SCIENCE

OXFORD SCIENCE 7

HELEN SILVESTER

SECOND EDITION

VICTORIAN CURRICULUM

OXFORD

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HELEN SILVESTER

2ND EDITION

VICTORIAN CURRICULUM

obook pro

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Oxford University Press is a department of the University of Oxford.
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Published in Australia by
Oxford University Press
Level 8, 737 Bourke Street, Docklands, Victoria 3008, Australia.

First published 2016
Second edition 2021

NATIONAL LIBRARY OF AUSTRALIA

A catalogue record for this book is available from the National Library of Australia

ISBN 9780190331818

Edited by Jocelyn Hargrave
Typeset by Q2A Media Services Pvt. Ltd., Noida, India
Proofread by Monica Schaak
Indexed by Max McMaster
Printed in Singapore by Markono Print Media Pte Ltd

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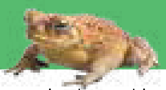
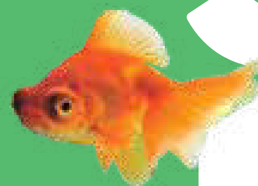


1 Science toolkit

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 Water

Like many substances, water can exist in three states: solid, liquid and gas. Water is one of our most valuable resources and it cycles through our environment in a process called the water cycle.

5 Resources

Humans rely on the natural resources of the Earth. Some of the Earth's resources are renewable, but others are non-renewable. Managing resources is a key priority.

6 Earth, Sun and Moon

The position of the Sun, Earth and Moon in the night 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.

7 Classification

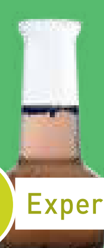
Living things are called organisms. There are differences within and between groups of organisms. Classification is a system that helps organise the diversity of life on Earth. The system of classification continues to develop and change.

8 Interactions between organisms

Organisms interact with each other 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.

9 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.



10 Experiments

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CONTENTS

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INTRODUCING *OXFORD SCIENCE 7–10 VICTORIAN CURRICULUM*

Oxford Science Victorian Curriculum has been developed to meet the requirements of the *Victorian 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 at VCE.

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

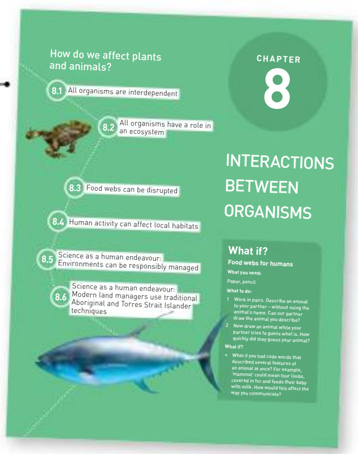
> Student Book
> Student obook pro
> Teacher obook pro.

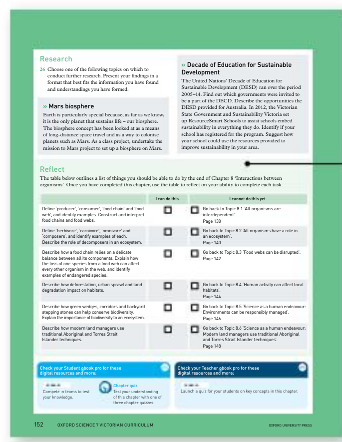
Key features of this Student Book

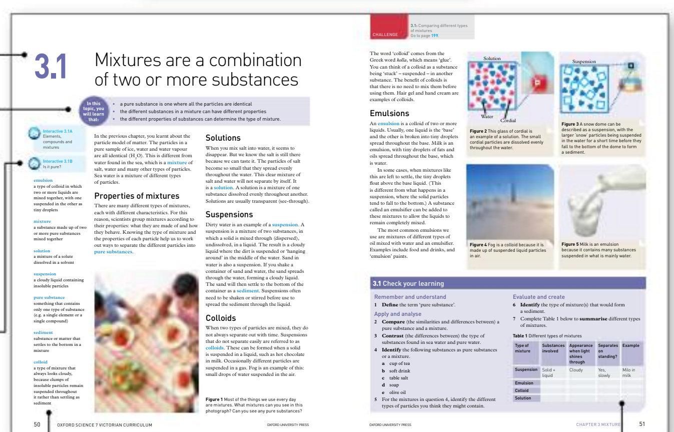
> This Student Book combines complete curriculum coverage with clear and engaging design.

> Each print Student Book comes with complete access to all the digital resources available on Student obook pro.

Focus on concept development







Chapter openers

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

Reflect

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

Concept statements

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

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 Bloom's taxonomy. Questions are phrased using bolded task words (also called command verbs), which state what is expected of a student and prepares them for studying VCAA science subjects.

Focus on science inquiry skills and capabilities

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.

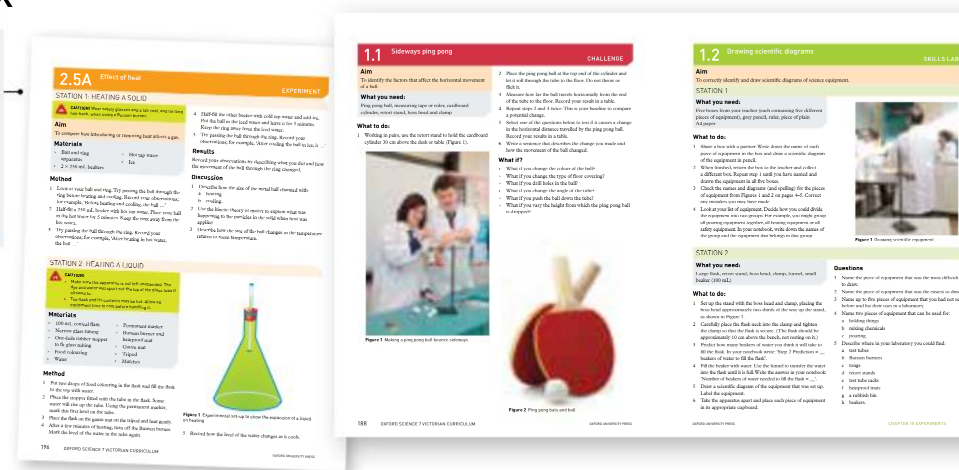
Develop your abilities

- 'Develop your abilities' provide 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

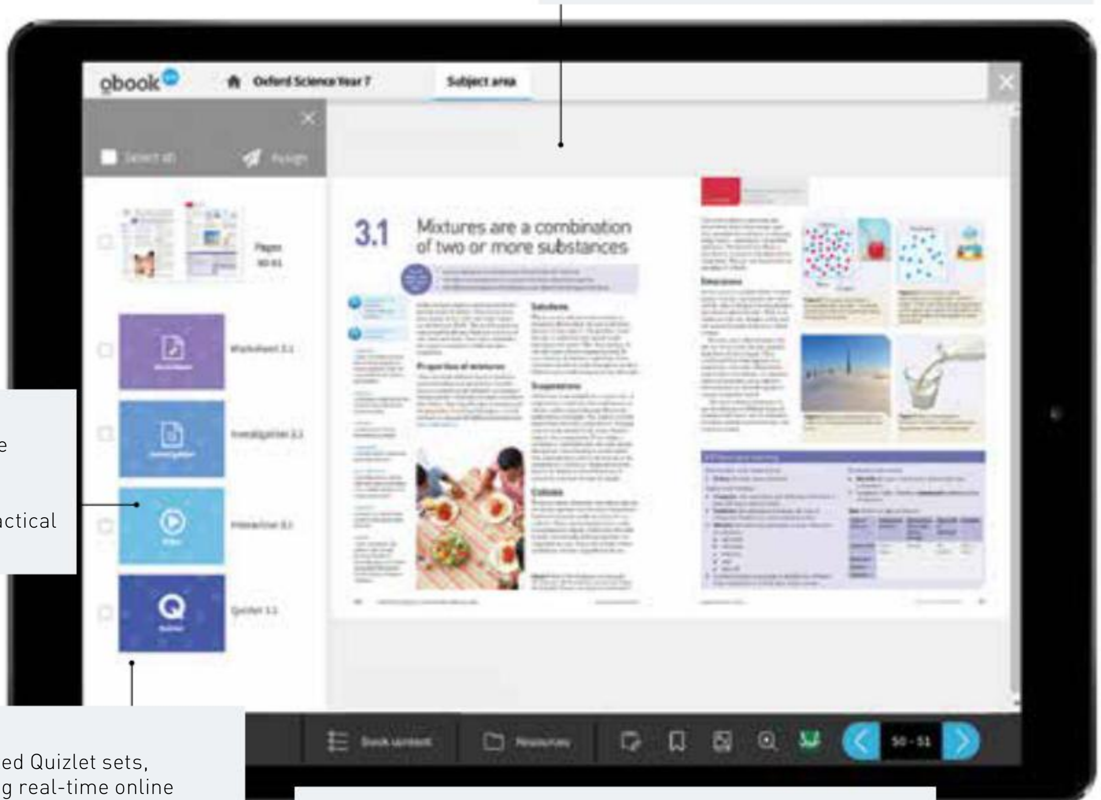
obook pro

> 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 are autocorrecting, 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**.

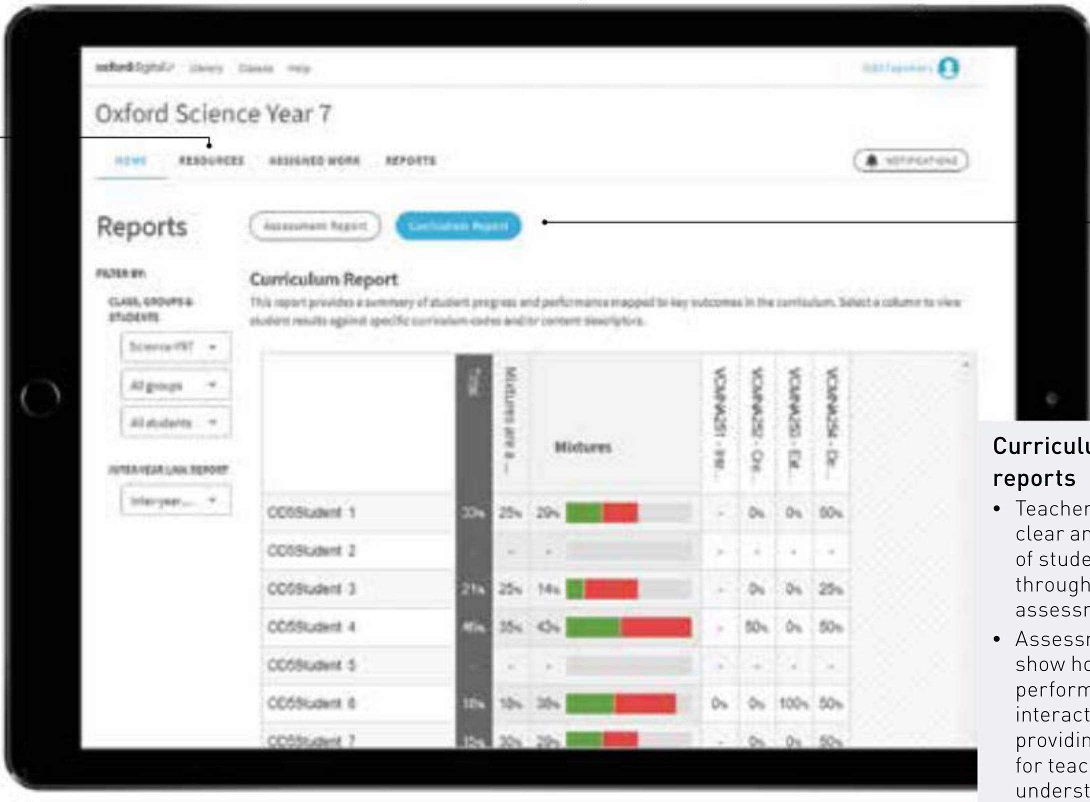
> Each chapter and topic of the Student Book is accompanied by full teaching support. Teaching programs are provided that clearly direct learning pathways throughout each chapter, including ideas for differentiation and practical activities.

> 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.



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 descriptors and curriculum codes.

Additional resources

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

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.

VICTORIAN CURRICULUM: SCIENCE 7 SCOPE AND SEQUENCE

LEVELS 9 AND 10 DESCRIPTION

In Levels 7 and 8, the curriculum focus is on explaining phenomena involving science and its applications. Students explain the role of classification in ordering and organising information about living and non-living things. They classify the diversity of life on Earth into major taxonomic groups and consider how the classification of renewable and non-renewable resources depends on the timescale considered. Students classify different forms of energy and describe the role of the energy in causing change in systems, including the role of heat and kinetic energy in the rock cycle. They use and develop models including food chains, food webs and the water cycle to represent and analyse the flow of energy and matter through ecosystems and explore the impact of changing components within these systems. Students investigate relationships in the Earth–Sun–Moon system and use models to predict and explain astronomical phenomena. They explain changes in an object's motion by considering the interaction between multiple forces. Students link form and function at a cellular level and explore the organisation and interconnectedness of body systems. Similarly, they explore changes in matter at a particle level, and distinguish between chemical and physical change. Students make accurate measurements and control variables in experiments to analyse relationships between system components and explore and explain these relationships using appropriate representations. They make predictions and propose explanations, drawing on evidence to support their views.

LEVELS 7 AND 8 CONTENT DESCRIPTIONS	
Science as a human endeavour	
Chapter 3 Chapter 4 Chapter 5 Year 8	Scientific knowledge and understanding of the world changes as new evidence becomes available; science knowledge can develop through collaboration and connecting ideas across the disciplines and practice fo science (VCSSU089)
Chapter 3 Chapter 4 Chapter 9 Year 8	Science and technology contribute to finding solutions to a range of contemporary issues; these solutions may impact on other areas of society and involve ethical considerations (VCSSU090)
Biological sciences	
Chapter 7	There are differences within and between groups of organisms; classification helps organise this diversity (VCSSU091)
Year 8	Cells are the basic units of living things and have specialised structures and functions (VCSSU092)
Chapter 8	Interactions between organisms can be described in terms of food chains and food webs and can be affected by human activity (VCSSU093)
Year 8	Multicellular organisms contain systems of organs that carry out specialised functions that enable them to survive and reproduce (VCSSU094)
Chemical sciences	
Chapter 3	Mixtures, including solutions, contain a combination of pure substances that can be separated using a range of techniques (VCSSU095)
Chapter 2	The properties of the different states of matter can be explained in terms of the motion and arrangement of particles (VCSSU096)
Year 8	Differences between elements, compounds and mixtures can be described by using a particle model (VCSSU097)
Year 8	Chemical change involves substances reacting to form new substances (VCSSU098)

LEVELS 7 AND 8 CONTENT DESCRIPTIONS	
Earth and space sciences	
Chapter 6	Predictable phenomena on Earth, including seasons and eclipses, are caused by the relative positions of the Sun, Earth and the Moon (VCSSU099)
Chapter 5	Some of Earth's resources are renewable, but others are non-renewable (VCSSU100)
Chapter 4	Water is an important resource that cycles through the environment (VCSSU101)
Year 8	Sedimentary, igneous and metamorphic rocks contain minerals and are formed by processes that occur within Earth over a variety of timescales (VCSSU102)
Physical sciences	
Chapter 9	Change to an object's motion is caused by unbalanced forces acting on the object; Earth's gravity pulls objects towards the centre of Earth (VCSSU103)
Year 8	Energy appears in different forms including movement (kinetic energy), heat, light, chemical energy and potential energy; devices can change energy from one form to another (VCSSU104)
Year 8	Light can form images using the reflective feature of curved mirrors and the refractive feature of lenses, and can disperse to produce a spectrum which is part of a larger spectrum of radiation (VCSSU105)
Year 8	The properties of sound can be explained by a wave model (VCSSU106)
SCIENCE INQUIRY SKILLS	
Questioning and predicting	
Chapter 1 Chapter 10 Year 8	Identify questions, problems and claims that can be investigated scientifically and make predictions based on scientific knowledge (VCSIS107)
Planning and conducting	
Chapter 1 Chapter 10 Year 8	Collaboratively and individually plan and conduct a range of investigation types, including fieldwork and experiments, ensuring safety and ehtical guidelines are followed (VCSIS108)
Chapter 1 Chapter 10 Year 8	In fair tests, measure and control variables, and select equipment to collect data with accuracy appropriate to the task (VCSIS109)
Recording and processing	
Chapter 1 Chapter 10 Year 8	Construct and use a range of representations including graphs, keys and models to record and summarise data from student's own investigations and secondary sources, and to represent and analyse patterns and relationships (VCSIS110)
Analysing and evaluating	
Chapter 1 Chapter 10 Year 8	Use scientific knowledge and findings from investigations to identify relationships, evaluate claims and draw conclusions (VCSIS111)
Chapter 1 Chapter 10 Year 8	Reflect on the method used to investigate a question or solve a problem, including evaluating the quality of the data collected, and identify improvements to the methods (VCSIS112)
Communicating	
All chapters	Communicate ides, findings and solutions to problems including identifying impacts and limitations of conclusions and using appropriate scientific language and representations (VCSIS113)

ACKNOWLEDGEMENTS

The author and the publisher wish to thank the following reviewers: Professor Bradley Moggridge, James Kennedy, Paguiel Meunier, Michelle Moore and Eliza Ba Than.

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CHAPTER 1

SCIENCE TOOLKIT

What do scientists do?

What if?

Bubbology

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.

CAUTION! Do not suck on 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

In this topic, you will learn that:

- 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 wondering '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. **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. 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, and mostly for the better.

scientist
a person who studies the natural and physical world

science
the study of the natural and physical world

philosopher
someone who studies ideas, theories and questions

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.

CHALLENGE

1.1: Sideways ping pong
Go to page **188**.

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

Remember and understand

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

2 Suggest one reason why being curious and asking questions is important in science.

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

Apply and analyse

4 a Ask an adult to recall one idea or invention that has changed in their lifetime due to science.

b **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.

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.

Evaluate and create

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.

cell
(in biology) the building block of living things

atmosphere
the envelope of gases surrounding the Earth or another planet

1.2 Scientists use specialised equipment

In this topic, you will learn that:

- an experiment is a way to solve a problem or to find the answer to a question
- 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.

Interactive 1.2
Types of equipment used in the laboratory

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

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**.

Figure 1 Types of equipment used in the laboratory

SKILLS LAB
1.2: Drawing scientific diagrams Go to page 189.

Challenge: 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.

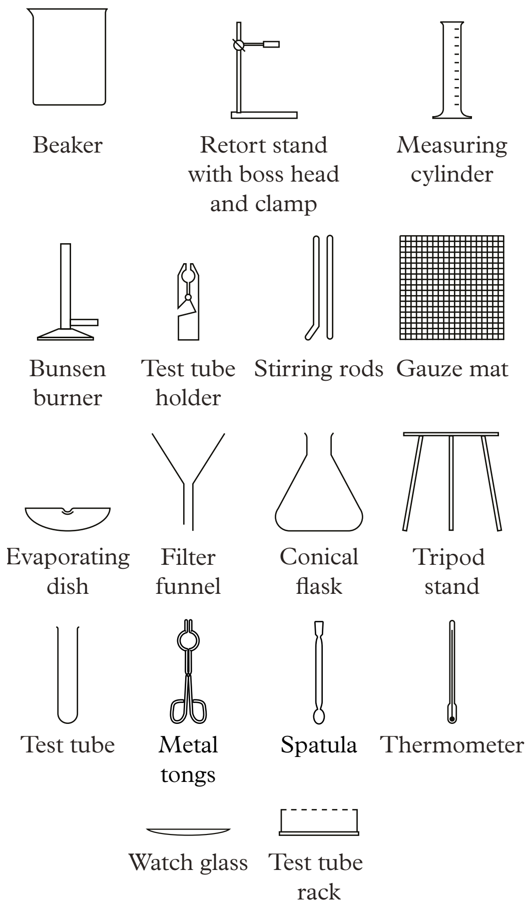


Figure 2 Scientific drawings of laboratory equipment

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

Remember and understand

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

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 …

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

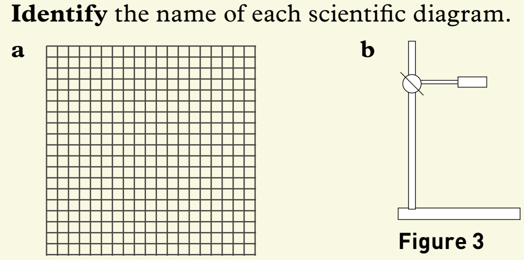


Figure 3

1.3 Scientists take safety precautions

In this topic, you will learn that:

- 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.

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 2 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.

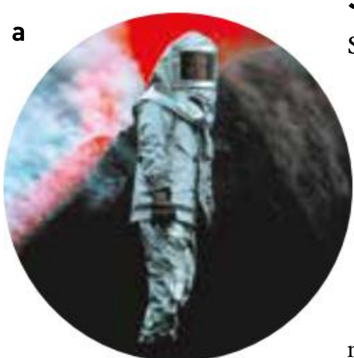
In the laboratory do:

- 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.

a



b

Figure 1 a Vulcanologists (scientists who study volcanoes) wear amazing 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.

Figure 2 Do you know what each of these symbols means?

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

Remember and understand

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.

Apply and analyse

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

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

Evaluate and create

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

1.4 Scientists use observation and inference to answer questions

In this topic, you will learn that:

- 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.

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.

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

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.

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.

SKILLS LAB

1.4: Observation versus inference Go to page 190.

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

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

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

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

> Which is your strongest sense and which is your weakest?

> Did you discover anything surprising while looking at 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.

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

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

Remember and understand

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.

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

Apply and analyse

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.

Evaluate and create

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.

1.5 Science relies on measuring with accuracy

In this topic, you will learn that:

- 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).

Video 1.5
Measurement, errors and accuracy

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. 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.

millilitre (mL)
unit of volume used to measure small or exact quantities of liquids, equivalent to one-thousandth of a litre

meniscus
the curved upper surface of a liquid in a tube

cubic centimetre (cm^3)
a volume equivalent to that of a cube of length 1 centimetre

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

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.
3. Half fill the third container with very warm water.

CAUTION! Make sure it is safe to put your hand in the 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?

1.5: Measuring mass and volume Go to page **190**.

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, from the Greek word *metron*, meaning 'to measure'.

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 Wonthaggi, Victoria, as in New York, USA. A temperature of 37°C is just as hot in Kolkata, India, as in Kyabram, Victoria. 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.

units
standard measurements

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

kilometre (km)
a metric unit of length, equal to 1000 metres

centimetre (cm)
a metric unit of length, equal to one-hundredth of a metre

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)**.

millimetre (mm)
a metric unit of length, equal to one-thousandth of a metre

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

gram (g)
unit of mass

kilogram (kg)
unit of mass, equivalent to 1000 grams

tonne (t)
unit of mass, equivalent to 1000 kilograms

milligram (mg)
unit of mass, equivalent to one-thousandth of a gram

second (s)
a second is a sixtieth of a minute

Celsius (°C)
a temperature scale and unit of measurement of temperature

litre (L)
unit of volume used to measure liquid

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'.

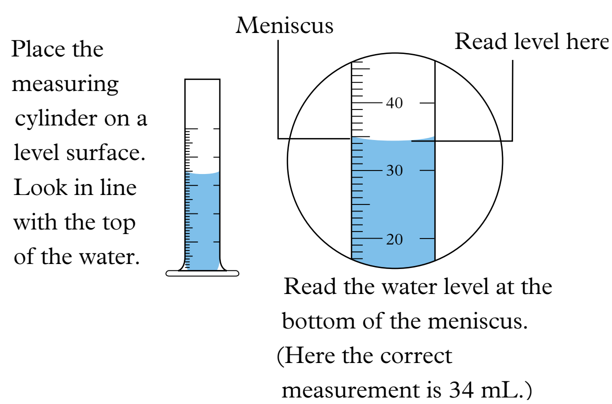


Figure 5 Volume This measures how much space something takes up. Measurements of liquid volumes can be shown with units called **litres (L)** or **millilitres (mL)**. In science, beakers and measuring cylinders are used to measure the volume of liquids. Some beakers have a measuring scale on them, but 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)**.

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

- 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.

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

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 m (divide by 100)
295 cm = 2.95 m

Therefore the 2.95 m pipe will fit in the 3 m postage cylinder and will be too long for the 2.5 m cylinder.

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**.

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

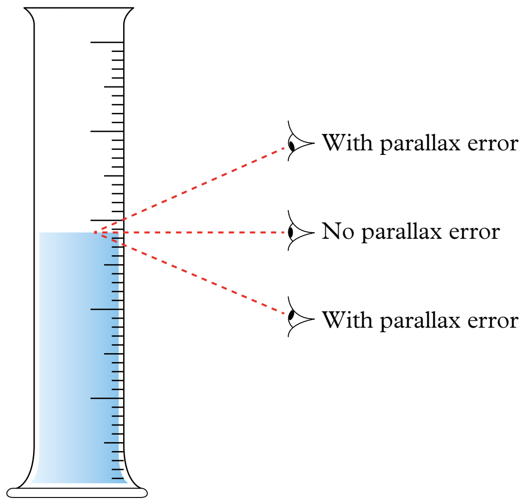


Figure 7 Parallax error occurs when you read a scale from an angle.

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 that occurs due to reading a scale from an angle

error
an inaccuracy or inconsistency in measurement

1.5 Check your learning

Remember and understand

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

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

3 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.

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

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

Apply and analyse

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

7 **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

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

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

10 Convert 1 km into metres, centimetres and millimetres.

Evaluate and create

11 Use an example to **explain** that errors in measurement are sometimes unavoidable.

1.6 A Bunsen burner is an essential piece of laboratory equipment

In this topic, you will learn that:

- 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).

Video 1.6 How to use a Bunsen burner

Interactive 1.6 Lighting a Bunsen burner

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

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

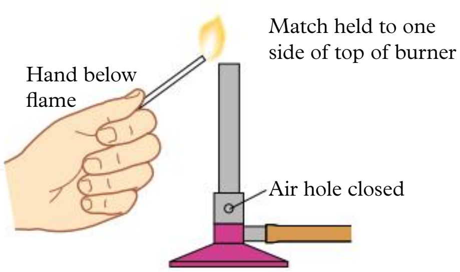


Figure 1 The right way to light a Bunsen burner

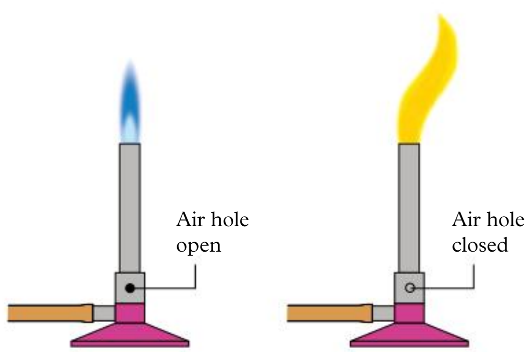


Figure 2 Blue (heating) and yellow (safety) flames on the Bunsen burner

Figure 3 A scalded hand

Figure 4 A burnt hand

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.

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.

Materials

- Bunsen burner
- Heatproof mat
- Matches
- Notebook
- Coloured pencils
- Grey pencil
- Metal tongs
- 2 pieces of white ceramic or porcelain

A Bunsen burner is lit using five steps.

1 Place the Bunsen burner on a heatproof mat.
2 Connect the rubber hosing firmly to the gas tap.
3 Close the air hole by turning the collar.
4 Light a match and place it above the barrel, with your hand below the flame.
5 Open the gas tap fully.

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

Figure 1 Place the Bunsen burner on a heatproof mat.

Figure 2 Connect the rubber hosing firmly to the gas tap.

Figure 3 Close the air hole by turning the collar.

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

Figure 5 Open the gas tap fully.

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

Method

1 Follow the steps shown in Figures 1–6 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

Remember and understand

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.

Apply and analyse

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.

Evaluate and create

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.

1.7 A fair test is a controlled experiment

In this topic, you will learn that:

- 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
- fair testing occurs when scientists control the variables and repeat their experiments.

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 logic and evidence, and 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.

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.

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?

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 due to changes to the independent variable

Once you ask a 'What if' question, you can predict what may happen (see Figure 2). A 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 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. This is to make it a fair test.

Fair 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 any measurements during the experiment?

IF the amount of vinegar is increased, THEN the chemical reaction will be greater.

Independent variable: the variable that is deliberately changed

Dependent variable: the variable that is tested or measured at the end

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

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?

Asking 'What if?'

Choose one of the questions on page 16 to investigate.

1 Write a 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 List the variables that you will need to control to ensure a fair test.
5 Describe how you will control these variables.
6 Test your prediction. Repeat your test at least three times to make sure your results are reliable.
7 Record your results in a table.
8 Write a summary of your results.

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.

1.7 Check your learning

Remember and understand

1 **Define** the term 'variable'.
2 **Explain** why most variables need to be controlled.
3 **Identify** the name given to something that is being tested and therefore changed on purpose.

Apply and analyse

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 **Evaluate** whether Justin conducted a fair 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.

Evaluate and create

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

1.8 Graphs and tables are used to show results

In this topic, you will learn that:

- 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 that is collected should be neatly presented in a table. 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. 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 is 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.

1.8: Heating water
Go to page **191**.

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).

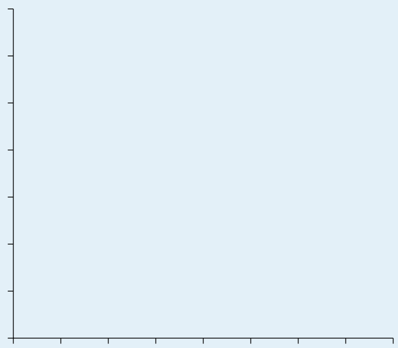


Figure 2 Drawing a set of axes

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

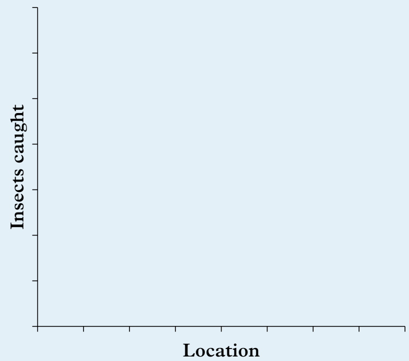


Figure 3 Labelling each axis

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.

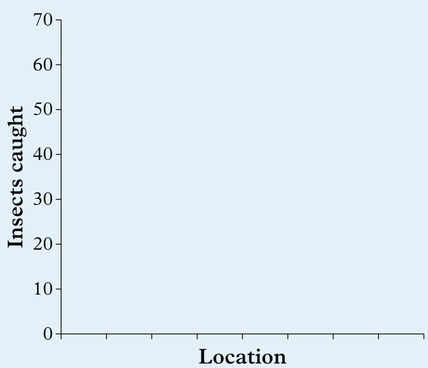


Figure 4 Adding numbers to the axes at regular intervals

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.

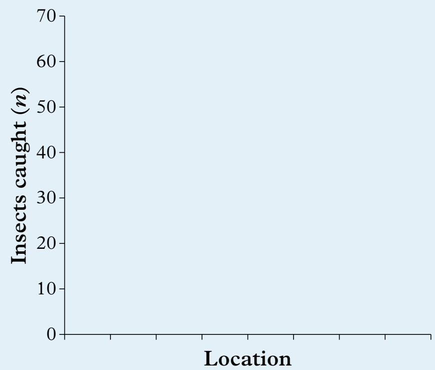


Figure 5 Adding units to the axes

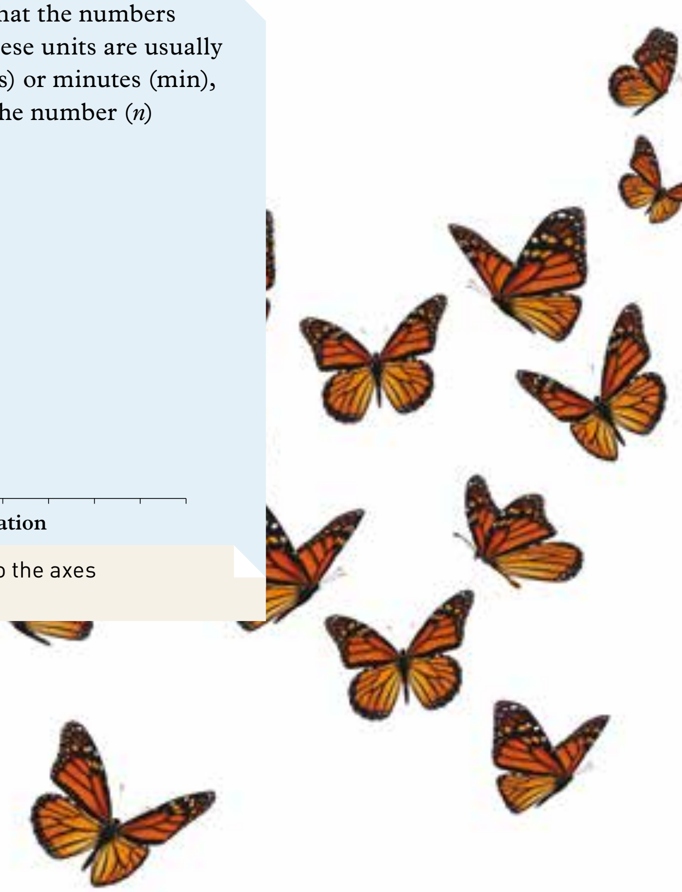


Figure 6 Make sure to keep a careful record of insects caught at different locations.

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

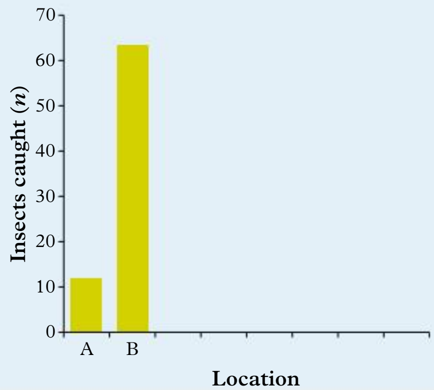


Figure 7 Plotting data on the column graph

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

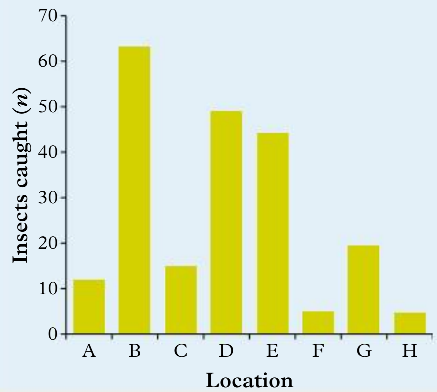


Figure 8 Finishing the column graph

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.

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 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

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.

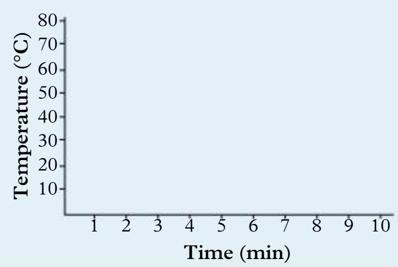


Figure 10 Adding numbers to axes at regular intervals

line of best fit
the line on a scatter graph that passes through, or nearly through, as many data points as possible

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.

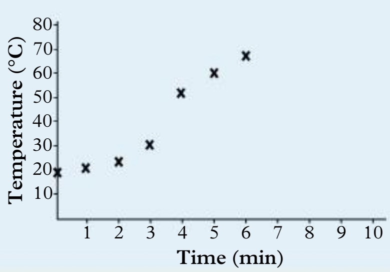


Figure 11 Potting data on the graph using small crosses

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.

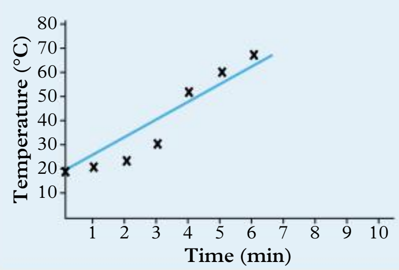


Figure 12 Drawing a line of best fit

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.

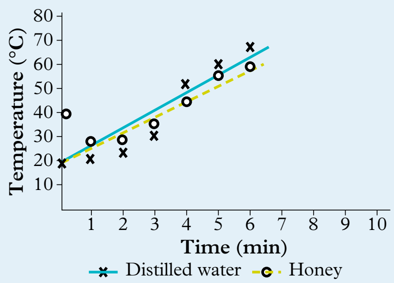


Figure 13 Using small crosses and crosses when plotting more than one set of data

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

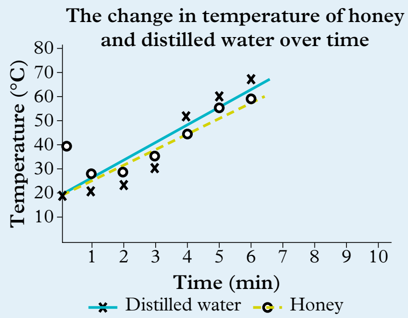


Figure 14 Writing a descriptive title for the scatter graph

1.8 Check your learning

Remember and understand

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

2 **Identify** which variable (independent or independent) 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.

Apply and analyse

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

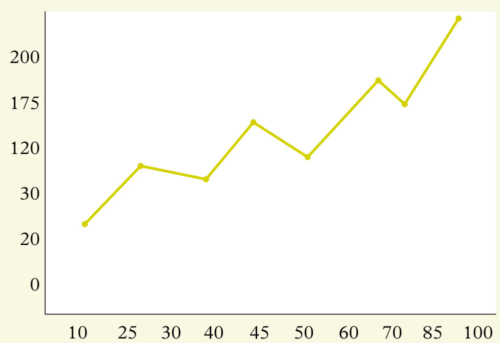


Figure 15 A graph drawn by a student

Evaluate and create

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

1.9 Scientific reports communicate findings

In this topic, you will learn that:

- 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. (Note: Not all experiments contain a hypothesis.)

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 findings, why they are important, any problems that were encountered and 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 23.

> 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

- 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.

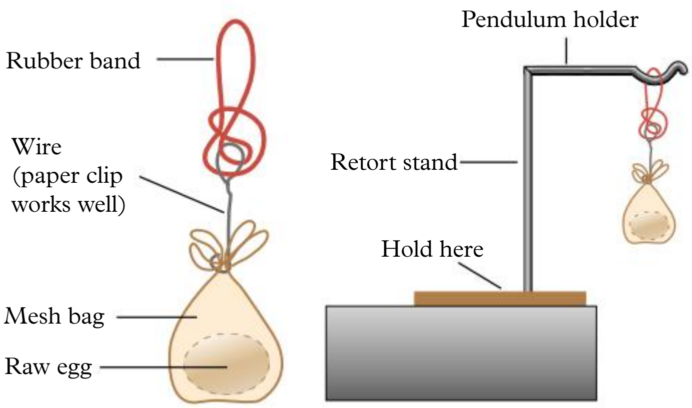


Figure 1 Connecting the rubber band around the wire loop and then hooking it over the retort stand clamp

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

This is a list of what you need.

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

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 controlled.

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

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.

1.9 Check your learning

Remember and understand

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

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

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

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

Apply and analyse

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.

//SCIENCE AS A HUMAN ENDEAVOUR//

1.10 Science skills are used to solve important problems

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.

Figure 2 A cane beetle

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

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. 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. 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.

1.10 Develop your abilities

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.

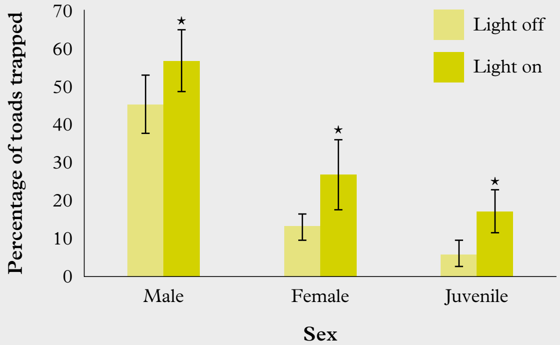


Figure 4 The percentage of male, female and young juvenile cane toads trapped with and without lights

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.

1.11 Aboriginal and Torres Strait Islander peoples use science

In this topic, you will learn that:

- Aboriginal and Torres Strait Islander peoples come from many diverse nations that have their own unique cultures and knowledge
- Aboriginal and Torres Strait Islander peoples use science skills.

Aboriginal and Torres Strait Islander cultures are one of the oldest continuous cultures in the world and have lived on this land for at least 60 000 years. Aboriginal and Torres Strait Islander 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 Aboriginal and Torres Strait Islander 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 Victoria. Language groups refer to Aboriginal and Torres Strait Islander peoples or groups who share the same language. So when you learn about the

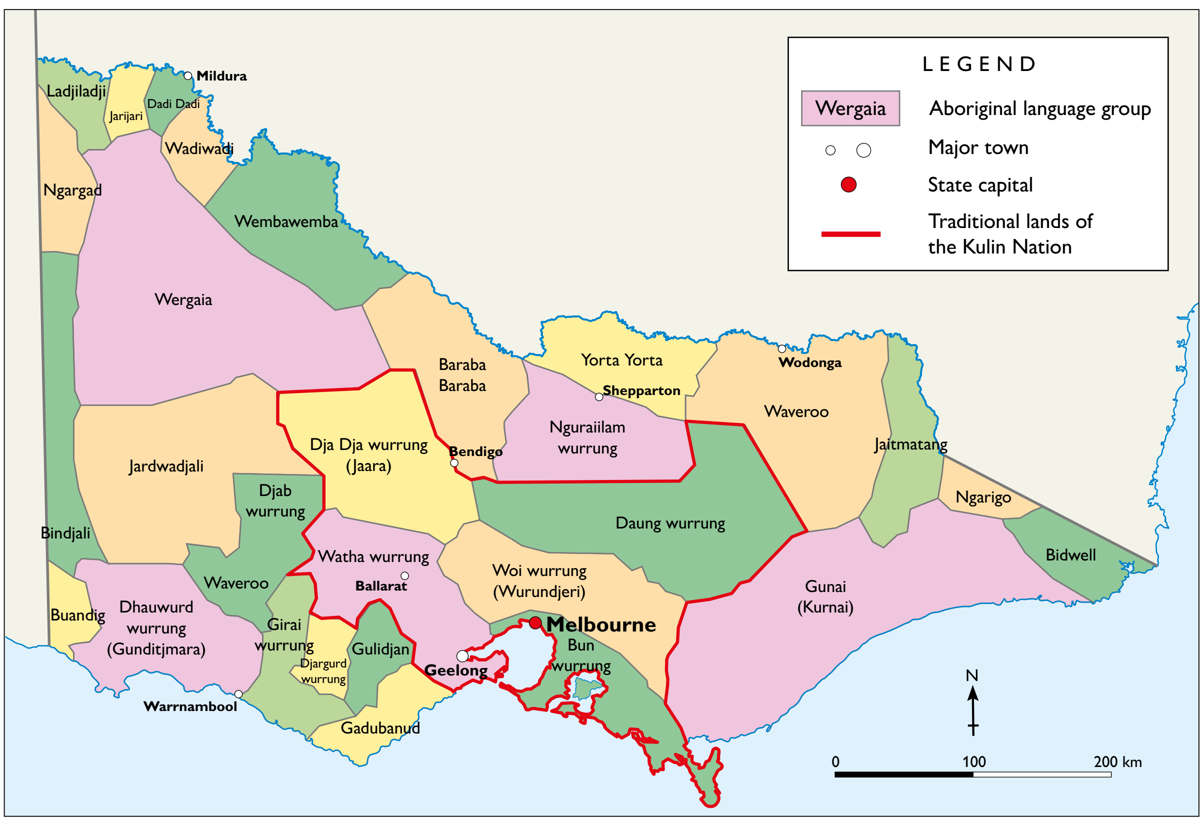


Figure 1 Aboriginal and Torres Strait Islander language groups and Nations in Victoria

Figure 2 A honeysuckle banksia

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

Melbourne is built on Kulin Nation land. The Kulin Nation is made up of five language groups: Wathaurong (Watha wurrung), Djadjawurung (Dja Dja wurrung), Taungurong (Daung wurrung), Woiworrung (Woi wurrung) and Boonwurrung (Bun wurrung).

Using science skills

The Aboriginal and Torres Strait Islander 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, the Aboriginal and Torres Strait 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. The Aboriginal and Torres Strait Islander 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, the Gunditjmara peoples in south-western Victoria used flowering honeysuckle banksia cones to filter the water from muddy pools when there was not enough drinking water available. The pollen on the flowers would also sweeten the water, which was best first thing in the morning before the birds got to the flowers. The traditional information is still being passed on from one generation to the next through stories, songs and dance.

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

1.11 Check your learning

Remember and understand

1 **Describe** why it is important to refer to Aboriginal and Torres Strait Islander peoples as 'peoples' and not 'people'.
2 **Define** the word 'observation'.
3 **Describe** one example of the Aboriginal and Torres Strait Islander peoples observing the world.
4 **Describe** one example of an experiment that the Aboriginal and Torres Strait Islander peoples may have conducted thousands of years ago.

Apply and analyse

5 **Identify** the traditional custodians of your school's land.
6 **Explain** why it is important to communicate the results of the experiment on producing clean water or plants that are safe to eat.

REVIEW 1

Multiple choice questions

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.

Short answer questions

Remember and understand

4 Draw a diagram of a:
- a conical flask
- b tripod stand
- c test tube.

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

Figure 1 Identifying safety signs

6 **Describe** a fair test.

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

8 **Define** the term **'**mass'.

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

10 **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.

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

12 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.

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

Apply and analyse

14 Make three observations and three inferences about:
- a this textbook
- b your own hand.

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

16 Draw the correct graph for 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

17 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 10) 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.

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

a What is the temperature inside a furnace?

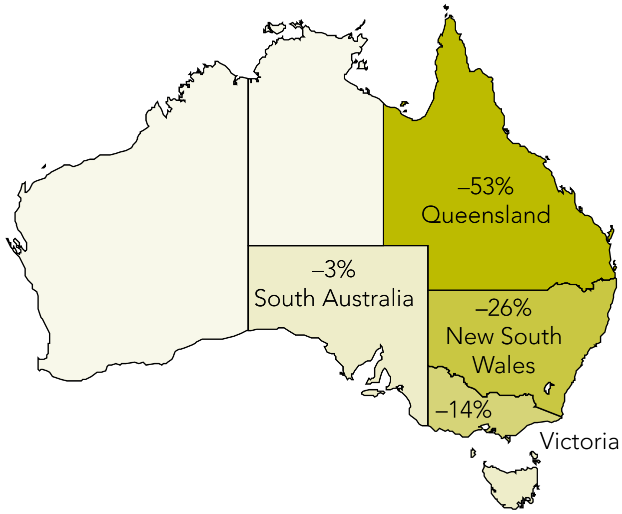
b What is the thickness of a sheet of paper?

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

Evaluate

19 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 2.

The decline of koala populations in Australia



Note: Overall population decline –24%

Source: Adams-Hoskin et al. (2016)

Figure 2 The decline of koala populations in Australia

a **Explain** 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 **Explain** why you could not use this data to determine which state has the largest koala population.

20 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 parts **a** and **b** to **determine** if astrology is a science or a pseudoscience

d write down two new things you learnt from this activity.

Social and ethical thinking

21 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. **Explain** 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

22 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 experimental 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

23 **Describe** how you would determine if you could trust the information you read on a website. **Identify** which of the following factors you will 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. Write one more question that you will ask when you read the website information.

Research

24 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

What big questions do you want to explore about a notable Australian scientist? You could consider Frank Macfarlane Burnet, Douglas Mawson, Gustav Nossal, Mark Oliphant, Helen Caldicott, Nancy Millis, William McBride, Struan Sutherland or Suzanne Corey.

» Depending on variables

Variables are sometimes described as 'controlled' instead of 'dependent' and 'experimental' instead of 'independent'. How are these terms similar? How are they different? When would each be used?

Reflect

The table below outlines a list of things you should be able to do by the end of Chapter 1 'Science Toolkit'. Once you've completed the chapter, use the table to reflect on your ability to complete each task.

