bunsen burner. Record the temperature of the water every minute for a total of 12 minutes.

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

Choose one of the inquiry questions below.

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

Answer the following questions about your inquiry question.

1 Write a hypothesis for your inquiry.

2 Identify the *independent* variable that you will change from the first method.

3 Identify the *dependent* variable that you will measure and/or observe.

4 List the variables you will need to control to ensure a reasonable test. Describe how you will control each variable.

5 Test your hypothesis by repeating the method with the independent variable you chose.

6 Collect the data in a table.

7 Draw an appropriate graph for your data.

## Questions

1 Identify the type of data you have collected.

2 Identify the type of graph you could draw for this type of data.

3 Explain how your graph supports or does not support your hypothesis.

4 Describe how your experiment was a reasonable test by providing a definition of a reasonable test and matching this to your method.

# 2.1A Comparing states of matter

EXPERIMENT

## Aim

To investigate the characteristics of solids, liquids and gases.

## Materials

- Clamp
- 250 mL beaker
- Water
- Food colouring
- Three different-shaped containers
- Plastic syringe
- Rubber stopper
- 100 mL beaker
- Electronic balance
- Balloon
- Balloon pump

## Method

1 Copy Table 1 into your notebook and complete it as you work through the method.
2 Examine the clamp and record its mass, shape, ability to be compressed and other data in the table.
3 One-third fill the 250 mL beaker with water. Add two drops of food colouring and mix carefully.
4 Pour the coloured water, in turn, into the three other containers. Record what happens to the shape of the water in each of the containers.
5 Half-fill the syringe with water. Hold the end of the syringe upward (plunger at the base) and gently push the plunger until all the air is removed from the syringe. Place the stopper on the bench and push the end of the syringe against it, as shown in Figure 1. Make sure that the syringe is well sealed before compressing it. Record whether water can be compressed (that is, made to take up less volume).
6 Set the empty 100 mL beaker on the electronic balance and press the 'TARE' button. Pour in the water from the syringe and measure the mass of the water. Record the results in the table.
7 Draw the syringe full of air and invert the syringe onto the stopper. Compress the syringe. Record whether air is compressible and takes the shape of the syringe.
8 Record the mass of the empty balloon and then use the balloon pump to blow it up. Record whether the air takes the shape of the balloon. Tie off the end and weigh the balloon again, this time with air in it. Subtract the mass of the empty balloon from that of the blown-up balloon to calculate the mass of the air inside the balloon (mass of blown balloon – mass of empty balloon).

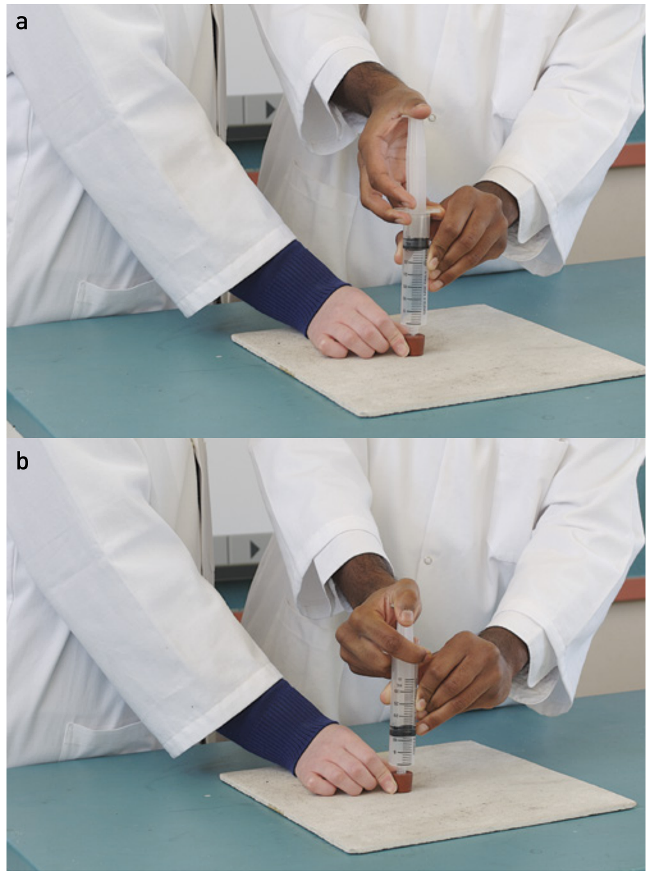


**Figure 1** Testing the compressibility of air: **a** before and **b** after depressing the plunger on the syringe.

## Results

Complete Table 1.

## Discussion

1 Identify which substances had a measurable mass.
2 Identify which substances were able to change their shape to match the container shape.
3 Identify which state of matter can be compressed into a smaller space. Describe how it changed.

## Conclusion

Write a short paragraph to describe the properties of each state of matter (solids, liquids and gases).

**Table 1** Comparing states of matter

| Matter | State of matter | Mass (g) | Able to take shape of container? | Able to be compressed? | Other characteristics observed |
|---|---|---|---|---|---|
| Clamp | Solid | | | | |
| Water | Liquid | | | | |
| Air | Gas | | | | |

# 2.1B Three states of water

CHALLENGE

**CAUTION!** Do not touch hot equipment.

## Aim

To observe the three states of water.

## What you need:

Large test tube, tap water, Bunsen burner, heatproof mat, wooden test-tube holders, ice cube, copper wire (approximately 8–10 cm long), pliers, matches, test-tube rack

## What to do:

1. Collect an ice cube that will fit into a test tube.
2. Wrap copper wire around the ice cube so it sinks in the water.
3. Pour tap water into the test tube until it is one-third full. Drop the ice cube with the wire around it into the water so that the water level is two-thirds up the test tube.
4. Light the Bunsen burner and turn it to a blue flame. Use the test-tube holder to gently heat the water at the top of the test tube. Face the opening of the test tube away from your face, body and other people.
5. Observe any changes in the water and ice as the water is heated. Record your observations; for example:
   > 'When the water in the top of the tube was heated, it …'
   > 'When the water was heated, the ice …'

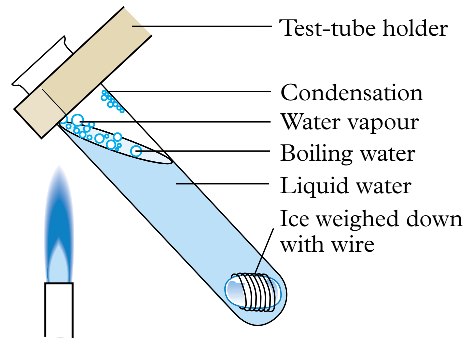



**Figure 1** Three states of water in a test tube

## Questions

1. Explain how you could have ice and boiling water in the same test tube.
2. Use the particle model to draw a picture of the three states of water.

# 2.3A Modelling matter

CHALLENGE

## Aim

To model the three states of matter.

## What you need:

Items such as table tennis balls, coins, lollies, marbles, pieces of modelling clay

## What to do:

1 Use one of the items listed to represent the particles of matter. Make models of a solid, a liquid and a gas.

2 Draw a labelled diagram of each model.

## Questions

1 Describe how your modelled particles represented the characteristics of real particles.

2 Describe how your model could represent the kinetic energy in a solid, liquid and gas.

3 Describe how your model of a solid could be used to explain the process of melting.


**Figure 1** Use your materials to model the three states of matter.

# 2.3B Making a cuppa

CHALLENGE

## Aim

To observe how tea moves through hot water and cold water.

## What you need:

Two large beakers, cold water, hot water, two tea bags

## What to do:

1 Fill one beaker with hot water and the other with cold water.
2 Allow the beakers to sit still for a few minutes so that the movement of the water inside them is reduced.
3 Place a tea bag in each beaker. Brown colour from the tea leaves should seep into the water and then diffuse throughout the beaker of water.
4 Compare qualitatively how quickly the colour diffuses through the hot water and the cold water; for example, 'In the hot water, the brown tea moved …'

## Questions

1 Identify which beaker of water diffused the brown tea fastest through the water.
2 Use particle theory to explain your observations of how the brown tea molecules spread through the water molecules.

**Figure 1** Tea diffuses in hot water.

# 2.4 The density den

EXPERIMENT

To calculate the density of a substance, you first need to know its mass and volume. The most appropriate units for the substances you will be working with are grams (g) for mass and millilitres (mL) or cubic centimetres ($cm^3$) for volume. Millilitres tend to be used for the volume of liquids, whereas cubic centimetres are used for solids.

$$\text{Density} = \frac{\text{mass (g)}}{\text{volume (cm}^3\text{)}}$$

Note that 1 mL is the same as 1 $cm^3$. Therefore, grams per millilitre (g/mL) is the same as grams per cubic centimetre ($g/cm^3$).

## STATION 1

### Aim

To measure the density of liquid water.

### Materials

- 10 mL measuring cylinder
- Electronic balance
- Water
- Calculator
- 50 mL measuring cylinder

### Method

1 Copy Table 1 into your notebook and use it to record your measurements.
2 Measure the mass of the 10 mL measuring cylinder. Record its mass in grams.
3 Remove the measuring cylinder from the balance and add 6 mL of water to it.
4 Measure the mass of the cylinder and water. Calculate the mass of the water by subtracting the mass of the cylinder from the combined mass of the cylinder and water (Mass of water = mass of measuring cylinder and water – mass of measuring cylinder).
5 Use the density equation to calculate the density of the water and record your answer. (Do not forget the units!)
6 Repeat the experiment with the 50 mL measuring cylinder and 20 mL of water. Calculate the density of the water.
7 To obtain a third measurement of the density of water, choose one of the two measuring cylinders and any amount of water. Measure the mass of the water and its volume. Calculate the density of the water.

### Results

Record your calculations and results in Table 1.

**Table 1** Recording the density of water

| Measuring cylinder | Mass of measuring cylinder (g) | Volume of water (mL) | Mass of measuring cylinder and water (g) | Mass of water (g) | Density of water = mass/ volume (g/mL) |
|---|---|---|---|---|---|
| 10 mL | | 6 | | | |
| 50 mL | | 20 | | | |
| | | | | | |
| | | | | | Average = |

### Discussion

1 The standard value for the density of water is 1.00 g/mL at 25°C. Compare the values you obtained to this value.
2 Describe one factor that could have affected the accuracy of your results.
3 Compare the accuracy of the density value of the small volume of water with the density value of the large volume of water.
4 Use your answer to question 3 to explain why scientists should repeat their experiments.

## STATION 2

### Aim

To measure the density of regular-shaped blocks made from different materials.

### Materials

- Several blocks made from different substances (e.g. wood, polystyrene, lead, zinc)
- Ruler
- Electronic balance
- Calculator

### Method

1 Copy Table 2 into your notebook, adding a row for each additional substance.
2 Measure and record the mass of each of the blocks.
3 Use a ruler to measure the length, width and height of each block.
4 Calculate the volume of each block (Volume = length × width × height). An example has been done for you in the first row of Table 2, using the measurements in Figure 1.
5 Calculate the density of each block.

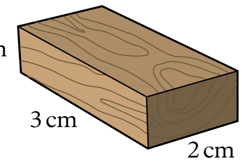



**Figure 1** Calculating the volume of a regular-shaped block

### Results

Record your measurements in Table 2.

**Table 2** Measuring the density of regular-shaped blocks

| Substance | Length (cm) | Width (cm) | Height (cm) | Volume ($cm^3$) | Mass (g) | Density ($g/cm^3$) |
|---|---|---|---|---|---|---|
| Wood | 3 | 2 | 1 | 3 × 2 × 1 = 6 | 3 | 3 ÷ 6 = 0.5 |
| | | | | | | |

### Discussion

1 Define parallax error.
2 Describe how parallax error could have affected the accuracy of your measurements.
3 Rank the blocks from least dense to most dense.

## STATION 3

### Aim

To measure the density of irregular-shaped objects.

### Materials

- Four different objects (e.g. spatula, a small rock, a lump of plasticine, an object of your choice) that each fit into the measuring cylinder
- Electronic balance
- 100 mL measuring cylinder

### Method

1 Copy Table 3 into your notebook with four blank rows.
2 Measure the mass of the first object. Record the mass (in grams) in your table.
3 Use the displacement method to work out the volume of the object:
   - Approximately half-fill the measuring cylinder. Record the volume of water in the cylinder (Volume 1).
   - Add the object to the measuring cylinder so that it is fully submerged. Record the volume of water in the cylinder (Volume 2).
   - Calculate the volume of the object by subtracting the volume of water in the cylinder before the object was added from the volume after the object was added (Volume 2 – Volume 1).
4 Calculate the density of the object.
5 Repeat the experiment with the remaining objects.

### Results

Record your measurements in Table 3.

**Table 3** Measuring the density of irregular-shaped objects

| Object | Mass (g) | Volume before (mL) | Volume after (mL) | Volume of object (after – before, in mL) | Density (g/mL) |
|---|---|---|---|---|---|
| | | | | | |

### Discussion

1 Describe some of the difficulties that you had using the displacement method for calculating density.
2 Describe an advantage of using the displacement method for measuring volume.
3 Compare the density of the water with the density of the objects.
4 Use the results from all the experiments to rank the objects from lowest to highest density.

### Conclusion

Describe how the density of objects can vary.

# 2.5A Effect of heat

EXPERIMENT

## Aim

To compare how introducing or removing heat affects a substance.

## STATION 1: HEATING A SOLID

**CAUTION!** Wear safety glasses and a lab coat, and tie long hair back when using a Bunsen burner.

### Materials

- Ball and ring apparatus
- 2 × 250 mL beakers
- Hot tap water
- Ice

### Method

1 Look at your ball and ring. Try passing the ball through the ring before heating and cooling. Record your observations; for example, 'Before heating and cooling, the ball …'

2 Half-fill a 250 mL beaker with hot tap water. Place your ball in the hot water for 5 minutes. Keep the ring away from the hot water.

3 Try passing the ball through the ring. Record your observations; for example, 'After heating in hot water, the ball …'

4 Half-fill the other beaker with cold tap water and add ice. Put the ball in the iced water and leave it for 5 minutes. Keep the ring away from the iced water.

5 Try passing the ball through the ring. Record your observations; for example, 'After cooling the ball in ice, it …'

### Results

Record your observations by describing what you did and how the movement of the ball through the ring changed.

### Discussion

1 Describe how the size of the metal ball changed with:

a heating

b cooling.

2 Use the kinetic theory of matter to explain what was happening to the particles in the solid when heat was applied.

3 Describe how the size of the ball changes as the temperature returns to room temperature.

## STATION 2: HEATING A LIQUID

**CAUTION!**

- Make sure the apparatus is not left unattended. The dye and water will spurt out the top of the glass tube if allowed to.
- The flask and its contents may be hot. Allow all equipment time to cool before handling it.

### Materials

- 100 mL conical flask
- Narrow glass tubing
- One-hole rubber stopper to fit glass tubing
- Food colouring
- Water
- Permanent marker
- Bunsen burner and heatproof mat
- Gauze mat
- Tripod
- Matches

### Method

1 Put two drops of food colouring in the flask and fill the flask to the top with water.

2 Place the stopper fitted with the tube in the flask. Some water will rise up the tube. Using the permanent marker, mark this first level on the tube.

3 Place the flask on the gauze mat on the tripod and heat gently.

4 After a few minutes of heating, turn off the Bunsen burner. Mark the level of the water in the tube again.

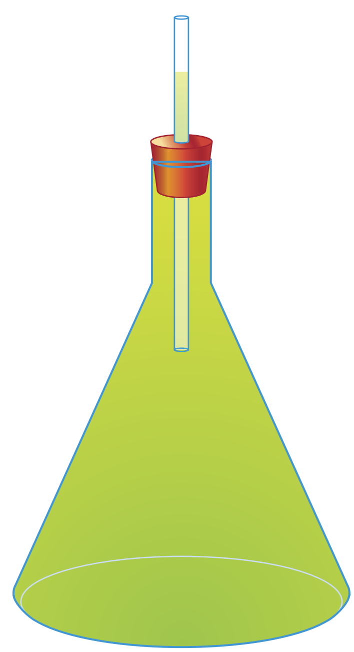


**Figure 1** Experimental set-up to show the expansion of a liquid on heating

5 Record how the level of the water changes as it cools.

## Results

Record your observations of the water level as the flask was:

a heated (for example, 'As the water was heated, the water level in the glass tubing ...')

b cooled (for example, 'As the water cooled, the water level in the glass tubing ...').

## Discussion

1 Use the kinetic theory of matter to explain how the liquid in the straw moved when it was:

a heated

b cooled.

# STATION 3: HEATING GASES

## Materials

- Balloon
- 100 mL conical flask
- String
- Ruler
- 250 mL beaker of hot water
- Ice bath (250 mL beaker of water and ice)
- Timer
- Balloon pump

## Method

1 Using a balloon pump, blow up the balloon to help stretch the rubber. Let the air out again until it is about the size of an apple.

2 Place the balloon over the neck of the flask.

3 Use the string and ruler to measure the circumference (the distance around the middle) of the balloon at room temperature. Copy Table 1 into your notebook and record this measurement.

4 Place the flask with the balloon in a beaker of hot water. Wait 2 minutes.

5 Measure and record the balloon's circumference.

6 Place the flask with the balloon in an ice bath with a small amount of water. Wait 4 minutes.

7 Measure and record the balloon's circumference.

## Results

Record your observations in Table 1.

**Table 1** Measuring balloon circumference at different temperatures

| Temperature | Balloon circumference (cm) |
|---|---|
| Room temperature | |
| Hot water | |
| Ice bath | |

## Discussion

1 Describe how the size of the balloon changed as the flask was moved from room temperature to hot water.

2 Describe how the size of the balloon changed as the flask was moved from hot water to ice.

3 Use the ideas of the particle model of matter to explain how the size of the balloon changed with the changes in temperature.

## Conclusion

Explain how heating can change the properties of a gas.

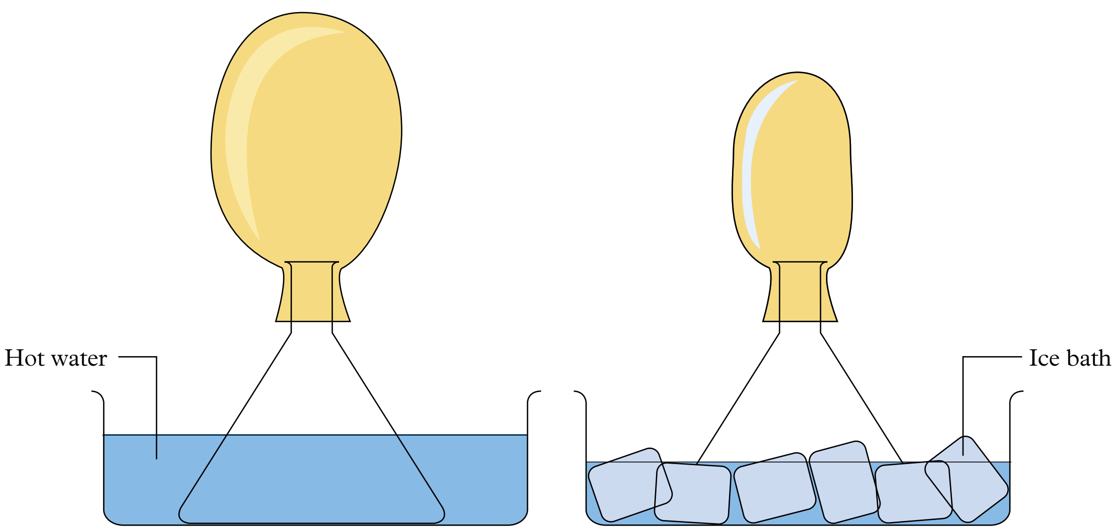



**Figure 2** Experimental set-up to show the expansion and contraction of a gas after heating and cooling

# 2.5B From ice to steam

EXPERIMENT

**CAUTION!**

- Steam and boiling water can both scald. Take great care when measuring the higher temperatures. If scalded, place the area of skin under cold running water for at least 5 minutes and show your teacher.
- Wear safety glasses and lab coat, and tie long hair back when using a Bunsen burner.

