GRAEME LOFTS | MERRIN J. EVERGREEN

JACARANDA SCIENCE QUEST 7

VICTORIAN CURRICULUM | THIRD EDITION

VICTORIAN CURRICULUM v2.0

learnon
www.jacplus.com.au

jacaranda
A Wiley Brand

JACARANDA SCIENCE QUEST 7

VICTORIAN CURRICULUM | THIRD EDITION

JACARANDA SCIENCE QUEST 7

VICTORIAN CURRICULUM | THIRD EDITION

GRAEME LOFTS

MERRIN J. EVERGREEN

CONTRIBUTORS

SARAH BEAMISH

CATHERINE BELLAIR

DANIELA CARBOON

LUCY CASSAR

SACHA O'CONNOR-PRICE

MICHAEL ROSENBROCK

STEPHANIE WHITEHEAD

LUKE WILLIAMS, GUMBAYNGGIRR

VICTORIAN CURRICULUM v2.0

jacaranda
A Wiley Brand

Third edition published 2025 by
John Wiley & Sons Australia, Ltd
Level 4, 600 Bourke Street, Melbourne, Vic 3000

First edition published 2014
Second edition published 2018

Typeset in 10.5/13 pt TimesLT Std

ISBN: 978-1-394-34017-0

Typeset in India by diacriTech

NATIONAL LIBRARY OF AUSTRALIA

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

The publisher of this series acknowledges and pays their respects to Aboriginal Peoples and Torres Strait Islander Peoples as the traditional custodians of the land on which this resource was produced.

This suite of resources may include references to (including names, images, footage or voices of) people of Aboriginal and/or Torres Strait Islander heritage who are deceased. These images and references have been included to help Australian students from all cultural backgrounds develop a better understanding of Aboriginal and Torres Strait Islander Peoples' history, culture and lived experience.

It is strongly recommended that teachers examine resources on topics related to Aboriginal and/or Torres Strait Islander Cultures and Peoples to assess their suitability for their own specific class and school context. It is also recommended that teachers know and follow the guidelines laid down by the relevant educational authorities and local Elders or community advisors regarding content about all Aboriginal and/or Torres Strait Islander Peoples.

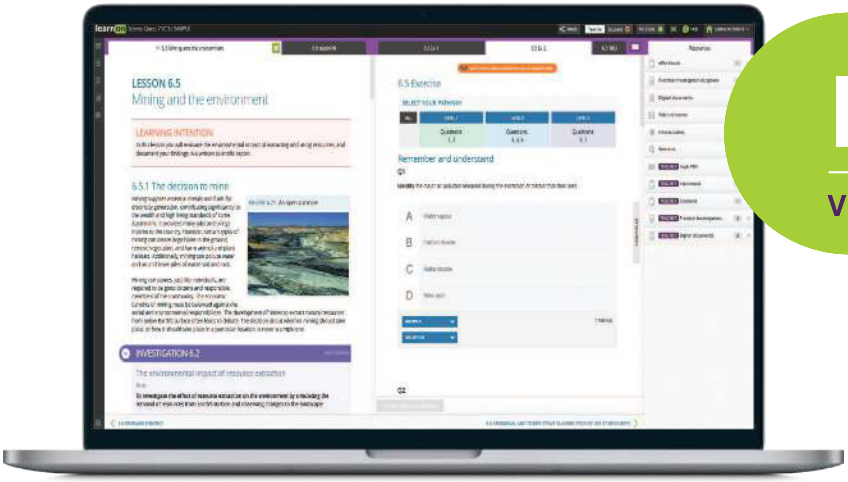
All activities in this resource have been written with the safety of both teacher and student in mind. Some, however, involve physical activity or the use of equipment or tools. **All due care should be taken when performing such activities**. To the maximum extent permitted by law, the author and publisher disclaim all responsibility and liability for any injury or loss that may be sustained when completing activities described in this resource.

The publisher acknowledges ongoing discussions related to gender-based population data. At the time of publishing, there was insufficient data available to allow for the meaningful analysis of trends and patterns to broaden our discussion of demographics beyond male and female gender identification.

Contents

PHYSICAL SCIENCES

About this resource



NEW FOR

VICTORIAN CURRICULUM V2.0

JACARANDA

SCIENCE QUEST 7 VICTORIAN CURRICULUM

THIRD EDITION

Developed by teachers for students

Tried, tested and trusted. Every lesson in the new *Jacaranda Science Quest* series has been carefully designed to support teachers and help students succeed by sparking their curiosity about the world around them.

Because both what **and** how **students learn matter**

Learning is personal

Students: Access lessons tailored to your needs, with interactive content and support to help you progress confidently.

Teachers: Deliver engaging, differentiated lessons with built-in scaffolding and tools to support every learner.

Learning is effortful

Students: Challenge yourself, build confidence, and grow through purposeful practice on Australia's leading platform.

Teachers: Encourage persistence with tasks that develop resilience and drive meaningful learning outcomes.

Learning is rewarding

Students: See your progress in real time, recognise your strengths, and focus on where to improve.

Teachers: Use rich analytics to track growth and target support exactly where and when it's needed.

Learn online with Australia's most

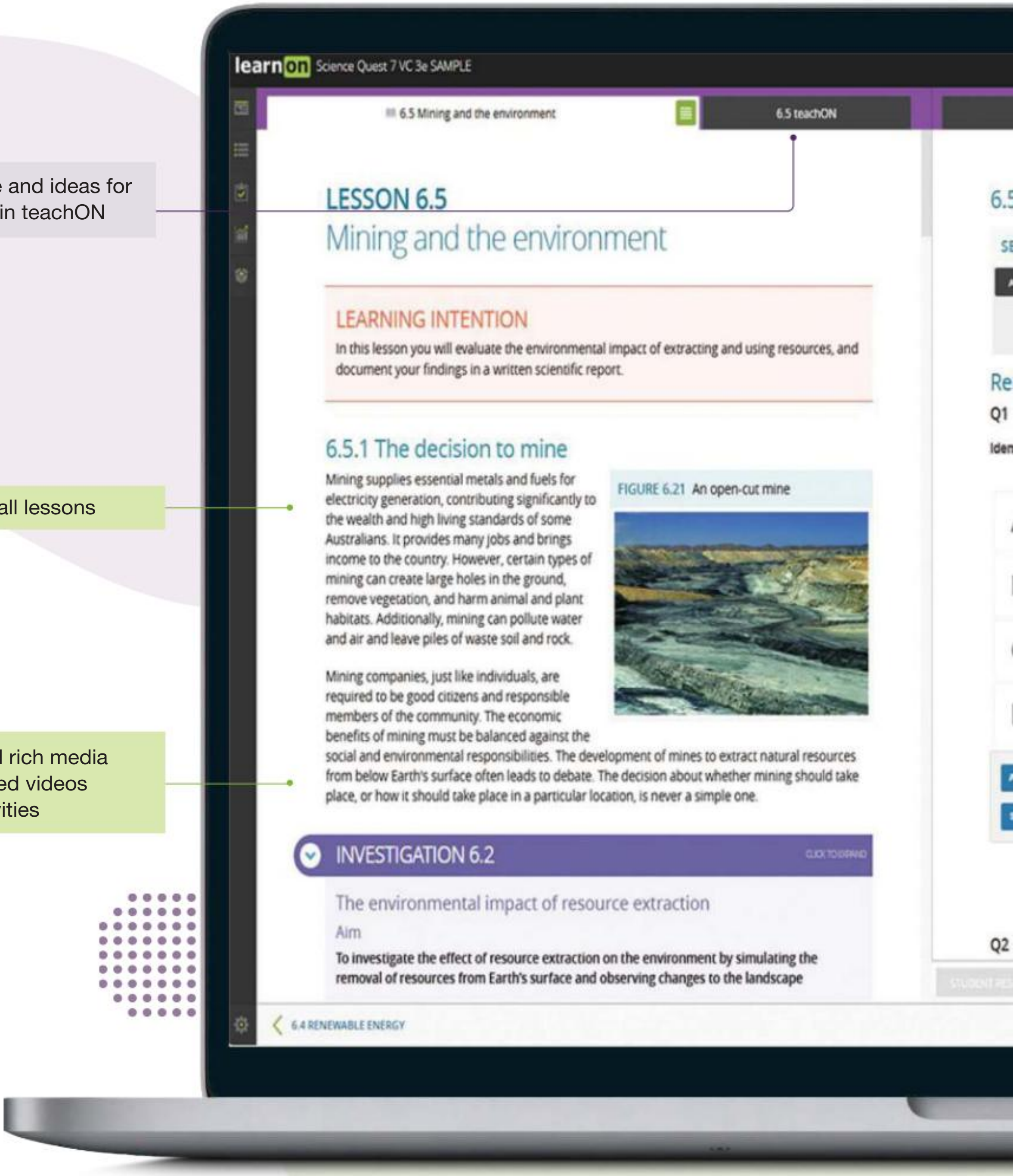
Everything you need for each of your lessons in one simple view

- **New: AI-powered personal tutor, jacTUTOR**
- **Trusted, curriculum-aligned content**
- **Engaging, rich multimedia**
- **Deep insights into progress**
- **Immediate feedback for students**
- **A full suite of lesson resources for teachers**

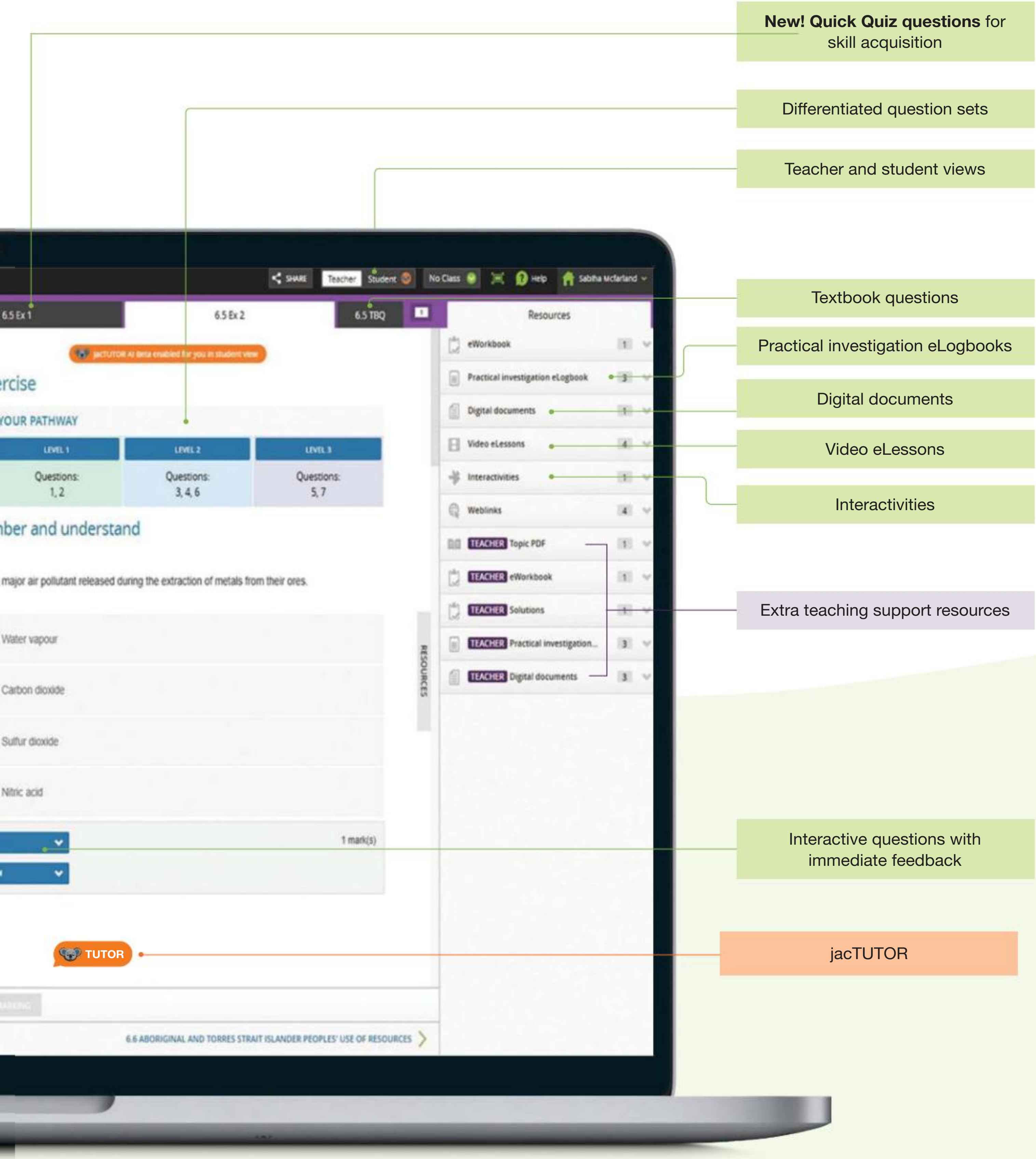
Practical teaching advice and ideas for each lesson provided in teachON

Teaching videos for all lessons

Reading content and rich media including embedded videos and interactivities



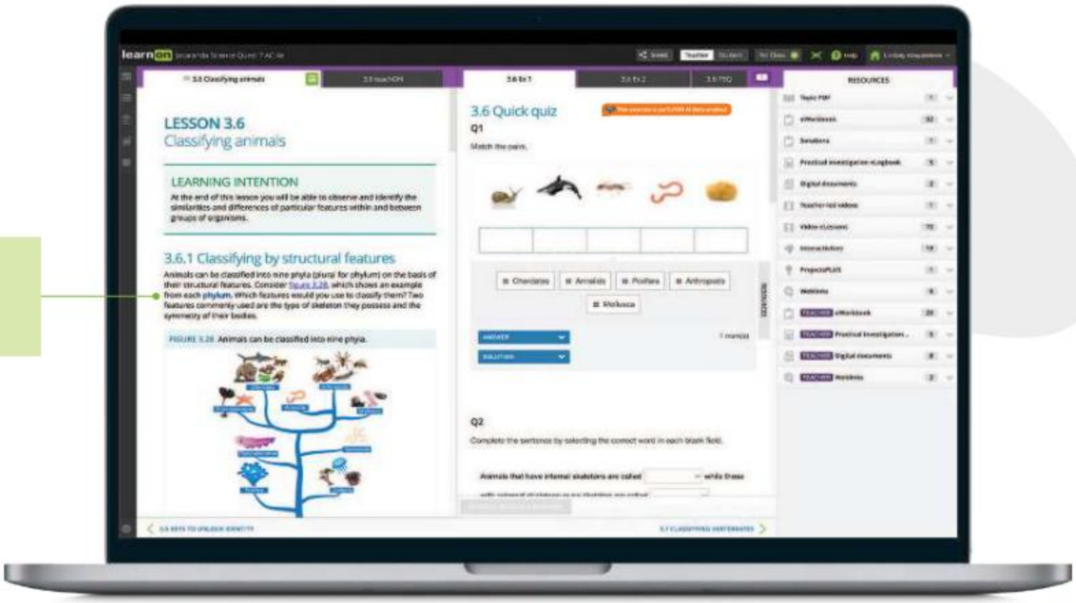
powerful learning tool, learnON



Get the most from your online resources

Online, these new editions are the complete package

Trusted Jacaranda theory, plus tools to support teaching and make learning more engaging, personalised and visible.

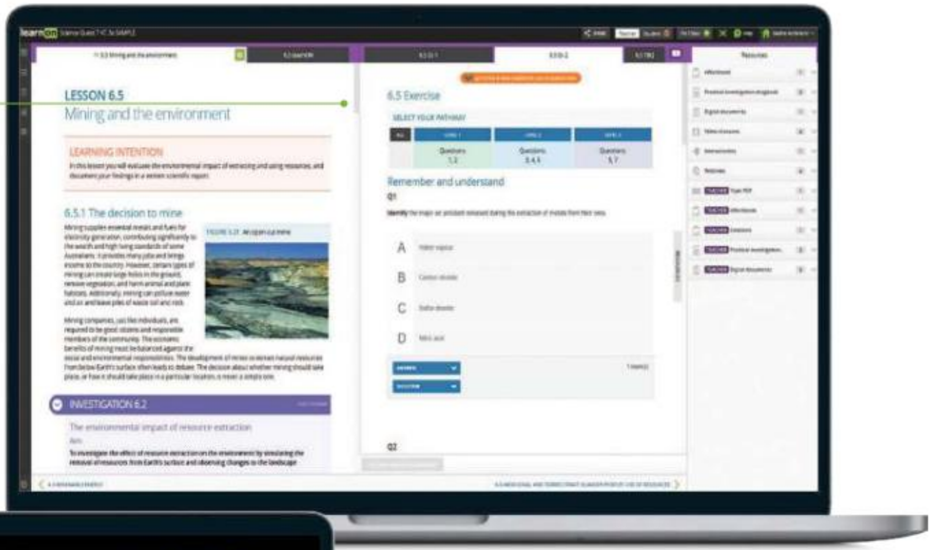


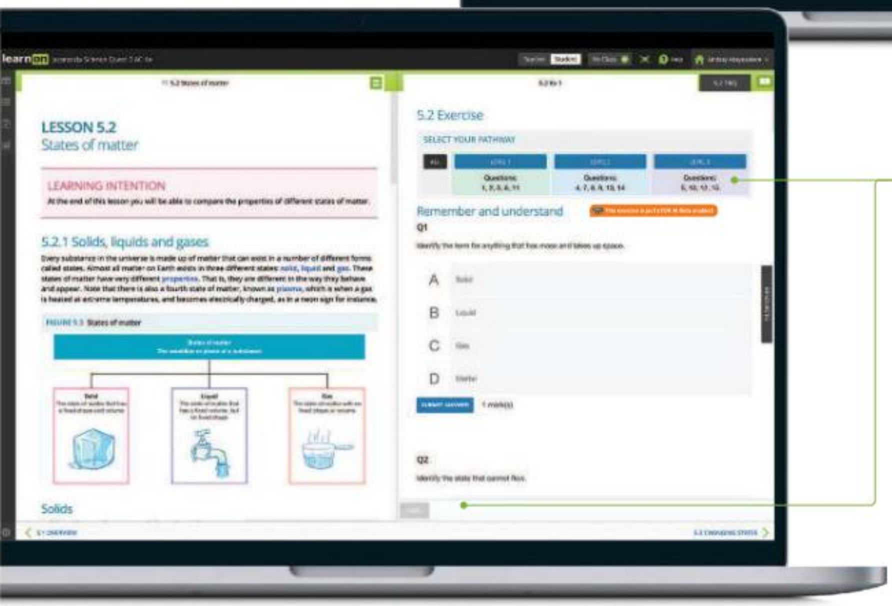
Interactive glossary terms help develop and support scientific literacy.

onResources link to targeted digital resources including video eLessons and weblinks.

Tables and images break down content, allowing students to understand complex concepts.

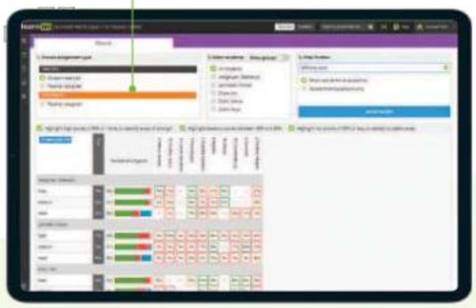
Quick Quiz questions for skill acquisition in every lesson.

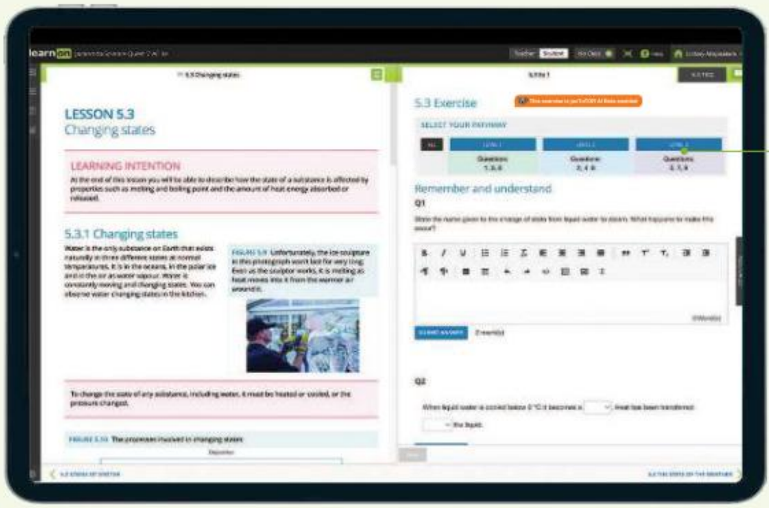




Three differentiated question sets, with immediate feedback in every lesson, enable students to challenge themselves at their own level.

Instant reports give students visibility into progress and performance.

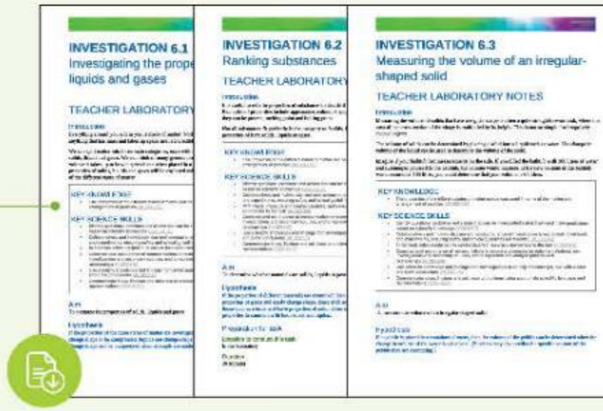




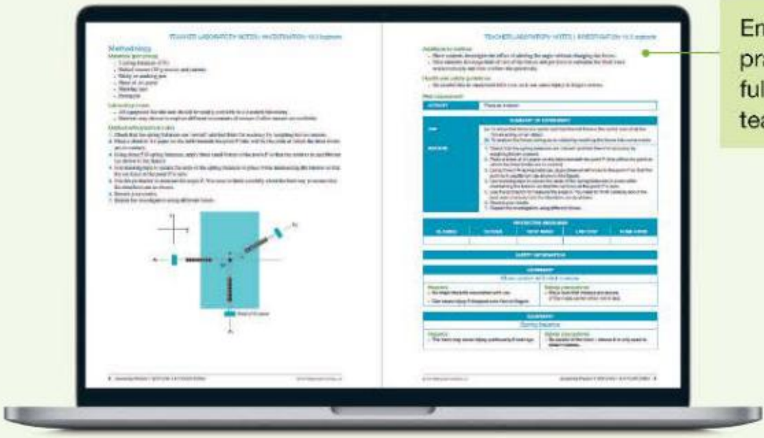
Every question has immediate, corrective feedback to help students overcome misconceptions as they occur and get unstuck as they study independently — in class and at home.

Practical Investigation eLogbook

The **practical investigation eLogbook** ignites curiosity through science investigation work, with an extensive range of exciting and meaningful practical investigations. Aligned with the scientific method, students can develop rich science inquiry skills in conducting scientific investigations and communicating their findings, allowing them to truly think and act like scientists! The practical investigation eLogbook is supported with an unrivalled teacher and laboratory guide, which provides suggestions for differentiation and alteration, risk assessments, expected practical results and exemplary responses.

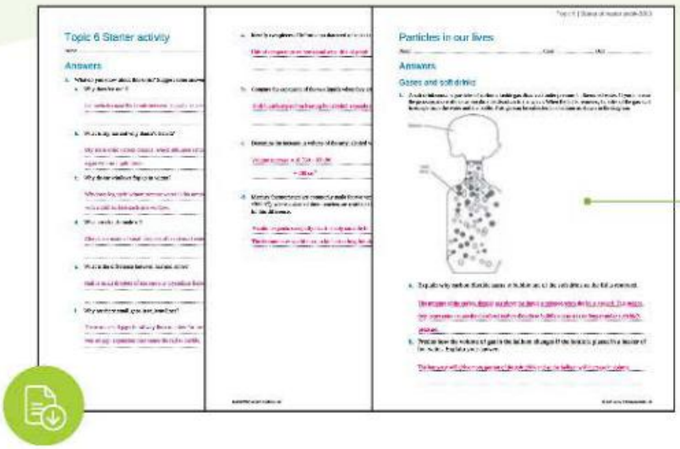


Risk Assess Included



Enhanced practical investigation support includes practical investigation videos and an eLogbook with fully customisable practical investigations — including teacher advice and risk assessments.

eWorkbook



The **eWorkbook** is the perfect companion to the series, adding another layer of individualised learning opportunities for students, and catering for multiple entry and exit points in student learning. The eWorkbook also features fun and engaging activities for students of all abilities and offers a space for students to reflect on their own learning. The new eWorkbook and eWorkbook solutions are available as a downloadable PDF or a customisable Word document in learnON.

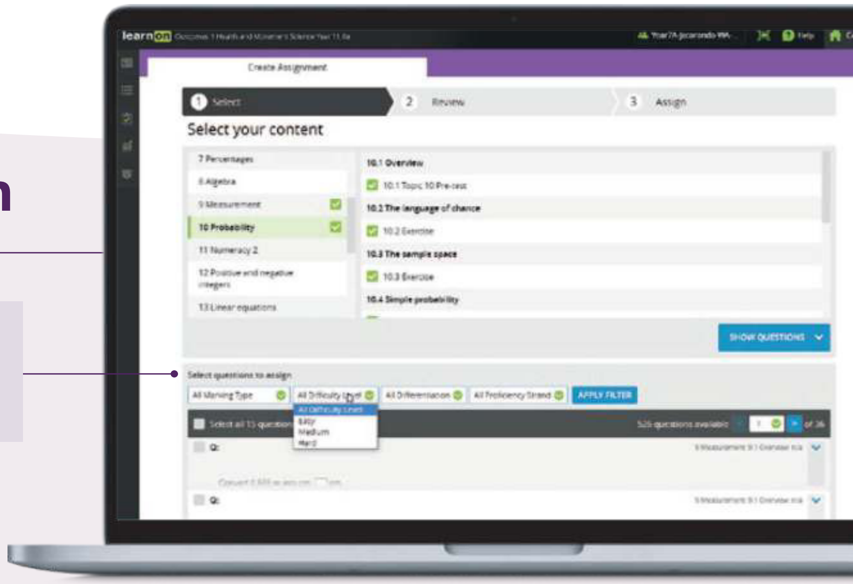
A wealth of teacher resources

Enhanced teacher support resources for every lesson, including:

- work programs and curriculum grids
- practical teaching advice
- three levels of differentiated teaching programs
- quarantined topic tests (with solutions)

Customise and assign

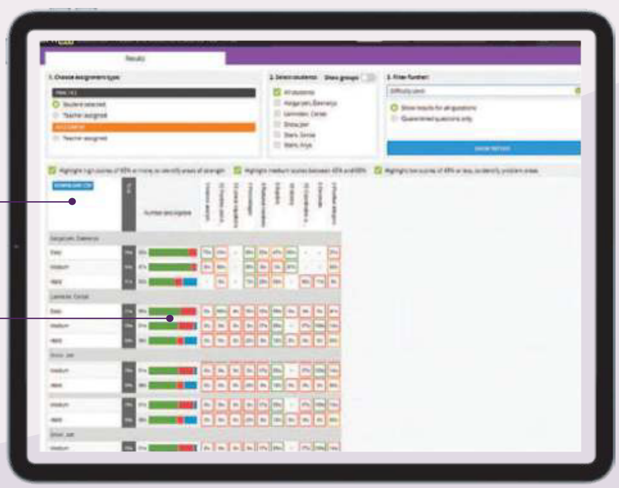
An inbuilt testmaker enables you to create custom assignments and tests from the complete bank of thousands of questions for immediate, spaced and mixed practice.



Reports and results

Data analytics and instant reports provide data-driven insights into progress and performance within each lesson and across the entire course.

Show students (and their parents or carers) their own assessment data in fine detail. You can filter their results to identify areas of strength and weakness.



The new jacTUTOR

Help when students (and teachers) need it — with jacTUTOR

With jacTUTOR, every student can have the help of a personal tutor when they get stuck, in class or at home. This purpose-built tool sits safely within your favourite Jacaranda resource, so guidance will always be specific to that lesson, question and curriculum.

A personal tutor for every student

Now every student can get the help they need, when they need it. jacTUTOR uses AI to create a fair and level playing field for all students.