	I can do this.	I cannot do this yet.
Understand the nature of science. Describe where and how scientific investigations can occur.	☐	☐ Go back to Topic 1.1 'Science is the study of the natural and physical world'. Page 2
Describe a variety of different pieces of specialised science equipment.	☐	☐ Go back to Topic 1.2 'Scientists use specialised equipment'. Page 4
Describe safe practices within the laboratory.	☐	☐ Go back to Topic 1.3 'Scientists take safety precautions'. Page 6
Define observation and inference as scientific terms. Explain the difference between qualitative and quantitative data.	☐	☐ Go back to Topic 1.4 'Scientists use observation and inference to answer questions'. Page 8
Understand and explain how to accurately measure data using a variety of different pieces of equipment.	☐	☐ Go back to Topic 1.5 'Science relies on measuring with accuracy'. Page 10
Use a Bunsen burner safely and accurately.	☐	☐ Go back to Topic 1.6 A 'Bunsen burner is an essential piece of laboratory equipment'. Page 14
Explain the term 'variable' and understand the difference between dependent and independent variables. Describe how repetition increases the reliability of results.	☐	☐ Go back to Topic 1.7 'A fair test is a controlled experiment'. Page 16
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'. Page 18
Construct a scientific report using the sections appropriately and writing in the third person.	☐	☐ Go back to Topic 1.9 'Scientific reports communicate findings'. Page 22
Consider how the scientists plan, conduct and communicate their investigative strategies and conclusions.	☐	☐ Go back to Topic 1.10 'Science as a human endeavour: Science skills are used to solve important problems'. Page 24
Describe how Aboriginal and Torres Strait Islander peoples use science skills in their own unique cultures.	☐	☐ Go back to Topic 1.11 'Aboriginal and Torres Strait Islander Peoples use science'. Page 26

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CHAPTER 2

PARTICLE MODEL

What is matter?

2.1 There are three states of matter

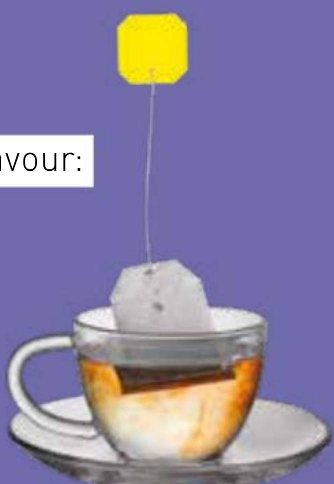
2.2 Scientists' understanding of matter has developed over thousands of years

2.3 The particle model explains matter

2.4 The particle model can explain the properties of matter

2.5 Increasing kinetic energy in matter causes it to expand

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



What if?

CAUTION: Do not eat in the laboratory.

M&M's

What you need:

M&M's (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

In this topic, you will learn that:

- 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

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

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 3 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.

Figure 1 Is jelly a solid, a liquid or a gas?

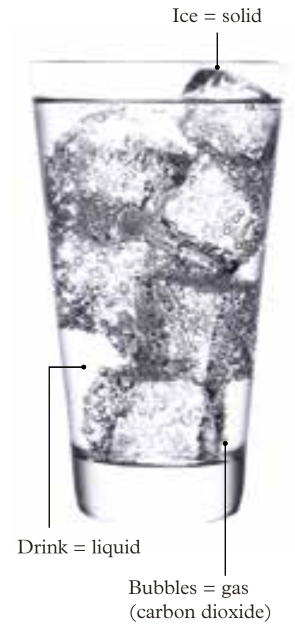


Figure 2 A glass of iced water contains the three states of matter.

Figure 3 Solid water (ice) floats on liquid water.

EXPERIMENT

2.1A: Comparing states of matter
Go to page **192**.

CHALLENGE

2.1B: Three states of water
Go to page **193**.

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

Figure 4 Honeycomb is a combination of solid and gas. Or is it?

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 5 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 6 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 7 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

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

condensation
the cooling down of gas into a liquid

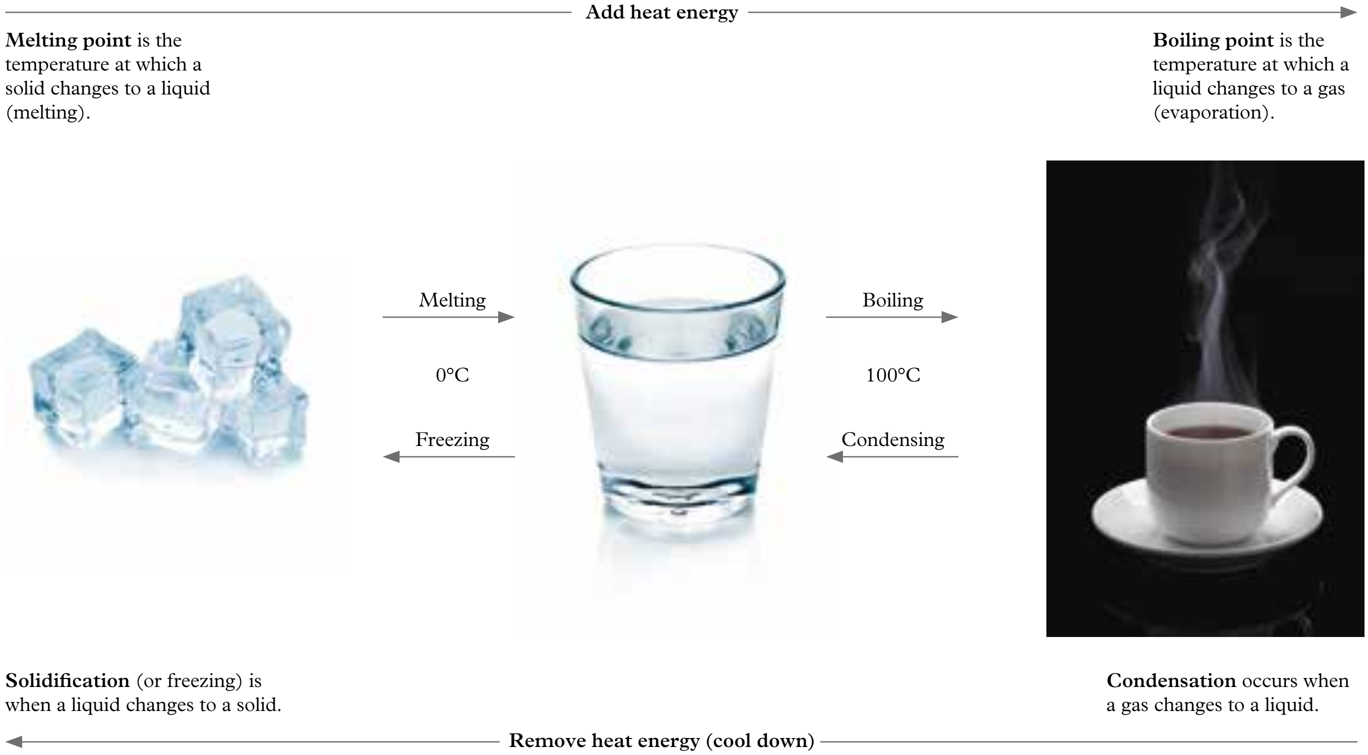


Figure 8 Adding or removing heat energy can change the state of water.

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

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.

Figure 9 Kettles boil water.

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, density and how much heat it can store (heat capacity). See Table 1 for an example.

2 **Chemical properties** are what a substance does in a chemical reaction. Examples include bubbling, permanent colour change and permanent change of state.

Table 1 Properties of water

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

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

Remember and understand

1 Group 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

2 **Describe** what happens to water when it:

- **a** evaporates
- **b** condenses
- **c** freezes.

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

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

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

Apply and analyse

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

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

8 **Identify** the:

- **a** melting point of water
- **b** boiling point of water.

9 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

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

Evaluate and create

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

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

In this topic, you will learn that:

- 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.

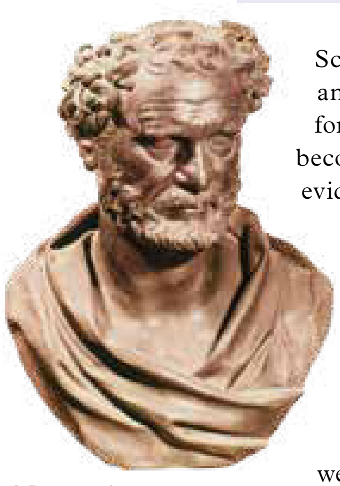


Figure 1 Democritus proposed that all matter is made of atoms.

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

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

atom
the smallest particle of matter

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

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

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**.

Democritus

Over 2400 years ago, Democritus (c. 460–370 BCE), 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**.

John Dalton

It was not until more than 2000 years later, in the early 1800s, that Englishman John Dalton (1766–1844) 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.

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

> All atoms of the same **element** are identical, but they 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.

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**.

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.

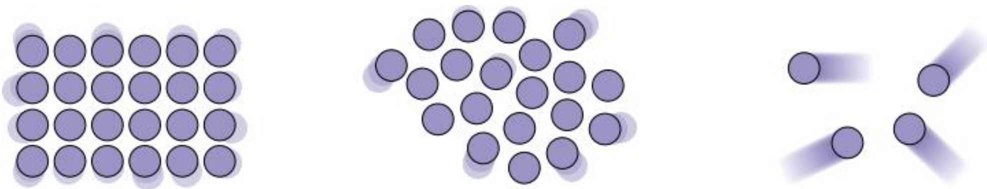


Figure 3 The particle model explains the differences between solids, liquids and gases.

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.

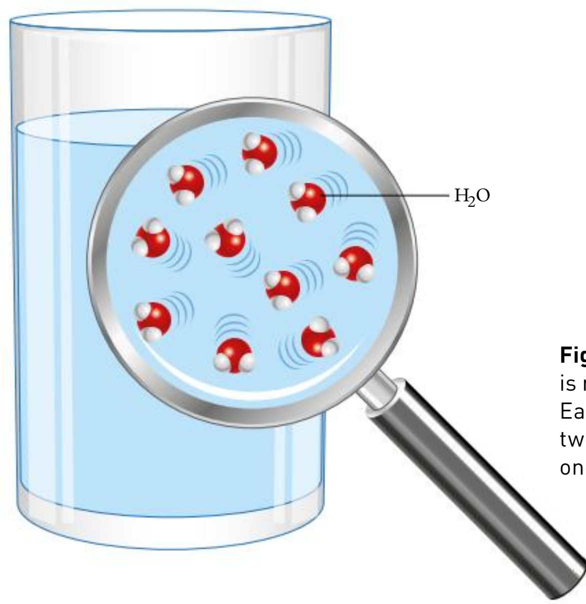


Figure 4 A glass of water is made of molecules. Each molecule contains two hydrogen atoms and one oxygen atom.

2.2 Check your learning

Remember and understand

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

2 Draw a table with two columns to **summarise** the ideas of Democritus and Dalton. Add Democritus's ideas in one column and Dalton's ideas in the other column.

Apply and 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 each other

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

2.3 The particle model explains matter

In this topic, you will learn that:

- 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.

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

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.

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.

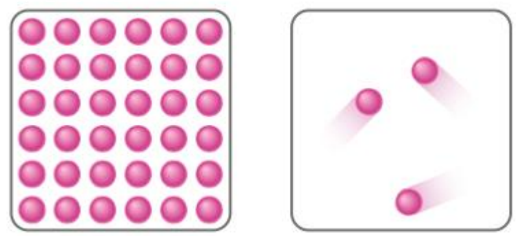


Figure 2 A container of a solid has more particles than the same container of gas.

A particular volume of solid or liquid has a greater mass than the same volume of gas because it has more particles in it. 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.

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.

CHALLENGE
2.3A: Modelling matter
Go to page 193.

CHALLENGE
2.3B: Making a cuppa
Go to page 193.

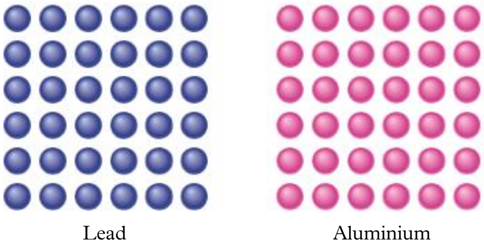


Figure 3 Lead atoms have a greater mass than aluminium atoms.

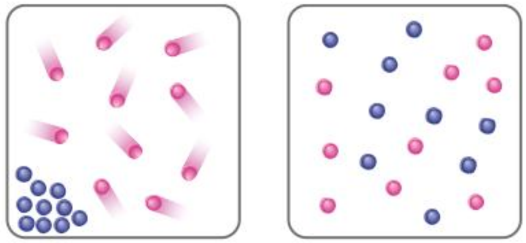


Figure 4 Before (left) and after (right) diffusion in a gas

Diffusion

When the lid is taken off a bottle of perfume, the smell of the perfume spreads throughout the room. 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. 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 5 Perfume diffuses when its bottle is open.

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.

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.

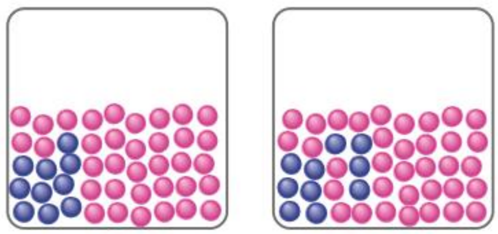


Figure 6 Diffusion is slow in liquids.

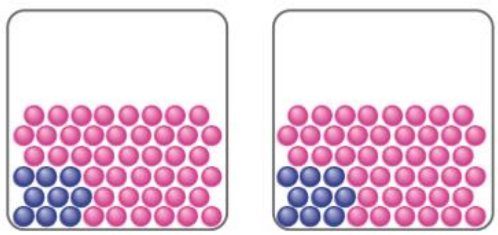


Figure 7 Solids do not diffuse.

Figure 8 Tea diffuses in hot water.

2.3 Check your learning

Remember and understand

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

2 From highest to lowest, rank (place in order from most to least) the states solid, liquid and gas in order of energy content.

3 **Define** the term 'mass'.

Apply and analyse

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 lump of lead will have a greater mass than a lump of wood.

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

a liquids

b gases.

2.4 The particle model can explain the properties of matter

Video 2.4
Calculating density

In this topic, you will learn that:

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

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

hardness
how easily a mineral can be scratched

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

compressibility
the extent to which a substance can be compressed (squashed)

incompressible
unable to be compressed; solids and liquids are incompressible

density
a measure of mass per unit of volume

Strength

The idea of strength can be considered in different ways. A rubber band is easily stretched, but what about a piece of wire? Different wires made of different metals will break if stretched. Tensile strength is a measure of the flexibility of the links or bonds between the particles. The bonds between the particles in steel are stronger than those between 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. 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.

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. Engine oils used in engines have different viscosities.

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. 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 are 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.

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

EXPERIMENT
2.4: The density den
Go to page **194**.

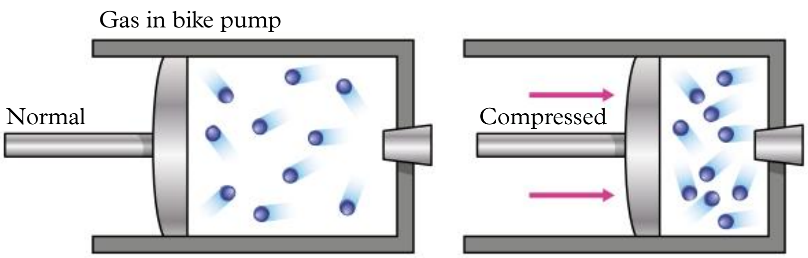


Figure 2 Compression reduces the space between particles.

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, in Figure 3, a piece of cork is floating on water. This is because the water has a higher density than the cork. On the other hand, there are coins that have sunk to the bottom of the water. This is because the coins have a higher density than the water.

Figure 3 Cork floats on water because it has a lower density than water.

One litre 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

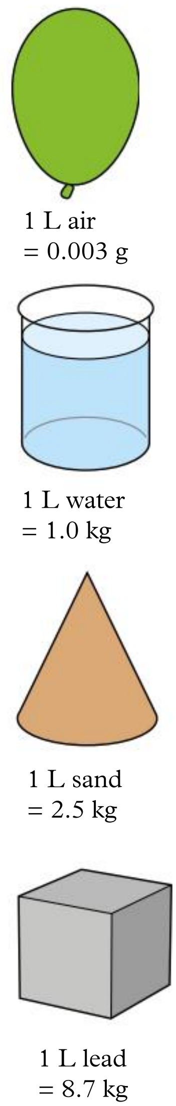


Figure 4 Density compares the mass of objects of the same volume.

2.4 Check your learning

Remember and understand

1 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

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

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

Apply and analyse

4 Rank (place the terms from least to most) the following in order of compressibility: solid, liquid, gas.

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).

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.

2.5 Increasing kinetic energy in matter causes it to expand

In this topic, you will learn that:

- 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.

Figure 1 Vaporisation explains steam rising from soup.

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.

Figure 2 Solidification occurs when a substance cools.

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.

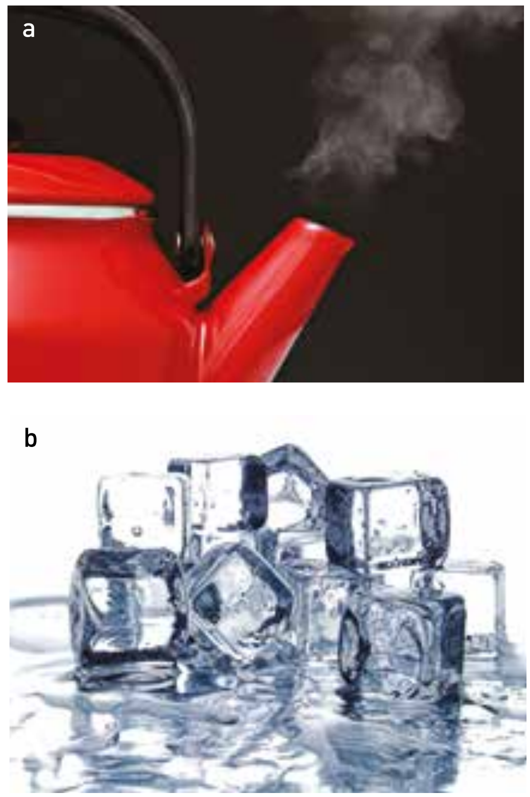


Figure 3 a The boiling point of water; **b** the melting point of ice

Figure 4 Diffusion occurs faster in hot water (right beaker) than in cold water (left beaker).

EXPERIMENT
2.5A: Effect of heat
Go to page **196**.

EXPERIMENT
2.5B: From ice to steam
Go to page **198**.

Heat causes expansion

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

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 5 An expansion joint in a suspension bridge

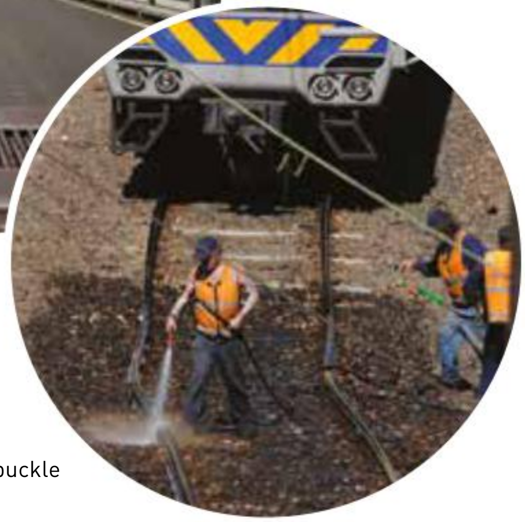
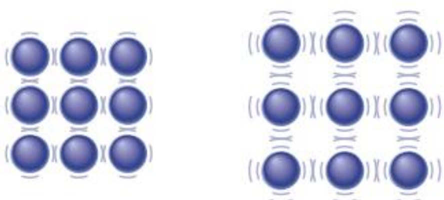
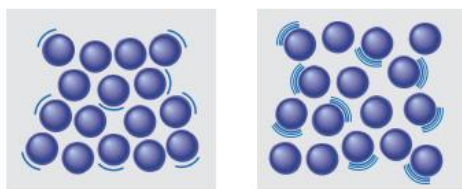


Figure 6 Train tracks would buckle in the heat without tiny gaps between them.



Cold Hot

Figure 7 In a hot solid, the particles vibrate harder, faster and wider than in a cold solid.



Cold water Hot water

Figure 8 In a hot liquid, the particles jostle around faster and take up more space than in a cold liquid.

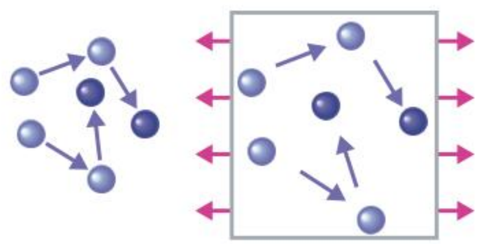


Figure 9 In a hot gas, the particles move faster, and collide with one another harder, than in a cold gas.

2.5 Check your learning

Remember and understand

1 Draw a diagram similar to that shown in Figure 10. Add labels to **identify** the energy changes between states.

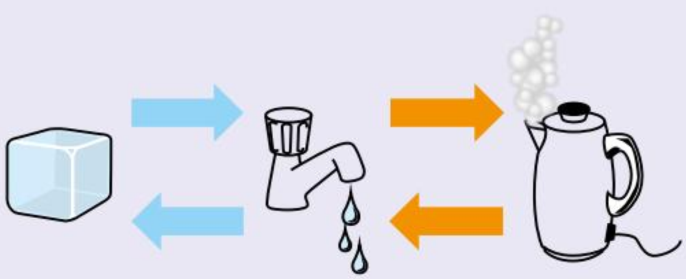


Figure 10 Energy changes between states

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.

Apply and analyse

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

5 **Explain** 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.

6 When a solid is heated, it expands. **Explain** why the increase in size is not caused by more particles (atoms) being added.

2.6 Scientists find ways to communicate

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.

Scientific models

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 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. 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.

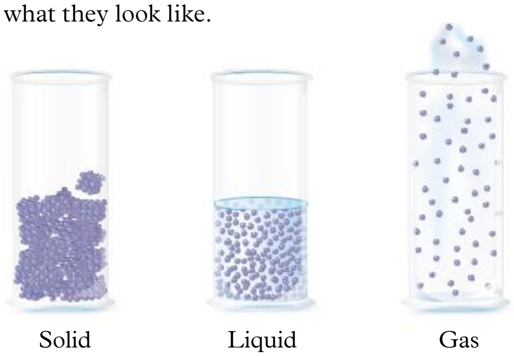


Figure 1 The particle model helps us to understand different states of matter, even though we cannot observe particles.

Figure 2 Scientific posters include a short summary of an experiment's hypothesis, method, results, discussion and conclusion.

Scientific posters

Before a scientist writes a paper for a scientific journal, they will often present it to other scientists as a poster. 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.

Scientific papers

Many scientists use formally written scientific reports (called 'papers') to describe how they did the research and the data they measured, and to explain how it affects the world around them. These papers 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.

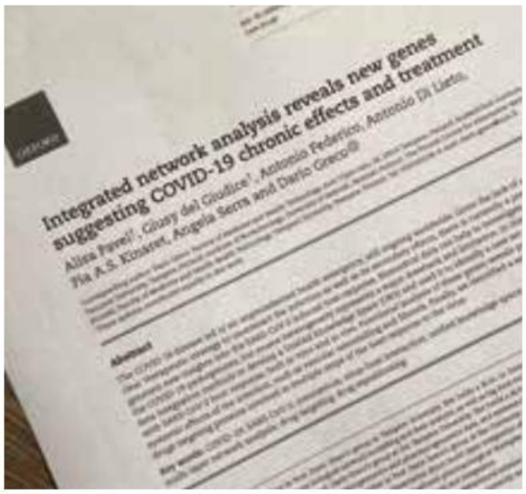


Figure 3 Scientific papers are reports published to share ideas or findings with other scientists.

Conferences

Scientists often share their research with other scientists by speaking at conferences around the world. 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. The chance to share ideas and to see their research from another person's perspective can cause good ideas to become great ideas. Every level of scientist attends these conferences – from world-famous 'celebrity' scientists to professors, researchers and even students. They are a great place to meet inspiring people and to learn.

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 advances in renewable energy. This means that scientists need to be able to share their ideas with non-scientists through newspapers, magazines, television or social media (online blogs, YouTube and Twitter).

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 Develop your abilities

Identifying your audience

Before a scientist can communicate effectively, they need to answer a few questions. Select one of the experiments you have completed in the last few weeks and prepare a way to communicate it to an audience.

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.

REVIEW 2

Multiple choice questions

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

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

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

Short answer questions

Remember and understand

4 **Define** the term 'volume'.

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

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

7 Select 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

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

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

10 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.

11 **Describe** where the word 'atom' came from.

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

13 **Contrast** (the differences between) mass and matter.

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

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

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

17 **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?

Apply and analyse

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

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

20 **Contrast** (the differences between) solidification and freezing.

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

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

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

Figure 4 The metal train tracks buckle on hot days.

24 Use Table 1 to decide which of the following items would have a greater density.

- **a** 1 L of water or 1 L of oil
- **b** a gold necklace or a crystal necklace
- **c** 10 planks of wood or 10 steel bars (assume they are all equal in size)

Table 1 Density of various substances

Substance	Density (g/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

Evaluate

25 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** Suggest 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.

26 **Explain** the following observations of solids, liquids and gases by describing the arrangement and/or the movement of particles within the substance. Use 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.

27 Design 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

28 Science is communicated in many different ways, including scientific journals and posters, television reports, newspapers and social media, such 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).

29 Democritus identified that all substances were made of tiny particles called *atomos*, while Dalton suggested how these particles were combined and how they moved. Prepare an argument to support the particle theory of matter being called either the Democritus Model or the Dalton Model.

Critical and creative thinking

30 The kinetic theory of matter is supported by data from many different experiments completed by many different scientists across multiple countries. **Explain** why a single experiment carried out by a single scientist is not a theory.

31 **Explain** how Democritus's ideas of an atom were expanded by Dalton to produce the current particle model of atoms.

Research

32 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.

» State of the matter

The changes between the states of matter have many uses. Research some of these uses and their impact on our society. Some ideas are how refrigeration and air conditioning work; making moulds and casts, such as chocolate, iron and aluminium castings; obtaining medical-grade oxygen and nitrogen from the air; and how the energy changes that occur during evaporation of water and the subsequent condensation of water vapour into rain affect thunderstorms and cyclones.

» 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. 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.

Reflect

The table below outlines a list of things you should be able to do by the end of Chapter 2 'Particle Model'. Once you have completed this chapter, use the table to reflect on your ability to complete each task.

	I can do this.	I cannot do this yet.
Describe the three states of matter and identify processes that change substances from one state to another (evaporation, condensation, freezing and melting).	☐	☐ Go back to Topic 2.1 'There are three states of matter'. Page 32
Describe how our understanding of matter has changed over time. 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'. Page 36
Define the particle theory of matter and diffusion. Explain how kinetic energy effects particle movement.	☐	☐ Go back to Topic 2.3 'The particle model explains matter'. Page 38
Define 'tensile strength', 'hardness', 'viscosity', 'compressibility' and 'density'. Explain these properties in terms of the particle model.	☐	☐ Go back to Topic 2.4 'The particle model can explain the properties of matter'. Page 40
Describe what happens to particles when they are heated. Explain how heat can cause expansion.	☐	☐ Go back to Topic 2.5 'Increasing kinetic energy in matter causes it to expand'. Page 42
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'. Page 44

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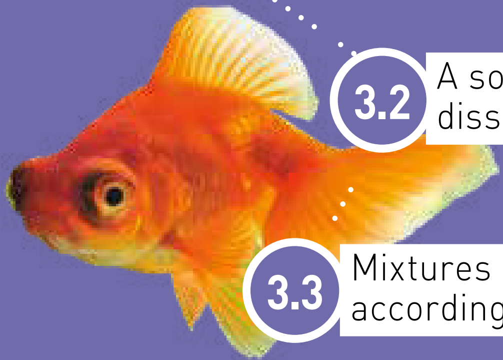
CHAPTER 3

MIXTURES

How can we make water safe to drink?

3.1 Mixtures are a combination of two or more substances



3.2 A solution is a solute dissolved in a solvent

3.3 Mixtures can be separated according to their properties

3.4 Mixtures can be separated according to their size and mass

3.5 The boiling points of liquids can be used to separate mixtures

3.6 Solubility can be used to separate mixtures

3.7 Science as a human endeavour: Wastewater is a mixture that can be separated

3.8 Science as a human endeavour: Materials recovery facilities separate mixtures

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

In this topic, you will learn that:

- 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.

Interactive 3.1A
Elements, compounds and mixtures

Interactive 3.1B
Is it pure?

emulsion
a type of colloid in which two or more liquids are mixed together, with one suspended in the other as tiny droplets

mixture
a substance made up of two or more pure substances mixed together

solution
a mixture of a solute dissolved in a solvent

suspension
a cloudy liquid containing insoluble particles

pure substance
something that contains only one type of substance (e.g. a single element or a single compound)

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

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. Sea water is a mixture of different 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**.

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. 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. 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 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?

CHALLENGE
3.1: Comparing different types of mixtures
Go to page 199.

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.

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.

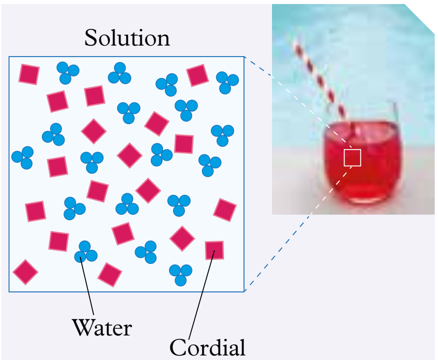


Figure 2 This glass of cordial is an example of a solution. The small cordial particles are dissolved evenly throughout the water.

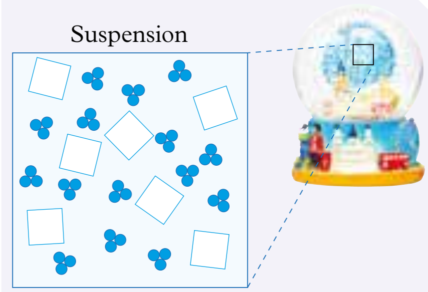


Figure 3 A snow dome can be described as a suspension, with the larger 'snow' particles being suspended in the water for a short time before they fall to the bottom of the dome to form a sediment.

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

Remember and understand

1 **Define** the term 'pure substance'.

Apply and analyse

2 **Compare** (the similarities and differences between) a pure substance and a mixture.

3 **Contrast** (the differences between) the type of substances found in sea water and pure water.

4 **Identify** the following substances as pure substances or a mixture.
- a cup of tea
- b soft drink
- c table salt
- d soap
- e olive oil

5 For the mixtures in question 4, identify the different types of particles you think they might contain.

Evaluate and create

6 **Identify** the type of mixture(s) that would form a sediment.

7 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				

3.2 A solution is a solute dissolved in a solvent

In this topic, you will learn that:

- a solvent can be used to dissolve a soluble solute
- a dilute solution has very little solute in the solvent
- the more solute (sugar) that is dissolved in the solvent (water), the more concentrated the solution
- a solution is saturated when no more solute will 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

soluble
can be dissolved in a liquid

solute
a substance that dissolves in a liquid (solvent)

solvent
a liquid in which other substances 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.

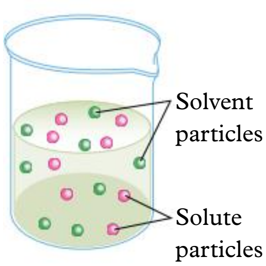


Figure 1 A solute dissolves in a solvent to create a solution.

Working with solutions

You have seen that a solution is a solute dissolved in a solvent. 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).

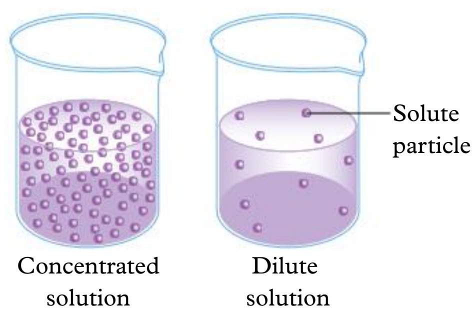


Figure 3 A concentrated solution contains more solute particles in a given volume than a dilute solution.

Figure 2 The concentration of salt in the Dead Sea is so high that when people try to swim in it, they float instead!

EXPERIMENT
3.2A: What if salt was dissolved in water?
Go to page **201**.

EXPERIMENT
3.2B: What if the solvent was heated when making a mixture?
Go to page **202**.

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.

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

Remember and understand

1 **Define** the following 's' words used in this section: solute, solvent, solution, soluble and saturated.
2 If someone asked for a dilute glass of cordial, would you add a lot of cordial or only a little?
3 **Describe** how you could increase the amount of a solute that will dissolve in a solvent.
4 True or false? You can see the particles of a solute in a solution.

Apply and analyse

5 **Explain** why water cannot be a solute for all substances.
6 **Explain** what happens to the sugar particles when they dissolve in water.

Evaluate and create

7 **Compare** the solubility of particles in suspensions, colloids, emulsions and solutions.

3.3 Mixtures can be separated according to their properties

In this topic, you will learn that:

- 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.

Video 3.3 Separation techniques

Figure 1 Different separations need different techniques.

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

Simple separation

Some mixtures are quite simple to separate. Sometimes we can simply pick out the bits we need to separate. A bag of mixed lollies may contain a few of your favourites. You could easily use your fingers to pick these lollies out so that you could eat them first. This works well if it is a small bag and you can see the individual lollies. But what if the bag contained hundreds of lollies that were too small to see? You may need another way of separating out your favourites.

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.

Figure 2 Magnets are used to separate metals in recycling plants.

Tin cans are magnetic, whereas aluminium cans are not. Sometimes large magnets are used to separate tin cans in the rubbish from aluminium cans. This means both types of cans can be recycled in different ways.

Figure 3 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 sediment from wine.

The objects or liquids that sink are denser than the liquid on the top. The particles in dense objects are packed together more tightly than 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.

SKILLS LAB **3.3A:** Separation using magnetic properties Go to page **203**.

SKILLS LAB **3.3B:** Separating mixtures using sedimentation and flotation Go to page **203**.

EXPERIMENT **3.3C:** What if a flocculant was added to muddy water? Go to page **204**.

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. 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. 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.

Aboriginal and Torres Strait Islander 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.

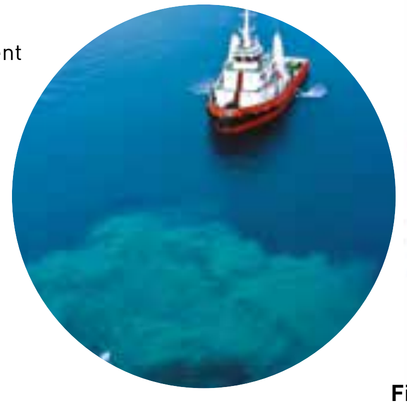


Figure 5 Oil floats on the surface of water.

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

Figure 6 Decanting wine separates the undrinkable sediment.

3.3 Check your learning

Remember and understand

1. **Define** the following words.
   a. sediment
   b. flocculation
   c. decant
   d. density
2. **Describe** the property that allows the separation of tin cans from aluminium cans.

Apply and analyse

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.

Evaluate and create

6. **Describe** a situation where magnetism cannot be used to separate a mixture. **Explain** how the properties of the materials cause this problem.

3.4 Mixtures can be separated according to their size and mass

In this topic, you will learn that:

- large particles (residue) can be separated from liquids (filtrate) by filtering
- heavy particles can be separated from light particles by using a centrifuge.

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

centrifuging
a technique used to separate light and heavy particles by rapidly spinning the mixture

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 lets through small things but traps 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.

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. 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. 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.

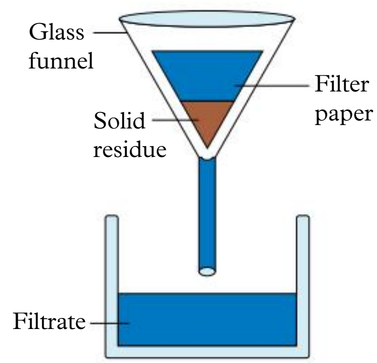


Figure 3 Filters are used in science to separate substances. Particles that pass through the filter are called the filtrate. The filter paper traps the residue.

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.

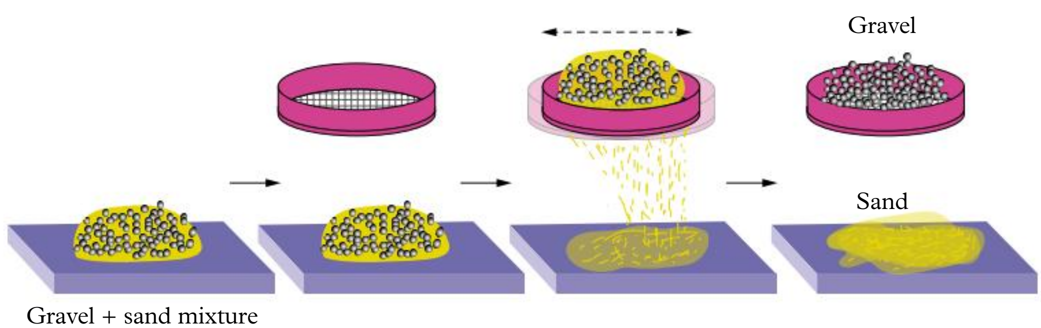


Figure 2 Sieves can be used to separate solids of different sizes, such as gravel and sand.

SKILLS LAB
3.4A: Filtering a mixture of sand and water
Go to page **205**.

EXPERIMENT
3.4B: What if you centrifuge tomato sauce?
Go to page **206**.

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 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. 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 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).

Figure 5 A spinning washing machine is a centrifuge, separating water from the clothes.

Figure 7 A butterfly net separates the large butterfly from other butterflies.

3.4 Check your learning

Remember and understand

1 **Describe** the filters used around your home and school. Identify the substances that these filters allow to pass through them and the substances they collect.

2 Complete the sentences below by filling in the missing words.

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 ____________.

3 List two places where centrifuges are used.

Apply and analyse

4 **Contrast** (the differences between) each of the following pairs.

a mixture – pure substance

b sedimentation – flotation

c residue – filtrate

5 **Explain** 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.

Evaluate and create

6 **Explain** why a butterfly net is an example of a filter. (HINT: Compare how a filter works with how the net works.)

3.5 The boiling points of liquids can be used to separate mixtures

In this topic, you will learn that:

- 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.

distillation
a technique that uses evaporation and condensation to separate a solid from the solvent in which it has dissolved

Figure 1 Water will evaporate from a mixture of salt and water, leaving behind salt crystals.

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

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

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 evaporates at a different temperature. 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. This process of evaporating the solvent (the water) and leaving behind the solute (salt) is called **crystallisation**.

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. 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 **206**.

CHALLENGE

3.5B: Design a way to purify water from sea water
Go to page **207**.

The crude oil that is removed from the earth is a mixture of different liquids that all have different boiling points. When the crude oil is heated, petrol is one of the first substances to evaporate. The petrol gas rises up the column until it cools and condenses. The liquid petrol is then collected on one of the trays in the column. The oil used in heating has a higher boiling point. It evaporates more slowly and condenses quicker. It is collected on a tray lower in the column.

Figure 4 Crude oil can be separated into different fuels because each boils at a different temperature.

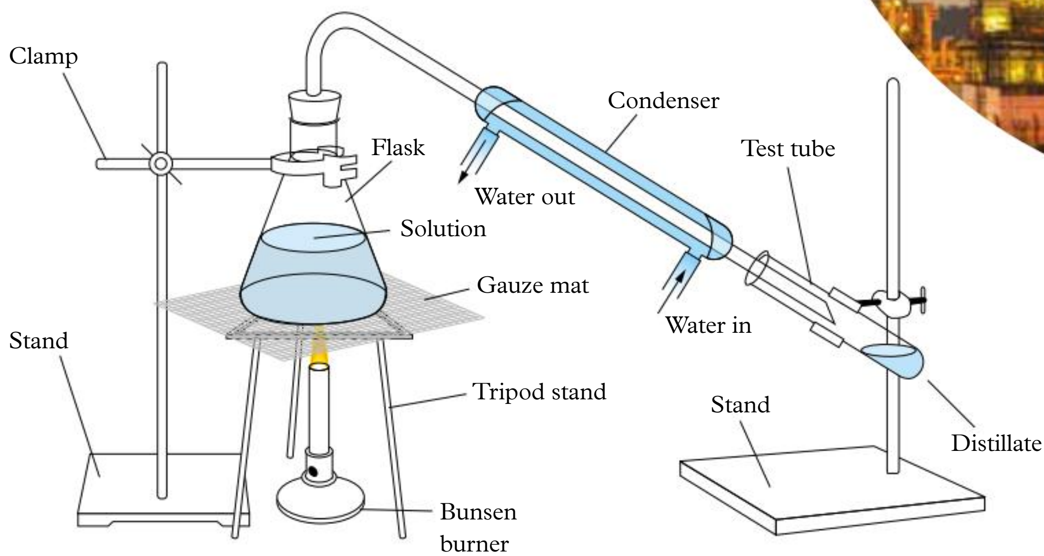


Figure 3 Equipment set-up for distillation

3.5 Check your learning

Remember and understand

1 **Explain** the difference between evaporation and crystallisation.

Apply and analyse

2 **Identify** an example of a mixture that could be separated by evaporation and crystallisation. **Explain** why distillation may not be appropriate.

3 **Identify** the separation technique that is being conducted in Figure 5.

4 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.)

Evaluate and create

5 Draw the equipment set-up that could be used to produce pure water from sea water by distillation.

6 Draw how you would answer question 5 without using the science equipment found in a laboratory.

Figure 5 Conducting a separation technique

3.6 Solubility can be used to separate mixtures

In this topic, you will learn that:

- 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

chromatography
a technique used to separate substances according to their differing solubilities

solubility
how easily a substance dissolves in a solvent

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. 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 the absorbent paper is dipped in water, allowing the water to slowly move up the paper. As the water moves past the dye mixture, the most soluble dye dissolves 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. 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.

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 **208**.

EXPERIMENT

3.6B: Who wrote the nasty note?
Go to page **209**.

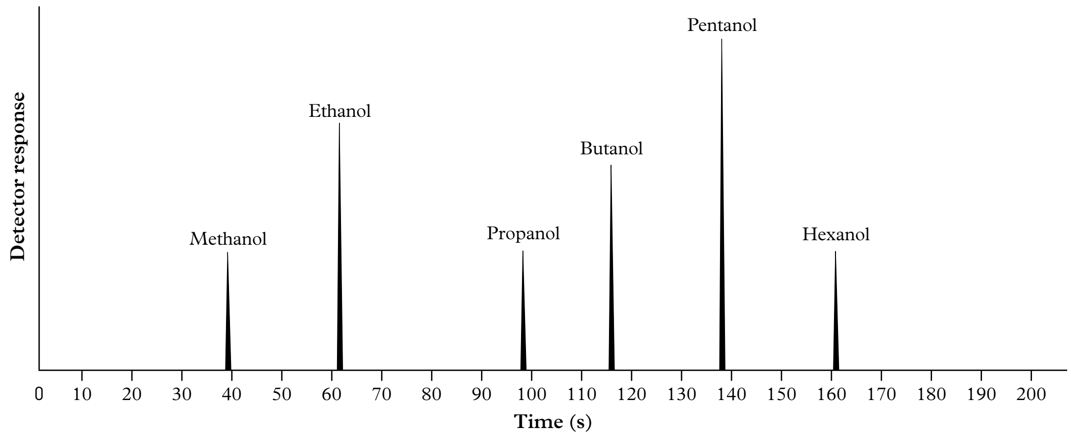


Figure 3 A gas chromatogram obtained from performing chromatography shows what is in an alcohol mixture. The higher the peak, the more a substance is present.

Scientists use chromatography to find out what substances are in a mixture. Chromatography works because different substances move through the chromatography equipment at different times, and produces 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. 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

Remember and understand

1 **Identify** the substances that were used to make the first inks.

2 **Explain** how chromatography can be used to separate inks and dyes.

3 **Describe** an example of chromatography being used in real life to separate a substance.

4 **Identify** the solvent that is used in the chromatography for drugs at airports.

5 **Define** the term 'solubility'.

Apply and analyse

6 Some people think they can disguise drugs at airports by putting them in a strong-smelling substance, such as coffee beans. **Explain** why this will not work with airport security that uses chromatography.

Figure 5 Strong-smelling coffee beans

//SCIENCE AS A HUMAN ENDEAVOUR//

3.7 Wastewater is a mixture that can be separated

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.

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. 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. 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

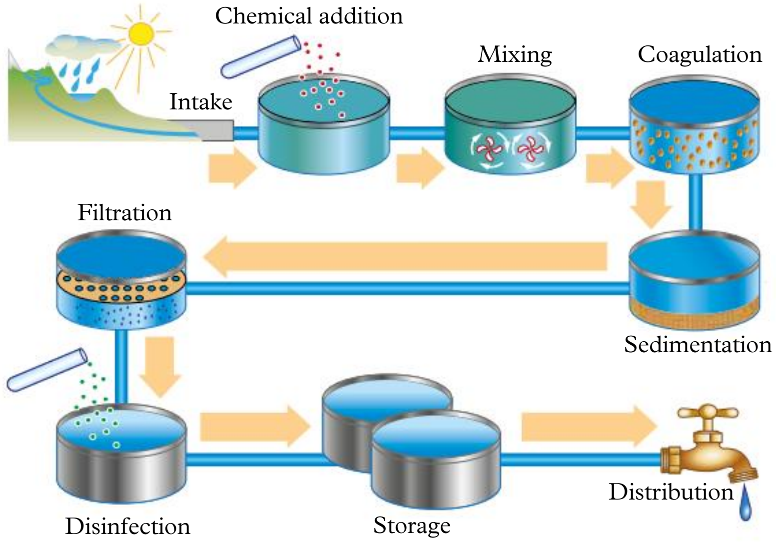


Figure 5 Summary of the water treatment process

3.7 Develop your abilities

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 is shown in Figure 6.

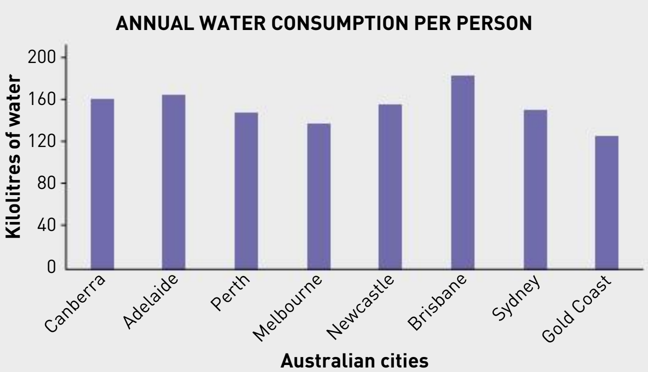


Figure 6 Annual water consumption per person

  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 uses more water than a person living in Melbourne.

2 Target 155 is a program started by the Victorian Government to encourage every person in Victoria to limit their water consumption to 155 L per person per day. In the last three years the average person used 162 L per person per day.

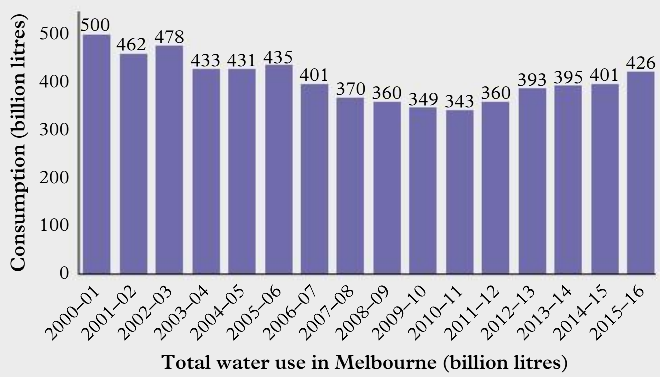


Figure 7 Total water use in Melbourne

  a Use Figure 7 to **identify** the year that Melbourne used the most water.
  b **Identify** the year that Melbourne used the least water.
  c **Identify** in which year Melbourne would have had the highest rainfall. **Explain** how you reached this conclusion.
  d The number of people (population) of Melbourne has continued to increase for each of the years shown on the graph in Figure 7. Use this information to **explain** whether Melbournians have become more or less efficient with their water usage between 2013 and 2016.