## Aim

To investigate the melting and boiling points of water.

## Materials

- 250 mL beaker
- Crushed ice
- Water
- Tripod stand
- Bunsen burner and heatproof mat
- Gauze mat
- Stirring rod
- Timer
- Retort stand, clamp and boss head
- Thermometer (0–110°C) or thermistor probe
- Matches

## Method

1. Place some crushed ice and a small amount of tap water in the beaker. Stir with the stirring rod for approximately 1 minute.
2. Measure and record the temperature of the water and ice mixture in Table 1. This is the melting point of water at 0 minutes.
3. Set up the equipment as shown in Figure 1, checking to make sure the thermometer is not touching the bottom of the beaker and that it is secure in the clamp. Do not stir with the thermometer.
4. Light the Bunsen burner and start heating the ice and water.
5. Measure and record the temperature of the mixture in the beaker every minute until the water starts to boil and produce steam. This is the boiling point of water.
6. Continue heating for another 4 minutes, unless most of the water has evaporated.
7. Using graph paper, or a suitable computer program, draw an appropriate graph with temperature on the vertical axis and time on the horizontal axis.

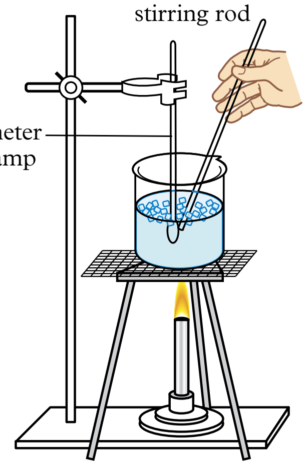



**Figure 1** Experimental set-up for measuring the melting point of ice

## Results

Record your observations, including your table and graphs.

**Table 1** Recording melting and boiling points

| Time (m) | Temperature (°C) |
|---|---|
| 0 | |
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |

## Discussion

1. a Identify the temperature of the melting point you measured.
   b Contrast between your measured melting point of ice and the standard measurement of 0°C.
2. a Identify the temperature of the boiling point of water you measured.
   b Contrast between your measured boiling point of water and the standard measurement of 100°C.
3. Identify one assumption that could have affected the accuracy of your results. Describe how you could improve this if you repeated the experiment.
4. Compare your results with those of the rest of the class. Suggest why there may be a variation or anomalies in the answers.

## Conclusion

Describe what you know about the melting and boiling points of water.

# 3.1 Comparing different types of mixtures

CHALLENGE

## Aim

To observe the characteristics of different mixtures.

## PART A: DIRTY WATER

### What you need:

Soil, water, jar with screw-top lid, timer

### What to do:

1 Put some soil and water in the jar to create a watery mixture.
2 Screw the lid on tightly and then shake the jar. Observe the jar for 5 minutes.

> Describe the movement of the soil particles; for example:
  – 'When the soil and water was shaken, it …
  – 'After 5 minutes …'
> Identify the types of particles that may float, sink or stay suspended.
> Use the terms 'solution', 'suspension' and 'sediment' to describe the behaviour of this mixture.
> Identify the type of mixture that is dirty water.

## PART B: MAKING A FOAM

**CAUTION!** Check for egg or dairy allergies.

### What you need:

Cream or egg white, hand or electric whisk, large metal bowl

### What to do:

Whip the cream or egg white until it increases significantly in size and holds its shape.

> Explain why the foam you have created is classified as a colloid by defining the term and comparing it with the mixture you have produced.

## PART C: MIXING OLIVE OIL AND WATER

### What you need:

Olive oil, water, jar with screw-top lid, detergent

### What to do:

1 Two-thirds fill a jar with equal parts of water and oil. Observe what happens and draw a labelled picture to record your observations.
2 Screw the lid on the jar tightly and shake the mixture vigorously. Observe what happens immediately after mixing. Record your observations; for example, 'After mixing the oil and water …'
3 Wait 5 minutes and record your observations again; for example, 'After leaving the mixture to sit for 5 minutes, it …'
4 Add a couple of drops of detergent to the mixture and shake the jar again.
   > Describe how the mixture changes when you add the detergent; for example, 'After adding detergent to the oil and water mixture and shaking it, …'
5 Wait 5 minutes and record your observations again; for example, 'After leaving the mixture to sit for 5 minutes, it …'
   > Explain what is happening using the terms 'colloid', 'mixture', 'emulsion' and 'emulsifier'.

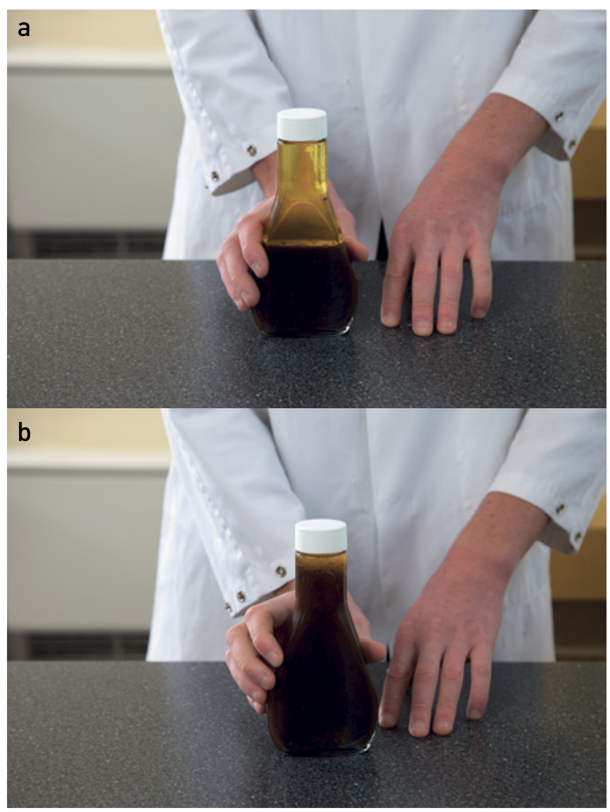



**Figure 1** Olive oil and water **a** before and **b** after adding an emulsifier

## PART D: ADDING SUGAR TO WATER

### What you need:

Water, table sugar, teaspoon, beaker or glass

**Figure 2** Do sugar cubes react differently from granulated sugar?

### What to do:

1 Add a small amount of sugar to water in a glass and stir.
   > Describe what happens to the sugar; for example, 'When sugar is added to a glass of water, it …'

## PART E: MAKING PERFUME

### What you need:

Lavender flowers, methylated spirits, scissors, jar with a lid, cotton bud

### What to do:

1 Cut the lavender flowers into tiny pieces and place them in the jar.
2 Cover the lavender flowers with methylated spirits.
3 Seal the jar and leave overnight.
4 The following day, dip the cotton bud in the methylated spirits.
5 Allow the methylated spirits to evaporate and then smell the cotton bud.
   > Explain why this mixture is a solution. Identify the solute and the solvent.
   > Predict if this experiment would work if you put the lavender flowers in a jar of water.
   > Explain why it is important that the methylated spirits evaporate easily.

**Figure 3** Lavender is often used in perfume.

# 3.2A What if salt was dissolved in water?

EXPERIMENT

## Aim

To investigate whether a mixture of salt and water forms a solution.

## Materials

- Test tubes
- Test-tube rack
- Spatula
- Salt
- 10 mL measuring cylinder

## Method

1. Add 5 cm of water to a test tube.
2. Add 1 spatula of salt to the test tube. Carefully stir the mixture. Observe what happens to the mixture.
   - Explain why this mixture is called a solution. Identify the solute and the solvent.

**Figure 1** Dissolving salt in water

## Inquiry: What if other substances were mixed with water?

Additional powders to test include:

- copper carbonate
- bath salts
- talcum powder
- brown sugar
- flour.

## Questions

Answer the following questions about your inquiry question.

1. Identify the *independent* variable that you will change from the first method.
2. Describe how you will know if your powders are able to form a solution.
3. List three variables you will need to control to ensure a reasonable test. Describe how you will control each variable.
4. Identify the equipment you will need to complete this experiment.
5. Predict which powders will form a solution.
6. Write down the method you will use to complete your investigation. (HINT: Use the method above as a guide.)
7. Prepare a table that shows the powder you are testing, your prediction and your results.
8. Show your teacher your planning to obtain approval before starting your experiment.

## Results

Complete your investigation by filling in your table of results.

## Discussion

1. Identify which substances were soluble in water.
2. Identify which substances formed a suspension.
3. Identify which substances took the longest to dissolve.
4. Compare your results with those of the rest of the class. Explain any unexpected results.
5. Name two other substances you know dissolve in water.
6. Use the results of your experiment to complete the following sentence: 'Water is a good solvent because …'
7. Describe how you could change this experiment to find out more about dissolving substances.

## Conclusion

Define the terms 'solution' and 'dissolve' by using examples from your experiment.

# 3.2B What if the solvent was heated when making a mixture?

EXPERIMENT

**CAUTION!** Do not eat or drink in the laboratory. Hot plate may cause burns – do not touch.

Many solutes dissolve only in certain solvents. Some dissolve very slowly and, when they do, only a certain amount of solute dissolves before the solution becomes saturated.

## Aim

To investigate ways to alter the rate (speed) at which a solute dissolves and/or the amount of solute that will dissolve.

## Materials

- MILO®
- Milk
- Teaspoon
- Small beaker
- Measuring cylinder
- Thermometer
- Hot plate to heat milk

## Method

1. Measure out 50 mL of milk and add it to the small beaker.
2. Carefully measure 1 teaspoon of MILO by smoothing the surface until it is even with the edges of the spoon.
3. Add the spoonful of MILO to the milk and stir until it dissolves.
4. Repeat steps 2 and 3 until the MILO no longer dissolves.
5. Identify how many spoonfuls of MILO dissolved in the room temperature milk. Record your results; for example, 'The number of level teaspoons of MILO dissolved in 50 mL of room temperature milk was …'

## Inquiry: What if the milk was heated?

1. Identify the *independent* variable that you will change from the first method.
2. Identify the *dependent* variable that you will measure to determine if it was changed by the independent variable.
3. Identify three variables you will need to control to ensure a reasonable test. Describe how you will control each variable.
4. Identify the equipment you will need to complete this experiment.
5. Predict how many spoonfuls of MILO will dissolve in warm milk.
6. Write down the method you will use to complete your investigation. (HINT: Use the method above as a guide.)
7. Prepare a table to record your results.
8. Show your teacher your planning for approval before starting your experiment.

## Results

Complete your investigation, and record your results in the table you prepared.

## Discussion

1. Describe how the amount of MILO that dissolved changed when the milk was heated.
2. Identify a variable that was difficult to control. Describe how you would change your method to make your results more accurate in the future.
3. Describe a situation in everyday life that would benefit from understanding the results of your investigation.

## Conclusion

Describe how heating a solvent affects the amount of solute that can be dissolved.


**Figure 1** MILO must be used in this experiment because of the way it dissolves. What might happen if you used a different chocolate mix?

# 3.3A Separation using magnetic properties

SKILLS LAB

## Aim

To use a magnet to separate the metal from a mixture.

## What you need:

Mixture of iron filings and sand, magnet, plastic bag

## What to do:

1. Place the magnet inside the plastic bag.
2. Pass the bagged magnet over the mixture so that the iron filings are attracted.
3. Turn the plastic bag inside out so that all the iron filings are trapped.

## Questions

1. Evaluate how effective this method was for separating the iron filings from the sand by:
   a. describing if ALL the iron filings were removed
   b. suggesting any alternative method of removing iron filings
   c. comparing which method would remove the most iron filings.
2. Identify one metal that could not be removed in this way. Explain why the properties of the metal would prevent this method from being used.

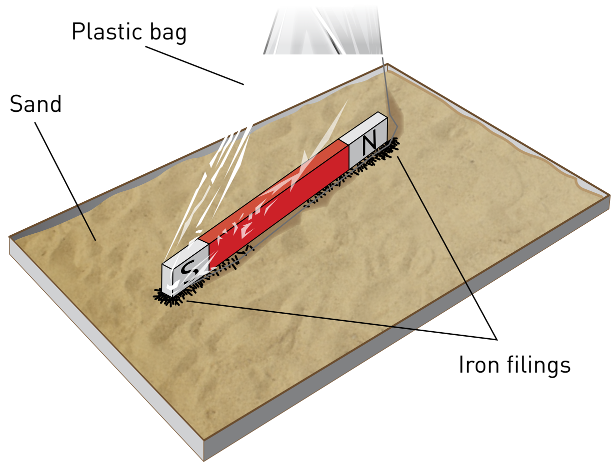



**Figure 1** Separation using magnetic properties

# 3.3B Separating mixtures using sedimentation and flotation

SKILLS LAB

## Aim

To use sedimentation and flotation to separate parts of a mixture.

## What you need:

Two mixtures ('A' contains sand and sawdust; 'B' contains sand and salt), water, spatula, stirring rod, two beakers

## What to do:

1. Place at least three heaped spatulas of mixture A into a beaker.
2. Add water and stir the mixture.
3. Wait until sedimentation has occurred.
4. Scoop off any floating material from the top of the water. Decant the water to retrieve the sand.
5. Repeat the procedure for mixture B.
6. Draw a labelled diagram of both mixtures before and after separation.

## Clean up:

After separating a mixture, make sure that all insoluble solids go into a specially provided container. Only throw substances in the bin if your teacher says it is okay to do so. Never wash solids down the sink.

## Questions

1. Describe how successful this method was for separating and collecting the sand from mixture A.
2. Describe how successful this method was for separating and collecting the sand from mixture B.
3. Describe some of the difficulties with using decanting for separating mixtures.
4. List the advantages of the combined sedimentation–flotation separation system.
5. After separating the two substances from mixture B, describe a method that could be used to collect the salt as a solid.
6. Think of three reasons why disposing of solids down the sink is not a good idea.

# 3.3C What if a flocculant was added to muddy water?

EXPERIMENT

**CAUTION!** Handle the aluminium sulfate solution with care, wear eye protection and avoid contact with skin.

## Aim

To investigate the effect of a flocculant when separating a mixture.

## Materials

- Muddy water (3 g dirt in 50 mL water)
- 2 jars or beakers
- 0.5 M sodium carbonate solution
- 0.5 M aluminium sulfate solution
- Test tubes
- Marker pen
- Timer

## Method

1. Half-fill each jar with muddy water and label one jar 'A' and the other jar 'B'.
2. Add half a test tube of aluminium sulfate solution to A.
3. Slowly add half a test tube of sodium carbonate solution to B.
4. Leave both A and B undisturbed for approximately 15 minutes.
5. Record your observations, comparing the water in A with that in B; for example:
   - 'After 15 minutes, the muddy water and aluminium sulfate in jar A was …'
   - 'After 15 minutes, the muddy water and sodium carbonate in jar B was …'

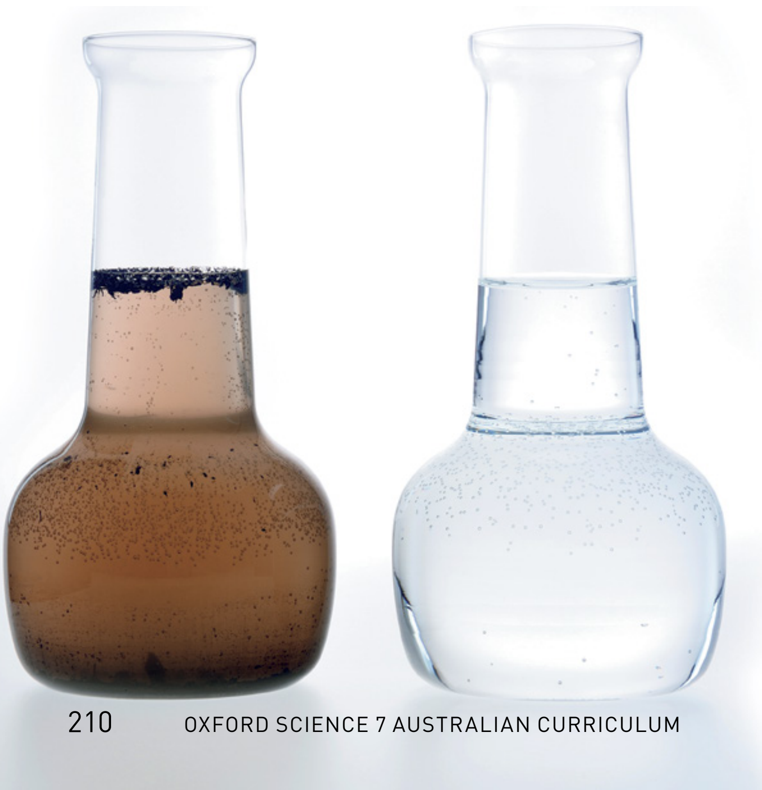


Figure 1 Adding a flocculant to muddy water

## Inquiry: How much flocculant is needed to effectively separate a mixture of mud and water?

1. Identify which flocculant you will test.
2. Identify the amounts of the flocculant that you will add to the muddy water mixture.
3. Describe how you will measure if the muddy water is separated enough. (HINT: How much light should shine through the mixture?)
4. Name three variables you will keep the same as those in the first method.
5. Write down the method you will use to complete your investigation. (HINT: Use the method above as a guide.)
6. Prepare a table to record your results.
7. Show your teacher your planning to obtain approval before starting your experiment.

## Results

Complete your investigation, filling in your table of results.

## Discussion

1. Describe the effect the aluminium sulfate solution had on the muddy water.
2. Describe the effect the sodium carbonate solution had on the muddy water.
3. Identify which of the two substances – aluminium sulfate or sodium carbonate – acted as a flocculant. Justify your answer by providing data from your results.
4. Explain why it might be important for water treatment plants to minimise the amount of flocculant added to wastewater.

## Conclusion

Describe the effect a flocculant has on some mixtures.

# 3.4A Filtering a mixture of sand and water

SKILLS LAB

## Aim

To use filtration to separate sand from water.