Get guidance, not the answer

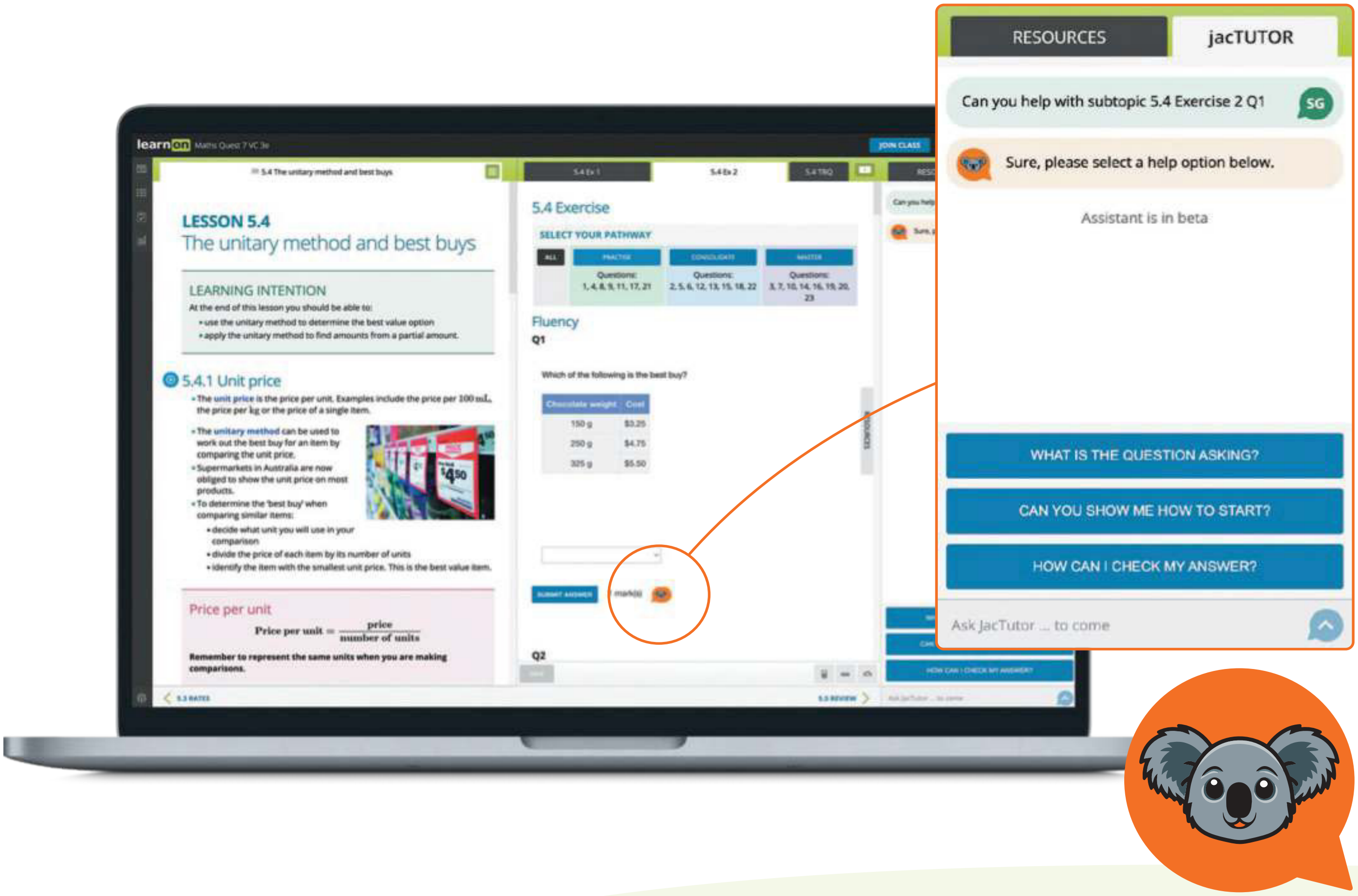
jacTUTOR doesn't just give the answer away. Students are given prompts to help understand what they should be asking to get to a correct answer.

Combat anxiety

Afraid to raise a hand or ask more questions? With jacTUTOR, students will find a safe space to ask questions, get clarification and try again.

A safe space

To keep students safe, any concerning or inappropriate comments are automatically flagged and sent to their teacher.



Meet our author team

Sarah Beamish

Sarah Beamish has been a dedicated teacher of Science and VCE Biology for 18 years, extending this in the last 5 years to becoming a leading teacher in Biology and Geography. She is a committed learner, continually deepening and extending her understanding of the world around her. She is a passionate educator with a desire to make education fun and accessible for all abilities. She has been a VCAA Assessor in both Biology and Geography.

Catherine Bellair

Catherine Bellair is an experienced VCE Physics, Science, Mathematics and STEM educator with over 20 years of teaching experience. She is very involved in the science teaching community, often presenting at conferences in addition to being on the board of the Science Teachers Association of Victoria (STAV). Her teaching interests include improving both science literacy and general literacy as it applies to science, and improving student access to STEM learning opportunities in secondary schools. Her qualifications include a Bachelor of Science, a Graduate Diploma of Education, a Certificate in Education (STEM) and a Masters of Education (Student Wellbeing).

Daniela Carboon

Daniela Carboon is a passionate educator dedicated to making science engaging and accessible for all learners, inspiring students to develop a lifelong love for the subject. With over 15 years of experience teaching Chemistry, Science and Mathematics, she has authored chapters in science textbooks and held leadership roles, including Learning Leader in Science and Technology. Daniela holds a Bachelor of Applied Science in Chemistry and a Diploma of Education in Secondary Education. Her experience in the science industry, including work as an Analytical Chemist, informs her ability to foster curiosity, critical thinking and a deeper understanding of scientific concepts in her students.

Lucy Cassar

Dr Lucy Cassar is a distinguished VCE Biology, Science and STEM educator with 15 years of experience. She is currently the Vice President of the Science Teachers Association of Victoria (STAV) and is committed to advancing science and STEM education. Her qualifications include a Bachelor of Science, a Bachelor of Biomedical Science (Honors), a Diploma of Education, and a PhD from Monash University.

Sacha O'Connor Price

Sacha O'Connor-Price is an experienced VCE Biology and Science educator with 15 years of experience. She is currently the Deputy Head of Science and Head of Units 3 and 4 Biology at Haileybury College and is passionate about improving metacognition in students. Her qualifications include a Bachelor of Science, a Bachelor of Education, Master of Education (student wellbeing) and is an alumni of the Teacher Excellence Program.

Michael Rosenbrock

Michael Rosenbrock is an accomplished physics, science and mathematics educator with over 15 years of experience in teaching and educational leadership. A former Assistant Principal and VCAA STEM Specialist Teacher, Michael is dedicated to improving engagement and outcomes in science for all students. His qualifications include a Bachelor of Aerospace Engineering, a Bachelor of Business, and a Graduate Diploma of Education.

Stephanie Whitehead

Stephanie Whitehead is an experienced Science teacher and head of department. Her foundation degree is Bachelor of Applied Science (Medical Science) with a graduate degree in education. She has developed science programs for high schools as well as collaborated on science resources for primary schools. A passionate advocate for STEM education, Stephanie has also worked with state government entities.

Luke Williams

Dr Luke Williams is a proud Gumbaynggirr man of Northern NSW. Luke is a researcher who primarily focuses on the traditional uses of native Australian plants with an emphasis on understanding how these traditional plants can contribute to our modern food and medicine systems. Aside from experimenting with these plants, Luke brings together Indigenous knowledge holders with Western science to explore how these two knowledge systems can add value to our society. Luke is passionate about empowering the next generation of scientist to think holistically about their research.

Acknowledgements

The authors and publisher would like to thank all copyright holders for their assistance and for permission to reproduce copyright material in this book.

The full list of acknowledgements can be found here:
www.jacaranda.com.au/acknowledgements/#2025

Every effort has been made to trace the ownership of copyright material. Information that will enable the publisher to rectify any error or omission in subsequent reprints will be welcome. In such cases, please contact the Permissions Section of John Wiley & Sons Australia, Ltd.

Understanding command terms in the Victorian Curriculum

The Victorian Curriculum aims to develop students' disciplinary knowledge, skills, understanding and general capabilities across the curriculum. Students are also expected to progressively develop their thinking skills.

In the Victorian Curriculum, command terms are used as signposts for this depth of thinking. Command terms signify different types of thinking and are already used in the classroom by many teachers and students.

Questions within Jacaranda resources use these command terms to support students in command terms 'thinking'.

For a full list of the command verbs used throughout the Science Quest series, visit learnON.

1 Discovering science

LESSON SEQUENCE

LESSON 1.1 Overview

1.1.1 Introduction

The word 'science' comes from a Latin word that means 'knowledge'. For thousands of years, scientists have been trying to learn as much as they can about the world. Long ago, before we had the amazing technology we have today, scientists were called philosophers and used their best thinking to explain what they saw around them.

Now, scientists use special equipment to investigate and add to what we know about the world. But science is not just a big list of facts; it is about exploring and discovering! It is a way of expanding curiosity as well as a willingness to investigate the changing world. As a young explorer, you will learn how to investigate things scientifically, so that what you find out is based on good thinking and real evidence.

FIGURE 1.1 Forensic scientists use science to help investigate and solve crimes.

DISCUSSION

1. What do scientists do?
2. Do people other than scientists use science in their work or leisure activities?
3. How is a science laboratory different from other rooms?
4. Is the science laboratory a dangerous place?
5. What type of exploration do you do in your life? Do you think you are a good explorer?

SCIENCE INQUIRY: Exploring patterns in plant growth

Plants need specific conditions to grow, such as light, water and nutrients. Scientists often conduct experiments to test relationships between these factors and plant growth to better understand how plants respond to their environment.

For example, sunlight provides energy for photosynthesis, the process plants use to create food. Investigating how different amounts of light affect growth rates can reveal important patterns.

Imagine you are testing how light intensity affects the growth of a plant. What elements will you need for the investigation?

- An **independent variable**: the amount of light the plant receives each day (e.g. 2, 4, 6 or 8 hours)
- A **dependent variable**: the height or number of leaves the plant grows over 2 weeks
- Controlled variables:
  - type of plant used
  - amount of water given daily
  - soil type and pot size.

1. How does the amount of light affect the height of a plant over 2 weeks?
2. Does more light result in faster growth, or is there a limit beyond which growth slows?
3. What patterns can be identified in leaf size or colour based on light exposure?

Prediction: Plants exposed to more light will grow taller and have healthier leaves than those with less light.

Hypothesis: If plants receive more light then they will produce more energy through photosynthesis, leading to greater growth.

Investigable questions, reasoned predictions and hypotheses can be developed in guiding investigations to identify patterns, test relationships, and analyse and evaluate scientific models (VC2S8I01)

ACTIVITY: Engaging with investigation

1. Look around the laboratory. Identify five features special to this working environment.
2. Identify five everyday devices that have been invented with the assistance of science.
3. Do you know anyone working in science? Describe what they do.
4. These two pieces of equipment are used for measuring volumes of liquids.
   Identify an important difference between them, other than their shape. Outline when each should be used.

5. Some of the skills that scientists use are the same as those used by detectives in solving a crime. Careful observations are required before any conclusions can be drawn. Look carefully at the drawing and describe what you think has happened.

learnon

Pre-test	Topic 1 Pre-test
eWorkbooks	Topic 1 eWorkbook Student learning matrix
Practical investigation eLogbook	Topic 1 Practical investigation eLogbook
Digital document	Key terms glossary

LESSON 1.2 What scientists do

LEARNING INTENTION

In this lesson you will:

- recognise how scientific knowledge can be represented in branches of biology, chemistry, physics and geology
- consider how modern scientific knowledge is interdisciplinary and transdisciplinary.

1.2.1 Different types of scientists

You can find scientists just about anywhere. They could be in a desert finding out how plants survive without water. They could be digging deep into the ice in Antarctica. You might find a scientist searching for fossils on a rocky shore, counting rare animals in a rainforest or monitoring **electricity** in a power station. Some scientists work in laboratories, searching for a cure for a disease. Others work in the chemical industry. You might even find a scientist in space.

There are many types or disciplines of study in science. A few are shown in figure 1.2.

FIGURE 1.2 There are many disciplines of science.

Earth science

Geologists study rocks and mountains.

Seismologists study earthquakes.

Palaeontologists study fossils and ancient rocks.

Vulcanologists study volcanoes.

Biology

Biologists study living things.

Microbiologists study microscopic living things.

Zoologists and **veterinarians** study animals.

Botanists and **horticulturists** study plants.

Chemistry

Chemists study the structure and properties of substances.

Pharmacists work with chemicals that are used to treat illness and disease.

Metallurgists study the chemical properties of metals.

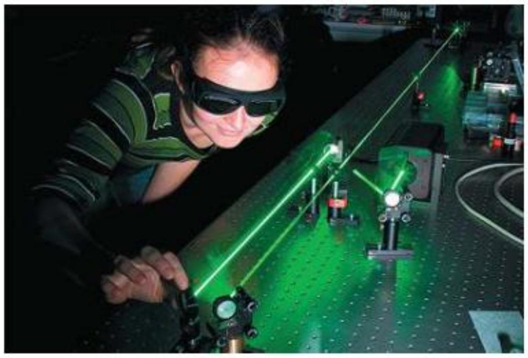
Environmental chemists study the impact of human-made substances in our air, water and soil.

(continued)

FIGURE 1.2 There are many disciplines of science. *(continued)*

Physics

Physicists study things like movement, heat, nuclear energy, light and electricity.



Mechanical engineers design and construct machines and tools for a variety of purposes.

Astronomers study objects found in the sky, including stars, moons, galaxies and meteorites.

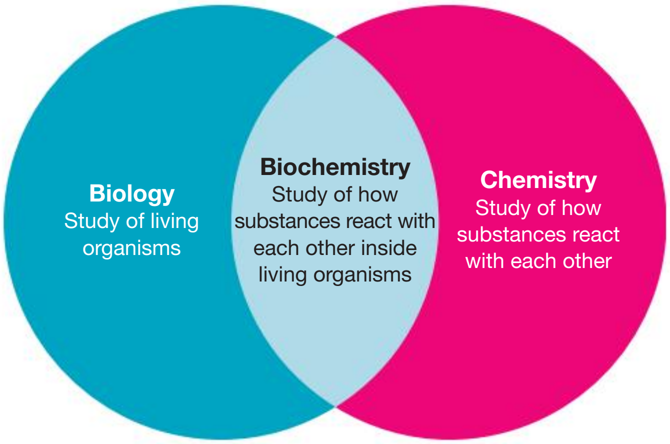
Aerodynamics scientists study the way air moves around objects such as cars and aircraft.

1.2.2 A mix of science

Some scientists work in areas that involve more than one scientific field. Such sciences are said to be **interdisciplinary**.

For example, a biochemist is a scientist who studies the chemical processes inside living organisms. They use knowledge from both biology and chemistry in their work.

FIGURE 1.3 Some sciences are a mix of scientific fields.



ACTIVITY: Scientific fields

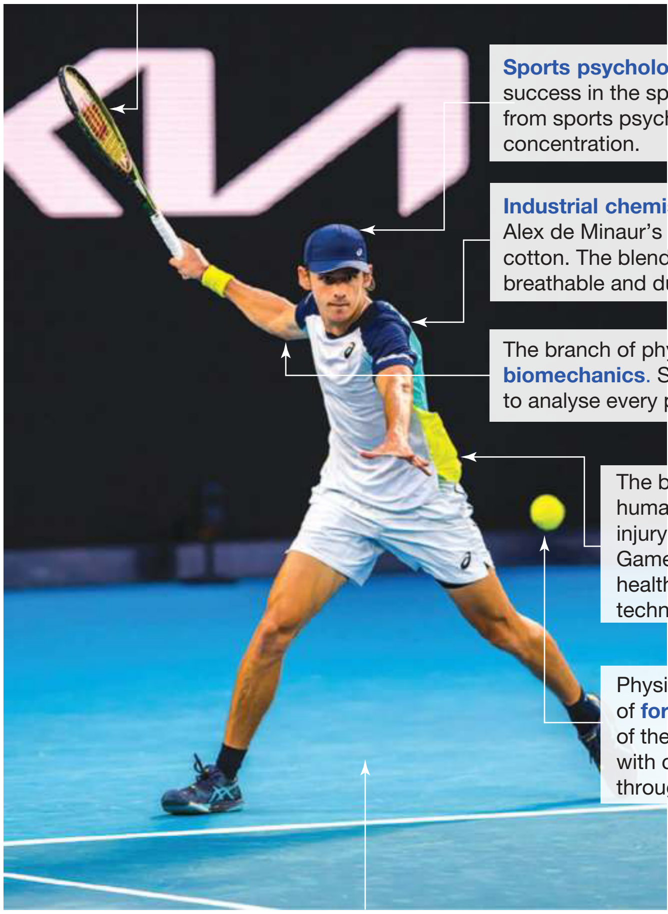
Working in groups, identify the scientific fields studied by each type of scientist listed here.

- Biophysicist
- Geochemist
- Astrobiologist
- Neuropsychologist

1.2.3 Specialist scientists

Within each discipline of science, scientists specialise in a specific area. For example, in psychology, neuropsychologists study the different areas of the brain to better understand brain functions such as memory and learning. **Sports psychologists** advise athletes on self-image and on maintaining the motivation to persist and succeed in their chosen sport.

FIGURE 1.4 Scientists from different fields, such as chemistry, physics and biology, analyse and improve the performance of athletes in different ways.



1.2.4 Scientists working together

Quite often, different types of scientists will need to work together to solve a problem. This is certainly true in criminal investigations, where the solving of a crime might rely on the **observations** and **conclusions** of scientists from many disciplines.

FIGURE 1.5 Investigating a crime scene involves many types of science.

1.2.5 Scientists solving problems over time

Science advances because scientists build on the knowledge of the pioneering scientists who came before them.

DISCUSSION

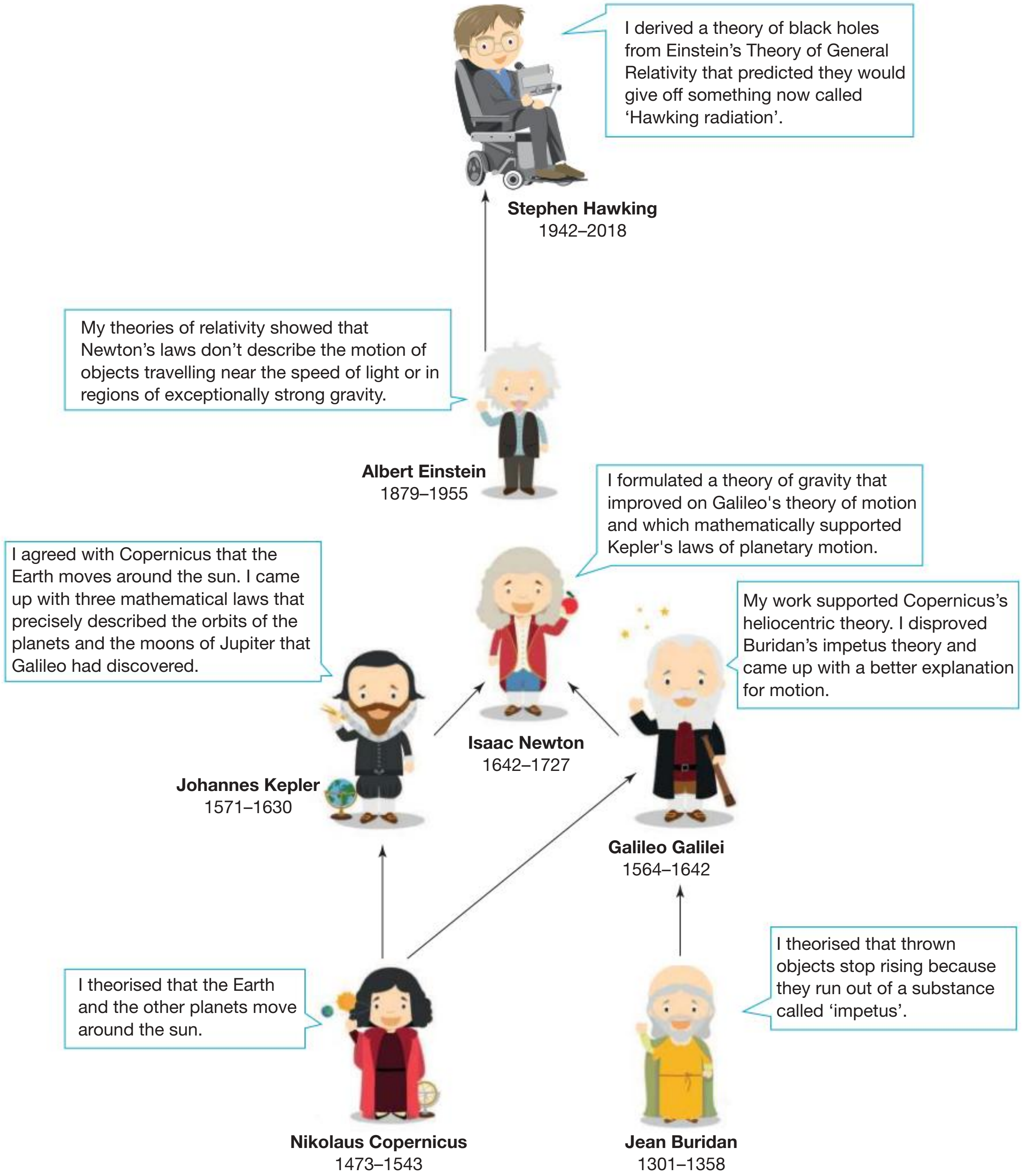
In 1675, Sir Isaac Newton wrote to fellow scientist Robert Hooke, saying:

> *'If I have seen further, it is by standing on the shoulders of Giants.'*

Discuss what you think Newton meant by this.

Can you give examples where the work of one person has contributed to the success of another?

FIGURE 1.6 Our understanding of how objects move, the Theory of Motion, has been developed over many centuries.



The development of penicillin

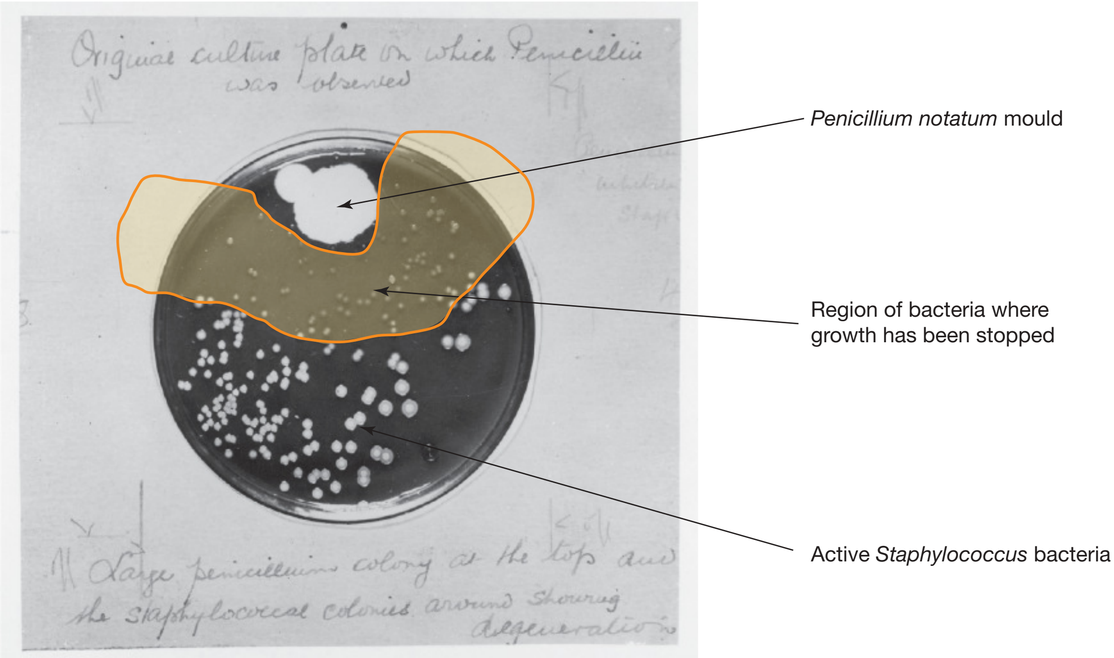
In 1928, Scottish bacteriologist Alexander Fleming was working on an experiment when he discovered that some mould spores in the air had contaminated one of his Petri dishes growing bacteria. He observed that the bacteria had stopped developing where the mould had landed. Fleming **inferred** that there was some substance in the mould that was affecting the bacteria. He named the substance **penicillin**.

Fleming realised that penicillin could be a cure for bacterial diseases, but was not able to isolate the penicillin from the mould. He published his discovery in a British science journal.

In 1938, Australian-born scientist Howard Florey read Fleming's paper and saw its potential for treating the many bacterial infections that killed so many people worldwide. In 1939, Howard Florey, Ernst Chain and their colleagues at Oxford University in the United Kingdom, successfully purified the mould so that it could be used as a commercial **antibiotic**.

Penicillin was the first antibiotic to be widely used, and it is still used for the treatment of serious bacterial infections. Fleming, Florey and Chain were jointly awarded the 1945 Nobel Prize for Medicine for the parts they had each played in the development of penicillin.

FIGURE 1.7 A photo of Fleming's original Petri dish, showing the effect of the mould *Penicillium notatum* on the bacteria



From amber to electricity

From around the sixth century BCE, the Ancient Greeks observed that amber (fossilised tree sap) was able to pick up small grains of sand and dust and lift hair fibres after it was rubbed with fur.

For centuries this remained a curiosity, until in 1600 William Gilbert theorised that there was some sort of force acting between the rubbed amber and the particles it picked up. He used the term electricity to describe this force, because the Greek word for amber was *elektron*.

FIGURE 1.8 Amber attracting pieces of paper

In 1660, Robert Boyle expanded on Gilbert's work and identified that the electrical force could pull charged objects together or push them apart.

Electric charge was able to be stored in a device called a **Leyden jar**, invented by the Dutch scientist Pieter van Musschenbroek in 1746.

In 1752, the American scientist Benjamin Franklin proved that lightning bolts were made of electricity. He famously flew a kite attached to a metal wire during a thunderstorm and collected the electricity in a Leyden jar.

FIGURE 1.9 Artist's impression of Benjamin Franklin and his son performing the kite experiment

SCIENCE AS A HUMAN ENDEAVOUR: How scientific knowledge changes over time

Scientific knowledge is always changing as new evidence is discovered. Early scientists believed Earth was the centre of the universe until observations by Copernicus and Galileo showed that the planet orbits the Sun. Similarly, our understanding of atoms has changed. Early models described them as solid spheres, but later experiments revealed protons, neutrons and electrons inside them.

New technology and experiments continue to reshape what we know. For example:
- Plate tectonics theory replaced earlier ideas about continental drift when evidence of seafloor spreading was discovered.
- DNA structure was uncovered in 1953, changing our understanding of genetics and how traits are inherited.

Science is always evolving, and models and theories improve as new data is found.

1. Why do scientific models and theories change over time?
2. Describe an example of new evidence leading to a change in scientific knowledge.
3. How might future discoveries further change our understanding of science?

Scientific knowledge, including models and theories, can change because of new evidence (VC2S8H01)

1.2 Activities

learnon

1.2 Quick quiz on | **1.2 Exercise**

LEVEL 1	LEVEL 2	LEVEL 3
1, 4	2, 5, 7	3, 6, 8

Remember and understand

1. Select the correct terms to complete the following sentence:
   A botanist is a *biologist* / *chemist* / *physicist* who studies *animal cells* / *plants* / *clouds*.
2. **Identify** the important observation Alexander Fleming made that led to the development of the first antibiotic.
3. **State** the hypothesis that Benjamin Franklin tested in his experiments on electricity.

Apply and analyse

4. Place the following theories in order from earliest to latest.
   I. Buridan's impetus theory
   II. Galileo's laws of motion
   III. Newton's laws of motion
   IV. Einstein's Theory of Special Relativity
5. **Identify** whether the following statement is true or false.
   A biochemist uses knowledge from both biology and chemistry in their work.
6. Science helps elite sportspeople perform to the best of their ability. **Explain** the role of sports psychology in improving the ability of elite athletes.
7. **Suggest** how firefighters might use science in their daily work.

Evaluate and create

8. Read the main section of a daily newspaper, either online or offline. Find an article in which a scientist is referred to or quoted. For this article, **identify**:
   a. the scientist's name
   b. the discipline or specific field of science they study
   c. which organisation they work for
   d. what the newspaper article is about and why the scientist has been included in the article.

Answers and sample responses are available in your digital formats.

LESSON 1.3 The science laboratory

LEARNING INTENTION

In this lesson you will identify, assemble and use appropriate equipment and resources to perform an investigation safely.

1.3.1 Getting to know the science lab

Scientists often conduct experiments in a laboratory (also known as a lab). The science laboratory in your school is different from other classrooms. It is filled with a range of equipment to help you undertake scientific investigations safely.