3 The more water that is used by people living in Melbourne, the greater the amount of sewage that needs to be treated. Design 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 2.)

//SCIENCE AS A HUMAN ENDEAVOUR//

3.8 Materials recovery facilities separate mixtures

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.

Figure 1 A materials recovery facility

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. 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.

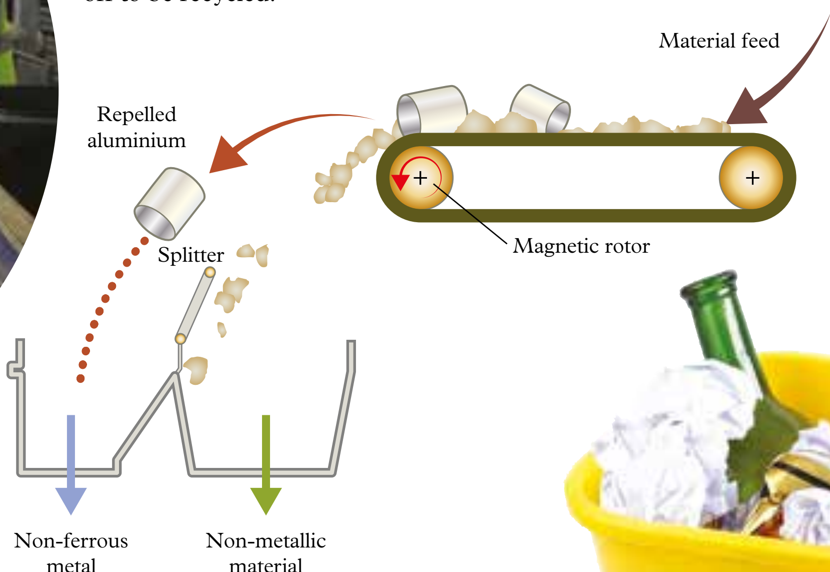


Figure 2 How an eddy current separator works

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 Develop your abilities

Discussing ethical issues

Ethics is the study of making decisions based on what is right and what is wrong. Each person will often make different ethical decisions based on what they consider is ethically the right thing to do. For example, many people think throwing rubbish away to be buried in a landfill site is wrong.

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. **Decide** 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 the decisions made in questions 2 and 5.

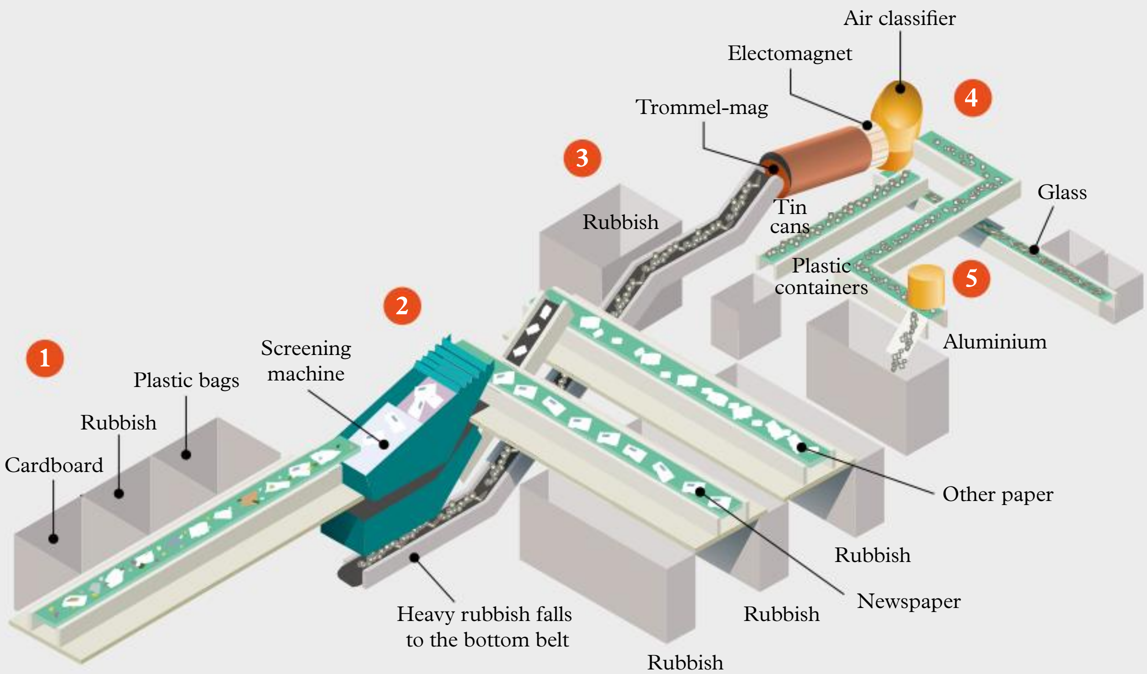


Figure 5 An illustration of a materials recovery facility

Figure 3 Household recyclables

REVIEW 3

Multiple choice questions

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

Short answer questions

Remember and understand

4 **Examine** Figure 1 and identify the suspension, the solution and the colloid.

Figure 1 Identifying mixtures

5 **Contrast** evaporation and distillation.

6 a **Identify** 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.

7 **Describe** an example of a mixture that could be separated into its parts by filtration.

8 List two safety recommendations that you would give to someone using evaporation and crystallisation.

9 Imagine dropping salt in sawdust. **Explain** how you would separate the parts of this mixture.

10 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.

11 **Identify** the property used to separate substances through centrifuging.

12 **Define** the term 'flocculation'.

13 **Describe** each of the processes involved in the primary, secondary and tertiary treatment of wastewater.

Apply and analyse

14 Nail polish remover and paint stripper are both useful solvents.
  a **Define** the term 'solvent'.
  b **Identify** the solute for each solvent.

15 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 2 shows what he saw.

Use the words 'dissolve', 'solvent', 'solute' and 'suspension' to **explain** what has happened in each test tube.

Figure 2 Test tube A (left) and test tube B (right)

16 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.

17 A particular coloured dye is being created for Fashion Week.

Figure 3 Chromatogram of a dye mixture

a Look at the chromatogram of the dye mixture in Figure 3. **Identify** how many pure dyes were mixed to create the colour.

b **Explain** how chromatography could help to create an exact copy of the dye for a rival manufacturer.

Evaluate

18 **Examine** the chromatograms in Figure 4, 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.

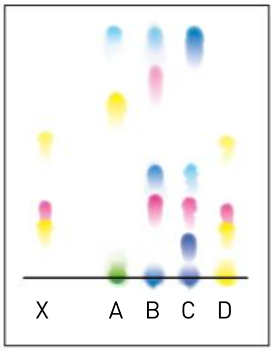


Figure 4 Which suspect is the likely culprit?

19 List the techniques, and the order, that you could use to separate a mixture of iron filings, sand, marbles and salt. Present your answer as a flow chart.

20 People sometimes need to enter environments containing poisonous gases. In these situations, they will wear gas masks. Use the internet or other research tool 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.

Social and ethical thinking

21 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 support an argument for or against drug testing competing athletes.

Critical and creative thinking

22 Until recently, Australia would ship all their plastic waste to other countries to be processed. This is no longer possible as most countries are refusing to accept the waste. Suggest why Australia did not previously process their own plastic waste.

Research

23 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 your chosen separation technique. 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. Research what these plates do and what they filter. In addition, investigate how whales are different from other filter-feeders, such as barnacles, sponges and flamingos.

» Distillation for survival

Imagine that you were hiking in central Australia, became separated from your group and then ran out of drinking water. Research some techniques of distilling water from gum leaves. As part of your report, you may like to demonstrate one technique to the class.

» Human filtration

The human body needs to control what goes into it and what comes out. In particular, the kidneys' filtering system prevents us from being poisoned by our own wastes, and tiny hairs in our noses filter dust and germs as we breathe. Find out more about these human filtration systems. See if you can identify others.

» 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.

Reflect

The table below outlines a list of things you should be able to do by the end of Chapter 3 'Mixtures'. Once you have completed this chapter, use the table to reflect on your ability to complete each task.

	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 50
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.	☐	☐ Go back to Topic 3.2 'A solution is a solute dissolved in a solvent'. Page 52
Describe the processes of decanting, sedimentation, flotation and magnetic separation. Define sediment, magnetism and flocculent. 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 54
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.	☐	☐ Go back to Topic 3.4 'Mixtures can be separated according to their size and mass'. Page 56
Describe the processes of evaporation, distillation and crystallisation. 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 58
Describe the process of chromatography. 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 60
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 62
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 64

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CHAPTER 4

WATER

Where do clouds and rain come from?

4.1 Water cycles through the environment

4.2 Factors in nature affect the water cycle

4.3 Human management affects the water cycle

4.4 Science as a human endeavour: Water is a precious resource

What if?

Water wise

What you need:

Pens, 2 packets of sticky notes per group

What to do:

1 In groups of four or five, write down on separate sticky notes every use of water you can think of in two minutes. (HINT: Do not just think of water that individual humans use; think about animals, the environment, businesses, farms and so on.)

2 When time is up, arrange the notes into common topics and display your group's uses of water on a wall.

3 Check displays created by other groups and note any uses you did not think of.

4 Count the number of different uses the whole class described.

What if?

» What if there was a drought? How would water use be affected?

» What if the water was contaminated by a toxin? How would contamination affect water use?

4.1 Water cycles through the environment

In this topic, you will learn that:

- water on Earth is precious and has always been recycled
- water moves constantly between the three states in a process called the water cycle
- plants are part of the water cycle.

precipitation
the process in which water vapour in the upper atmosphere becomes liquid water in the form of rain, snow or sleet and falls to the ground

groundwater
water beneath the Earth's surface

Evaporation in the water cycle

In the water cycle, heat energy from the Sun evaporates water from lakes, rivers, oceans and the land. Most of the Earth's surface is covered by the oceans and seas, so most of the water vapour in the air comes from these places. When water evaporates to a gas, it leaves behind any solutes that were dissolved in it (like crystallisation, when you separate mixtures).

Condensation in the water cycle

As the water vapour (gas) rises, it is cooled by the air. Eventually the air becomes saturated (filled) with water vapour and cannot hold any more. When this happens, some of the water vapour will condense and change into tiny water droplets (liquid). This is how clouds form.

Precipitation in the water cycle

The tiny warm water droplets rise in the atmosphere and form clouds. The higher the clouds go, the cooler the air becomes. The small droplets then join together to form larger droplets and can fall as rain, hail or snow, which are different forms of **precipitation** (see Figure 3). In this way, the same water that evaporated is returned to the land, flowing through rivers until it finally returns to the oceans.

Sometimes the water droplets in the clouds are moved by the wind to the mountains where the air is very cold. This causes the liquid water droplets to freeze into snow and ice (another form of precipitation).

Groundwater

Once the liquid water is on the Earth's surface, it can soak into the ground and form **groundwater**. Deep underground there are rivers and lakes that store water. To get there, the rainwater must soak in through and around the small rocks and pebbles that make up the earth. Eventually, it reaches solid rock and forms small pools of water called aquifers.

Figure 1 Rain, hail and snow are all types of precipitation.

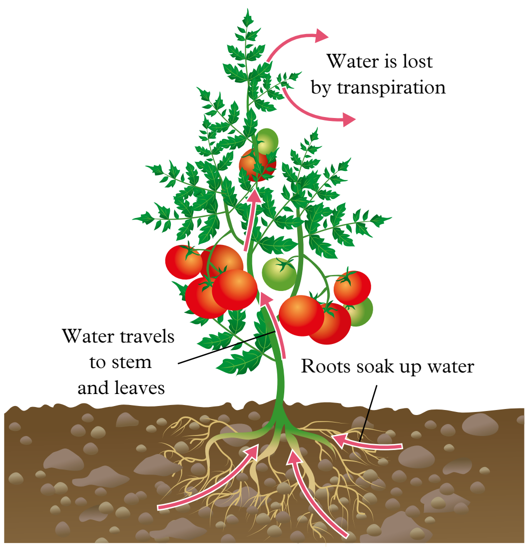


Figure 2 Transpiration in a plant

EXPERIMENT

4.1: What if the temperature was increased in the water cycle? Go to page 211.

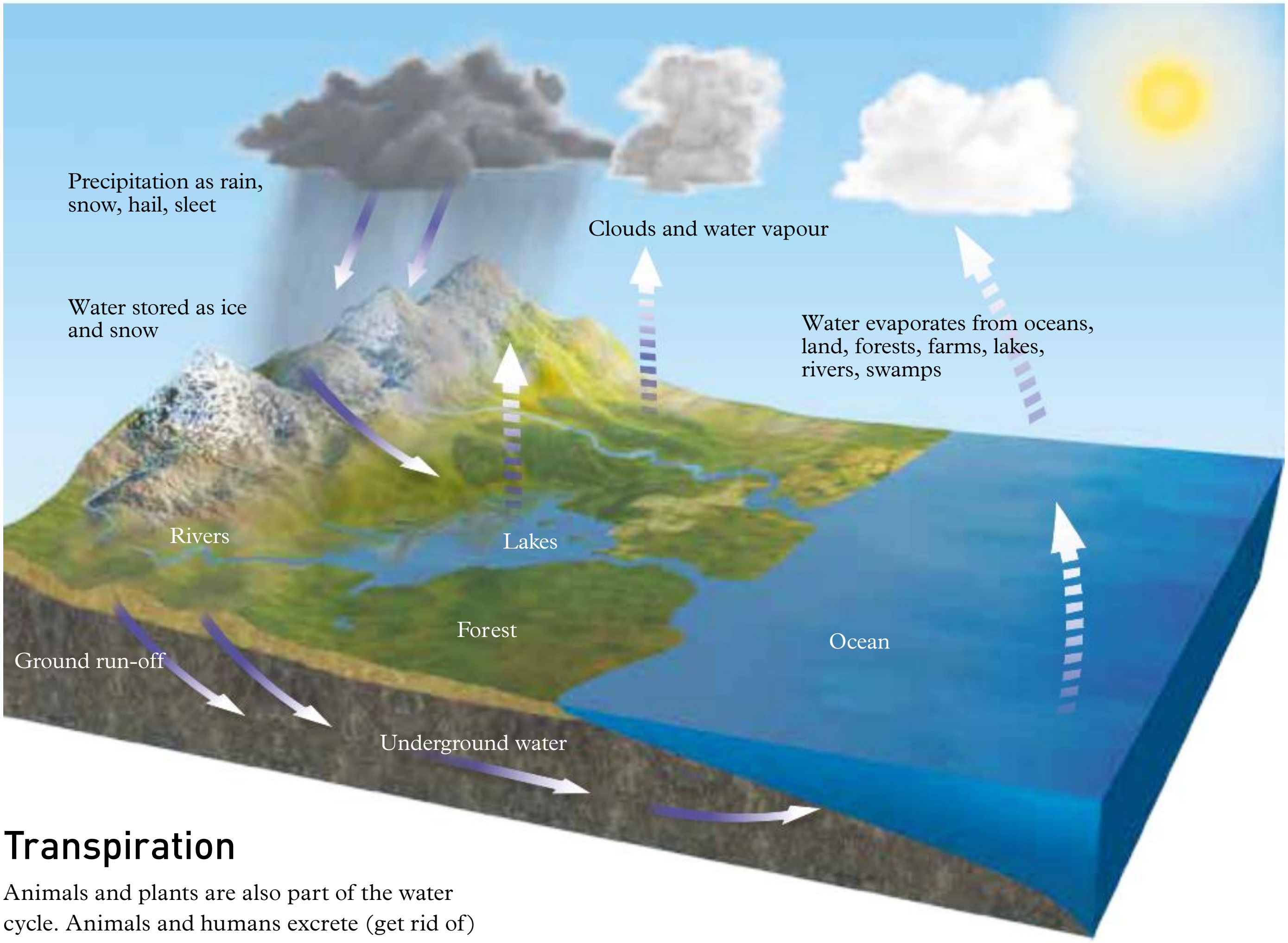


Figure 3 The water cycle. Water is constantly on the move. It changes from rain to water vapour to clouds to rain again, over and over. By constantly changing state, water never disappears – it is just recycled through the environment.

Transpiration

Animals and plants are also part of the water cycle. Animals and humans excrete (get rid of) water as waste or through evaporation (sweat). Plants take in water from the soil through their roots. This water travels through the plant to the leaves. Once the water has reached the leaves, it can evaporate. The evaporation of water from a plant is called **transpiration**.

transpiration
the process of water evaporating from plant leaves

4.1 Check your learning

Remember and understand

1 **Explain** why the movement of water around the environment is called a cycle.

2 **Identify** one example from the water cycle of:
- a frozen water
- b water gas
- c liquid water.

Apply and analyse

3 Draw a simple labelled diagram to **summarise** the water cycle that includes the following terms: evaporation, condensation, precipitation, solid ice, liquid water, water vapour and clouds.

Evaluate and create

4 True or false? The same water you drank today could have been drunk by a dinosaur millions of years ago. **Explain** your answer.

5 Research how much water on Earth is salt water. **Explain** why drinking water is considered a precious resource.

6 Use what you learnt about the particle model in Chapter 2 to **describe** what happens to a water molecule during the water cycle.

4.2 Factors in nature affect the water cycle

In this topic, you will learn that:

- the water cycle can be affected by the movement of water vapour in the air
- changes in temperature, the direction of the wind and the number of plants can change the amount of water vapour.

Figure 1 Areas in Australia affected by **a** drought and **b** flood

a

b

The effect of El Niño on Australia

You may have heard of the El Niño effect. Fisher people in Peru, South America, originally used this term to describe the appearance, around Christmas, of a warm ocean current off the coast that brought heavy rain and floods. Nowadays, 'El Niño' describes the extensive warming of the central and eastern Pacific Ocean. Combined with this ocean warming are changes in the atmosphere that affect weather patterns across countries around the Pacific Ocean, including Australia. In Australia, El Niño events usually mean less rain will fall.

El Niño events occur approximately every 4–7 years and usually last for about 12–18 months. They are a natural part of the climate system and have been affecting the Pacific countries for thousands of years.

Each El Niño event is unique in terms of how much the ocean temperature warms and how rainfall patterns change. El Niño events usually result in less rain across parts of eastern and northern Australia, particularly during winter, spring and early summer. Where and when this happens differs a lot from one event to another, even with similar changes and patterns in the Pacific Ocean. In 2015–16, a relatively weak El Niño event resulted in severe drought.

The effect of La Niña on Australia

More recently, in 2020–21, a La Niña event caused widespread flooding. The opposite of El Niño, La Niña occurs when the ocean current

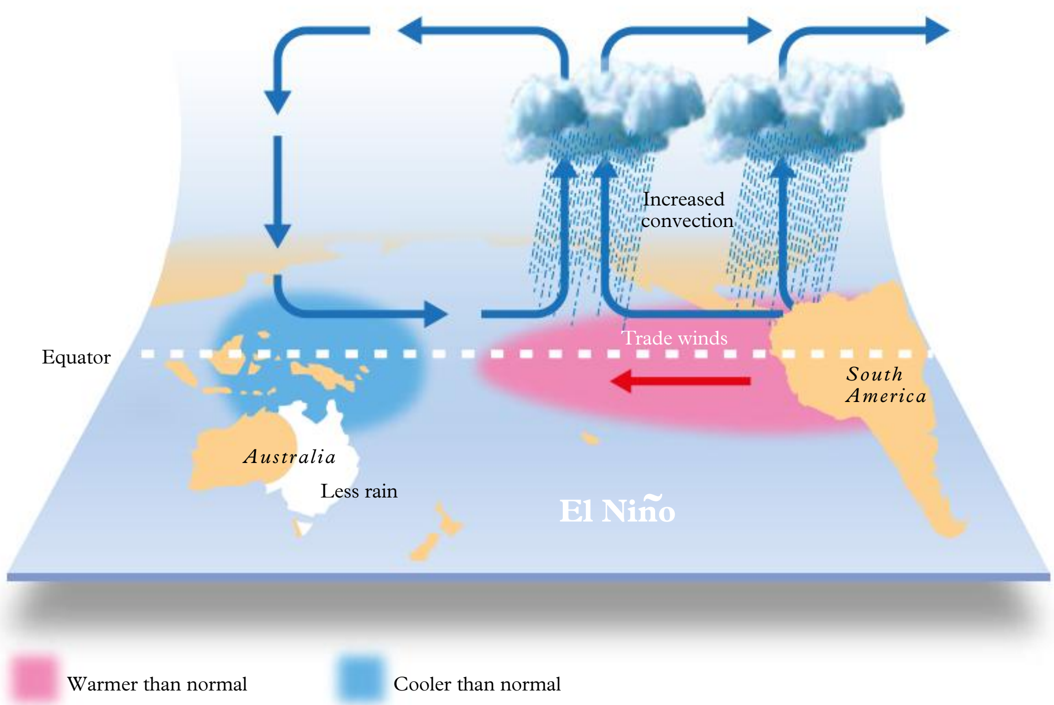


Figure 2 During an El Niño event, there is an increased chance of drier conditions in Australia because of the combined effects of ocean warming and changes in the atmosphere that affect weather patterns.

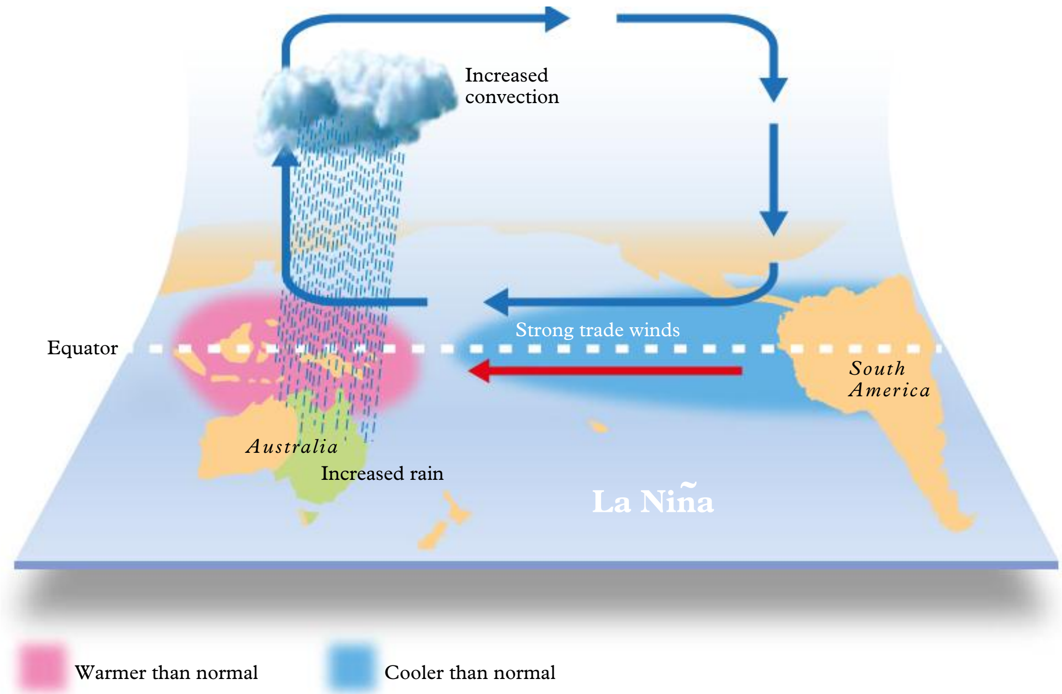


Figure 3 A La Niña event results in an increased chance of wetter conditions along the east coast of Australia because of ocean cooling and stronger winds.

is cooler and the winds are stronger. This results in greater-than-usual amounts of rain falling along the east coast of Australia.

Bushfires

The evaporation of water from plants (transpiration) contributes directly to the amount of water vapour in the air. When plants are burnt in a bushfire, it can prevent transpiration and decreases the amount of water vapour in the air. Any rain that does fall will wash the soot of dust into water storage areas, contaminating the water supply needed by animals and people. This decreases the amount of drinkable water available.

Volcanic eruptions

Volcanoes erupt regularly around the world every year. Occasionally there is a major eruption, like the 2011 Nabro eruption in Eritrea, Africa, that discharged large amounts of dust and particles into the air. The particles reflected the sunlight, preventing the Earth (and water) being heated. Less water evaporated, resulting in less water vapour condensing into precipitation (rain). Consequently, some countries experienced a drier climate in the year after the eruption.

volcano
a vent or hole in the Earth through which molten (melted) rock, ash and other materials escape to the surface

Figure 4 Volcanoes release large amounts of ash into the air when they erupt.

4.2 Check your learning

Remember and understand

1 **Describe** how El Niño affects Australia.
2 **Describe** how La Niña affects Australia.

Apply and analyse

3 **Explain** why Australians do not need to be concerned about erupting volcanoes in Australia.

Evaluate and create

4 Research where and when the last big volcanic eruption occurred in the world.
5 Draw a flow chart of how volcanic dust particles blocking sunlight affect the water cycle. Include all parts of the water cycle in your flow chart.
6 In 2019 bushfires burnt large parts of the Amazon rainforest. **Explain** how this could affect rainfall across other areas of South America.

4.3 Human management affects the water cycle

In this topic you will learn that:

- water is used for drinking, to grow the food we eat, to make the clothes we wear and to clean our homes and ourselves
- human activity can have an impact on the water cycle.

Figure 1 Baiame's Ngunnhu (Brewarrina Fish Traps), one of Australia's oldest heritage sites

greenhouse gas
a gas (carbon dioxide, water vapour, methane) in the atmosphere that can absorb heat

greenhouse effect
the trapping of the Sun's warmth in the lower atmosphere of the Earth caused by an increase in carbon dioxide, which is more transparent to solar radiation than to the reflected radiation from the Earth

Aboriginal and Torres Strait peoples' water knowledge

Many Aboriginal and Torres Strait peoples who lived near the coastal regions of Australia used their knowledge of the local waterways to control water levels so that fish could be farmed for food, a form of aquaculture. Any changes that were made to the flow of water in a river or on a beach needed to be carefully managed so that it did not affect other tribes or the environment downstream. The water was controlled by building small weirs or dams or used natural rock bars that raised the water level enough to trap the fish, while allowing some water to continue to flow downstream. An example of this is one of the oldest engineered fish traps in the world that is found on the Barwon River in Brewarrina, also known as Baiame's Ngunnhu (pronounced 'By-ah-mee's noon-oo'). The Ngemba people have a strong spiritual connection to the traps. According to stories passed down, the traps were built by the ancestral figure Baiame, who threw his net across the river, creating the shape of the traps with his two sons. The traps are also an important meeting site for other Nations, including the Morowai, Parrkinji Weilwan, Barabinja, Ualarai and Kamilaroi people.

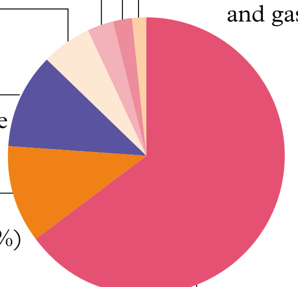


Figure 2 Water is used for many purposes across Australia.

Agriculture

Australia has one of the lowest rainfall levels in the world. Most of the water used by humans in Australia every year is for growing our food. The water is used for irrigation, the artificial watering of the Earth for agriculture. Often the water is sprayed onto crops to ensure they do not die in dry areas such as the Murray River Basin.

The water is taken from the groundwater or from rivers or lakes. This reduces the amount of water flowing into rivers, which affects the native plants downstream. It also washes dirt and fertilisers into the waterways, affecting the plants and animals that rely on the clean water to live. Increased watering in some areas can also result in an increase in the amount of groundwater that is stored in the aquifers. Groundwater is often salty, so the salt comes to the surface with the water, making the soil too salty to grow food. Farmers often need to carefully manage water levels so that they balance the need to grow the food with the need to maintain the water cycle.

Industry

One of the biggest impacts on the water cycle is the use of fossil fuels to produce electricity for factories. This burning of fossil fuels causes the production of carbon dioxide, which is a **greenhouse gas**. This means it can absorb heat, making the air around the Earth stay warm. The extra heat from high levels of carbon dioxide causes even more water to evaporate and stay in the air as water vapour. The increase in carbon dioxide and water in the air traps even more heat in the atmosphere. This increased **greenhouse effect** can cause changes in the climate, including more rain in some areas and droughts in other areas. It is also contributing to the melting of the ice caps, causing even more water to re-enter the water cycle. The long-term impact of **global warming** due to industry is becoming more noticeable every decade.

CHALLENGE

4.3: Can you reduce the evaporation of water in irrigation channels?
Go to page **212**.

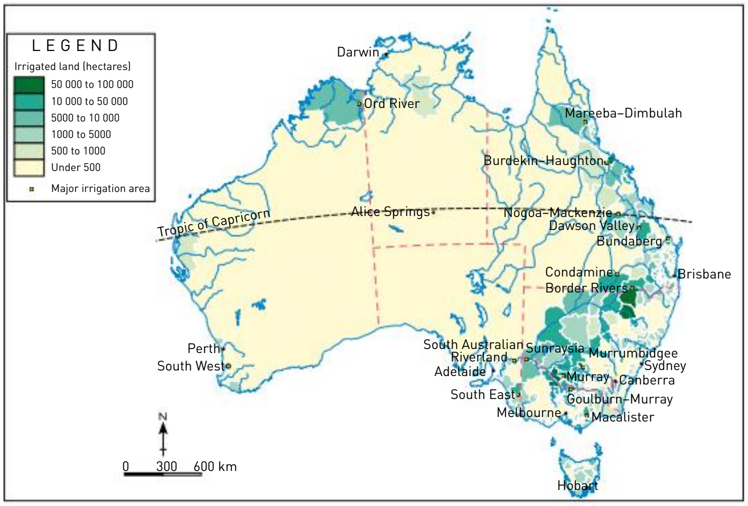


Figure 3 Agricultural irrigation to grow food accounts for 65 per cent of the water used in Australia.

Figure 4 Industry is responsible for the release of carbon dioxide and water vapour into the atmosphere.

global warming
the increase in temperature of the Earth's atmosphere caused by the greenhouse effect

distillation
a technique that uses evaporation and condensation to separate a solid from the solvent in which it has dissolved

desalination plant
a large facility set up to produce fresh water from salt water

Water storage

Australia is the world's driest continent. We store more water than any other country – more than 4 million L of water per person! Australia requires such a large storage capacity to ensure a reliable water supply during periods of drought.

Large dams and reservoirs have been built to collect and store water. Two of the largest storage reservoirs in Australia are the Warragamba Dam in Sydney, which can store 2 million megalitres (ML; 2 million million L), and the Thomson Dam in Victoria, which can store 1 million ML. Storing water in dams reduces the water flowing down rivers and into the ocean.

Distillation

Even though salt water is not suitable for drinking, in dry countries such as Australia the idea of changing salty water into fresh water is very appealing.

One way to do this is by **distillation**. In this separation process, heat is used to evaporate water from the salt. The steam is collected and condensed into pure liquid water.

Distillation has been used for many years in **desalination plants** to produce fresh water from sea water, particularly in some Middle Eastern countries. However, it is very expensive and uses a great deal of energy. The Victorian State Government has built a desalination plant that uses a special type of filtering called reverse osmosis. This process removes some of the water from sea water for use by humans, and then returns the more concentrated saltwater solution to the ocean.

Figure 5 The Victorian desalination plant was built in 2012 in Wonthaggi. It can supply up to one-third of Melbourne's water needs.

4.3 Check your learning

Remember and understand

1 **Describe** the greenhouse effect.
2 **Explain** why Australia needs to have large water-storage systems.

Apply and analyse

3 **Explain** how using too much water can cause high salt levels in the soil.
4 **Explain** why desalinisation can use a lot of energy.
5 **Identify** three ways you have used water in the last 24 hours.

Evaluate and create

6 Draw a water cycle and highlight where in the cycle the water you use comes from.
7 Research where the tap water you use comes from.

//SCIENCE AS A HUMAN ENDEAVOUR//

4.4 Water is a precious resource

Approximately two-thirds of the Earth's surface is covered with water, yet in Australia we have very little fresh water. Of all the water on Earth, 97.5 per cent is salt water – the remaining 2.5 per cent is fresh water. Of the tiny percentage of fresh water in the world, most of it is locked in ice caps and glaciers or in the soil. This leaves approximately 0.007 per cent of the Earth's water available for drinking. In Australia, we use drinkable water for many things around the house.

How water is used

Most of the water that we use in our home is considered drinkable. This means it is safe for a person to drink. Even the water that fills the cistern in the toilet and is used to flush our toilets is often drinkable. Table 1 identifies how much clean water is used around the house.

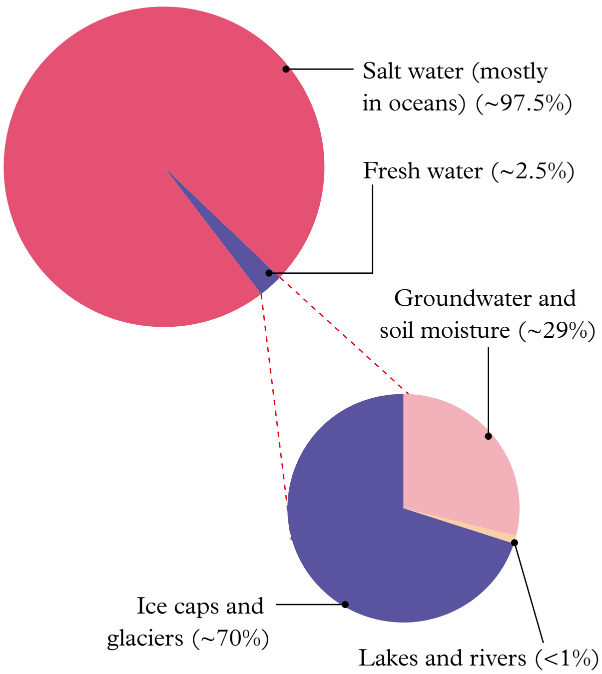


Figure 1 Only a very small percentage of water on the Earth is fresh and unfrozen.

Figure 2 Water-saving shower heads are used to reduce the amount of water we use when showering.

Table 1 Amount of water used around a house

Action	Amount of water used
Toilet	Dual-flush toilet = 3 L Single-flush toilet = 9–11 L
Shower	Water-saving shower head = 9 L/min Older shower head = 18 L/min
Bath	50–150 L
Dish washing	Hand wash = 18 L Automated dishwasher = 20 L
Clothes washing machine	Top loader = 120–150 L Front loader = 50 L
Washing hands, brushing teeth etc.	Approximately 18 L/person/day
Watering garden	Sprinkler = 1000 L/hour
Dripping tap or leaking toilet	3 drips/second = 68 L/day

Sustainable water use at home

Australia's weather can be unpredictable. To cope with this, Australians are encouraged to think carefully when building new homes, businesses and even gardens.

Drought-tolerant plants are big sellers in plant nurseries all over Australia. Gone are the days when 'English' country gardens were practical options; succulents and native species are now the plants of choice as they need less water to survive. As a result, we have reduced the watering needs of our gardens. In some places, the government has restricted our use of water and the price of water is increasing.

Rainwater tanks are appearing in backyards all over the country, more water-saving shower heads are being used and the use of grey water systems is increasing.

Figure 3 A rainwater tank is used to capture and store rainwater that can then be used to water the garden, flush toilets and even wash clothes.

4.4 Develop your abilities

Collecting data

The accurate collection of data is an important skill in science. It requires careful planning to ensure that all the variables are considered. Your goal is to collect data on the amount of drinkable water that is used in your house, and how it is used. This will then form the basis of recommendations that you will make to your household on how to reduce water wastage.

1 **Identify** all the ways that water is used in your house. Many of these will be obvious (drinking, dish washing, clothes washing), while others will be less obvious (evaporative air conditioner, brushing your teeth).

2 Construct a table that lists all the ways that water is used, the number of times this action is done each day by each person in the house, and the volume of water that is used in the action. Table 2 is an example.

Table 2 An example of water use

Action	Number of people in the house	Number of times each person does the action each day	Volume of water used in the action	Total volume of water used for the action each day
Example: shower	3 people	1/day	9 L × 3 min = 18 L	3 × 1 × 18 = 54 L

3 **Identify** the length of time you will need to collect the data. Things you might like to consider include:
- Does the number of people in the house change over a week?
- Does every person perform every action every day?
- How will you collect information on an action that may only occur every second day? (HINT: Someone who washes clothes every second day can be recorded as 0.5 action each day.)

4 After collecting your data, draw a column graph that shows the total volume of water that is used for each action per day.

5 Use the graph to **identify** which three actions use the most water each day.

6 **Describe** how each of these actions could be changed to reduce the amount of drinkable water that is used each day.

7 Use your communication skills to decide how this data information could be presented to other members of your house. Would they read a report or social media post? Use the data you have collected to support your suggestions.

Figure 4 Plants around the home use water to survive.

REVIEW 4

Multiple choice questions

1 **Identify** the term that describes the process in the water cycle when a gas cools to become a liquid.
- A condensation
- B evaporation
- C transpiration
- D desalination

2 **Identify** the percentage of the Earth's water resources that is suitable for drinking.
- A 97.25 per cent
- B 12 per cent
- C 2.5 per cent
- D 0.0007 per cent

3 **Identify** the process where rains soaks into the ground to become groundwater.
- A filtration
- B soaking
- C infiltration
- D desalination

Short answer questions

Remember and understand

4 List the three states in which water can be found.

5 **Define** the term 'transpiration'.

6 **Describe** the state of water that make up clouds.

7 **Identify** the percentage of the Earth's water that is suitable for drinking.

8 **Describe** where most of the fresh water is stored on Earth.

9 **Describe** how the way we live can affect the water cycle.

10 **Describe** the natural factors that can affect the water cycle.

11 **Contrast** the melting point and boiling point of water.

12 **Name** the gas state of water and explain how it forms.

13 List three places from which water evaporates as part of the water cycle.

14 **Recall** one way you can save water at home.

15 **Outline** how Aboriginal and Torres Strait Islander knowledge could be used to manage our water resources.

Apply and analyse

16 Salt water has a lower melting point than fresh water. In some areas of the United States of America, salt is spread over the footpaths in winter. **Explain** the purpose of the salt.

Figure 1 Salt is added to roads during the northern hemisphere winter.

17 **Describe** a factor that may affect the ability of soil to grow plants.

18 **Explain** why you should water the roots of a plant and not the leaves.

19 **Explain** how an El Niño event could affect your life.

20 In the eighteenth century, Captain James Cook embarked on several voyages to the Pacific Ocean, exploring unchartered lands, including Australia. **Explain** why being surrounded by water did not prevent his crew from being at risk of dying of thirst.

Evaluate

21 As lack of water becomes a bigger national problem, more people will be required to work in the water industry. This includes hydrologists, environmental scientists and environmental engineers. Choose one of these professions and **investigate** the following:

  a **Describe** the work that this person does.

  b **Explain** how their work could affect the water cycle.

22 The area around Queenstown, on the western coast of Tasmania, is now barren and lifeless (Figure 2). Research what happened here to cause the devastation. **Explain** in detail why this land has not been rehabilitated and why the area will take many thousands of years to recover.

Figure 2 What happened in the Queenstown hills?

23 **Create** a model of the water cycle. **Identify** what you could use to represent each stage, and **explain** how each stage is connected to others.

24 Certain plants can act as effective filters of rainwater. When it rains, some water ends up in the underground water table and can be pumped up for use elsewhere. **Investigate** plants as filters.

Social and ethical thinking

25 Your neighbours water their garden whenever they like for as long as they like. Research the best way and time to water plants in the garden. **Explain** how you would pass this knowledge on to your neighbours without making them upset.

26 Water management in Victoria causes a lot of stress for individuals, families and communities.

  a **Identify** what may cause someone your age to be stressed about water management. For example, is there enough water for farms? Will there be enough water for the future?

  b Suggest why this is a social and ethical concern.

27 Waterholes are culturally significant to the Martu people of the Western Desert, who have a strong connection to their country. Each waterhole makes up an important part of the dreaming stories passed down from elders, and is a significant meeting place for ceremonies and an important source of water. For many years, the waterholes have been at risk because of feral camels drinking the waterholes dry and contaminating them. **Investigate** how these feral camels are being managed, and **explain** why this is an ethical concern.

Critical and creative thinking

28 Working in a small group, **investigate** the advantages and disadvantages of desalination plants. **Create** a poster that lists the advantages and disadvantages of these plants.

29 Make a list of the different categories of water-saving devices currently available. If you could choose only three devices to install in your house, **identify** the three devices you would choose. **Describe** each of the three water-saving devices you have chosen. Include an image for each one and indicate how it helps to save water.

30 El Niño and La Niña have different effects. **Predict** what effects an El Niño year would have on Victoria's snow resorts. Then **investigate** whether your prediction is correct.

Research

31 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.

» Aboriginal and Torres Strait Islander peoples' management of waterways

In many parts of Australia, the water in rivers and creeks is protected by the state and national governments. This means there are often laws that govern the collection and use of water in the waterways. This can be in direct conflict with Aboriginal and Torres Strait Islander peoples' traditional views and values of inland waters, rivers, wetlands, reefs and islands. Research these points of view on managing water resources and suggest a way that both groups will be able to work together to find a solution.

» Sewage treatment

Find out more detail about how your city treats its sewage. Explain the difference between sewage and sewerage. Describe how sewage treatment in your city has changed over the last 100 years. Many countries drink water that was once sewage but has been treated. Explain why you may or may not chose to drink this water. Describe how your actions can affect sewage and water quality. Explain how you can make a difference to the water in your environment. Give a multimedia presentation to the class.

Reflect

The table below outlines a list of things you should be able to do by the end of Chapter 4 'Water'. Once you have completed this chapter, use the table to reflect on your ability to complete each task.

	I can do this.	I cannot do this yet.
Describe the water cycle. Define 'evaporation', 'condensation', 'precipitation' and 'transpiration'.	☐	☐ Go back to Topic 4.1 'Water cycles through the environment'. Page 70
Explain how El Niño and La Niña or volcanic eruptions can affect the water cycle in Australia.	☐	☐ Go back to Topic 4.2 'Factors in nature affect the water cycle'. Page 72
Describe an example of Aboriginal and Torres Strait Islander water management. Describe how the water cycle is important to agriculture, industrial and domestic use of water.	☐	☐ Go back to Topic 4.3 'Human management affects the water cycle'. Page 74
Define 'sustainable'. Contrast the amount of water on Earth and the amount of drinkable water on Earth.	☐	☐ Go back to Topic 4.4 'Science as a human endeavour: Water is a precious resource'. Page 76

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

Quizlet Live
Compete in teams to test your knowledge.

Chapter quiz
Test your understanding of this chapter with one of three chapter quizzes.

Check your Teacher obook pro for these digital resources and more: pro

Quizlet Live
Launch a quiz for your students on key concepts in this chapter.

CHAPTER

5

RESOURCES

What makes something renewable?

What if?

Sustainable fishing

What you need:

Buttons, trays, spoons, straws, stopwatch

What to do:

1 Place plates of 20 buttons (representing fish) around the room.

2 Each student should use a straw (no hands) to collect as many 'fish' as they can in 1 minute.

3 After 1 minute, the remaining fish are available for breeding. Add one new button 'fish' for every button left.

4 Repeat steps 2 and 3 several times

5 How long can you keep fishing before all fish will be gone?

6 Is the fishing sustainable?

What if?

» What if you use hands to help move your straws? (This represents fisher people using technology to help find fish.)

» What if you use a spoon instead of a straw? (This represents fishing with a net.)

5.1 Resources on Earth take different times to renew

In this topic, you will learn that:

- resources on Earth can be classified as easily renewable or long-term renewable
- easily renewable resources are either unlimited or quickly renewed
- long-term renewable resources can take millions of years to be produced.

long-term renewable refers to resources that are limited because, once used, they take a long time to replace

easily renewable made naturally and available in an almost unlimited amount

Humans have always relied on the natural resources of the Earth – in the air, the water and the ground. Oxygen and water are essential for keeping us alive. Soil is necessary for us to grow food for ourselves and our livestock. Minerals from the Earth that feed the mining industry are essential to manufacturing and to Australia's economy. Forests provide habitat for animals and timber products for our buildings. In fact, humans have found and used resources in almost every corner of the planet. As the human population continues to grow, we are putting more pressure on our resources than ever before.

Types of resources

Resources on Earth can be classified into two major groups: easily renewable resources and long-term renewable resources.

Easily renewable resources are either available in a continuous and unlimited supply (such as sunlight and wind) or able to naturally regrow in most conditions (such as fast-growing trees in a forest). Despite the fact that they can regrow naturally, renewable resources still need to be managed carefully and used sustainably.

Long-term renewable resources, also known as non-renewable resources, are resources that take a very long time to be replaced and are therefore only available in limited supply. If we use them at a faster rate than they can be replaced naturally, they will run out. Minerals such as coal and oil are non-renewable resources.