## What you need:

Mixture of sand and water, beaker, 100 mL conical flask, spatula, small funnel, filter paper, stirring rod

## What to do:

1 Fold the round filter paper in half, then in half again to get quarters and then in half again to get eighths, as shown in Figure 1.

**Figure 1** Folding the filter paper

2 Unfold the filter paper and lay it flat (Figure 2).

**Figure 2** Unfolding the paper and laying it flat

3 Re-fold back and forth over the creases in the filter paper to obtain a fluted shape as shown in Figure 3.

**Figure 3** Re-folding to obtain a fluted shape

4 Set up the funnel and flask as shown in Figure 4.

**Figure 4** Setting up the funnel and flask

5 Place the filter paper into the funnel as shown in Figure 5.

**Figure 5** Placing the filter paper into the funnel

6 Dampen the filter paper with some extra water to help it stick to the sides of the funnel (Figure 6).

**Figure 6** Dampening the filter paper

7 Swirl the sand mixture and slowly pour it from the beaker into the funnel (Figure 7). Do not overfill the funnel.

**Figure 7** Pouring the sand mixture into the funnel

8 Keep adding the mixture slowly until the beaker is empty.

9 Extra water can be added to the beaker mixture to pour out the last solid particles.

10 Wait for the filtering to finish. Remove the filter paper carefully and allow it to dry. In most experiments the residue (the solid on the paper) is kept and the filtrate (the liquid in the flask) is discarded.

## Questions

1 Draw a scientific diagram of your equipment. Label the filtrate and residue.

2 Identify the physical properties that are being used to separate mixtures by filtering.

3 Describe at least three things you need to be careful about when filtering.

# 3.4B What if you centrifuge tomato sauce?

EXPERIMENT

**CAUTION!** Do not eat or drink in the laboratory.

## Aim

To separate the components of tomato sauce by centrifuging.

## Materials

- Centrifuge
- Test tubes
- Test tubes to fit centrifuge
- Different brands of tomato sauce
- Ruler

## Method

1. Label your test tube with your name and partially fill it with tomato sauce.
2. Pass your test tube to the teacher and observe how the centrifuge is set up so that each side of the centrifuge is balanced.
3. Examine your test tube when the centrifuge completes the separation.
4. Use a ruler to measure the amount of each separated component of tomato sauce.
5. Draw your test tube after centrifuging. Identify and label the layers of the tomato sauce (i.e. water, tomatoes).

## Inquiry: What if different brands of tomato sauce were centrifuged?

1. Identify which tomato sauce you will test.
2. Identify the *independent* variable you will change in this experiment.
3. Identify what effect you expect to see on the *dependent* variable that you will measure and/or observe.
4. Identify two variables that you will need to control to ensure a reasonable test. Describe how you will control them.
5. Write down the method you will use to complete your investigation. (HINT: Use the method above as a guide.)
6. Draw a table to record your results.
7. Show your teacher your planning to obtain approval before starting your experiment.

## Results

1. Draw and label the various layers of the tomato sauce you selected.
2. Draw a column graph showing the type of tomato sauce and the amount of each component.

## Discussion

1. Describe the differences you noticed between the different brands of tomato sauce after they had been centrifuged.
2. Explain why the different types of tomato sauce might vary in their components.

## Conclusion

Describe how centrifuging can be used to separate the components in a mixture.

# 3.5A Crystallisation of salt water

EXPERIMENT

**CAUTION!** Wear safety glasses and lab coat, and tie long hair back when using a Bunsen burner.

## Aim

To separate a salt from a solution by evaporation and crystallisation.

## Materials

- Evaporating dish
- Tripod
- Clay triangle
- Bunsen burner and mat
- 250 mL beaker
- Concentrated salt solution
- Magnifying glass
- Matches

## Method

1. Collect a sample of the salt solution in the beaker.
2. Half-fill an evaporating dish with the salt solution.
3. Place the evaporating dish on the clay triangle over the tripod.
4. Heat the evaporating dish, with a blue flame.
5. When the solution starts boiling, half-close the Bunsen burner collar. (Do not change to a yellow flame – this is not the same.)
6. Add more solution to the dish as the level drops due to evaporation. Be careful as the evaporation nears completion because the hot salt may spit and splatter.
7. Turn off the Bunsen burner when just a little liquid remains with the salt. Leave the dish to cool.
8. Examine the salt crystals with a magnifying glass.

## Results

Draw a diagram of the salt crystals in your notebook.

## Discussion

1. Explain how effective this method would be if the solution contained a mixture of more than one solute.
2. Identify where the water solute in the solution went. Describe how the solute could be collected.

## Conclusion

Explain how evaporation and crystallisation can be used to separate a mixture of salt and water.

# 3.5B Design a way to purify water from sea water

CHALLENGE

## Design brief

You are preparing for a natural disaster that will affect the water supply. Using materials available from a supermarket, design equipment that will enable you to provide drinking water for a single person from sea water indefinitely.

## Criteria restrictions

- Your materials must be available in a supermarket or your home.
- You must provide the cost of building your equipment.
- Your only available heat source is the Sun.

## Planning and conducting

- How will you heat the water so that it evaporates?
- How will you collect the water vapour?
- How will you cool the water vapour so that it condenses?
- Draw a labelled diagram of your design.
- Build a prototype of your design.
- Check the effectiveness of your design with a test, and improve it as required.

## Processing, analysing and evaluating

1. Describe the changes you made to improve your design.
2. Identify the most successful feature of your design. Identify the least successful feature of the design.
3. Calculate the final cost of your design.
4. Describe a situation where your design could be useful.
5. Describe how you would modify your design to improve its effectiveness.

## Communicating

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

**Figure 1** Natural disasters can affect water supply.

# 3.6A Separation challenge

CHALLENGE

## Design brief

How can you separate the different parts of a sand, salt, sawdust and iron filing mixture?

Now that you are a scientist who has trained in separating techniques, it is time to separate a mixture of sand, salt, sawdust and iron filings.

## Criteria restrictions

You may only use equipment available in the laboratory.

## Questioning and predicting

> Think about the properties of each pure substance that is in the mixture. This may help you to decide on a way to separate the substances. Copy Table 1 and write what you know about the properties of sand, iron filings, sawdust and salt.

**Table 1** The properties of sand, iron filings, sawdust and salt

| Substance | Soluble in water? | Attracted to a magnet? | Floats/sinks in water? |
|---|---|---|---|
| Sand | | | |
| Iron filings | | | |
| Sawdust | | | |
| Salt | | | |

> Discuss with a partner some possible ways to separate the four substances.

## Planning and conducting

> Draw up a flow chart showing the steps you will take to separate the four substances.

> Devise an aim and a materials list for your experiment.

> Write a detailed method for separating the substances. Include at least two diagrams.

> Describe three safety issues that you need to consider when completing this experiment.

> Have your plan checked by your teacher.

> Perform your separation experiments and make relevant observations.

## Processing, analysing and evaluating

1 Describe the unique properties of each component of the mixture that allowed you to separate them.

2 Describe the different components of the mixture that you were able to separate from the mixture including the colour and texture of each final sample.

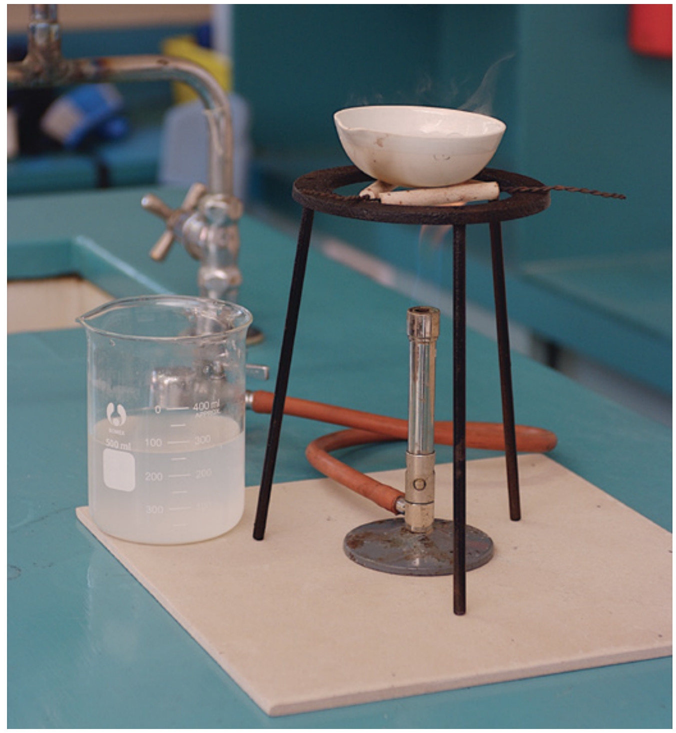


**Figure 1** Some of the equipment you may need for the separation challenge

3 Describe the purity of each sample by describing any contaminants that may have been mixed in the pure samples.

4 Describe one way you would change your method to improve the amount or the purity of your samples.

## Communicating

Present your investigation in a formal experimental report.

# 3.6B Who wrote the nasty note?

EXPERIMENT

Your forensic laboratory is investigating a crime of extortion: one person is forcing or frightening another into handing over money.

The police have identified that the extortion note was written with a black felt-tip pen. They have collected a black felt-tip pen from the three suspects: Aunt Aggie (A), Cousin Cranky (C) and Uncle Buncle (U).

Other forensic scientists in your laboratory have already run a chromatography test on the note written by the extortionist. After you have tested the three pens from the suspects, collect the chromatogram for the original note from your teacher for comparison.

## Aim

To separate the inks from three different water-soluble black felt-tip pens.

## Materials

- 3 black water-soluble felt-tip pens – they must all be different brands and labelled 'A', 'C' and 'U' (Note: Permanent markers are not suitable for this experiment because they are not water-soluble.)
- 250 mL beaker
- Glass rod or paddle pop stick
- Salt solution (1 per cent)
- Filter paper or chromatography paper
- Scissors
- Pencil
- Ruler

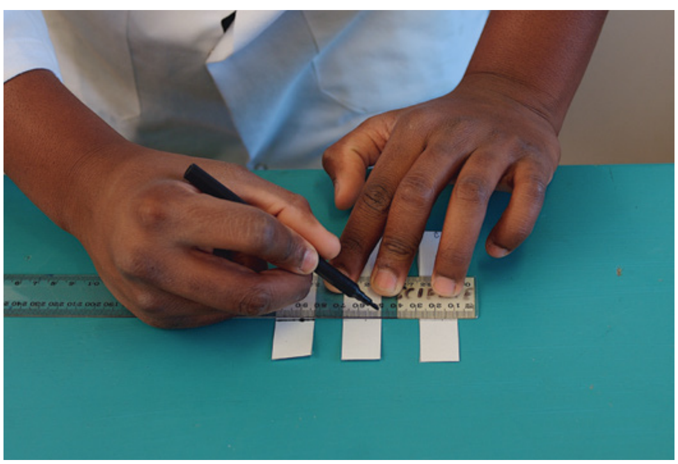


**Figure 1** Trace over the pencil lines at the bottom of the chromatography paper.

## Method

1. Cut the filter or chromatography paper into three strips measuring approximately 2 cm × 10 cm.
2. Draw a faint pencil line across the width of each paper strip, 3 cm from the bottom.
3. Label the first strip 'A', the second strip 'C' and the third strip 'U'. Make sure the label is at the very top of the paper strip.
4. Carefully trace over the pencil line at the bottom of A with the felt-tip pen labelled A, as shown in Figure 1. (Do not make the line too thick.)
5. Do the same for the other two pens on their separate strips.
6. Add the salt solution to the bottom of the beaker, no deeper than 2 cm.
7. Hang the paper strips over the glass rod so that they just dip into the salt solution (Figure 2). Make sure the salt solution does not touch the pen lines on the paper.

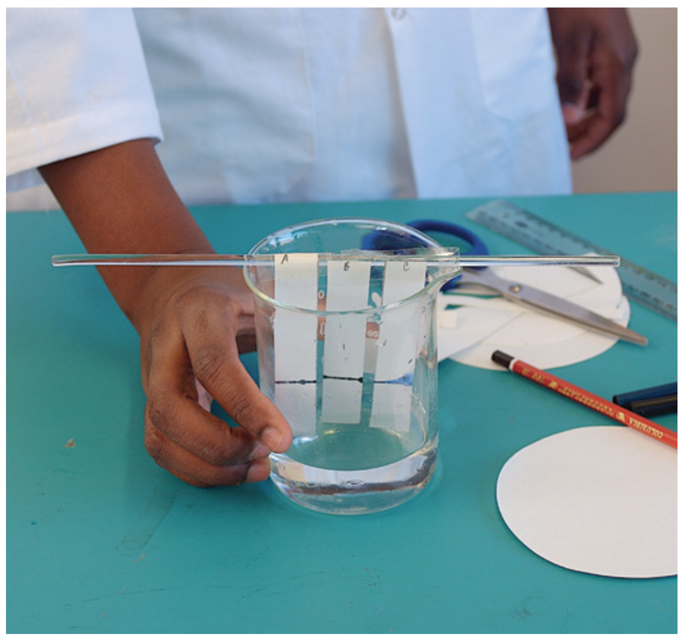


**Figure 2** Hang the paper strips over a glass rod so that they just dip into the salt solution.

*(Experiment continues on the next page.)*

8 Leave the papers to soak up the salt solution for approximately 10–15 minutes, or until the solvent level is up to the top of the paper.
9 In the meantime, draw a diagram of the chromatography equipment in your notebook, labelling all the parts.
10 When the chromatogram is finished, take the papers out of the solution to dry (Figure 3).

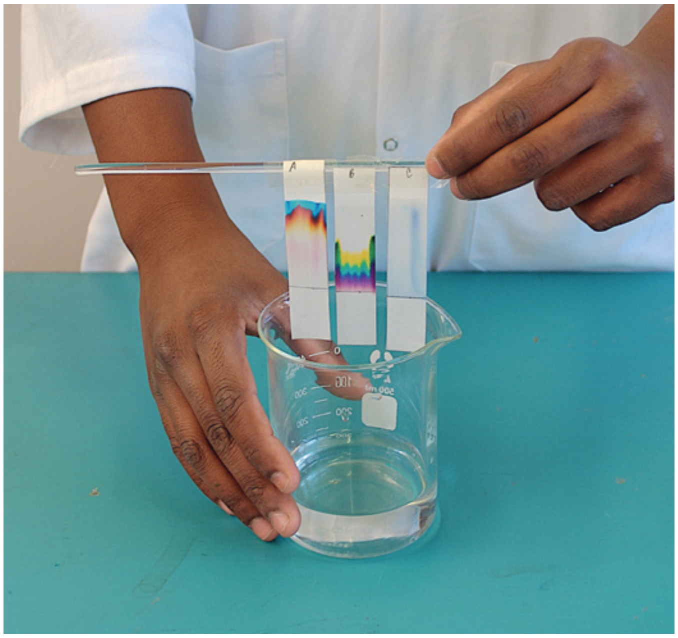


**Figure 3** Take the papers out to dry.

**Figure 4** Black felt-tip pens are composed of different inks.

## Results

Tape the dry chromatograms for suspects A, C and U in your notebook. Collect and copy the chromatogram from the original note. Label this as the extortionist's chromatogram.

## Discussion

1 Compare the chromatogram from the extortionist with the chromatograms from the three suspects. Identify if any of the suspects' chromatograms match the one from the original note. If so, who is most likely to be guilty?
2 Identify which felt-tip pen – A, C or U – had the most colours in its black ink.

## Conclusion

Describe how chromatography can be used to separate the inks from different black felt-tip pens.

# 4.1 Measuring forces

EXPERIMENT

## Aim

To measure a variety of forces in common situations.

## Materials

- Rubber band
- Thin strip of timber (or a ruler)
- Mass carrier and masses
- Pen

## Method

A rubber band can measure the size of forces in a similar way to a spring balance, but it must be calibrated. This means matching the stretch of the rubber band to the number of newtons pulling on it.

1 Calibrate the rubber band on the strip of timber, as shown in Figure 1.

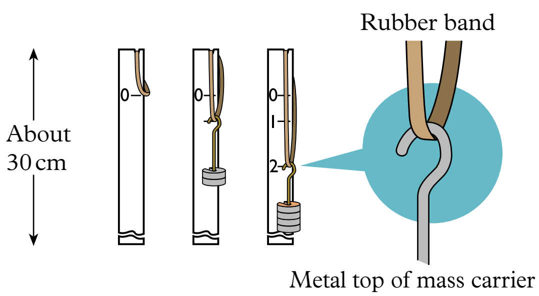



**Figure 1** Calibrating the force measurer

2 Mark the distance that the rubber band is stretched on the timber when the mass carrier holds a 100 g mass. Remember: The weight force of 100 g equals 1 N of force.

3 Repeat for masses of 200 g, 300 g, 400 g and so on, marking the timber each time.

4 Use your measuring device to measure the force needed to:
   a open the door to the room (Figure 2)
   b drag a chair across the floor
   c close a drawer in the laboratory (Figure 3)
   d move your pencil case
   e pull up your sock
   f do three other movements of your choice.

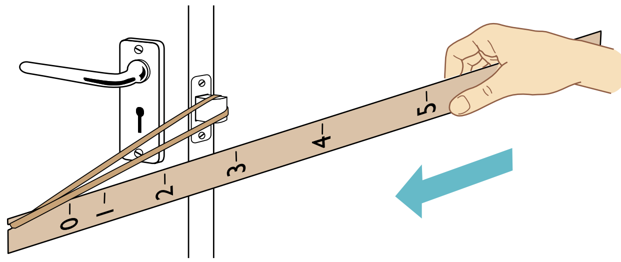



**Figure 2** Measuring the force needed to open a door

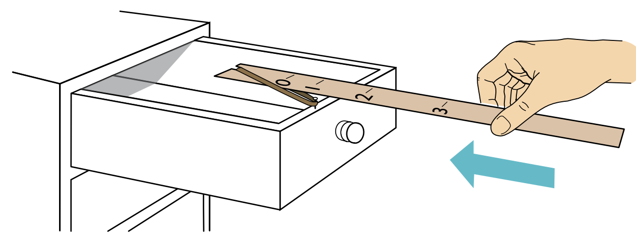



**Figure 3** Measuring the force needed to close a drawer

## Results

Draw a column graph showing the amount of force needed to move each object.

## Discussion

1 Describe the relationship between grams and newtons.

2 Identify if the force meter you constructed measures a pull or push force.

3 Describe how you could increase the amount of force needed to shift your pencil case.

# 4.2 Design a ball whacker

CHALLENGE

## Design brief

Design equipment that uses a block of wood to hit a tennis ball. A block of wood from home or your school's woodwork room is ideal. You must not push the block.

## Questioning and predicting

> Describe how you will generate a contact force between the wooden block and the ball.

> Describe how you will make the wooden block swing.

> Describe how far you want your ball to move.

## Planning and conducting

> Figure 1 shows one way to set this up. Suggest two ways to modify this design.