ACTIVITY: Getting to know your lab

1. Sit quietly for a minute or two and look around the science laboratory.
2. List as many differences as you can between the science laboratory and other general classrooms at your school.
3. Draw a map of the science laboratory, labelling each of the following items if they are present.
   - Student tables and work benches
   - Teacher's desk or demonstration bench
   - Gas taps
   - Sinks

- Fume cupboard
- Eye wash and safety shower
- Fire extinguisher
- Fire blanket
- Broken glass bin
- Rubbish bin
- Doors

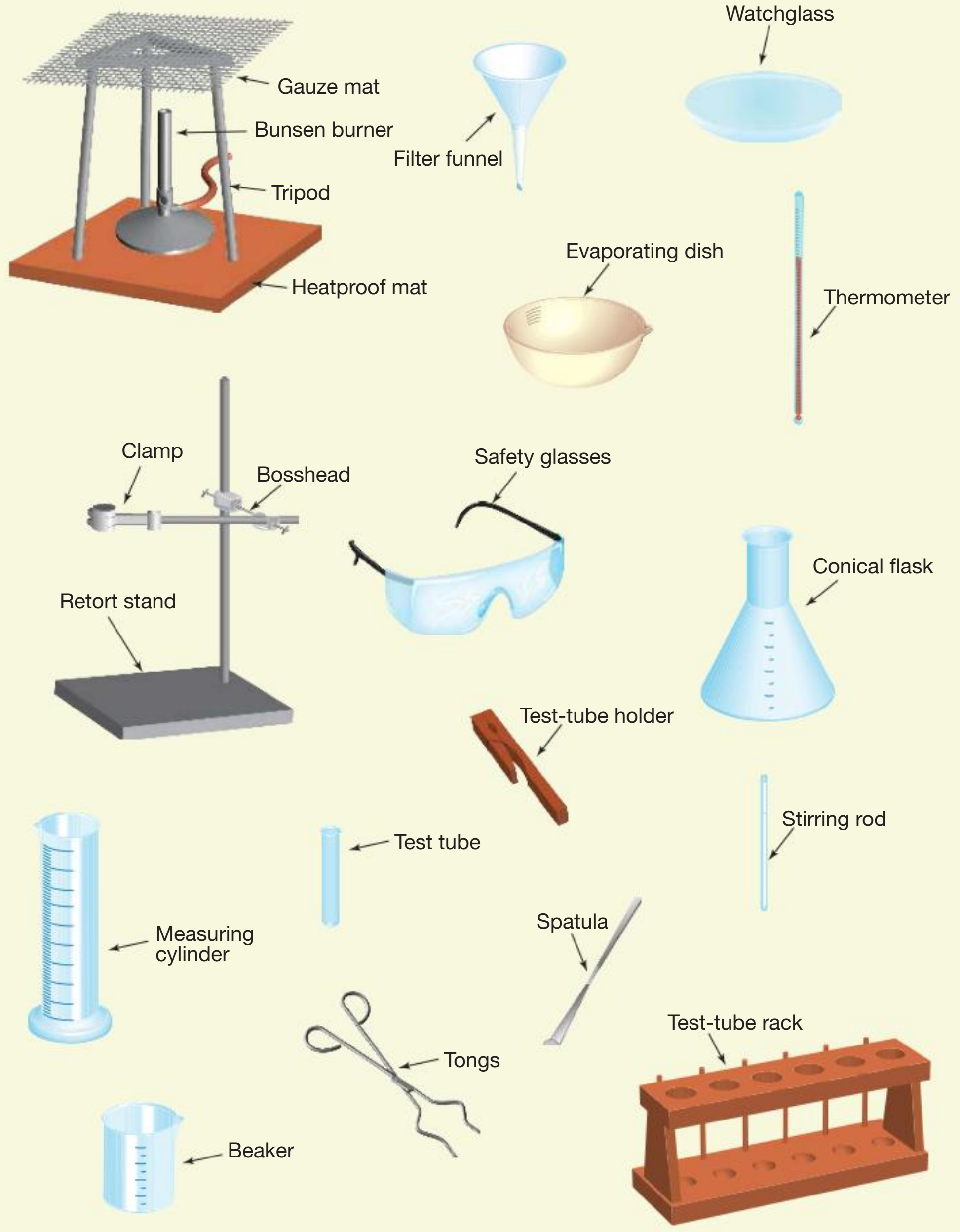
1.3.2 Laboratory equipment

Some of the equipment that you are likely to use in Science is listed in table 1.1 and illustrated in figure 1.10.

TABLE 1.1 Common laboratory equipment

Equipment	Use
Beaker	Container for mixing or heating liquids and other substances
Bosshead	Holds the clamp to a retort stand
Bunsen burner	Heats substances
Clamp	Holds objects at the required height on a retort stand
Conical flask	Container for mixing substances or collecting filtered substances
Evaporating dish	Container for heating small amounts of substances over a Bunsen burner
Filter funnel	Used with filter paper to filter substances
Gauze mat	Supports a container over a Bunsen burner while it is heated
Heatproof mat	Protects benches from damage
Measuring cylinder	Used to measure the volume of a liquid accurately
Retort stand	Used with a clamp and bosshead to hold equipment at the required height
Safety glasses	Protect eyes
Spatula	Used to pick up small amounts of solid substances
Stirring rod	Used to stir mixtures
Test tube	Container for holding, heating or mixing small amounts of substances
Test-tube holder	Holds a test tube while it is being heated
Test-tube rack	Holds test tubes upright
Thermometer	Measures temperature
Tongs	Used to hold small objects while they are heated or to pick up hot glassware
Tripod	Supports a gauze mat over a Bunsen burner
Watchglass	Holds small quantities of solids

FIGURE 1.10 Common laboratory equipment in the science laboratory



ACTIVITY: Identifying laboratory equipment

Looking around your science laboratory, work in groups to identify where to find each of the pieces of equipment listed in table 1.1 and shown in figure 1.10.

Make a list of which items are stored at your bench and which are found in cupboards around the lab.

1.3.3 Investigating safely

Investigating and exploring in science can be exciting, but it is important to be safe when doing experiments.

ALWAYS …

- follow the teacher's instructions
- wear safety glasses and a laboratory coat or apron, and tie back long hair when mixing or heating substances
- point test tubes away from your eyes and away from your fellow students
- push in chairs and keep walkways clear
- inform your teacher if you break equipment, spill chemicals, or cut or burn yourself
- wait until hot equipment has cooled before putting it away
- clean your workspace — don't leave any equipment on the bench
- dispose of waste as instructed by your teacher
- wash your hands thoroughly after handling any substances in the laboratory.

FIGURE 1.11 Always use appropriate safety equipment in a laboratory.

NEVER …

- enter the laboratory without your teacher's permission
- run or push in the laboratory
- eat or drink in the laboratory
- smell or taste chemicals unless your teacher says it is OK. When you do need to smell substances, fan the odour to your nose with your hand.
- leave an experiment unattended
- conduct your own experiments without the teacher's approval
- put solid materials down the sink
- pour hazardous chemicals down the sink (check with your teacher)
- put hot objects or broken glass in the bin.

FIGURE 1.12 Experiments should never be left unattended.

1.3.4 Working with dangerous chemicals

Your teacher will tell you how to handle the chemicals in each experiment. At times, you may come across warning labels on the substances you are using.

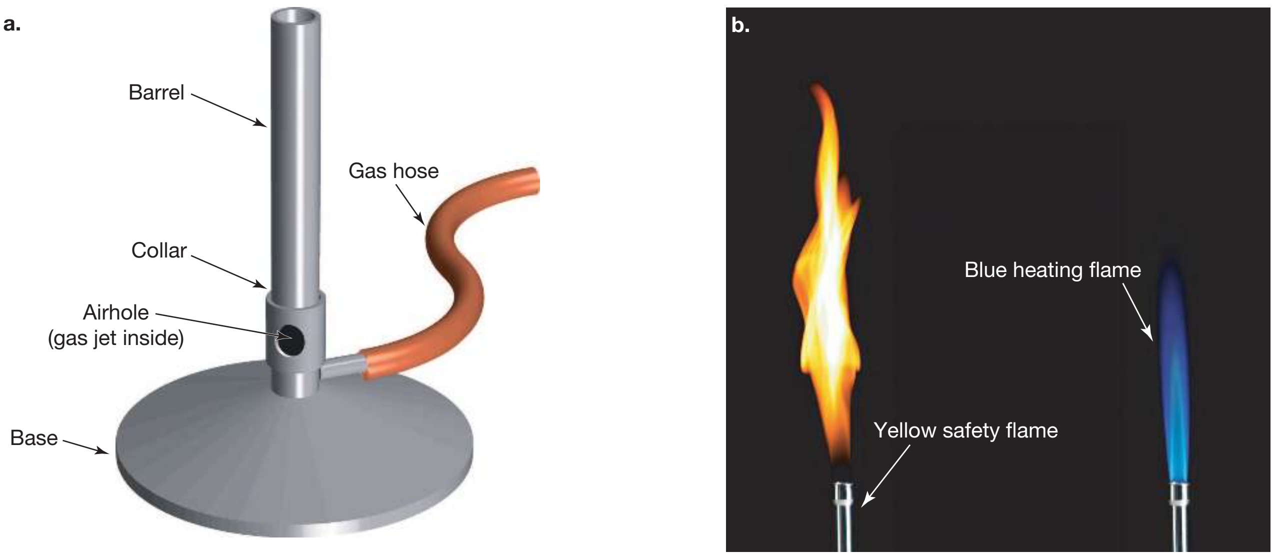
TABLE 1.2 Information about dangerous chemicals in the lab

Label	Why is this chemical dangerous?	What safety measures do I need to take?
	**Corrosive** substances can cause severe damage to skin and eyes. Acids are examples of corrosive substances.	Always wear gloves and safety glasses when using chemicals with this symbol.
	**Flammable** substances are easily set on fire. For example, methylated spirits is a flammable substance.	Always keep chemicals with these labels well away from flames such as lit matches and Bunsen burners.
	Chemicals with this label can cause death or serious injury if swallowed or breathed in. They are also dangerous when touched without gloves, because they can be absorbed by the skin. Mercury is a **poisonous** substance.	You should always wear gloves and **safety masks** when using chemicals with this symbol. Your teacher will instruct you if you need to use these chemicals in a **fume cupboard**.

1.3.5 Heating substances

In school laboratories, heating is usually done with a Bunsen burner. A Bunsen burner flame provides heat when a mixture of air and gas is lit.

FIGURE 1.13 a. The components of a Bunsen burner **b.** The yellow visible flame is known as the safety flame and is less hot than the blue flame.



KEY IDEA

The following steps describe how to use a Bunsen burner safely:

1. Place the Bunsen burner on a heatproof mat.
2. Check that the gas tap is in the 'off' position.
3. Connect the rubber hose to the gas tap.
4. Close the airhole of the Bunsen burner collar.
5. Light a match and hold it a few centimetres above the barrel.
6. Turn on the gas tap and a yellow flame will appear.
7. Adjust the flame by moving the collar until the airhole is open and a blue flame appears.
8. Remember to close the collar to return the flame to yellow when the Bunsen burner is not in use.

FIGURE 1.14 The process of lighting a Bunsen burner

INVESTIGATION 1.1

The Bunsen-burner flame

Aim

To determine which Bunsen-burner flame is hotter

Materials

- Bunsen burner
- heatproof mat
- matches
- tongs
- pieces of porcelain
- safety glasses
- clock or watch

CAUTION: Before you use your Bunsen burner, ensure you are wearing safety glasses, your Bunsen burner is on a heatproof mat and long hair is tied back.

Method

1. Light the Bunsen burner according to the guide above.
2. Open the airhole.
3. Using the tongs, hold a piece of porcelain over the flame with the airhole open.
4. Record how long it takes for the porcelain to turn red-hot.
5. Let the porcelain cool on the heatproof mat.
6. Examine the surface of the porcelain and record any changes to its surface.
7. Close the airhole.
8. Hold another piece of porcelain in the yellow flame.
9. Record how long it takes for the porcelain to turn red-hot.
10. Place the porcelain to cool on the heatproof mat and turn off the Bunsen burner.
11. Examine the surface of the porcelain and record any changes to its surface appearance.

Results

Use a table like the one below to record your findings.

Flame colour	Time to turn porcelain red-hot	Appearance of surface after heating
Blue		
Yellow		

Discussion

1. Describe the flame when the airhole is open. What colour is it? Does it make a noise?
2. Describe the flame when the airhole is closed. Is it easy to see?
3. Does the porcelain turn red-hot in the yellow flame when the airhole is closed?
4. Do you notice anything else about the porcelain after heating in the yellow flame?
5. Which flame would be the best to use if you were heating a beaker over a Bunsen burner? Explain your choice.

Conclusion

Write a sentence summarising which Bunsen-burner flame is the hottest.

INVESTIGATION 1.2

The hottest part of the flame

Aim

To determine the hottest part of a blue flame

Materials

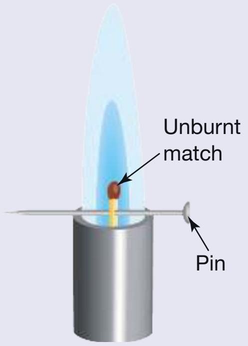
- Bunsen burner
- heatproof mat
- matches
- safety glasses
- nichrome wire
- tongs
- pin

CAUTION: Before you use your Bunsen burner, ensure you are wearing safety glasses, your Bunsen burner is on a heatproof mat and long hair is tied back.

Method

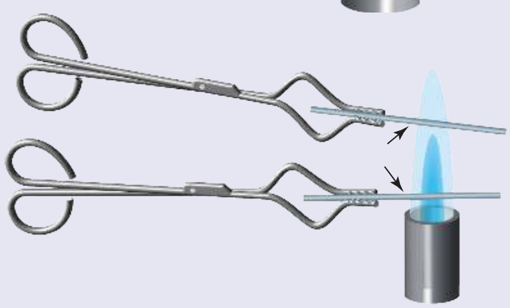
Part A

1. Use a pin to hang an unburnt match over the barrel of a Bunsen burner.
2. Light the Bunsen burner according to the guide above.
3. Turn the collar to produce a blue flame.
4. Turn the Bunsen burner off and remove the match and pin with tongs.
5. Examine the match and record your observations of its appearance.



Part B

1. Re-light the Bunsen burner and turn the collar to produce a blue flame again.
2. Use the tongs to hold the wire across the flame, close to the barrel of the Bunsen burner and observe the wire.
3. Move the wire up a little and continue observing.
4. Record your observations of what happens to the wire as it is moved.



Results

Use a table like the one below to record your findings.

	Observations
Part A	
Part B	

Discussion

1. What happens to the match hanging over the barrel? Explain why.
2. What colour does the wire become when held across the flame?
3. Is the colour of the wire different when it is held at the top of the flame?
4. Draw a diagram of the Bunsen-burner flame, labelling the parts that are hottest.
5. Students often heat substances in a test tube with a Bunsen burner. Why would it be unwise to position the test tube at the base of a blue flame?
6. Why is the yellow flame often called the safety flame?

Conclusion

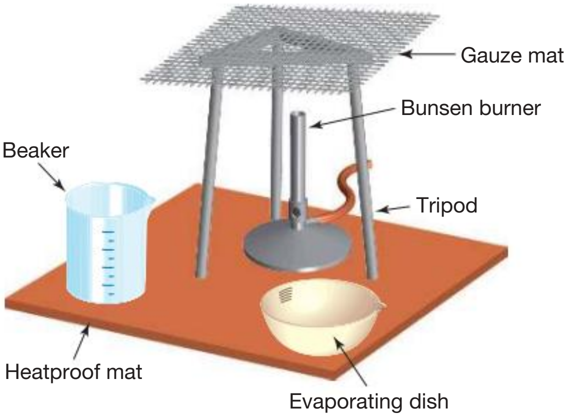
Write a sentence describing what part of a blue flame is the hottest.

Heating containers

There are some rules that must be followed when using heating containers:

- Beakers and evaporating dishes can be placed straight onto a gauze mat for heating.
- Never look directly into a container while it is being heated.
- Wait until the equipment has cooled properly before handling it.

FIGURE 1.15 The equipment used to heat substances and containers



INVESTIGATION 1.3

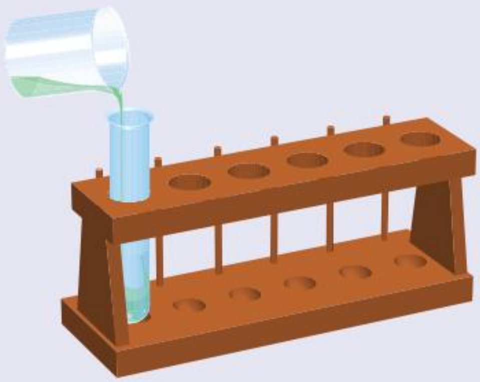
Heating a substance in a test tube

Aim

To practise heating a liquid in a test tube safely

Materials

- 100 mL beaker
- Bunsen burner and heatproof mat
- matches
- safety glasses
- test tube
- test-tube rack
- test-tube holder
- food colouring



CAUTION: Before you use your Bunsen burner, ensure you are wearing safety glasses, your Bunsen burner is on a heatproof mat and long hair is tied back.

Method

1. Carefully pour water from a beaker into a test tube to a depth of about 2 cm, as shown in the diagram above. Add a drop of food colouring to make it easier to see.
2. Light the Bunsen burner correctly and heat the test tube gently in the blue flame.
3. Make sure that the open end of the test tube points away from you and other students.
4. Move the base of the test tube gently in and out of the flame. This prevents the liquid from splashing out of the test tube.
5. Keep the test-tube holder away from the flame.
6. Once the liquid has started boiling, stop heating and turn off the gas to the Bunsen burner. Place the test tube in the test-tube rack. Leave it there until it has cooled, before emptying it and cleaning up.

Results

Record any changes that you observed inside the test tube as you heated the water.

Discussion

1. Why should the test-tube holder be positioned at the top of the test tube?
2. Why is the blue flame used for heating?
3. Describe any safety precautions to take when heating substances in a test tube that you did not have to take when heating a substance in a beaker.

Conclusion

Write a summary of the skills you practised to heat a substance in a test tube safely.

FIGURE 1.16 Review this image of students in a science laboratory. Can you find at least 20 dangerous activities occurring? There may be more!

1.3 Activities

learnon

1.3 Quick quiz (on)	1.3 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 4, 6	2, 5, 7, 9, 11	3, 8, 10

Remember and understand

1. Match each piece of laboratory equipment with its purpose.

a. Heatproof mat	1. Porcelain container for evaporating small amounts of substances over a Bunsen burner
b. Evaporating dish	2. Used with clamps and bossheads to hold equipment at the required height
c. Test-tube rack	3. Protects benches from heat damage
d. Retort stand	4. Holds test tubes upright

2. MC Which three of the following pieces of equipment are used when heating objects?
   A. Bunsen burner
   B. Heatproof mat
   C. Watchglass
   D. Safety glasses
   E. Spatula
3. **Identify** whether the following statement is true or false.
   You should always wear gloves when working with corrosive substances to prevent severe damage to the skin should the chemical be spilled.
4. **Identify** whether the following statement is true or false.
   If it is safe to smell a chemical, the appropriate technique is to place the flask containing the chemical just below the nose.
5. Complete the following sentence: The safety flame of a Bunsen burner is __________ and is obtained by __________.

Apply and analyse

6. **State** the item of equipment you would use to measure exactly 10 mL of water. **Explain** your choice.
7. MC Which of the following is an example of a violation of a lab safety rule?
   A. Tasting chemicals
   B. Smelling contents of a test tube directly
   C. Hair not tied back
   D. Eating food in the lab
   E. All of the above
8. **Describe** where you would find the hottest part of the Bunsen-burner flame.
9. MC Which of the following is an appropriate safety measure if using a chemical with this label?
   A. Keep it away from flames
   B. Avoid use altogether
   C. Dilute with water
   D. Wear safety glasses and gloves
   E. Ventilate the room

Evaluate and create

10. Select one of the safety rules for using a Bunsen burner and choose a strategy for publicising your message. Create a safety poster about your chosen rule.
11. Refer to figure 1.16. Create an alternative image or infographic that highlights some essential safety rules in a science laboratory.

Answers and sample responses are available in your digital formats.

LESSON 1.4 Making observations

LEARNING INTENTION

In this lesson you will use a variety of analog and digital measuring devices in scientific investigations to compare the range, sensitivity and accuracy of observations provided by those instruments.

Observations are bits of information we collect by using our senses, like seeing or hearing. We can also use tools to measure things and help us observe even more details. Observations can be either **qualitative** or **quantitative**.

TABLE 1.3 Different types of observations

Type of observation	Description	Examples
Qualitative	An observation that uses description and words	• The red kangaroo sheltered under a tree during the hottest part of the day. • The mixture became cloudy. • The solution smelled like rotten eggs.
Quantitative	An observation that involves a numerical measurement	• The male red kangaroo had a mass of 85.3 kg. • The water took 5 minutes and 10 seconds to reach boiling point. • The temperature of the solution increased by 5 degrees.

DISCUSSION

Are there some observations that can be only quantitative? Are there cases where the observations can be only qualitative? Discuss as a group and decide whether examples can be found to support each statement.

1.4.1 Making quantitative measurements

Common quantities that are measured in experiments include length, time, mass and temperature. Accurate measurements allow us to observe if the quantities change during an experiment and by how much they change.

Scientists around the world measure using the **metric system**, a decimal system (based on units of 10) that uses metres, litres and kilograms as base units to measure distance, volume and weight.

TABLE 1.4 Metric versus imperial units

Quantity	Metric unit	Imperial unit
Length	metre	foot
Time	second	second
Mass	kilogram	pound

CASE STUDY: Why units of measurement matter

In 1999, NASA's Mars Climate Orbiter crashed into the surface of Mars instead of going into orbit around the planet. The reason for this really expensive mistake was that the designers of the orbiter did their calculations using metric units, but the company that built the orbiter used a different measurement system called the imperial unit system. However, both teams assumed that they were using the same system when they were communicating with each other.

The result was that the orbiter was travelling on the wrong pathway when it was approaching Mars, causing the loss of a 9-month mission that had been years in the planning!

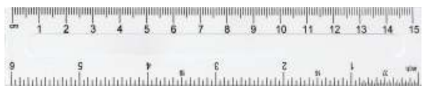
1.4.2 Analog and digital measuring instruments

Many different types of instruments are used to gather scientific measurements (called **data**). Measuring devices can be either **analog** or **digital**.

Analog measuring devices are usually marked with a series of lines; some of these lines will have numbers next to them. These lines and numbers together are called a **scale**. A ruler and a glass thermometer are examples of analog measuring instruments.

Digital measuring devices do not have a scale; instead, they provide a value that appears directly on the device's screen. The main advantage of digital measuring devices is that they are easier to read and more accurate than analog devices. Electronic kitchen scales and digital thermometers are examples of digital measuring devices.

TABLE 1.5 Either analog or digital instruments can be used to make quantitative measurements.

Quantity	Device that can be used to measure the quantity	
	Analog	**Digital**
Length	Ruler 	Digital calipers 
Mass	Pan scales 	Digital scales 
Time	Clock with a second hand 	Stopwatch 
Temperature	Glass thermometer 	Digital thermometer 

CASE STUDY: Data loggers

A data logger is a very useful digital device that can measure many different quantities. The measurement recorded by a data logger depends on the sensor that is connected to it. The sensor does the measuring and sends the information to the data logger. There are a number of different sensors available; for example, if a temperature sensor is attached to the data logger, temperature is measured and recorded.

Data loggers are useful devices because they generally measure quantities very accurately. For example, they may record temperature accurately to 0.1 °C. Some data loggers can also store thousands of individual measurements and allow them to be downloaded to a computer to be converted to tables and graphs.

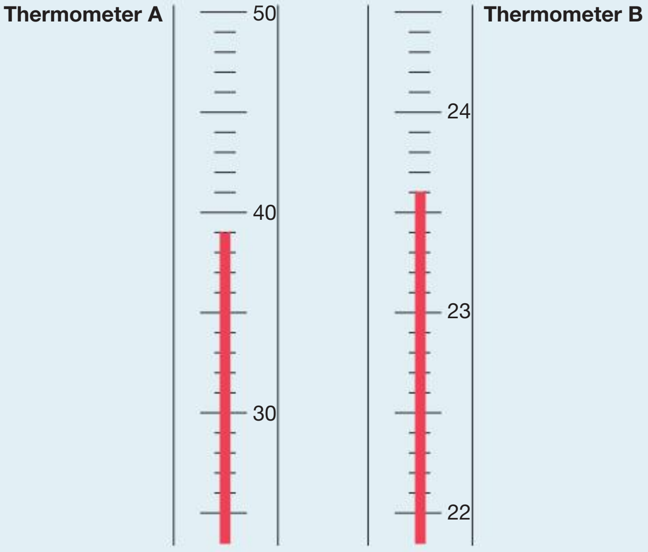
FIGURE 1.17 A data logger and temperature sensors

1.4.3 Reading scales

Analog devices such as rulers, measuring cylinders or glass thermometers are each marked with a scale or set of numbered markings. When reading a scale, it is important to determine what each of the markings on the scale represents.

SAMPLE PROBLEM 1 Reading a scale

What are the temperatures measured by thermometers A and B shown here?

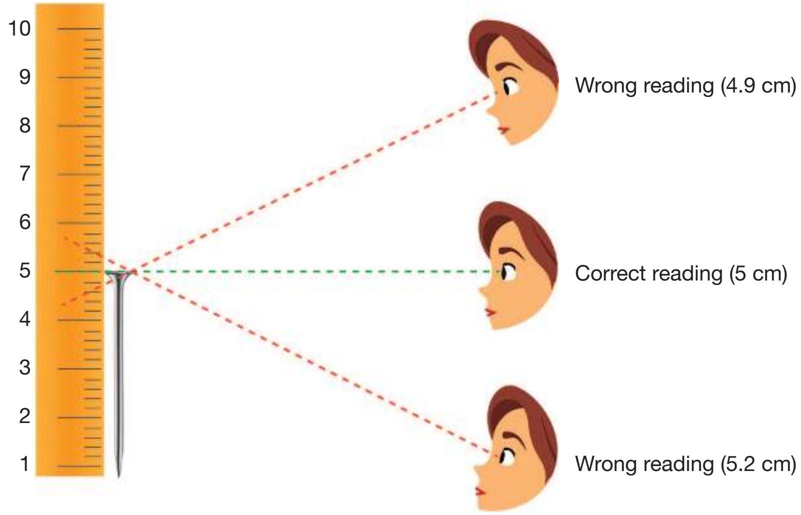


THINK	WRITE
Thermometer A	
1. First, look at the numbered measurement lines. We can see that they go up in jumps of 10 degrees: 30 degrees, 40 degrees, 50 degrees and so on. Therefore, the temperature shown by the red line will have a value higher than 30 degrees but less than 40 degrees.	
2. Next, count how many divisions lie between any two consecutive numbered lines; there are ten divisions between the 30-degree and 40-degree marks (the same is true for between 40 degrees and 50 degrees).	
3. Because there are ten divisions that are spaced out over the 10 degrees difference, this means that each division must be equivalent to 1 degree.	
4. Count how many divisions above the 30-degree mark the red line finishes. It ends at nine divisions above the 30-degree mark.	
5. Because each division equals 1 degree, the temperature must be 30 degrees + (9 × 1) degrees = 39 degrees.	39 °C
Thermometer B	
1. This time, the numbered measurement lines are increasing by 1 degree at a time. We can also see that the temperature shown by the red line is between 23 degrees and 24 degrees.	
2. There are ten divisions between the 23-degree and 24-degree marks.	
3. This means that each division on this thermometer is equal to 0.1 degree (= 1 degree / 10 divisions).	
4. The red line finishes at the sixth division after the 23-degree mark.	
5. Because each division is equal to 0.1 degrees, the temperature reading will be 23 degrees + (6 × 0.1) degrees = 23.6 degrees.	23.6 °C

1.4.4 Parallax error

When reading the scale on an analog measuring device, measurements should always be made with your eye in line with the reading you are taking. When scales are read from a different angle, the reading is not accurate — it will be either lower or higher than the true reading. This type of reading error is called **parallax error**.

FIGURE 1.18 If your eyes are not level with the reading, your measurement will not be accurate.



1.4.5 Measuring length

Scientists measure the lengths of different objects accurately to compare sizes and estimate growth. The biologists in figure 1.19 are measuring the mass and condition of a tranquillised polar bear as part of a study aimed at conserving these animals in their Arctic home.

FIGURE 1.19 Measuring mass and condition

The standard unit for length is the metre (m), but length can also be measured in millimetres (mm), centimetres (cm) or kilometres (km). table 1.6 shows how to convert between some common units of measurement.

TABLE 1.6 Converting measurements

Length	Volume
1 kilometre (km) = 1000 metres (m) 1 metre (m) = 100 centimetres (cm) 1 centimetre (cm) = 10 millimetres (mm)	1 litre (L) = 1000 millilitres (mL) 1 millilitre (mL) = 1 cubic centimetre (cm^3)
Mass	**Time**
1 kilogram (kg) = 1000 grams (g)	1 hour (h) = 60 minutes (min) 1 minute (min) = 60 seconds (s)

DISCUSSION

In Ancient Egypt, length was measured using cubits and digits.

- A cubit was equal to the distance between a person's elbow and the tip of their middle finger.
- A digit was equal to the width of a person's index finger.

How accurate would this system be if you had to measure the length of a textbook or your lab bench? Would everybody get the same answer?

1.4.6 Measuring volume

Liquids in containers such as measuring cylinders are often curved at the top edge. The curve is called a **meniscus**. The edges of the meniscus may curve up or down. We always measure the volume of liquids from the middle flat section of the meniscus.

FIGURE 1.20 Meniscus illustrated

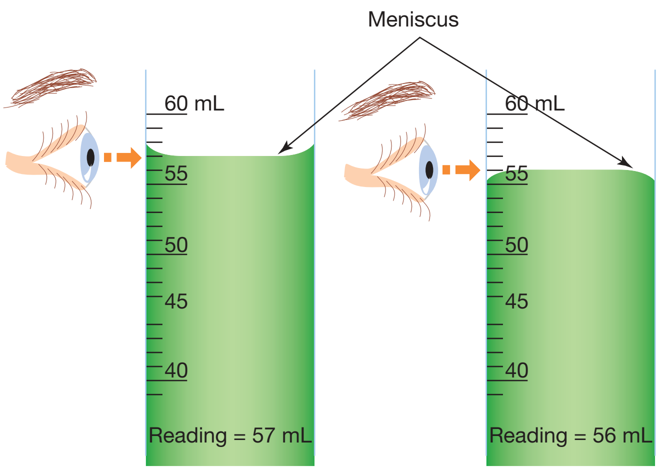


FIGURE 1.21 Water (left) has a meniscus that curves downwards, while the meniscus of mercury (right) curves upwards.