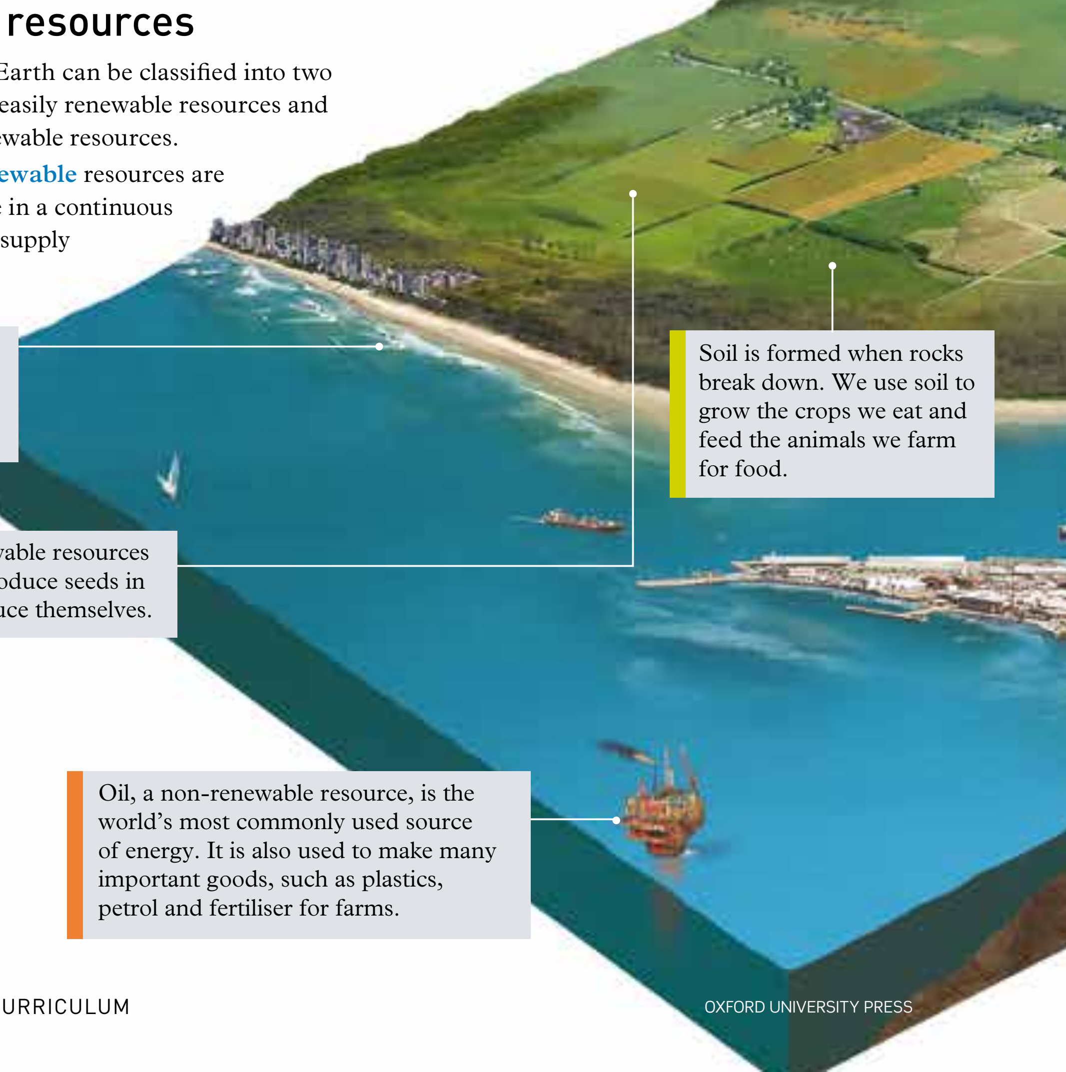
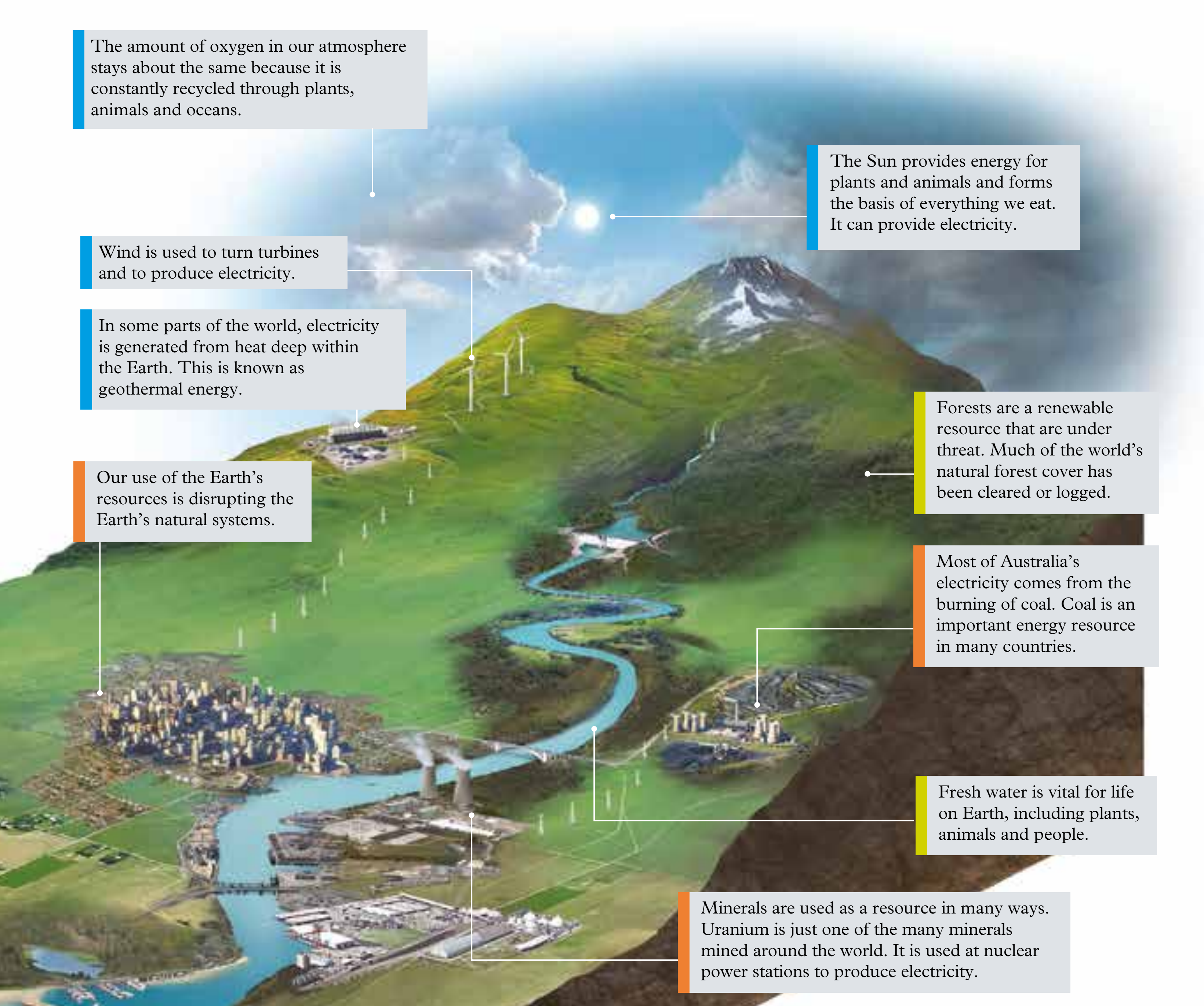


Figure 1 Our environment provides us with many resources.

Environmental resources

An overview of the many types of environmental resources

- Continuous resources
- Renewable resources
- Non-renewable resources



5.1 Check your learning

Remember and understand

1 **Name** the two major groups of resources.

2 **Name** one easily renewable resource that is continuous and one that is non-continuous.

3 **Identify** all the long-term renewable resources you have used in the past hour.

Apply and analyse

4 **Identify** all the resources from Figure 1. **Identify** which of the resources are available in your local area.

Evaluate and create

5 **Evaluate** the resources in Figure 1 that you consider are well managed. **Justify** your answer (by listing each resource in Figure 1, identifying the number of years it takes to produce the resource, describing how the resource is used and using this data to describe whether the resource is well managed).

6 Thousands of years ago, the Ngemba, Ualarai, Murrawarri and Wailwan peoples from the Brewarrina region built elaborate fish traps that caught the large mature fish while letting the smaller breeding stock escape. **Compare** the way we manage resources today with the way Aboriginal and Torres Strait Islander peoples traditionally managed the Earth's natural resources.

5.2 Easily renewable resources can be quickly replaced

In this topic, you will learn that:

- the Earth's energy resources are limited
- easily renewable resources such as sunlight are resources that can be replaced
- fossil fuels such as oil, petrol and coal are long-term renewable resources because they take millions of years to be produced.

solar energy
energy made by atoms colliding with each other in the centre of the Sun

energy resources
resources that can be used for the production of energy

Figure 1 Some of the Earth's natural resources: **a** timber, **b** fish and **c** solar energy

a

b

c

Easily renewable and long-term renewable resources

When you burn gas in a Bunsen burner, you are using a non-renewable resource. If you burn 1 L of gas, then there is 1 L less of that gas in the world. Many long-term renewable resources are continually being made, but on a time scale of hundreds of thousands or even millions of years. This makes them practically non-renewable in our lifetime. If we continue to use a long-term renewable resource and it is not recycled, then it will run out.

It is estimated that Australia's brown coal will last for another 500 years. By 2030, coal may still be one of our main energy resources, but there will be a shift to resources such as gas and easily renewable energy such as solar and wind.

Easily renewable resources are naturally made and available in an almost unlimited amount. **Solar energy** is energy that comes from the Sun. It is a renewable resource: an unlimited amount of it is available while the Sun shines in the sky. Of course, if the weather is cloudy, solar energy is not available; so it can have some disadvantages too. Other examples of easily renewable resources include clean air, timber and fish. Given the right conditions, they will be available if we do not use them too fast. We need to consider the consequences of taking too much.

Australia's energy resources

Australia has a variety of **energy resources** (see Table 1). For a long time, we have relied on resources such as coal and petrol for our energy needs.

Table 1 Use of Australia's energy resources

Resource	Use	Percentage of total electricity production 2007–08 (%)	Percentage of total electricity production in 2018 (%)
Long-term renewable resources			
Coal (brown and black)	Electricity generation	76.3	65
Gas	Electricity generation	15.9	21
Liquefied petroleum gas (LPG)	Transport fuel	0	0
Uranium	Exports	0	0
Crude oil	Transport fuel	0.9	2
Easily renewable resources			
Wind	Electricity generation	1.5	7
Solar	Solar heating and electricity generation	<0.1	7
Geothermal	Demonstration projects only	<0.1	<0.1
Hydro	Electricity generation	4.5	5
Wave, tidal	Demonstration projects only	0	0

CHALLENGE
5.2: Can you increase the output of a power station? Go to page **213**.

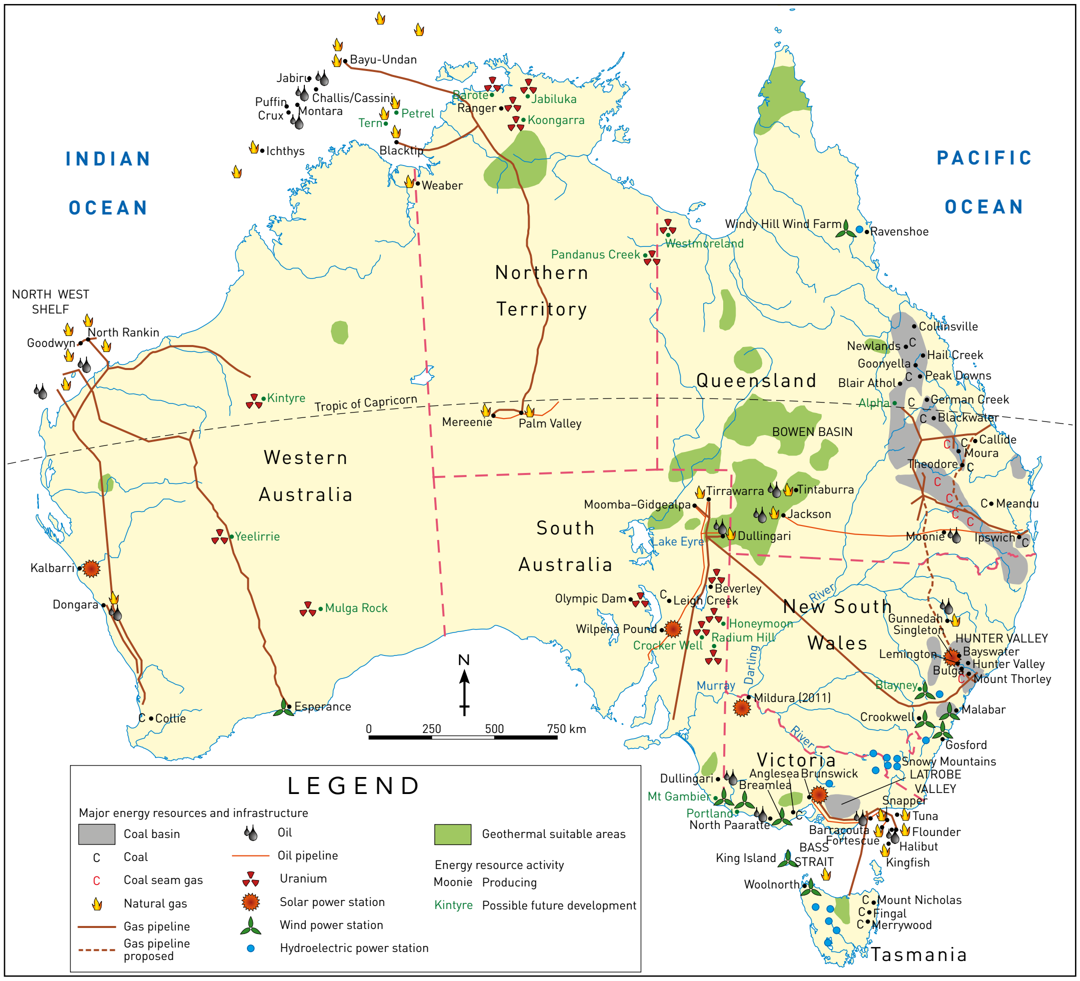


Figure 2 The location of Australia's energy resources

According to recent research, Australia is one of the highest greenhouse gas emitters per capita in the world. Our use of long-term renewable energy resources for transport and generating electricity around the home makes up approximately one-fifth of these **emissions**.

How a power station works

Coal-fired power stations burn coal and carbon dioxide gas to produce electricity. When coal is burnt, heat is released. This heat is used to boil water to make steam. The steam flows past a turbine, causing it to spin. A **turbine** is a large wheel with angled sections called vanes, like a propeller. The turbine is connected to a generator. A **generator** converts the movement from the turbine into electrical energy. This form of electrical energy takes much longer to renew than the easily renewable solar or wind energy.

emissions
the production and release of a substance into the air (e.g. gas)

turbine
a large wheel with angled sections called vanes, like a propeller, that is used to generate electricity

generator
a machine that uses the electromagnetic effect to separate charges and produce electricity

5.2 Check your learning

Remember and understand

1 **Identify** an example of a long-term renewable resource. **Explain** why it is sometimes considered non-renewable.

2 **Identify** an example of an easily renewable resource. **Justify** your decision (by describing how the resource is renewed).

3 **Describe** how long it takes for long-term renewable resources to form.

4 **Identify** Australia's third-largest electricity production resource in 2007–08.

Apply and analyse

5 **Explain** why the time scale of renewal of a resource is an important issue.

6 **Analyse** Table 1. **Compare** energy production in 2007–2008 and 2018.

Evaluate and create

7 **Describe** one reason that explains why electrical energy production has changed in Australia in the last 20 years.

5.3 Easily renewable resources can be harnessed to provide energy

In this topic, you will learn that:

- resources can provide a source of energy to meet our needs
- renewable resources can provide unlimited amounts of energy to generate electricity
- wind, solar, hydroelectric, tidal and geothermal power can be used to generate electricity.

Video 5.3A Creating solar energy from trash

Video 5.3B The future of wind energy

fossil fuels
a non-renewable energy source formed from the fossilised remains of plants and animals

wind turbine
a wheel with blades that turn in the wind

wind farm
a large group of wind turbines in the same location

solar cell
a device that transforms sunlight directly into electrical energy

Wind power

A very important step in generating electricity is turning a turbine. **Fossil fuels** are often burned to produce the steam that turns a turbine. Wind can also turn a turbine without steam and without emitting carbon dioxide.

To generate a significant amount of energy, many **wind turbines** are placed in long rows in a **wind farm**. The stronger the winds, the faster the turbines turn and the more energy is produced.

Figure 1 A wind farm in Australia

Solar power

In Australia we are familiar with solar power for things such as hot water, outdoor lighting and speed limit signs in school zones.

Solar energy is made when **solar cells** (in solar panels) convert sunlight into electrical energy. They do not release greenhouse gases; however, the mining and construction of the individual panels can have environmental impacts. This can be minimised by the recycling the minerals that are used in their construction.

a

b

c

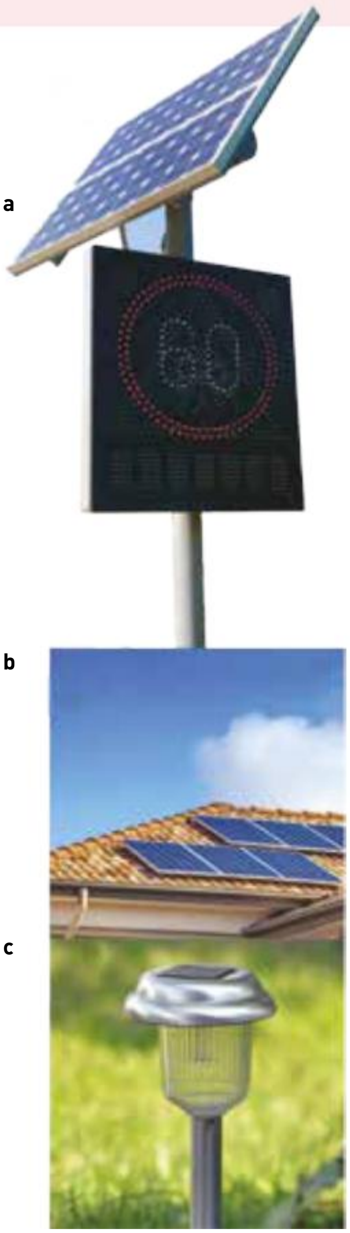


Figure 2 Solar power has many uses (**a**–**c**). Which of these have you seen?

CHALLENGE

5.3: Can you increase the power of solar cells?
Go to page 214.

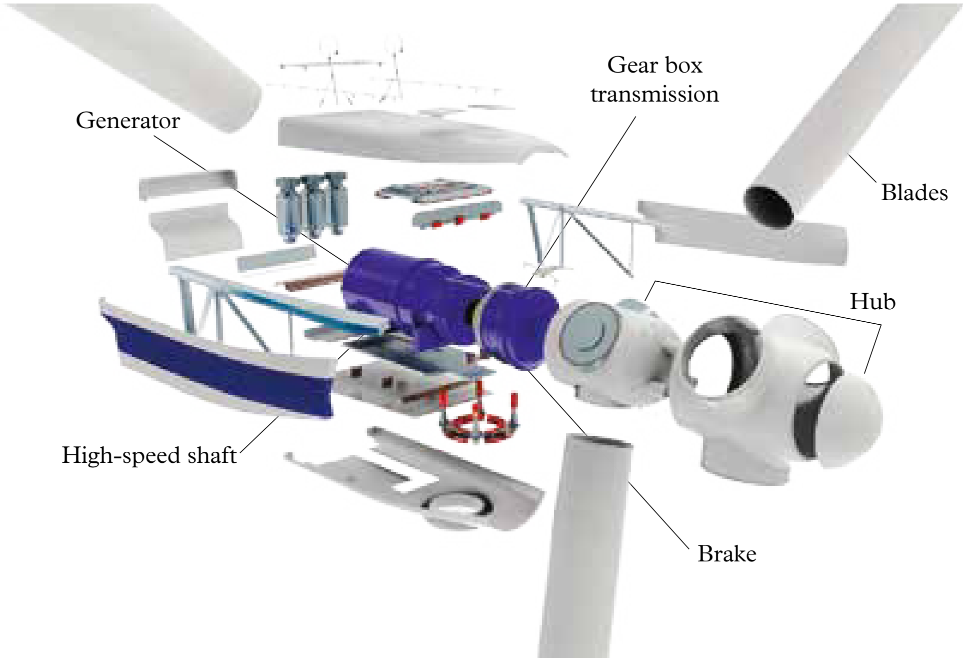


Figure 3 The parts of a wind turbine

Two-thirds of the Australian population live in cities and about 70 per cent of the mainland can be classified as arid or semi-arid desert. This means that Australia has large areas of sun-exposed land that can be used to convert the energy of the Sun into energy that can be stored in batteries.

Hydroelectric power

Hydroelectric energy (*hydro* meaning 'water') is produced by water falling through pipes to turn turbines to produce electricity. It accounts for approximately 19 per cent of the world's energy production. Hydroelectric schemes need a constant water supply and are often built high above sea level, like mountains. The water supply is held in dams and then released to cause fast-flowing water, which turns the turbines efficiently. Hydroelectric power in Australia meets approximately 5 per cent of our electricity needs.

hydroelectric energy energy produced by falling water that turns turbines to generate electricity

Case study 5.3: Australian oceans to power floating wind and wave project

The Land Downunder is well known for its beaches, its sunshine and its oceans. We are the country that is 'girt' by sea, after all. Now we are set to harness the power of our oceans in a significant floating wind and wave project that will generate 6 MW of power.

The offshore platform is the brainchild of Australia and UK-based energy company Bombora in collaboration with global energy infrastructure and engineering group TechnipFMC.

This project will centre around mWave technology that Bombora developed in Perth. A sister project will also test the technology in a Marine Energy Testing Area off Pembrokeshire, Wales.

The process involves air-filled concave cell modules covered by a rubber membrane being placed under the ocean to capture the optimal amount of power.

'As waves pass over mWave, under-water pressure increases, causing each rubber membrane to compress sequentially, forcing air from inside the cells into a duct. Valves control a one-way airflow to the turbine — directly spinning a generator converting this rotation into electricity' the Bombora website explains.

'After passing through the turbine, the air is recycled to re-inflate each membrane in a continuous sequence. The sustainable power generated is transferred to the electrical grid via the same sub-sea cable used for the wind turbine.'

Source: 'Australian oceans to power floating wind and wave project' 2021, Energy Matters, 14 April, www.energymatters.com.au/renewable-news/australian-oceans-to-power-floating-wind-and-wave-project-2/.

tidal energy
the energy in the rise and fall of tides, which can be used to drive turbines in the water, producing electricity

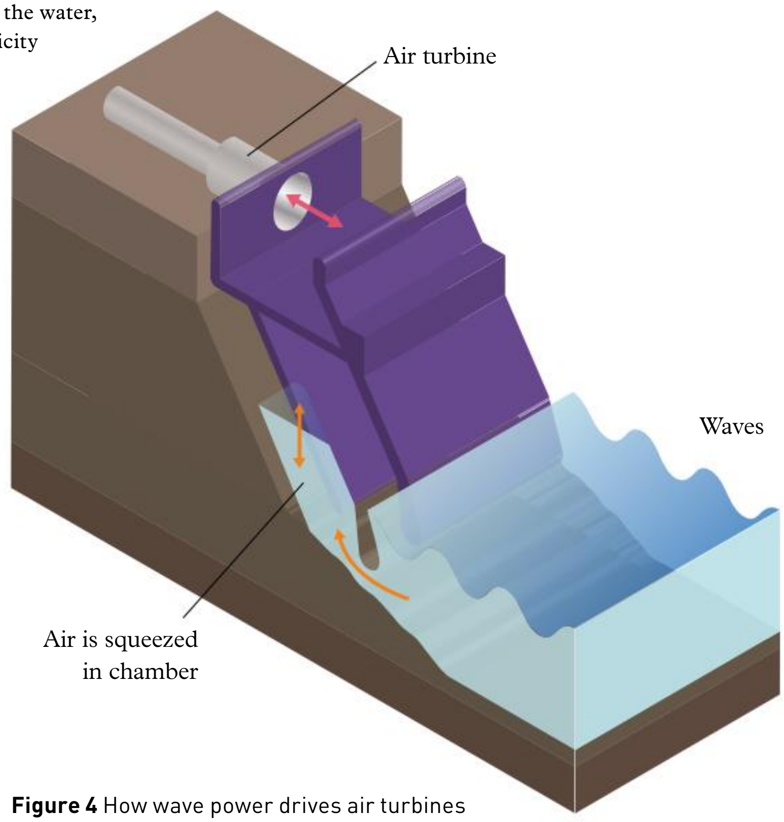


Figure 4 How wave power drives air turbines

Tidal and wave power

Have you ever been to a surf beach and experienced the strength of the waves? It has been estimated that wave energy alone could power the entire Earth five times over! The problem has been working out how to do it. Wave energy uses the energy of waves to spin air turbines (as explained in Case study 5.3).

Tidal energy can also be used to drive turbines in the water. The major disadvantage of tidal power is that it only provides a relatively small amount of electricity and has a negative impact on the nearby natural environment. The world's largest tidal power station is in France.


Figure 5 Superheated water is produced at the geothermal power plant in Birdsville, Queensland.

Geothermal energy

Geothermal energy comes from heat beneath the Earth's surface. The super-heated liquid rock under the Earth's surface is called magma. Magma heats the layers of rock above and below it. This heat is geothermal energy and some of it is released as steam. The steam can be used to turn a turbine in a generator, producing electricity.

Australia's only geothermal power station is in Birdsville, in western Queensland. The power station has a bore (pipe) that extends 1230 m into the ground and taps into 98°C water from the Great Artesian Basin. This power station provides approximately one-quarter of Birdsville's energy supply. After the steam has been used to drive the turbine, the cooled water becomes the town's water supply.

Australia has access to a technology that could produce electricity for many years. This technology is called **hot dry rock geothermal energy**. Australia has the world's best geology for this type of energy. Hot dry rock has been found in Central Australia, and reserves in the Hunter Valley in New South Wales are being tested. To use the energy from the hot dry rock, water is injected through bore holes into hot granite rock that is 5 km underground. The hot rocks cause the water to evaporate into water vapour or steam. The steam produced can be used to generate electricity. This technology consumes none of the Earth's valuable resources because the steam can be condensed back into liquid water and injected again.

Once the energy has been produced, it often needs to be transferred or stored until it can be used. This can be done through the use of a battery. Most batteries are made of metals, such as lithium, cobalt, nickle and manganese. Australia is one of the largest producers of lithium for batteries in the world. Lithium is a nonrenewable resource.

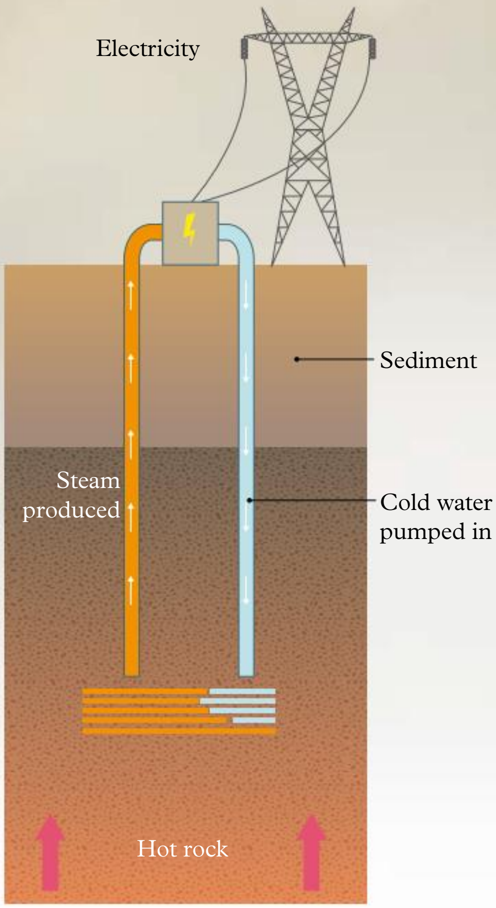


Figure 6 How hot dry rock technology works

geothermal energy
energy that comes from heat beneath the Earth's surface

hot dry rock geothermal energy
a method of pumping water into deep hot rocks in the ground in order to produce steam, which is then used to drive a turbine to provide electricity

5.3 Check your learning

Remember and understand

1 **Describe** two advantages of hydroelectric power over fossil fuels.

2 **Describe** how energy is generated by a hydroelectric power station.

Apply and analyse

3 A large group of wind turbines in the same location is called a wind farm. **Identify** the important features of a suitable location for a wind farm.

4 **Explain** why most wind turbines are mounted on towers 40–100 m high.

5 The major hot dry rock resource is in Central Australia. **Identify** why this location could be a disadvantage for energy generation.

Evaluate and create

6 Coal-fired power stations in Victoria run 24 hours a day, 7 days a week. **Explain** why this is considered more reliable than wind power.

7 New Zealand produces a large amount of its energy from geothermal power. **Explain** why Australia does not rely on geothermal power for all of its electricity.

5.4 Some resources are limited

In this topic, you will learn that:
- fossil fuels are produced when fossilised plant and animal remains decompose
- uranium is a radioactive substance that can be used to heat water in energy generation.

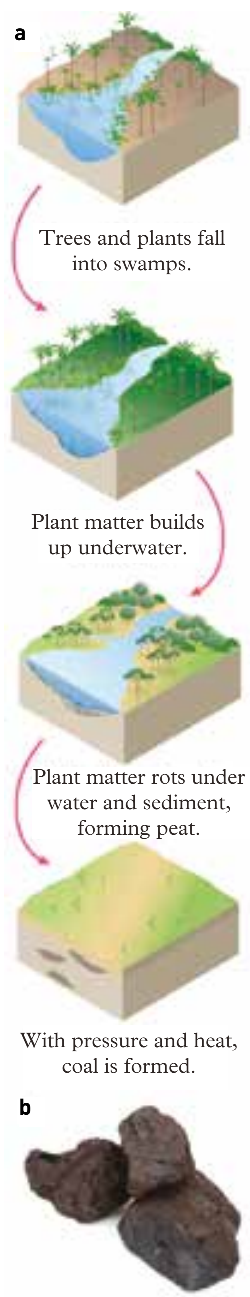


Figure 1 a Formation of fossil fuels; **b** a piece of brown coal

Coal and other fossil fuels

Most of the energy used to produce electricity in Australia comes from coal (a fossil fuel). The energy stored in the coal is converted into electrical energy in a power station. In Victoria, most electricity is generated by power stations in the Latrobe Valley using brown coal. Large black coal resources are found near Sydney and in central and eastern Queensland. Coal is mined in open-cut mines if it is close to the surface, or in underground mines.

Figure 2 Loy Yang Power, in the Latrobe Valley in Victoria, generates approximately one-third of Victoria's electricity.

To produce and provide electricity to homes and businesses, we use a 'big circuit'. This circuit begins with the generators at a **power station**. Electrical energy is transported from the power station to homes, businesses and factories by transmission wires.

Forming fossil fuels

Fossil fuels were formed about 300 million years ago during the Carboniferous period, before the time of the dinosaurs. **Coal** is formed from the remains of trees and other plants that grew in tropical swamps during the Carboniferous period. When the trees and other plants died, they fell into the swamps. Because they were underwater where there was not much oxygen, the dead plants could not rot completely. The partly rotted plant material gradually built up, forming a layer of peat.

Figure 3 An artist's impression of a tropical swamp in the Carboniferous period

Over time, the layers of peat built up and then rocks formed on top of them. The pressure from the rocks on top and the heat from the Earth's crust underneath caused chemical reactions that gradually changed the peat into coal.

When coal is burnt, the chemical energy originally stored in the plants is released. Carbon dioxide and water are also produced in the burning of the coal.

Uranium

Uranium is the most common radioactive element on Earth, and Australia has the world's largest supply. Uranium is a non-renewable resource because it is formed in an exploding star. Uranium gives out energy, called radiation, as it splits into other elements. Many of these other elements are also radioactive. This splitting process continues for a long time until a stable element is formed.

EXPERIMENT

5.4A: What if a muffin was mined in different ways? Go to page **215**.

EXPERIMENT

5.4B: What if a metal was obtained from a mineral? Go to page **216**.

Figure 4 A nuclear power station

Figure 5 Bauxite ore contains aluminium.

Figure 6 This Mount Isa Mine in Queensland produces lead, zinc, copper and silver.

The energy from the splitting of uranium heats water, turning it into steam. The steam drives turbines, which drive generators, just as in a conventional coal-fired power station. Unlike coal-fired power, nuclear power produces hardly any carbon dioxide emissions; however, it does produce radioactive waste that takes a long time to become safe or stable. Too much exposure to radiation can be harmful for humans.

Minerals

Most of the human-made objects we use every day are made from materials that come from the Earth. The process of extracting useful minerals from the Earth is known as mining. **Minerals** are tiny grains or crystals that are the building blocks of rocks. Only a few minerals are found in a pure state, such as gold. Mostly they are combined with other substances and need to be purified before they can be used.

Aluminium, for example, is not found as solid sheets in the ground. It is part of the **ore** called bauxite, which is made of aluminium, oxygen and iron. Ores are materials that contain a lot of a useful minerals mixed in with other substances. Australia is rich in ore deposits and many mines have been in operation for a long time.

How a mineral is mined depends on the location of the ore body. If the ore is on or close to the surface, then open-cut mining is used (see Figure 6). If the ore body is deeper, then underground mining is used and shafts are cut down into the ground to reach the ore. This attempts to protect the surface environment but can be expensive and sometimes dangerous.

mineral
a naturally occurring solid substance with its own chemical composition, structure and properties

ore
a mineral containing a large amount of useful metal

5.4 Check your learning

Remember and understand

1 **Name** three examples of a fossil fuel.
2 **Outline** how coal is formed.
3 **Explain** why minerals are classified as a long-term renewable resource.

Apply and analyse

4 **Compare** (describe the similarities and differences between) energy generation from a nuclear power station and a coal-fired power station.
5 **Contrast** (describe the differences between) a mineral and an ore.

Evaluate and create

6 **Describe** one reason why some people in Australia may be reluctant to agree with establishing a nuclear power station.
7 Arthur wants to design an experiment for a school project to observe how long it takes to for trees to transform into coal.
   a **Evaluate** this idea for an experiment. Do you think it is possible? Why or why not?
   b Suggest one quantitative and one qualitative observation that Arthur could realistically make about coal instead.

power station
a place where energy is converted into electricity

coal
a fossil fuel formed from the remains of trees and plants that grew about 300 million years ago

5.5 Soil is one of our most valuable resources

In this topic, you will learn that:

- soil consists of minerals, gases, liquids, and living and dead organisms
- soil provides the essential nutrients for all plants.

Most people think of soil as dirt, but good soil contains everything plants need to stay alive and grow. Without plants, many of our food sources would not exist. Pick up some soil – you will be holding your life in your hands.

Figure 1 Soil is a valuable resource.

Figure 2 Crops do best in soils that are carefully maintained.

Ingredients of soil

Soils are complex mixtures of many materials, including sand, silt, clay and humus (decomposed plants and animals), as well as various minerals that plants need for healthy growth. Soils are formed when weather breaks down rocks over extremely long periods of time. Sand, silt and clay are all valuable natural resources because they can be mixed for use in construction and supply the essential nutrients for the plants we rely on for food.

Soil for life

Good gardeners know what makes good soil and they add different things to the soil to improve it. They might add compost or animal manure to the soil to improve its organic content. They might add fertiliser, wetting agents or chemicals to change the soil structure. Gardeners also need to monitor the tiny organisms that live in the soil. Many organisms, such as worms, help to keep the soil healthy.

Figure 3 Sand is one of the materials in concrete mix.

Water-loving soil

Many Australians are frustrated by soils that do not let water soak in. How well a soil holds water plays a big part in how well plants will grow in that soil. Water drains easily through sandy soils, but sandy soils dry out easily. Heavy clay soils drain slowly; however, if the water cannot run off, the clay becomes waterlogged and muddy.

Figure 4 Healthy soil grows healthy plants.

Managing soils

When Europeans arrived in Australia, they used the land in very different ways from Aboriginal and Torres Strait Islander peoples. The Europeans cleared the forests and had large numbers of sheep and cattle grazing the grasslands. This meant there were few grasses and plants to absorb the rain. As a result, water stored underground (the water table) rose, bringing salty water closer to the surface. In addition, much topsoil was compacted by

EXPERIMENT
5.5: What if different soils were exposed to water?
Go to page **217**.

Figure 6 Many plants and trees cannot survive in soils that are high in salt.

Figure 5 Additives are used to improve soil.

animal hooves. Land clearing and grazing have caused significant amounts of soil to be washed away in a process called **erosion**. Thankfully, many farmers now practise sustainable agriculture (including rotating crops, limiting the tilling of soil and the careful management of water resources), and land care groups help manage damage to the land.

Figure 7 Planting trees helps prevent further soil erosion.

erosion
the movement of sediment to another area

5.5 Check your learning

Remember and understand

1 **Identify** the basic components of soil.
2 **Describe** how soils are formed.
3 **Define** the term 'erosion'.

Apply and analyse

4 **Outline** (list the main ways) how your life would be affected if there was no soil.
5 **Propose** four ways that a good gardener might improve their soil.
6 **Explain** how clearing all the plants from an area can cause the soil to become salty.

Evaluate and create

7 Clay-based soils prevent water from moving down into the roots, while sandy soils cause water to drain quickly past the roots. **Explain** how the type of soil can affect the growth of a plant.

5.6 Our future depends on careful management of resources

In this topic, you will learn that:

- resources can be sustainably managed
- designers are considering the end of life of a product during the design process
- a circular economy considers how materials can be reused rather than 'used up'.

hybrid
describes a car that uses both petrol and electricity

The large increase in solar panels in Australia has encouraged people to look for ways to use this renewable resource. Electrical energy is being used to power cars and stored in batteries so that houses can have energy overnight. Minerals used in the batteries are becoming increasingly difficult to find. This encourages the producers of the batteries and other electronic devices to consider how the items can be recycled and the materials reused in the future. Planning this before the batteries are made will make it easier to dismantle the electronic waste (e-waste) at the end of its life. This process of extracting and reusing materials is part of a circular economy.

Electric cars

low-emissions vehicles
cars or buses that release very few exhaust gases, including carbon dioxide

In Australia, gas emissions from cars are a major contributor to greenhouse gases. Most car companies have designed one or more **low-emissions vehicles** (LEVs). These cars include hybrids, as well as very efficient petrol and diesel models. Cars with efficient engines use very little fossil fuel.

Hybrid cars use a mix of petrol and electricity. The electric motor works with the petrol engine to reduce fuel consumption and emissions, but it does not eliminate them. Some car manufacturers, such as Tesla, are completely electric.

New types of batteries have made electric vehicles a reality. Although these cars can only run a certain distance before they need to recharge, the battery life is improving all the time.

Figure 1 The Tesla company produces a variety of sustainable electric cars and batteries.

Figure 2 Electric cars can be charged using a normal household power point.

CHALLENGE

5.6: Resources for your future
Go to page **218**.

The largest battery

When the Sun shines on a solar panel, it generates electricity. This electricity is either used by the people in the house, or it is put into the energy grid. The energy grid includes all the high energy wires connecting houses and the electrical substations that control the level of electrical energy houses can use. As the number of solar panels on people's homes increases, the amount of energy in the grid increases. If it becomes too high, it could damage the electrical equipment in the houses. To prevent the energy produced by wind or the Sun from being wasted, some Australian states have large batteries to store the extra energy. If there is a sudden need for energy on a cloudy day, or if there is a sudden drop in wind, the supersized battery can maintain the energy supply.

Figure 3 South Australia's Tesla big battery, officially known as the Hornsdale Power Reserve

Homes of the future

Scientists are collaborating with engineers and architects to make our homes smarter and more energy efficient. Homes of the future will have technology that switches off lights when the Sun comes out, will be built from 'smart materials' (including paint that helps insulate the walls) and will have plants and solar panels on the roof. 'Smart plugs' will monitor electricity use of each appliance, and you could get an alert at school or work if you have left your television on, allowing you to switch it off remotely. Rainwater tanks will be located under the eaves, meaning that the water can flow into toilets and laundry appliances using gravity rather than a pump. Every external window and surface will have a role in the overall efficiency of the home, and surfaces will be designed to store heat during the day and release it at night. Homes will be smaller and will be designed to not only save energy but also generate energy.

Figure 4 Homes of the future will be designed to be 'smarter' and more energy efficient.

5.6 Check your learning

Remember and understand

1. **Describe** a hybrid car.
2. **Explain** why the energy grid needs to cope with different amounts of energy.
3. **Describe** how a supersized battery can be used to stabilise the electricity in the energy grid.
4. **Define** the term 'circular economy'.

Apply and analyse

5. Some people do an audit of all the energy they consume. Suggest one reason why a person might do an energy audit of their home.

Evaluate and create

6. Should a designer consider what will happen to the minerals and parts at the end of a product's life? **Justify** your response.
7. The longest range of current electric cars is 500–550 km. **Evaluate** how easy it would be to use this car in different parts of Australia (by describing the advantages and disadvantages of using an electric car in different parts of Australia and deciding the locations that would benefit from electric cars).

//SCIENCE AS A HUMAN ENDEAVOUR//

5.7 Green jobs will increase in the future

With the importance of renewable energy becoming widely acknowledged, more jobs in the 'green' sector are being created. There are many jobs and industries to choose from. Most of these jobs involve preparing a report on local resources.

Adrian Morphett, Senior Emissions Auditor at Carbon Planet Australia

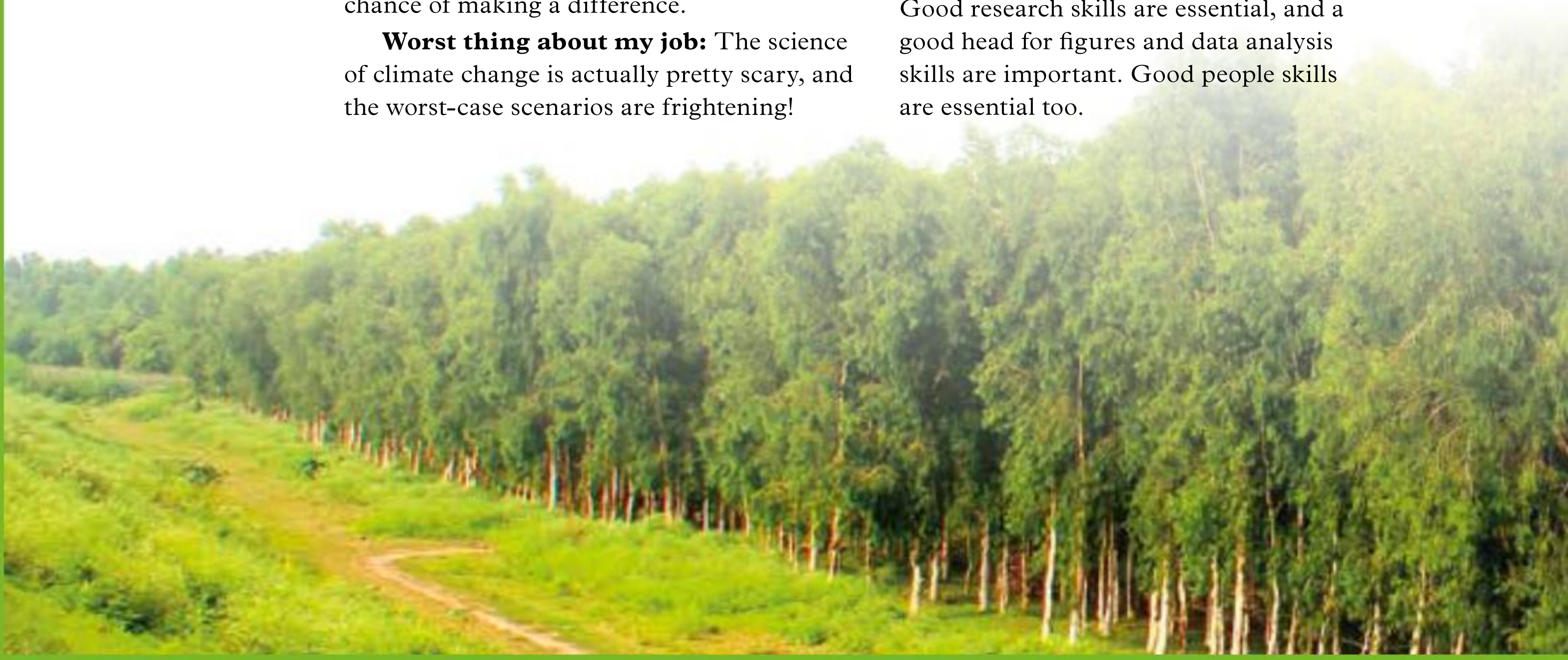
My typical day at work: I work with businesses to help them understand their environmental impacts and then come up with ideas to reduce their emissions. I go out to businesses and do energy audits, where I look for energy and greenhouse gas savings and then tell the business how to make the changes.

Why I love my job: Hopefully it makes a difference. This industry must go well, and be smart, effective and help other businesses drive their emissions down if we are to have a chance of making a difference.

Worst thing about my job: The science of climate change is actually pretty scary, and the worst-case scenarios are frightening!

Figure 1 Adrian Morphett, Senior Emissions Auditor at Carbon Planet Australia

Skills, courses or training people need for this job: You need a degree in something like mechanical engineering. Good research skills are essential, and a good head for figures and data analysis skills are important. Good people skills are essential too.



Why my work and Carbon Planet's work are important: We are working towards reducing greenhouse gas emissions, informing businesses about climate change and what they can do about it.

General salary range for this type of job: $75 000–110 000.

Melissa Supangat, Environmental Engineer at Earth Systems

My typical day at work: I write proposals on energy efficiency projects, usually for developing countries, calculate greenhouse gas emissions of specific sites and research new ways to reduce greenhouse gas emissions.

Why I love my job: I can help other people and companies to cut down their emissions by applying what I learnt in school.

Worst thing about my job: I encounter people who are still sceptical about global warming or who are reluctant to implement emissions reduction strategies because they may affect the money the organisation makes.

Skills, courses or training people need for this job: You need to study something like environmental science, environmental engineering or other areas of engineering (chemical, civil, mechanical, electronic and electrical).

Figure 2 Melissa Supangat, Environmental Engineer at Earth Systems

Why my work and Earth Systems' work are important: We work with other countries, especially developing countries, that are most in need of education about global warming and ways to prevent it.

General salary range for this type of job: $60 000–70 000 (for someone starting out).

5.7 Develop your abilities

Developing a case study

1 **Examine** your local area. This might be within 10 km of your home or further if necessary – you or your teacher will choose the distance. List all of the natural resources you can locate. **Identify** how each resource is used. Present your findings on a large map in the classroom where every student can contribute their research.

2 Focus on one resource from your list that really interests you. Develop a case study for that resource.

A case study looks in detail at:

- the history of the resource
- how it is extracted or used
- what humans use it for
- the impact on the environment of developing that resource
- issues that affect that resource, now and into the future.

3 Present your case study to your class as an oral presentation, a written paper or a poster.

Figure 3 Examining your local area

REVIEW 5

Multiple choice questions

1 **Identify** which of the following is considered a non-renewable resource.
   A wind power
   B solar power
   C nuclear power
   D wave power

2 **Identify** which of the following is considered a renewable resource.
   A metal ore
   B fossil fuel
   C biofuel
   D nuclear power

3 Tidal power is obtained from the:
   A biosphere
   B hydrosphere
   C lithosphere
   D atmosphere.

Short answer questions

Remember and understand

4 **Define** the terms 'easily renewable' and 'long-term renewable'.

5 **Identify** two examples each of:
   a easily renewable resources
   b long-term renewable resources.

6 **Examine** Figure 2 in Topic 5.2 on page 85. Identify a resource that is close to your area. Describe how this resource could be used.

7 **Describe** three different uses of electrical energy.

8 **Describe** the role of a generator in a windmill.

9 **Describe** how coal is used to generate electricity.

10 **Explain** what tidal and wave power are.

11 **Explain** why e-waste should be recycled.

12 **Describe** the factors that can affect the amount of electricity generated by a solar panel.

13 **Describe** the advantages and disadvantages of using uranium as an energy resource.

14 **Define** the term 'geothermal energy'.

Figure 1 What is geothermal energy?

Apply and analyse

15 **Explain** the advantages and disadvantages that electric vehicles have over petrol-driven cars.

16 **Explain** why the terms 'easily renewable' and 'long-term renewable' are more accurate than renewable and non-renewable.

17 **Explain** the advantages and disadvantages of using wind farming for energy production.

18 Suggest one reason why it is important for soil to be 'water-loving'.

19 Look at Table 1 in Topic 5.2 on page 84.
   a **Identify** the percentage of total electricity production in 2007–08 for wind and solar power.
   b **Compare** the 2007–2008 percentage with the 2018 percentage for wind and solar power.

20 **Explain** how soil can become full of salt. Describe how this can affect growing plants.

Evaluate

21 **Explain** why coal, oil and gas are described as fossil fuels.

22 Coal is still widely used for generating electricity. **Explain** why some people are concerned about building new coal-fired power stations.

23 Topic 5.6 talks about homes of the future. Create your own version of a future home that has an energy-efficient design.

24 **Classify** (select one option) a hybrid car as a low-emission vehicle or a zero-emission vehicle. **Justify** your answer (by defining the terms 'low-emission' and 'zero-emission', comparing the hybrid car to these definitions, and deciding which definition best matches the car).

25 The Victorian government is aiming for government-operated buildings to be powered by 100 per cent renewable energy by 2025. **Discuss** the positives of this outcome for the environment.

26 Coal is considered to be a non-renewable fossil fuel. **Discuss** the truth of this statement by presenting arguments for and against.

Social and ethical thinking

27 **Explain** Greenpeace's attitude towards coal and nuclear power. **Describe** the alternatives they support for Australia.

28 **Evaluate** the probability of nuclear power being used in Australia in the future (by defining the term 'nuclear power', describing the advantages and disadvantages of using nuclear power and deciding if the advantages are greater than the disadvantages).

29 Passenger cars, like those your parents drive, are responsible for a significant amount of the population's energy consumption. **Evaluate** the effectiveness of people walking, cycling or taking public transport to reduce their energy consumption (by describing the access to walking and cycling tracks or public transport in your area, and deciding if improvements need to be made to make them more effective).

Figure 2 Cycling to reduce energy consumption

30 Google plans to calculate the most eco-friendly directions via Google Maps. These directions will show you the route that has the least CO_2 impact. This information empowers individuals to act in an environmentally friendly way, when considering the resources involved in their transport.

- a **Identify** how ideas such as this can educate people about their CO_2 consumption.
- b **Explain** what might stop people from taking the eco-friendly route.
- c Research another eco-friendly initiative that has happened in the world, such as bike lanes in Melbourne and Finland.

Critical and creative thinking

31 **Create** a name for your own electricity company. Produce an A4 fact sheet with a diagram of your own electricity company, describing how electricity is produced at your power station. **Justify** your choices (by providing a reason for each choice that you make).