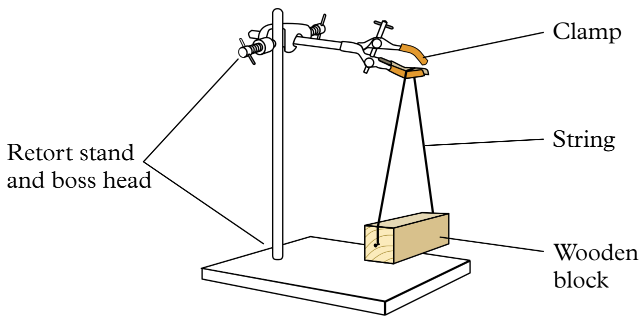



**Figure 1** A possible design for the experiment

## Processing, analysing and evaluating

1 Describe the changes you made to move the ball further.
2 Identify the most successful feature of your ball whacker.
3 Contrast the effectiveness of a heavy block and a light block.
4 Describe a real-life example of a 'whacker' similar to this.
5 Describe how you would modify your design if you were doing this experiment again.

## Communicating

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

# 4.3 Can you use the push and pull of a magnet?

CHALLENGE

## Design brief

Choose one of the following design briefs.

- Create a magnet race to identify who can push a magnet across the length of a desk the fastest using another magnet.
- Use the push force between two magnets to suspend the end of one magnet above the end of the other.
- Design an experiment to determine how far away your magnet needs to be to attract a metal paperclip.
- Design an experiment to test if a second magnet has a stronger pulling force than the first magnet. Remember to control all other variables.

## Questioning and predicting

- Identify the arrangement of poles that would be most appropriate: like or unlike poles.
- Identify the part of a magnet that has the strongest force.

## Processing, analysing and evaluating

1 Describe the changes you would make to improve your design.
2 Describe the most successful feature of your design.
3 Describe how you would modify your design if you were doing this experiment again.

## Communicating

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

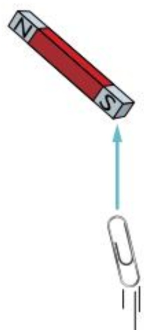



**Figure 1** Magnets have poles that can attract or repel.

# 4.5 What if a balloon was electrostatically charged?

EXPERIMENT

**CAUTION!** Some students may be allergic to latex balloons.

## Aim

To examine the push or pull forces involved in electrostatically charged balloons.

## Materials

- Balloon pump
- Two balloons
- String
- Wool/nylon material

## Method

1. Using the balloon pump, inflate both balloons and tie knots in the ends.
2. Tie string to the ends of both balloons.
3. Rub one of the balloons on your jumper or with the material provided.
4. Hold the balloon by the string so that it does not lose its charge.
5. Hold the second balloon by the string and bring it close to the first balloon.
   - Identify the force as a push or pull force.
   - Describe the balloon as a contact or non-contact force. Justify your answer by defining each term.

## Inquiry: What if both balloons are charged?

1. Write a hypothesis for your inquiry.
2. Identify the *independent* variable you will change in this experiment.
3. Identify what effect you expect to see on the *dependent* variable that you will measure and/or observe.
4. Identify two variables that you will need to control to ensure a reasonable test. Describe how you will control them.
5. Write down the method you will use to complete your investigation. (HINT: Use the method above as a guide.)
6. Draw a table to record your results.
7. Show your teacher your planning to obtain approval before starting your experiment.

## Discussion

1. Identify electrostatic charges as contact or non-contact forces. Justify your answer.
2. Describe the movement of the balloons as a push or pull force.
3. Explain how the balloons became charged.
4. Explain why the balloons moved during your experiment.

## Conclusion

Describe what you know about electrostatic forces.

**Figure 1** Balloons can be filled with different types of gas, such as air, helium or hydrogen.

# 4.6A Calculate weights in the solar system

SKILLS LAB

## Aim

To determine how the weight of a person could vary on different planets.

The effects of gravity depend on the mass of the objects involved. Gravity on Earth is determined by the mass of the Earth.

By doing some simple calculations, you can work out what your weight would be if you lived on the Sun, on other planets in the solar system or on the Moon. Note that the Earth has a gravity factor of 1.00, which is often referred to as 1*g*. To calculate weight, multiply mass (the reading on the bathroom scales) by the gravity factor for the planet, the Sun or Moon. Remember that weight is measured in newtons.

## Questions

1 Using the Earth's gravity factor, calculate the weight of a 65 kg person on the Earth and record it in Table 1 (in the first row).
2 Complete Table 1, filling in the weight for the 65 kg person on the other planets, the Sun and the Moon.
3 Imagine holding an Olympic Games on the different astronomical bodies listed in Table 1. Based on your calculations, explain how the gravity factor for the planet would affect the results of the events. For example, would diving or high jump be affected?
4 Describe how gravity would affect your lifestyle on Jupiter. Identify one everyday task that would be easier or harder. Justify your answer by explaining how it would be affected.

**Table 1** A person's weight in the solar system

| Planet | Gravity factor | Person's mass (kg) | Person's weight (N) |
|---|---|---|---|
| Earth | 1.00 | 65.00 | |
| Mercury | 0.38 | 65.00 | |
| Venus | 0.90 | 65.00 | |
| Mars | 0.38 | 65.00 | |
| Jupiter | 2.87 | 65.00 | |
| Saturn | 1.07 | 65.00 | |
| Uranus | 0.93 | 65.00 | |
| Neptune | 1.23 | 65.00 | |
| Sun | 27.80 | 65.00 | |
| Moon | 0.16 | 65.00 | |

# 4.6B Modelling gravity in the solar system

CHALLENGE

Many scientists describe the gravity in space as acting like a trampoline. If the trampoline is flat, a marble is able to roll straight across the surface, much like an asteroid through empty space. If the trampoline is not flat because a brick is sitting on it, the marble will curve around the object as it rolls along, much like the distortion of space and time that causes an asteroid to curve around a planet as it moves through the solar system. You can mimic this using a hula hoop to represent space.

## Aim

To model how the gravity of a planet could affect the movement of an asteroid.

## What you need:

1 thin stretchable plastic sheet (e.g. garbage bag, cling wrap), 2–4 small marbles, 5 cm Styrofoam® ball, ½ cup playdough, 1 small hula hoop

## What to do:

1 Cover the hula hoop with the thin sheet of plastic.
2 Suspend your model universe on books or bricks.
3 Roll a marble across the tight plastic sheet. Describe its movement.
4 Place a marble one-third of the way across the plastic, and the second two-thirds of the way across the plastic. Describe how the marbles move.
5 Place the rounded half-cup of play dough in the centre of the plastic sheet.
6 Describe what happens when one marble is placed one-third of the way across the plastic and the second two-thirds of the way across the plastic.
7 Replace the play dough with the Styrofoam ball. Describe the motion of the marbles when they are dropped onto the sheet a second time.

## Questions

1 In your model, describe how gravity was represented.
2 Identify the item that had the strongest 'gravitational pull': the play dough ball or the Styrofoam ball. Describe the evidence that supports your answer.
3 Identify the type of object in the solar system that the Styrofoam ball represented. (HINT: Think about large and low densities.)
4 Black holes are space objects with such strong gravity that nothing can escape them. Explain why they are called *black* holes.

# 4.7 What if the amount of friction was changed?

EXPERIMENT

## Aim

To investigate how friction may be reduced.

## Materials

- Force measurer (see Experiment 4.1) or spring balance
- Thick textbook
- Wooden rollers (round pencils)
- Book
- Sand
- Safety glasses

## Method

1 Use your force measurer or spring balance to measure the friction of your textbook being dragged along the table. (HINT: Drag it at constant speed.)
2 Place two books on top of each other and measure the friction.

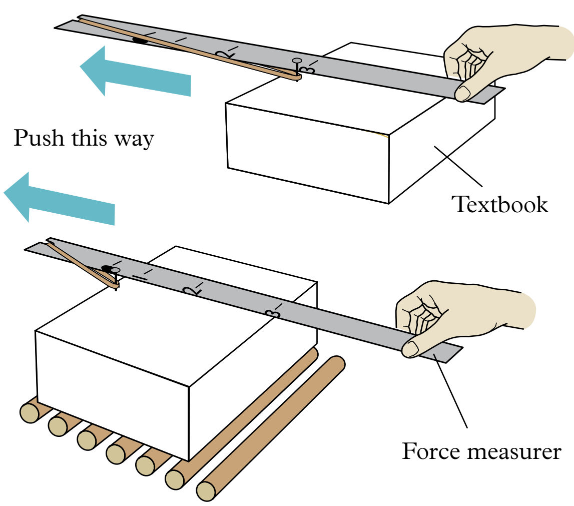



**Figure 1** Measuring the friction of a textbook

## Inquiry: What if different objects were placed under the textbook?

Choose one of the inquiry questions below.

- What if rollers were placed under the textbook?
- What if sand was placed under the textbook?

Answer the following questions about your inquiry question.

1 Write a hypothesis for your inquiry.
2 Identify the *independent* variable you will change in this experiment.
3 Identify what effect you expect to see on the *dependent* variable that you will measure and/or observe.
4 Identify two variables that you will need to control to ensure a reasonable test. Describe how you will control them.
5 Write down the method you will use to complete your investigation. (HINT: Use the method above as a guide.)
6 Draw a table to record your results.
7 Show your teacher your planning to obtain approval before starting your experiment.

## Results

1 Copy Table 1 in your notebook and record your results.

**Table 1** Force needed to move a textbook

| Object | Force needed to make it move (N) | | | |
|---|---|---|---|---|
| | Trial 1 | Trial 2 | Trial 3 | Average |
| Textbook | | | | |
| Textbook with a second book on it | | | | |
| Textbook with rollers under it | | | | |
| Textbook with sand under it | | | | |

2 Draw a column graph showing the effect of sand or rollers on the object's friction.

## Discussion

1 Compare your results with those of others in the class.
2 Describe the best way to reduce friction when moving the textbooks.
3 Explain if five rollers would be better than two for reducing friction.
4 Explain if bigger or smaller rollers would be better for reducing friction.
5 Provide a practical example of rollers being used to reduce friction.
6 Evaluate if fine sand or coarse (large-grained) sand is better for increasing friction.

## Conclusion

Describe what you know about how to reduce friction.

# 4.8A Using a first-class lever to lift weights

EXPERIMENT

## Aim

To determine how a first-class lever balances different weights.

## Materials

- Wooden or metal ruler
- 50 g weights
- Rounded glue stick
- Blu-Tack®

## Method

1 Place the glue stick flat on the desk and hold it in place with Blu-Tack.
2 Place the centre of the ruler over the glue stick so that it forms a simple see-saw or balance.
3 Add three 50 g weights 4 cm from the centre of the fulcrum on one side.
4 Add three 50 g weights to the other side so that the see-saw becomes balanced (both weights are equal height from the desk).

## Inquiry: What if a different weight was placed in a different location?

Choose one of the inquiry questions below.

- What if a greater weight was placed closer to the fulcrum?
- What if greater weight was placed further from the fulcrum?
- What if less weight was placed closer to the fulcrum?
- What if less weight was placed further from the fulcrum?

Answer the following questions about your inquiry question.

1 Write a hypothesis for your inquiry.
2 Identify the *independent* variable that you will change from the first method.
3 Identify the *dependent* variable that you will measure and/or observe.
4 Identify two variables that you will need to control to ensure a reasonable test. Describe how you will control these variables.
5 Write down the method you will use to complete your investigation.
6 Draw a table to record your results.
7 Show your teacher your planning to obtain approval before starting your experiment.

## Results

Record your results by copying and completing Table 1.

**Table 1** Using first-class levers to lift weights

| Left-hand side | | | Right-hand side | | |
|---|---|---|---|---|---|
| Number of 50 g weights | Position from fulcrum (cm) | Number of weights × distance from fulcrum | Number of 50 g weights | Position from fulcrum (cm) | Number of weights × distance from fulcrum |
| 3 | 4 | 12 | 3 | | |
| 3 | | | 2 | | |
| 3 | | | 1 | | |
| 1 | | | 5 | | |

## Discussion

1 Describe the pattern of weights and position from the fulcrum on both sides of the lever.
2 Define the term 'mechanical advantage'.
3 Calculate the mechanical advantage of the lever when the single weight on the left-hand side lifts the five weights on the right-hand side.
4 Provide another example of a first-class lever that you have used.

## Conclusion

Draw and label a first-class lever and describe how to determine its mechanical advantage.

# 4.8B Using a second-class lever to lift weights

EXPERIMENT

## Aim

To investigate the mechanical advantage of a second-class lever.

## Materials

- Shoebox
- 2 spring balances
- Cardboard
- Sticky tape
- 2 rulers
- Weights

## Method

1. Use sticky tape to stick the rulers together in a 'V' shape.
2. Divide the shoebox into two compartments using the cardboard.
3. Attach the box on the top of the rulers so that it looks like a wheelbarrow with front and rear compartments.
4. Add weight to the front of your second-class lever.
5. Use the spring balances on the handles to calculate the total effort needed to lift this weight.
6. Repeat this measurement three times.

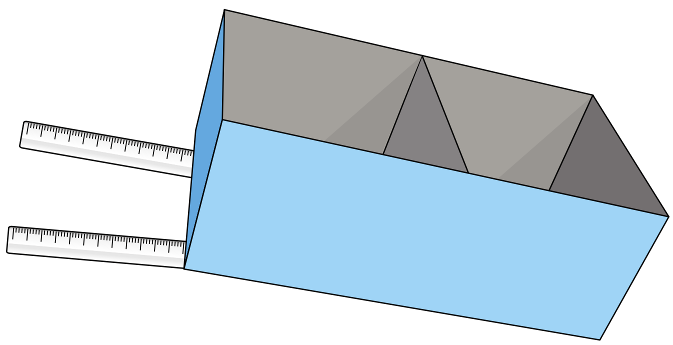


**Figure 1** Experimental set-up

## Inquiry: What if the weight was placed further from the fulcrum?

1. Write a hypothesis for your inquiry.
2. Identify the *independent* variable that you will change from the first method.
3. Identify the *dependent* variable that you will measure and/or observe.
4. Identify two variables that you will need to control to ensure a reasonable test. Describe how you will control these variables.
5. Write down the method you will use to complete your investigation.
6. Draw a table to record your results.
7. Show your teacher your planning for approval before starting your experiment.

## Results

1. Copy and complete Table 1 to show the effort required when the front of the wheelbarrow is loaded.

**Table 1** The effort required when the front of the wheelbarrow is loaded

| | Spring balance 1 | Spring balance 2 | Total effort |
|---|---|---|---|
| Attempt 1 | | | |
| Attempt 2 | | | |
| Attempt 3 | | | |
| Average | | | |

2. Copy and complete Table 2 to show the effort required when the rear of the wheelbarrow is loaded.

**Table 2** The effort required when the rear of the wheelbarrow is loaded

| | Spring balance 1 | Spring balance 2 | Total effort |
|---|---|---|---|
| Attempt 1 | | | |
| Attempt 2 | | | |
| Attempt 3 | | | |
| Average | | | |

## Discussion

1. Explain why you repeated each measurement three times.
2. Describe the difference in total effort required when the weight was shifted further from the fulcrum on the second-class lever.
3. Use the data from your experiment to explain the most effective way to load a wheelbarrow.

## Conclusion

Describe the mechanical advantage of using a second-class lever.

# 4.9 Calculating mechanical advantage

EXPERIMENT

## Aim

To see how the number of pulleys affects the size of the effort needed to lift a load and the distance this load travels.

## Materials

- Retort stand
- 500 g weight
- Spring balance
- Sets of pulley systems (two-, three- and four-pulley systems)
- String

## Method

1. Set up a pulley system using one pulley. Attach the spring balance.
2. Pull on the spring balance to raise the load by 10 cm.
3. Record the average reading on the spring balance and the distance moved by the spring balance.
4. Calculate the mechanical advantage of the pulley arrangement.
5. Repeat steps 2–4 with a two-pulley system.
6. Repeat steps 2–4 with a three-pulley system.
7. Repeat steps 2–4 with a four-pulley system.

## Results

1. Copy and complete Table 1.
2. Draw a column graph showing the relationship between the number of pulleys and the mechanical advantage.

## Discussion

1. Describe how adding more pulleys changed the effort needed to lift a load.
2. Compare the distance the effort moves with the distance the load moves.

**Figure 1** A one-pulley system

3. Calculate the effort needed to lift 500 g with six pulleys.
4. Calculate the length of string that would have to be pulled through four pulleys to lift the 500 g load 20 cm.

## Conclusion

Describe how the number of pulleys affects the size of the effort and the distance moved by the load.

**Table 1** The mechanical advantage of pulley systems

| Number of pulleys | Effort reading on the spring balance (N) | Distance the effort has to move (cm) | Mechanical advantage (load ÷ effort) |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |

# 4.10 Comparing different machines

EXPERIMENT

## Aim

To determine the force magnification of different machines.

## PART A: RAMPS

### Materials

- 50 g mass (with a hook to attach to the spring balance)
- Ramp (30 cm ruler or a wider or longer piece of thin wood or plastic)
- Box (or pile of books or plastic tub upside down)
- Spring balance
- Metre ruler

### Method

1. Measure and record the height of the box (or pile of books).
2. Using the spring balance, measure and record the force required to carefully lift the 50 g mass vertically at a constant speed on to the top of the box.
3. Repeat step 2 several times and calculate the average force.
4. Position the ramp against the box and measure and record its length.
5. Slowly pull the 50 g mass up the ramp using the spring balance and record the force required.
6. Repeat step 5 three times and calculate the average force.

### Discussion

1. Identify the method – lifting or dragging up the ramp – that provided the greatest mechanical advantage. Justify your answer by using data from your experiment.
2. A student claimed an incline plane was not a machine. Use evidence from the experiment to evaluate the truth of this statement.

**Figure 1** A pile of books

## PART B: WEDGES

### Materials

- 2 blocks of wood
- 2 thick, tight rubber bands
- Wedge-shaped piece of wood

### Method

1. Place the rubber bands over the two pieces of wood to hold them tightly together.
2. Try pulling the blocks apart with your hands.
3. Place the pointed edge of the wedge between the two blocks and push it in.

### Discussion

Describe the advantage of using a wedge to separate the two blocks of wood.

**Figure 2** Wedge

## PART C: SCREWS

### Materials

> G-clamp
> 2 matchboxes filled with play dough

### Method

1 Try crushing the matchbox using only your fingers. Record your observations.
2 Place the matchbox between the faces of the G-clamp and tighten it until it crushes. Record your observations.

### Discussion

1 Contrast the effort needed to crush the matchbox using both methods.
2 Explain how the screw mechanism in the G-clamp provides a mechanical advantage in crushing the matchbox.

**Figure 3** A G-clamp

## PART D: WHEELS AND AXLES

### Materials

> Simple machine kit with a wheel-and-axle model or one made from LEGO® or K'NEX®
> Cotton thread or string
> 2 weights

### Method

1 Design and build your own working model of a simple wheel-and-axle machine.
2 Use cotton thread or string and two weights to demonstrate how your model can work as a force magnifier.
3 Modify your model or build another one to demonstrate how it can work as a distance magnifier.