ACTIVITY: Observing a meniscus

Observe the meniscus formed by the surface of different liquids (such as water, honey, glycerine, cooking oil, methylated spirits) when you pour them into a measuring cylinder. Are some more curved than others?

1.4.7 Measuring temperature

The units of temperature are **degrees Celsius** (written as °C). Water boils at 100 °C and freezes to form ice at 0 °C.

CASE STUDY: Hot and cold

The highest air temperature ever measured on Earth is 56.7 °C. This measurement was taken in 1913 in the United States. The lowest temperature ever measured was in 1983 in Antarctica. That temperature was –89.2 °C.

The highest air temperature ever recorded in Australia is 50.7 °C.

FIGURE 1.22 Antarctica, 1983

Temperature is usually measured with a thermometer or a **data logger**. The analog thermometers used in schools are sealed glass tubes filled with alcohol, which is dyed red so that they are easier to read.

KEY IDEA

The following steps describe how to use a glass thermometer safely:

- Read the thermometer with your eye level with the top of the alcohol column to avoid parallax error.
- If measuring the temperature of a liquid, make sure that the liquid fully covers the thermometer bulb.
- Do not rest the bulb of the thermometer on the bottom of a container being heated, because the bottom may be hotter than the rest of its contents.
- **Never** use the thermometer as a stirring rod.
- **Never** rest a thermometer near the edge of a bench where it is likely to fall off.

1.4.8 Measuring mass

Mass is usually measured in kilograms (kg); however, in the science laboratory, you will often measure smaller masses and so you will use smaller units, grams (g) or milligrams (mg). You will usually use **electronic scales** to measure mass accurately.

KEY IDEA

The following steps describe how to use an electronic scale:

1. Turn the scales on.
2. Adjust the balance reading to zero by pressing the tare button (this is often marked with just a 'T').
3. Place the object to be measured on the scales.
4. Read the mass from the digital display.

INVESTIGATION 1.4

Estimating mass

Aim

To accurately measure and record the masses of some common objects

Materials

- electronic scales
- pen
- safety glasses
- watchglass
- teaspoon
- watch
- 100 mL beaker
- 50 mL water
- sugar

Method

1. Estimate the masses of each of the following items: pen, watch, a pair of safety glasses, 50 mL of water and two teaspoons of sugar. Record your estimates in grams (g).
2. Use electronic scales to measure the masses of the pen, watch and safety glasses. Record your measurements.
3. The water and the sugar cannot be put directly on the pan. Record the masses of the beaker and the watchglass on their own.

4. Add 50 mL of water to the beaker. Record the combined mass of the water and the beaker. Subtract the mass of the beaker alone from the combined mass. Do the same with two teaspoons of sugar in the watchglass. Alternatively, put the empty container on the electronic scales before adding the water or sugar, and press 'tare'.

Results

1. Draw a table like the one shown below and enter the values of your estimates and measurements.

Qualitative and quantitative observations

Item	Estimated mass (g)	Measured mass (g)	Difference (g)	Percentage error (%)
Pen				
Watch				
Safety glasses				
50 mL water				
2 teaspoons of sugar				

2. In the 'Difference' column of the table, record the difference in grams between the measured mass and the estimated mass for each item. If the estimated mass was lower than the measured mass, place a minus sign (–) in front of the number.
3. For each item, calculate the percentage error using:

$$\frac{\text{difference (g)}}{\text{measured mass (g)}} \times 100 = \text{percentage error}$$

Enter these values into the last column of the table.

Discussion

1. Which was your most accurate estimation?
2. By what percentage did your least accurate estimation vary from the measured mass?
3. Is it easier to estimate larger or smaller masses? Explain why you think this is the case.

Conclusion

Write a sentence describing why instruments are needed for accurate measurement of quantities.

1.4.9 Measuring time

We use clocks and watches to tell the time, but scientists often need to record how long an event takes. To do this accurately, they use stopwatches or electronic counters. The standard unit for measuring time is the second (s).

Familiarise yourself with a stopwatch. There is generally a start/stop button and a reset button. Push the reset button when you wish to start timing in a new experiment, and when you have finished timing your experiment and need to return your stopwatch to zero.

FIGURE 1.23 A stopwatch can be used to record time accurately.

INVESTIGATION 1.5

Timing a fall

Aim

To practise timing an event

Materials

- Stopwatch
- Pen

Method

1. Time how long it takes for a pen to fall from the top of the bench to the ground. Repeat two more times.
2. Calculate the average time taken for the three trials.
3. Repeat your experiment but swap roles within your group so that each member has a turn timing, recording and managing (such as saying 'go' when it is time to start the drop).

Results

Use a table like the one below to record your findings.

Name of student timing	Time taken (s)			
	1	2	3	Average

Discussion

1. Was the time taken to fall the same in each trial? Can you explain why?
2. Explain why it is useful to calculate an average.
3. Explain why you used a stopwatch in this experiment instead of the second hand of a clock or watch.

Conclusion

Describe what you learned about using a stopwatch accurately in this investigation.

INVESTIGATION 1.6

Recording observations in a table

Aim

To record observations from experiments

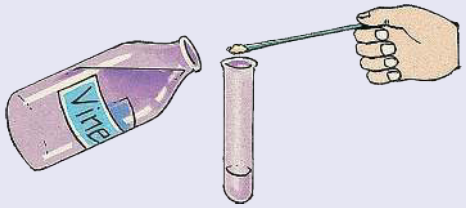
Materials

- test tubes
- 50 mL beaker
- eye-dropper
- vinegar
- sodium carbonate
- methylated spirits
- starch suspension
- safety glasses
- test-tube rack
- spatula
- drinking straw
- sodium bicarbonate
- copper sulfate
- limewater
- iodine solution

CAUTION: Safety glasses should be worn while conducting these experiments.

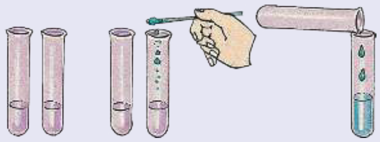
Method

Activity 1



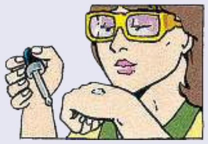
1. Pour vinegar into a clean test tube to a depth of about 1 cm.
2. Add a spatula-full of sodium bicarbonate.
3. Record your observations.

Activity 2



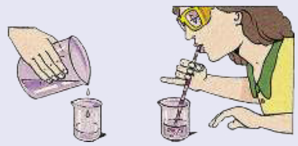
1. Quarter-fill two clean test tubes with water.
2. Add a dry spatula-full of sodium carbonate to one test tube. Shake the tube until the sodium carbonate dissolves.
3. Add a dry spatula-full of copper sulfate to the other test tube and shake it until the crystals dissolve.
4. Pour the contents of the second test tube into the first.
5. Record your observations.

Activity 3



1. Use an eye-dropper to put one drop of methylated spirits onto the back of your hand.
2. Blow air gently across the back of your hand.
3. Record your observations.

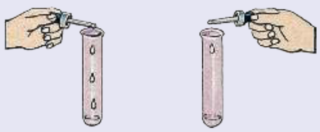
Activity 4



1. Quarter-fill a very small beaker with limewater.
2. Gently blow out through a drinking straw into the limewater. Be careful not to share straws.
3. Record your observations.

Activity 5

CAUTION: Take care not to get iodine solution on your skin or clothes.



1. Put a few drops of starch suspension in a clean test tube.
2. Add a drop of iodine solution.
3. Record your observations.

Results

Use a table like the one below to display a summary of what was done and the observations you made for each activity.

Activity	Summary of what was done	Observations
1		
2		
3		
4		
5		

Discussion

1. What senses did you use in making your observations?
2. Outline two safety precautions involved in this investigation.

3. Explain why it is important to use small quantities of chemicals when doing experiments like these.
4. Explain why it is useful to present the observations in a table.
5. In activity 4, you had to pour limewater into the beaker. If you took more limewater than required, explain why it is not a good idea to return any unused limewater to the original bottle.

Conclusion

Write a sentence describing which of the observations in the investigation were qualitative and which were quantitative.

1.4 Activities

learnon

1.4 Quick quiz	1.4 Exercise

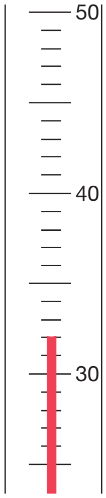
LEVEL 1	LEVEL 2	LEVEL 3
1, 4, 7, 9	2, 5, 8, 10	3, 6, 11

Remember and understand

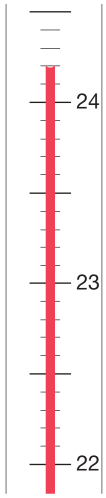
1. **Identify** whether the following statement is true or false.
   A measuring cylinder is an example of an analog measuring instrument.
2. **Describe** a parallax error.
3. **Explain** how you avoid a parallax error.
4. **Outline** a way to achieve an accurate measurement of the mass of a quantity of water.

Apply and analyse

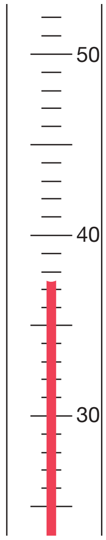
5. **Identify** the temperature measured by this thermometer.



6. **Identify** the temperature measured by this thermometer.



7. **Identify** the temperature measured by this thermometer.



8. **Identify** whether each of the observations in the table is quantitative or qualitative.

Qualitative and quantitative observations

Observation	Qualitative	Quantitative
The plant in sunlight grew faster than the plant in shade.		
The nail had a mass of 1.3 g.		
The air temperature is 28 degrees.		
The mouse has brown spots.		

9. Convert 120 g into kilograms.
10. Luke measured the mass of a beaker of water as 240 g. He poured out the water and measured the mass of the beaker as 105 g.
Calculate the mass of the water in grams.

Evaluate and create

11. Which of your five senses is the most important for making observations in science investigations, and which is the least important?
Justify your response.

Answers and sample responses are available in your digital formats.

LESSON 1.5 Reporting on investigations

LEARNING INTENTION

In this lesson you will present your investigation findings and ideas in the form of a scientific report, including using relevant scientific terms, diagrams and graphical representations.

1.5.1 Experiment reports

Once scientists have completed an investigation, they need to communicate to other scientists what they did, their qualitative and quantitative observations and their conclusions. This is done using a **scientific report**.

KEY IDEA

The format of a scientific report should be as follows.

- **Aim:** This is what you intended to do in the investigation.
- **Materials:** This is a list of all the equipment and chemicals that were used.
- **Method:** This is the procedure followed in the investigation, described as a series of steps. It may be useful to include a labelled diagram of the set-up of equipment used. Be sure to include what you were actually recording in the experiment.
- **Results:** This is a presentation of your data, and it may include qualitative observations. Data are usually organised into tables and presented as graphs.
- **Discussion:** In this section, scientists explain their results and why they think they obtained the results they did. They may refer to the research of other scientists. They may also describe any problems encountered in the investigation and make suggestions for improvements.
- **Conclusion:** This is a summary of the overall findings, and must relate to the aim of the investigation.

FIGURE 1.24 A good quality report of an experiment

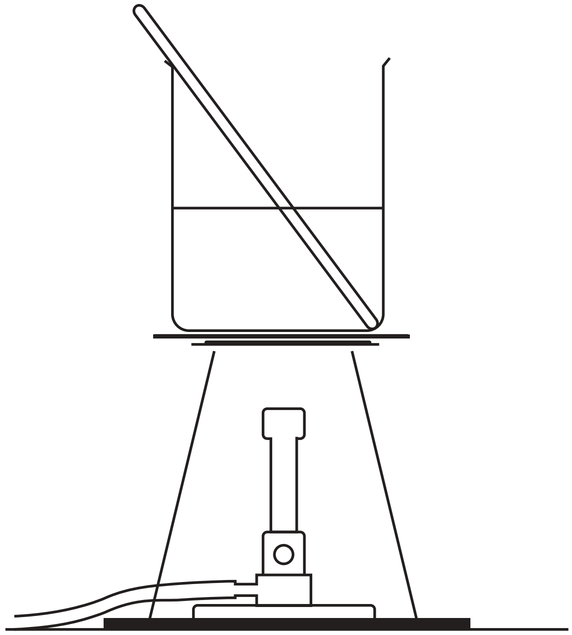
Dissolving sugar

Aim
To find out how much sugar will dissolve in hot water compared with cold water

Materials
- beaker
- heatproof mat
- Bunsen burner
- tripod
- gauze mat
- matches
- spatula
- stirring rod
- sugar
- water

Method
1. A spatula was used to add sugar to 100 mL of cold water in a beaker. The sugar was stirred and more added until no more would dissolve. The amount of sugar dissolved was recorded.
2. The mixture of sugar and water was heated with a Bunsen burner for 4 minutes and the extra amount of sugar that could be dissolved was recorded.

The equipment was set up as shown in the following diagram.



Results

Water temperature	Initial amount of sugar added	Extra sugar added	Total amount of sugar dissolved
Cold water	2 spatulas	1 spatula	3 spatulas
Hot water	2 spatulas	7 spatulas	9 spatulas

Discussion
More sugar can dissolve in hot water than in cold water. This experiment could be improved by using a thermometer to measure the temperature of the water. The sugar could be measured more accurately by adding smaller amounts at a time, or weighing it.

Conclusion
Three times as much sugar dissolves in hot water as in cold water.

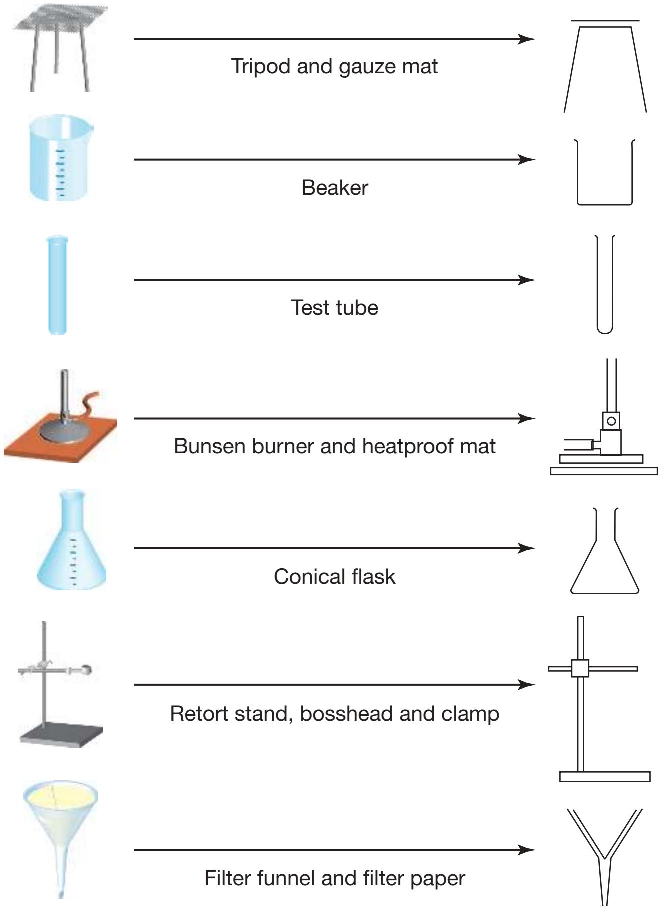
1.5.2 Drawing laboratory equipment

Scientific drawings can be used in laboratory reports to show how equipment was set up. It is important for the drawings to be clear and easy to understand. When drawing scientific diagrams, you should:

- always draw in pencil
- use a ruler to draw straight lines
- label the equipment drawn
- draw only a cross-section of the equipment
- not draw lines closing the top of open glassware.

Some examples of equipment drawn scientifically are shown in figure 1.25.

FIGURE 1.25 Diagrams in scientific reports should be simple. In each case here, the apparatus is shown on the left and the diagram of this apparatus on the right.



DISCUSSION

Do you have to be a talented artist to be able to draw a neat scientific diagram? Discuss ways in which you can produce a clear labelled diagram of your equipment even if you are not good at drawing.

1.5.3 Recording observations in tables

When recording observations, it is helpful to organise the data in a table. Information presented in this way is often easier to read. Graphs can then be constructed from the table to make it even easier to see patterns in the data.

The heading for each column is a clear label of what has been measured.

Always include the units used in the headings.

Distance (cm)	Time for ant to travel between markers (s)
0	0
2	3
4	7
6	8
8	12

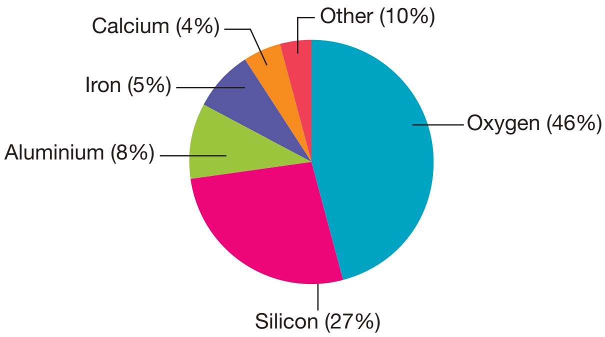
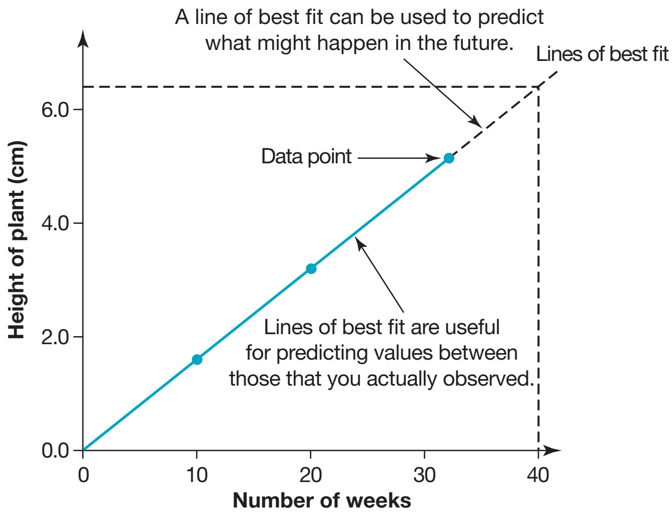
Enter the data in the body of the table. Do not include units in this part of the table.

Use a ruler to draw lines for rows, columns and borders.

1.5.4 Graphing

Graphs are used to make data easier to interpret. The type of graph used depends on the type of data to be displayed.

TABLE 1.7 Types of graphs

Type of graph	When is it used?	Example
Pie graph or pie chart	For showing the parts that make up a whole	A pie chart can be used to show the percentages of different substances in Earth's crust. 
Bar or column graph	To display data that can be placed in categories	A column graph can be used to show the number of students in a class with a particular hair colour. 
Scatter plot	To show how a measurement changes	A scatter plot can be used to show how quickly a plant grows over time. Data points are plotted on the graph and a line is drawn that best matches the positions of the data points. This line of best fit may be a straight line or a curve. Avoid playing 'dot-to-dot'. 

INVESTIGATION 1.7

Graphing temperature

Aim

To observe how the temperature of water changes while it is heated over a Bunsen burner

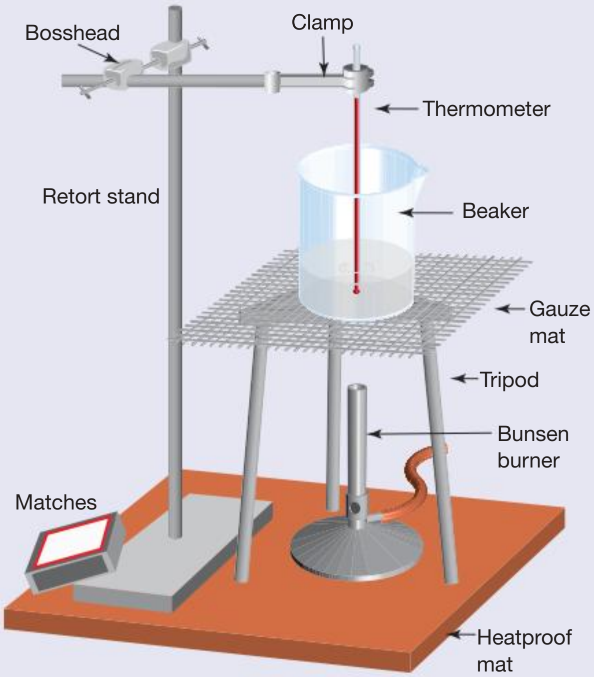
A scatter plot is a useful way to present the results of an experiment and helps to identify any trends or patterns in the results. A line of best fit can be drawn on the scatter plot and used to predict values that occur between, or outside, those measured during an experiment.

Materials

- 100 mL measuring cylinder
- 250 mL beaker
- Bunsen burner
- heatproof mat
- matches
- tripod
- gauze mat
- retort stand, bosshead and clamp
- thermometer or data logger and temperature sensor
- stopwatch
- safety glasses

Method

1. Use a measuring cylinder to measure 100 mL of water.
2. Pour the water into the beaker.
3. Set up the equipment as shown in the diagram. Make sure that the bulb of the thermometer is not on the bottom of the beaker or out of the water.



4. Wait for a minute to allow the thermometer to adjust to the water temperature.

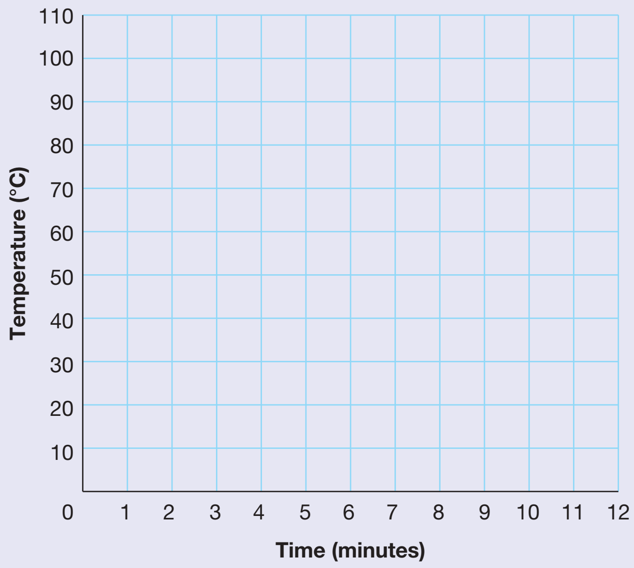
5. Measure the initial temperature of the water and record it in a table like the one shown below. The initial temperature is recorded when time is 0 minutes.

Time (min)	Temperature (°C)	Time (min)	Temperature (°C)
0		6	
1		7	
2		8	
3		9	
4		10	
5			

6. Put your safety glasses on.
7. Light the Bunsen burner according to the guide in section 1.3.5.
8. Open the airhole and heat the beaker over a blue flame.
9. Measure and record the temperature of the water every minute for 10 minutes.
10. Turn off the Bunsen burner and allow the equipment to cool.

Results

1. Plot the data you have collected on a sheet of graph paper using labels like those below. Don't forget to give your graph a title.



2. Complete the graph by drawing a smooth line near as many points as possible to show the overall trend in the water temperature over time.

Discussion

1. Describe in words how the temperature increases over time.
2. Explain why you didn't record the starting temperature of the water as soon as it was poured into the beaker.
3. How does your graph compare with those of other groups? If your graph is different, give a possible explanation for this.
4. The line of best fit can be used to predict values that occur between, or outside, those measured during an experiment. Looking at your graph, predict what would happen to the temperature of the water if you continued heating for another 2 minutes.

Conclusion

Write a sentence describing the shape of your graph and state the change in temperature of the water over the 10-minute period.

1.5 Activities

1.5 Quick quiz on	1.5 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 4	2, 6, 8	3, 5, 7

Remember and understand

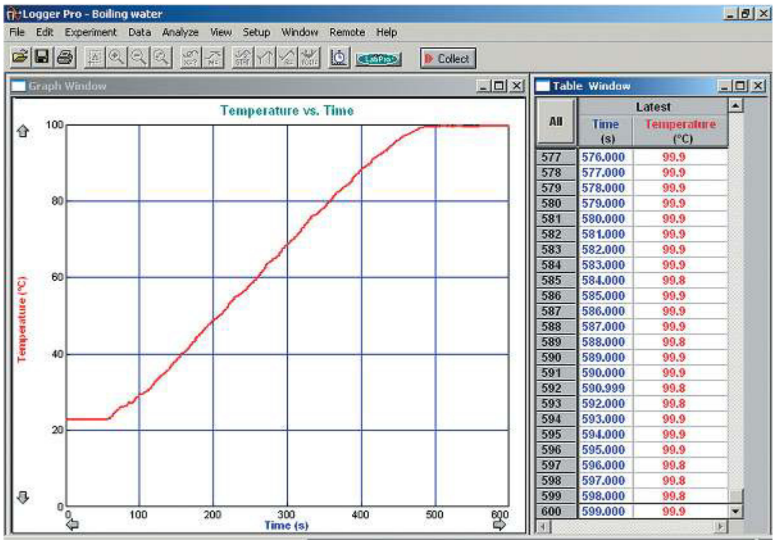
1. MC Select all the rules for drawing the equipment used in an experiment from the options provided.
   A. Use a pencil.
   B. Draw in three dimensions.
   C. Use a ruler to draw straight lines.
   D. Shade in glassware.
   E. Label the equipment drawn.
2. Place the following in the correct order for the sections of a scientific report:
   Aim, *Conclusion*, *Discussion*, *Materials*, *Method*, *Results*, *Title*
3. Match each section heading of a laboratory report with the information contained in that section.

a. Materials	1. Suggestions for improvements to your experiment
b. Procedure	2. The data collected
c. Conclusion	3. A description of how the experiment was undertaken
d. Discussion	4. A list of the equipment used
e. Results	5. A statement saying what you discovered by doing the experiment

4. **Identify** the correct terms and complete the sentences.
   The *aim* / *method* section of a scientific report is a statement of what you intended to find out in the experiment.
   The *aim* / *method* section is a list of steps explaining how the experiment was performed.

Apply and analyse

5. Consider the figure below. The computer screen shows data collected by a data logger for an experiment in which water is heated to boiling point in a beaker. A temperature sensor was used to take the measurements.



If you were at this computer, you could scroll through every temperature measurement in the table. The computer has graphed all these data.

a. MC How often did the data logger collect temperature readings?
  A. Each minute
  B. Each second
  C. Each 0.1 second
  D. Each 0.001 second
b. **Identify** the number of individual temperature readings the data logger has stored.
c. **Identify** the approximate time at which heating of the water began.
d. MC **Identify** the temperature of the water when heating began.
  A. 23 °C
  B. 32 °C
  C. 50 °C
  D. 100 °C
e. **Identify** the approximate temperature of the water when heating finished.
f. **Identify** the time at which the water began to boil.
g. MC **Calculate** the rate (in degrees per second) at which the water temperature rose between 100 and 400 seconds.
  A. 0.19 °C/s
  B. 30 °C/s
  C. 58 °C/s
  D. 300 °C/s

6. **Explain** why it is useful to present observations in a table.
7. **Identify** one reason that we might use scatter plots to present the results of an experiment.

Evaluate and create

8. **Construct** scientific diagram showing the equipment set-up for the following experiment. You may use an online program to help you draw.
Muddy salt water is being poured from a 100 mL beaker into a filter funnel (with filter paper). The filter funnel is resting in the opening of a 150 mL conical flask.

Answers and sample responses are available in your digital formats.

LESSON 1.6 Designing investigations

LEARNING INTENTION

In this lesson you will:

- describe how observations of natural phenomena can be used to make inferences and testable predictions
- identify that scientific theories and laws are based on repeated experiments and observations that describe or predict a range of natural phenomena.

In many of the experiments you have done so far, the aim and the method you need to follow have been provided for you. In some cases, though, you will need to design your own experiments as part of your investigation.

Let's look at some important principles to consider when designing investigations.

1.6.1 Inferences

After making some initial observations, scientists make an **inference** about what has happened. Many inferences can often be made for the same set of observations. Inferences not only help scientists interpret observations but also form the basis for **predictions** — educated and specific guesses about what might happen under certain conditions.

ACTIVITY: Inferences

Consider the picture. What inferences can you make? What observations led you to these inferences?

FIGURE 1.26 Observations and inferences

1.6.2 Hypotheses

After making an inference, scientists will come up with a **hypothesis**.

Here are some examples of hypotheses.

- Wearing makeup causes your skin to get pimples.
- The rate at which coffee in a cup gets colder depends on the shape of the cup.
- Plants grow faster in full sunlight than in shady positions.
- Bees prefer flowers that are red rather than white.

Each of these can be tested in an experiment, and the results of the experiment will either **support** the hypothesis or cause the hypothesis to be **rejected**.

DISCUSSION

Consider the following statement: Honey kept in the fridge is less runny than honey that has been kept in the cupboard.