32 Write a letter to the Federal Minister for Resources and Energy, suggesting changes you would like to see happen in Australia. In your letter, include evidence that compares the advantages and disadvantages of the current energy sources being used. **Explain** how your plan will be more sustainable than current uses of our country's energy source.

33 Scientists continuously suggest new ways to reduce reliance on coal. Recently scientists have invented solar-powered roads. These roads are built using hexagon-shaped solar panels, which would store power and deliver it to surrounding homes.

A problem with solar roads is that the solar panels might become covered in dust and be obscured by shadows from traffic.

Propose a different place solar panels could be placed in the community (such as over buildings). **Explain** why you have chosen your location and how this would limit the amount of dust and shadows falling on the solar panels.

Research

34 Choose one of the following topics to research. An important part of your report must be to include references to the 'big picture' – thinking about how your topic relates to the entire planet.

» Clean coal

Explain what is meant by the term 'clean' coal. **Explain** why coal needs to be cleaned. Find out about this technology and how it applies to Australia.

» Trapping carbon

The use of fossil fuels causes the release of CO_2 into the atmosphere. This has been linked to the gradual increase in global temperatures. Many countries are now finding ways to trap CO_2 and store it in a less-destructive way. **Describe** how Australia and other countries are encouraging industry to use fewer fossil fuels. **Describe** one way that carbon can be trapped and stored. **Identify** which countries are using this method of trapping carbon.

» A simple pencil

Examine a normal wooden pencil and determine all of its component parts, including lettering on the side. You could even dismantle the pencil and isolate each part. Next, think of all the steps needed to make the pencil. **Describe** the different components. Identify the source of each component's resources. **Describe** the resources needed to assemble and finish the pencil in the factory. Present your research in a creative way.

Reflect

The table below outlines criteria for successfully understanding Chapter 5 'Resources'. Once you have completed this chapter, reflect on your ability to do the following:

	I can do this.	I cannot do this yet.
Contrast easily renewable and long-term renewable resources, and provide examples of each.	☐	☐ Go back to Topic 5.1 'Resources on Earth take different times to renew'. Page 82
Explain the characteristics of a renewable resource. Describe the ways in which electricity is generated in Australia in terms of easily renewable and long-term renewable resources.	☐	☐ Go back to Topic 5.2 'Easily renewable resources can be quickly replaced'. Page 84
Provide examples of easily renewable resources that can be used to generate electricity.	☐	☐ Go back to Topic 5.3 'Easily renewable resources can be harnessed to provide energy'. Page 86
Explain the characteristics of long-term renewable resources of energy and provide examples. Define the terms fossil fuel, mineral and ore.	☐	☐ Go back to Topic 5.4 'Some resources are limited'. Page 90
Explain why soil is an important resource and provide examples of how it is used.	☐	☐ Go back to Topic 5.5 'Soil is one of our most valuable resources'. Page 92
Explain why it is important to use resources sustainably and provide examples for conserving resources.	☐	☐ Go back to Topic 5.6 'Our future depends on careful management of resources'. Page 94
Describe green jobs and their importance to the planet, using examples.	☐	☐ Go back to Topic 5.7 'Science as a human endeavour: Green jobs will increase in the future'. Page 96

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Quizlet Live
Compete in teams to test your knowledge.

Chapter quiz
Test your understanding of this chapter with one of three chapter quizzes.

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Quizlet Live
Launch a quiz for your students on key concepts in this chapter.

CHAPTER

6

EARTH, SUN AND MOON

How do the Sun and Moon affect the Earth?

6.1 The Earth, Sun and Moon interact with one another

6.2 The Moon reflects the Sun's light

6.3 Seasons are caused by the tilt of the Earth

6.4 Science as a human endeavour: Astronomers explore space

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 balloon was closer to the Earth? Would we notice any difference?

6.1 The Earth, Sun and Moon interact with one another

In this topic, you will learn that:

- 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.

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

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

solar system
the Sun and all the planets, dwarf planets, moons and asteroids that travel around it and each other

orbit
the path a planet follows around the Sun or a star; the path a moon follows around a planet

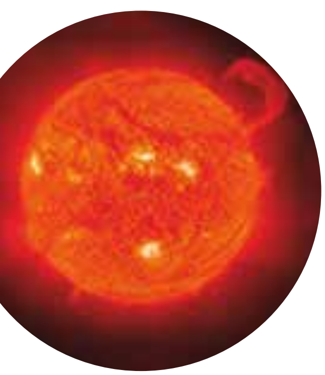

Figure 2 A solar flare is just one indicator of the powerful nuclear reactions happening inside the Sun. Solar flares begin as bright regions and result in explosions (top right).

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 one million 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 the Earth 365.25 days 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 3, 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 3 The half of the Earth facing the Sun experiences day and the half in shadow experiences night.

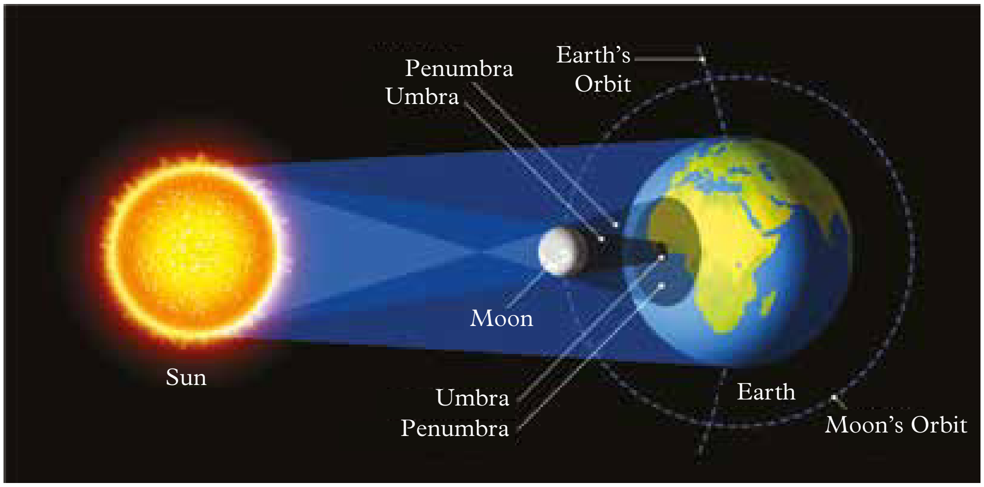

Figure 4 When the Moon is positioned between the Sun and the Earth, it is called a solar eclipse.

Have you ever watched the New Year's Eve celebrations around the world on television? The celebrations in New Zealand are always just before those in Australia. The Earth rotates west to east. We know this because as the Earth spins toward the Sun, we see the Sun rise above the horizon in the eastern sky. Sunset occurs when your part of the Earth rotates away from the Sun. New Zealand is east of Australia, so the Sun rises in their sky first.

Solar eclipse

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**. 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.

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.

You should never look directly into a solar eclipse as 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

6.1 Check your learning

Remember and understand

1 **Define** the terms 'rotation' and 'orbit'.

2 Match 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.

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

4 **Explain** the difference between a total solar eclipse and a partial solar eclipse.

Apply and analyse

5 **Explain** why a person in Victoria and their friend in Darwin do not see exactly the same solar eclipse.

6 Figure 4 shows the shadow caused by the Moon during a solar eclipse. If people living in the region of the darkest shadow (the umbra) experience a total solar eclipse, **describe** the type of eclipse seen by the people living in the penumbra.

Evaluate and create

7 **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.

6.2 The Moon reflects the Sun's light

In this topic, you will learn that:

- 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.

Interactive 6.2
The path of the Sun

phases of the Moon
changes in the shape of the Moon as seen from Earth

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 aeroplane (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.

Figure 1 Phases of the Moon

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.

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

CHALLENGE
6.2: Modelling the phases of the Moon
Go to page **218**.

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. 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.

Figure 3 A time-lapse photograph of a lunar eclipse

Lunar eclipse

A lunar eclipse occurs when the Earth moves between the Moon and the Sun. The Moon passes into the Earth's shadow and appears dark (see Figure 3)

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 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 4 Australian scientists at the Parkes Observatory played a critical role in the Moon landing.

6.2 Check your learning

Remember and understand

1 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.

Apply and analyse

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

3 **Explain** why astronauts can jump higher on the Moon than on Earth.

4 Use Figure 3 to **compare** the waxing and waning of the Moon.

Evaluate and create

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

6.3 Seasons are caused by the tilt of the Earth

In this topic, you will learn that:

- 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.

solstice
either of the times when the Sun is furthest from the equator

equinox
a day when day and night are the same length; occurs twice each year

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 inhabitants 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).

Figure 1 The Wathaurong people who lived between Melbourne and Geelong marked the movement of the Sun with waist-high stones.

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. 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.

Figure 2 Deciduous plants change with the seasons described by Europeans.

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.

The local Aboriginal and Torres Strait Islander peoples have lived in south-eastern

CHALLENGE

6.3: Modelling the seasons
Go to page 219.

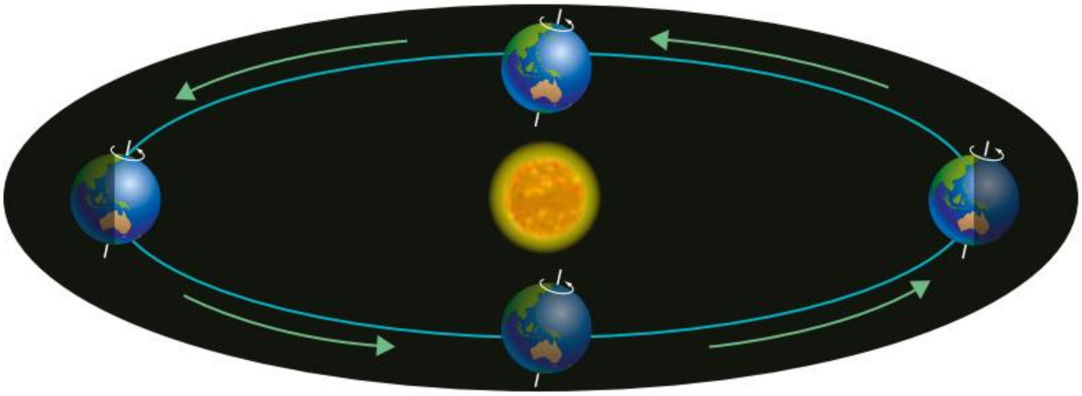

Figure 3 The Earth's rotation and orbit cause day and night, as well as the seasons.

Australia (Victoria) for more than 40 000 years. In the Grampians/Gariwerd regions, there are six seasons that are recognised due to the changing climate, flowering plants and animal behaviour. The season of the eels (Kooyang) occurs from January to February, when the rivers dry and eels can be easily found. The season of the honeybees (Gwangal moronn) has cooler weather and the native honeybees often swarm. Chunnup, or the season of cockatoos (May to June), is the coldest time of year when the yellow-tailed cockatoos seek new feeding grounds. Larneuk (July to August) is the season for nesting birds, while Petyan (September to October) is the season of wildflowers. The final season is Ballambar and occurs when the weather is warm and butterflies fill the air.

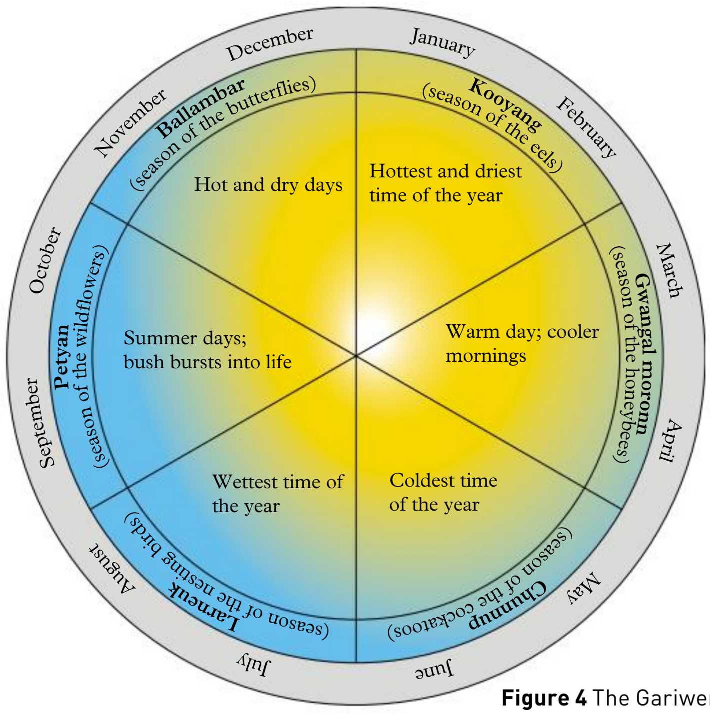

Figure 4 The Gariwerd calendar

6.3 Check your learning

Remember and understand

1 Match the four seasons experienced in Australia with the letters on Figure 5.

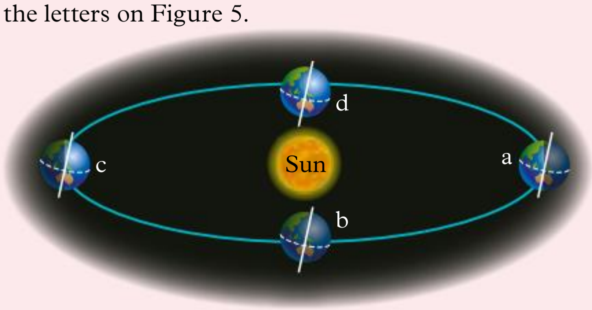

Figure 5 Four seasons in Australia

2 **Identify** the angle of the Earth's rotational tilt away from the Sun.

Apply and analyse

3 **Compare** the winter solstice with the summer solstice.

4 Use the motion of the Earth around the Sun to **explain** why January is hotter than July in Australia.

5 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 six Gariwerd seasons.

Evaluate and create

6 Write a paragraph that **describes** how the Wathaurong people gathered and recorded data over many years before placing stones to represent the solstice and equinox.

//SCIENCE AS A HUMAN ENDEAVOUR//

6.4 Astronomers explore space

It can take many years of travel for a rocket to land on another planet. Scientists therefore need to rely on other methods to learn about space.

Astronomy

Astronomy is one of the oldest sciences, and astronomy and astrology used to be intertwined. Ancient astronomers believed that stars were permanently fixed to a heavenly sphere and never changed. Both European and Aboriginal and Torres Strait Islander 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.

Today it is still impossible to send a space probe to galaxies, stars or even gas clouds that are millions of light-years from Earth, and yet we know so much about these bodies. To view stars and galaxies, we use instruments such as telescopes and spectroscopes.

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

Figure 1 The Antennae galaxies are about 45 million light-years away from the Milky Way.

Telescopes

Telescopes have been used since the 17th 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 An early example of a telescope to view the stars

THE HUBBLE SPACE TELESCOPE

Our atmosphere distorts and blocks the light coming from planets and stars. In 1990, NASA launched the Hubble Space Telescope. The Hubble Space Telescope orbits the Earth at 569 km above our atmosphere. This has given scientists a view of our universe far beyond what any ground-based telescope can because different forms of electromagnetic radiation, such as gamma rays, X-rays and **ultraviolet radiation**, are available for observation.

From the images beamed back to Earth from the Hubble Space Telescope, astronomers have been able to make an enormous number of new observations. The Hubble Space Telescope is available for observations by people throughout the international astronomical community, and information and observations

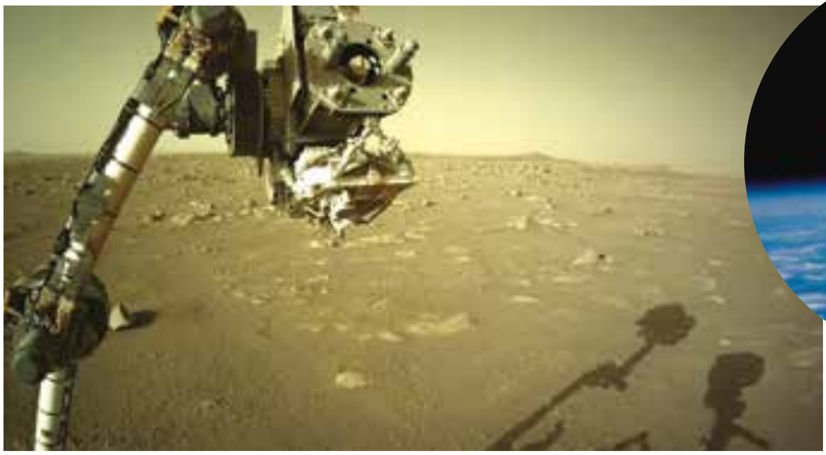

Figure 3 NASA's Mars *Perseverance* rover took this photo using one of its onboard cameras.

Figure 4 The Hubble Space Telescope orbiting the Earth

Figure 5 An artist's impression of the *New Horizons* space probe during its Pluto flyby

are available worldwide. Astronomers have been able to see galaxies developing and have estimated the age of the universe more accurately at around 13–14 billion years.

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'. These have since been followed with *Curiosity*, which has been exploring Mars since August 2012.

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. Analysis by 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 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.

6.4 Develop your abilities

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. Since then, there has been an ongoing set of negotiations between the different countries over who has the right to claim the land on the Moon and other celestial bodies. 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 should face if your rocket crashed into a city on another country.
5 **Compare** your opinions with others in your class.

REVIEW 6

Multiple choice questions

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 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 is a description of a geocentric understanding of the solar system.
- A The Earth orbits the Sun.
- B The planets orbit the Sun.
- C The Sun orbits the Earth.
- D The Earth orbits the Moon.

Short answer questions

Remember and understand

4 **Explain** what causes day and night.

5 **Identify** the name for one revolution of the Earth around the Sun.

6 **Identify** the season in Norway when it is summer in Australia.

7 **Identify** the name of the event that occurs when the Moon totally blocks the light from the Sun.

8 **Describe** how the Sun affects day and night and seasons at the Antarctic.

9 **Describe** the six seasons identified by the Gariwerd people.

10 **Compare** solar eclipse and lunar eclipse.

11 **Describe** the phases of the Moon.

12 Look at Figure 1, which shows a total eclipse of the Sun as it would be seen in the middle of the day from the Earth. Draw and label a diagram to illustrate a:
- a solar eclipse
- b lunar eclipse.

Figure 1 Total eclipse of the Sun

Apply and analyse

13 **Compare** astronomy and astrology.

14 **Explain** why February 29 only occurs every four years.

15 Figure 2 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.

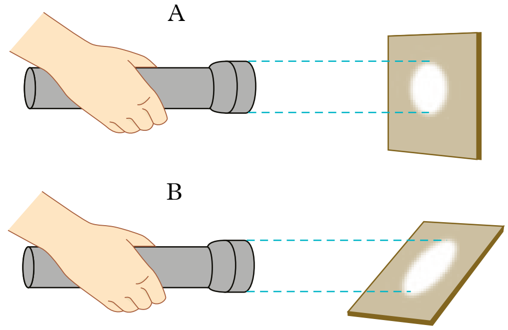

Figure 2 How the seasons occur

Evaluate

16 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. **Explain** why the exact time of the New Year changes from one year to the next.

17 A student claims that the Moon is a mini Sun that shines at night. **Explain** why they are incorrect.

18 **Explain** the purpose of the Hubble Space Telescope.

19 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.

Social and ethical thinking

20 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).

21 Many early European settlers claimed that Aboriginal and Torres Strait Islander peoples did not use any of the sciences. **Provide** evidence that refutes this claim.

22 Scientists are continuously exploring space, including Mars. **Discuss** the ethical implications of finding life on one of these planets.

Critical and creative thinking

23 **Identify** when and where the next solar total eclipse will occur.

24 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.

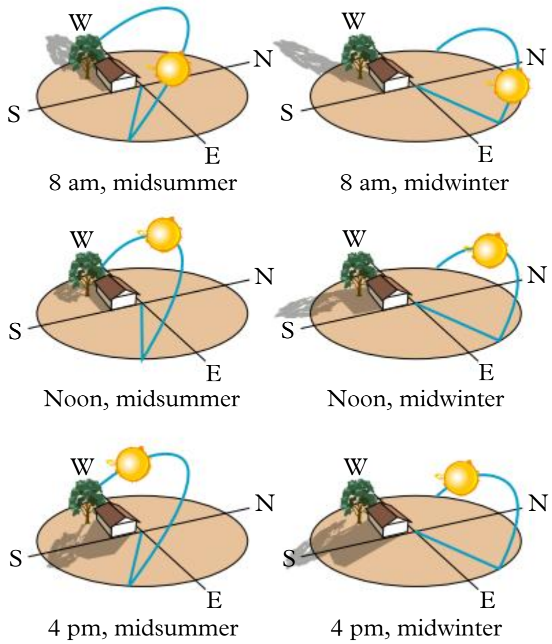

Figure 3 The path of the Sun across the sky in winter and summer

25 Find data for the sunrise and sunset times over seven days in summer and winter. From this information, **calculate** the length of the day and the length of the night. Present your findings in a table. **Describe** what you notice about the lengths of the days and nights for each season. **Explain** why this difference occurs.

26 In May 2021 there was a lunar eclipse visible in Australia. The Moon was referred to as a 'supermoon'. Research what the criteria for a supermoon are, and **explain** why a lunar eclipse may be a supermoon.

Figure 4 The Moon

Research

27 Choose one of the following topics on which to conduct further research. Present your findings in a format that best fits the information you have found and understandings you have formed.

» Search for extraterrestrial intelligence

Astronomers are also involved in a Search for Extraterrestrial Intelligence (SETI). Find out what instruments that 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.

» *Galileo* space probe

Investigate the path of the *Galileo* space probe. To reach Jupiter more quickly, it used the gravitational field of some planets. Describe how this was done.

» 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.

» 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? The far side of the Moon has been seen. Find out who saw it and how, how it compares with the side we know from Earth, and what future missions to the Moon might be tasked with.

Reflect

The table below outlines a list of things you should be able to do by the end of Chapter 6 'Earth, Sun and Moon'. Once you have completed this chapter, use the table to reflect on your ability to complete each task.

	I can do this.	I cannot do this yet.
Describe the differences between a total and partial solar eclipse. Explain how the length of a day and a year relates to the movement of the Earth.	☐	☐ Go back to Topic 6.1 'The Earth, Sun and Moon interact with one other'. Page 102
Identify and describe the phases of the moon and lunar eclipse. Contrast a solar and a lunar eclipse.	☐	☐ Go back to Topic 6.2 'The Moon reflects the Sun's light'. Page 104
Define the terms 'solstice' and 'equinox'. Explain how seasons are related to the position of the Sun and Earth.	☐	☐ Go back to Topic 6.3 'Seasons are caused by the tilt of the Earth'. Page 106
Identify examples that show how advances in technology and scientific knowledge have improved our understanding of the solar system.	☐	☐ Go back to Topic 6.4 'Science as a human endeavour: Astronomers explore space'. Page 108

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Launch a quiz for your students on key concepts in this chapter.

CHAPTER 7

CLASSIFICATION

What type of animal am I?

7.1 Classification organises our world

7.2 Living organisms have characteristics in common

7.3 Classification keys are visual tools

7.4 The classification system continues to change

7.5 All organisms can be divided into five kingdoms

7.6 Animals that have no skeleton are called invertebrates

7.7 Vertebrates can be organised into five classes

7.8 Plants can be classified according to their characteristics

7.9 The first Australian scientists classified their environment

7.10 Science as a human endeavour: Taxonomists classify new species

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 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?

7.1 Classification organises our world

In this topic, you will learn that:

- classification systems help scientists to communicate
- scientists identify all living things through scientific names
- Carolus Linnaeus developed the modern Linnaean classification system.

Figure 1 The mature pine tree looks very different from its sapling.

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 (Figure 2). 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.

a

b

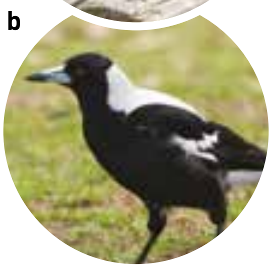


Figure 2 a The American magpie *Pica hudsonia* and **b** the Australian magpie *Cracticus tibicen*

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 17th century the early classification systems used a hierarchy list of names, starting with large general groups (such as plants and animals) and then dividing 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.

Figure 4 Part of Linnaeus's classification system

Aristotle (384–322 BCE) sent his students out to gather local samples and stories. He ordered the samples and stories from least important (rocks) to the most important (wild animals, men, kings, fallen angels, angels and God).

Andrea Cesalpino (1519–1603) suggested classifying plants into groups according to their trunks and fruits.

John Ray (1627–1705) suggested that organisms needed to be observed over the whole of their lifespans.

Augustus Quirinus Rivinus (1652–1723) and Joseph Pitton de Tournefort (1656–1708) suggested using a hierarchy of names. Each organism had a long Latin name that described the characteristics of each level of the hierarchy.

Figure 3 A timeline of classification

CHALLENGE
7.1: Department store classification
Go to page **220**.

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.

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 5 Peacock spiders are unique to Australia.

Figure 6 The rainforests of Brazil contain many undiscovered plant species.

7.1 Check your learning

Remember and understand

1 **Explain** why Linnaeus simplified the classification system used by previous scientists.

2 Suggest two reasons why scientists still classify organisms today.

Apply and analyse

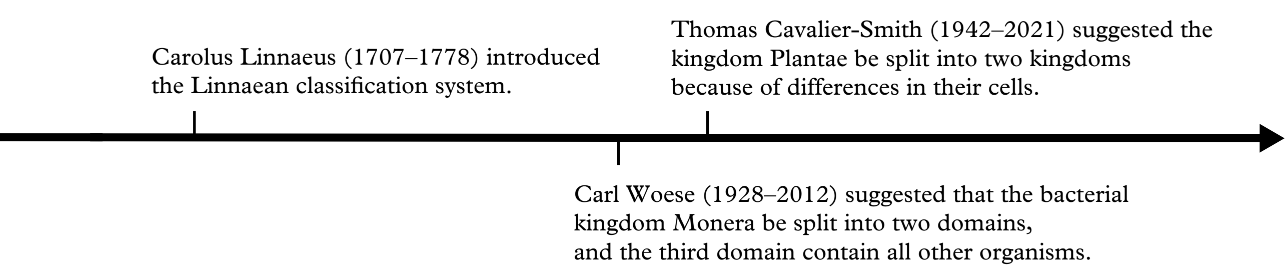
3 **Explain** why it would be difficult to classify frogs and tadpoles using the early methods of classification.

Evaluate and create

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.

Figure 7 Carolus Linnaeus



7.2 Living organisms have characteristics in common

Interactive 7.2
Classifying living, non-living and dead

In this topic, you will learn that:

- 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 micro-organisms 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 environment (the sudden brush of leaves or

Figure 5 Living things respond to change.

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,

Figure 6 The axolotl has gills to exchange gases with its environment.

such as fish and the axolotl (Figure 6), have gills. 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.

7.2 Check your learning

Remember and understand

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.

Apply and analyse

3 **Consider** the following things: eucalyptus tree, water, paper, robot, leather belt, wombat, roast chicken, plastic chair.

a With a partner or by yourself, decide whether each of the items meets the requirements to be classified as a living thing.

b **Classify** each thing as living, non-living or dead.

4 **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).

5 **Contrast** non-living and dead things.

Evaluate and create

6 Use the characteristics of a living thing to **describe** a bushfire.

7 **Identify** a bushfire as either alive or dead. **Justify** your answer (by describing the characteristics of a living thing and comparing it with the properties of a fire).

7.3 Classification keys are visual tools

In this topic, you will learn that:

- 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 7.3
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.

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

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.

Figure 1 Dr Redback's family

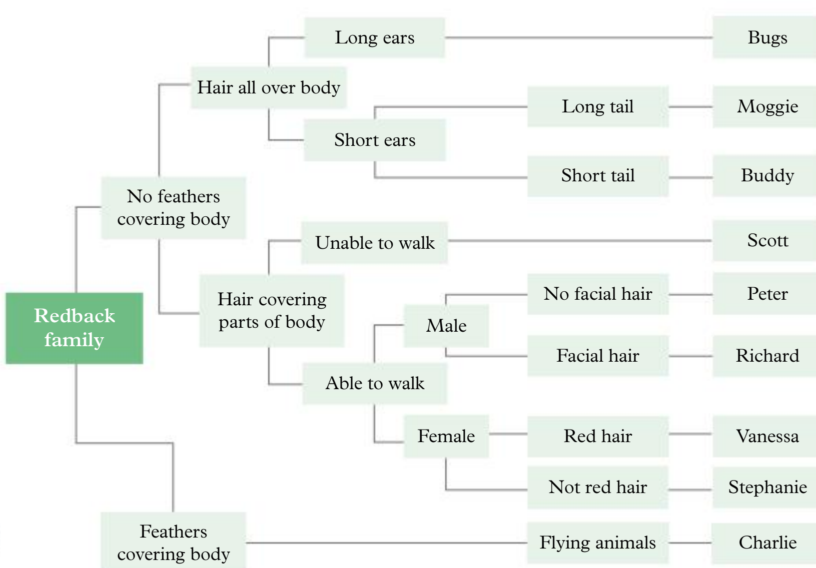


Figure 2 A dichotomous key for Dr Redback's family

CHALLENGE

7.3: Dichotomous key
Go to page 221.

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

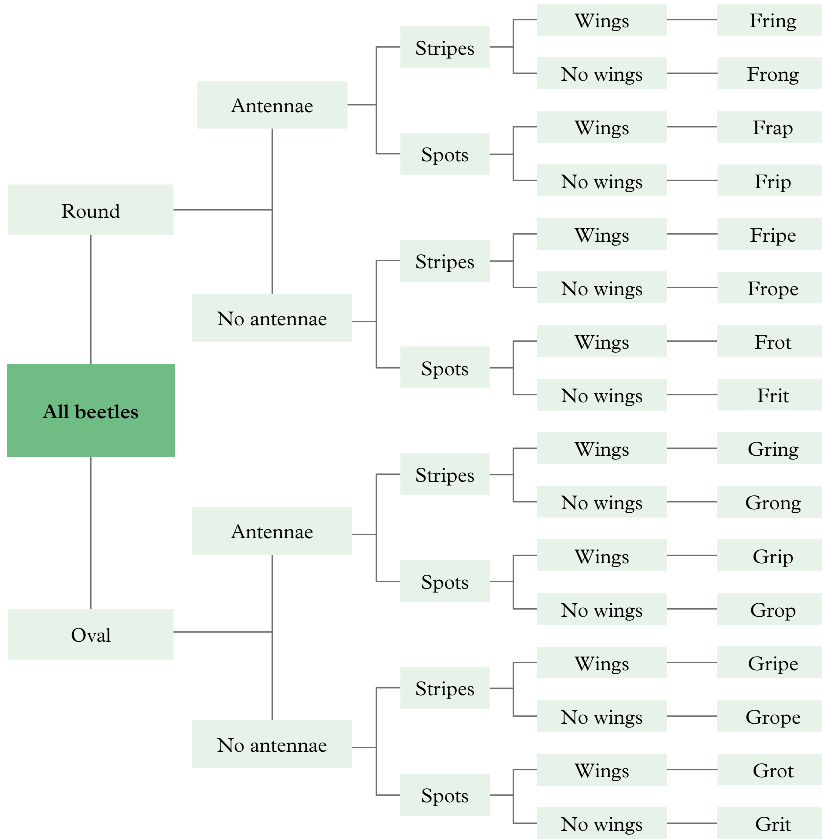


Figure 4 A dichotomous key to help identify 16 different types of beetles

7.3 Check your learning

Remember and understand

1 **Define** the term 'dichotomous key'.

2 **Explain** why it is called 'dichotomous'.

3 **Define** the term 'classify'.

Apply and analyse

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
- **d** a broken leg
- **e** sitting on the ground

Evaluate and create

5 Draw 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** and **name** the four beetles in Figure 5.
- **b** Draw a simple sketch of the following:
  - **i** frope beetle
  - **ii** gring beetle
  - **iii** gripe beetle
  - **iv** frong beetle.

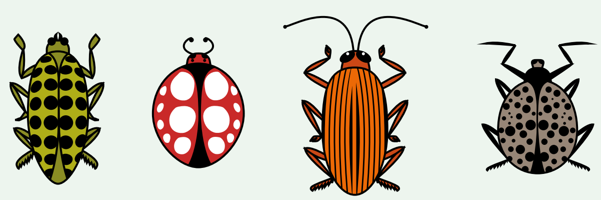


Figure 5 Four types of beetles

7.4 The classification system continues to change

In this topic, you will learn that:

- 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?

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

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'.)

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 is* 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.

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

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 2 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
7.4: Can you understand scientific names?
Go to page **222**.

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 each other. 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.

Figure 3 *Musa sapientum* is the Linnaean name for a banana.

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 are currently testing this idea 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 each other, and can breed in natural conditions and produce fertile young

7.4 Check your learning

Remember and understand

1 **Identify** the person responsible for the naming system that is still used today to name living things.

2 **Identify** 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.

3 **Explain** how you would know whether two organisms are the same species.

Apply and analyse

4 Select three species of animal. For each animal:
   a **describe** its appearance
   b **identify** its common and scientific names.

5 **Identify** which two organisms would be most alike: *Felis catus, Canis familiaris* or *Felis bieti*.

Evaluate and create

6 **Discuss** how an understanding of genetic material changed the classification of bacteria.

7.5 All organisms can be divided into five kingdoms

In this topic, you will learn that:

- 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 7.5
Kingdoms

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**. Many living things, such as bacteria, consist of only one cell. These are single-celled or **unicellular** organisms.

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 the first big group called kingdoms.

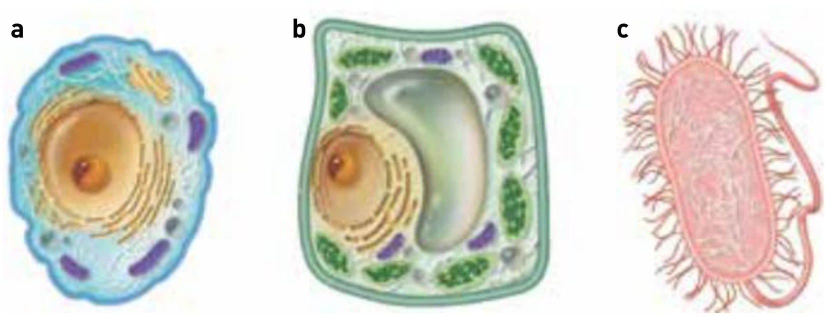


Figure 1 a Simple animal, **b** plant cell, and **c** bacterial cell

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

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.

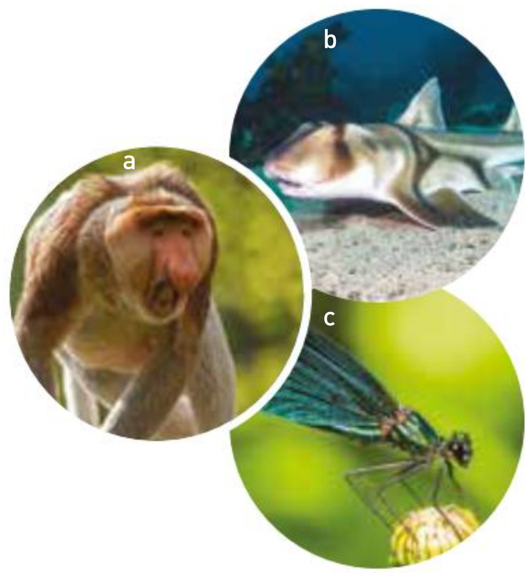


Figure 2 Kingdom Animalia: **a** the proboscis monkey (*Nasalis larvatus*); **b** the Port Jackson shark (*Heterodontus portusjacksoni*); and **c** the damselfly (*Calopteryx virgo*)

Kingdom Plantae

Plants include trees, vines, bushes, ferns, mosses, weeds and grasses. They all gain energy by converting the energy from sunlight into food (autotrophs). They are multicellular and their cells have a cell wall around the outside of the cell, as well as a nucleus inside the cell. Botanists are the scientists who study the plant kingdom.

CHALLENGE
7.5: Classifying living things
Go to page **223**.

Kingdom Fungi

Kingdom Fungi includes mushrooms, toadstools, yeasts, puffballs, moulds and truffles. 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.

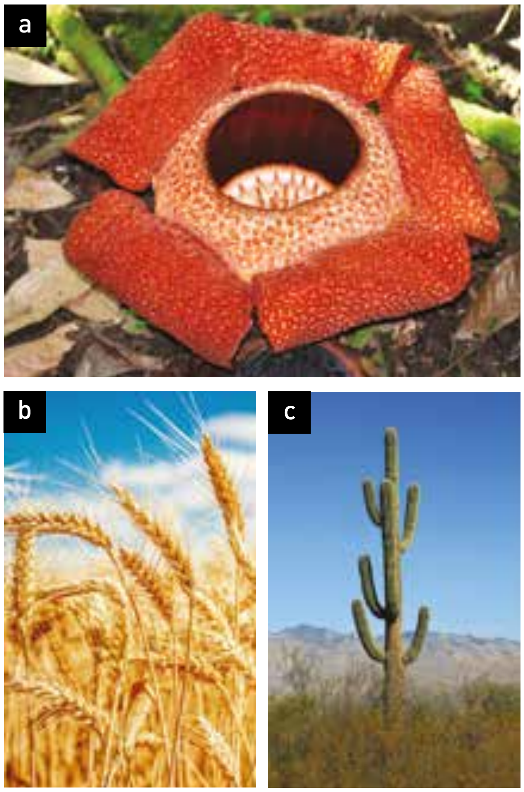


Figure 3 Kingdom Plantae: **a** The smelliest plant, the *Rafflesia*, is found in South-East Asia (its flower can measure up to 90 cm across and weigh about 11 kg, and it gives off a rotten meat odour when it blossoms to attract insects); **b** wheat; **c** cactus

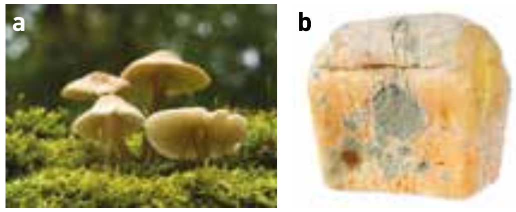


Figure 4 Kingdom Fungi: **a** mushrooms; **b** mould

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. 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. Microbiologists are the scientists who study micro-organisms 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.

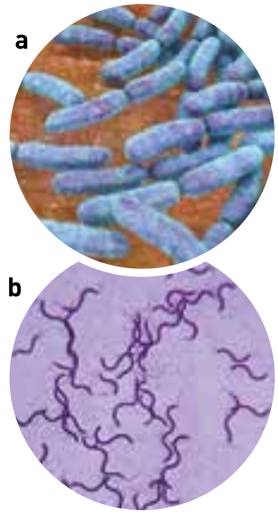


Figure 5 Kingdom Monera, as seen under a microscope: **a** *Lactobacillus casei*; **b** *Spirillum volutans*

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

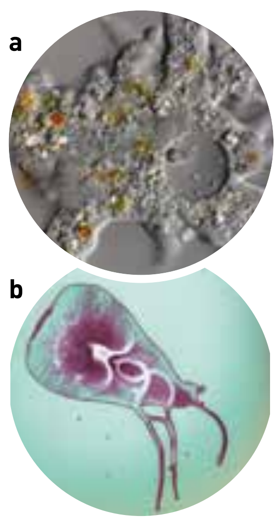


Figure 6 Kingdom Protista, as seen under a microscope: **a** amoeba; **b** *Giardia lamblia*

7.5 Check your learning

Remember and understand

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.

Apply and analyse

5. **Contrast** a protist with a bacterium.
6. **Compare** the cells in Kingdom Plantae with those in Kingdom Fungi.

Evaluate and create

7. **Explain** why the invention of the microscope was important to our understanding of living things.

7.6 Animals that have no skeleton are called invertebrates

In this topic, you will learn that:

- 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 7.6A Squid dissection

Video 7.6B Classification confusion

endoskeleton
an internal skeleton

vertebrate
an organism that has an endoskeleton

exoskeleton
an external skeleton

invertebrate
having 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, 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
7.6A: Dissecting skeletons
Go to page **224**.

CHALLENGE
7.6B: Identifying invertebrates
Go to page **225**.

Arthropods

Arthropods have segmented bodies, paired and jointed legs and exoskeleton. Examples include insects, spiders, centipedes and scorpions.

Poriferans

Poriferans have spongy bodies with holes and are found in water, attached to rocks. Examples include breadcrumb sponges and glass sponges.

Molluscs

Molluscs have soft bodies and usually have a protective shell. Examples include snails, octopuses and oysters.

Cnidarians

Cnidarians have soft, hollow bodies with tentacles and live in water. Examples include coral, sea jellies and anemones.

Nematodes, platyhelminths and annelids

Nematodes, platyhelminths and annelids have soft, long bodies and can be segmented, flat or round. Examples include leeches, tapeworms and flatworms.

Echinoderms

Echinoderms have rough, spiny skin, their arms radiate from the centre of the body, and are found in the sea. Examples include sea urchins, sea cucumbers and brittle star.

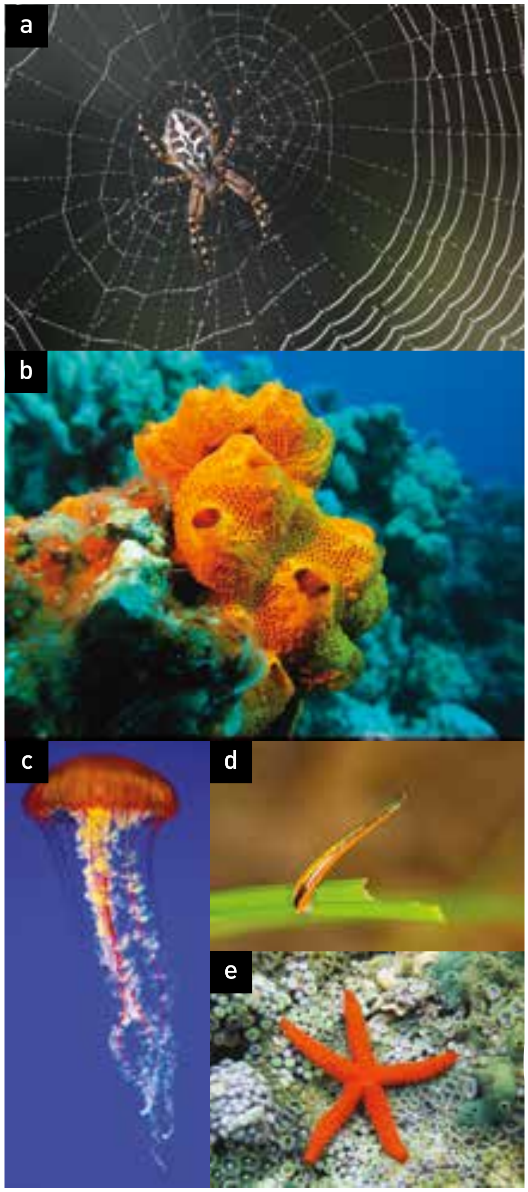


Figure 2 Some commonly found invertebrate phyla: **a** spider, **b** breadcrumb sponge, **c** jellyfish, **d** leech and **e** starfish

Figure 3 A snail is a mollusc.

7.6 Check your learning

Remember and understand

1 Animals are divided into two main groups.
   a **Identify** the names of the groups.
   b **Describe** the main characteristic of each group.
2 **Identify** the percentage of animals that are invertebrates.
3 **Identify** two examples of animals with an exoskeleton.
4 **Identify** two examples of animals with no skeleton at all.

Apply and 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 with: a non-spongy soft body, with many tentacles around the mouth.

Evaluate and create

7 Eighty per cent of animals on the Earth are arthropods.
   a **Comment on** the characteristic that 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.

7.7 Vertebrates can be organised into five classes

Video 7.7
Classes of vertebrates

In this topic, you will learn that:

- 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.

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.

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.

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. All animals in this class lay eggs with a hard shell.

Class Reptilia

The skin of reptiles, such as snakes 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.

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.

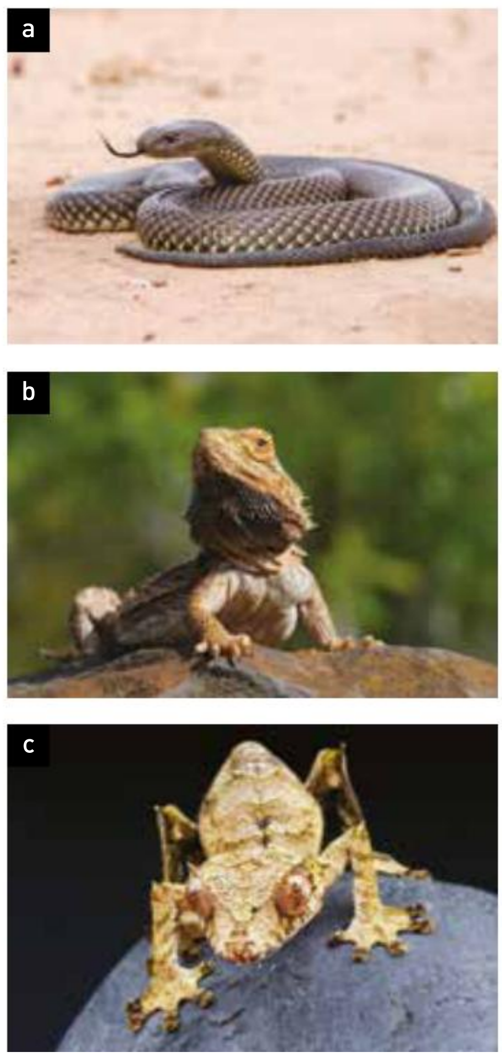


Figure 2 Class Reptilia: **a** a king brown snake; **b** a bearded dragon; **c** a gecko

CHALLENGE
7.7: Who are the vertebrates?
Go to page **225**.

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.

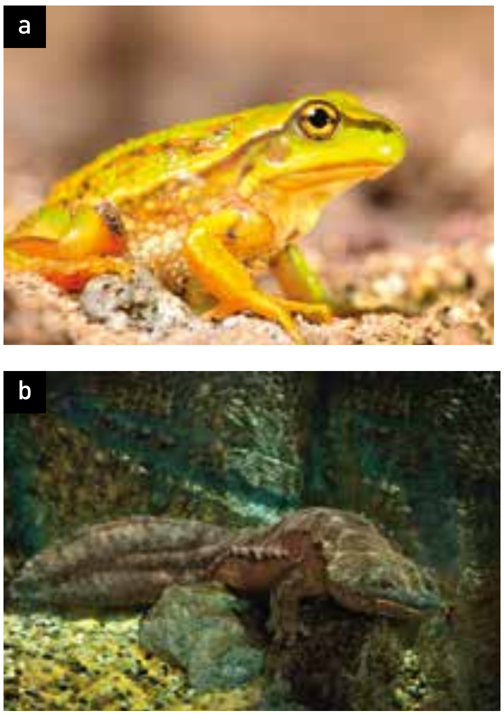


Figure 3 Class Amphibia: **a** a growling grass frog; **b** a Chinese giant salamander

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.

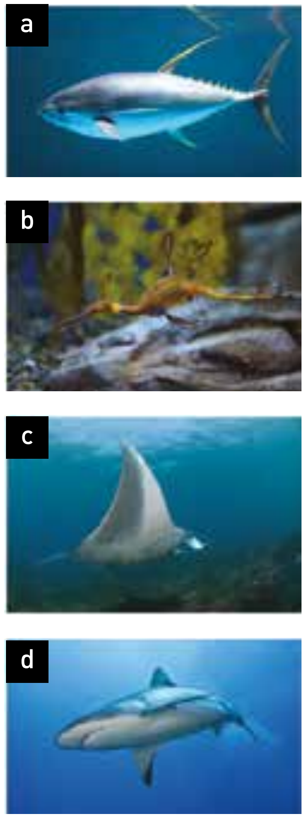


Figure 4 Class Pisces: **a** tuna; **b** weedy seadragon; **c** manta ray; **d** reef shark

Figure 5 Despite having a hard outer shell, turtles and tortoises have a hard backbone with a nerve cord running through it.