### Discussion

1 Contrast a force magnifier with a distance magnifier.
2 Describe the change you made for the second wheel-and-axle model.
3 Explain how the change affected the effectiveness of the second model compared with the first model.

**Figure 4** A wheel and axle

# 4.11 Comparing the forces in flight

EXPERIMENT

## Aim

To model and compare the forces involved in flight.

## PART A: LIFT

### Materials

> A strip of paper (3 cm × 15 cm)

### Method

1 Use your thumb and index finger to hold one of the short ends of the paper strip under your bottom lip so that it flows forward from your face (Figure 1). The far end of the paper should hang down in a curve from your face. Make sure that your finger is not in front of your lip.

2 Gently blow across the top of the paper.

### Discussion

1 Describe the action of the lift force on the far end of the paper.

2 Use your knowledge of the wings of a plane to explain why the lift force was generated.

**Figure 1** Hold the strip of paper under your bottom lip.

## PART B: WEIGHT

### Materials

> A light ping pong ball

> A dense golf ball

### Method

1 Hold both identically sized balls at the same height from the ground.

2 Gently let go of both balls at the same time and observe the time it takes for the balls to hit the ground.

### Discussion

1 Compare the mass of each ball.

2 Describe how each ball was affected by gravity by comparing the time it took for the balls to hit the ground.

**Figure 2** A golf ball and a ping pong ball

## PART C: DRAG

### Materials

> A strip of paper (3 cm × 15 cm)
> A dense golf ball

### Method

1 Hold both the strip of paper and the golf ball at the same height from the ground.
2 Gently let go of the ball and the paper at the same time and observe the time it takes for them to hit the ground.
3 Scrunch the paper strip into a ball and repeat step 2.

### Discussion

1 Describe the shape of the two objects.
2 Describe how each object was affected by air resistance by describing the time it took for them to hit the ground.

**Figure 3** Scrunched up ball of paper

## PART D: THRUST

### Materials

> A6 paper (1/4 of A4 paper)
> Scissors
> Paper clip

### Method

1 Cut out the pattern of a paper helicopter shown in Figure 4.
2 Fold the paper into the paper helicopter shape.
3 Clip the paper clip to the bottom of the base of the paper helicopter.
4 Hold the paper helicopter at a height above your head and give it a quick twist as you drop it.

### Discussion

1 Describe how the paper helicopter moved as it was dropped.
2 Compare the motion of the paper helicopter and the paper in part C.

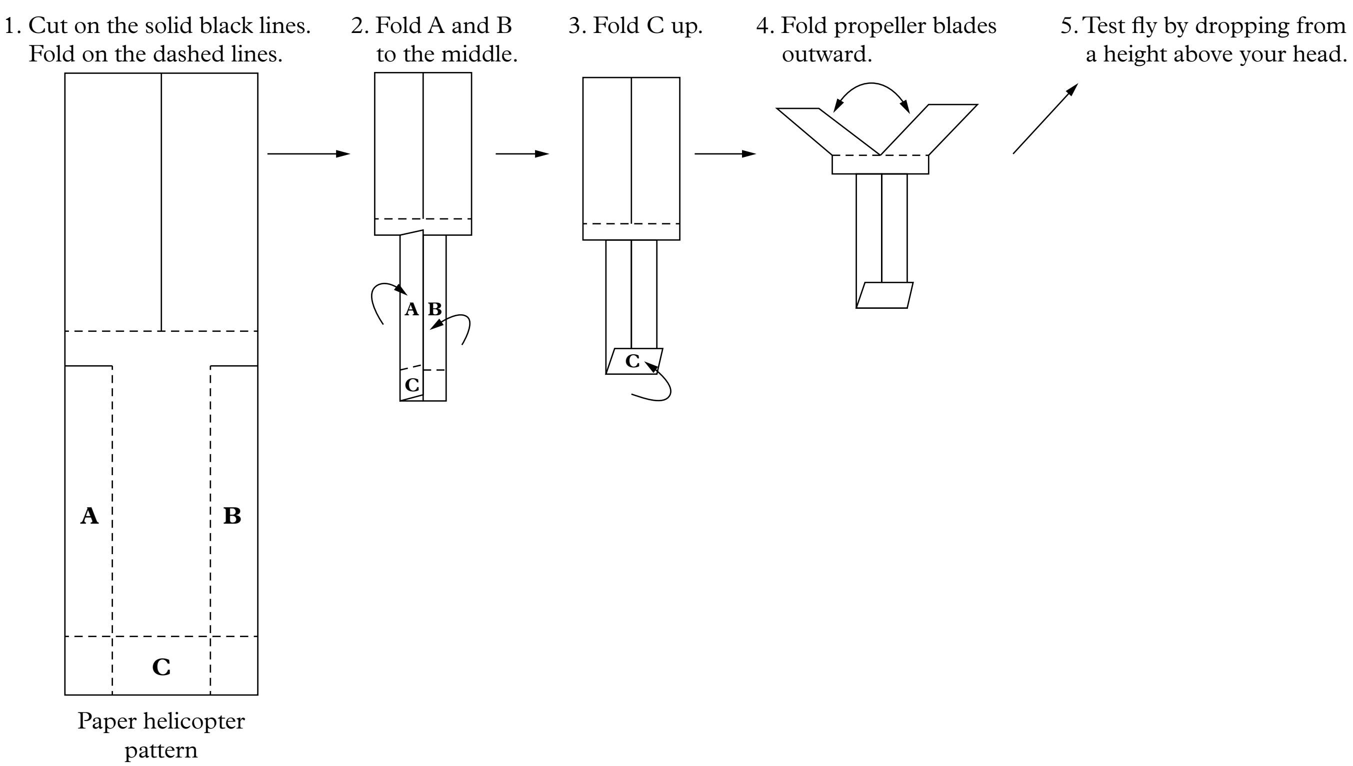



**Figure 4** Making a paper helicopter

# 5.1 Department store classification

CHALLENGE

## Aim

To use the characteristics of different items to classify them into identifiable groups.


1 With a partner, divide the items listed below into six department store groupings of your choice. Justify your choices.

   Snowboard, CD, 'miracle' moisturiser, waterproof tent, golf balls, jeans, mountain bike, T-shirt, atlas, cricket bat, Hacky Sack®, laptop computer, sleeping bag, nail polish, digital alarm clock, TV celebrity poster, backpack, surfing magazine, ultrashine lip gloss, smart TV, winter coat, wetsuit, R&B CD box set, glitter eye shadow, perfume, swimming costume, MP3 player, travel book, CD player, hoodie jumper

2 Divide the products in your six departments into smaller groups or 'sub-departments'.

3 Draw a plan of your department store layout. Think carefully about what departments you will put next to each other and why.

4 Join up with another pair and 'take them on a tour' through your department store.

5 Describe how your department store is different from the one prepared by the other pair. Contrast the advantages and disadvantages of each design.




**Figure 1** Department store classification

# 5.3 Dichotomous key

CHALLENGE

## Aim

To design a dichotomous key.

## Questioning and predicting

Think about objects that could be sorted into two groups; for example, you might like to use snack foods, such as corn chips, flavoured chips or plain chips, or common products, such as bolts, nuts and screws.

## Planning and conducting

- Compare the similarities and differences of each object.
- Describe the similarities that will allow the objects to be divided into two groups.
- Select one of the groups and compare the similarities and differences of objects in that group.
- Describe the similarities that will allow these objects to be divided into two groups.
- Repeat this procedure until all objects are in a group of one.

## Processing, analysing and evaluating

1 Draw a dichotomous key to show how you grouped the objects.
2 Describe the difficulties of classifying the objects into groups.
3 Describe how you would improve your grouping if you repeated the challenge.

## Communicating

Swap your dichotomous key with another group. Ask them to evaluate your key by comparing how easy it was to identify the key feature of each object that allowed it to be classified.

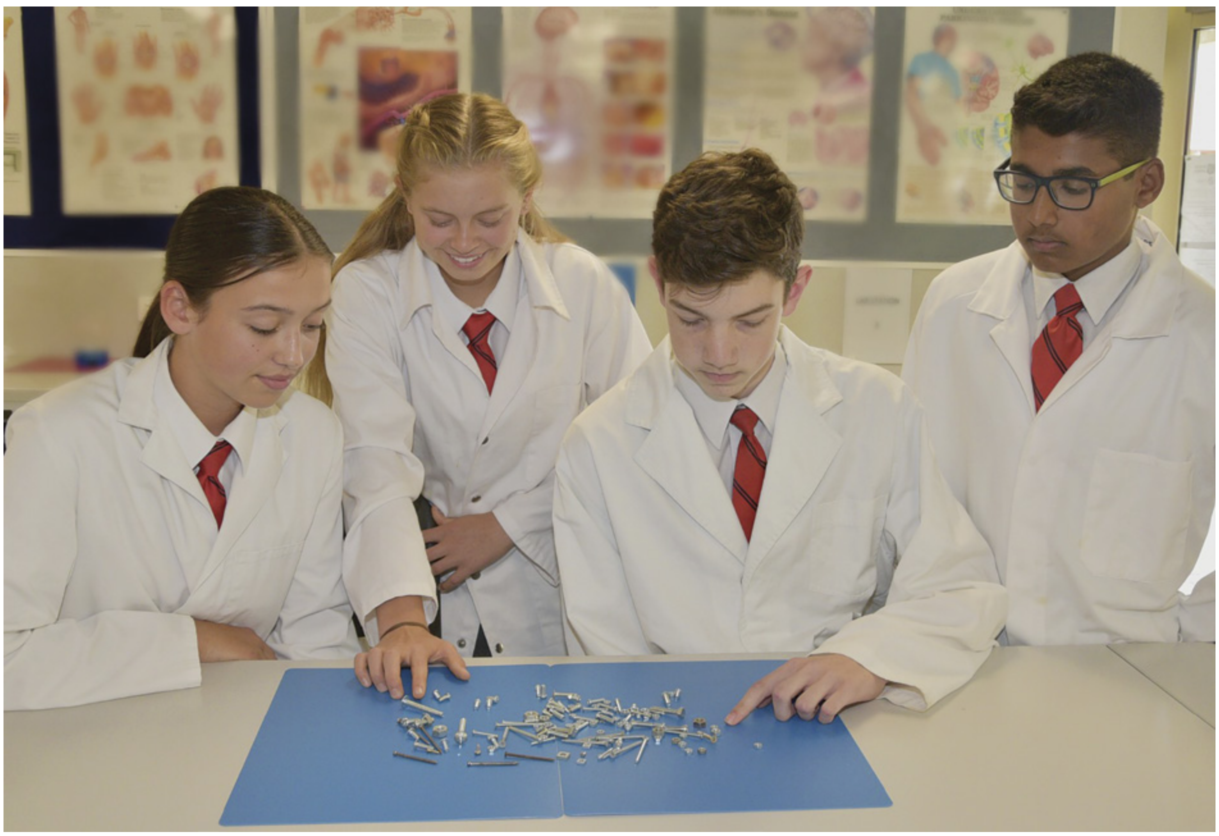


**Figure 1** Swap your dichotomous key with another group to evaluate.

# 5.4 Can you understand scientific names?

CHALLENGE

## Aim

To identify the scientific names of different animals.

The scientific names of organisms usually come from Latin (and sometimes Greek) words. Latin was the language of science for many centuries. This enabled scientists who lived in different countries and spoke different languages to communicate their work and discoveries with one another.

The words used in the scientific names of organisms describe physical features, behaviours and even colours. Some examples are given in Table 1.

**Table 1** Some scientific words and their meanings

| Latin or Greek root word | English meaning |
|---|---|
| Aculeat | Spiny |
| Arctos | Bear |
| Anatinus | Duck-like |
| Cinereus | Grey |
| Gloss | Tongue |
| Hynchus | Snout |
| Macro | Large |
| Ornitho | Bird |
| Phascol | Pouch |
| Pus | Foot |
| Rufus | Red |
| Tachy | Fast |
| Chlamy | Caped |
| Saurus | Lizard |

1 Use the information in Table 1 to match the scientific names of the Australian animals with their pictures in Figure 1.
  a *Macropus rufus*
  b *Tachyglossus aculeatus*
  c *Phascolarctos cinereus*
  d *Ornithorhynchus anatinus*
  e *Chlamydosaurus kingii*

2 What do you think a *Macroglossus aculeatus* might look like? On a sheet of A4 paper, sketch this imaginary animal, using the information in Table 1 to help you.

**Figure 1** What are the scientific names of these Australian animals?

# 5.5 Classifying living things

CHALLENGE

The scientist whose main role it is to classify living things is known as a taxonomist. In this activity, you become the taxonomist.

## Aim

To use the identifying features of different organisms to classify them into kingdoms.

## What you need:

A3 card or paper, scissors, glue, pictures of different living things from Figure 1 (or from the internet or magazines)

## What to do:

1 On a sheet of A3 card or paper, mark up a table with four columns.
2 Label the columns 'Animalia', 'Plantae', 'Fungi' and 'Other (Monera and Protista)'. (Do not try to distinguish between Monera and Protista.)
3 Go to your obook pro to access and print out Figure 1. Cut and paste each of the pictures in Figure 1 into the correct column of your table.

## Questions

1 Describe the identifying features for each kingdom.
2 Name one organism that was difficult to identify. Describe why it was difficult to identify the key feature that allowed it to be classified.

**Figure 1** A collection of living things

# 5.6A Dissecting skeletons

EXPERIMENT

**CAUTION!**

- Scalpels are extremely sharp. Use with great care.
- Always wear gloves when handling the animals. Some students may have latex allergies.
- Animals must always be on the dissecting board when they are being handled or dissected.
- Cut away from hands.
- If cut, remove gloves and wash the cut under clean water. Tell your teacher. Apply antiseptic to the cut and cover it with a dressing.

## Aim

To examine the skeletal structures of three marine organisms.

## Materials

- 1 fish (whole)
- 1 prawn
- 1 squid
- Newspaper
- Dissecting board
- Dissecting kit
- Pair of vinyl or latex gloves

## Method

1 Observe the external features of the fish.

**Figure 1** Observe the external features of the fish.

2 Carefully cut the fish in half lengthways so that you can see the internal skeleton.

**Figure 2** Cut the fish in half.

3 Observe the skeleton of the fish.

4 Touch the outside surface of the prawn. Identify the connections between the hard surfaces. Peel the prawn.

5 Cut the prawn in half and observe the insides.

**Figure 3** Cut the prawn in half.

6 Feel the outside surface of the squid.

7 Cut the squid in half and observe the insides.

8 Place scalpels in a container to be cleaned. Wrap dissected fish, squid and prawn in the newspaper. Place in a sealed plastic bag and dispose of in the general rubbish bin.

**Figure 4** Cut the squid in half.

## Results

Draw labelled diagrams of the skeleton of each specimen.

## Discussion

1 Consider the fish.
   a Identify the location of the fish skeleton.
   b Identify the type of skeleton found in the fish.

2 Consider the prawn.
   a Identify the location of the prawn skeleton.
   b Identify the type of skeleton found on the prawn.

3 Describe how the squid maintains its shape.

4 Identify the group of animals (vertebrate or invertebrate) that each of the organisms – prawn, fish and squid – belongs to. Justify your answer by comparing the key features that are used to identify the classification group with features you identified on your organism.

5 Identify the classification group to which you belong: a vertebrate or an invertebrate. Justify your answer by comparing the features that are used to identify you with the features that are used to identify your chosen group.

## Conclusion

Describe the types of skeletons that you observed and how they helped you in classifying the organism.

# 5.6B Identifying invertebrates

CHALLENGE

## Aim

To use the identifying features of invertebrates to classify using a tabular key.

## What you need:

Magnifying glass or stereomicroscope, Petri dishes, jars with lids, tweezers, vinyl or latex gloves, newspaper

Alternatively, your teacher may provide prepared samples for you to look at. Complete the classification exercise for each prepared sample.

## What to do:

1. Visit a local natural environment (e.g. a garden, beach, park or pond) and observe invertebrate specimens.
2. Wearing gloves, use tweezers to collect up to 10 invertebrate specimens in separate jars.
   > Do not touch any animal that might bite or sting. Check with your teacher if you are unsure.
   > Use tweezers to pick up the animals.
   > Place any animal immediately in a jar and secure the lid.
3. Use the tabular key in Table 1 on page 126 of Chapter 5 to classify the invertebrates into their particular phylum.
4. Use a magnifying glass or stereomicroscope to help you sketch each animal. Write the common name for the animal (if you can) and write down its classification group under the drawing.
5. Return the invertebrates to their natural environment after you have finished.

**Figure 1** Some common invertebrates

## Questions

1. Identify the common characteristic that all invertebrates displayed.
2. Describe the key characteristics that allowed you to recognise and classify the organisms you collected.

# 5.7 Who are the vertebrates?

CHALLENGE

## Aim

To identify a variety of different vertebrates.

## What you need:

A3 paper, pencils

## What to do:

### Task 1: Vertebrate alphabet graffiti

This task could also be completed as a webpage, with images and links to further information about each animal.

1 Divide students into five groups, each of which will be allocated one class of vertebrate.
2 Label an A3 sheet of paper with the name of your class of vertebrate.
3 Write the letters of the alphabet down the left-hand side of the page.
4 For each letter, write the name of an animal that fits this category.
5 When finished, you will have the names of up to 26 different vertebrates. Some categories will be harder to fill than others.
6 Put the finished sheets up around the room.

### Task 2: Jellyfish organiser for vertebrates

A jellyfish graphic organiser is a good way to show how subgroups make up a whole. It can also be used to list specific examples at the same time.

1 Individually, go around to each of the five lists of vertebrates from Task 1 and select six animals from each class.
2 On a full page, draw five 'jellyfish' connected to the main group (vertebrates), as shown in Figure 1.

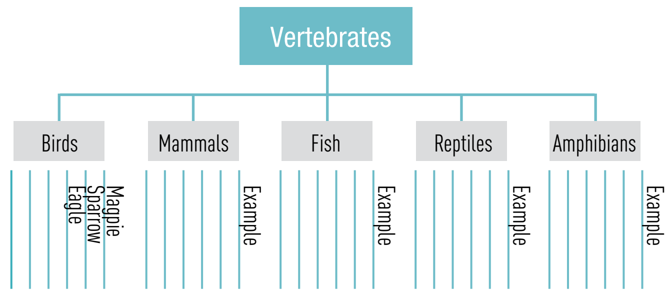



**Figure 1** A jellyfish organiser for vertebrates

3 Label each jellyfish with the class name: birds, mammals, fish, reptiles and amphibians.
4 Write a description of the characteristics of each class in the appropriate body of each jellyfish.
5 Place the six animals you selected along the six tentacles of each jellyfish.

# 5.8 Identifying plants

CHALLENGE

## Aim

To identify the different characteristics that can be used to classify a plant.

## What you need:

Camera, measuring tape, pencils, paper

## What to do:

1 Observe and take digital photos of at least five different types of plants from a local bushland or from your garden.
2 Make detailed observations of each plant, including:
  a the height of the plant
  b the width of the plant
  c the shape, smell, texture and size of the leaves (take a close-up photo of the leaves)
  d the position and number of leaves on the plant.
3 Describe the plant's flowers, seeds or nuts.
4 Describe any other unusual or special features of the plant.
5 Repeat steps 2–4 for all the plants you observed.