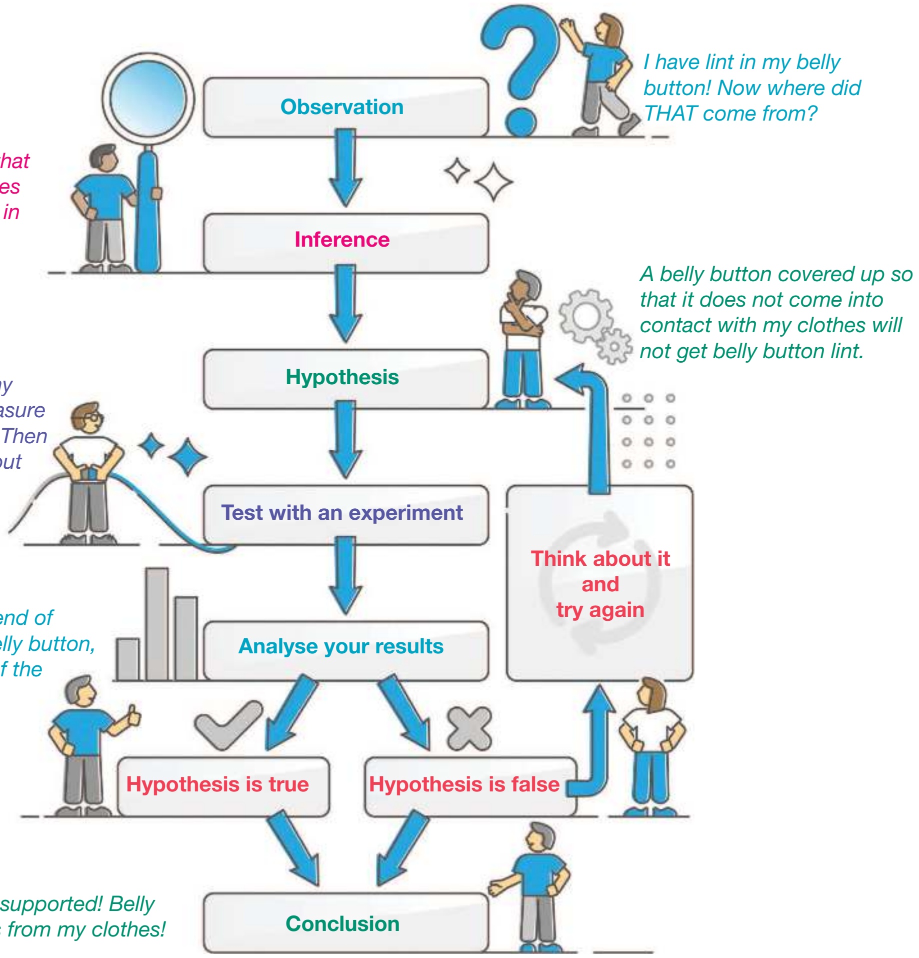
- How would we test whether this statement is always true?
- What hypothesis would we come up with?
- What experimental results would support the hypothesis?
- What results would lead to the hypothesis being rejected?

1.6.3 The scientific method

The word *science* comes from the Latin word *scientia*, meaning 'to know'. Scientists of all kinds gain knowledge through a process of making observations and conducting experiments to come up with explanations for those observations. This process is called the **scientific method**.

The scientific method can be described in a series of steps, as shown in figure 1.27.

FIGURE 1.27 Belly button lint and the scientific method



INVESTIGATION 1.8

Observing and inferring

Aim

To observe the changes that occur in a burning candle

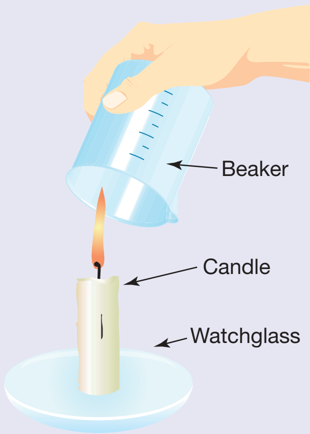
Materials

- large beaker
- short candle
- lid or watchglass
- matches
- electronic scales

Method

1. Weigh the candle and lid (or watchglass) using electronic scales, and record your results.
2. Light the candle.
3. Observe the candle for several minutes and record as many observations as you can while it is alight. (Michael Faraday, a nineteenth-century scientist famous for his discoveries in electricity and chemistry, was able to make 53 observations of a burning candle!)

4. After several minutes, place an upturned beaker over the candle and continue to record your observations.



5. Weigh the candle and lid (or watchglass) again and record your results.

Results

List your observations in a table similar to that shown below. Note whether the observation was qualitative or quantitative.

	Observations	Qualitative or quantitative?
Before the beaker is placed over the candle		
After the beaker is placed over the candle		

Discussion

1. How many observations did you record? What was the greatest number recorded by a member of your class?
2. What change occurred in the mass of the candle and lid? Is this an example of a quantitative observation or a qualitative observation?
3. What inferences can you make as to why the mass of the candle may have changed?
4. Write a hypothesis that allows you to test one of your inferences.

Conclusion

Describe the difference between your observations and your inferences.

1.6.4 Laws and theories

Scientific laws and **scientific theories** are very different things. It is important to note that theories cannot become laws.

TABLE 1.8 Scientific laws versus scientific theories

Laws	Theories
Predict what will happen	Explain how or why things happen
Can be proven experimentally or mathematically	Are hypotheses that have been repeatedly supported by evidence but cannot be proven
May often be written in the form of mathematical equations	May be replaced by other theories that are a better explanation for observations

DISCUSSION

Which of the following have you heard about?
- The Law of Gravity
- The Theory of Evolution
- The Laws of Motion
- The Theory of Relativity
- The Distributive Law
- The Greenhouse Theory

Discuss what people mean when they say something is 'just a theory'. Do they mean that it isn't always true? What is the difference between a theory and a law?

1.6.5 Fair tests

An important part of any investigation is to consider all the factors, or variables, that may affect the outcome of an experiment.

In a fair test, you need the following elements to ensure accuracy and reliability.
- **Independent variable**: the variable that is deliberately changed in the experiment
- **Dependent variable**: the variable that is measured in the experiment
- **Controlled variable**: the variable/variables that must be kept constant to ensure that the experiment is fair.

The phrase 'Cows Moo Softly' can be useful in remembering how to plan a fair test with all the necessary elements.
- **C**hange one thing.
- **M**easure something.
- Keep everything else the **S**ame.

When designing fair tests, you might find it helpful to use a table like table 1.9 to identify all the variables.

TABLE 1.9 Investigation: Does the height from which a ball is dropped affect the height of its bounce?

Independent variable (What I will change)	Dependent variable (What I will measure)	Controlled variables (What I will keep the same)
• The height from which the ball is dropped	• The height of the ball's bounce	• The type of ball • How much air is in the ball • The type of surface onto which it is dropped • Dropping the ball from a stationary point

DISCUSSION

Dana loves playing tennis, and it seems to her that the Schmick brand of tennis ball bounces higher than the Swish brand. She wants to test this hypothesis experimentally.

What variable will be the independent variable? What will be the dependent variable?

Discuss what variables Dana would need to control (keep the same) throughout her testing to make it a fair test. Are there any variables that are beyond her ability to control?

1.6.6 Including a control

In some investigations, it is important to include a **control**. A control is a trial of the experiment in which the independent variable being tested is not applied. Results from the control are compared with those obtained when the independent variable has been included. This allows us to test whether the independent variable we are investigating really has an effect, or whether other variables that we may not have thought of could be playing a part.

For example, Toby is going to test whether powdered laundry detergent gets his clothes cleaner than liquid laundry detergent. A suitable control would be a trial in which no laundry detergent is used at all.

FIGURE 1.28 The laundry test

1.6.7 Reliability

If the results obtained are similar for each trial using the same independent variable value, then we say the results are **reliable**.

Errors often arise in experiments. The most common errors are **one-off errors** (or **random errors**). These may happen because the experiment was not done in the same way in every trial. The results of these errors are just as likely to be too high as too low.

Examples of one-off errors include:
- the person timing the drop of a ball is distracted and is late stopping the stopwatch
- the distance a paper plane travels is being measured when, suddenly, there is a gust of wind that pushes against the plane
- the person weighing powder on a digital scale forgets to subtract the mass of the powder's container during one of the trials, so the weight recorded for that trial is too high.

KEY IDEAS

The following steps help avoid random errors affecting your conclusions.
1. Tests should be repeated several times (at least three) and the average value found.
2. When repeating tests, they should be done in exactly the same way each time.
3. If reading scales, ensure that there is no parallax error.
4. If there was a significant difference between your results for each test, you may need to review the way in which the experiment was done.

DISCUSSION

When doing the official weighing-in for a match, a boxer is found to have a mass of 95 kg. However, the scales he used in the changing room 5 minutes before showed him to be 93 kg. What is the most likely explanation for the difference in weight? Discuss how you could find out which of the scales to believe.

CASE STUDY: The smoking gun

It is vital that all people timing a race start their stopwatches at the same time. For this reason, they start to time when they see the smoke first appear from the starter's gun. In important events such as at the Olympic Games, the timing is started and stopped by a system of sensors and computers.

FIGURE 1.29 All stopwatches must be started at the same time when timing a race.

SCIENCE INQUIRY: Investigating the efficiency of renewable energy

Scientists often design experiments to test whether a specific variable makes a difference. In investigations like this, it is important to include a control to compare the results. A control helps determine if the independent variable being tested is responsible for the observed outcome or if other factors are affecting the results.

For example, to test whether powdered detergent is more effective than liquid detergent at cleaning stains, an experiment can be conducted using dirty fabric samples.

Scientific inquiry example:

Question: Does powdered detergent clean stained fabric more effectively than liquid detergent?

Independent variable: Type of detergent used (powdered, liquid or none)

Dependent variable: Cleanliness of the fabric, measured by how much of the stain is removed

Controlled variables:
- Amount of detergent used
- Water temperature and volume
- Washing time and machine settings
- Type of fabric and stain applied

Control group: Fabric sample washed with no detergent

1. Does powdered detergent remove more stains than liquid detergent?
2. How does the control group (no detergent) compare to the test groups?
3. Are there any patterns in stain removal between the types of detergent tested?

Prediction: Powdered detergent will remove more stains than liquid detergent or no detergent.

Hypothesis: If powdered detergent contains stronger cleaning agents, then it will result in cleaner fabric compared to liquid detergent or no detergent.

Reproducible investigations to answer questions and test hypotheses can be planned and conducted, including identifying independent, dependent and controlled variables where applicable, stating assumptions, recognising and managing risks (VC2S8I02)

SCIENCE AS A HUMAN ENDEAVOUR: Science and ethics — solving socio-scientific issues

Science is often used to solve real-world problems, but solutions can raise ethical and social questions. For example:

- Vaccines are developed to prevent diseases, but some people worry about safety and side effects.
- Renewable energy reduces carbon emissions, but building wind farms can affect local wildlife and land use.
- Genetic engineering can help cure diseases, but it also raises concerns about privacy and fairness.

Scientists must balance benefits with risks when developing new technologies. Public debates and policies often guide decisions to make sure solutions are fair, safe and sustainable.

1. Why is it important to consider ethical, environmental and social factors when making scientific decisions?
2. What are some examples of socio-scientific issues that involve these considerations?
3. How can communities influence scientific policies and regulations to ensure fairness and safety?

Proposed scientific responses to socio-scientific issues impact on society and may involve ethical, environmental, social and economic considerations (VC2S8H03)

CASE STUDY: Experimental design and Louis Pasteur

To properly test an idea, a fair test of a hypothesis needs to be made. In a fair test, all factors should remain the same except one: the independent variable. In a simple experiment, you change one independent variable at a time and observe what happens.

Observations of maggots appearing in rotten meat and mould forming on bread led the fourth-century BCE philosopher Aristotle to infer that living things could suddenly be created from non-living things. He called this theory 'spontaneous generation'. Many scientists continued to believe this theory for 2000 years.

However, the spontaneous generation theory was dealt a serious blow by the work of the French scientist Louis Pasteur in 1859. Pasteur had been filtering air through wads of gun cotton when he observed that the gun cotton was getting filled with microbes.

FIGURE 1.30 Louis Pasteur

He inferred that the microbes must have been in the air. He designed an experiment to test his hypothesis that the microbes growing on old food came from the air, not the food.

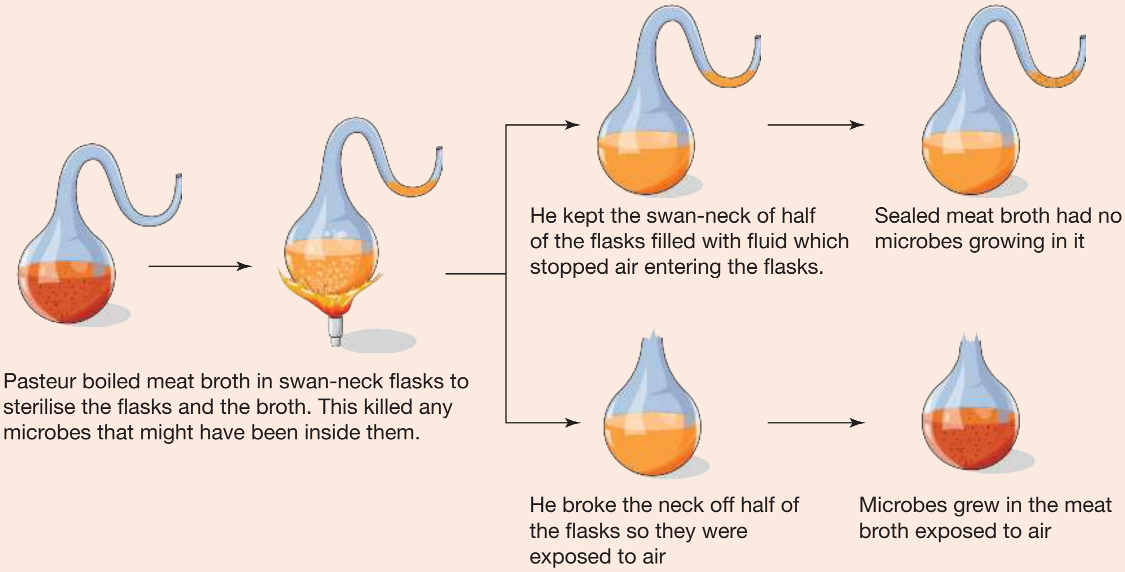
In his experiment, Pasteur's independent variable was whether the meat broth in the flask remained sealed away from air or not.

His dependent variable was the number of microbes that grew in each flask after a set period of time.

Some of the variables that he controlled were:

- the size and volume of flask used
- the period of time that the meat broth and flasks were boiled for at the start to sterilise them
- the volume of meat broth added to each flask
- keeping the flasks in the same area/environment.

FIGURE 1.31 The Pasteur experiment



The result of his experiment was that microbes grew in the meat broth in the flasks open to the air, but not in the ones that remained sealed by the fluid in the swan-neck.

He concluded that the microbes in the air became trapped in the fluid in the bent section of the neck, and so could not travel into the meat broth.

Because microbes grew in the flasks exposed to the air but not in the others, this experiment supported Pasteur's hypothesis that germs arrived from the air outside the flask.

INVESTIGATION 1.9

Stopping the growth of bacteria

Aim

To investigate whether preservatives can stop the growth of bacteria

Materials

- chicken stock cube
- vinegar
- beaker (1 L)
- salt
- hot tap water (750 mL)
- masking tape
- stirring rod
- pen or marker
- 3 beakers (250 mL each)
- teaspoon

Method

1. Place a chicken stock cube in a 1 L beaker and add 750 mL of hot tap water.
2. Stir the solution with a stirring rod until it is consistent.
3. Pour 200 mL of the mixture into each of three 250 mL beakers.
4. Add one teaspoon of vinegar to one small beaker and use the pen and masking tape to label the solution 'vinegar'.

5. Add one teaspoon of salt to another small beaker and label the solution ‘salt’.
6. Label the third beaker ‘control’.
7. Place the three small beakers on a warm windowsill for 7 days.

Results

Large amounts of bacteria will make the solutions go cloudy.

Examine the three beakers after 2 days and again after 7 days. Record your observations in a table like the one below. Describe the degree of cloudiness of each solution.

Beaker	Observations	
	After 2 days	After 7 days
Vinegar		
Salt		
Control		

Discussion

1. What was (a) the independent variable and (b) the dependent variable in this investigation?
2. What role did the control play in this experiment?
3. Salt is one of the most widely used of all food preservatives. Suggest a hypothesis relating to salt that could be tested by this experiment.
4. Which preservative was the most effective at stopping bacterial growth?

Conclusion

Write a brief statement explaining whether your hypothesis (from question 3 in the Discussion) was supported by the results of this experiment.

INVESTIGATION 1.10

Floating in salty water

Aim

To investigate whether the salinity of water affects how high an object floats in water

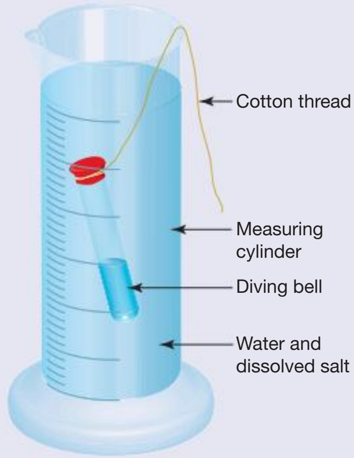
The water in the Dead Sea, a lake near Jordan in the Middle East, has an unusually high salinity; in fact, it is nine times more saline than the ocean. Tourists flock to the lake because it is believed the water has health benefits and to experience the water’s unusually high buoyancy.

Materials

- 100 mL measuring cylinder
- small test tube
- cork or rubber stopper
- cotton thread
- permanent marker
- scissors
- table salt
- teaspoon or spatula

Method

1. Fill the measuring cylinder to the 100 mL mark with tap water.
2. Make a 'diving bell' by half-filling a test tube with tap water; seal the top with a stopper.
3. Tie a piece of cotton thread securely around the top of the test tube so it can be carefully moved in and out of the measuring cylinder.
4. Check that the test tube floats off the bottom but not higher than halfway up the measuring cylinder. If not, adjust the volume of water in the test tube.
5. Put the diving bell in the measuring cylinder and mark the position of the *bottom* of the diving bell on the measuring cylinder's scale. Record this value.
6. Carefully remove the diving bell.
7. Add a level teaspoon of table salt to the measuring cylinder and dissolve it in the water by shaking carefully or stirring.
8. Put the diving bell back in and mark and record its position.
9. Repeat this experiment using a second, a third and, finally, a fourth teaspoon of salt.



Results

1. Design a suitable table to record your results — you will need a column indicating the number of teaspoons of salt added and a column listing the position of the diving bell (using the scale on the measuring cylinder).
2. Draw a line graph of salinity (teaspoons of salt added) on the *x*-axis versus the height of the diving bell (reading on the measuring cylinder) on the *y*-axis, and draw a smooth line of best fit.

Discussion

1. Identify the independent variable and the dependent variable in this experiment.
2. Identify the control in this experiment.
3. What variables were controlled throughout this experiment? (Remember — this will not be the same as the control variable.)
4. What happens to the height of the diving bell as the number of teaspoons of salt added is increased?
5. Repeating this experiment would be very time-consuming so, to check the reliability of your findings, compare your results with those of other groups. The easiest way to do that is to compare others' graphs with yours. Describe any differences that stand out between your results and those of other groups.
6. List the most likely causes of error in your experiment. In each case, state how this error could be avoided if the experiment was done again.
7. Use your graph to predict the position of the diving bell if six teaspoons of salt were added. (This sort of prediction beyond the values used in the experiment is called extrapolation.)

Conclusion

Write a conclusion to the experiment about whether the salinity of water affects how high an object floats in water.

1.6 Activities

learnon

1.6 Quick quiz on	1.6 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 4, 7, 9	2, 5, 8, 10	3, 6, 11

Remember and understand

1. **Identify** whether the following statement is true or false.
   Only one variable at a time should be changed in experiments, so that it is possible to assess the effect of just that one variable on the outcome.
2. MC Which of the following statements is NOT a hypothesis?
   A. Red cars get hotter interiors than white cars when parked in the sun.
   B. Dogs are better pets than cats.
   C. Tea cools at a faster rate than coffee.
   D. Sugar is more soluble in water than salt.
3. Place the following steps of the scientific method in their correct order:
   Observation, *Inference*, *Hypothesis*, *Experiment*, *Analyse results*, *Determine whether the hypothesis is supported or rejected*, *Conclusion*
4. **Identify** whether the following statement is true or false.
   In science, a theory can never become a law.
5. **Identify** whether the following statement is true or false.
   Louis Pasteur tested the hypothesis that food spoiled when left open in the air.
6. **List** the three characteristics that the control used by Louis Pasteur in his experiments had.

Apply and analyse

7. MC Which two of the following variables might affect how quickly a pot plant grows?
   A. The amount of light received
   B. The colour of the pot
   C. The nursery from which it was purchased
   D. The species of plant
8. Imagine that you are conducting an experiment to test the effectiveness of different washing powders at removing mud stains from cricket shirts.
   a. MC Which of the following would be an independent variable in your experiment?
      A. Amount of mud on a cricket shirt
      B. Temperature of the water
      C. Brand of washing powder
      D. Amount of washing powder
   b. MC Which of the following would be a dependent variable in your experiment?
      A. Amount of mud on a cricket shirt
      B. Brand of washing powder
      C. Amount of washing powder
      D. Visibility of stain remaining after washing
   c. MC Which of the following would be controlled variables in your experiment?
      A. Temperature of the water
      B. Visibility of the stain after washing, visibility of the stain before washing
      C. Amount of washing powder, visibility of the stain after washing
      D. Time shirt is washed for, amount of washing powder, temperature of the water

d. MC Which of the following variables in your experiment could be measured quantitatively? Select all that apply.

A. Brand of cricket shirt
B. Amount of mud on a cricket shirt
C. Temperature of the water
D. Brand of washing powder
E. Amount of washing powder
F. Time shirt is washed for

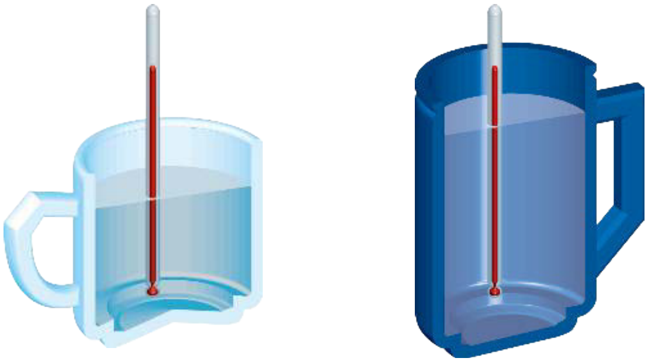
9. Simon and Jessie conducted an experiment to find out how effectively two plastic cups maintain the temperature of near boiling water. Their data are shown below.

Temperature in each cup over time

Time (min)	Temperature (°C)	
	Simon's cup	Jessie's cup
0	90	90
10	47	58
20	29	39
30	22	31
40	20	26
50	20	23

Estimate the temperature of the water in Simon's cup 15 minutes after timing commenced.

10. Catherine and Celine are trying to find out whether ceramic or glass cups are better for keeping water hot. The illustration shows their experiment in progress.



a. The temperature of the water is the *dependent* / *independent* variable and the type of cup is the *dependent* / *independent* variable.
b. **Identify** two errors in their experimental design.
c. **Outline** a procedure that they could use to find out which cup keeps water hotter.

Evaluate and create

11. Design an experiment to investigate what conditions affect the time taken for seeds to germinate.

Answers and sample responses are available in your digital formats.

LESSON 1.7 Review

1.7 Success criteria

Tick the column to indicate that you have completed the lesson and how well you think you have understood it using the traffic light system.

(**Green:** I understand; **Yellow:** I can do it with help; **Red:** I do not understand)

Lesson	Success criteria	Green	Yellow	Red
1.2	I can recognise how scientific knowledge can be represented in branches of biology, chemistry, physics and geology.			
	I can consider how modern scientific knowledge is interdisciplinary and transdisciplinary.			
1.3	I can identify, assemble and use appropriate equipment and resources to perform an investigation safely.			
1.4	I can use a variety of analog and digital measuring devices in scientific investigations to compare the range, sensitivity and accuracy of observations provided by those instruments.			
1.5	I can present investigation findings and ideas in the form of a scientific report, including using relevant scientific terms, diagrams and graphical representations.			
1.6	I can describe how observations of natural phenomena can be used to make inferences and testable predictions.			
	I can identify that scientific theories and laws are based on repeated experiments and observations that describe or predict a range of natural phenomena.			

learnon

Post-test Topic 1 Post-test

eWorkbook Topic 1 eWorkbook

Digital document Key terms glossary

1.7 Activities

learnon

1.7 Review questions

LEVEL 1	LEVEL 2	LEVEL 3
1, 4, 7, 10, 13, 16, 19, 22	2, 5, 8, 11, 14, 17, 20	3, 6, 9, 12, 15, 18, 21

Remember and understand

1. Match the following scientists with their field of work.

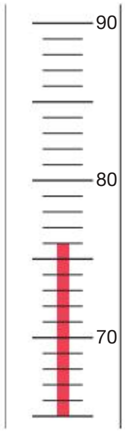
a. Physicist	1. Studies living things
b. Chemist	2. Investigates the formation of rocks and mountains
c. Biologist	3. Studies the night sky
d. Astronomer	4. Investigates movement and light
e. Earth scientist	5. Studies how substances react together

2. MS Which three of the following are parts of a Bunsen burner?
   A. Gas hose
   B. Barrel
   C. Collar
   D. Bosshead
   E. Conical flask
   F. Test tube rack
   G. Evaporating basin
3. Match the piece of laboratory equipment with its correct use.

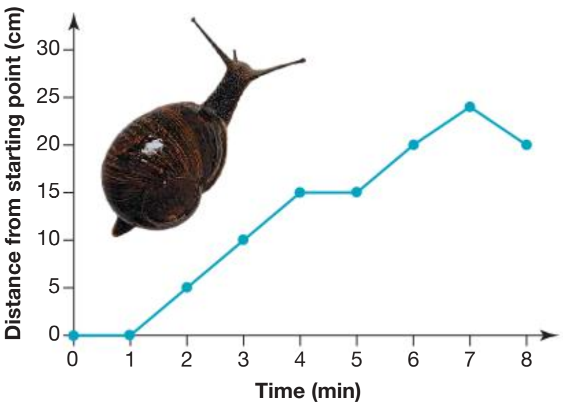
a. Bosshead	1. Holds test tubes upright
b. Conical flask	2. Container used for heating small amounts of substances over a Bunsen burner
c. Test-tube rack	3. Holds a clamp to the retort stand
d. Evaporating basin	4. Container used for mixing substances or collecting filtered substances

4. a. When lighting a Bunsen burner, light the match *immediately before* / *while* / *immediately after* turning on the gas.
   b. When using a thermometer to measure the temperature of a liquid as it is heated, place the bulb of the thermometer *at the bottom* / *near the centre* / *at the top* of the beaker.
5. When heating a test tube, hold the test tube using _______ at the top of the test tube and _________ over the flame.
6. MC **Identify** which of the following is an important safety rule in the science lab.
   A. When smelling chemicals, place your nose carefully over the container.
   B. Dispose of all materials in the rubbish bin.
   C. When reading the volume of a liquid, always read the top of the meniscus.
   D. Point test tubes away from your eyes and away from your fellow students.

7. Place the following important steps involved in using a Bunsen burner in the correct order.
   I. Light a match and hold it over the barrel.
   II. Adjust the flame by moving the collar until the airhole is open.
   III. Connect the rubber hose to the gas tap.
   IV. Turn on the gas tap and a yellow flame will appear.
   V. Close the airhole of the Bunsen burner collar.
8. MC The equipment used for measuring the volume of liquids includes:
   A. conical flask, beaker, measuring cylinder.
   B. measuring cylinder, crucible, beaker.
   C. watchglass, filter funnel, conical flask.
   D. evaporating basin, test tube, beaker.
9. Convert the following quantities to standard units.
   Note: Use numerals to write your answers.
   a. 240 cm = ______ m
   b. 650 mL = ______ L
   c. 3500 g = ______ kg
10. **Identify** the temperature measured by the thermometer shown below.



11. MC Luke was tired of being bitten by mosquitoes. He counted several bites each evening when he sat outside to have dinner. He had heard that a burning citronella candle was a good way to keep mosquitoes away.
    If you were to design an experiment using the principles of fair testing to test Luke's idea, **identify** the independent variable.
    A. The type of candle used
    B. The number of mosquito bites on Luke
    C. The time of night the candle is burned
    D. A plain unscented candle
12. The graph shows how far from the starting point a snail moves in an experiment.



    a. How far from the starting point was the snail 7 minutes after timing began?
    b. MC During which times did the snail not move at all?
       A. None — it was always moving
       B. Between the second and third minutes
       C. Only at the very beginning
       D. During the first and fifth minutes
    c. MC What does the graph tell us about the snail's movement between 7 and 8 minutes after timing began?
       A. The snail was slowing down.
       B. The snail was moving back towards the start.
       C. The snail had stopped moving.
       D. The snail was travelling down a slope.

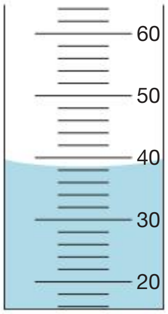
13. The following table shows the winning times for the men's 400-m freestyle swimming event at various Olympic Games from 1908 to 2016.