7.7 Check your learning

Remember and understand

1 **Describe** the main characteristics of mammals.

Apply and analyse

2 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).

3 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.

4 **Contrast** the appearance of a placental mammal when it is born with that of monotremes and marsupials.

Evaluate and create

5 Seals have fins like fish and live on the land and in the water like amphibians.
   a Research 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.

6 The vertebrates have five classes: Mammalia, Reptilia, Amphibia, Aves and Pisces. **Determine** the common names for each of these classes.

Figure 6 A cockatoo is part of Class Aves.

7.8 Plants can be classified according to their characteristics

In this topic, you will learn that:

- 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

pollination
the transfer of pollen to a stigma, ovule, flower or plant to allow fertilisation

vascular tissue
in a plant, tube-like structures that transport water from the roots to the leaves

Figure 2 Mosses and liverworts can absorb water through all parts of their structure.

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 Not all plants germinate from seeds. Ferns produce spores instead.

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.

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. 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.

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 3 Some plants use flowers or cones to produce seeds.

CHALLENGE
7.8: Identifying plants
Go to page **226**.

Figure 4 A dicot flower

Figure 5 The number of petals on a monocot flower is always a multiple of three.

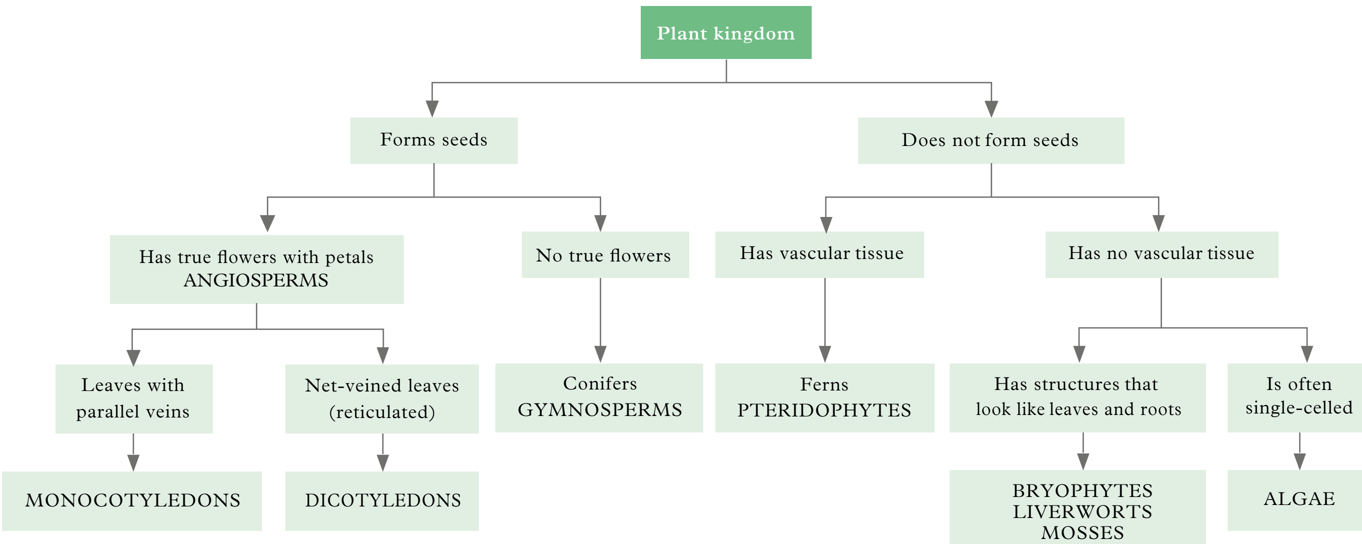


Figure 6 A sample plant key

7.8 Check your learning

Remember and understand

1 Use the key in Figure 6 to **identify** the kinds of plants below.
  a ferns
  b mosses
2 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
3 **Describe** how mosses, ferns and conifers reproduce.
4 **Contrast** vascular and non-vascular plants.

Apply and analyse

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. **Classify** the plant phylum I belong to.

Evaluate and create

6 Locate a plant in your garden.
  a Draw a labelled diagram of the plant.
  b **Identify** the features that could be used to classify your plant.
  c **Propose** at least one feature that is not currently present that would help you to classify your plant.

7.9 The first Australian scientists classified their environment

In this topic, you will learn that:

- Australia is the second driest continent in the world and the driest inhabited continent
- despite the harsh climate, Australia is home to hundreds of different organisms
- Aboriginal and Torres Strait Islander peoples were the first to identify and 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.

Reptiles are particularly suited to the *Puli* environment. The thorny devil (Ngiyari, pronounced 'Nee-ah-ree'), like all reptiles, uses the environment to regulate its temperature. When it wants to become active, it lies in the Sun; but, when it is too hot outside, it hides in a burrow until the heat has passed.

Figure 1 *Puti* habitat

Figure 2 *Pila* habitat

Figure 3 *Puli* habitat

One fascinating thing the thorny devil can do is drink water with its feet! It places its feet in a puddle and water moves up by capillary action along grooves in its skin to the corner of its mouth.

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

7.9 Check your learning

Remember and understand

1 Find out about 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.

2 Early Europeans left this environment because they could not survive. Suggest why they struggled to find food and water here.

Apply and analyse

3 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.

4 **Explain** why the Anangu people devised a system of classification for the natural habitats around them.

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 One of the classes of vertebrate is Amphibia. **Consider** 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.

7 **Identify** one reason why the bilby's pouch is rear facing.

8 **Explain** why monotremes would find it difficult to breed in arid environments.

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.

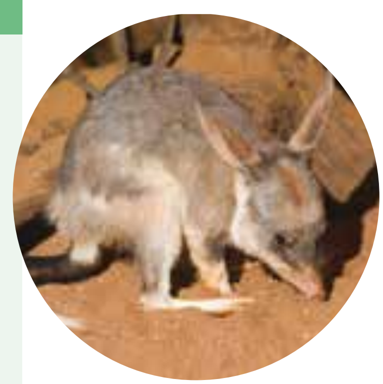


Figure 5 A bilby

//SCIENCE AS A HUMAN ENDEAVOUR//

7.10 Taxonomists classify new species

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 in order 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.

type specimen the specimen used for naming and describing a new species

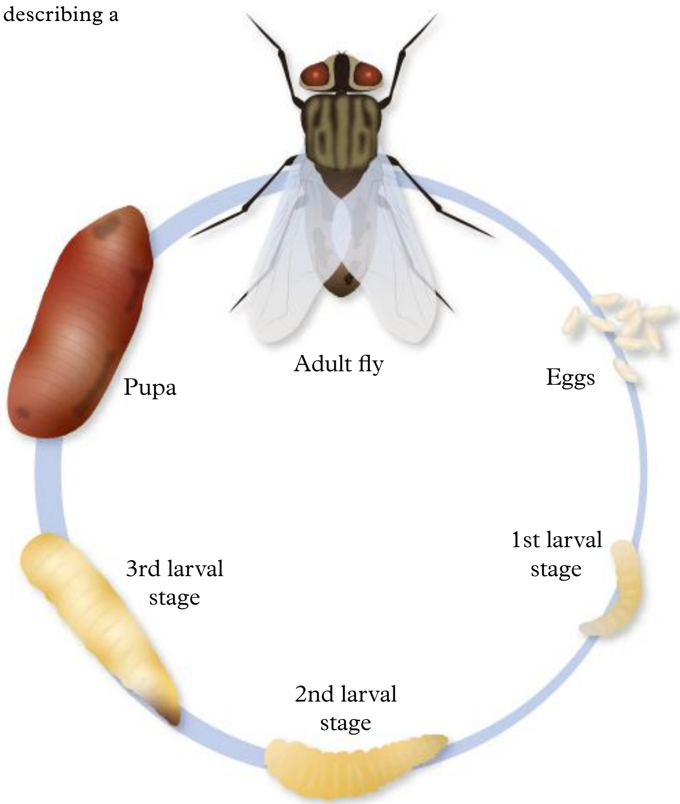


Figure 1 The fly has many different stages.

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. 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 includes 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

Figure 3 This leafcutter bee was collected in Canberra in 1934 and is stored in the Australian National Insect Collection.

process, you could not use your own name. 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.

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.

7.10 Develop your abilities

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?

REVIEW 7

Multiple choice questions

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** which of the following adaptations may help an animal survive in the snow.
  A a long tongue
  B big ears
  C a long neck
  D thick fur

Short answer questions

Remember and understand

4 **Define** the term 'organism'.

5 **Identify** an example of plants moving by themselves.

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 **Contrast** vertebrates and invertebrates by writing a definition for each.

9 List the five main classes of vertebrates and give an example of each.

10 List two phyla of invertebrates and give an example of each.

11 **Describe** an example of a plant that has the following characteristic:
  a spores
  b seeds
  c vascular tissues.

12 **Identify** an example of a plant that does not have flowers with petals. Describe the alternative structure that allows the plant to produce seeds.

13 **Contrast** a monocotyledon leaf and a dicotyledon leaf.

Apply and analyse

14 '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.

15 Imagine that an unknown organism was discovered during a space mission and brought back to Earth. Briefly **outline** two different methods that scientists could use to decide whether it was living or non-living.

16 Refer to Figure 1 in Topic 7.3 showing Dr Redback's family. **Explain** 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.

17 Place the items in the following list in 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?

Evaluate and create

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.

Table 2 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) Animals without a backbone (invertebrates)	64 788 1 359 365	80 500 6 755 830	0.7 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 numberof species	1 885 230	>10 927 630	100

Source: Chapman, A. D. 2009, *Numbers of Living Species in Australia and the World*, 2nd edn.

19 Look at Table 2, 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).

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 1 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.

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 **Explain** why the invention of the microscope was important to the development of the classification system.

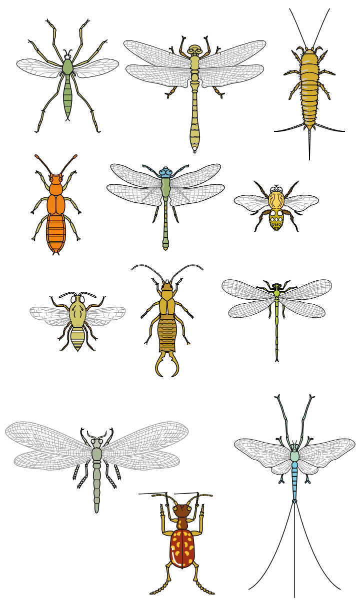


Figure 2 Collection of insects

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 un familiar 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

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).

1. Draw six different versions of these organisms.
2. Create a dichotomous key for these six new organisms so that you can describe them to other scientists.
3. Name each of the groups at the bottom of your key.
4. Assuming they are a type of bacterium, identify the kingdom to which they would belong.

Reflect

The table below outlines a list of things you should be able to do by the end of Chapter 7 'Classification'. Once you have completed this chapter, use the table to reflect on your ability to complete each task.

	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 7.1 'Classification organises our world'. Page 114
Describe the eight characteristics shared by all living things using the acronym MR N GREWW.	☐	☐ Go back to Topic 7.2 'Living organisms have characteristics in common'. Page 116
Construct and read tabular and dichotomous keys for classification.	☐	☐ Go back to Topic 7.3 'Classification keys are visual tools'. Page 118
Describe the two-part naming system devised by Linnaeus. Identify the genus and species of an organism from its two-part name.	☐	☐ Go back to Topic 7.4 'The classification system continues to change'. Page 120
Explain that life on Earth is classified by scientists into five kingdoms. Explain that classification is based on cell structure, what organisms look like and how they absorb nutrients.	☐	☐ Go back to Topic 7.5 'All organisms can be divided into five kingdoms'. Page 122
Explain that invertebrates have either an exoskeleton or no skeleton. Identify the six main phyla of invertebrates.	☐	☐ Go back to Topic 7.6 'Animals that have no skeleton are called invertebrates'. Page 124
Distinguish between vertebrates and invertebrates. Identify the five classes of vertebrates and use the terms 'endotherm' and 'ectotherm' to group them.	☐	☐ Go back to Topic 7.7 'Vertebrates can be organised into five classes'. Page 126
Explain that plants are generally classified according to how they transport nutrients or how they reproduce.	☐	☐ Go back to Topic 7.8 'Plants can be classified according to their characteristics'. Page 128
Describe some of the ways in which Aboriginal and Torres Strait Islander peoples classified and communicated their understanding of local flora and fauna.	☐	☐ Go back to Topic 7.9 'The first Australian scientists classified their environment'. Page 130
Describe the role of taxonomists in identifying and naming new species. Evaluate the reliability of primary and secondary data.	☐	☐ Go back to Topic 7.10 ' Science as a human endeavour: Taxonomists classify new species'. Page 132

CHAPTER

8

INTERACTIONS BETWEEN ORGANISMS

How do we affect plants and animals?

What if?

Food webs for humans

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 our partner draw the animal you describe?
2. Now draw an animal while your partner tries to guess what 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?

8.1 All organisms are interdependent

Interactive 8.1
Food chains

In this topic, you will learn that:

- 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 chain
a diagram that shows who eats whom in an ecosystem, and how nutrients and energy are passed on

producer
a plant or plant-like organism that is at the start of food chain because it produces its own food, usually using sunlight

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. The wolf spider provides the centipede with energy to grow and move.

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 to get the energy they need in order 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 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 and a primary consumer. In this food web, the snail is only a primary consumer because it only eats producers.

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.

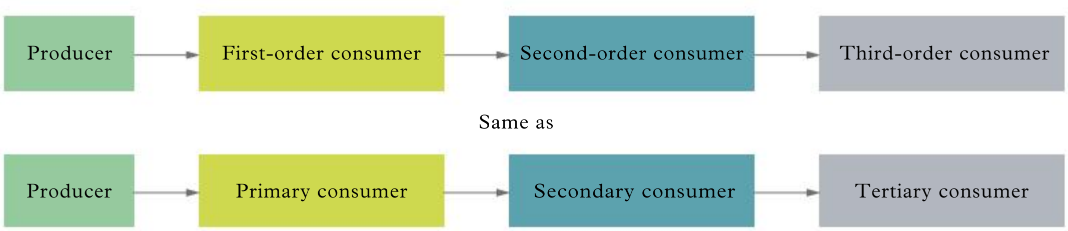


Figure 3 A food chain starts with producers, such as plants, and moves through several orders of consumers.

Figure 2 An example of a backyard food chain

CHALLENGE
8.1: Studying food webs
Go to page 226.

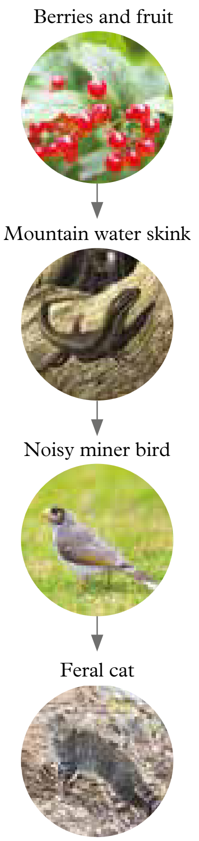


Figure 4 A food chain showing the feral cat as a third-order consumer

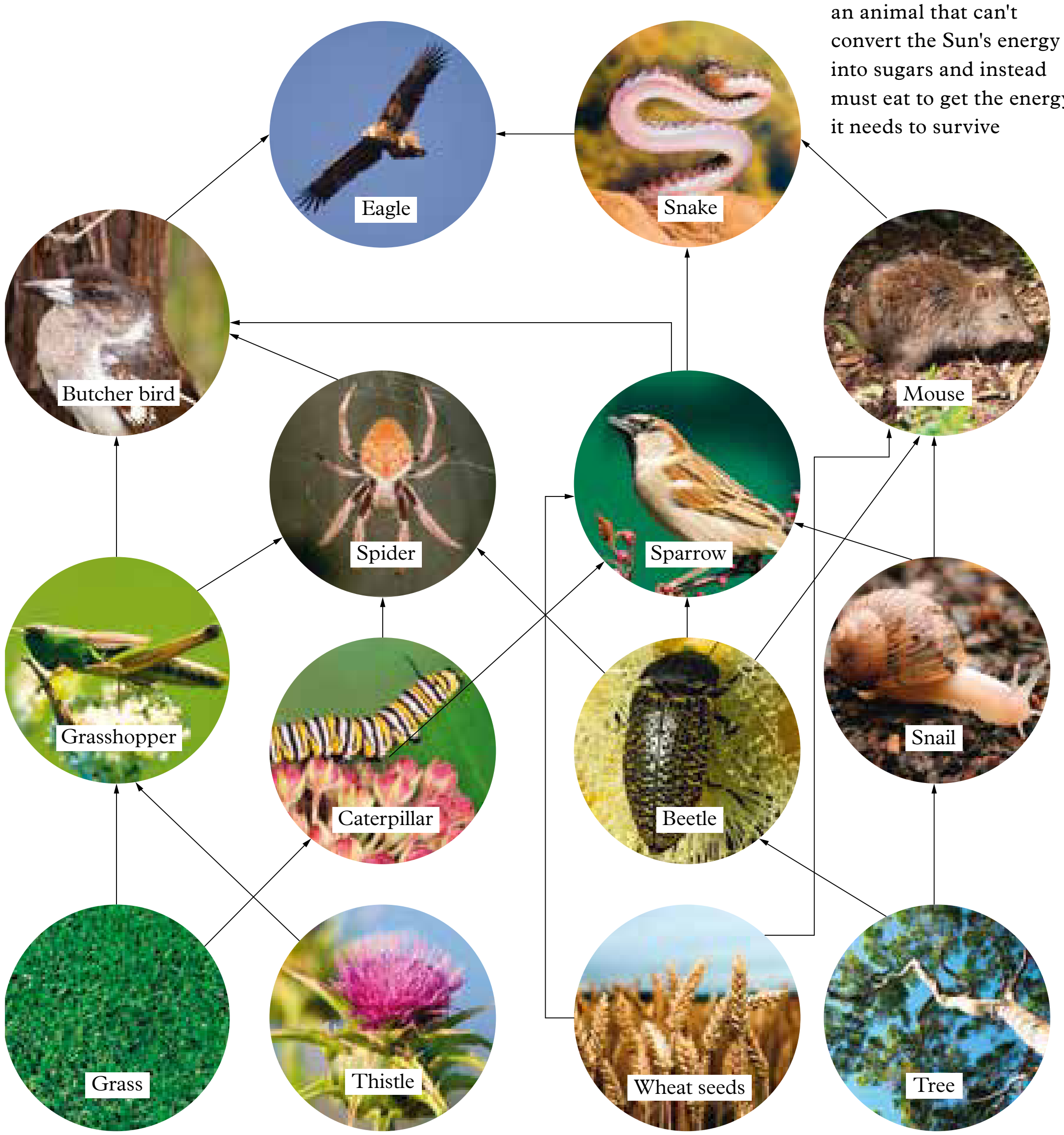


Figure 5 A food web shows the extended relationships between various organisms.

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

8.1 Check your learning

Remember and understand

1 **Identify** where producer plants get their energy.

2 **Contrast** food chains and food webs.

3 **Describe** how the direction of arrows in a food chain is decided.

Apply and analyse

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.

5 Imagine that you were asked to find out how many different types of animals lived in your backyard or local park. **Explain** how you would go about finding this out. (HINT: Would it be possible to individually count them all?)

Evaluate and create

6 **Construct** your own food web of organisms that you would find in the local park. Correctly **identify** the producer and all the consumers.

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

8.2 All organisms have a role in an ecosystem

In this topic, you will learn that:

- 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 many humans, are called omnivores
- decomposers obtain energy by breaking down dead organisms.

Video 8.2
Ants and caterpillars

herbivore
an animal that eats only plants

carnivore
an animal that eats other animals

omnivore
an animal that eats both plants and animals

decomposer
an organism that gains nutrients by breaking down dead organisms into simpler nutrients

There are many different organisms in an ecosystem that are interdependent on one another. That is, they each have a role in maintaining the survival of one another. While plants convert the energy from the Sun into new leaves and stems, the **herbivores** that eat the plants use this stored energy to move and grow. **Carnivores** such as dogs eat the herbivores as part of their meat diet. Most humans eat both meat and plants, making them **omnivores.**

Insects, birds and bats pollinate plants

Plants and animals interact in their search for food. Bees and other insects, as well as some birds and bats, transfer pollen from plant to plant. While stopping at a flower for a sip of nectar, the animals or insects get dusted with pollen.

When the animals or insects fly to another flower of the same or similar species, some of that pollen brushes off and the pollinated flowers are then able to produce seeds. Pollination is important not only for wild plants but also for crop plants. More than 70 per cent of plant species worldwide, including fruits and vegetables, are pollinated by animals, insects or birds.

Some organisms decompose organic matter

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 prevents the dead organisms from piling up. Instead, the nutrients stored in the dead organisms are used for energy by the decomposers. When another organism eats a decomposer, the nutrients once again become part of the food chain. The nutrients that pass through the decomposers as waste end up in the soil in simpler forms. Plant roots can then absorb the nutrients and the cycle starts again. Imagine what life would be like without decomposers!

Figure 1 Some plants use bats to transfer pollen from one plant to another.

Figure 2 Insects, such as bees, are important pollinators of plants.

Figure 3 Decomposers recycle important nutrients in an ecosystem.

CHALLENGE

8.2A: Exploring leaf litter
Go to page **227**.

EXPERIMENT

8.2B: What if water was filtered through a pot with native grasses?
Go to page **227**.

Figure 4 Forested water catchment areas are vital for keeping Melbourne's water supplies clean.

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 Mushrooms (fungi) are decomposers. They get the nutrients they need by feeding on dead things, such as rotting logs.

8.2 Check your learning

Remember and understand

1 **Identify** the name used for animals that eat both meat and plants.

2 **Describe** one of the consequences that may occur if decomposers did not exist.

3 List three organisms that act as decomposers.

Apply and analyse

4 **Describe** how you could be affected if all bees died as a result of infection.

5 We get the energy we need by eating other living organisms. **Identify** the source of energy for the following organisms.

a producers

b first-order consumers

c decomposers

Evaluate and create

6 Design an organism for a food web. **Identify** the role of your organism in a food web.

7 **Describe** the factors that could affect the survival of your organism in a bush environment.

8.3 Food webs can be disrupted

In this topic, you will learn that:

- most food webs have a balance between producers and consumers
- introduced organisms can disrupt the balance between organisms in an environment
- the loss of organisms can affect the survival of other species in an environment.

Video 8.3
Food webs can be disrupted

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. This balance can be disrupted by the introduction of new organisms or the removal of predators.

Introduced organisms

Introduced organisms may become pests or weeds. An example of the accidental introduction of a pest into Victoria is the European wasp, otherwise known as a 'picnicker's nightmare'. The first European wasp in Australia was recorded in Tasmania in 1959, and the wasps are now common there. For the mainland, the European wasp was reported in Melbourne in 1977 and in Sydney in 1978. The wasps may have originally arrived in wood shipments; however, with few predators, no diseases and no competition for nest sites, their numbers have increased quickly.

Figure 1 European wasps are a threat to many Australian ecosystems.

So, how does this affect a food web? If it had no predators and no competition for nest sites, the European wasp may have been able to fit in without affecting other organisms in an ecosystem. However, every living thing consumes resources to live, and the European wasp is no exception. By the end of an Australian summer, each European wasp nest may contain several thousand individuals. The larvae complete their development after being fed a diet that consists mainly of other insects that the workers catch and kill. This means that each European wasp nest has the potential to remove several thousand native insects – often the caterpillars of moths and butterflies – from the environment. This can have a devastating effect on local animal populations.

Unfortunately, European wasps do not just consider other insects as food – they also attempt to steal food from picnics and barbecues. This, along with a very painful sting, can make outdoor eating in summer a very difficult task!

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.

Amphibians feed mainly on insects and other invertebrates. It has been estimated that a single population of approximately 1000 frogs could consume almost 5 million invertebrates in 1 year. Amphibians are significant predators of small invertebrates and abundant prey for larger predators.

EXPERIMENT

8.3: What if the effectiveness of pollinators were reduced?
Go to page **228**.

Figure 2 The corroboree frog is one of Australia's many endangered species.

Figure 3 Predatory fish, such as tuna, are in decline.

In areas of the world where numbers of amphibians have declined, there has been an increase in invertebrate pests that damage crops and carry human diseases.

Fish numbers in the oceans are dwindling as the demand for seafood continues to increase across the globe. Larger predatory fish, such as tuna, marlin and salmon, are often the most prized, but their numbers are declining, allowing smaller species to thrive in their absence.

Commercial fishing boats with large nets (Figure 4) are removing large numbers of many species, including 'by-catch' – fish and other marine species that are not wanted but are left to die before being thrown back.

Figure 4 Commercial fishing boats using nets catch many species, including some that are not wanted (by-catch).

8.3 Check your learning

Remember and understand

1 **Identify** an example of an introduced animal.

2 **Define** the term 'indicator species'.

Apply and analyse

3 **Explain** why some animals and plants can become pests when introduced into Australia.

4 Organism numbers can decrease for a number of reasons, including loss of habitat, climate change and direct removal by humans. **Describe** an example of each.

Evaluate and create

5 One way to control an introduced organism is to introduce another organism that eats it. This is called biological control. When it works, it can be very effective. However, sometimes things can go wrong and the organism introduced to help the problem becomes a much bigger problem. Research the introduction of the prickly pear moth or caterpillar, and the cane toad. **Analyse** the effectiveness of this introduction (by identifying the organisms involved, how they were affected by the introduction and deciding whether the advantages of introducing the prickly pear moth and cane toad outweighed the disadvantages).

6 In winter and spring after it has rained, the most common animal to find outside is the humble garden snail. Do not be fooled by this animal – it is probably the most successful of all introduced animals and causes millions of dollars of damage to food production each year. Research the introduction of the garden snail. **Analyse** the effectiveness of this introduction.

8.4 Human activity can affect local habitats

In this topic, you will learn that:

- organisms constantly have an impact on the environment around them (their habitat)
- people make both positive and negative changes to the environment
- understanding the impacts is the first step to reducing and reversing them.

Animals use resources such as food and water and, in turn, provide resources for other organisms. Humans are certainly no exception. Human impact on environments is considerable because of our population numbers and our ability to manipulate our surroundings to suit our needs. Many environmental changes so far have been detrimental.

Figure 1 Only one specimen of the Hastings River mouse has ever been found. It is considered extinct due to changes brought about by European settlement.

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.

Since European settlement, over 44 per cent of Australia's original bushland has been cleared. 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.

Land degradation

Human activities have led to a degradation of the physical environment. Soil erosion is a major problem caused by the clearing of land for agriculture. In ecosystems with many trees, the soil is stabilised by a dense mat of plant roots. Its surface is covered by a layer of leaf litter, which protects the soil surface from erosion by wind and water. Water from rainfall is quickly absorbed through the top layers of soil.

Once land is cleared of trees for agriculture, there is little to protect the soil from the action of wind and water. Grazing by animals with hard hooves, such as cattle, compacts the soil. This slows water absorption 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 2 In 1983, large amounts of topsoil were carried across Melbourne and into the Southern Ocean as a result of wind erosion.

CHALLENGE

8.4: Calculating your ecological footprint
Go to page **229**.

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.

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 3 Urban sprawl around many of Australia's capital cities is on the increase.

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 4 Alpine areas are reducing as the climate changes.

8.4 Check your learning

Remember and understand

1 **Define** the term 'urban sprawl'.

2 Suggest four things you can do to reduce the damage you may do to the environment (your ecological footprint).

Apply and analyse

3 The 'Australian dream' is a term that has been used to describe the wish of many Australians to own a home on a block of land in the suburbs. **Describe** the problems that are caused by many Australians 'living this dream'.

4 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. **Explain** how a warming climate could affect the mountain pygmy possum's ability to hibernate and survive each winter.

Evaluate and create

5 **Create** a two-column table with the headings 'Problems' and 'Solutions'. In the 'Problems' column, list the things that people do that affect wildlife, such as building homes and roads, and cutting down trees. In the 'Solutions' column, **propose** some solutions to each problem.

Figure 5 A mountain pygmy possum

//SCIENCE AS A HUMAN ENDEAVOUR//

8.5 Environments can be responsibly managed

Changes to food webs and habitats have had a significant impact on the number and variety of organisms in an environment (the **biodiversity**). We can do a lot to reduce our demands on the natural environment. Calculation of your ecological footprint will give you some ideas about how you can reduce your demands on the environment.

biodiversity
the variety of life; the different plants, animals and micro-organisms and the ecosystems they live in

green wedges
non-urban areas around metropolitan areas

Corridors of green

Many cities have set aside permanent 'green belts' as part of their future planning. **Green wedges** are the non-urban areas of metropolitan areas. These active, living areas protect a city's open spaces and natural areas from overdevelopment. In some places they are important habitats for animals such as the platypus. They are also important for tourism and recreation. Some green wedges include areas with high heritage value for local Aboriginal and Torres Strait Islander peoples.

Figure 1 Green wedges around a city provide 'green lungs' for the city.

Figure 2 Bushland near urban areas is important for native animals and people.

Green corridors allow animals to move from one location to another, through farmland or developed areas. Young animals can use these corridors to move out and form their own territories. Areas of bush with a range of vegetation are linked to provide a safe and suitable area for native birds and animals to live in and travel through. These areas benefit farmers by acting as windbreaks and shelter belts. Pest problems are significantly reduced because of the increased number of predatory birds and insects that thrive in these native habitats.

Backyard stepping stones

Maintenance of biodiversity is essential to the health and functioning of ecosystems. The greater the variety of different organism species, the more likely each species will be able to survive. If one species was removed from an environment, such as spraying herbicides that kill some plants, this will kill the homes and shelters for some animals and remove a food supply for other animals. The ways organisms interact in an ecosystem are complex and losing even one key species could have a devastating effect on the whole ecosystem.

At one time, conservation was thought to be the responsibility of politicians and scientists. Today, individuals and local communities also work to help conserve the biodiversity of ecosystems.

There are also many cultural reasons for maintaining biodiversity. Native plants, animals and ecosystems are part of our cultural identity. People value such areas for relaxation and enjoyment, as well as outdoor activities such as bushwalking and bird watching. The Australian natural landscape has featured in films, literature and photographs. Our natural environment is a major international tourist attraction. Aboriginal and Torres Strait Islander peoples are the traditional custodians of Australian land, and it is of immense value and importance to them.

CHALLENGE
8.5: Making a biosphere
Go to page **230**.

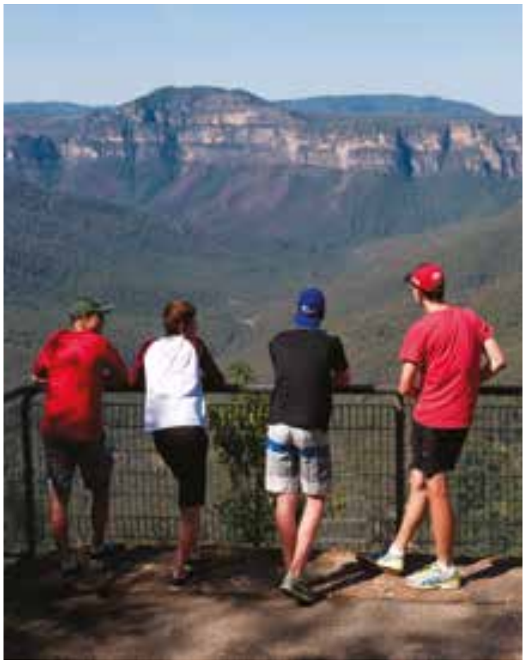


Figure 3 The Australian bush is a wonderful place to relax.

If you have access to a piece of land, no matter how large or small, such as your backyard, school grounds or local reserve, you have the power to conserve a part of our biodiversity. The secret is learning how to share our living space with the plants and animals around us.

Figure 4 We are only one of many species on the planet.

Microbes and gene banks

Conserving biodiversity is not only about habitats and food webs. Some scientists are working to preserve biodiversity by storing seeds and micro-organisms. Keeping samples of as many organisms (or parts of organisms) as possible provide us with options for the future. Seeds are a great way to preserve plant information because they can be stored for many years without being destroyed. Many micro-organisms are resilient and can be dried or frozen indefinitely and then revived when needed.

Figure 5
The Svalbard Seed Vault was established in 2008 on a remote island in the Arctic Circle. When it started, 100 million seeds from 100 different countries were shipped there.

8.5 Develop your abilities

Conducting surveys

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.

1 Complete the following survey to **determine** your personal 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 (10) Most (7.5) Half (5) Some (2.5) None (0)
   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) None (0)
   6 The size of the car is:
   Large (20) Medium (10) Small (5) None (0)
   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)

2 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 with your results.

3 **Evaluate** how you could reduce your impact on the environment by:
   a considering alternative responses to the questions
   b **determining** how these changes will impact on you and your family
   c making a judgement as a result of considering whether the changes are more or less important than the impact.

8.6 Modern land managers use traditional Aboriginal and Torres Strait Islander techniques

As the oldest continuous culture on Earth, Aboriginal and Torres Strait Islander peoples are custodians of the land. This means their role is that of a caretaker, responsible for looking after the land and passing it on to the next generation in a better state.

Figure 1 Foods of the Australian bush

Aboriginal and Torres Strait Islander peoples across Australia come from diverse cultures that are influenced by the varied climate and landscapes they live in. The environment influences what people use for clothing, what they eat and what they use for building materials. The seasons influence activities or sources of food.

Responsible cultivation

People of the Kulin Nation use their understanding of the seasons and features of their environment to live sustainably. A large variety of food is eaten to ensure no one thing is overeaten, thus preventing extinction. Stories warn of overusing the land. When hunting bird eggs, some eggs are always left to hatch. This ensures that there will always be more birds (and therefore eggs) in the future.

The hunting techniques ensure a balance is maintained. The Ngemba, Ualarai and Wailan Peoples of the Brewarrina region used the inspiration of the pelican beak to build a series of small stone dams along 1.8 km of the Barwon River to trap fish. The traditional name given to the fish traps by the Ngemba people is Baiame's Ngunnhu (pronounced 'By-ah-mee's noon-oo'). This trapped the large mature fish, while letting the smaller breeding stock fish escape and so giving them a chance to breed. This ensured that the river environment (and the other organisms that rely on it) was not affected by the Aboriginal and Torres Strait Islander peoples' activities.

The early European settlers to the Colac region of Australia described the soil as being protected by mosses and lichens. This made it an ideal region for growing edible lilies, mosses and yams. The ground cover was destroyed by the introduction of sheep, goats, pigs and cattle. As a result, the vegetation was flattened and the ground became hard, and the rain ran directly into rivers causing them to flood. Modern farmers are learning from the traditional approach and are starting to reintroduce ground cover plants to maintain the moisture in the soil.

Firestick farming

Aboriginal and Torres Strait Islander peoples are respectful of fire and work with it to ensure the continuing health of plant and animal life. It is also a key component of traditional ceremonies, and is used for healing. The first Europeans to arrive described the bush as being very open – coaches were able to be driven between the trees. This was largely due to Aboriginal and Torres Strait Islander peoples' ritual use of fire to regularly burn off the bush in cooler times. The regular small fires prevented the build-up of dense eucalypts and scrub. This meant there was plenty of sunlight for new shoots to grow.

CHALLENGE

8.6: Looking at eucalypt adaptations
Go to page **230**.

Figure 2 This 1817 painting is titled *Aboriginals Using Fire to Hunt Kangaroos*.

The Wurundjeri people of the Kulin Nation in Victoria use firestick farming. Their technique involves creating a controlled patchwork (mosaic) of burnt land and unburnt land, which helps plant life to grow and encourages the herbivores, such as kangaroos, to live in that habitat. It also makes the herbivores easier to hunt.

Learning from the past

Many land managers are learning the skill of firestick farming. They are researching local plants and how flammable they are. At the Top End of Australia, it has been found that woodland areas should be burnt in the early dry season every two to three years. This removes the thick undergrowth and allows time for new plant growth, which, in turn, attracts animals to grow and breed. In contrast, rainforest areas should not be burnt at all. Instead, they need areas of clear land around them to act as firebreaks, protecting the plants and animals that live there. The goal is to develop the skills that Aboriginal and Torres Strait Islander peoples used for thousands of years and therefore learn to manage the landscape effectively.

Figure 3 The shoots on these eucalypt trees have sprouted from epicormic buds under their bark after a fire.

Figure 4 Modern land managers are now using traditional methods of regenerating bushlands.

8.6 Develop your abilities

Conducting interviews

Aboriginal and Torres Strait Islander peoples have a tradition of using oral stories to pass on their history and culture. These stories have passed on important environmental information to modern scientists. For example, elders of the Boonwurrung people have shared the knowledge for generations that Port Phillip Bay – *Nerm* – was once a kangaroo hunting ground. This land was lost around 7000 years ago when the sea levels rose.

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. Use the following points to plan an interview:

1. A good practice is to get approval to ask questions, and approval to record and take photos if you intend to.
2. Find a good location: people are often more comfortable in a familiar place and will therefore tell better stories.
3. 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?
4. 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.
5. 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.
6. Record the answers: this can be as simple as a voice or video recording on your phone. Alternatively, you could write down the answers; however, this can interrupt the flow of conversation.
7. 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.

REVIEW 8

Multiple choice questions

1 **Identify** the organism in Figure 1 that is the producer in the food chain.

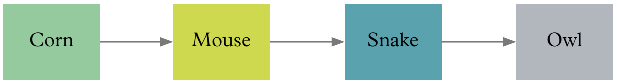


Figure 1 A food chain

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

Short answer questions

Remember and understand

4 True or false?
a School ovals and nature strips are known as green wedges.
b A frog pond in your backyard or school could help protect the diversity of frogs in your area.
c The world's population is decreasing.

5 **Contrast** a producer and a consumer.

6 **Define** the term 'ecological footprint'.

7 **Compare** a herbivore and a carnivore.

8 **Explain** the term 'firestick farming'.

9 **Describe** two ways that Aboriginal and Torres Strait Islander peoples made sure they did not disrupt the environment too much.

10 **Compare** a vegetarian (someone who does not eat meat) and a herbivore.

11 **Describe** how building a frog pond in your school grounds would impact the local wildlife.

Figure 2 A well-designed backyard pond can provide a habitat for frogs.

12 **Define** the term 'biodiversity'.

13 **Explain** why it is important to have biodiversity in an environment.

Apply and analyse

14 Compile a list of introduced organisms that can be found around your school.
a Choose one organism from the list. Try to find out how the organism came to your area.
b **Explain** how this organism interferes with the local ecosystem.

15 With a growing population, humans are requiring more from the land around them. **Consider** three ways in which humans are changing the environment.

Evaluate

16 **Consider** the food web in Figure 5 of Topic 8.1 (page 139). If the mouse were to become locally extinct, list the possible changes that might occur to the other organisms in the food web.

17 **Discuss** what would happen if another animal was introduced into an ecosystem. **Compare** how the outcome would change if the animal was a herbivore or a carnivore.

18 Draw up a table of advantages and disadvantages of controlled burning of bushland. **Evaluate** the points you raise in the table by judging which points are more important, and deciding whether the controlled burning advantages are better or worse than the disadvantages.

Social and ethical thinking

19 **Compare** stepping on an ant with squashing a spider. **Explain** how this is similar or different from killing a larger animal.

20 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. **Explain** 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).

Critical and creative thinking

21 Imagine a world without spiders. **Describe** what the world would be like. In your answer, **consider** what spiders eat and which organisms eat spiders.

22 In some cases, introduced animals, such as the monkeys introduced to Hobart, 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 **explain** how your actions impact on biodiversity.

Figure 3 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. **Explain** 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.

Figure 4 The introduction of rabbits to Australia has resulted in considerable environmental damage.

Research

26 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.

» 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.

» Decade of Education for Sustainable Development

The United Nations' Decade of Education for Sustainable Development (DESD) ran over the period 2005–14. Find out which governments were invited to be a part of the DECD. Describe the opportunities the DESD provided for Australia. In 2012, the Victorian State Government and Sustainability Victoria set up ResourceSmart Schools to assist schools embed sustainability in everything they do. Identify if your school has registered for the program. Suggest how your school could use the resources provided to improve sustainability in your area.

Reflect

The table below outlines a list of things you should be able to do by the end of Chapter 8 'Interactions between organisms'. Once you have completed this chapter, use the table to reflect on your ability to complete each task.

	I can do this.	I cannot do this yet.
Define 'producer', 'consumer', 'food chain' and 'food web', and identify examples. Construct and interpret food chains and food webs.	☐	☐ Go back to Topic 8.1 'All organisms are interdependent'. Page 138
Define 'herbivore', 'carnivore', 'omnivore' and 'composers', and identify examples of each. Describe the role of decomposers in an ecosystem.	☐	☐ Go back to Topic 8.2 'All organisms have a role in an ecosystem'. Page 140
Describe how a food chain relies on a delicate balance between all its components. Explain how the loss of one species from a food web can affect every other organism in the web, and identify examples of endangered species.	☐	☐ Go back to Topic 8.3 'Food webs can be disrupted'. Page 142
Describe how deforestation, urban sprawl and land degradation impact on habitats.	☐	☐ Go back to Topic 8.4 'Human activity can affect local habitats'. Page 144
Describe how green wedges, corridors and backyard stepping stones can help conserve biodiversity. Explain the importance of biodiversity to an ecosystem.	☐	☐ Go back to Topic 8.5 'Science as a human endeavour: Environments can be responsibly managed'. Page 146
Describe how modern land managers use traditional Aboriginal and Torres Strait Islander techniques.	☐	☐ Go back to Topic 8.6 'Science as a human endeavour: Modern land managers use traditional Aboriginal and Torres Strait Islander techniques'. Page 148

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CHAPTER

9

FORCES

Why do objects speed up or slow down?

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?

9.1 A force is a push, a pull or a twist

In this topic, you will learn that:

- a force is a push or pull that happens when two objects interact
- the effect of forces can be measured
- gravity affects the movement of objects on Earth.

gravity
the force of attraction between objects due to their masses

Figure 1 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

Forces in action

Forces act on everything around us all the time. Usually, more than one force is acting on any 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 create a push force. This force causes the ball to move. When you catch a ball, you are still giving 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**. 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 2 The force of Ronaldo kicking the ball is easy to identify and describe, but what is pulling him towards the centre of the Earth?

EXPERIMENT

9.1: Measuring forces
Go to page 231.

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 tyre, causing the tyre 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.

9.1 Check your learning

Remember and understand

1. **Define** the term 'force'.
2. **Identify** seven things that forces can do.
3. **Describe** how force can be measured.
4. **Identify** the unit used when measuring a force.
5. **Identify** the person whom the unit of force is named after.

Apply and analyse

6. 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
7. Use an example to **describe** how you can see the effects of a force, but not see the force.
8. 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.)

Evaluate and create

9. A student was using the force measurer in Experiment 9.1 when the rubber band broke. **Explain** how using a different rubber band would affect the results.

9.2 An unbalanced force causes change

In this topic, you will learn that:

- 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

Pushing on a brick wall does not usually cause the brick wall to move. This does not mean your push force did not exist. There are many forces around us, but most of them do not cause movement. 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. **Balanced forces** are very important. Two tug-of-war teams will be balanced if they pull with the same amount of force but in opposite directions.

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

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 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.

Play dough sitting on the bench will not change unless you add a push force with your finger. Your finger unbalances the forces. The evidence for this unbalanced force is a change in shape.

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

CHALLENGE

9.2: Design a ball whacker
Go to page 232.

stronger than the other team. Which team will win? What evidence will you see in real life that this team is stronger?

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 it speed (by speeding up or slowing down), shape or direction, then a net unbalanced force must be acting on it. Worked example 9.2 shows how to calculate net force.

Worked example 9.2: 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.

9.2 Check your learning

Remember and understand

1 **Describe** the evidence that shows the forces acting on the objects is 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 **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

Apply and analyse

5 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.

6 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.

net force
the vector sum of all the forces acting on an object; also known as resultant force

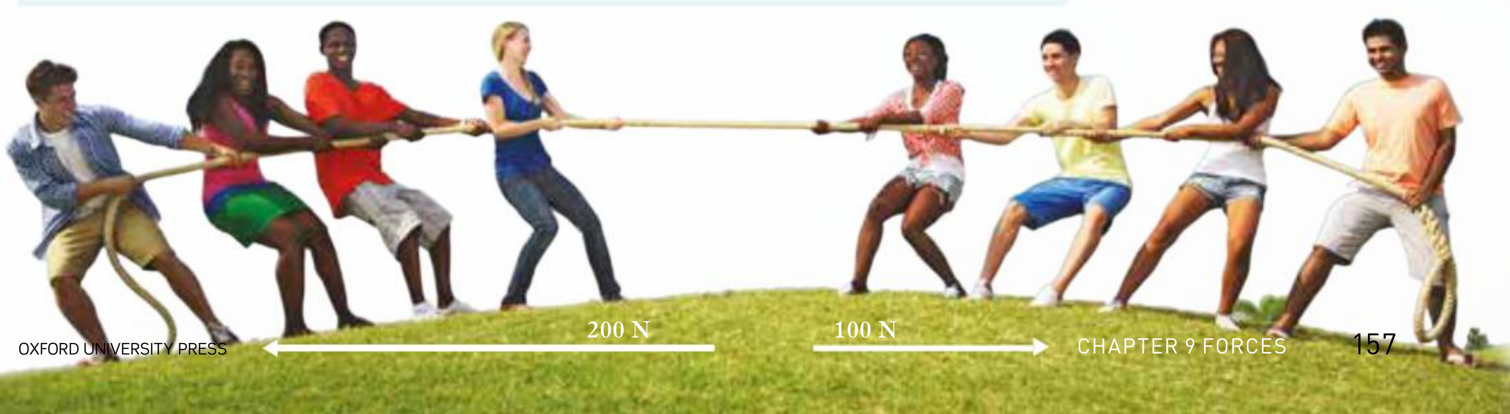

Figure 3 When forces are unbalanced, a change in motion will occur, with the greatest force 'winning'. In a game of tug-of-war, if one team pulls with a force of 200 N to the left and the other team pulls with a force of 100 N to the right, the net force is 100 N to the left. The team on the left will win the game because both teams will move that way. Unbalanced forces lead to a movement in the direction of the greater force.

9.3 Forces can be contact or non-contact

In this topic, you will learn that:

- contact forces involve two objects touching each other
- friction is an example of a contact force
- 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.

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

like poles
two north poles or two south poles of a magnet

non-contact force
a force acting between two bodies that are not in direct contact

repulsion force
a force that pushes one object away from another

magnetic poles
(here) the north and south ends of a magnet

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. It is much easier to move a pencil if you push it with your finger. 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. 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**. 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**. The two magnets do not need to touch to be affected by the repulsion force. It is a non-contact force.

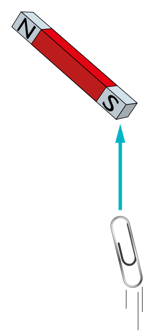

Figure 1 The attraction between the paperclips and the magnet is a non-contact force.

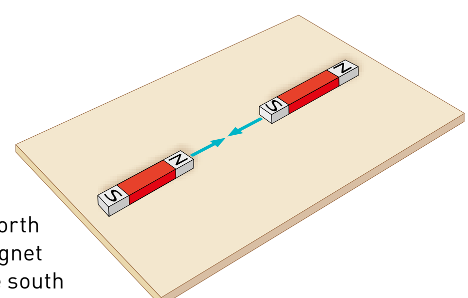

Figure 2 The north pole of one magnet is pulled by the south pole of another magnet.

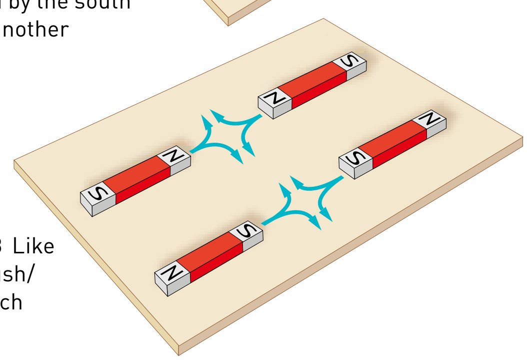

Figure 3 Like poles push/repel each other.