## Questions

1 Identify and describe the features the plants have in common.
2 Contrast the features that you have observed between the plants.
3 Use these differences to develop a dichotomous key that can be used by students in other year levels.

**Figure 1** Identifying plants

# 6.1 Studying food webs

CHALLENGE

## Aim

To identify the producers and consumers in a local food web.

## What you need:

Metre-long stick, metric rulers, poster board, markers, photographs of ecosystems

## What to do:

1. Think about what you know about food webs in your school grounds or a local park. Write a list of at least 10 organisms you might find in these food webs. Compare the number of different animals found in different areas of the school ground or park. Use this to generate a scientific question. For example, would you expect to find more or less animals in an area with a lot of paths?
2. Write a hypothesis that matches your scientific question.
3. Select two 1 $m^2$ areas in your backyard, schoolyard or neighbourhood to study. The study areas should be near each other but in two different habitats (e.g. on a footpath and on some grass, or just inside a forest and in a clearing).
4. Observe and record all organisms in the area above and within this study area.
5. Construct a food web that identifies where each organism gets its energy (who they eat).

## Questions

1. Identify the organisms that are producers.
2. Identify the organisms that are consumers.
3. Compare the number (of individuals and species) of producers and consumers you observed in each area.

**Figure 1** Identify the food webs in your neighbourhood.

# 6.2 What if more seeds were planted in a pot?

EXPERIMENT

## Aim

To investigate some factors that affect competition in plants.

## Materials

- Packets of seeds (a variety of vegetables or flowers is needed)
- Small plot (20 × 20 cm) in a garden, divided into thirds, or 3 medium-sized pots containing good-quality potting mix
- Measuring cylinder or graduated jug for watering

## Method

1. Prepare the plots (or pots) so the soil is moderately deep and smooth. Label them A, B and C.
2. In each plot, plant six seeds of the same type, spread evenly apart.
3. Plant more seeds in plots B and C as described in the inquiry section, below.
4. Water the soil in all plots each day as evenly as possible with the same amount of water.
5. Record the growth of the seeds. If possible, take photographs each week or every few days when the seeds begin to germinate. If the seeds become seedlings (small plants), measure their heights and record the results in a table.

## Inquiry: What if seeds were planted in a different way?

Choose one of the inquiry questions below.

- What if more of the same seeds were planted close together in plot B?
- What if different seeds were planted between the original seeds in plot C?

Answer the following questions about your inquiry question.

1. Identify the types of seeds that you will test.
2. Write a hypothesis (If … then … because …) for your inquiry.
3. Identify the *independent* variable that you will change from the first method.
4. Identify the *dependent* variable that you will measure and/or observe.
5. Identify two variables that you will need to control to ensure a reasonable test. Describe how you will control these variables.
6. Identify the materials that you will need for your experiment.
7. Write down the method you will use to complete your investigation in your logbook.
8. Draw a table to record your results.
9. Show your teacher your planning to obtain approval before starting your experiment.

## Results

Record all results. You could take photos showing the progress of growth and/or record the average heights of plants of different species and record them in a table.

## Discussion

1 Identify one piece of advice that you would provide to another student who wants to carry out the experiment.

2 Compare the growth of the plants in each plot by summarising your key observations in 2–3 sentences.

3 Use evidence from your results to describe any competition between the seeds as they germinated. Use statements such as, 'The plants in Pot … grew … than the plants in Pot … This implies that competition between the plants…'.

3 Identify one other variable that might have affected the growth of the seeds. Describe how this variable could have affected the results of your experiment.

4 Describe how the competition you observed would affect organisms in the natural environment.

## Conclusion

Write a conclusion about the factors that affect competition between germinating seeds.


**Figure 1** What affects the growth of seeds?

# 6.3 Exploring leaf litter

CHALLENGE

Leaf litter is the dead and rotting leaves that lie on the ground under trees and in gardens. Leaf litter helps protect soil and is home to many tiny, fragile invertebrates that work together to keep the soil in good condition.

**CAUTION!** Before you start, ask your teacher about any bull ants, poisonous spiders or centipedes in your area. There may be some animals that could bite you. If in doubt, leave the animals alone and ask your teacher.

## Aim

To identify the organisms that make up a leaf litter community.

## What you need:

Newspaper, gloves, plastic specimen jars with lids, wet paintbrush, hand lens, pen, paper

## What to do:

1 Find an undisturbed area approximately 50 cm long by 50 cm wide. Work only in this area.

2 Lift up the leaves slowly. Use your brush to pick up the tiny animals and make sure not to crush them.

3 Make a list of the animals you find. Make a separate list for eggs, cocoons, larvae or types of fungi.

4 Return the animals to the place where you found them.

## Questions

1 Explain why it is important to know about the animals you are likely to find before looking for them in the leaf litter.

2 Explain why you should return animals to the place where you found them.

3 A leaf litter community does not contain any producer organisms, such as healthy green plants. Identify the energy source for this community.

4 Describe how this leaf litter community improves the health of the soil.

**Figure 1** Leaf litter

# 6.4 Bead counting

CHALLENGE

## What you need:

Small beads, permanent marker, paper bag, A4 graph paper, pencil, ruler

## PART A: CAPTURE–RECAPTURE

### What to do:

1 Place a random number of beads in a paper bag.
2 Draw 10 beads out of the bag. Mark each of the 10 beads with the permanent marker. Place the 10 beads back into the bag. This is the same as tagging the beads and releasing them.
3 Mix the beads in the bag and draw another 10 beads out of the bag. Count the number of 'tagged' beads you collected in the 'recapture'.
4 Use the formula to estimate how many beads are in the bag. Total number of beads= $\frac{N_1 \times N_2}{M_2}$ where $N_1$ is the number of beads drawn out the first time (10), $N_2$ is the number of beads drawn the second time (10) and $M_2$ is the number of tagged beads drawn during the second draw.
5 Count the number of beads that are actually in the paper bag.

## PART B: QUADRATS

1 Divide the graph paper into 20 equal-sized squares.
2 Spread a large handful of beads over the graph paper. These represent insects in an ecosystem.
3 Count the number of 'bead insects' in four of the squares. Include the beads that are on the top lines or left lines of the squares. Do not include the beads that are on the bottom lines or right lines of the squares. Divide the number counted by 4 to determine the average number of bead insects in each square.
4 Multiply the number of 'bead insects' found in each square by 20 to estimate the size of the population in the ecosystem.
5 Count the number of beads that were actually spread over the graph paper.

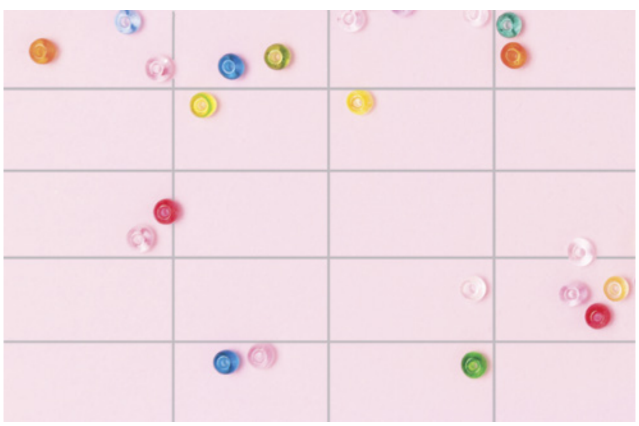


**Figure 1** Counting the number of 'bead insects'

### Discussion

1 Identify the types of organism populations that could be counted using:
   a capture–recapture
   b quadrats.
2 Describe the accuracy of the capture–recapture method in determining population size (by comparing the number of beads estimated in part A step 4 to the 'true value' counted in part A step 5).
3 Explain which of the following animals would be more likely to be recaptured:
   > an animal that was fed and treated well during the first capture
   > an animal that became frightened and was roughly handled during the first capture.

   Justify your answer (by describing how each animal will react the next time it sees or smells a trap, and deciding which behaviour is more likely to lead to them being recaptured).
4 Describe the accuracy of the quadrat method in determining the population size.
5 Identify the size a quadrat would need to be to measure a population of fully grown trees.

# 6.5A Rabbit and fox chasey

CHALLENGE

## What you need:

Large packet of popcorn, material to represent rabbit tails, outdoor space, container, measuring wheel, timer

## PART A: RABBIT POPULATIONS

### What to do:

Many scientists use simulations or modelling to determine how the number of organisms of the same species (the population) will be affected by the introduction of a new species.

**Figure 1** How does food affect a rabbit population?

1 Measure a 30 $m^2$ area outside in the schoolyard. Count out 40 pieces of popcorn. Randomly throw handfuls of the counted popcorn through the area.
2 Select five students to represent rabbits. Each 'rabbit' should tuck a piece of material into their belt to represent a tail. In order to survive, each rabbit must collect at least five pieces of popcorn in the 15-second 'season'. The retrieved popcorn is placed in a container at the end of the time-period and is removed from the available resources.
3 Simulate a second season by adding another 30 pieces of popcorn and having the rabbits collecting popcorn during another 15-second period. After the second season, any rabbit that survives then 'reproduces'. This involves selecting another student to join the simulation as a rabbit. The simulation is repeated, using popcorn in varying amounts to represent the food production in good and poor years, until 'starvation' begins to reduce the population.
4 Copy Table 1 and record your data for six seasons. Highlight the seasons that are droughts (poor food supplies) and those that are bumper years (good food supplies).

**Table 1** Population of rabbits over many seasons

| Season | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Number of rabbits at end of season | | | | | | |

## PART B: INTRODUCING FOXES

**Figure 2** How do predators affect a rabbit population?

1 Repeat the simulation from Part A but this time with additional students modelling foxes. A fox must catch a rabbit in order to survive. A fox catches a rabbit by removing the cloth tail hanging from their belt (similar to flag football).
2 Copy Table 2 and record your data for six seasons.

**Table 2** Populations of rabbits and foxes over many seasons

| Season | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Number of rabbits at end of season | | | | | | |
| Number of foxes at end of season | | | | | | |

## Discussion

1 Graph the results of the model as a bar graph showing the number of each animal at the end of a time period.
2 Identify how the following factors were represented in the model.
   a increased food supplies
   b decreased food supplies
   c competition between rabbits or foxes
3 Use data from the modelling to explain the effect of:
   a increased food supplies
   b decreased food supplies
   c competition on predator populations.
4 Explain the characteristics in a population that will help some animals to survive.

# 6.5B What if the effectiveness of pollinators was reduced? EXPERIMENT

## Aim

To examine factors that affect the pollination of fruit.

## Materials

- 10 chairs
- 2 large bags of popcorn
- 10 paper bags
- Timer

## Method

1 Divide the class into groups, with six students in each group. Each group represents a team of bees.
2 Gather the bees in one corner of the room or on the oval. This is the beehive.
3 Place approximately 10 chairs around the room or oval to represent apple trees. On the seat of each tree, place one handful of popcorn and an empty paper bag.
4 The bees must fly from tree to tree, taking a single piece of popcorn from one tree and putting it in the paper bag of another tree. This represents a bee pollinating the apple trees. Twenty seconds represents one growing season. This can become a competition if the number of pieces of popcorn on each tree is controlled.
5 At the end of 20 seconds, the bees gather back in the hive. A representative counts how many pieces of popcorn are in each paper bag. Each piece of popcorn represents one apple that was able to grow on that tree during the season.
6 Record how many apples are grown in each team's first season. Calculate the average number of apples grown that season for all the teams.
7 Empty the paper bags and reset the popcorn on each chair tree.

## Inquiry: What factors can affect the effectiveness of pollinators?

Choose one of the inquiry questions below.

- What if the weather becomes colder so that the bees fly (walk) more slowly?
- What if a harsh winter kills half the bees in the hive?
- What if overcrowding in the hive causes half the bees to swarm out of the area?
- What if the apple trees are damaged and lose half their leaves?

Answer the following questions about your inquiry question.

1 Write a hypothesis for your inquiry.
2 Identify how you represent your *independent* variable in the pollination model.

**Figure 1** A bee, an effective pollinator

3 Identify what effect you expect to see on the *dependent* variable that you will measure and/or observe.
4 What variables will you need to control to ensure a reasonable test? How will you control them?
5 Write down the method you will use to complete your investigation. (HINT: Use the method above as a guide.)
6 Draw a table to record your results.
7 Show your teacher your planning to obtain approval before starting your experiment.

## Results

Draw up an appropriate table and graph to show the results of your inquiry.

## Discussion

1 Describe the effect that changing bee populations has on the amount of fruit produced.
2 Describe one way your pollination model was not an accurate depiction of real-world pollination.
3 Suggest one way to improve the model you used.
4 Name one situation where scientists may use computer modelling to research.

## Conclusion

Describe why pollinators are important to the supply of fruit.

# 6.6A Natural disasters in Australia

CHALLENGE

## What you need:

Large map of Australia, colour-coded pins or small cardboard squares (e.g. red for bushfires, blue for floods, black for cyclones), copy of Table 1

**Table 1** Some natural disasters in Australia, 1974–2022

| Year | Nature of disaster | Location |
|---|---|---|
| December 1974 | Cyclone Tracy | Darwin, NT |
| February 1983 | Ash Wednesday bushfires | Victoria and South Australia |
| 1989 | Earthquake | Newcastle, NSW |
| February 1993 | Heatwave | South-eastern Australia |
| 1997 | Landslide | Thredbo, NSW |
| 2003 | Bushfires | Canberra, ACT |
| June 2007 | Storm and flood | Hunter Valley and central coast, NSW |
| February 2009 | Black Saturday bushfires | Victoria |
| December 2010–January 2011 | Flooding | Queensland and Victoria |
| February 2011 | Cyclone Yasi | Queensland |
| October 2013 | Bushfires | New South Wales |
| February 2015 | Cyclone Lam | Northern Territory |
| March 2017 | Cyclone Debbie | Queensland |
| March 2018 | Bushfires | New South Wales |
| September 2019–March 2020 | Bushfires | Queensland, New South Wales, Victoria, ACT, South Australia and Western Australia |
| February 2021 | Bushfires | Wooloroo, WA |
| March 2021 | Floods | Queensland and New South Wales |
| April 2021 | Cyclone Seroja | Western Australia |
| February–April 2022 | Floods | Queensland and New South Wales |

## What to do:

1. Work in small groups to place pins or attach squares of the appropriate colour to the map where Australia was affected by each natural disaster.
2. If a large area is involved, place a number of pins or squares across the area.

## Questions

1. Identify the areas that were more affected by these natural events than others.
2. A student suggested that monsoonal rains should have been included in this map. Evaluate this suggestion (by defining ‘natural disaster’, describing monsoonal rains and deciding whether monsoon rains are classified as a natural disaster).
3. Describe the positive and negative effects of these events.
4. Identify and describe patterns in the alternation of floods and bushfires.

**Figure 1** Bushfires occur frequently in Australia.

# 6.6B Calculating your ecological footprint

CHALLENGE

## Aim

To determine your personal ecological footprint.

## What to do:

Scientists often need to calculate the effect an organism has on the environment. There are a number of different methods to do this. Most commonly, scientists assign value to different activities according to their impact on the environment.

Complete the following survey to determine your personal ecological footprint.

1 The amount of my food that has packaging is:
All (10) Most (7.5) Half (5) Some (2.5) None (0)
2 The amount of food I waste each day is:
All (10) Most (7.5) Half (5) Some (2.5) None (0)
3 The amount of my food that is grown locally is:
All (0) Most (2.5) Half (5) Some (7.5) None (10)
4 The amount of meat I eat each day is:
> Once (60) Once (40) < Once (30)
Vegetarian (20) Vegan (15)
5 The number of cars in my family is:
> 2 (30) 2 (20) 1 (10)
6 The size of the car is:
Large (20) Medium (10) Small (5)
7 The number of times I shower each day is:
> 1 (10) Once (5) 3–4 times/week (2.5)
8 The number of energy-saving appliances I have is:
All (0) Some (2.5) None (10)
9 The number of electronic devices that I have is:
>15 (20) 10–15 (10) 5–10 (7.5) < 5 (2.5)
10 I reuse items before putting them in the rubbish:
Yes (0) No (2.5)

Add the number of points to determine the impact you have on the environment. Compare your results with the rest of your class. Describe how their environmental impacts were increased or reduced compared to your results.

## Questions

Evaluate how you could reduce your impact on the environment and provide a response to the following prompts.

1 Describe two alternative responses to the questions.
2 Describe how these changes will impact on you and your family.
3 Decide if the changes are more or less important than the impact.

**Figure 1** Food waste

# 6.7 Eucalypt adaptations

CHALLENGE

## What you need:

Ripened eucalyptus nuts (gumnuts), leaves and bark of a eucalypt

## What to do:

1 Place the nuts in a 40°C oven for 24 hours to open and release the seeds. Each of these thick, woody capsules contains hundreds of tiny seeds.
2 Feel the leaves of the eucalypt. They have a thick cuticle that is effective in preventing water loss.
3 Hold a leaf up to the light or place under a binocular microscope. Notice the numerous small dots, which are oil glands on the leaf.
4 Have a close look at the bark of the tree. Many eucalypt trees have bark that is thick and fibrous.

## Questions

1 Explain why the seed of the gumnut is protected with such a thick external capsule.
2 Identify what might trigger the release of the seed from the gumnut.
3 Explain the function of the oil glands in a eucalypt leaf.
4 Explain the function of thick, fibrous bark.

**Figure 1** Gumnuts have a thick external capsule.

# 7.2 Modelling the phases of the Moon

CHALLENGE

## Aim

To model the different phases of the Moon.

## What you need:

Torch or lamp with exposed light bulb, globe or basketball, tennis ball, small foam ball, black permanent marker

## What to do:

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

## Questions

1. Explain why people on Earth only see one side of the Moon.
2. Draw each phase of the Moon as you saw it on the foam ball in step 3.
3. Describe and identify the phenomenon that you modelled in step 4.
4. Explain why the statement 'the dark side of the Moon' does not refer to the side of the Moon away from Earth.

**Figure 1** The Moon

# 7.4 Modelling the seasons

CHALLENGE

## Aim

To model how the movement of the Earth can generate different seasons.

## What you need:

Torch or lamp with exposed light bulb, globe or basketball

## What to do:

1. Use a torch or light bulb in a fixed position to represent the Sun. One person should then hold the globe or basketball to represent the Earth.
2. The Earth is tilted as it orbits the Sun. Hold your globe or basketball (model Earth) so that it is tilted slightly. Imagine that the axis is tilted to point towards the numbers 1 and 7 on a clock face. Do not change this tilt during the activity.
3. Walk slowly in a circle around the lamp, at the same time rotating the model Earth. Make sure the tilt always points in the same direction. When it is summer in Australia, the Sun is almost overhead. In winter, the sunlight arrives at an angle and is more spread out.