Winning times for the men's 400 m freestyle, Olympic Games, 1908–2016

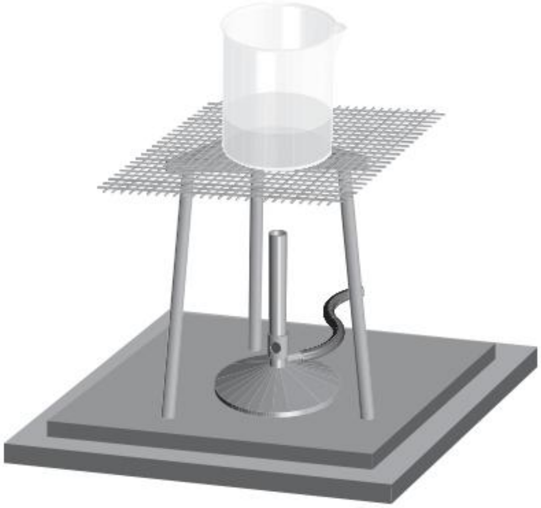
Year	Name, Country	Time (min:s)
1908	Henry Taylor, Great Britain	5:36.8
1920	Norman Ross, USA	5:26.8
1932	Buster Crabbe, USA	4:48.4
1948	Bill Smith, USA	4:41.0
1960	Murray Rose, Australia	4:18.3
1972	Bradford Cooper, Australia	4:00.27
1984	George DiCarlo, USA	3:51.23
1996	Danyon Loader, New Zealand	3:47.97
2000	Ian Thorpe, Australia	3:40.59
2004	Ian Thorpe, Australia	3:43.10
2008	Taehwan Park, Korea	3:41.86
2012	Yang Sun, China	3:40.41
2016	Mack Horton, Australia	3:41.55

a. Is data available for each Olympic Games every 4 years?
b. What was the winning time in seconds for Taehwan Park, Korea, in 2008? Round off to the closest second.
c. **Discuss** how the winning times have changed over the 108-year period and suggest two reasons for the change in winning times.
d. **Discuss** how times for the men's 400-m freestyle might change over the next 40 years.

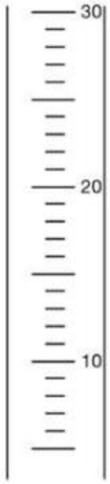
14. MC The liquid level in the measuring cylinder shown is:
A. 34 mL.
B. 38 mL.
C. 40 mL.
D. 42 mL.



15. Draw a scientific diagram of the experiment below, suitable for inclusion in a report. Label each part of your diagram.



16. A student wanted to investigate which brand of paper towel was the most absorbent. **Identify** the following variables for the experiment.
   a. The independent variable
   b. The dependent variable
   c. Two important controlled variables
17. Copy and colour the thermometer below to show a temperature of 14 °C.



18. A group of students carried out an investigation to study the types of birds that visited the school playground during lunchtime. They recorded five native miners, two cockatoos, seven Indian mynahs and three pigeons. What is the most suitable type of graph to present their data? **Justify** your answer.
19. A group of students investigated the time taken for a headache tablet to dissolve in a glass of water as the temperature of the water was increased. They obtained the following results.

Temperature over time

Temperature (°C)	15	20	25	30	35	40
Time (s)	60	40	30	20	15	10

   Draw a scatter plot of this data, including a line of best fit.
20. Look at the photograph.
   a. What qualitative observations do you think the scientist can make from this experiment?
   b. **Propose** two different quantitative observations the scientist might make during this experiment.
   c. **Propose** what the aim of this experiment might be.

21. **Construct** a table with three columns headed 'Observation', 'Inference' and 'Prediction'. In the table, write each of the statements below under the correct heading and in their correct sequence, so that a scenario is followed across each row.
- I am afraid of heights.
- A snail has eaten holes in the leaves of my African violet plant, but hasn't touched the flowers.
- I will experience similar symptoms if I stand at the top of another building, a cliff or a bridge.
- My charger cable is faulty.
- Snails eat leaves, but not flowers.
- My phone doesn't charge when I plug it in.
- When visiting the top deck of Sydney Tower, my heart started beating more quickly and loudly, my palms sweated and I felt a bit dizzy.
- If I put a different flowering plant in place of my African violet each night, the snail will eat only the leaves of each plant, and ignore the flowers.
- If I use another charger cable, my phone will charge.

22. Four students each measured the temperature in the same classroom using a thermometer. Their results are shown in the table.

Classroom temperatures per student

Student	Temperature (°C)
1	23.5
2	24.0
3	25.0
4	22.0

a. **Construct** a bar graph of these results.
b. **Propose** some possible reasons for the differences between measurements.

Answers and sample responses are available in your digital formats.

on To test your understanding and knowledge of this topic, go to your learnON title at jacplus.com.au and complete the **post-test**.

2 Classification

CONTENT DESCRIPTION

There are similarities and differences within and between groups of organisms living on Earth; the development and use of classification tools, including dichotomous keys, help order and organise human understanding of the diversity of life (VC2S8U01)

Source: Victorian Curriculum F–10 Version 2.0

LESSON SEQUENCE

LESSON 2.1 Overview

2.1.1 Introduction

Our planet contains an amazing variety of living things. Scientists classify these living things into groups based on their similarities and differences.

Using names to label things can help us to sort out what we know (what is familiar) from what we do not (what is unfamiliar). We can also look for clues in names to help us to make the unfamiliar more familiar. Although this linking can often be useful, sometimes it may result in confusion.

A sea dragon, for example, is a type of seahorse. If you were to use the clues in the name of the sea dragon to describe it to someone who was unfamiliar with sea dragons, would they imagine it to look like a combination of a horse and a dragon that lived in the sea?

The use of the term 'dragon' in the common name of some **organisms** may result in confusion or misunderstanding. Look at the image of the sea dragon in figure 2.1 and compare it to images of other examples of 'dragons' in figure 2.2. Although the sea dragon, dragonfly, Komodo dragon and snapdragon all share the term 'dragon' in their names, they do not share many other features. This is another example of how the use of common names can lead to confusion. To reduce confusion and misunderstanding, scientists use a shared **classification** and naming system. This system provides the opportunity for both shared understanding and more effective communication.

FIGURE 2.1 A sea dragon

FIGURE 2.2 a. Dragonfly **b.** Komodo dragon **c.** Snapdragon flower

a.

b.

c.

DISCUSSION

1. Why bother classifying living things?
2. Which animals have their skeletons on the outside?
3. I have scales and lungs and live on land. What am I?
4. How can you use a key to unlock the door to classification?
5. In terms of biological classification, which class do you belong to?
6. Do you think red pandas are more closely related to giant pandas or to raccoons? How do you know?
7. Who were Snugglepot and Cuddlepie, and what is their link to Australian native plants?

SCIENCE INQUIRY: Dragon mapping

Why does the term 'dragon' appear in the names of so many different plants and animals?

Task

1. Form a group of four and allocate the roles of scribe (someone to write everything down), captain/organiser, timekeeper and motivator.
2. Brainstorm all that your group knows about dragons. Your group scribe should construct a tree map of different dragons and their features that result from your brainstorm.
3. Compare your tree map with those of other groups in your class. On a new piece of paper, assist your group scribe in summarising the key dragon features identified by the class into a tree map.
4. Your group should now have two maps — your own group brainstorm tree map and your class summary tree map.
5. On your class summary tree map, use one colour to highlight the features that you would consider to be common to all dragons. In a second colour, highlight features that you would consider to be different between dragons.
6. Review the images of the dragonfly, Komodo dragon and snapdragon in figure 2.2.
   a. Do they share any features? If so, what are they?
   b. Do they possess any of the features that you have identified as being common to all dragons? If so, what are they?
7. Research other plants and animals that contain the term 'dragon' in their common names. Do these other plants and animals share any of the dragon features that you have identified? Summarise your findings.
8. Stories about dragons have featured in many cultures around the world, but do dragons really exist? Did dragons ever exist? If dragons did exist, are there organisms still alive to which they may have been related? Provide reasons for your response.
9. Use evidence from your investigation to suggest why the term 'dragon' is used in the common names of some plants and animals. Create a poster outlining your findings.

Data and information can be organised and processed by selecting and constructing representations including tables, graphs, keys, models and mathematical relationships (VC2S8I04)

learnon

Pre-test	Topic 2 Pre-test
eWorkbooks	Topic 2 eWorkbook Student learning matrix
Practical investigation eLogbook	Topic 2 Practical investigation eLogbook
Digital document	Key terms glossary

LESSON 2.2 Classification systems

LEARNING INTENTION

In this lesson you will be able to:
- identify similarities and differences within and between groups of organisms
- recognise that biological classification has changed over time, including systems used by Aboriginal and Torres Strait Islander Peoples.

2.2.1 The importance of classification

Is it alive? What is it? Is it friendly or dangerous? Can I eat it?

Our brain is very good at recognising patterns and grouping similar patterns together. By organising information into patterns, it is easier to remember. Sometimes your survival can depend on recognising important patterns in the world around you.

We classify things into groups to make them easier to identify, remember and describe. Classification of living things (or organisms) enables scientists to categorise the natural world. In this way, scientists can communicate with each other and know whether they are talking about the same or different kinds of organisms.

Classification is also useful when dealing with diseases, disease-carrying organisms and disease control. For example, there are thousands of different types of mosquitoes, but only a small number of these transmit the **parasite** that causes malaria. Instead of spraying all mosquito populations, scientists can identify those that may result in malaria and then take steps to control them.

DISCUSSION

Discuss why the ability to classify organisms might be important in the following situations:

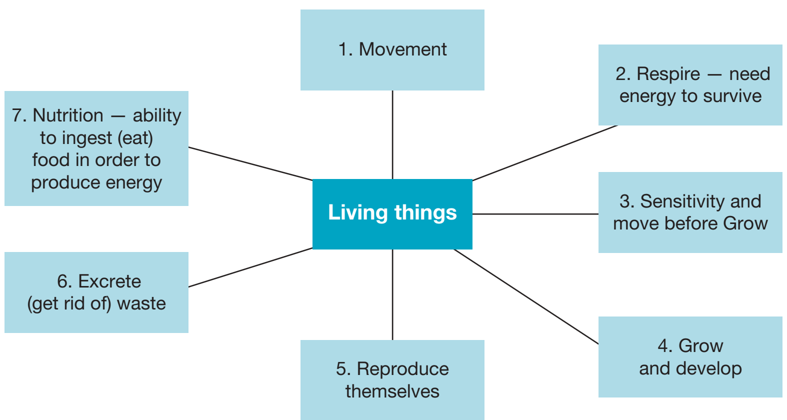
- You have been bitten by an ant.
- You are hungry and find wild berries in the bush.

Can you think of everyday situations in which understanding the classifications of organisms might be important?

2.2.2 Living, dead or non-living

Prior to classifying organisms, we need a shared understanding of their features.

FIGURE 2.3 Features common to all living things

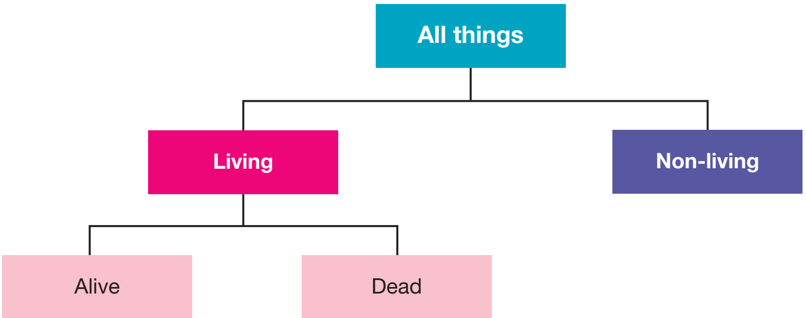


A helpful way of remembering the common and essential characteristics of living things is by using the acronym **MRS GREN**.

- ***M**ovement*: living things can move to **respond** to changes in their environment.
- ***R**espiration*: living things need and create energy to survive.
- ***S**ensitivity*: living things can sense changes in their environment and adapt to them.
- ***G**rowth*: living things grow by producing new cells and tissues.
- ***R**eproduction*: living things can create new offspring or new cells.
- ***E**xcretion*: living things remove waste from their bodies.
- ***N**utrition*: living things can eat food to produce energy.

One method we can use to sort all things is shown in figure 2.4, in which things can be distinguished as **non-living** or living. Once an organism is no longer living, it is considered **dead**. For something to be considered non-living, it never expresses all the characteristics of living things. For example, a fallen tree in the forest is dead, whereas a rock and a computer are non-living.

FIGURE 2.4 Living, non-living or dead?



2.2.3 Classification — grouping to order and organise

Taxonomy is the study of the classification of organisms. A taxonomist is a scientist who specialises in classification. Swedish botanist, zoologist and physician Carl Linnaeus (1707–1778) is considered by many to be the 'father of modern taxonomy' because his classification system formed the basis of our current system.

The Linnaeus classification system

Linnaeus (see figure 2.5) sorted organisms into groups based on their physical similarities. He called the largest grouping **kingdom** and the smallest grouping **species**. Organisms classified into the same kingdom are more similar to each other than organisms classified into different kingdoms. As you move down the hierarchy of groupings (see figure 2.6), the more alike the members are.

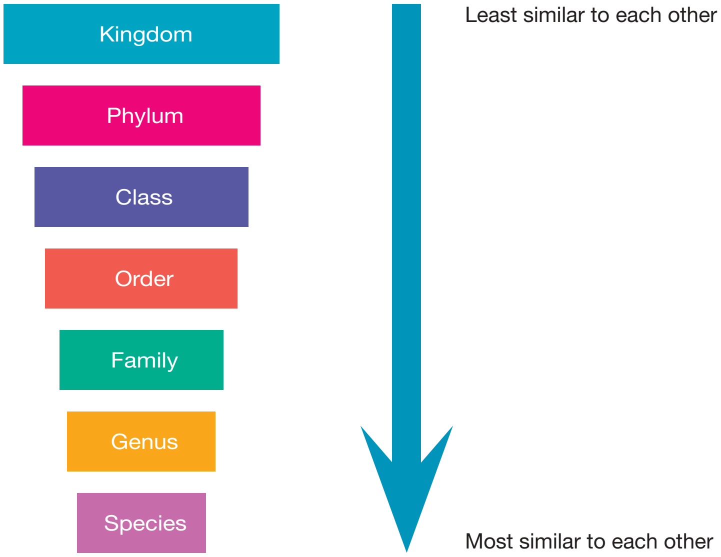
A way to recall the hierarchy of groups is by creating a mnemonic such as the following:

Kind Pirates Cook Octopus for Great Snacks

- ***K**ind*: Kingdom
- ***P**irates*: Phylum
- ***C**ook*: Class
- ***O**ctopus*: Order
- ***F**or*: Family
- ***G**reat*: Genus
- ***S**nacks*: Species

FIGURE 2.5 A portrait of Carl Linnaeus as a young man

FIGURE 2.6 The hierarchy of groupings



In the 1700s, Linnaeus proposed that living things could be grouped into three kingdoms: mineral, vegetable and animal. However, the development of the microscope led to the discovery that all living things were made up of cells, and it also revealed that some organisms did not fit into the three proposed kingdoms. Scientists have revised the classification system to include six kingdoms (discussed later in this topic).

2.2.4 Classification systems used by Aboriginal and Torres Strait Islander Peoples

Aboriginal and Torres Strait Islander Peoples developed a complex and diverse classification system that differs significantly from the Linnaean classification system. This system includes reference to an organism's age, use, stage in the life cycle, sex and place within the kinship system. This includes any special significance of the organism to Aboriginal and Torres Strait Islander Peoples. Organisms are classified as being edible or inedible, useful or not useful, living or dead. One way Aboriginal and Torres Strait Islander Peoples classify plants is in terms of whether they can be used for medicine or not. For example, fresh plant sap can be used for medicine. Plants, such as trees that can be used to make spears, string, shields, canoes and resin, are classified as being dead and also by their use in the community. Turtles, barramundi and dugongs are grouped together because they are all aquatic organisms with fins or flippers.

FIGURE 2.7 Fresh sap oozing from a tree is a remedy traditionally used by Aboriginal and Torres Strait Islander Peoples for healing wounds, relieving pain and treating infections.

Aboriginal and Torres Strait Islander Peoples' classification of organisms focusses on their importance to the community and has been developed from their knowledge of the different stages of an organism's lifecycle, interactions, cultural significance and use as food, medicine, tool or clothing.

SCIENCE AS A HUMAN ENDEAVOUR: Bogong moth

An excavation in 2021 of Cloggs Cave in eastern Victoria by Monash University researchers and Gunaikurnai Land and Waters Corporation, revealed microscopic Bogong moth (*Agrotis infusa*) remains on a 2000-year-old grinding stone. This was the first conclusive archaeological evidence of insect food remains on a stone artefact globally.

FIGURE 2.8 Bogong moth *(Agrotis infusa)*

Bogong moths, which are rich in fat, migrate annually from Queensland to Victoria's alpine regions. The Gunaikurnai people traveled seasonally to feast on these moths, cooking them in fires or grinding them into paste or cakes, which could be preserved for weeks. This discovery underscores the cultural importance of these food practices.

Cloggs Cave's limestone environment preserved the moth remains, which were identified using biochemical staining, a rare technique that fluoresces proteins and collagen under a microscope. The grindstone's residues provided invaluable insight into diets over 80 generations.

Professor Bruno David emphasised the collaborative nature of the project, contrasting it with earlier excavations in 1972 that excluded Traditional Owners. 'Aboriginal people know their cultures better than anyone else — that's why listening and good partnership is so important, because it's not up to us to tell people what to do with their histories,' Professor David said.

The discovery also highlights the Bogong moth's ecological plight. Populations have dropped from billions to near extinction due to pesticides, drought and urban light pollution. People are encouraged to report sightings via the Zoos Victoria Moth Tracker initiative to aid conservation efforts.

1. As a class, discuss some advantages of the Monash University researchers and Gunaikurnai Land and Waters Corporation working together.
2. Research the Zoos Victoria Moth Tracker initiative.

Multidisciplinary endeavours to advance scientific knowledge make use of people's different perspectives and worldviews (VC2S8H02)

2.2.5 Made up of cells

Cells are the building blocks that make up all living things. Organisms may be made up of one cell (**unicellular**) or many cells (**multicellular**).

There are two main categories of cells: **prokaryotic** and **eukaryotic**. Prokaryotic cells are single cell organisms that lack a nucleus and membrane-bound organelles. A **nucleus** contains genetic information and controls the growth and reproduction of a cell. Eukaryotic cells contain a defined nucleus and specialised structures called organelles. The word organelles derives from a Latin term meaning 'little organs'. Organelles have a specific role in keeping a cell alive.

Scientists have discovered particles called **viruses**, **viroids** and **prions**. These show some features of living things but are considered to be non-living entities. Therefore, they are not included in classification systems.

2.2.6 Kingdom systems

In the 1960s, helped by improvements in **microscopy**, a five-kingdom system of classification was proposed by ecologist Robert Whittaker that grouped organisms based on the structure of their cells.

Classification systems are continuously evolving, based on genetic information rather than physical characteristics to group organisms. Carl Woese, an American microbiologist, built on Whittaker's five-kingdom system and suggested six categories to classify living things.

Both the five- and six-kingdom systems divide eukaryotes (living things made up of one or more cells with a nucleus) into four kingdoms: animalia, plantae, **fungi** and Protista. In the six-kingdom system, prokaryotes are divided into two categories: archaea (ancient bacteria) and bacteria (true bacteria), as shown in figure 2.9 and table 2.1.

FIGURE 2.9 The kingdom system suggested by Carl Woese

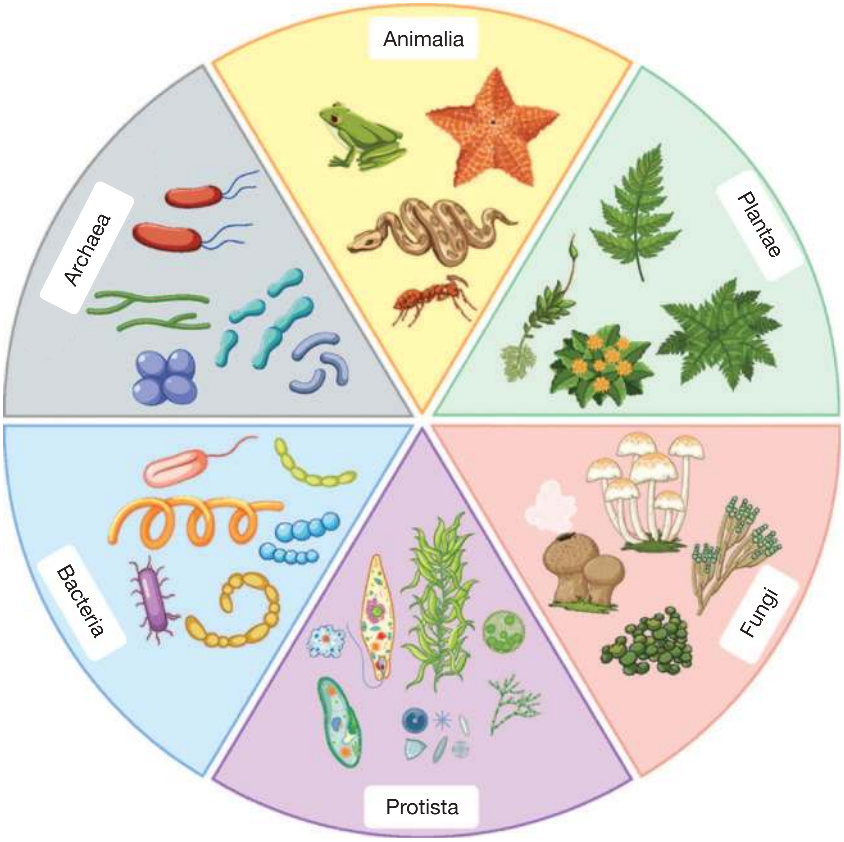


TABLE 2.1 Features used to divide organisms into five kingdoms proposed by Whittaker

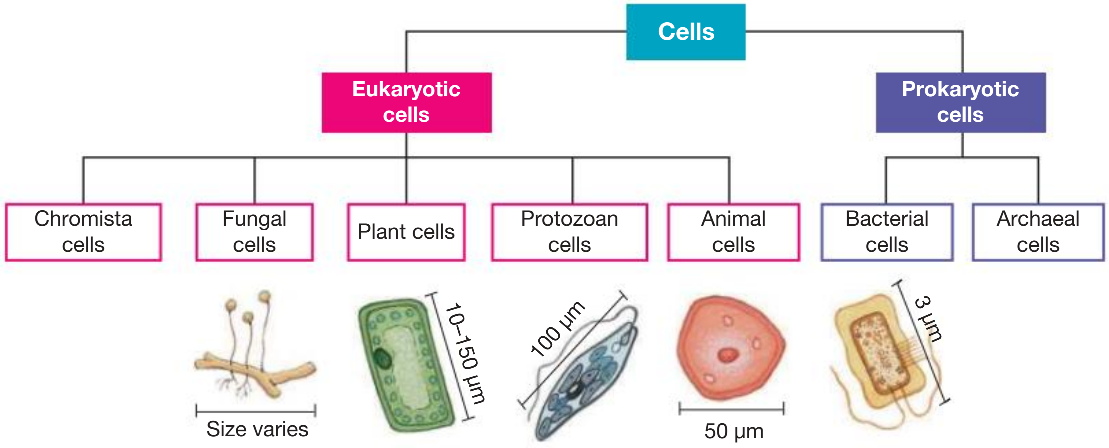
Kingdom	Animalia	Plantae	Fungi	Protista	Bacteria	Archaea
Unicellular or multicellular	Multicellular	Multicellular	Most multicellular; some unicellular	Unicellular	Unicellular	Unicellular
Cell wall	No cell wall	Cell wall present (cellulose)	Predominantly chitin (a long, fibrous sugar molecule)	Many have no cell wall; some have a cell wall	Cell wall present; composition varies	Present
Nucleus	Present	Present	Present	Present	Absent	Absent
Mode of nutrition	Eat or absorb other organisms	Photo-synthesise to produce carbohydrates (e.g. sugars)	Produce chemicals that break down the material on which they grow and absorb the nutrients released	Some photo-synthesise; some ingest food	Some absorb nutrients from surroundings; some photo-synthesise; some use other chemical processes	Most absorb nutrients from surroundings

Kingdom	Animalia	Plantae	Fungi	Protista	Bacteria	Archaea
Chloroplasts	Absent	Present	Absent	Present in those that photo-synthesise	Absent	Absent
Examples	Animals (e.g. pigeon, ant, camel, human)	Plants (e.g. Eucalyptus tree, grass, wheat, rose bush)	Yeast, mushrooms, mould	Algae, amoeba	Bacteria (e.g. *Escherichia coli, Staphylococcus aureus)*	Ancient micro-organisms with a similar structure to bacteria

2.2.7 Classification systems are still changing

In 2015, a classification system consisting of seven kingdoms was proposed. Five of these fall within the eukaryote 'empire' (protozoa, chromista, plants, fungi and animals) and two within the prokaryote 'empire' (bacteria and archaea). This system is shown in figure 2.10.

FIGURE 2.10 Some recent classification systems have seven kingdoms of organisms. *Note*: While there are some differences, the terms protist, protoctista and protozoa can be used to describe simple eukaryotes that don't fit into the other categories.



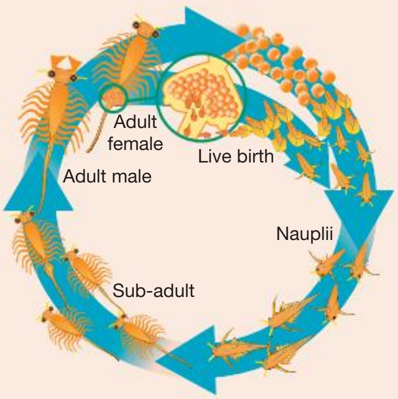
CASE STUDY: Instant life?

Just add water and, 'hey presto', you've brought sea monkeys to instant life! Are they really alive? Are they really monkeys? Can you create them just by mixing up sachets of powdered ingredients and adding water?

Sea monkeys are not really monkeys, but they are alive! They are made up of cells that require nutrients and produce wastes. They belong to the animal kingdom and are classified as members of the Arthropoda phylum and Crustacea class. They are actually a type of brine shrimp belonging to the species *Artemia salina.* They can tolerate very salty water so they are naturally found in salt lakes. Their gills help them to cope with high levels of salt by absorbing and excreting ions and producing very concentrated urine from their maxillary glands.

The 'magic' behind the sea monkeys appearing to become instantly alive is the process of cryptobiosis. This is a type of 'suspended animation' of the egg. During this, the sea monkeys stay in a suspended state until conditions are favourable again for them to survive. One of the powders in the sachets sold in the sea monkey package contains *Artemia*

FIGURE 2.11 The life cycle of the sea monkey (*Artemia salina*)



salina eggs in their cryptobiotic stage. When these eggs come into contact with water, this phase ends and they begin their next stageof development and grow into 'sea monkeys', which swim around in their watery environment.

In 1972, a US patent was granted for 'hatching brine shrimp or similar crustaceans in tap water to give the appearance of instantaneous hatching'.

1. What does it mean to 'patent' something?
2. What do you think about the idea of patenting these living organisms?
3. Should there be restrictions or bans on any or all patents related to living organisms?

FIGURE 2.12 Sea monkeys require nutrients and produce waste.

2.2 Activities

learnon

2.2 Quick quiz on | 2.2 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 3, 5	2, 4, 6, 8	7, 9, 10

Remember and understand

1. a. **Identify** whether the following statements are true or false.
    i. Living things are also referred to as organisms.
    ii. All living things need energy to survive.
    iii. If a living thing stops living, it is referred to as non-living.
    iv. Organisms made up of many cells are called unicellular.
    v. Organelles are small structures inside cells that have particular jobs.
    vi. Cells can be classified on the basis of the presence or absence of particular organelles or structures.
    vii. Viruses are made up of cells.
    viii. Taxonomy is the formal classification of living things.
    ix. Members of the same species have less in common than members of the same kingdom.
    x. Bacterial cells are larger than animal cells.
    xi. Plant cells possess a cellulose cell wall.
    xii. Bacterial cells possess a true nucleus.
    xiii. *Staphylococcus aureus* is an example of a bacterium.
    xiv. Earthworms are made up of prokaryotic cells.

    b. Rewrite any false statements to make them accurate and true.
2. Match each term with its definition.

Term	Definition
a. Cells	1. Describes something that has never been alive (e.g. a clock)
b. Kingdom	2. The smallest grouping of living things used by Linnaeus
c. Non-living	3. The building blocks that make up all living things
d. Plant	4. Describes an organism made up of only one cell
e. Species	5. The largest grouping of living things used by Linnaeus
f. Taxonomy	6. The use of a formal system for classifying living things
g. Unicellular	7. A multicellular organism containing chloroplasts and a cellulose cell wall

3. **List** two examples for each of the following.
   a. A non-living object (abiotic)
   b. A living organism (biotic)
   c. A dead organism

Apply and analyse

4. SI **Explain** why scientific definitions of classification systems may change over time.
5. a. In the table, **list** two examples of organisms in each of the kingdoms shown.

Examples of organisms in different kingdoms

Kingdom	Example
a. Animals	
b. Plantae	
c. Fungi	
d. Protista	
e. Prokaryotae	

   b. **Name** the scientist who proposed this classification system of five kingdoms.
   c. **Compare** how it differs from the classification systems used today.
6. **Compare** the characteristics of the following, **explaining** how they differ.
   a. A living thing and a non-living thing
   b. Protoctistan cells and bacterial cells
   c. Kingdom and species
   d. Plant cells and animal cells
7. **Outline** the relationship between:
   a. living things, non-living things and dead things
   b. fungal cells, plant cells and animal cells
   c. Linnaeus, Whittaker and Woese.
8. Use a flowchart to order the following in terms of their complexity, from simplest to most complex.
   kingdom, species, family, phylum, class, genus, order

Evaluate and create

9. SI **Evaluate** why it is important for scientists to classify living things into groups and provide reasons to support your response.
10. a. Use the table to **identify** the correct features for each kingdom.