CHALLENGE
9.3: Can you use the push and pull of a magnet? Go to page **232**.

What causes a magnetic force?

An iron needle can be made to become 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.

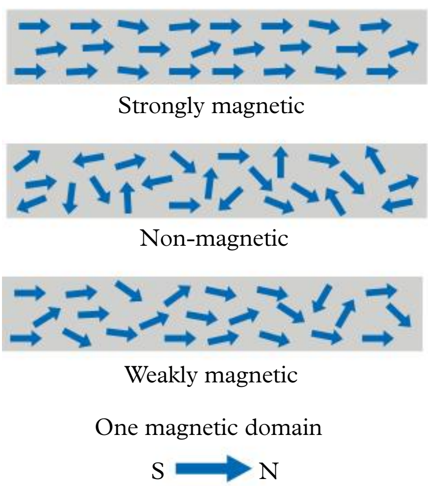

Figure 4 The magnetic domain theory

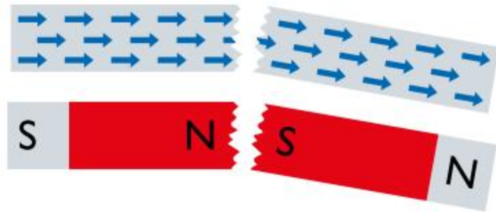

Figure 5 When a magnet is broken, it forms two magnets.

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.

The push forces of magnets are used in the design of Maglev (magnetic levitation) trains. 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 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.

9.3 Check your learning

Remember and understand

1 **Name** three places where you might find a magnet.

2 **Identify** a magnetic force as either a contact or a non-contact force. Justify 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

5 Draw how you might arrange bar magnets to spell out the letters of your name. Label the north and south poles of the magnets.

Figure 7 Spelling out your name using magnets

Apply and analyse

6 **Describe** 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.

9.4 Magnetic fields can apply a force from a distance

In this topic, you will learn that:

- 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.

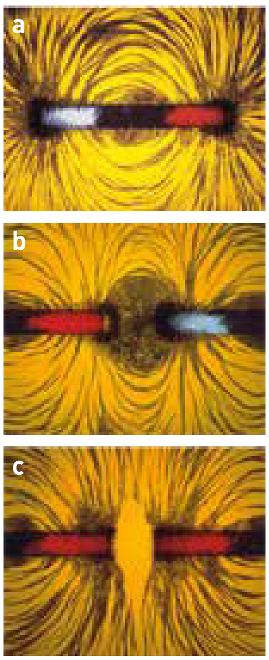

Figure 1 Magnetic fields: **a** around a single bar magnet; **b** between two attracting bar magnets; **c** between two repelling magnets

magnetic pole
(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.

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.

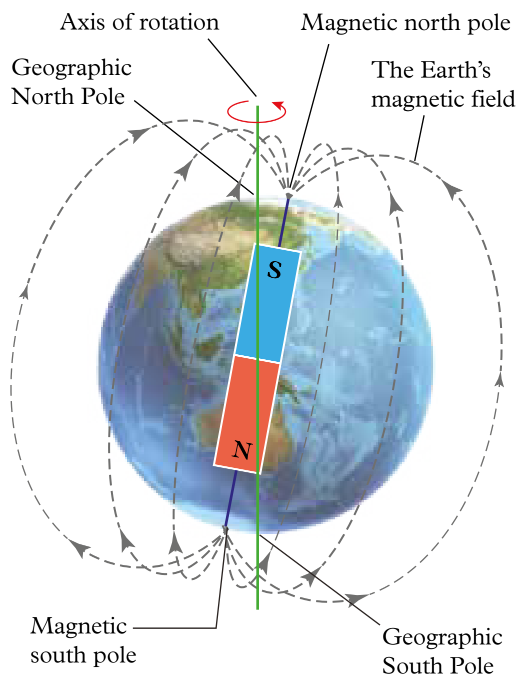

Figure 2 The Earth's geographic poles are not in the same place as its magnetic poles.

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. 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. How will this affect the turtles being able to find their beach?

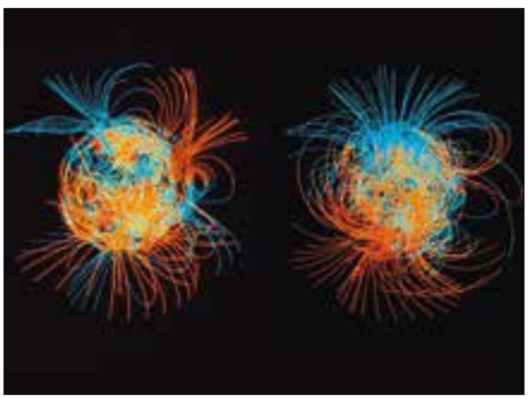

Figure 4 The Earth's magnetic poles between reversals and during a reversal

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. 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.

9.4 Check your learning

Remember and understand

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. Draw 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.

Apply and analyse

6. **Explain** how a compass works.
7. **Explain** why you should never leave a library card on the demagnetising panel of a shop.

9.5 Electrostatic forces are non-contact forces

In this topic, you will learn that:

- friction causes 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 the balloon on hair causes the hair to become positively charged and the balloon to become negatively charged. When the (negative 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).

Figure 2 Sparks jump across to a Van de Graaff generator when negative charges come close enough.

EXPERIMENT

9.5: What if a balloon was electrostatically charged? Go to page **233**.

It is not just negatively charged objects that are pulled or attracted to the dome. Uncharged objects (neither positively nor negatively charged) are also attracted to the positively charged dome. If you stand too close to the Van de Graaff generator, your uncharged hair might be attracted to the dome.

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 each other.

The rules of electrostatic forces are:

- unlike charges attract
- charged objects attract uncharged objects
- like charges repel.

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.

9.5 Check your learning

Remember and understand

1 **Identify** if electrostatic charges are contact or non-contact forces.

2 **Describe** how electrostatic forces can be created.

3 Finish these statements.

a Unlike charges ____________.

b ____________ charges repel.

c Charged objects ____________ uncharged objects.

4 **Explain** why the hair of a person touching a Van de Graaff machine may be standing up.

Apply and analyse

5 Isaac was leaving the carpeted library to go home. When he touched the door handle, he received an electric shock. **Explain** why this happened.

6 When it is about to rain, the water particles in the clouds rub against one another and electrostatic charges form. **Explain** how this may cause lightning.

9.6 Earth's gravity pulls objects to the centre of the Earth

In this topic, you will learn that:

- Earth's gravity can cause a non-contact force
- large objects (such as planets) pull objects towards their centre.

Video 9.6
Geomagnetism

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.

weight
a measure of the gravitational pull on an object

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. The more matter an object has, the stronger its pull force.

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 the brick will change. On Earth, the brick may weigh 9.8 newtons, but on a large planet such as

Figure 2 The Earth pulls base jumpers towards its centre, 6371 km below.

SKILLS LAB

9.6A: Calculate weights in the solar system
Go to page **234**.

CHALLENGE

9.6B: Modelling gravity in the solar system
Go to page **234**.

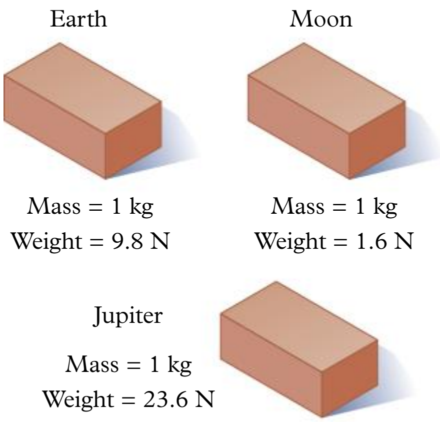

Figure 3 The mass of a brick does not change, but its weight is affected by gravity.

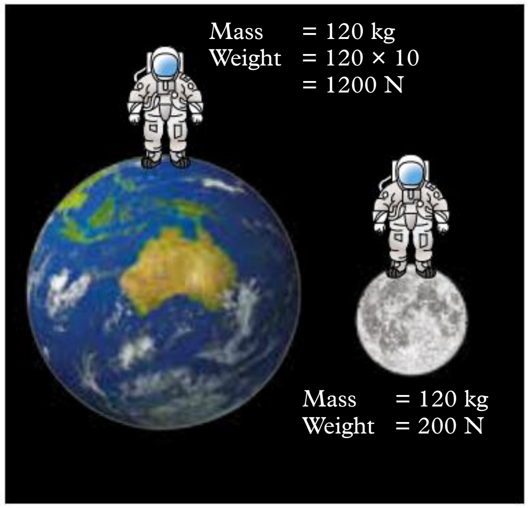

Figure 4 A person who wants to lose weight could go to the Moon. A person who wants to lose mass could take their shoes off.

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.

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.

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 accelerate at the same rate and hit the ground at the same time.

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.

9.6 Check your learning

Remember and understand

1 **Contrast** mass and weight.

2 **Identify** the person who first described gravity.

3 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, **identify** which bottle would hit the ground first.

4 True or false? The pull of the Earth is stronger on an elephant than on a feather.

Apply and analyse

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. **Explain** why the feather and hammer hit the ground at the same time.

Evaluate and create

6 Building a settlement on the Moon has been suggested several times since Neil Armstrong first walked on the Moon. **Compare** the advantages and disadvantages of building such a structure in a low-gravity environment.

9.7 The Moon's gravity causes tidal movements

In this topic, you will learn that:

- the Earth's pull force holds the Moon in orbit
- the relationship between the Moon and the tides was recognised by early Aboriginal and Torres Strait Islander peoples.

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

The relationship between the Moon and the tides was recognised by early Aboriginal and Torres Strait Islander peoples. Arnhem Land stories tell of high tides filling the Moon. As the tide falls, the Moon is left empty for three days before filling once more.

What causes tidal movements?

The effect of gravity between two objects is related to the size of each of these objects and how far apart they are from each other. The Earth's pull force holds the Moon in orbit. The Moon has its own pull force that causes the Earth's oceans to bulge towards 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 towards the Moon (and away from the water on the opposite side), so another high tide occurs on the opposite side of the Earth. As the Moon travels around the Earth and as both bodies travel around the Sun, the combined pull force from gravity causes the world's oceans to rise to high tides and fall to **low tides**. Because the Earth is rotating while this is happening, two high tides occur each day, approximately 11 hours apart. High tides happen when the land at the beach turns towards the water being pulled by the Moon or Sun. Low tides happen when the land turns away from the water bulge. Worked example 9.7 shows how to calculate tides.

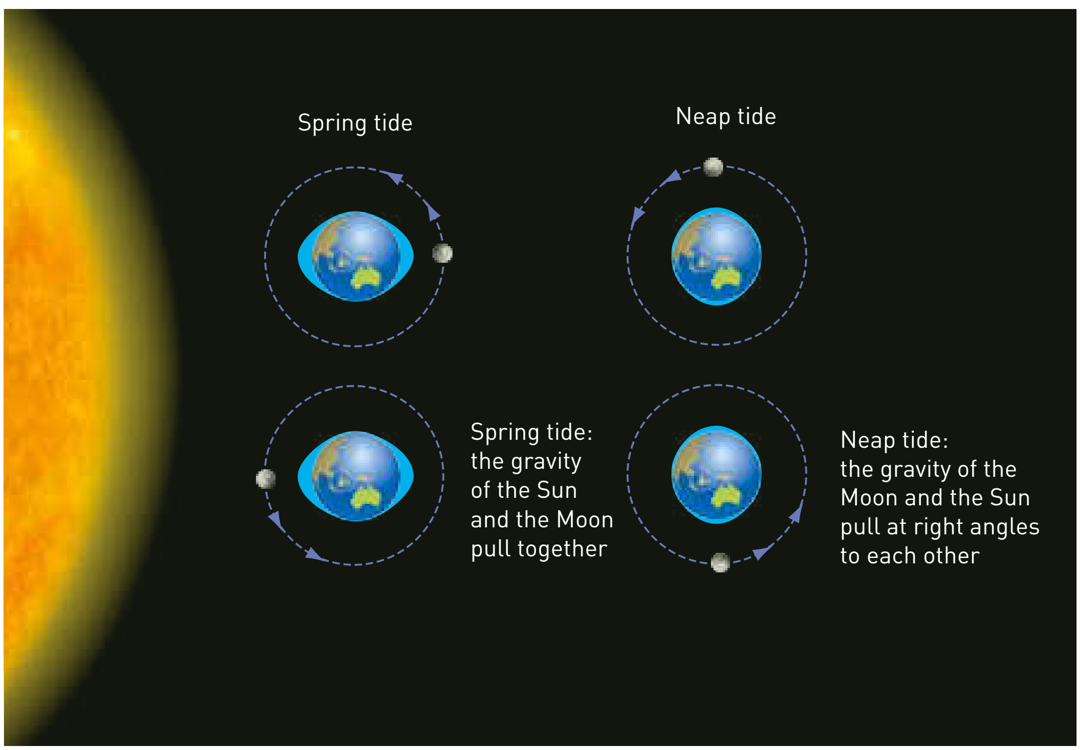

Figure 2 The Moon's pull on the oceans creates spring and neap tides. (The bulges shown here have been exaggerated so that they are easier to see.)

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** (Figure 2). 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.

World's biggest tides

The biggest change in the depth of water between low and high tide occurs at the Bay of Fundy in Nova Scotia, Canada. Twice a day, 100 billion tonnes of sea water flow in and out of the Bay of Fundy. This is more than the combined flow of the world's freshwater rivers. The narrow, funnel-shaped inlet causes changes in depth of up to 17 m, making life interesting for boating.

Figure 3 The Bay of Fundy in Nova Scotia, Canada

Worked example 9.7: Calculating tides

Table 1 shows the times of high tide at Williamstown, in Melbourne, Victoria, over three days in December 2020. Calculate the difference in height between the two high tides on the Friday.

Solution

One high tide is 0.88 m at 6.25 am and the other high tide is 0.72 m at 5.46 pm.

Subtract the smaller tide from the larger tide: 0.88 – 0.72 = 0.16 m

Figure 4 **a** High tide and **b** low tide at the Bay of Fundy, Nova Scotia, Canada

Table 1 High tides in Williamstown, Melbourne, in December 2020

Friday 4 December 2020		Saturday 5 December 2020		Sunday 6 December 2020	
Time	Height (m)	Time	Height (m)	Time	Height (m)
12:18 pm	0.10	12.55 am	0.09	1.31 am	0.09
6.25 am	0.88	7.00 am	0.88	7.35 am	0.87
1.14 pm	0.35	1.14 pm	0.34	2.24 pm	0.33
5.46 pm	0.72	6.24 pm	0.72	7.03 pm	0.72

9.7 Check your learning

Remember and understand

1 **Explain** why the Moon has a greater effect on the tide levels than the Sun.

Apply and analyse

2 Referring to Table 1, **calculate** the difference between:

   a the last high tide on Saturday and the next one on Sunday

   b one high tide and the following low tide on Saturday.

3 Use the data in Table 1 to **predict** the times and heights of the tides for Monday.

Evaluate and create

4 For one week, graph the high and low tide levels of a beach in your state. **Compare** this against the times the Moon rises and sets. **Describe** the relationship between the Moon's position and tide levels.

5 Gravity is not considered a force. Instead, it is the distortion of space and time caused by a large object. This allows the large object to have a pull force. Rewrite the following sentence so that it is correct.

   The force of the Moon's gravity pulls the water on Earth to cause high tides.

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

9.8 Friction slows down moving objects

In this topic, you will learn that:

- friction is a contact force
- friction (such as air resistance) slows down moving objects
- friction can be reduced by streamlining, lubricants or ball bearings.

friction
a force that acts to oppose the motion between two surfaces as they move over each other

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. 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 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 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

9.8: What if the amount of friction was changed? Go to page **235**.

Figure 3 Oil is added to a car engine to reduce friction between engine parts.

Lubricants, such as oils and grease, also reduce friction. 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.

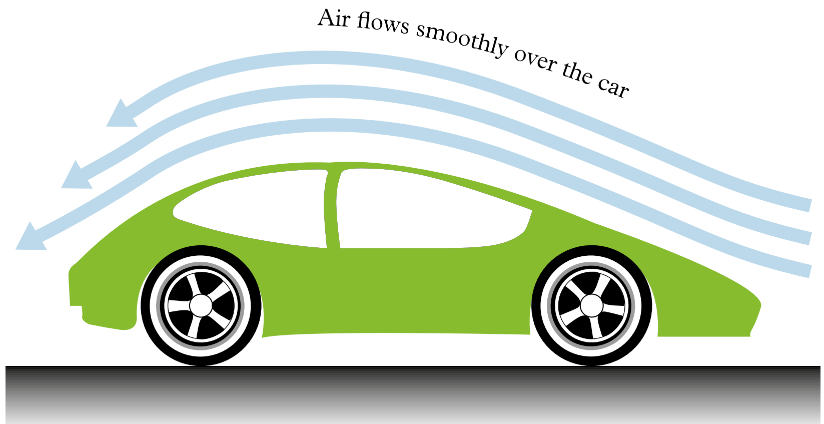

Figure 4 Streamlining reduces friction.

air resistance
friction between a moving object and the air it is moving through

streamlining
give an object a form that presents the least resistance to motion

lubrication
the action of applying a substance such as oil or grease to an engine or component so as to reduce friction

9.8 Check your learning

Remember and understand

1 List three examples where friction is useful and three examples where friction is a problem.

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. **Describe** this in terms of force.

5 A hovercraft moves across water on a cushion of air. **Describe** this in terms of friction.

Apply and analyse

6 In a world without friction, **describe** what would happen if you tried to:

 a go down a slide in a playground

 b play tenpin bowling

 c tie your shoelaces.

7 **Explain** how speed and friction are related.

8 Select 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).

9.9 Simple machines decrease the amount of effort needed to do work

In this topic, you will learn that:

- 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.

Interactive 9.9A
Simple machines

Interactive 9.9B
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

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. 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**.

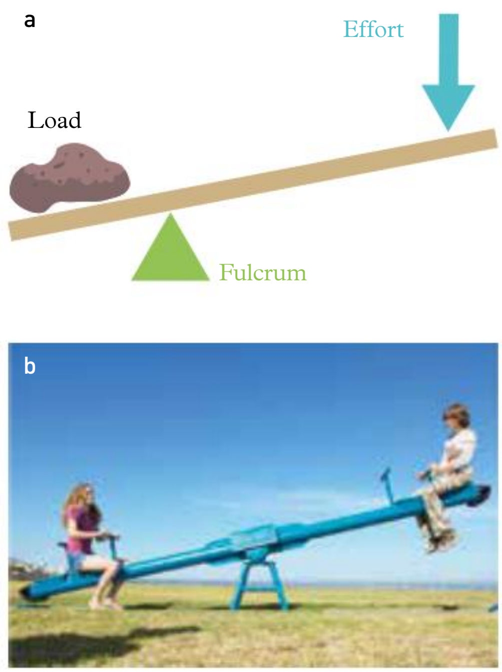

Figure 2 **a** A lever has three features: the fulcrum, effort and load. **b** A see-saw is an example of a lever.

EXPERIMENT

9.9A: Using a first-class lever to lift weights
Go to page **236**.

EXPERIMENT

9.9B: Using a second-class lever to lift weights
Go to page **237**.

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 9.9A shows how to calculate mechanical advantage. Worked example 9.9B 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 when the effort moves a short distance, the load will move a long distance. The disadvantage is 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.

Worked example 9.9A: 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 9.9B: 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 3 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

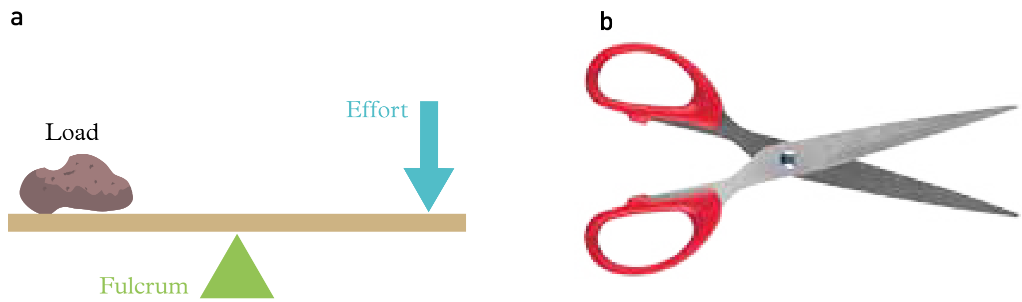

Figure 4 **a** In a first-class lever, the fulcrum is between the load and the effort. **b** Scissors are an example of a first-class lever.

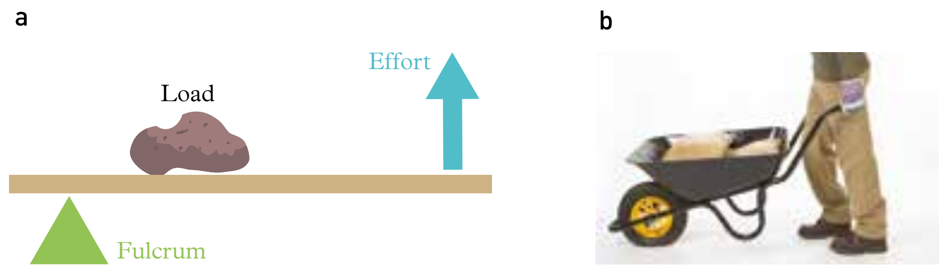

Figure 5 **a** In a second-class lever, the load is between the effort and the fulcrum. **b** A wheelbarrow is an example of a second-class lever.

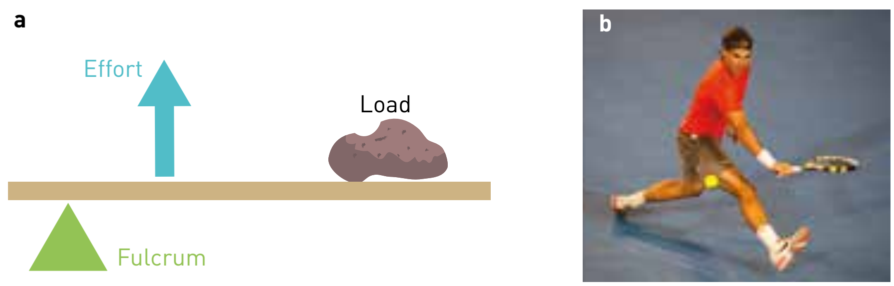

Figure 6 **a** In a third-class lever, the effort is between the load and the fulcrum. **b** A tennis racquet is an example of a third-class lever. When a person uses a tennis racquet to hit a ball, the muscles exerting the effort are between the shoulder fulcrum and the ball load.

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

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).
- **Second-class lever**: the load is between the effort and the fulcrum (ELF).
- **Third-class lever**: the effort is between the load and the fulcrum (LEF).

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!)

Aboriginal and Torres Strait Islander levers

Many Aboriginal and Torres Strait Islander 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 Aboriginal and Torres Strait Islander 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 7 A woomera is a lever.

9.9 Check your learning

Remember and understand

1 **Define** the term 'lever'.

2 **Describe** how you would identify a first-class lever.

3 **Compare** a second-class lever with a third-class lever.

Apply and analyse

4 **Examine** Figure 8.

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.

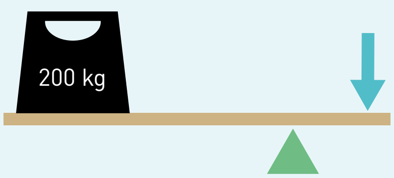

Figure 8 A lever

5 A crowbar can be used to move a load. (see Figure 9).

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.

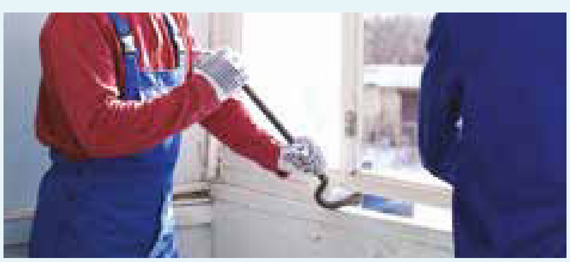

Figure 9 A crowbar moving a load

6 Modern cranes use leverage to lift heavy objects (see Figure 10).

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 10 A modern crane

9.10 A pulley changes the size or direction of a force

In this topic, you will learn that:

- 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.

Video 9.10A
Example of pulleys (abseiling)

Video 9.10B
Example of pulleys (gym equipment)

Video 9.10C
Example of pulleys (oil pump)

Video 9.10D
Example of pulleys (zip line)

History of the pulley

Between the 15th and 17th 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*. 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. 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 2 The simplest pulley system is made of one pulley.

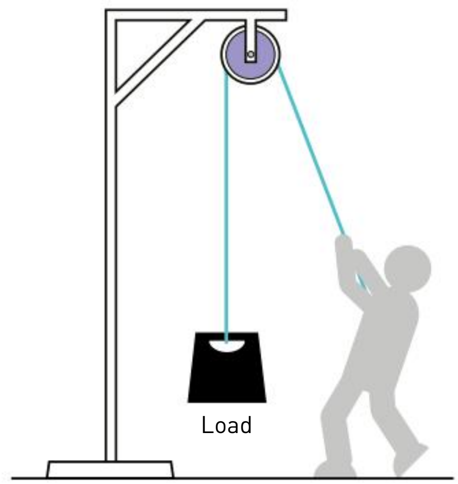

Figure 3 A single-pulley system – rope is guided through the groove of a rotating wheel.

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).

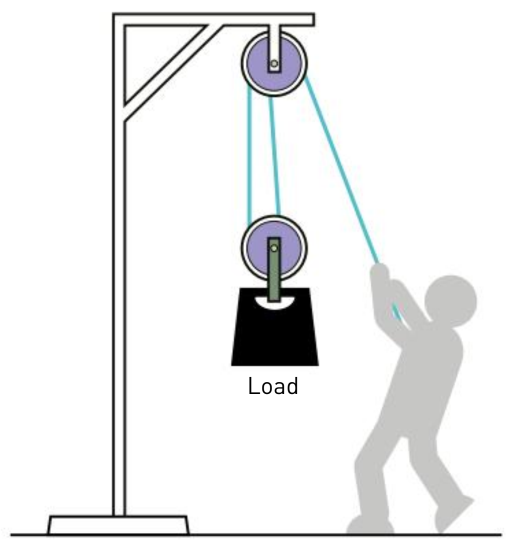

Figure 4 A two-pulley system doubles the mechanical advantage.

EXPERIMENT

9.10: Calculating mechanical advantage
Go to page **238**.

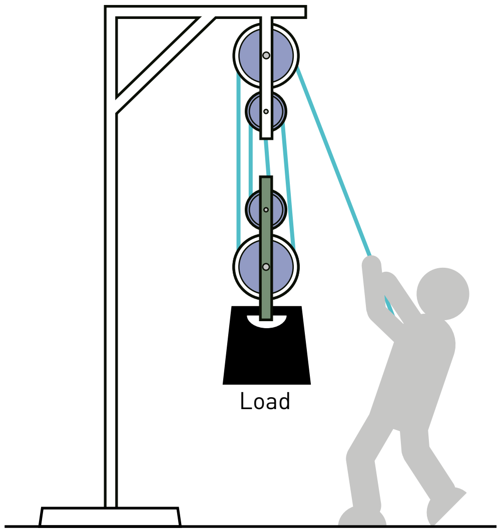

Figure 5 A four-pulley system increases the mechanical advantage by a factor of four.

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 9.10 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** (Figure 6). A small effort pulling through a long distance lifts a large load through a much smaller distance.

Figure 6 This block-and-tackle system is used to lift heavy objects.

Worked example 9.10: 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.

9.10 Check your learning

Remember and understand

1 **Explain** why two pulleys are better than one.

2 A block and tackle provides a mechanical advantage because it can lift heavy loads. **Describe** the disadvantages of this system.

3 **Describe** three examples where single pulleys or pulley systems are used.

4 **Describe** how pulleys have made loading and sailing huge cargo vessels possible.

Figure 7 Using a pulley on a cargo vessel

5 Choose 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.

Apply and analyse

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.

block and tackle
a group of pulleys mounted together in a frame or block, which provides significant mechanical advantage

9.11 There are different types of machines

In this topic, you will learn that:

- inclined planes such as a ramp 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.

Figure 1 An escalator is an example of a ramp.

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 2 An axe is an example of a wedge.

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.

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 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. The effort needed to turn a screw into an object is much less than that required to hammer the screw into the same object.

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

EXPERIMENT
9.11: Comparing different machines
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axle exerts a force on the load (the latch), which opens the door.

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.

wheel and axle
a type of lever that can rotate about its centre, magnifying force or distance

Figure 4 A Ferris wheel is an example of a wheel and axle.

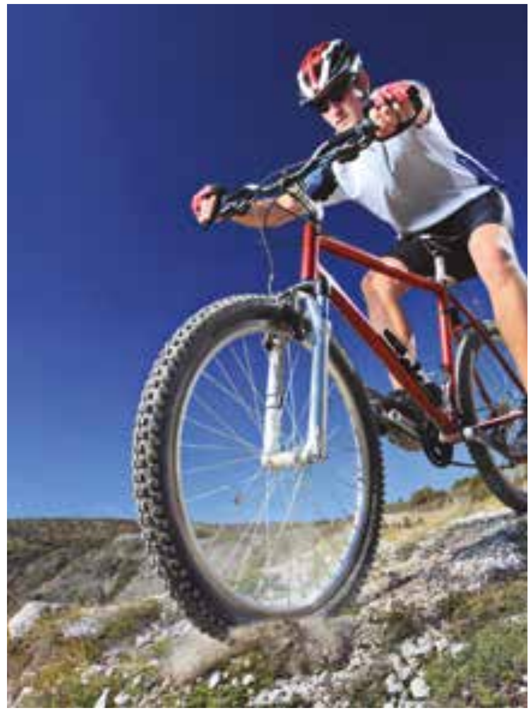

Figure 5 A bike wheel is an example of a distance magnifier.

9.11 Check your learning

Remember and understand

1 List the six types of simple machines.

2 **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

3 **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.

Apply and analyse

4 **Compare** a wedge with a ramp.

5 **Identify** a circular doorknob as either a force magnifier or a distance magnifier.

6 **Explain** 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.

//SCIENCE AS A HUMAN ENDEAVOUR//

9.12 Seatbelts and safety helmets save lives

When objects are stationary or moving at a constant speed in a straight line, the forces are balanced. When the forces are unbalanced, they can cause a change in speed, shape or direction. People in cars or on bicycles that stop suddenly experience unbalanced forces. Australian Government regulations mandate the wearing of seatbelts or safety helmets to prevent these unbalanced forces causing damage to the passengers.

Seatbelts and car safety

When a car starts to move, the engine provides a driving push force on the wheels. The friction between the road and the wheel stops the wheel from spinning freely, and the car starts to move forward. This means all the other parts of the car also start to move forward. If you are sitting in the car, then the seat pushes you forward. This unbalanced push force changes your speed from zero to 100 km/h.

Once you are travelling at an unchanging speed on a straight road, the forces between the forward driving force of the car and the backward air resistance and friction forces are balanced. This means the forces between you and the car are also balanced. Balanced forces mean there is no change in speed, shape or direction. Often when you are in a moving car, you might not notice that you are moving at 100 km/h. If you stop to think about it, you might realise that 100 km/h is the same as running a 100 m race in 3.6 seconds. Yet you do not notice the forces involved because they are balanced. You do notice the forces when the car stops suddenly. Most cars stop when the engine stops its driving force, and the brakes prevent the wheels from moving. Because the car is still moving forward, there is friction between the wheels and the road. This means there are more forces stopping the car than pushing it forward. The unbalanced forces change the car's speed from 100 km/h to zero. But what stops you?

As a passenger, your speed will only change if there is an unbalanced force on you. The friction between the wheels and road, the weight of the car and the air resistance stop the car; however, it does not stop you. You need a force to stop you moving forward. Fortunately, the laws in Australia require everyone to wear a seatbelt. When the car stops, the seatbelts attached to the car also stop. These seatbelts then provide an unbalanced force to change your speed from 100 km/h to zero.

Just imagine what would happen if you were not wearing a seatbelt? The car would stop, and you would keep going at 100 km/h until there was a force to slow you down. This could be the seat in front of you, the windscreen or the road in front of the car. This type of unbalanced force would change not only your speed but also your direction and shape.

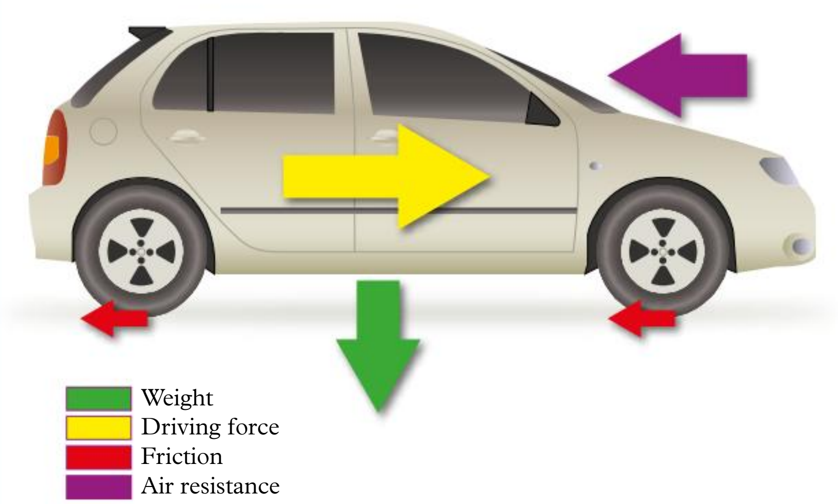

Figure 1 There are many forces acting on a moving car.

Safety helmets

Safety helmets are an essential item when riding a bicycle and are tightly regulated by Australian law. Just like a car, a bicycle rider can experience unbalanced forces when stopping suddenly. In an accident such as a bicycle hitting a car door, the unbalanced force stops the bicycle; however, the rider keeps moving forward until their forces become unbalanced. As bicycles do not have seatbelts, this stopping force is often the road. The unbalanced force usually results in a change in the rider's shape as well as speed. If this change in shape occurs in the rider's head, the rider might become brain damaged. For this reason, Australian regulations require all bicycle riders to wear an appropriate safety helmet.

Figure 2 Bicycle safety infographic

9.12 Develop your abilities

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.

Select two of the sets of data in Tables 1 to 3 below and plan an infographic that will pass the information on to your peers:

1. **Identify** the key information in the set of data. For example, which time of day, day of the week or month of the year is the most dangerous to ride a bicycle?
2. **Predict** one possible reason why more accidents occur at this time, day or month.
3. **Create** a picture that represents a bicycle 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.

Table 1 Cycling deaths each day

Day of week	Number of fatalities
Monday	199
Tuesday	189
Wednesday	198
Thursday	182
Friday	189
Saturday	185
Sunday	173

Table 2 Cycling deaths at a specific time

Time of day	Number of fatalities
1–4 am	16
4–7 am	133
7–10 am	250
10–1 pm	181
1–4 pm	236
4–7 pm	332
7–10 pm	122
10–1 am	45

Table 3 Cycling deaths each month

Month	Number of fatalities
January	121
February	117
March	154
April	104
May	120
June	113
July	90
August	88
September	80
October	110
November	110
December	108

//SCIENCE AS A HUMAN ENDEAVOUR//

9.13 Forces are involved in sport

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. 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. 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.

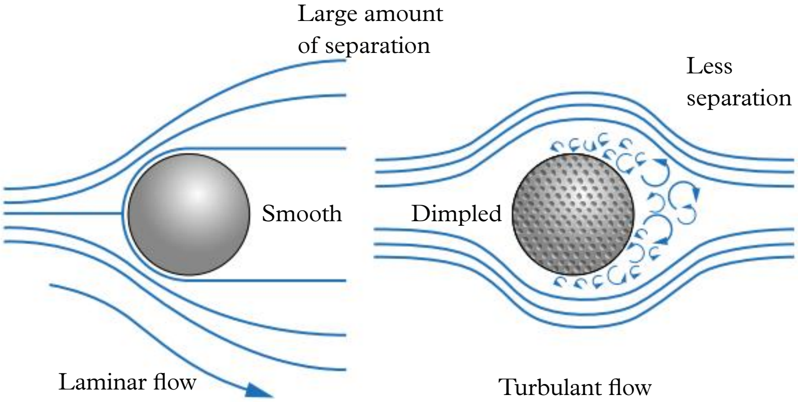

Figure 3 Air flows over a smooth ball differently from how it flows over a dented ball so that air resistance is decreased over the dented ball and it flies further.

9.13 Develop your abilities

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, the 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.

REVIEW 9

Multiple choice questions

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 If magnets are pushed together, they will:
   A repel
   B attract
   C remain where they are
   D move sideways.

Short answer questions

Remember and understand

4 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.

5 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 ___________.

6 **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

7 **Explain** how mechanical advantage is calculated.

8 **Compare** a contact force and a non-contact force.

9 **Compare** a lever and a pulley.

10 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.

11 **Describe** what happens to the magnetic properties of a magnet when it is broken into two.

12 **Explain** why a person jumping on a trampoline may have their hair standing out from their head.

Apply and analyse

13 **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.

14 **Consider** the pulley system in Figure 1. **Calculate** how far the 100 kg load will rise if 2 m of rope is pulled through the pulleys.

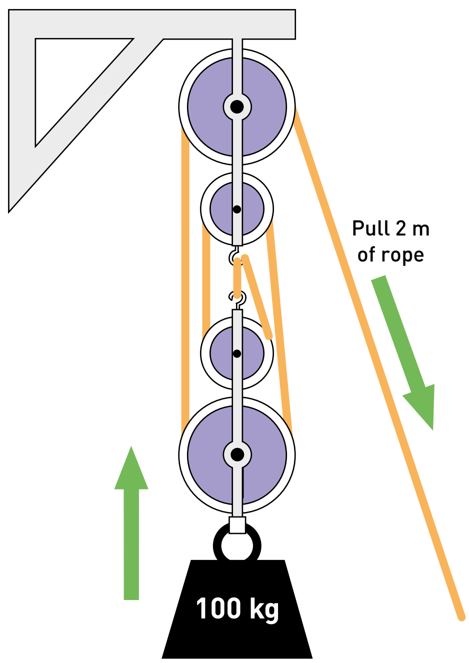

Figure 1 A pulley system

15 When skydivers step out of an aeroplane, they begin to fall towards the Earth. **Describe** the forces acting on the skydivers.

16 Figure 2 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.

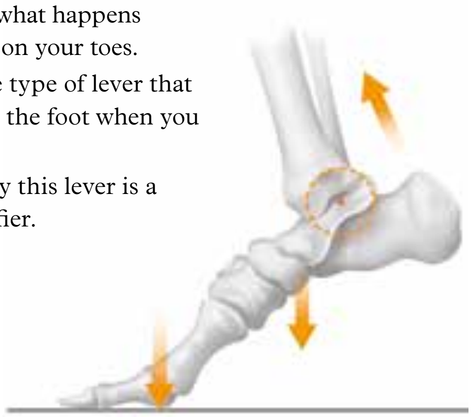

Figure 2 Standing on your toes

17 **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.

Evaluate

18 Think about how far a toy car and a marble would roll along a flat bench. **Identify** which has the least friction and which rolls the furthest. **Explain** how friction can be minimised.

19 **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.

Social and ethical thinking

20 The wearing of seatbelts was made law in 1970 in Victoria. At the time, some people protested that they 'had the right' to make the decision to wear or not wear seatbelts themselves and that they should not be 'forced by the law'. **Describe** the possible consequences to the driver of not wearing a seatbelt. **Describe** the possible consequences to other people on the road if one driver decided not to wear a seat belt. **Evaluate** whether a driver should have the right to make their own decision about wearing a seatbelt (by comparing the consequences of all people that might be affected by the decision).

Critical and creative thinking

21 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 **Identify** which part of the trip would use more petrol.

  b **Explain** your answer using your knowledge of forces and friction.

22 **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

23 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.

» Musical instruments

Musical instruments often use simple machines. For instance, levers are used in pianos. Consider the following as part of your research:

- **Describe** how are levers are used in pianos.
- **Identify** which other musical instruments use levers.
- **Describe** how the lever helps to make a sound.

» Careers with space

Becoming an astronaut is one way to be involved in working in space. Research other 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.

» Seatbelts

The wearing of seatbelts in cars was first made law in Victoria in 1970. Research the materials that are used to make seatbelts. Use your knowledge of forces to explain how seatbelts prevent injury in a car accident.

Reflect

The table below outlines a list of things you should be able to do by the end of Chapter 9 'Forces'. Once you have completed this chapter, use the table to reflect on your ability to complete each task.

	I can do this.	I cannot do this yet.
Explain why a measuring device must be calibrated and provide examples of forces in real-life situations.	☐	☐ Go back to Topic 9.1 'A force is a push, a pull or a twist'. Page 154
Describe how force diagrams can represent forces in a situation.	☐	☐ Go back to Topic 9.2 'An unbalanced force causes change'. Page 156
Define and provide examples of contact forces and non-contact forces.	☐	☐ Go back to Topic 9.3 'Forces can be contact or non-contact'. Page 158
Describe the natural magnetic field of the Earth and provide examples of using magnetism in real-life situations.	☐	☐ Go back to Topic 9.4 'Magnetic fields can apply a force from a distance'. Page 160
Define 'electrostatic forces' and 'charge' and relate electrostatic forces and magnetic forces.	☐	☐ Go back to Topic 9.5 'Electrostatic forces are non-contact forces'. Page 162
Calculate weight given the mass of an object and gravitational force, and explain why the weight of an object does not affect its acceleration during a fall.	☐	☐ Go back to Topic 9.6 'Earth's gravity pulls objects to the centre of the Earth'. Page 164
Describe how the positions of the Moon and Sun affect the size of the tide on Earth.	☐	☐ Go back to Topic 9.7 'The Moon's gravity causes tidal movements'. Page 166
Define and provide examples of friction, lubrication, air resistance, drag and streamlining.	☐	☐ Go back to Topic 9.8 'Friction slows down moving objects'. Page 168
Compare and contrast distance magnifiers and force magnifiers and calculate mechanical advantage. Provide examples of first-, second- and third-class levers.	☐	☐ Go back to Topic 9.9 'Simple machines decrease the amount of effort needed to do work'. Page 170
Explain how a pulley makes it easier to lift a load.	☐	☐ Go back to Topic 9.10 'A pulley changes the size or direction of a force'. Page 174
Define and provide examples of ramps, wedges, screws and wheels.	☐	☐ Go back to Topic 9.11 'There are different types of machines'. Page 176
Explain how seatbelts and safety helmets prevent unbalanced forces causing damage to passengers when a vehicle stops suddenly.	☐	☐ Go back to Topic 9.12 'Science as a human endeavour: Seatbelts and safety helmets save lives'. Page 178
Explain how understanding of forces has improved sporting abilities and technologies.	☐	☐ Go back to Topic 9.13 'Science as a human endeavour: Forces are involved in sport'. Page 180

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CHAPTER 10

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.

Learning and working in a laboratory

*

Working in a science laboratory requires you to use a variety of special skills. Many of these you may not use anywhere else. You must know how to identify, prepare and clean up equipment safely to prevent chemicals contaminating future experiments, or harming yourself or someone else.

Wear a lab coat and safety glasses, and have hair tied back

Figure 1 Wear correct safety equipment.

How to clean equipment

Figure 2 Place warm water in the equipment, such as a beaker. Then add a small amount of detergent.

Figure 3 Use a brush to wipe around the equipment.

Figure 4 Tip out water and rinse the equipment with fresh water to prevent contamination in the next experiment. Can you spot what's wrong with this image? Long hair should be tied back.

Figure 5 Place the equipment upside down to drain.

What to do with broken glass

Figure 6 Place the shards in a special glass bin. Alternatively, wrap the glass in newspaper and dispose of in the normal rubbish.

CAUTION! Tell your teacher. Do not use your hands to pick up the glass!

How to clean up common spills

Figure 7 If it is safe, wipe the spill up with paper towel and dispose of in the normal rubbish. Can you spot what's wrong with this image? When cleaning up spills, wear gloves to protect your hands!

CAUTION! Tell your teacher first. Wear safety glasses and gloves when cleaning up spills.

Figure 8 Let your teacher know immediately if there is a chemical spill. Follow your teacher's directions. Laboratories should have a special spill kit for use in these circumstances.

Safely smelling chemicals

Figure 9 Hold the chemical slightly away from your face. Use your hand to gently waft a small amount of air above the container towards your face.

CAUTION! Check with your teacher if it is safe to smell the chemical, and only proceed if it is.

1.1 Sideways ping pong

CHALLENGE

Aim

To identify the factors that affect the horizontal movement of a 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 4–5. 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 together, all heating equipment or all safety equipment. 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.

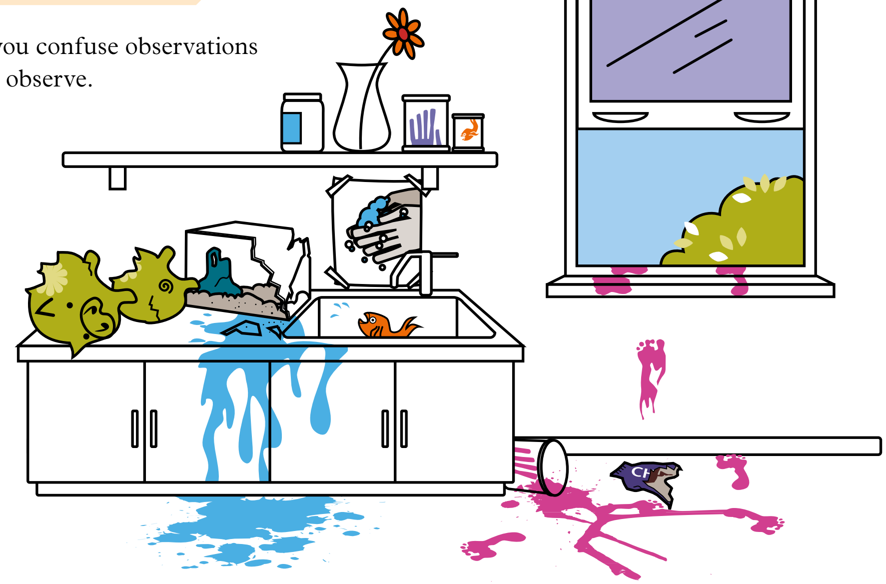


Figure 1 Drawing of a crime scene

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 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.

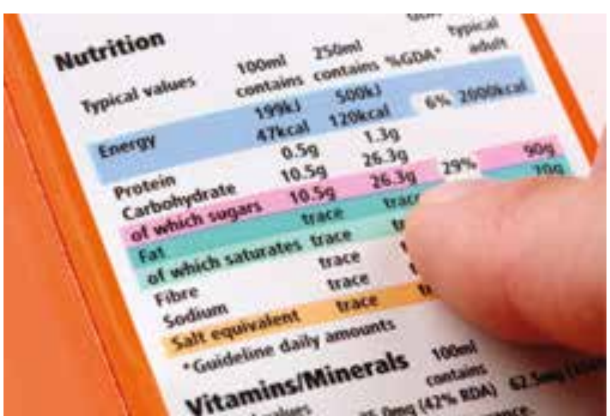


Figure 1 A nutrition panel

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.

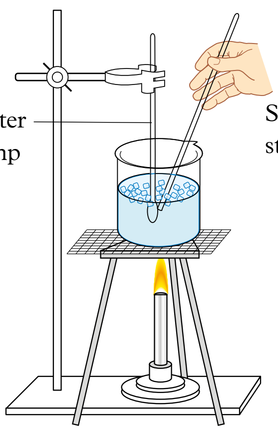


Figure 1 Equipment set-up

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.

> Write a hypothesis for your inquiry.

> Identify the *independent* variable that you will change from the first method.

> Identify the *dependent* variable that you will measure and/or observe.

> List the variables you will need to control to ensure a fair test. Describe how you will control each variable.

> Test your hypothesis by repeating the method with the independent variable you chose.

> Collect the data in a table.

> 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 fair test by providing a definition of a fair 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 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).