## Questions

1. When you have walked half a circle around your Sun, stop and look at the model Earth. Describe which part of the model Earth would be experiencing summer.
2. Describe how the seasons changed on one point of the model Earth as it moved around the Sun.
3. A student claimed it is hotter in summer because Australia is closer to the Sun. Evaluate the truth of this statement using your model as evidence.

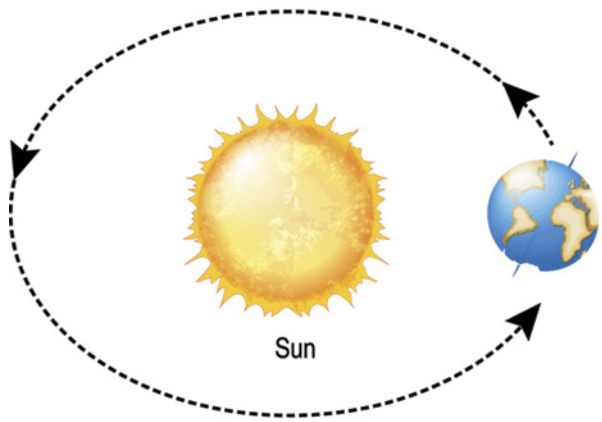



**Figure 1** The Earth is tilted as it orbits the Sun.

[STEAM project 1]

# How can we reduce pollution in local waterways so that biodiversity is protected?

Australia is one of the driest continents in the world. But according to an Australian Government report, Australians consume more water per person than any other country, using an average of 100 000 L per person every year.

Water is an important resource in Australia, so it is critical to manage our waterways carefully.

Australia has many waterways, including rivers, groundwater systems, wetland environments and other human-made passages for water. Waterways are vital to our existence and are valuable economic assets.

Waterways play an important role in supporting biodiversity in our local areas, by providing habitats for wildlife (such as fish and turtles) and plants.

Humans rely on local waterways for drinking water, irrigation of crops, industrial processes and recreational activities. But sometimes these human activities can impact waterways, endangering the biodiversity of a local area.

Waterways also hold spiritual significance for many people. Due to the importance of local waterways to First Nations peoples, waterways are part of our cultural heritage.

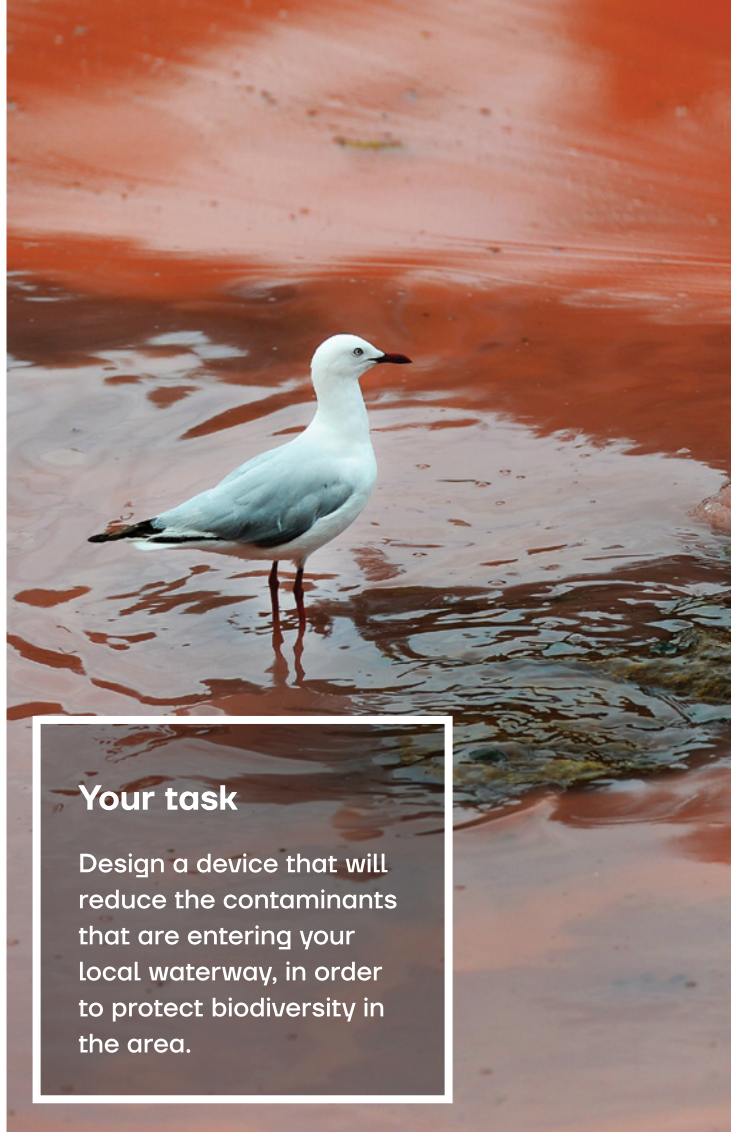
We must, therefore, manage our waterways to maintain their complex ecosystems.

## Water quality and contaminants

A contaminant is a substance that pollutes or poisons something. Contaminants can occur naturally, or be caused by humans – such as microplastics, pesticides and litter. Litter is an example of a physical contaminant, while pesticides are examples of chemical contaminants. There are many types of contaminants, which are often more heavily concentrated in industrial, urbanised or agricultural areas.

Human land use and major weather events, such as floods and bushfires, can introduce contaminants into local waterways and affect the water quality.

When water becomes contaminated, it can affect the health of an entire ecosystem, leading to serious environmental issues, such as acidic soil or algal blooms. So it is important for all waterways to be managed to protect the organisms that rely on them to survive.



### Your task

Design a device that will reduce the contaminants that are entering your local waterway, in order to protect biodiversity in the area.

**Figure 1** Algal blooms occur when an oversupply of nutrients in the water allows algae populations to quickly increase, covering the water's surface. Contaminants, such as industrial fertiliser running into waterways, can cause algal blooms. Algal blooms are often toxic to other aquatic life.

**Figure 2** Litter is a contaminant in local waterways, such as the River Torrens in Adelaide.

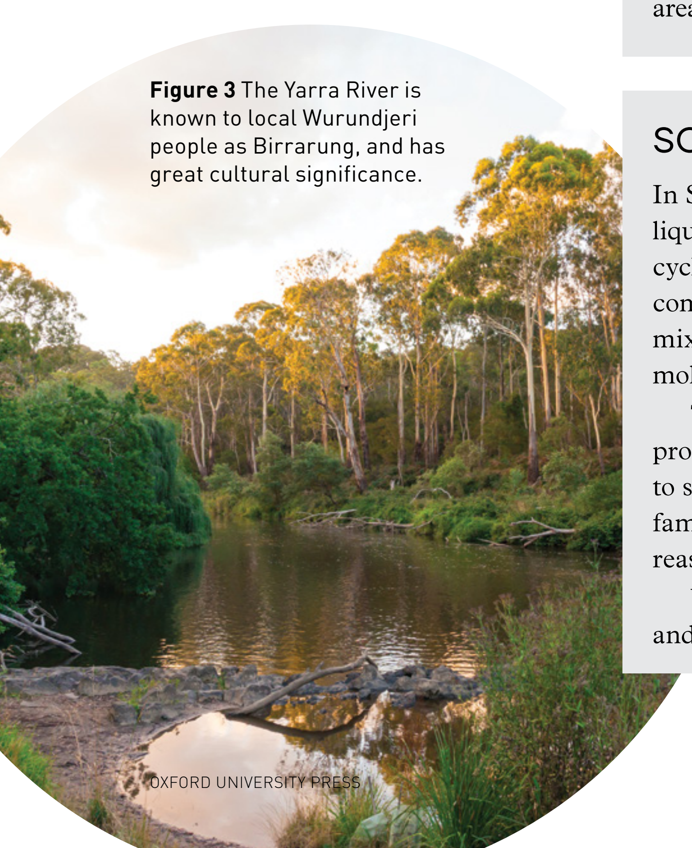


**Figure 3** The Yarra River is known to local Wurundjeri people as Birrarung, and has great cultural significance.

## HUMANITIES

In Geography this year, you will learn about water as a resource and how it connects places as it moves through the environment. You will also study the variability and scarcity of water in Australia.

In History, you will investigate the importance of water in sustaining ancient civilisations.

To complete this task successfully, you will need to investigate the health of a local waterway and the nearby land uses that may be introducing contaminants to the water. You will then need to research strategies that will help to reduce these contaminants.

You will find more information on this in Chapter 2 'Water as a resource' and Chapter 3 'Valuing and managing water' of *Oxford Humanities and Social Sciences 7 Australian Curriculum*.

## MATHS

In Maths this year, you will consolidate your understanding of area and volume and different units for measuring them. You will learn to perform calculations involving fractions, decimals and percentages – both with and without digital technology.

To complete this task successfully, you will need to combine these mathematical skills with your understanding of chemical and physical changes. You can then determine the scale of the problem and design your prototype in detail. You may need to perform calculations that relate the concentrations of contaminants, the dimensions of your prototype, the volume of water that can and needs to be processed, and the quantity of contaminants that need to be disposed of.

You will find help for applying these maths skills in Chapter 3 'Fractions and ratios', Chapter 4 'Decimals and percentages' and Chapter 9 'Length, area and volume' of *Oxford Maths 7 Australian Curriculum*.

## SCIENCE

In Science this year, you will learn about how particles move in solids, liquids and gases. Each of these states of matter occurs during the water cycle, which is influenced by both nature and humans. When water is combined with other particles, it forms different types of solutions and mixtures. The unique properties of each particle (including the water molecule) can allow it to be isolated and purified once more.

To complete this task successfully, you will need to consider the properties of each contaminant, and how these properties can be used to separate the contaminants from the water. You will also need to be familiar with the scientific method, and understand how to conduct a reasonable test.

You will find more information on this in Chapter 2 'Particle model' and Chapter 3 'Mixtures' of *Oxford Science 7 Australian Curriculum*.

# The design cycle

To successfully complete this task, you will need to complete each of the phases of the design cycle.


## Discover

When designing solutions to a problem, you need to know who you are helping and what they need. The people you are helping, who will use your design, are called your end-users.

Consider the following questions to help you empathise with your end-users:

- Who am I designing for?
- What problems are they facing? Why are they facing them?
- What do they need? What do they not need?
- What does it feel like to face these problems?
- What words would you use to describe these feelings?

To answer these questions, you may need to investigate using different resources, or even conduct interviews or surveys.

## Define

Before you start to design your device, you need to define the criteria that you will use to test that the problem is solved.

### Define your version of the problem

Rewrite the problem so that you describe the group you are helping, the problem they are experiencing and the reason it is important to solve it. Use the following question as a guide:

'How can we help (the group) to solve (the problem) so that (the reason)?'

### Determine the criteria

1 Define each contaminant that is present in the waterway. Describe the properties of each contaminant.
2 Describe how you could test whether the contaminant was present in the water.
3 Describe how the contaminant would affect the biodiversity of the area if it were not removed from the waterway.

## Ideate

Once you know who you're designing for, and what the criteria are, it's time to get creative!

- Outline the criteria or requirements your device must fulfil (for example, the weight and height of your design).
- Brainstorm at least one idea per person that fulfils the criteria.
- Consider whether your idea will prevent contamination from occurring or solve the problem after it has already occurred.

Remember that there are no bad ideas at this stage. One silly thought could lead to a genius innovation!

## Build

Draw each individual design for your device. Label each part of the design. Include the materials that will be used for its construction.

Include in the individual designs:

**a** the method you will use to isolate each contaminant

**b** the location of the device in the waterway.

If there is more than one separation method used in your design, identify the order in which you will carry out each method.

Present your design to your group. Use the criteria or requirements that you identified to decide which design your group will build.

### Build the prototype

Build and test the prototype of your group's chosen device.

Use the following questions as a guideline for your prototype:

- What materials will you need to build your prototype?
- How will you test whether each step of the design is successful? What will the outcome of each step look like?
- How will you record the steps you use when testing your device?
- How will you record the details of each extracted contaminant?
- How will you dispose of the extracted contaminants after your project is completed?

## Test

Use the scientific method to design and experiment with each separation method to ensure its success. You will need to control your variables between each test.

What criteria will you use to determine the success of your prototype?

Conduct your tests and record your results in an appropriate table.

## Communicate

Present your design to the class as though you are trying to get your peers to invest in your device.

In your presentation, you will need to:

- explain why removing the contaminant is important for the local wildlife
- describe the key features of your design and how it will reduce the amount of contaminant in the waterways
- construct a labelled diagram of your prototype in the natural environment
- explain the principles that support your design – the importance of water in the local environment and in sustaining civilisations, how some waterways become contaminated and how these contaminants can be reduced
- estimate the number of devices needed to reduce contaminants in the waterways in your local area
- calculate the cost of implementing your design.

**Check your Student obook pro for the following digital resources to help you with this STEAM project:**

**Student booklet**
This helpful booklet will guide you step-by-step through the project.

**What is the design cycle?**
This video will help you to better understand each phase in the design cycle.

**How to manage your project**
This 'how-to' video will help you to manage your time throughout the design cycle.

**How to pitch your idea**
This 'how-to' video will help you with the 'Communicate' phase of your project.

# How can we reduce waste so that we are not exploiting resources?

In 2019, the United Nations estimated that every year, 90 billion tonnes of resources (including fossil fuels, precious metals and non-metals) are extracted from the earth and turned into usable products. When these products are no longer used or wanted, only 9 per cent are recycled.

If we want to have enough resources left for future generations, humans cannot continue to extract materials from the earth in this way. It is unsustainable.

## E-waste

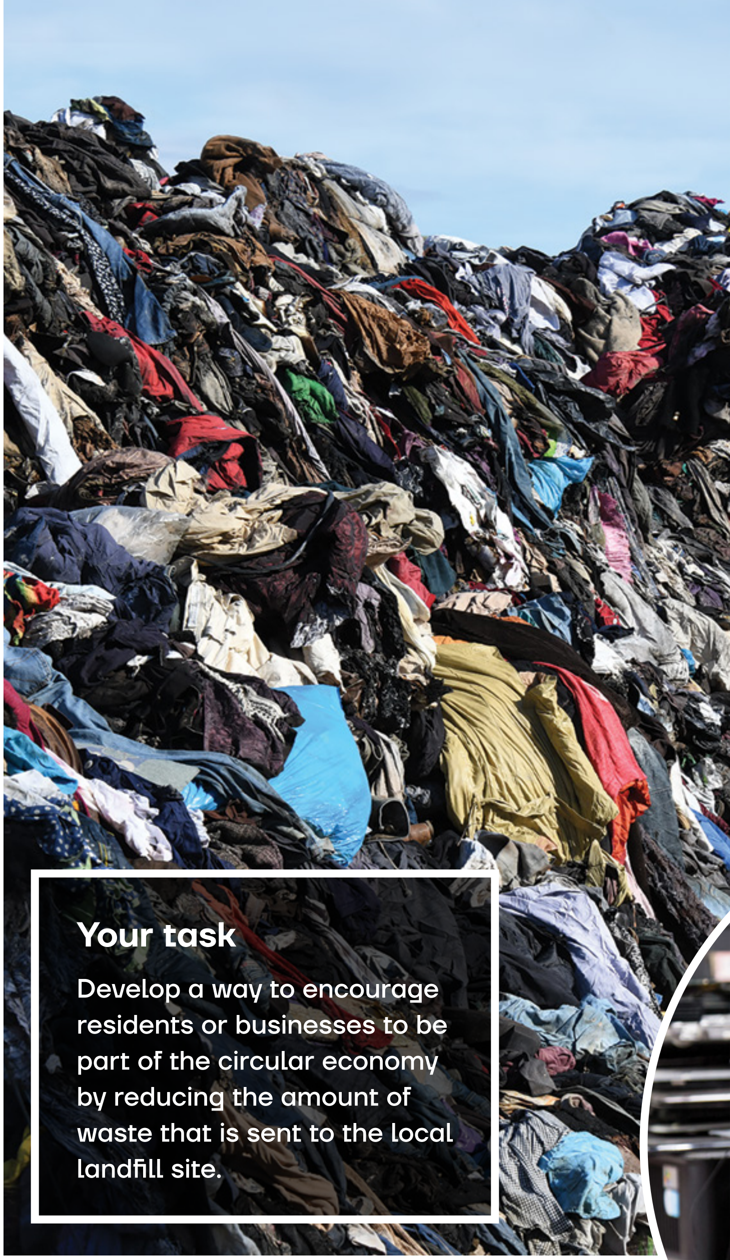
In Australia, millions of electronic devices are thrown away every year. This is known as e-waste. E-waste can be difficult to recycle, but it often contains valuable metals.

The average mobile phone contains 0.034 g of gold, 16 g of copper and 0.35 g of silver. When a phone is thrown into landfill (along with all the other e-waste that once used electricity or batteries) the materials can take many decades to break down (sometimes releasing toxins into the ground).

Recycling these materials reduces the need to mine new resources.

## Fast fashion

Fast fashion is the term used for affordable clothing produced rapidly for the general public. It is designed and produced quickly to reflect current fashion trends. When fashion becomes outdated, the clothes or products that reflect that fashion are often thrown away. The Australian Bureau of Statistics (2020) identified that, on average, each person sends 23 kg of clothing to landfill each year. Over 60 per cent of this clothing is made of synthetic fibres (made from fossil fuels) that can take many years to biodegrade.



**Your task**

Develop a way to encourage residents or businesses to be part of the circular economy by reducing the amount of waste that is sent to the local landfill site.

**Figure 1** In Australia, 6000 kg of textiles and clothing are dumped in landfill every 10 minutes.

## What is a circular economy?

One potential solution to our unsustainable use of resources is a 'circular economy'. In a circular economy, resources are used and reused as much as possible. This benefits businesses because the longer a resource can be used, the more value it has. A circular economy is based on three key principles:

1. eliminate waste or pollution in the production of a product
2. keep products and materials in use
3. regenerate natural systems.

Some companies are already using the principles of a circular economy in the products they sell in Australia.

**Figure 2** Electronic waste does not belong in landfill. Laptops that are no longer working or wanted are examples of e-waste.

**Figure 3** The average mobile phone contains gold, copper and silver.

## HUMANITIES

In Economics and Business this year, you will learn how consumers and producers respond to and influence each other in the market, particularly through price mechanisms. You will consider how resources are distributed, allocated or used in the production of food, clothing and electronics, and the growing consumer demand for sustainable products.

In Geography, you will investigate how the environment can affect the liveability of a place. You may survey the local area to understand the role of services and facilities provided to minimise, reduce and prevent waste, and strategies used to enhance liveability.

To complete this task successfully, you will need to consider the products you buy and the decisions businesses make when deciding what to produce, and the consequences when a product reaches its end-of-life. You will also need to gain an understanding of people's perceptions in your local area towards waste management, recycling and the importance of the environment in measuring liveability.

You will find more information on this in Chapter 5 'Liveable cities' and Chapter 15 'Economic choices, rights and responsibilities' of *Oxford Humanities and Social Sciences 7 Australian Curriculum*.