Features of different kingdoms

Kingdom	Unicellular or multicellular	Absent or present cell wall
i. Animalia		
ii. Plantae		
iii. Fungi		
iv. Protista		
v. Prokaryotae		

   b. **Summarise** at least three other features within each kingdom.

Answers and sample responses are available in your digital formats.

LESSON 2.3 Patterns in scientific language

LEARNING INTENTION

In this lesson you will be able to explain how language patterns can provide hints about the meaning of scientific terminology.

2.3.1 Unlocking the meaning of words

Etymology is the term used to describe the study of words, their origin and grammar. Words are often made up of a prefix at the beginning of the word and a suffix at the end. Being aware of this pattern will help you to unlock the meaning of many new scientific words that you come across.

2.3.2 Unlocking patterns

Many scientific terms, like others in our language, begin with a particular prefix (letters added to the start of a word) and end with a specific suffix (letters added to the end of a word). These can give you hints about what the words mean. Let's look at some examples.

Dinosaur names

Tyrannosaurus, Megalosaurus, Stegosaurus … Did you ever wonder why dinosaurs have such long names? Do you know what they mean? The term 'dinosaur' was decided on by British anatomist and palaeontologist Sir Richard Owen in 1842. Derived from Greek words, *dino* means 'terrifying' and *saur* means 'lizard'. Some dinosaurs were named for their unusual head or body features, others for their teeth or feet, and others after a person or place.

FIGURE 2.13 Based on their structural features, suggest criteria to separate these dinosaurs into groups.

Plants and pigments

The terms 'chlorophyll' and 'chloroplast' both begin with *chloro*, which comes from the Greek word *chloros*, meaning 'green'. Chlorophyll is the green pigment found in the chloroplasts of plant cells. This green pigment captures light energy so that plants can make their own food using the process of photosynthesis (prefix *photo* — 'light' and suffix *synthes*is — 'to make' or 'to put together'). The presence of chlorophyll in the chloroplasts is the reason that they (and plants) appear to be green.

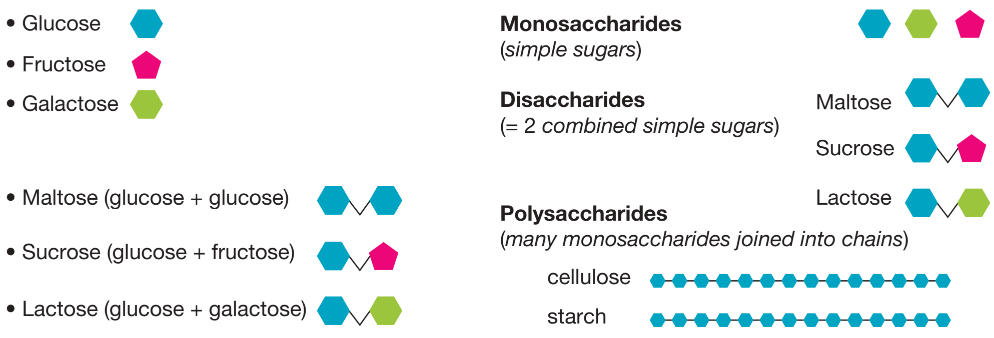
FIGURE 2.14 Chlorophyll, the green pigment located in plant chloroplasts, captures light energy so plants can make their own food.

Leucoplasts (*leuco* — 'white') and chromoplasts (*chromo* — 'colour'), like chloroplasts, are plastids found in plant cells. Leucoplasts are not coloured because they do not contain coloured pigments. Chromoplasts are coloured and contain pigments other than chlorophyll. They are responsible for pigment synthesis and storage, and are found in the coloured parts of plants, such as fruit and petals, giving them their characteristic colours. These pigments can be extracted and used as plant dyes.

Naming chemicals and substances

Chemicals, such as those in foods that you eat, also have clues in their names that help you to work out what they are made of. You may have heard of glucose, sucrose and starch. Gluc*ose* and sucr*ose* are both sugars. Glucose is a *mono*saccharide (*mono* — 'one' and *saccharide* — 'sweet'). Sucrose is a *di*saccharide and is made up of two monosaccharides (*di* — 'two'). Starch is a *poly*saccharide and is made up of many monosaccharides (*poly* — 'many'). (Note: If a word ends in '-ose', it usually means it is a sugar, such as fructose, lactose and maltose.)

FIGURE 2.15 Monosaccharides contain only one saccharide; disaccharides are made up of two monosaccharides; and polysaccharides are made up of many monosaccharides.



Cell speak

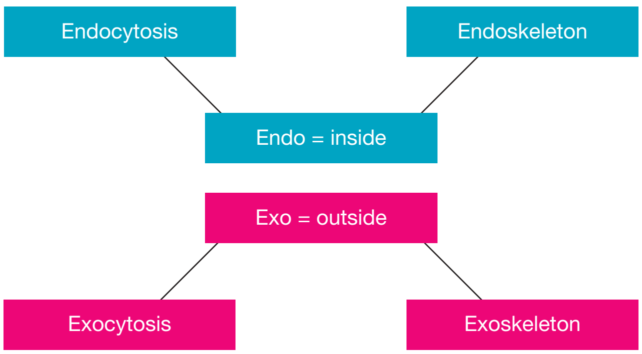
When you study different types of blood cells, you will come across terms containing the suffix or prefix *cyte*. This is a variation of *cyto*, which means 'cell'. Examples of terms that you may come across include:

- cytokinesis
- cytology
- cytoplasm
- cytoskeleton
- cytosol
- cytotoxic
- endocytosis
- erythrocyte
- exocytosis
- leucocyte
- lymphocyte
- monocyte
- phagocyte
- phagocytosis.

Inside or within

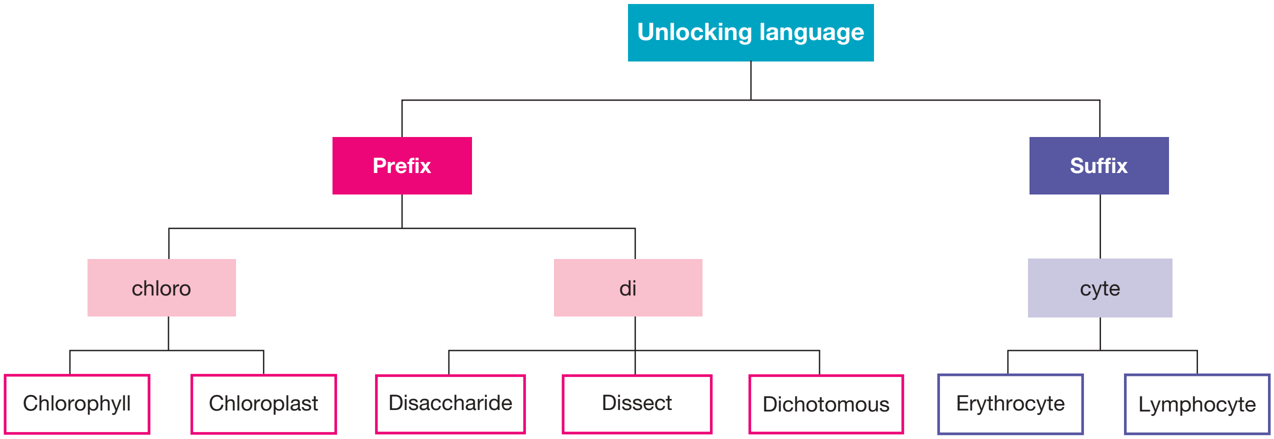
In science, you will learn about **endoskeletons**, endocytosis, endoplasmic reticulum, the endocrine system and endoparasites. The prefix *endo* in these words tells you that they all have something to do with 'inside' or 'within'. The prefix *exo* (as well as the prefix *ecto*) refers to 'outside' (**exoskeleton**, **ectotherm**, exocytosis). Even without knowing their full definitions, you can begin to see patterns and get an idea about what they may refer to.

FIGURE 2.16 Terminology using the prefixes 'exo' and 'endo'



Armed with your new awareness of how to use the patterns of specific prefixes and suffixes, you should now be able to predict or unlock the meaning of many previously unfamiliar scientific terms.

FIGURE 2.17 The prefixes and suffixes of scientific terms often give you hints about what they mean.



SCIENCE AS A HUMAN ENDEAVOUR: Tiny footprints — big discovery!

Dr Anthony Romilio is a palaeontologist at the University of Queensland's Dinosaur Lab, specialising in the study of fossilised dinosaur footprints and trackways. He has pioneered the use of 3D techniques and python-based analytical tools to enhance data collection and analysis in palaeontology.

One of Dr Romilio's notable contributions includes solving a decades-old mystery surrounding dinosaur footprints on a cave ceiling in Mount Morgan, Queensland. Initially, these ceiling tracks were thought to indicate that a carnivorous theropod walked on all four legs — a behaviour considered highly unusual. Through meticulous research, including the examination of high-resolution photographs and detailed notebooks from geologist Ross Staines, Dr Romilio determined that the tracks were actually made by a different type of dinosaur, providing new insights into dinosaur behaviour and track formation.

In another significant discovery, Dr Romilio was part of an international team that identified fossilised dinosaur footprints in the courtyard of a restaurant in Sichuan Province, China. These tracks, measuring 50–60 cm in length, were attributed to long-necked sauropod dinosaurs from the Cretaceous period, approximately 100 million years ago. This finding underscores the unexpected locations where dinosaur evidence can be found and highlights the importance of careful observation in paleontological discoveries.

Dr Romilio's work exemplifies the integration of modern technology with traditional paleontological methods, leading to a deeper understanding of dinosaur behaviour and their environments.

1. How do tools like 3D-imaging help scientists study dinosaur footprints and learn more about dinosaurs?
2. What can dinosaur footprints in unusual places, like on a cave ceiling or a restaurant courtyard, teach us about how dinosaurs lived and moved?

Scientific knowledge, including models and theories, can change because of new evidence (VC2S8H01)

ACTIVITY: Dinosaur structures

Scientific names can provide clues about structural differences.

1. Carefully observe the information in the boxes and then construct Venn diagrams to compare the different types of dinosaurs.
   a. *Microceratops* and *Triceratops*
   b. *Triceratops* and *Pentaceratops*
   c. *Microdontosaurus* and *Heterodontosaurus*
   d. *Microdontosaurus* and *Microceratops*

Triceratops
- Name means 'three-horned face'
- 'Frilled' dinosaur
- Had three horns on its head
- 8 m long
- Lived about 75–65 million years ago

Heterodontosaurus
- Name means 'different-toothed lizard'
- Had three types of teeth
- 2.2 m long
- Lived about 208–200 million years ago

Pentaceratops
- Name means 'five-horned face'
- Had three horns on its head
- 8 m long
- Lived about 75–65 million years ago

Microceratops
- Name means 'small-horned face'
- Only 76 cm long
- Lived about 83–65 million years ago

Microdontosaurus
- Name means 'tiny-toothed lizard'
- 8 m long
- Lived about 75–65 million years ago

2. Suggest the meanings of the prefixes *micro*, *tri*, *penta* and *hetero.*
3. What do you think the prefix *donto* might refer to? Justify your response.
4. Based on the information provided, draw a sketch of each dinosaur. Research what it actually was thought to look like and comment on any differences and similarities. An image of a Triceratops has been provided to get you started.

FIGURE 2.18 *Triceratops*

5. Create a specific question that could be researched for each type of dinosaur.
6. Write a paragraph to discuss what you have learned about the prefixes used in scientific terms.

INVESTIGATION 2.1

Cryptonym game

Aim

To investigate how understanding the etymology of scientific prefixes and suffixes can help students predict the meanings of unfamiliar scientific terms

Materials

- blank cards
- pen or marker

Method

1. In teams, begin by writing each of the scientific terms from the table on a card.

Latin/Greek prefix or suffix	Meaning	Scientific term
bio + ology	life + study	Biology
etymon + ology	true + study	Etymology
heteros + trophe	different, other + to feed or eat	Heterotroph
echinus + dermis	spiny + skin	Echinodermata (e.g. sea urchin)
anthros + zoion	flower + animal	Anthrozoa (e.g. sea anemone)
epi + dermis	outside + skin	Epidermis
arthron + pous	joint + foot	Arthropod (e.g. insect)
gastro + pous	stomach + foot	Gastropod (e.g. snail)
poly + dactylus	many + finger or toe	*Polydactylus*
kroko + deilos	pebble + worm	*Crocodylus*
photo + synthesis	light + make, build	Photosynthesis
exo + skeleton	outer, external + skeleton	Exoskeleton

2. One player should shuffle the cards and then observe which term is on the top card without letting others in the team see.
3. Place the card face down and act out its meaning.
4. The first team member to identify the term gets to shuffle the cards and act out the next term.

Results

Record the terms you guessed correctly, the terms you provided clues for and the terms you missed.

Discussion

1. *Cryptography* refers to secret writing and a *cryptonym* is a secret name. Suggest the meaning of *crypto*.
2. Identify the types of questions that were most helpful in predicting the correct name on the card.
3. Identify and list some of your biggest challenges in this task.
4. Explain how you could transfer what you have learned in this activity to predict the meanings of scientific terms.

Conclusion

Write a conclusion to summarise your findings about prefixes and suffixes from the cryptonym game.

2.3 Activities

learnon

2.3 Quick quiz on	2.3 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3, 9, 12	4, 6, 7, 10, 14	5, 8, 11, 13

Remember and understand

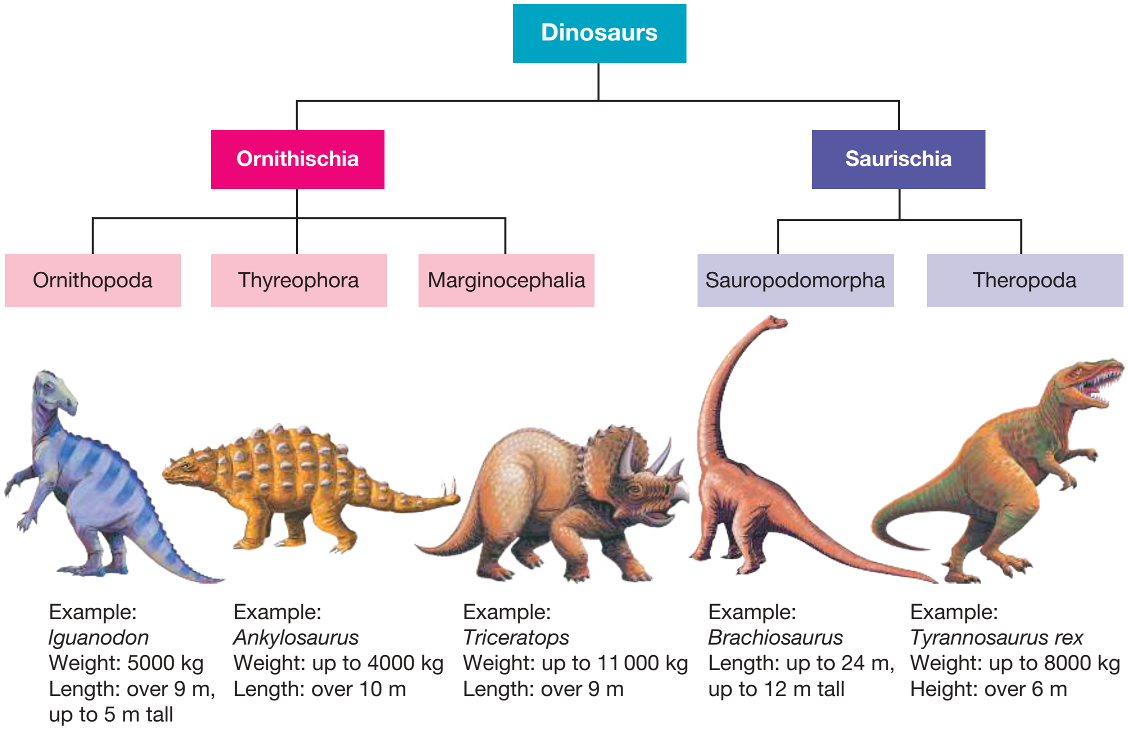
1. a. **Identify** whether the following statements are true or false.
      i. Words are often made up of a suffix at the beginning and prefix at the end.
      ii. Leucoplasts, chromoplasts and chloroplasts are types of plastids found in plant cells.
      iii. Monosaccharides are made up of polysaccharides.
      iv. Chlorophyll and chloroplasts are both blue.
      v. Phagocytes, erythrocytes and leucocytes are all types of cells.
      vi. The term ‘micro’ suggests that something is small, whereas the term ‘macro’ suggests that it is large.
      vii. You would expect an endoskeleton to be on the outside of an animal and an exoskeleton to be on the inside of an animal.
      viii. Photosynthesis is a process in which light energy is used by plants to make their own food.
   b. Rewrite any false statements to make them accurate and true.
2. **State** the difference between the terms ‘prefix’ and ‘suffix’.
3. MC **Identify** which of the following is a suffix commonly found in the names of sugars.
   A. Saccharide
   B. Cyte
   C. Plast
   D. Synthesis
4. **Analyse** the common feature shared by the following groups.
   a. Chlorophyll and chloroplast
   b. Monocytes, leucocytes and erythrocytes
5. **Describe**:
   a. two similarities shared by leucoplasts, chromoplasts and chloroplasts
   b. one way in which leucoplasts, chromoplasts and chloroplasts differ.
6. **Distinguish** between monosaccharides, disaccharides and polysaccharides.

Apply and analyse

7. SI Chlorine is an element. Based on its name, **predict** the colour of chlorine.
8. Find at least five examples of scientific terms that begin with each of the following prefixes: *endo*, *bio*, *anti*, *chloro*, *thermo*, *bi*, *hetero*.
9. Determine the role of palaeontologists.
10. a. **Predict** the prefixes for the numbers one, two, three, four, ten and one hundred.
    Hint: The prefixes are derived from Latin or Greek origins and are commonly used in science.
    b. Check if your predictions from part a were accurate by researching the correct prefixes. **List** the correct prefixes if your initial predictions were wrong.
    c. **State** an example of a scientific term that uses each prefix.
11. a. **Predict** the meaning of each of the following terms.
       i. microscope, telescope, periscope
       ii. millimetre, centimetre, nanometre, kilometre
       iii. binary fission, dichotomous key, binocular
       iv. *Tyrannosaurus, Pterosaurs Stegosaurus*
       v. anatomist, scientist, palaeontologist
       vi. cardiac, renal, pulmonary
       vii. dehydrated, deoxygenated, denatured
    b. **Identify** whether your predictions were correct.
    c. SI **Examine** the arrangement of each word and **discuss** the similarities and differences between the terms in the groups listed in part a.

Evaluate and create

12. Look at the term ‘photosynthesis’. By breaking down the word into *photo* (meaning ‘light’) and *synthesis* (meaning ‘to put together’), **explain** how understanding these parts can help you **deduce** what the process of photosynthesis involves.
13. Consider the scientific term ‘thermophile’. Using your knowledge of word parts (*thermo* meaning ‘heat’ and *phile* meaning ‘loved’), create a detailed description of a thermophile’s characteristics, including its habitat, behaviour and any specific adaptations that enable it to thrive in its environment.
14. Use the information in the diagram provided to construct Venn diagrams of the following.
    a. Dinosaurs with horns and spikes and dinosaurs without horns and spikes
    b. Dinosaurs that weighed less than 8000 kg and dinosaurs that weighed more than 8000 kg



Answers and sample responses are available in your digital formats.

LESSON 2.4 Understanding scientific names

LEARNING INTENTION

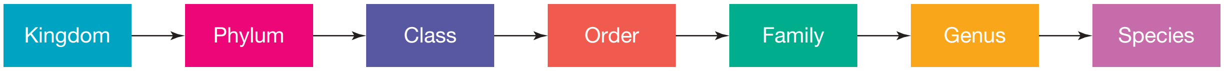
In this lesson you will be able to name and classify species using scientific conventions from the Linnaean hierarchical classification system, such as kingdom, phylum, class, order, family, genus and species.

2.4.1 Levels of classification

Now that you are more aware of the patterns in scientific language, you can apply what you know to the classification of living things.

You may recall that living things can be grouped into six kingdoms and that these kingdoms contain a number of subgroups. As you move from kingdoms to species, the members of the group have more characteristics in common. Organisms of the same species can interbreed to produce fertile offspring.

FIGURE 2.19 In the classification hierarchy, organisms that are grouped as being the same species would have more in common than those grouped in the same kingdom.



Remember, you can memorise the order of the hierarchy using the mnemonic: Kind Pirates Cook Octopus For Great Snacks.

2.4.2 Binomial nomenclature

As well as developing a system of kingdoms (see section 2.2.3), Linnaeus developed a naming system called **binomial nomenclature** in which each species has a name made up of two words. The scientific names given to organisms are from Latin origins.

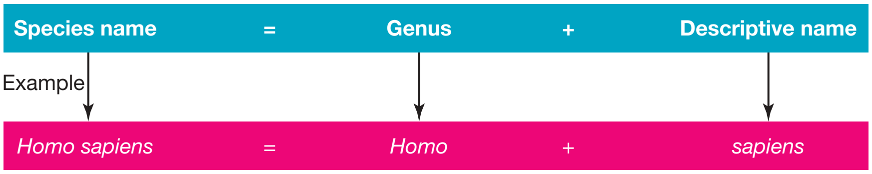
In this system, the species name is made up of the:
- genus name (first word)
- descriptive or specific name (second word).

The genus name begins with a capital letter and lower case is used for the descriptive name.
- If handwritten, the species name should be underlined.
- If typed, the genus and species names should be in *italics*.

KEY IDEA

- The word 'binomial' comes from the Latin terms *bi*, meaning 'two', and *nomen*, meaning 'name'. The word 'nomenclature' is used to describe naming systems.
- The word 'taxonomy' comes from two Greek words: *taxis,* meaning 'order' or 'arrangement', and *nomos,* meaning 'law' or 'science'.

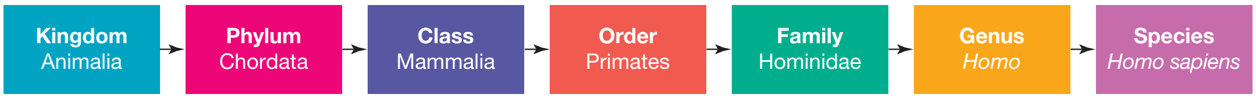
FIGURE 2.20 The species name is made up of the genus name (first word, with a capital letter) and the descriptive name (second word, with a lower case first letter).



2.4.3 Classifying and comparing

Where do you, as *Homo sapiens*, fit into the various classification levels?

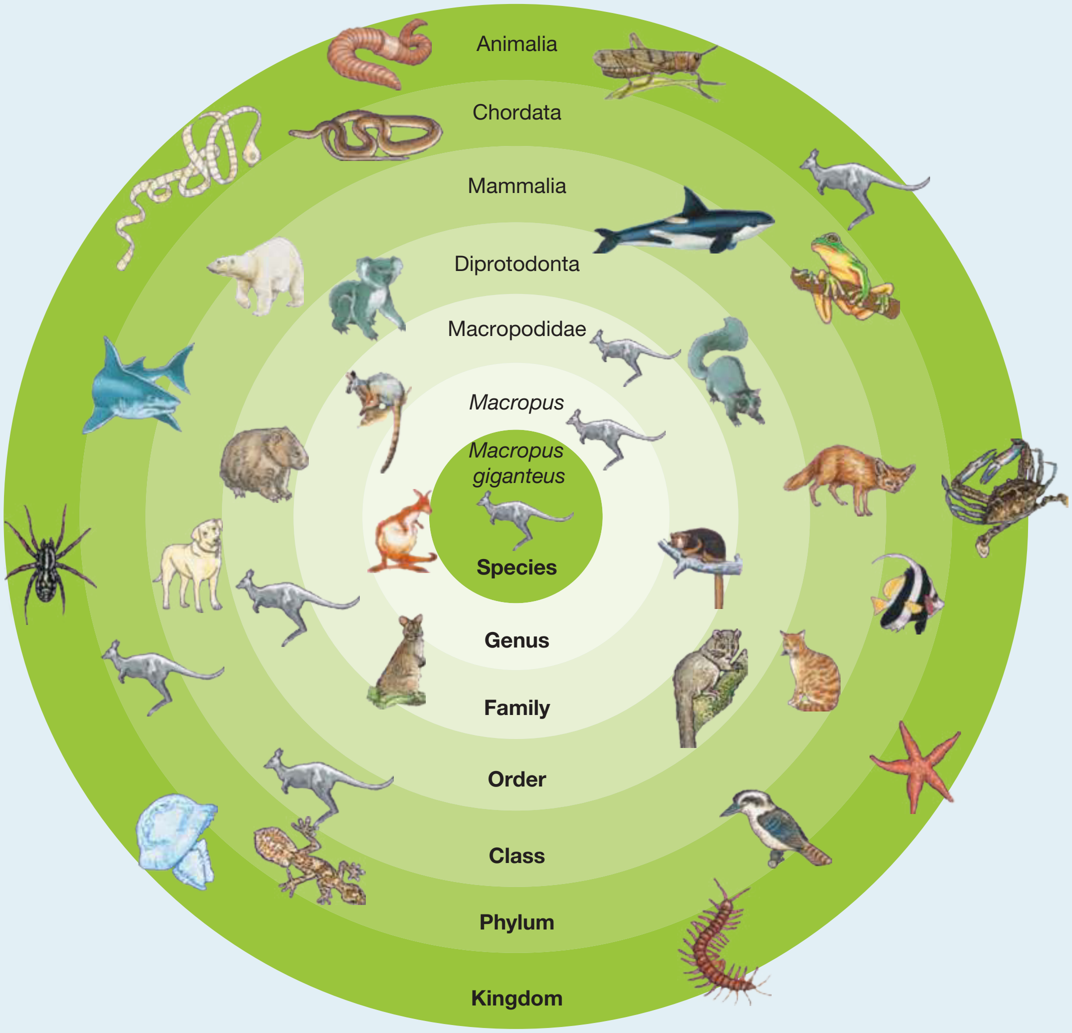
FIGURE 2.21 This flowchart shows the various groups that humans belong to.



DISCUSSION

The scientific name for the Eastern grey kangaroo is *Macropus giganteus. Macropus* is the genus name and *giganteus* is the descriptive name.

FIGURE 2.22 This target map shows the classification groupings of *Macropus giganteus* (the Eastern grey kangaroo).



Can you see any hints in these names that might describe these kangaroos? Which levels of classification do these kangaroos share with you?

2.4.4 Unlocking names

Many of the words used in our classification system tell a story about history and language.

TABLE 2.2 Some Australian animals and their species names

Common name: Major Mitchell's cockatoo
Species name: *Cacatua leadbeateri*

What's the story?

- *Cacatua* — derived from the Greek terms meaning 'dawn' and 'crest', referring to a crest like the rising dawn
- *leadbeateri* — named after British naturalist Benjamin Leadbeater
- cockatoo — originating from the Malay name for the bird, *kakaktua*, from *kakak* meaning 'sister', and *tua*, meaning 'old'

Common name: Freshwater crocodile
Species name: *Crocodylus johnstoni*

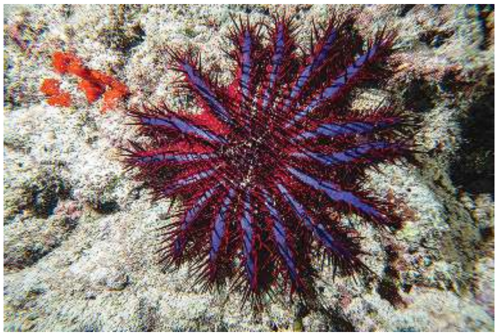
What's the story?

- *Crocodylus* — derived from the Greek terms *kroko*, meaning 'pebble', and *deilos*, meaning 'worm'
- *johnstoni* — named after Johnstone, the first European to discover and report it

Common name: Crown-of-thorns starfish
Species name: *Acanthaster planci*

What's the story?

- *Acanthaster* — derived from the Greek terms *acantha*, meaning 'spiny' or 'thorny', and *aster*, meaning 'star'
- *planci* — possibly named after Max Planck, a German physicist



Common name: Box jellyfish
Species name: *Chironex fleckeri*

What's the story?

- *Chironex* — derived from the Greek and Latin terms *cheiro*, meaning 'hand', and *nex*, meaning 'murder' or 'violent death'
- *fleckeri* — named after Dr Hugo Fleck, a radiologist in Cairns, Qld, for his contribution to science

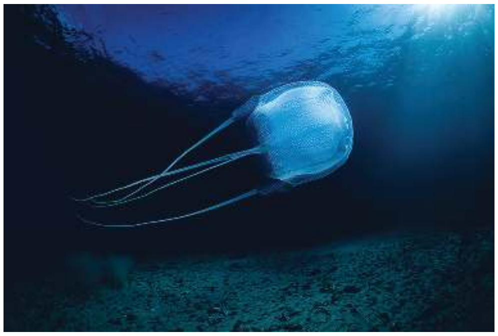


TABLE 2.3 Some drought-tolerant Australian plants and their species names

Common name: Native wisteria, 'Happy Wanderer'
Species name: *Hardenbergia violacea*

What's the story?

- *Hardenbergia* — named after Countess von Hardenberg
- Wisteria — named after American anatomist Caspar Wistar, by the English botanist Thomas Nuttall

Common name: Snow gum
Species name: *Eucalyptus pauciflora*

What's the story?