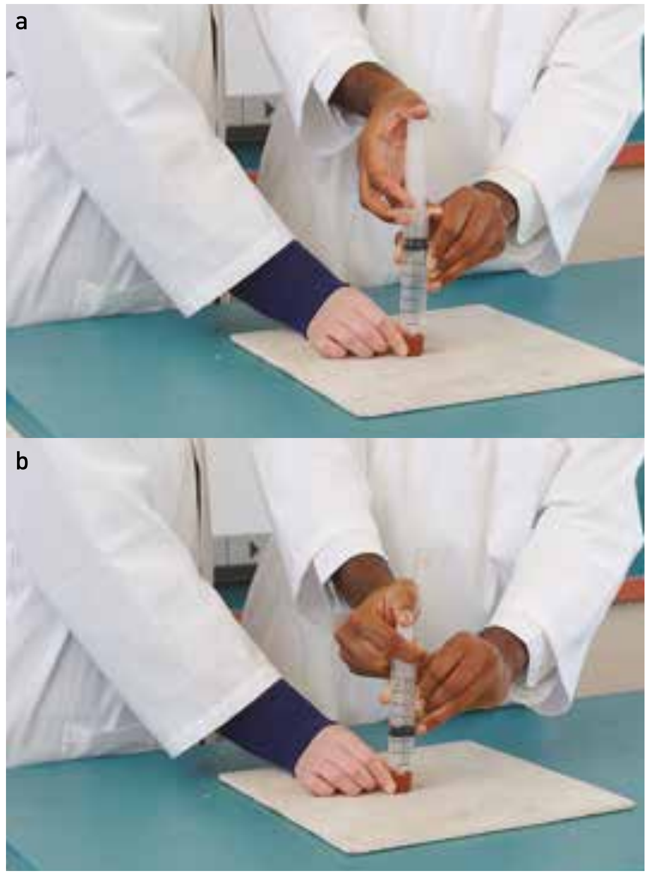


Figure 1 Testing the compressibility of air: **a** before and **b** after depressing the plunger on the syringe.

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 test tube opening 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 …'

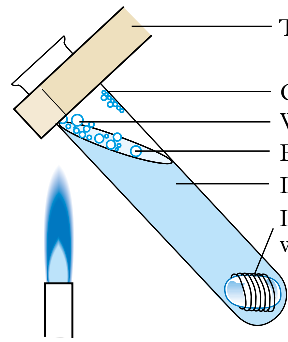


Figure 1 Three states of water in a test tube

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 a model 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.

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 Describe your observations of how the brown tea molecules spread through the water molecules.

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

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 measuring cylinder	6			
50 mL measuring cylinder	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 Figure 1 and the first row of Table 1.
5 Calculate the density of each block.

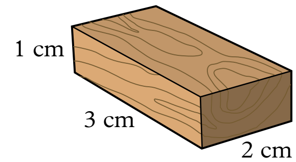


Figure 1 Calculating the volume of a regular-shaped block

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 and 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 subtract 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 blocks

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

STATION 1: HEATING A SOLID

CAUTION! Wear safety glasses and a lab coat, and tie long hair back, when using a Bunsen burner.

Aim

To compare how introducing or removing heat affects a gas.

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.

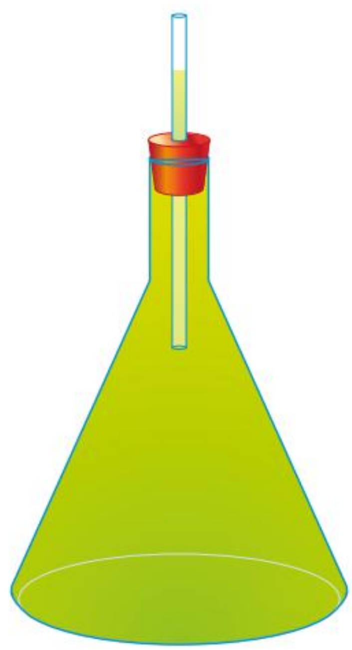


Figure 1 Experimental set-up to show the expansion of a liquid on heating

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.

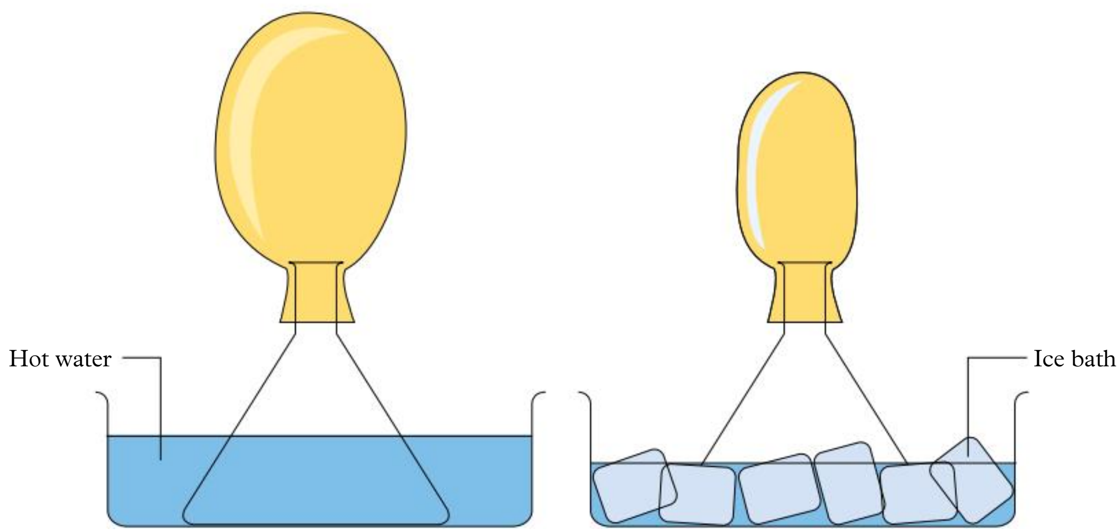


Figure 2 Experimental set-up to show the expansion and contraction of a gas after heating and cooling

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

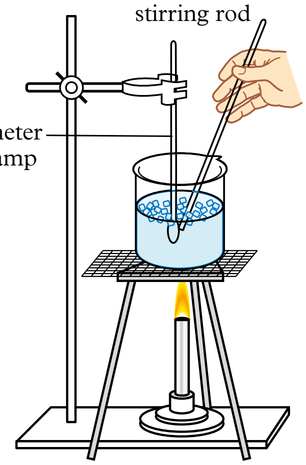


Figure 1 Experimental set-up for measuring the melting point of ice

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.

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 factor 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 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’.

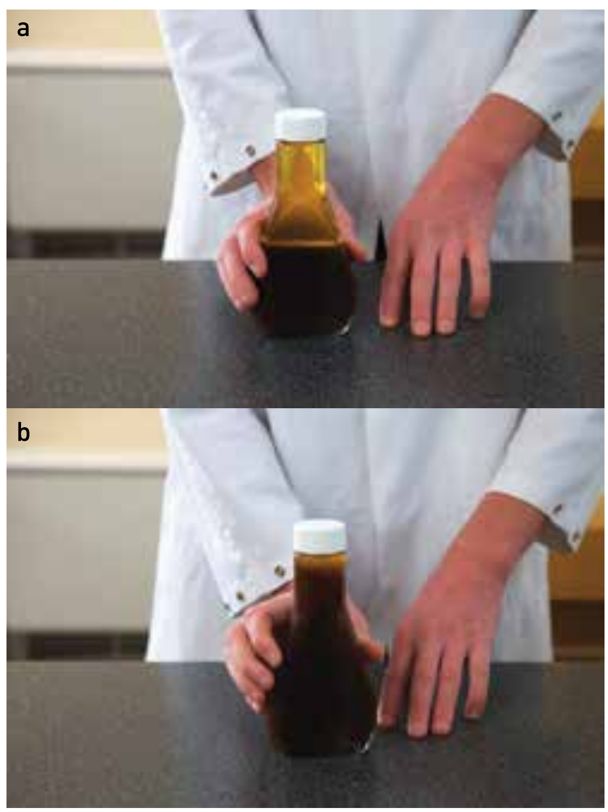


Figure 1 Salad dressing **a** before and **b** after adding an emulsifier.

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 – ANOTHER SOLUTION

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.
3. 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 fair 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 that 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 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 fair 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 you 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 solute affects the amount of solvent 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.

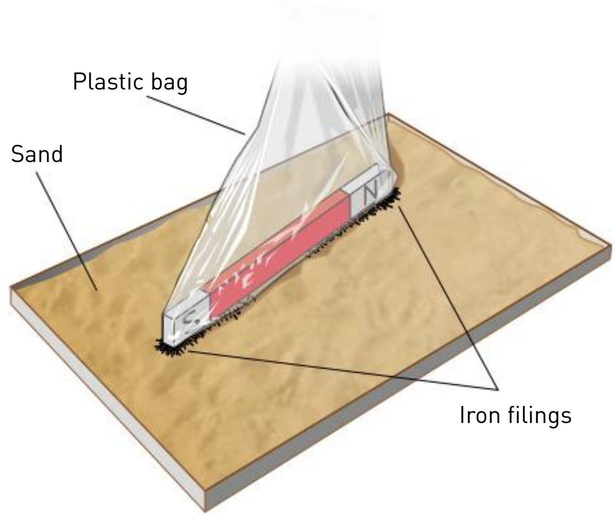


Figure 1 Separation using magnetic properties

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 test tubes
- 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:
   - '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 …'

Inquiry: How much flocculent 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 flocculent. 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 affect a flocculant has on some mixtures.

Figure 1 Adding a flocculant to muddy water

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 (see 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

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 fair 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. Design equipment available from a supermarket 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 and improve it.

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. Write what you know about the properties of sand, iron filings, sawdust and salt in Table 1.

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 an equipment 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 first felt-tip pen, 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 (Figure 3).

Figure 3 Take the papers out to dry.

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.

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 for 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.

Figure 4 The suspects

4.1 What if the temperature was increased in the water cycle?

EXPERIMENT

Aim

To design and create a model of the water cycle.

Materials

- Large clear plastic bowl
- Plastic wrap
- Small weight
- Smaller container, such as the bottom half of a yoghurt pot
- Water
- Large elastic band or string and tape

Method

1. Place the small container in the middle of the large clear bowl.
2. Pour a little water into the large bowl, without getting any in the small container.
3. Cover the bowl with plastic wrap and fix the plastic wrap to the rim of the bowl with a rubber band or string.
4. Put a small weight on top of the plastic wrap in the centre so that it hangs over, but does not touch, the smaller container.
5. You have now created a portable water cycle. Place your water cycle in partial shade under a tree. Record the time it takes for water to appear in the small container. Draw a labelled diagram of your equipment. Label and describe each stage of the water cycle.

Inquiry: What if the temperature was hotter in the water cycle?

- Write a hypothesis for your investigation.
- Identify the *independent* variable that you will need to change to test your hypothesis.
- Identify the *dependent* variable you will measure and/or observe to determine if the independent variable has an effect.
- Identify two variables you will keep the same or control. Describe how you will control them.
- Write down the method you will use to complete your investigation. (Hint: Use the method above as a guide.)
- Prepare a table to record your results.
- Show your teacher your planning to obtain approval before starting your experiment.

Results

Record your measurements in your table.

Discussion

1. Describe the movement of the water as it continued to collect on the plastic wrap.
2. None of the water in your mini water cycle model could escape. Compare this with the actual water cycle.
3. Describe how adding heat to the water cycle affected the time it took for water to appear in the smaller container.

Conclusion

Describe the movement of the water through the water cycle.

Figure 1 Water drops

4.3 Can you reduce the evaporation of water in irrigation channels?

CHALLENGE

Design brief

The Mulwala Canal, in the Murray River region of New South Wales, discharges approximately 9000 million L of water a day. Over 700 000 hectares (ha) of land is irrigated from 2880 km of channels in the area.

These open channels allow a lot of water to evaporate before a single drop reaches the plants. Prepare a report that describes a cost-effective way to prevent the loss of water from the irrigation channels.

Figure 1 An open irrigation channel

Criteria restrictions

- All materials must be available in Australia.
- All prices must be in Australian dollars.

Questioning and predicting

- Research the average width of the channels.
- Identify the materials that you could use to replace 1 m of channel.

Planning and conducting

- Calculate the cost of 1 m of each of these materials.
- Select one of these materials and identify two other materials with similar properties. Compare the costs of all three materials.
- Calculate the cost of the materials required for 1 km of channel.
- Calculate the cost of 2880 km of channels.

Processing, analysing and evaluating

1. Compare the cost of your design with that of other students' designs.
2. Describe one feature of your design that was an improvement on other students' designs.
3. Identify one feature you would change if you were doing this challenge again. Explain how this change would improve the effectiveness of your design.

Communicating

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

5.2 Can you increase the output of a power station?

CHALLENGE

CAUTION!

- Handle the kettle carefully to avoid burns and scalds.
- The boiling water in the beaker will have made the sides of the beaker hot. Be careful to avoid burns when placing the foil.

Design brief

Modify the design of a model power station so that you increase the rate at which the turbine spins.

Criteria restrictions

Only the following materials can be used:

- Square paper (15 cm × 15 cm) cut from one A4 sheet
- Ruler
- Pencil with eraser on the end
- Scissors
- Pin
- Electric kettle
- Bunsen burner
- Tripod
- Gauze mat
- 250 mL beaker
- Aluminium foil (1 piece, 10 cm × 10 cm)
- Large nail

Questioning and predicting

- Describe how you could improve the turbine of a power station.
- Describe how you could increase the production of steam.
- Describe how you could improve the quantity and speed of the steam that hits the turbine.

Planning and conducting

The turbine

1 Mark the square paper as shown in Figure 1 using a pencil and a ruler. Draw a circle in the centre about the size of a 5 cent piece.

2 Cut along the lines but stop at the edges of the circle.

3 Fold all four corners in towards the centre, one at a time, and hold them in place.

4 Insert a pin through the four corners and into the tip of the pencil's eraser.

Figure 1 Marking the square paper

Figure 2 Blowing on the pinwheel

5 Blow on the pinwheel to see if it spins (Figure 2). If not, pull the pin out slightly to create room for the paper to spin. The pinwheel will act like the turbine of the power station.

The boiler

1 Set up your Bunsen burner, tripod and gauze mat. Place the beaker on top of the gauze mat.

2 Boil the kettle and transfer the boiling water to half-fill the 250 mL beaker.

3 Use the nail to punch a small hole in the centre of the aluminium foil.

4 Place the aluminium foil over the top of the beaker and fold it down the sides of the beaker.

5 Light your Bunsen burner and heat the water until it boils again.

6 Steam should be coming out of the hole. Hold your pinwheel over the hole and let the steam spin the 'turbine'.

Processing, analysing and evaluating

1 Describe what happened to your pinwheel when it was placed in the steam flow.

2 Describe what else you would need to add to make your 'power station' generate electricity.

3 Identify the fuel in your power station.

Communicating

Describe how a power station generates electrical energy.

5.3 Can you increase the power of solar cells?

CHALLENGE

Design brief

Modify the design of the solar cell so that it produces the highest voltage.

Materials

- Small solar cells
- Electrical wires
- Voltmeter
- Transparency sheet

Questioning and predicting

- Describe how you could maximise the amount of sunlight a solar cell receives.
- Describe how a solar panel can be cleaned. Contrast the voltage produced by a clean and dusty solar panel.
- How could you connect more than one solar cell so that the amount of voltage produced increases?

Planning and conducting

1. While inside a building, connect a solar cell to the voltmeter using the electrical wires.
2. Record the voltmeter reading with the limited light available.
3. Cover the solar cell with your hand and record the voltmeter reading.
4. Take the solar cell to a window and record the voltmeter reading.
5. Take the solar cell outside, face it towards the Sun and record the voltmeter reading. If it is cloudy outside, take a reading and then repeat the measurement when the clouds clear or on another day when it is sunny.
6. Cover the solar cell with a thin transparency sheet and repeat the measurement.
7. Connect solar cells together in series (i.e. in a line) and record the voltmeter reading.

Processing, analysing and evaluating

1. Copy Table 1 into your notebook and record your results.

Table 1 Recording the power of solar cells

Location	Number of solar cells	Voltmeter reading (V)
Inside		
Inside, covered		
Window		
Outside, sunny		
Outside, cloudy		
Outside, dusty		
Outside, multiple cells		

2. Use your data to identify the best conditions for generating electricity from a solar cell.
3. Explain why a house with a solar energy installation will have six, eight or more solar cells on its roof.
4. Explain why the solar panels on a house roof should be cleaned regularly.

Communicating

Describe the conditions that will maximise the electricity produced by solar cells.

Figure 1 The power of solar cells

5.4A What if a muffin was mined in different ways?

EXPERIMENT

CAUTION! Do not eat or drink in the laboratory.

Aim

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

Materials

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

Method

1. Imagine each muffin is an area of land that contains a valuable ore: chocolate chips.
2. Use spoons to 'mine' the chocolate from the first muffin using the 'open cut' method, taking layers off the top and collecting the chocolate as it appears.

Inquiry: What if the muffin was mined using the underground method?

1. Describe how you could mine this muffin so that the top remains intact.
2. Identify the *dependent* variable that you will measure and/or observe to determine the most effective method.
3. Identify two variables that you will need to control to ensure a fair test. Describe how you will control these variables.
4. Write down the method you will use to complete your investigation.
5. Draw a table to record your results.
6. Show your teacher your planning to obtain approval before starting your experiment.

Results

Draw or take a picture of your two muffins.

Discussion

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

Figure 1 Equipment for 'muffin mining'

5.4B What if a metal was obtained from a mineral?

EXPERIMENT

Aim

To obtain pure copper from the mineral copper sulfate.

Materials

- 2–12 V power supply
- 2 electrical leads with alligator clips on one end
- 2 carbon rods
- 250 mL beaker
- 0.5 M copper sulfate solution
- Safety glasses
- Paper towel
- Timer

Method

1 Plug the electrical leads into the DC terminals of the 2–12 V power supply.
2 Connect the top end of the carbon rods to the alligator clips on the end of the electrical leads.
3 Fill the beaker with approximately 100 mL of the copper sulfate solution.
4 Place the carbon rods into the copper sulfate solution, being careful not to let them touch each other or the beaker.
5 Set the 2–12 V power supply knob to 6 V and turn the power on.
6 Observe the rods over the next 10 minutes.
7 After 10 minutes, turn the 2–12 V power supply off. Remove the carbon rods and place them on paper towel.

Inquiry: Improving metal production

Choose one of the inquiry questions below.

- What if the voltage was increased?
- What if more copper sulfate was used?

Questions

Answer the following questions with regard to 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 you will need to control to ensure a fair test. Describe how you will control them.
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 observations about the appearance of the rods and the copper sulfate solution.

Discussion

1 Examine something else made of copper, such as an old 1 or 2 cent coin or a copper water pipe. Identify the copper as either whole (entirely made of copper) or a coating.
2 Describe how the object could have been coated with copper.
3 Identify where the copper that formed the coating came from.

Conclusion

Describe the conditions that produced the most copper coating in the shortest time.

Figure 1 Experimental set-up

5.5 What if different soils were exposed to water?

EXPERIMENT

Aim

To compare the components found in different soils.

PART A: LOOKING AT DRY SOIL

Materials

- 4 soil samples (beach sand, dry clay, good garden soil, Potting mix)
- 4 Petri dishes
- 4 white tiles
- Hand lens (or magnifier)
- Mortar and pestle

Method

1. Grind each sample with a mortar and pestle and then spread each thinly on a Petri dish on top of a white tile.
2. Examine each sample with a hand lens.
3. Draw a labelled diagram and describe the following properties of each soil type:
   - colour
   - size
   - clear and glossy or dull and grey
   - rounded or sharp edges.

PART B: WHAT IS IN SOIL?

Materials

- Small sample of good garden soil
- 100 mL measuring cylinder

Figure 1 Adding soil to measuring cylinder

Method

1. Place the soil in the measuring cylinder and add water (Figure 1).
2. Carefully shake the mixture by holding the top of the measuring cylinder and rotating the base of the measuring cylinder.
3. Allow the mixture to stand undisturbed for at least 48 hours, or longer if needed. This will allow the components of the soil to separate into layers.
   - Describe each of the layers that formed.
   - Describe the components that floated to the top or settled on the bottom.

PART C: TESTING

After examining the dry soil (part A) and what is in the soil (part B), predict which sample the water will flow through fastest (part C).

Materials

- 4 × 100 mL measuring cylinders
- 4 filter funnels
- 1 × 20 mL measuring cylinder
- 4 cotton balls
- 4 soil samples (beach sand, dry clay, good garden soil, potting mix)
- Stopwatch

Figure 2 Experimental set-up

Method

1. Press a cotton ball firmly into the 'V' of each filter funnel.
2. Add 3 teaspoons of each soil sample to different funnels and press down firmly.
3. Place a funnel in the top of the measuring cylinder and add 20 mL of water.
4. Record the time it takes for the water to flow into the funnel.
5. Repeat steps 3 and 4 for the remaining three samples.

Results

Record your observations for parts A, B and C in separate tables and measurements in a table.

Discussion

1 Identify the independent variable and dependent variable in your experiment.
2 Identify which soil drained the fastest.
3 Identify which soil stopped the most water from flowing.
4 Identify which soil absorbed the most water.
5 Explain why the water-holding abilities were different between the soils.
6 Describe the qualities a good soil needs for plants to grow well.

Conclusion

Compare the water-holding ability of the four soils.

5.6 Resources for your future

CHALLENGE

Aim

To prepare a report on a natural resource that is being depleted.

Working in a small group, research and prepare a report about the depletion (using up) of one of the world's natural resources. In your report, include:

> a brief summary of the topic
> the cause of the depletion of your chosen natural resource
> the effects of depletion of this natural resource
> short- and long-term solutions to this problem
> the role of public education in solving this problem
> what you could do about this problem.

Present your report to the class as a speech and short multimedia presentation.

Figure 1 Resources for the future

6.2 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.

6.3 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 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 basketball would be experiencing summer.

2 Describe how the seasons changed on one point of the basketball 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 Modelling the seasons

7.1 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, plasma 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 ar disadvantages of each design.

Figure 1 Department store classification

7.3 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 your 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 on each object that allowed it to be classified.

Figure 1 Swapping your dichotomous key with another group to evaluate

7.4 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?

7.5 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

7.6A 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 prawns 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 to observe its insides.

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 describing the key feature that was used to identify the classification group.

5 Identify the classification group to which you belong: a vertebrate or an invertebrate.

Conclusion

Describe the types of skeletons that you observed and how they helped you in classifying the organism.

7.6B 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 130 to classify the invertebrates into their particular phylum.

Figure 1 Some common invertebrates

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.

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.

7.7 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 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.

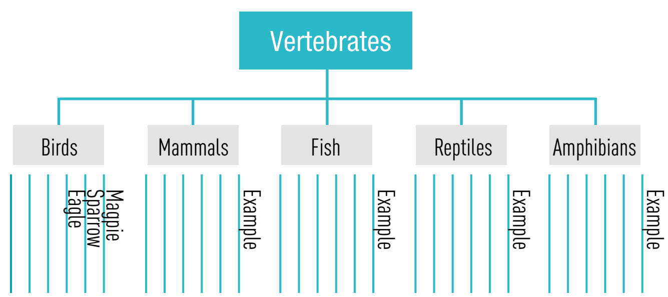


Figure 1 A jellyfish organiser for vertebrates

3. Label each jellyfish with the class name: fish, reptiles, amphibians, mammals and birds.
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 on each jellyfish.

7.8 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 this plant.
5 Repeat steps 2–4 for all the plants you observed.
6 Identify and describe the features the plants have in common.
7 Contrast the differences you observed between the plants.

Figure 1 Identifying plants

8.1 Studying food webs

CHALLENGE

Aim

To identify the producers and consumers in a local food web.

What you need:

- Metre-long sticks
- Metric rulers
- Poster board
- Markers
- Photographs of ecosystems

What to do:

1 Think about what you know about food webs in your area. Write a list of at least 10 living things within these food webs. Compare the number of different animals found in different areas.
2 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).
3 Observe and record all organisms in the area above and within this study area.

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.

8.2A Exploring leaf litter

CHALLENGE

Aim

To identify the organisms that make up a leaf litter community.

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.

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.

8.2B What if water were filtered through a pot with native grasses?

EXPERIMENT

Aim

To find out how effective natural systems can be at filtering water.

Materials

> 2 medium-sized plastic pots
> 2 plastic buckets
> Native grasses
> Timer
> Gravel

Method

1 A few weeks in advance, prepare two plastic pots with a layer of gravel, then sand and finally soil. Plant some native grasses in one of the pots. Wait until the grasses have established themselves in the pot before proceeding. (Hint: You should be able to see the roots of the plant in the bottom of the pot.)
2 Mix the castor oil, dirt, finely shredded paper, salt and any other materials you wish to include in a bucket of water. The mixture should be very cloudy and have an odour.
3 Swirl your mixture to mix it, start the timer and slowly pour half of the mixture through the pot with the grasses. Use the second bucket to capture the solution that filters out of the base of the pot. Record and time the flow of solution out of the base of the pot. Also note and record the odour and colour of the solution.

Inquiry: What if the water was filtered through a pot with no plant?

1 Write a hypothesis for your question.
2 Identify the *independent* variable that you will change from the first method.
3 Describe how you will determine if the absence of the plant makes a difference to the filtering of the water.
4 Describe how you will make sure that all parts of the plant are removed.
5 What variables will you need to control to ensure a fair test? How will you control them?
6 Write down the method you will use to complete your investigation. (Hint: Use the method above as a guide.)
7 Draw a table to record your results.
8 Show your teacher your planning to obtain approval before starting your experiment.

Results

Create a table to record the time taken for the solution to flow out of the base of each pot. Include a description and/or photograph of the appearance of the solution before and after it has gone through each pot.

Discussion

1 Explain any differences you observed in the rate of the water flow through the two pots.
2 Explain any differences you observed in the cloudiness of the final filtered solutions.
3 Explain any differences you observed in the odour of the final filtered solutions.

Conclusion

Describe the most effective natural systems for filtering water.

8.3 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 variations below to investigate.

- 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?

Questions

Answer the following questions with regard to 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 fair 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.

8.4 Calculating your ecological footprint

CHALLENGE

Aim

To determine your family's ecological footprint.

Ecological footprint calculators are online surveys that help you and your family to compare the impact of different activities you do or decisions you make.

1 Search the internet for an ecological footprint calculator. Calculate the ecological footprint for your home or school.
2 Calculate your greenhouse gas emissions and the impact of your car, if your family owns one.

Questions

1 Describe one factor that makes your home sustainable.
2 Describe the changes you and your family could make to your lifestyles to live more sustainably.
3 Describe how these changes could save you and your family money.

Figure 1 Ecological footprint

8.5 Making a biosphere

CHALLENGE

Design brief

Use what you have learnt in this topic to construct a stable ecosystem for aquatic plants and macroinvertebrates (water fleas or pond snails).

Criteria restrictions

- Your materials are limited to those you find in a local pond or those provided by your teacher.
- A 1 L bottle should be recycled for this challenge.

Questioning and predicting

- Describe how producers and consumers interact with each other.
- Describe the primary source of energy in any environment.
- Predict which organism – producer or consumer – needs to be more common in your environment.
- Describe how the water cycle will operate in your environment.

Planning and conducting

- Describe how you will place each organism in the bottle.
- Calculate the quantities of each organism you will use.
- Describe the role each organism will play in your ecosystem.
- Describe how you will evaluate the health of your organisms.
- All scientists must consider the ethics of their experiment before beginning. Describe what you will do if you find your organisms are unable to survive in the environment you create.

Processing, analysing and evaluating

1. Describe the most successful feature of your design.
2. Describe how you would modify your design if you were doing this experiment again. Justify your decision by explaining the consequences of your decision.

Figure 1 Biosphere in a bottle

Communicating

Present the various features of your design in a detailed poster.

8.6 Looking at eucalypt adaptations

CHALLENGE

Aim

To determine how eucalypts have adapted to the Australian environment.

What you need:

Ripened eucalyptus nuts, leaves and bark of a eucalypt an incubator set at 40°C

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.
   - Explain why the seed of the gumnut is protected with such a thick external capsule.
   - Identify what might trigger the release of the seed from the gumnut.
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 under a binocular microscope. Notice the numerous small dots, which are oil glands in the leaf.
   - Explain the function of the oil glands in a eucalypt leaf.
4. Have a close look at the bark of the tree. Many eucalypt trees have bark that is thick and fibrous.
   - Explain the function of thick fibrous bark.

9.1 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
- Safety glasses
- Incubator set at 40°C

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.

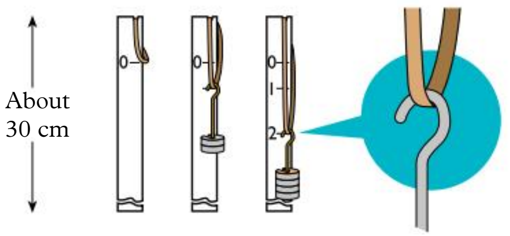


Figure 1 Calibrating the force measurer

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
   b drag a chair across the floor
   c close a drawer in the laboratory
   d move your pencil case
   e pull up your sock
   f do three other movements of your choice.

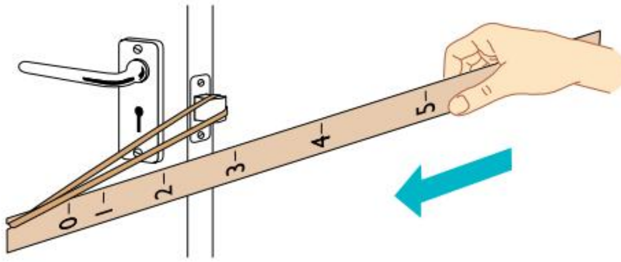


Figure 2 Measuring the force needed to open a door

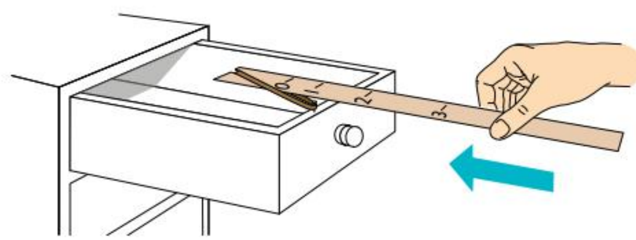


Figure 3 Measuring the force needed to close a drawer

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.

9.2 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.

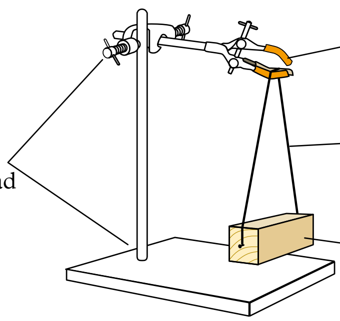


Figure 1 A possible design for the experiment

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.

9.3 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. 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.

9.5 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?

Answer the following questions with regard to 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 fair 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.

9.6A 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 the Earth is determined by the mass of 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	

9.6B Modelling gravity in the solar system

CHALLENGE

Aim

To model how the gravity of a planet could affect the movement of an asteroid.

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.

What you need:

- 1 thin stretchable plastic sheet (e.g. garbage bag or cling wrap)
- 2–4 small marbles
- 5 cm Styrofoam ball
- ½ cup of play dough
- 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.

9.8 What if the amount of friction was changed?

EXPERIMENT

Aim

To investigate how friction may be reduced.

Materials

- Force measurer (see Experiment 9.1) or spring balance
- Thick textbook
- Wooden rollers (round pencils)
- Book
- Sand
- Safety glasses

Method

1 Use your force meter 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.

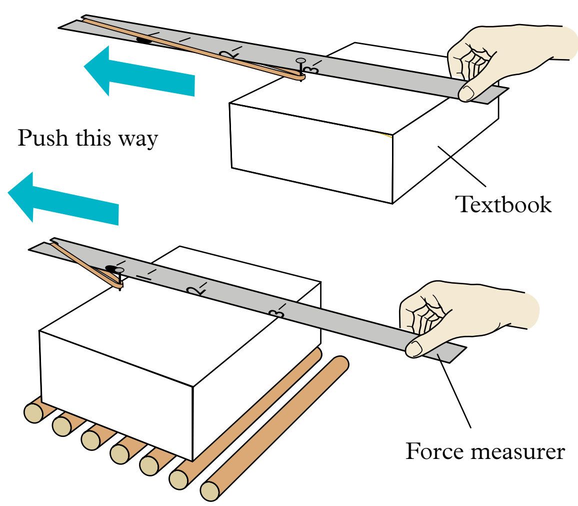


Figure 1 Measuring the friction of a textbook

Inquiry: Choose one question to investigate

Choose one of the variations below to investigate.

- What if rollers were placed under the textbook?
- What if sand was placed under the textbook?

Questions

Answer the following questions with regard to 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 fair 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 Write 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.

9.9A 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 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: Choose one question to investigate

Choose one of the variations below to investigate.

> 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?

Questions

Answer the following questions with regard to 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 fair 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.

9.9B 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.

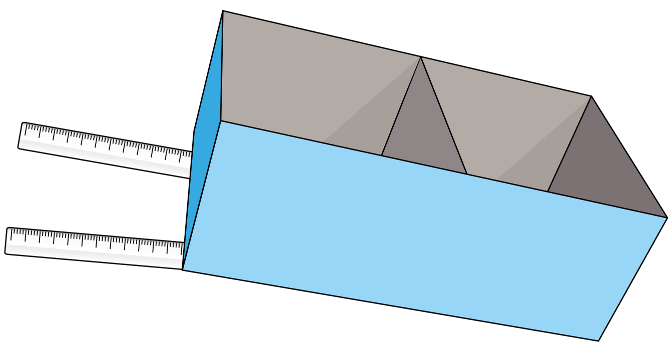


Figure 1 Experimental set-up

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 fair 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.

9.10 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			

9.11 Comparing different machines

EXPERIMENT

Aim

To determine the force magnification of different machines.

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

PART A: INCLINED PLANES

Method

1. Measure and record the height of the shoebox (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.

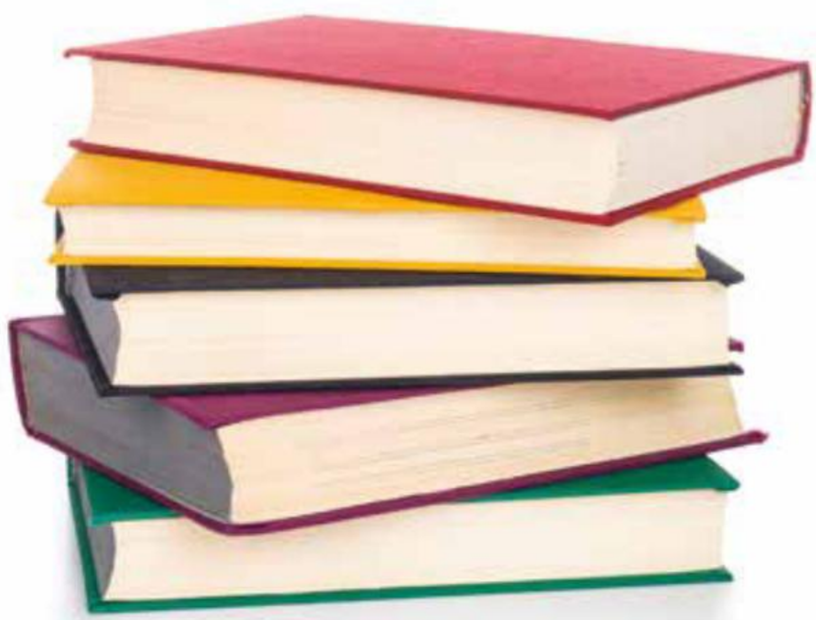


Figure 1 A pile of books

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 Wedges

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

[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 Aboriginal and Torres Strait Islander 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,

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.

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.

Figure 2 Litter is a contaminant in local waterways, such as the River Torrens in Adelaide.

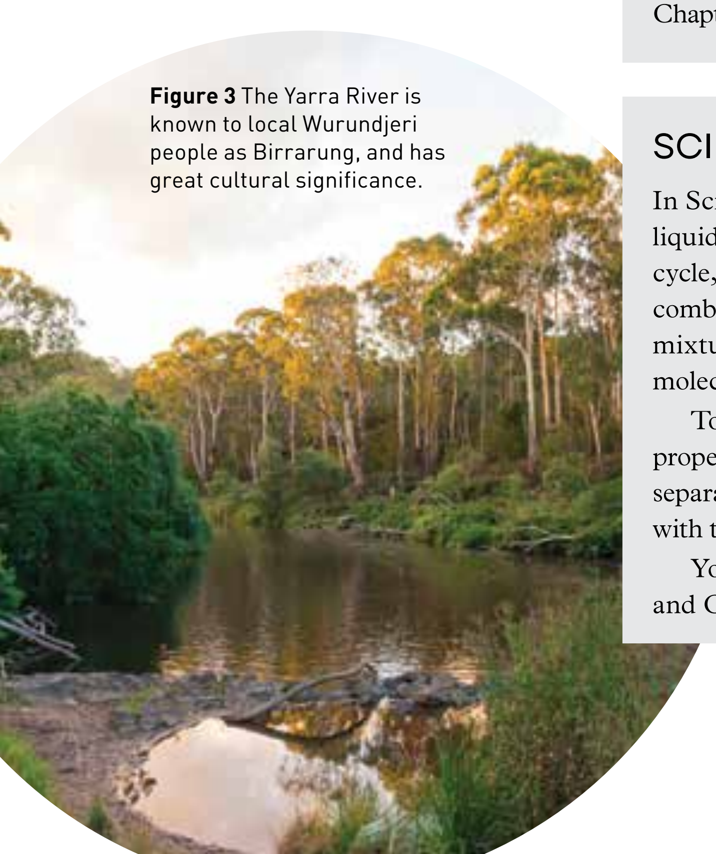


Figure 3 The Yarra River is known to local Wurundjeri people as Birrarung, and has great cultural significance.

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 7 Victorian Curriculum*.

MATHS

In Maths this year, you will consolidate your understanding of volume and capacity 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 Victorian 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 fair test.

You will find more information on this in Chapter 2 ‘Particle model’ and Chapter 3 ‘Mixtures’ of *Oxford Science 7 Victorian Curriculum*.

The design cycle

To successfully complete this task, you will need to complete each of the phases of the design cycle.

Discover

When designing solutions to a problem, you need to know who you are helping and what they need. The people you are helping, who will use your design, are called your end-users.

Consider the following questions to help you empathise with your end-users:

- Who am I designing for?
- What 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: pro

Student guidebook
This helpful booklet will guide you step-by-step through the project.

What is the design cycle?
This video will help you to better understand each phase in the design cycle.

How to manage your project
This 'how-to' video will help you to manage your time throughout the design cycle.

How to pitch your idea
This 'how-to' video will help you with the 'Communicate' phase of your project.

Check your Teacher obook pro for these digital resources and more: pro

Implementation advice
Find curriculum links and advice for this project.

Assessment resources
Find information about assessment for this project.

[STEAM project 2]

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

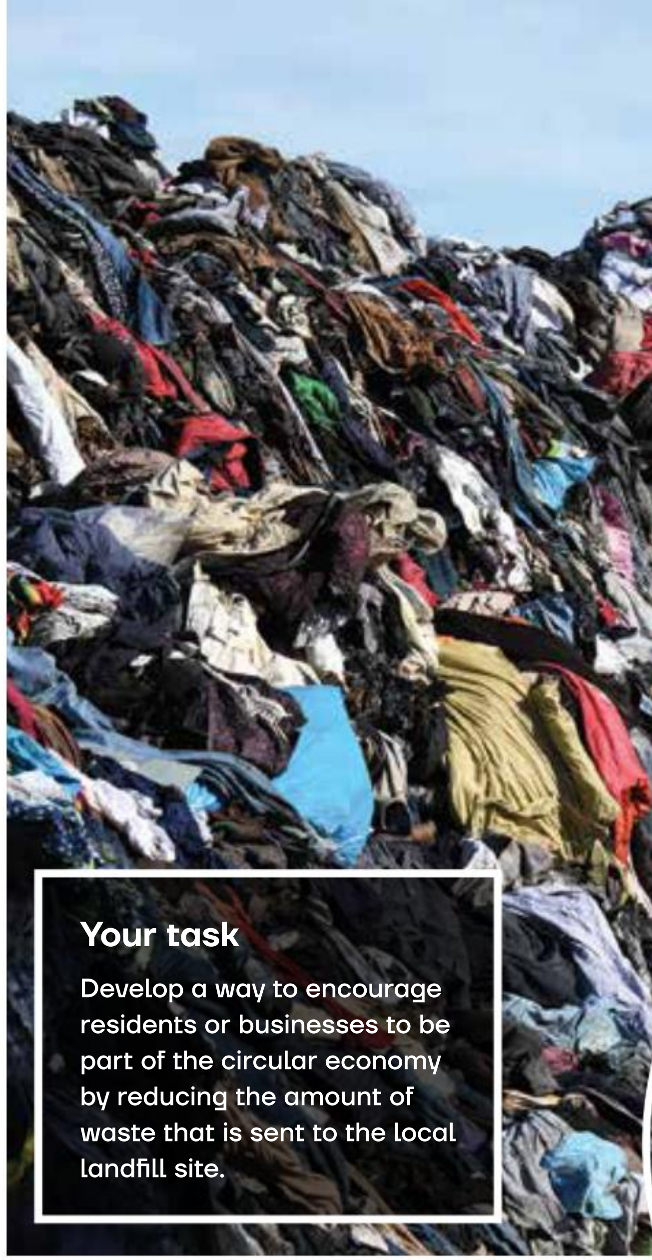
In Australia, millions of electronic devices are thrown away every year. This is known as e-waste. E-waste can be difficult to recycle, but it often contains valuable metals.

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 17 'Economic choices' of *Oxford Humanities 7 Victorian 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 Victorian Curriculum*.

SCIENCE

In Science this year, you will learn how different resources can take different amounts of time to be regenerated. 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 on resources in Chapter 5 'Resources' in *Oxford Science 7 Victorian Curriculum*.

The design cycle

To successfully complete this task, you will need to complete each of the phases of the design cycle.

Discover

When designing solutions to a problem, you need to know who you are helping and what they need. The people you are helping, who will use your design, are called your end-users. 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 guidebook
This helpful booklet will guide you step-by-step through the project.

What is the design cycle?
This video will help you to better understand each phase in the design cycle.

How to manage your project
This 'how-to' video will help you to manage your time throughout the design cycle.

How to define a problem
This 'how-to' video will help you to narrow your ideas down and define a specific problem.

Check your Teacher obook pro for these digital resources and more:

Implementation advice
Find curriculum links and advice for this project.

Assessment resources
Find information about assessment for this project.

GLOSSARY

A

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

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

biodiversity
the variety of life; the different plants, animals and micro-organisms and the ecosystems they live in

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

carnivore
an animal that eats other animals

cell wall
a structure that provides support around the cell in some organisms, such as plants and fungi

cell
(in biology) the building block of living things

Celsius (°C)
a temperature scale and unit of measurement of temperature, in which water boils at 100°C and freezes at 0°C

centimetre (cm)
a metric unit of length, equal to one-hundredth of a metre

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

coal
a fossil fuel formed from the remains of trees and plants that grew about 300 million years ago

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

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

concentrated
containing a large number of solute particles in the volume of solution

conclusion
a statement that 'answers' the aim of an experiment; should be clear and reasoned and relate closely to the aim

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 is measured and can be any value

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

cubic centimetre (cm^3)
a volume equivalent to that of a cube of length 1 centimetre

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

desalination plant
a large facility set up to produce fresh water from salt water

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

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

E

easily renewable
made naturally and available in an almost unlimited amount

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

emissions
the production and release of a substance into the air (e.g. gas)

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

energy resources
resources that can be used for the production of energy

equinox
a day when day and night are the same length; occurs twice each year

equipment
items used in the laboratory to conduct experiments

erosion
the movement of sediment to another area

error
an inaccuracy or inconsistency in measurement; can be random or systematic

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

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

fossil fuel
a non-renewable energy source formed from the fossilised remains of plants and animals

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

generator
a machine that uses the electromagnetic effect to separate charges and produce electricity

genus
a group of closely related species

geothermal energy
energy that comes from heat beneath the Earth's surface

global warming
the increase in temperature of the Earth's atmosphere caused by the greenhouse effect Earth's atmosphere by human activity

gram (g)
unit of mass

gravity
the force of attraction between objects due to their masses

green wedges
non-urban areas around metropolitan areas

greenhouse effect
the trapping of the Sun's warmth in the lower atmosphere of the Earth caused by an increase in carbon dioxide, which is more transparent to solar radiation than to the reflected radiation from the Earth

greenhouse gas
a gas (carbon dioxide, water vapour, methane) in the atmosphere that can absorb heat

groundwater
water beneath the Earth's surface

H

hardness
how easily a mineral can be scratched; measured using the Mohs hardness scale

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

hot dry rock geothermal energy
a method of pumping water into deep hot rocks in the ground in order to produce steam, which is then used to drive a turbine to provide electricity

hybrid
describes a car that uses both petrol and electricity

hydroelectric energy
energy produced by falling water that turns turbines to generate electricity

I

incompressible
unable to be compressed; solids and liquids are incompressible

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

invertebrates
having an exoskeleton (external skeleton) or no skeleton

K

key
(in biology) a visual tool used to classify organisms

kilogram (kg)
unit of mass, equivalent to 1000 grams

kilometre (km)
a metric unit of length, equal to 1000 metres

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

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

litre (L)
unit of volume used to measure liquid

load
(in physics) resisting force

long-term renewable
refers to resources that are limited because, once used, they take a long time to replace

low tide
when the ocean covers slightly less land; the lowest level on the shore that the tide recedes to

low-emissions vehicles
cars or buses that release very few exhaust gases, including carbon dioxide

lubrication
the action of applying a substance such as oil or grease to an engine or component so as to reduce friction

M

magnetic poles
1. the north and south ends of a magnet;
2. 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

milligram (mg)
unit of mass, equivalent to one-thousandth of a gram

millilitre (mL)
unit of volume used to measure small or exact quantities of liquids, equivalent to one-thousandth of a litre

millimetre (mm)
a metric unit of length, equal to one-thousandth of a metre

mineral
a naturally occurring solid substance with its own chemical composition, structure and properties

mixture
a substance made up of two or more pure substances mixed together

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

multicellular
consisting of two or more cells

N

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
1. in biology: a membrane-bound structure in cells that contains most of the cell's genetic material; 2. in chemistry: the centre of an atom, containing protons (positive charge) and neutrons (no charge)

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

ore
a mineral containing a large amount of useful metal

P

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

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

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

power station
a place where energy is converted to electricity

precipitation
1. in meteorology: the process in which water vapour in the upper atmosphere becomes liquid water in the form of rain, snow or sleet and falls to the ground;
2. in chemistry: the process of forming a precipitate

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

pure substance
something that contains only one type of substance (e.g. a single element or a single compound)

Q

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

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 its load between the point of effort and the fulcrum

second-order (secondary) consumer
a carnivore that eats primary consumers

second (s)
a second is a sixtieth of a minute

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 cell
a device that transforms sunlight directly into electrical energy

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 each other, 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
give an object a form that presents the least resistance to motion

suspension
a cloudy liquid containing insoluble particles

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

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

tidal energy
the energy in the rise and fall of tides, which can be used to drive turbines in the water, producing electricity

tonne (t)
unit of mass, equivalent to 1000 kilograms

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

transpiration
the process of water evaporating from plant leaves; causes water to move up through the plant from the roots

turbine
a large wheel with angled sections called vanes, like a propeller, that is used to generate electricity

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

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

volcano
a vent or hole in the Earth through which molten (melted) rock, ash and other materials escape to the surface

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
1. a measure of the gravitational pull on an object; 2. a property of rocks used to identify them

wheel and axle
a type of lever that can rotate about its centre, magnifying force or distance

wind farm
a large group of wind turbines in the same location

wind turbine
a wheel with blades that turn in the wind

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S

Scientists observe animals in their natural environment to learn more about them. This image shows a group of researchers observing an Antarctic minke whale off the coast of the Antarctic Peninsula. The scientific name of the Antarctic minke whale is *Balaenoptera bonaerensis*.

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