## MATHS

In Maths this year, you will use fractions, percentages and decimals to represent numbers, and ratios between quantities. You will consolidate your knowledge of volume, learning about cubic units and how to convert between different units of volume. You will perform calculations with and without digital technology.

To complete this task successfully, you will need to quantify the problem, which will include using ratios or fractions to scale between individual, local, national and global situations. You will need to cost your solution, accounting for any costs saved by recycling valuable materials.

You will find help for applying these maths skills in Chapter 3 'Fractions and ratios', Chapter 4 'Decimals and percentages' and Chapter 9 'Length, area and volume' in *Oxford Maths 7 Australian Curriculum*.

## SCIENCE

In Science this year, you will learn about separating mixtures, recycling different materials and disruptions to ecosystems. You will need to use your knowledge to consider the role of renewable and 'non-renewable' resources in different products, and how constantly sourcing new materials will affect the surrounding ecosystem.

To complete this task successfully, you may need to consider how the change in state of matter can aid a circular economy. You will also need to be familiar with the scientific method and understand how to conduct a fair test.

You will find more information about these issues in Chapter 3 'Mixtures' and Chapter 6 'Ecosystems' in *Oxford Science 7 Australian Curriculum*.

# The design cycle

To successfully complete this task, you will need to complete each of the phases of the design cycle.


## Discover

When designing solutions to a problem, you need to know who you are helping and what they need. The people you are helping, who will use your design, are called your end-users. This stage involves thinking about the problem (not possible solutions).

Consider the following questions to help you empathise with your end-users:

- Who am I designing for?
- What problems are they facing? Why are they facing them?
- What do they need? What do they not need?
- Who is producing the waste? Why is the waste being produced?
- What does it feel like to face these problems?
- What words would you use to describe these feelings?

To answer these questions, you may need to investigate using different resources, or even conduct interviews or surveys.

## Define

Before you start to design your solution, you need to define the criteria that you will use to test the success of your solution.

### Define your version of the problem

Rewrite the problem so that you describe the group you are helping, the problem they are experiencing and the reason it is important to solve it. Use the following phrase as a guide.

'How can we help (the group) to solve (the problem) so that (the reason)?'

### Determine the criteria

1 Describe the product that is being used. How much product is needed for normal functions?

2 Describe the waste that is being produced. In what units could you measure the amount of waste? How could you estimate how much waste is currently being produced?

3 Describe the different things that currently happen to this waste. To what fraction of the waste does this happen?

4 Describe the criteria that you will use to measure the success of your design.

## Ideate

Once you know who you're designing for, and what the criteria are, it's time to get creative!

As a group, brainstorm ways to solve the problem. Remember that there are no bad ideas at this stage. One silly thought could lead to a genius innovation!

Once you have many possible solutions, select three to five ideas and research whether these ideas have already been produced by someone else. If the prototype idea is already on the market, can you make a better version? If it's not, what will be needed to make it?

## Build

Draw your top two ideas. Label each part of the designs. Include the materials or skills required for their construction.

Include in the designs:

a a description of how the users will interact with the prototype idea
b a description of how the amount of waste will be decreased, and by roughly how much
c a description of how the design will contribute to the circular economy
d at least one advantage and disadvantage of each design.

Select one of the designs to take to the building and testing stage.

## Build the prototype

You will need to build at least three versions of your prototype idea. The first version will be tested for usefulness; the second will be used to test or survey the group you are helping; the third will be used for the presentation.

Use the following questions as a guideline for your prototype idea.

- What skills will you need?
- How will you produce a physical version of your prototype idea?
- How will you collect data on the effectiveness of your idea?

# Test

## Prototype 1

Use the scientific method to design an experiment that will test the effectiveness and strength of your first prototype. You will test the prototype more than once so that you can compare, but you will need to control your variables between tests.

What criteria will you use to determine the success of your solution?

Conduct your tests and record your results in an appropriate table.

## Prototype 2

If your prototype will be used to reduce waste, then you will need to generate a survey to test whether the prototype is appropriate for the user. (How would they use it? Would it make their work easier or harder? How likely do you think they are to buy it, and why? How will the prototype affect normal behaviours? How will the production of the prototype affect the environment?)

## Prototype 3

Use the information you have obtained from testing the first two versions  to adapt your last prototype to be more effective and usable for the group you are helping. You may want to use the first two prototypes to demonstrate how the design has been improved over time.

# Communicate

Present your solution to the class as though your peers are going to invest their money. How will you convince them it is a good idea?

In the presentation, you will need to:

- explain why we need to reduce the amount of waste going to the local landfill
- describe the key features of your design and how they will reduce the amount of waste in the landfill, using calculations to justify a quantitative estimate of that reduction
- construct a labelled diagram of your prototype in the natural environment
- describe how the ecosystem will be impacted by your prototype idea
- explain the principles that support your design – such as the circular economy
- use calculations to estimate the cost of implementing your design.

**Check your Student obook pro for the following digital resources to help you with this STEAM project:**

**Student booklet**
This helpful booklet will guide you step-by-step through the project.

**What is the design cycle?**
This video will help you to better understand each phase in the design cycle.

**How to manage your project**
This 'how-to' video will help you to manage your time throughout the design cycle.

**How to define a problem**
This 'how-to' video will help you to narrow your ideas down and define a specific problem.

# GLOSSARY

## A

**abiotic factors**
non-living factors that influence an ecosystem, such as wind, water, salinity and temperature

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

**aim**
the purpose of an experiment

**air resistance**
friction between a moving object and the air it is moving through

**amoeba**
a type of single-celled organism belonging to the Protista kingdom

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

**apparatus**
equipment placed together for an experiment

**atmosphere**
the envelope of gases surrounding the Earth or another planet

**atom**
the smallest particle of matter; cannot be created, destroyed or broken down (indivisible)

**attraction force**
the force that attracts one object to another

**autotroph**
an organism that makes its own food (e.g. plants)

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

## B

**bacteria**
unicellular organisms that have a cell wall but no nucleus

**balanced forces**
two forces equal in size and opposite in direction

**binomial**
the double-name system created by Linnaeus to name organisms; the first name is the genus, the second name is the species

**biological control**
a method of controlling a population by releasing a living organism into an ecosystem

**biotic factors**
living factors that influence an ecosystem, such as animals, plants and bacteria

**block and tackle**
a group of pulleys mounted together in a frame or block, which provides significant mechanical advantage

**boiling point**
the temperature at which a liquid boils and becomes a gas

**Bunsen burner**
a piece of equipment used as a heat source in the laboratory

## C

**calibrate**
check the accuracy of a meter or measuring device against known measurements

**capture–recapture**
a method of estimating the number of organisms by capturing, marking and releasing a sample of the organisms

**carnivore**
an animal that eats other animals

**carrying capacity**
the maximum number of organisms in a population that can be sustained by an ecosystem

**cell**
(in biology) the building block of living things

**cell wall**
a structure that provides support around the cell in some organisms, such as plants and fungi

**centrifuging**
a technique used to separate light and heavy particles by rapidly spinning the mixture

**chemical property**
how a substance behaves in a chemical reaction, such as how it reacts with an acid

**chemistry**
the branch of science that deals with matter and the changes that take place within it

**chromatography**
a technique used to separate substances according to their differing solubilities

**classify**
arrange in classes or categories

**cognitive verb**
a doing word that requires you to perform a specific thinking task

**colloid**
a type of mixture that always looks cloudy, because clumps of insoluble particles remain suspended throughout it rather than settling as sediment

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

**commensalism**
a type of relationship between two organisms of different species, in which one organism benefits and the other is not affected

**community**
different populations living in the same location at the same time

**competition**
contest between organisms that require or seek similar resources such as shelter and food

**compound**
substances made up of two or more types of atoms bonded together, e.g. water

**compressibility**
the extent to which a substance can be compressed (squashed); gases can be compressed but solids and liquids cannot

**compressional strength**
the ability of a substance to withstand large forces

**concentrated**
containing a large number of solute particles in the volume of solution

**conclusion**
a statement that 'answers' the aim of an experiment

**condensation**
the cooling down of gas into a liquid

**consumer**
an animal that can't convert the Sun's energy into sugars and instead must eat to get the energy it needs to survive

**contact force**
a force acting between two bodies in direct contact

**continuous data**
data that are measured and can be any value

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

**crystallisation**
a separation technique used with evaporation to remove a dissolved solid from a liquid; after the liquid has been evaporated the solid remains, often in the form of small crystals

## D

**decanting**
a technique used to separate sediment from the liquid it is in by carefully pouring the liquid away

**decomposer**
an organism that gains nutrients by breaking down dead organisms into simpler nutrients

**density**
a measure of mass per unit of volume

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

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

**dilute**
containing a small number of solute particles in the volume of solution

**discrete data**
data where the numbers can only be whole numbers

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

**disease**
a disorder or condition that interrupts the normal functioning of an organism

**distance magnifier**
a lever that changes a strong force that acts over a short distance into a weak force that acts over a longer distance

**distillation**
a technique that uses evaporation and condensation to separate a solid from the solvent in which it has dissolved

**domain**
a small section of a magnet where the magnetic field of all the atoms is aligned in the same direction

**drought**
a period in which an area experiences water shortage

## E

**ecosystem**
a community of living organisms and their non-living surroundings

**ectotherm**
an organism with a body temperature that changes with the environment

**effort**
the force used to operate a lever

**electrostatic force**
the force between two objects caused by a build-up of negative charges

**element**
a pure substance made up of only one type of atom, e.g. oxygen, carbon

**emigrate**
when an animal leaves an ecosystem

**emulsion**
a type of colloid in which two or more liquids are mixed together, with one suspended in the other as tiny droplets

**endoskeleton**
an internal skeleton

**endotherm**
an organism that has a constant body temperature regardless of the temperature of its environment

**equinox**
a day when day and night are the same length; occurs twice each year

**equipment**
items used in the laboratory to conduct experiments

**error**
an inaccuracy or inconsistency in measurement

**evaporation**
a change in state from liquid to gas; also a technique used to separate dissolved solids from water

**exoskeleton**
an external skeleton

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

## F

**filtering**
a technique used to separate different-sized particles in a mixture depending on the size of the holes in the filter used

**first-class lever**
a lever that has its fulcrum between the point of effort and the load

**first-order (primary) consumer**
an organism thats eat only producers such as plants, algae and bacteria; it does not eat other consumers

**flocculant**
a chemical added to a mixture to make suspended particles clump together

**flood**
the overflow of a large body of water

**flotation**
the action of floating in a liquid or gas

**food chain**
a diagram that shows who eats whom in an ecosystem, and how nutrients and energy are passed on

**food web**
several intertwined food chains, showing the extended relationships between different organisms

**force magnifier**
a device that can increase the amount of force available (e.g. to shift something); an example is a lever

**friction**
a force that acts to oppose the motion between two surfaces as they move over each other

**fulcrum**
the turning point of a lever

## G

**genus**
a group of closely related species

**gravity**
the force of attraction between objects due to their masses

## H

**hardness**
how easily a mineral can be scratched

**herbivore**
an animal that eats only plants

**heterotroph**
an organism (e.g. fungi, animals) that absorbs nutrients from other living things

**high tide**
when the ocean covers slightly more land; the highest level that the tide reaches on the shore

**hypothesis**
a proposed explanation for a prediction that can be tested

## I

**immigrate**
when an animal enters a new ecosystem

**immune**
able to fight an infection as a result of prior exposure

**incompressible**
unable to be compressed; solids and liquids are incompressible

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

**indicator species**
an organism that can be used to measure the environmental condition of an area

**infrared radiation**
invisible light that has longer wavelengths than visible light

**introduced species**
an organism that has been brought to and has established itself in an area it is not native to

**invertebrate**
an organism that has an exoskeleton or no skeleton

## K

**key**
(in biology) a visual tool used to classify organisms

**kinetic energy**
the energy possessed by moving objects

**kingdom**
the highest category in taxonomic classification

## L

**laboratory**
a specially designed space for conducting research and experiments

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

**lever**
a simple machine that reduces the effort needed to do work

**like poles**
two north poles or two south poles of a magnet

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

**Linnaean taxonomy**
a hierarchical system of classification developed by Carl Linnaeus (1707–1778) in which all organisms are grouped into kingdom, phylum, class, order, genus and species, with each individual organism known by its genus and species names

**load**
(in physics) resisting force

**low tide**
when the ocean covers slightly less land; the lowest level on the shore that the tide recedes to

**lubrication**
the action of applying a substance such as oil or grease to an engine or component so as to reduce friction

## M

**magnetic pole**
the north and south ends of a magnet; each of the points near the extremities of the axis of rotation of the Earth or another body where a magnetic needle dips vertically

**magnetic separation**
the process of using magnets to separate magnetic materials from non-magnetic materials

**mass**
the amount of matter in a substance, usually measured in kilograms; the mass of an object never changes, even in space

**matter**
anything that has space and volume; matter is made up of atoms

**meniscus**
the curved upper surface of a liquid in a tube

**method**
a series of steps explaining how to do an experiment

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

**mixture**
a substance made up of two or more pure substances mixed together

**molecule**
a group of two or more atoms bonded together

**multicellular**
consisting of two or more cells

**mutualism**
a type of relationship between two organisms of different species, in which both organisms benefit

## N

**natural disasters**
natural events such as floods, volcanic eruptions, tsunamis and earthquakes that can cause severe damage and fatalities

**neap tide**
when the difference between high and low tides is smallest; occurs during the Moon's quarter phase, when the Sun and the Moon pull in different directions

**net force**
the vector sum of all the forces acting on an object; also known as resultant force

**newton**
the unit used to measure force; symbol N

**non-contact force**
a force acting between two bodies that are not in direct contact

**nucleus**
a membrane-bound structure in cells that contains most of the cell's genetic material

## O

**omnivore**
an animal that eats both plants and animals

**orbit**
the path a planet follows around the Sun or a star; the path a moon follows around a planet

## P

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

**parasitism**
a relationship in which one organism (parasite) lives in or on the body of another organism (host) and benefits while the host is harmed

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

**phases of the Moon**
changes in the shape of the Moon as seen from Earth

**philosopher**
a 'lover of knowledge'; someone who studies ideas, theories and questions

**photosynthesis**
a chemical process used by plants to make glucose and oxygen from carbon dioxide, sunlight and water

**physical property**
a property of a substance that can be measured or observed without changing the substance into something else; examples are colour and boiling point

**plankton**
microscopic organisms that float in fresh or salt water

**pollination**
the transfer of pollen to a stigma, ovule, flower or plant to allow fertilisation

**population**
a group of individuals of the same species living in the same location at the same time

**population dynamics**
the study of changes in species population numbers and the factors that may contribute to these changes

**predator**
an animal that hunts and feeds on another (prey) for food

**prey**
an animal that is hunted and killed by another (predator) for food

**producer**
a plant or plant-like organism that is at the start of food chain because it produces its own food, usually using sunlight

**pure substance**
something that contains only one type of substance (e.g. a single element or a single compound)

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

## Q

**quadrat**
a randomly selected square plot used to estimate the number of organisms

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

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

## R

**ramp**
a sloping surface joining two different levels

**reasonable test**
a test where all variables are controlled except for the one being changed on purpose

**reproduction**
the production of offspring by a sexual or asexual process

**repulsion force**
a force that pushes one object away from another

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

## S

**saturated**
describes a solution in which no more solute can be dissolved

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

**science**
the study of the natural and physical world

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

**scientific model**
a physical, mathematical or conceptual representation of an object, system, event or process that is used to explain or predict the behaviour of a scientific process or phenomenon

**scientist**
a person who studies the natural and physical world

**screw**
a sharp-pointed metal object with a spiral thread running along its length and a slotted head

**second-class lever**
a lever that has its load between the point of effort and the fulcrum

**second-order (secondary) consumer**
a carnivore that eats primary consumers

**sediment**
substance or matter that settles to the bottom in a mixture

**sedimentation**
the process of a substance settling to the bottom in a mixture

**sieving**
a separation technique based on the difference in particle size

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

**solar energy**
energy made by atoms colliding with each other in the centre of the Sun

**solar system**
the Sun and all the planets, dwarf planets, moons and asteroids that travel around it and each other

**solstice**
either of the times when the Sun is furthest from the equator

**solubility**
how easily a substance dissolves in a solvent

**soluble**
can be dissolved in a liquid

**solute**
a substance that dissolves in a liquid (solvent)

**solution**
a mixture of a solute dissolved in a solvent

**solvent**
a liquid in which other substances dissolve

**species**
a group of organisms that look similar to one another, and can breed in natural conditions and produce fertile young

**spore**
a tiny reproductive structure that, unlike a gamete, does not need to fuse with another cell to form a new organism

**spring balance**
a device consisting of a spring and a scale, used to measure forces

**spring tide**
when there is maximum difference between high and low tides; caused by the combined pull of the Moon and the Sun

**star**
a celestial body appearing as a luminous point in the night sky

**streamlining**
giving an object a form that presents the least resistance to motion

**suspension**
a cloudy liquid containing insoluble particles

**symbiosis**
a close physical relationship between two organisms of different species

## T

**taxonomist**
a scientist who classifies living things into groups

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

**tensile strength**
a measure of the flexibility of the bonds between particles in a substance

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

**third-class lever**
a lever that has its point of effort between the fulcrum and the load

**third-order (tertiary) consumer**
a carnivore that eats primary and secondary consumers and is therefore at the top of the food chain

**thread**
the spiral ridge of a screw

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

**totem**
a spiritual being, symbol or object that is sacred to a group of people

**type specimen**
the specimen used for naming and describing a new species

## U

**ultraviolet radiation**
invisible rays that are part of the energy that comes from the Sun

**unbalanced forces**
describes two or more forces that are unequal in size and direction and therefore change an object's speed, direction or shape

**unicellular**
consisting of only one cell; an example is bacteria

**units**
standard measurements

**unlike poles**
the north and south poles of a magnet

**urban sprawl**
the spreading and expansion of cities and houses into undeveloped land

## V

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

**vascular tissue**
in a plant, tube-like structures that transport water from the roots to the leaves

**vertebrate**
an organism that has an endoskeleton

**viscosity**
a measure of how slowly a liquid changes its shape; the thickness of a liquid

## W

**wedge**
a piece of wood, metal or other substance that tapers to a thin edge and is driven between two objects or parts of an object to secure or separate them

**weight**
a measure of the gravitational pull on an object

**wheel and axle**
a type of lever that can rotate about its centre, magnifying force or distance

# INDEX

## D



## E



## F

## N



## O



## P



## Q



## R

## S



## T



## U



## V

## W



## Y



## Z

Notes

Notes

Notes

## Notes

Notes

Forces act on everything around us all the time. We don't notice them, but they cause objects to move, speed up, slow down, change direction and remain still. This image shows a woman bungee jumping. As the woman jumps off the cliff, gravity pulls her down towards the centre of the Earth. When the bungee cord attached to her body is stretched, it will start pulling her up in the opposite direction and stop her from falling to the ground.

OXFORD UNIVERSITY PRESS

visit us at **oup.com.au** or
contact customer support at **oup.com.au/help**