- *Eucalyptus* — derived from the Greek terms *eu*, meaning 'good' or 'well', and *calyptos* or *kalyptos*, meaning 'veiled' or 'covered'
- *pauciflora* — derived from the Latin terms pauci, meaning 'few', and *florus*, meaning 'flowered'

Common name: Kangaroo paw
Species name: *Anigozanthos flavidus*

What's the story?

- *Anigonzanthos* — derived from the Greek terms *ani*, meaning 'unequal', and *anthos*, meaning 'flower'
- *flavidus* — a Greek term meaning 'yellow'
- Kangaroo paw — due to its similarity in appearance to a kangaroo paw

Common name: Golden wattle
Species name: *Acacia pycnantha*

What's the story?

- *Acacia* — derived from the Greek term *akakia*, meaning 'thorny Egyptian tree' (after the first thorny species discovered)
- *pycnantha* — derived from the Greek terms *pyknos*, meaning 'dense', and *anthos*, meaning 'flower'
- Proclaimed Australia's national floral emblem in 1988

ACTIVITY: Remembering classification

To help reinforce your understanding of key scientific concepts, create a mnemonic, song or ad jingle. Your piece needs to include the following information:

- the order of the groupings: kingdom, phylum, class, order, family, genus and species
- rules for writing scientific names
- which groups you belong to.

To help you write something catchy, think of a song or jingle that you know well and rewrite the lyrics.

2.4 Activities

learnon

2.4 Quick quiz on	2.4 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 4, 8, 10	3, 6, 9, 12	5, 7, 11, 13

Remember and understand

1. a. **Identify** whether the following statements are true or false.
   i. As you move from kingdoms to species, the members of the group have increasingly less in common with each other.
   ii. Organisms of the same species resemble each other and can interbreed to produce fertile offspring.
   iii. In binomial nomenclature, the name of each species is made up of four words.
   iv. A species' scientific name is made up of its genus name with a lower case letter and its descriptive name with a capital letter.
   v. Major Mitchell is the person recognised as having developed the naming system for all living things.
   b. Rewrite any false statements to make them accurate and true.
2. Use a flowchart to show the names of the groupings in the hierarchical classification system, from largest to smallest.
3. **Identify** the common names of each of the following:
   a. *Crocodylus johnstoni* b. *Cacatua leadbeateri* c. *Chironex fleckeri* d. *Acacia pycnantha.*
4. **Describe** the binomial system of nomenclature and give an example.
5. In each of the following pairs, **identify** which group includes members that share more similarities.
   a. Kingdom or species b. Genus or family c. Order or phylum d. Class or order

Apply and analyse

6. SI Detail how the box jellyfish, *Chironex fleckeri*, received its scientific name and report on the various types of jellyfish found in Australian waters. **Evaluate** the importance of knowing the names of these jellyfish and **identify** the features used to classify them.
7. **Outline** features that crayfish, yabbies and lobsters have in common. How does the classification system deal with them?
8. Use the information in the table to answer the following questions.

The species and common names for some organisms

Species name	Common name
Cherax destructor	Crayfish
Rhyothemis phyllis	Dragonfly
Crocodylus johnstoni	Freshwater crocodile
Felis domestica	House cat
Panthera leo	Lion
Crocodylus porosus	Saltwater crocodile
Antirrhinum australe	Snapdragon

   a. **Identify** the species name of a lion.
   b. **State** the common name of the organism that belongs to the species *Felis domestica*.
   c. **State** the name of the genus to which a crayfish belongs.
   d. **Suggest** why it might be useful to know whether a crocodile was of the species *Crocodylus porosus* or *Crocodylus johnstoni*.

9. Use the information in the table to answer the following questions.

Category	Group	Common features
Kingdom	Animalia	Made up of more than one cell; eats food
Phylum	Chordata	Backbone
Class	Mammalia	Hair or fur; feeds its young milk
Order	Primate	Opposable thumb; nails instead of claws; binocular vision
Family	Hominidae	Arms shorter than legs; nails flattened; upright stance
Genus	*Homo*	Walks upright on feet only; cares for young for a long time
Species	*Homo sapiens*	Large brain; can talk and think abstractly; complex social structures

Shared features for different groupings within the Animalia kingdom

a. **State** which group contains more living things — the Animalia kingdom or the Primate order? **Justify** your response.
b. Dogs belong to the Animalia kingdom, Chordata phylum and Mammalia class. Use the table to **list** some characteristics that dogs and humans have in common.
c. Chimpanzees and humans are closely related. **Evaluate** which group in the table includes chimpanzees.

Evaluate and create

10. **Construct** a Venn diagram to show the similarities and differences between the classifications of saltwater and freshwater crocodiles.
11. a. SI **Investigate** the features, classification and life cycle of the crown-of-thorns starfish. **Analyse** how it differs from other types of starfish found in Australian waters and **evaluate** its impact on the Great Barrier Reef.
    b. Imagine that you are investigating the impact of the starfish on the Great Barrier Reef. Formulate questions that you would need to consider in your research.
12. SI **Discuss** Carl Linnaeus and the binomial system of nomenclature. Document his contributions to the taxonomy of plants and animals.
13. **Construct** a target map to show the classification groups that you belong to in a scientific context and then do the same for another animal that does not belong to the same kingdom as you.

Answers and sample responses are available in your digital formats.

LESSON 2.5 Keys to unlock identity

LEARNING INTENTION

In this lesson you will be able to create, modify and use a dichotomous key to classify organisms into groups and subgroups.

2.5.1 Why classify?

Scientific curiosity has led to the discovery of an increasing number of different types of living things. This has resulted in the increased need to classify living things into groups. Classifying things makes them easier to remember, describe and identify. It also enables us to identify newly discovered organisms.

When scientists find an unknown organism, they make observations about its features and behaviour. Various technologies can also be used to obtain information about its chemistry and genetic make-up. This information is used to sort organisms into groups on the basis of similarities and differences. Classification of organisms into groups enables more effective communication and understanding.

SCIENCE AS A HUMAN ENDEAVOUR: Giants of the world

Discoveries in a lost world

In 2009, scientists discovered creatures trapped within a 'lost world' in an extinct volcano (Mount Bosavi) in Papua New Guinea. One of the creatures they discovered was a gigantic silvery-grey rat with thick woolly fur. It was about 82 centimetres long and weighed around 1.5 kilograms — the size of a domestic cat. Along with the discovery of this new species of rat (*Mallomys* spp.) were 16 species of frogs, one species of gecko, three species of fish and at least 20 species of insects and spiders. Since this significant discovery, there have been no widely reported follow-up expeditions or studies specifically focusing on Mount Bosavi's unique ecosystem. The area remains remote and challenging to access, which may contribute to the limited subsequent research. However, the initial findings underscore the rich biodiversity of Papua New Guinea's rainforests and highlight the importance of conservation efforts to protect these unique habitats.

Giant 'animal-eating' plants

In 2007, scientists on an expedition to catalogue the different species of pitcher plant found in an area in the Philippines discovered giant 'rat-eating' carnivorous pitcher plants. The pitchers of these plants were open and completely filled with fluid containing digestive enzymes that broke down the bodies of the large insects (and possibly rats by misadventure) that were trapped in them. The International Union for Conservation of Nature (IUCN) has classified *Nepenthes attenboroughii* as critically endangered. Its limited distribution, coupled with threats from habitat destruction and potential poaching, underscores the need for conservation efforts to protect this unique species.

1. What kinds of new species did scientists discover inside the extinct volcano at Mount Bosavi in Papua New Guinea? Why were these creatures called part of a 'lost world'?
2. How does the giant 'rat-eating' pitcher plant discovered in the Philippines catch its prey? What makes it different from other plants?

FIGURE 2.23 A gigantic silver-grey rat (*Mallomys* spp.) was found in Papua New Guinea in 2009, in an extinct volcano.

FIGURE 2.24 Giant 'rat-eating' pitcher plant *Nepenthes attenboroughii*, named in honour of Sir David Attenborough

Communication of scientific knowledge has a role in informing individual viewpoints, and community policies and regulations (VC2S8H04)

2.5.2 Keys for identification

Keys and field guides can be used to identify organisms. A variety of criteria are used to classify an unknown organism into smaller groups on the basis of whether it has a particular feature.

Dichotomous keys

Dichotomous keys provide choices at each branch (*dichotomous* — 'cutting in two'). A dichotomous key is constructed using observable traits or features such as size and colour. Behaviour and habitat are not specific and effective in classification because they can change throughout the life of the organism. Therefore, scientists classify organisms by examining the presence or absence of structural features and the differences in these features, because this is more reliable than using other characteristics.

FIGURE 2.25 In a dichotomous key, you always select from two choices. In this key, you decide whether an organism has a particular feature.

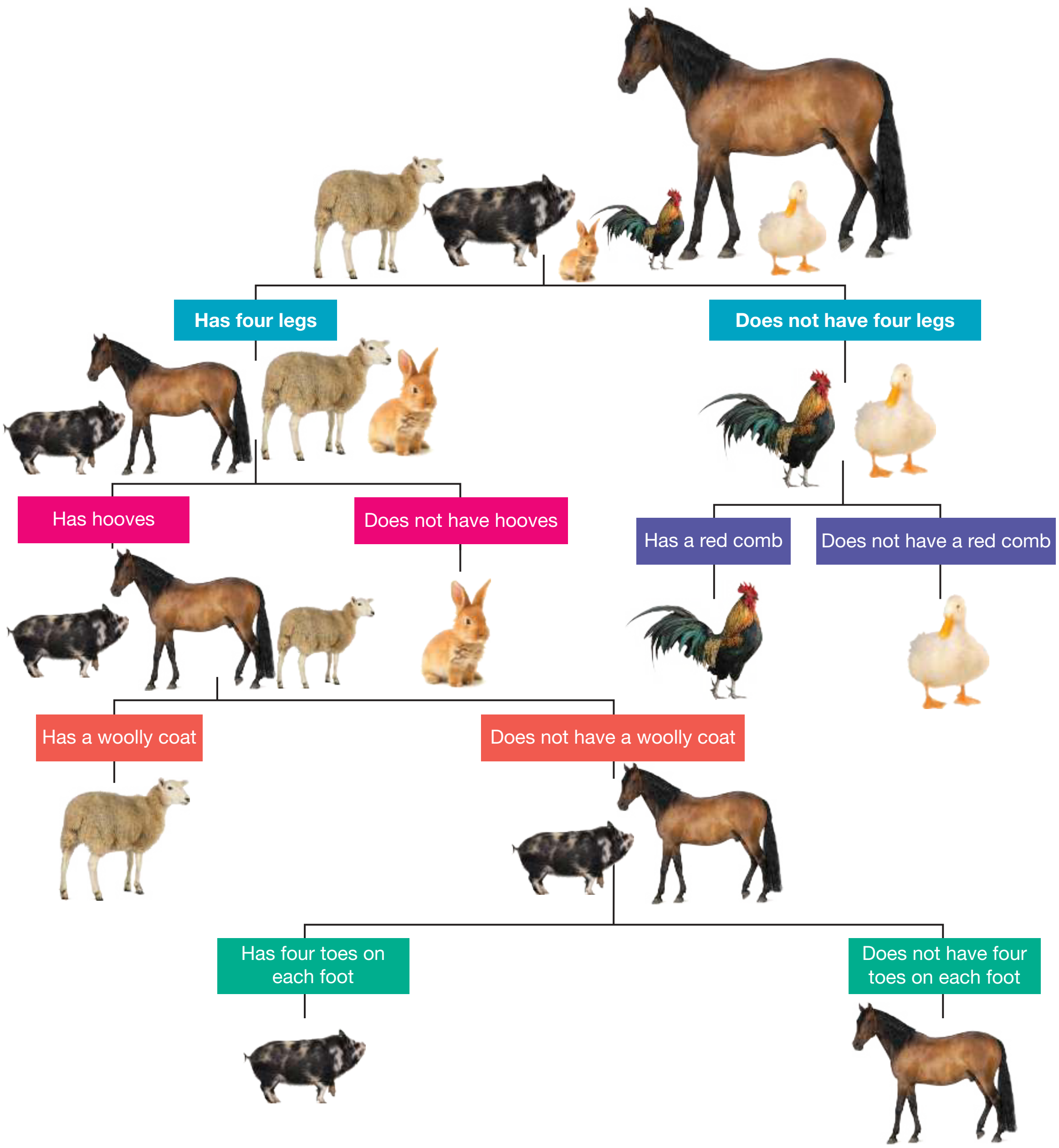
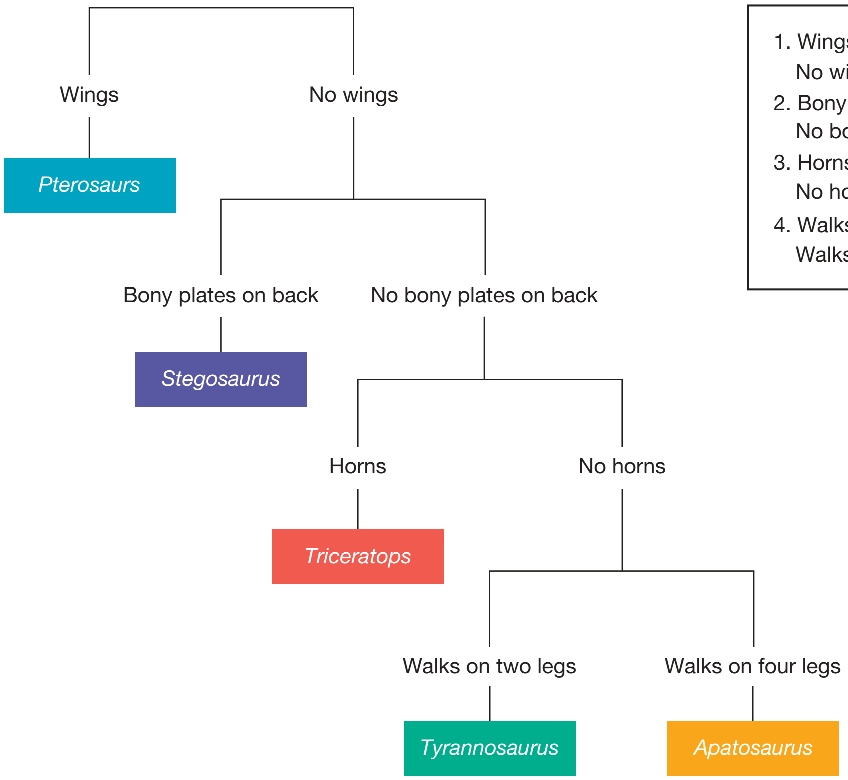


FIGURE 2.26 Dinosaurs can be classified using different dichotomous keys, such as a branching or tabular key.

Branching key



Tabular key

1. Wings	*Pterosaurs*
No wings	Go to 2
2. Bony plates on back	*Stegosaurus*
No bony plates on back	Go to 3
3. Horns	*Triceratops*
No horns	Go to 4
4. Walks on two legs	*Tyrannosaurus*
Walks on four legs	*Apatosaurus*

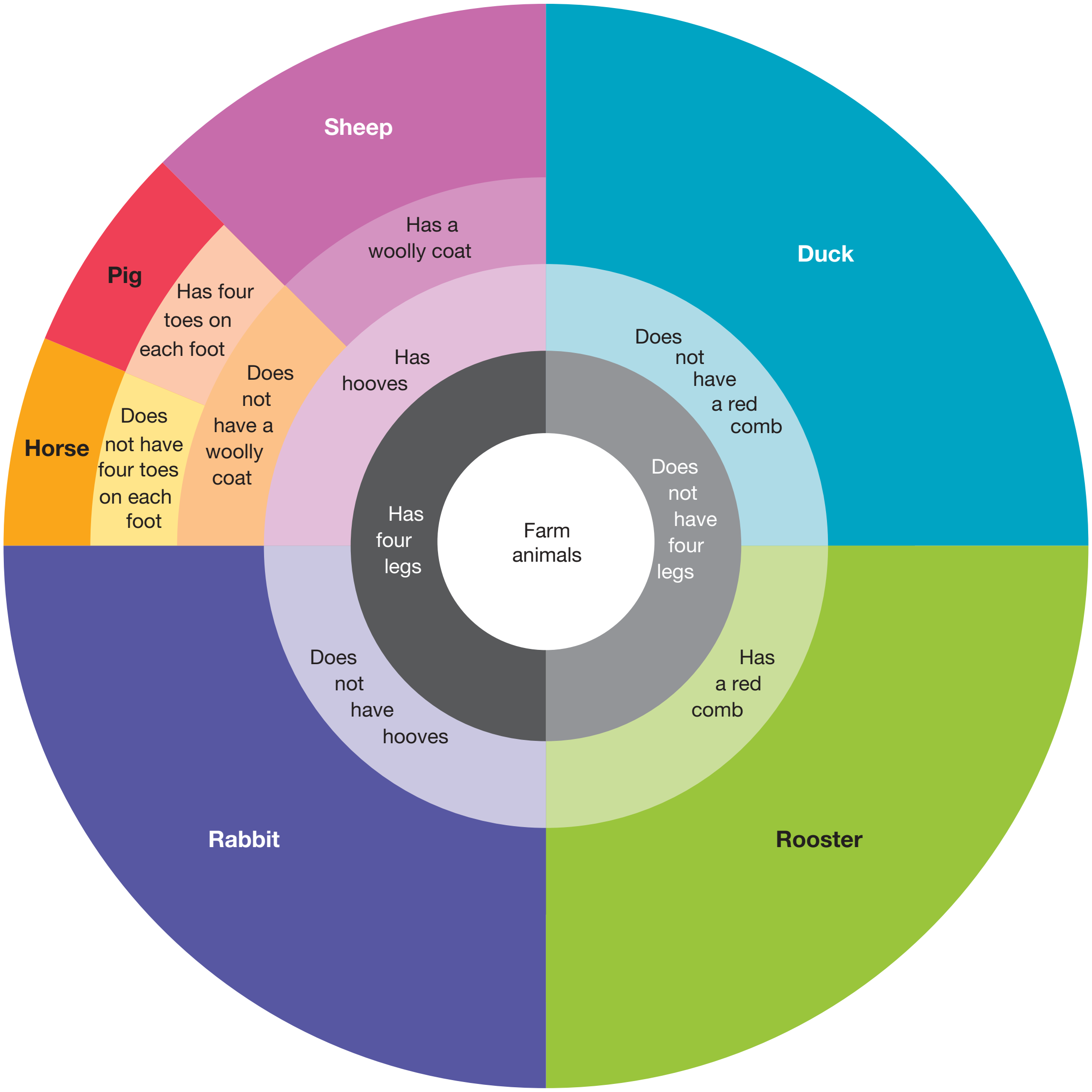
Circular keys

Circular keys can also be used to unlock identity. To read this type of key, you start in the middle and work outwards, choosing one of the options in each layer. The final layer provides you with the organism's identity.

DISCUSSION

Carefully observe the dinosaurs shown in figure 2.26 and consider features that could be used to separate them into groups. Consider how you could use these features in the design of a circular key that would enable each individual to be identified.

FIGURE 2.27 A circular key to unlock farm animal identity



SCIENCE INQUIRY: Different systems

1. Explain how supermarkets are a great example of how a classification system works effectively. Be sure to include the different criteria supermarkets use to organise items, such as type of product or food category. For example, think about how products like fruits, vegetables and dairy are grouped in different sections to make it easier for customers to find what they need. Construct a dichotomous key that would enable ten different supermarket items to be identified.
2. Collect a single leaf from eight different plants in the school grounds. On an A3 sheet of paper, create a branching dichotomous key to classify the leaves. Then construct the key as in a tabular key.

Data and information can be organised and processed by selecting and constructing representations including tables, graphs, keys, models and mathematical relationships (VC2S8I04)

INVESTIGATION 2.2

Making a class key

Aim

To construct a class key using a dichotomous classification system based on the identification of specific characteristics to differentiate between individuals in the class

Materials

- fabric tape measures or tape measures and wooden rulers

Method

1. Measure, observe and record 8–10 different characteristics for each class member. You may like to include some of the following.
   a. Arm span (cm)
   b. Distance from elbow to shoulder (cm)
   c. Foot length (cm)
   d. Height (cm)
   e. Eye colour
   f. Hair colour
   g. Wearing a watch
   h. Pierced ears
2. Every class member will need to select an appropriate secret code name.
3. Use the recorded class characteristics to create a key (either a tree map or dichotomous key) that distinguishes as many individuals (by their code names) as possible. (*Tip:* It may be helpful to describe measurements as 'greater than' or 'less than' a specific value.)
4. Have someone from outside the class use the key to find the identity of one of the class members.

Results

Draw and clearly label the key you created, ensuring all branches and classifications are accurately marked using appropriate scientific notation.

Discussion

1. Evaluate your key's success in identifying individuals and create a list of what worked well, including which characteristics were most useful for classification.
2. Suggest changes you would make to improve the key's success if you were to do the activity again.
3. Did some characteristics prove more valuable than others? Justify your answer.

Conclusion

Summarise your findings from the investigation in three to four sentences, describing how the key helped classify students in the class based on their unique traits.

2.5.3 Field guides

Field guides are a commonly used type of reference book to help people identify organisms. These guides are specially designed to assist in 'on-the-spot' identification, often containing brief written descriptions and pictures, and small enough to take outside when you are observing wildlife. There are also a number of electronic field guide databases available online or through apps, such as Field Guide to Victorian Fauna (Museums Victoria), iNaturalist, Frog Census (Melbourne Water) and Butterflies Australia.

ACTIVITY: Identifying poisonous plants

Table 2.4 provides information about some poisonous plants.

Your task is to research other plants that look like the ones listed. Focus on how they are similar and what features make them hard to tell apart.

Create a warning poster for two of these plants. You may include important details about what they look like, why they are dangerous and tips to stay safe. Make sure your poster is clear and easy to understand, and includes pictures with labels.

TABLE 2.4 Poisonous plants

Common name and image	Botanical name	Poisonous parts	Symptoms	Degree of toxicity	Type of plant
Bird of paradise 	*Caesalpinia gilliesii*	Pods, seeds	Gastroenteritis	Mild*	Shrub
White cedar 	*Melia azedarach*	Fruit (6–8 can kill small child)	Nausea, spasms	High***	Tree
Daphne 	*Daphne odora*	All parts, especially berries	Burning sensation in mouth/stomach, vomiting, collapse	High***	Shrub
Oleander 	*Nerium oleander*	All parts, and smoke from burning wood	Vomiting, dizziness, irregular pulse, collapse	High***	Shrub
Poinsettia 	*Euphorbia pulcherrima*	Leaves, sap, seeds	Delirium, gastroenteritis; sap injurious to eyes and mouth	Moderate**	Shrub
Wisteria 	*Wisteria sinensis*	Seeds, pods	Gastric pain, vomiting	Mild*	Climber

* Mild symptoms may occur if a large quantity of the poisonous parts is eaten.
** Causes discomfort and irritation but is not lethal.
*** Can cause serious illness or death.

INVESTIGATION 2.3

Making a class field guide

Aim

To use clear classification criteria to construct a class field guide that accurately identifies different organisms

Materials

- paper
- pencils

Method

1. Create an avatar of yourself. The avatar can be digitally generated or a hand-drawn sketch.
2. In pairs, swap your avatars. If your class has an odd number of students, your teacher may join.
3. Carefully observe your partner's avatar and record specific physical characteristics, such as the height in centimetres, hair colour and eye colour.
4. Conduct an interview with your partner to gather additional details, including their favourite genre of music, favourite movie title, preferred sport, favourite colour and favourite food.
5. Use half an A4 page for each classmate to present both the collected information and the avatar. Ensure the layout is clear and easy to read.
6. Assemble all the pages into a bound class book or create a large class poster displaying everyone's data and image.

Results

Use the class field guide to assess how easily each student can be identified. As you do this, collect data on the accuracy and time taken for each identification, noting any challenges or errors encountered during the process.

Discussion

1. Explain the benefits of using a field guide.
2. Identify the features that would be most useful to include in a field guide for identifying a class member. Justify your choices.
3. Describe any problems that you encountered when you were constructing the field guide.
4. Identify the features that would be most useful to include in a field guide for:
   a. plants
   b. birds
   c. insects.

Conclusion

Summarise your findings in three to four sentences, connecting them to the experiment's aim.

2.5 Activities

learnon

2.5 Quick quiz on	2.5 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 5, 8, 9, 17	3, 4, 7, 10, 11, 13	6, 12, 14, 15

Remember and understand

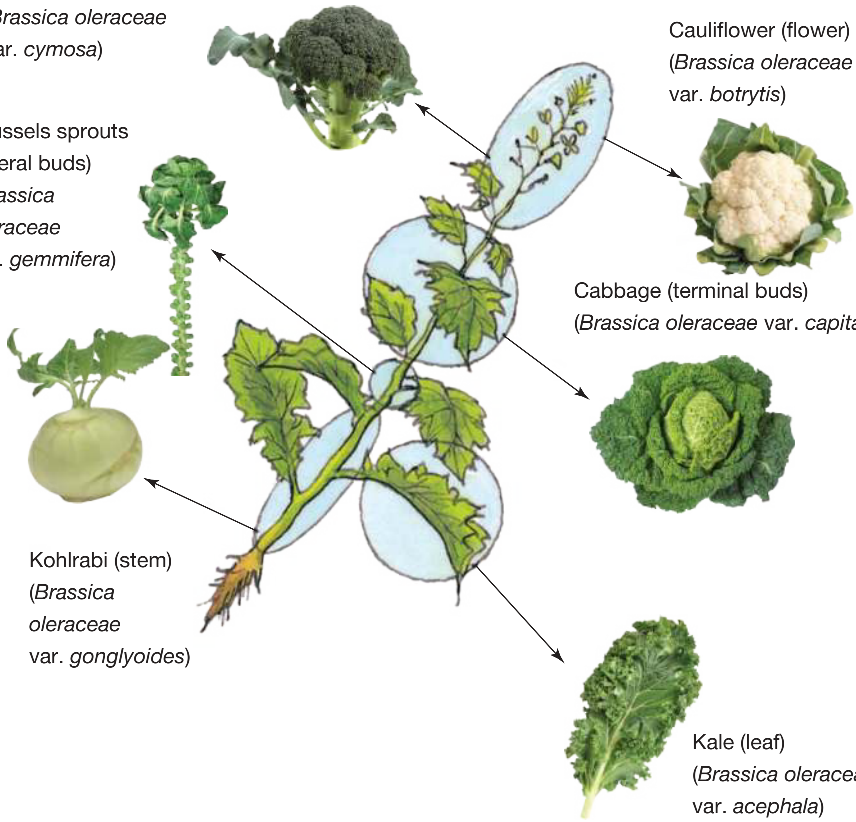
1. a. **Identify** whether the following statements are true or false.
   i. Organisms are classified into groups on the basis of their similarities and differences.
   ii. Dichotomous keys provide three choices at each branch.
   iii. Dichotomous keys can be presented as branching keys or tabular keys.
   iv. The size and colour of an organism is a more appropriate means of classification than the presence or absence of structural features.
   b. Rewrite any false statements to make them accurate and true.
2. **State** the genus of the giant rat discovered in the extinct volcano in Papua New Guinea in 2009.
3. The giant 'rat-eating' carnivorous pitcher plant was discovered in the Philippines in 2007. **State**:
   a. its species name
   b. who it was named after.
4. **State** the name of the Swedish biologist that our current classification system is based on.
5. **Suggest** why scientists classify living things.
6. Some types of features are not very useful as classification criteria. **Explain** why this is the case, including examples.
7. **Identify** three features that would be useful as classification criteria.
8. **Define** a dichotomous key and provide an example of how it is used.

Apply and analyse

9. Imagine that you have landed on another planet and have seen the two creatures shown.

   a. Use the circular key to identify them.
   b. Redraw this circular key as both a tabular and a branching key.
   c. **Explain** which key (circular, tabular or branching) was easier to use to identify the creatures.

10. **Suggest** reasons why the current classification system may change.
11. **Suggest** why tabular keys are sometimes used instead of branching keys.
12. SI **Investigate** and report on the different types of pitcher plants and their classification.
13. Refer to table 2.4, which provides information about some poisonous plants.
    a. **Construct** a dichotomous key that allows identification of each plant.
    b. Considering two plants at a time, use the information in the table to **construct** four different Venn diagrams.
14. SI Carefully observe the features of vegetables in the figure shown.



    a. **State** the species names for the following vegetables.
        i. cauliflower
        ii. cabbage
        iii. broccoli
        iv. Brussels sprouts
    b. **State** the genus to which all of these vegetables belong.
    c. **Outline** your observations on the features of the vegetables in a short paragraph.

Evaluate and create

15. SI Examine the plants in question 14.
    a. **Construct** a mind map to record as many features for each vegetable as you can.
    b. **Compare** your mind map with those of others in the class.
    c. Based on the features recorded in your mind map, **construct** a tree map or a dichotomous key that would enable the identification of each vegetable species.
    d. These vegetables were produced by artificial selection and share a common ancestor. Discover what artificial selection is and then research and report on the history of these vegetables.
16. SI **Construct** a simple key to classify something in your local environment; for example, birds or insects.

Answers and sample responses are available in your digital formats.

LESSON 2.6 Classifying animals

LEARNING INTENTION

In this lesson you will be able to observe and identify the similarities and differences of particular features within and between groups of organisms.

2.6.1 Classifying by structural features

Animals can be classified into one of nine phyla (plural for phylum) on the basis of their structural features. Consider figure 2.28, which shows an example from each phylum. Which features would you use to classify them? Two features commonly used are the type of skeleton they possess and the **symmetry** of their bodies.

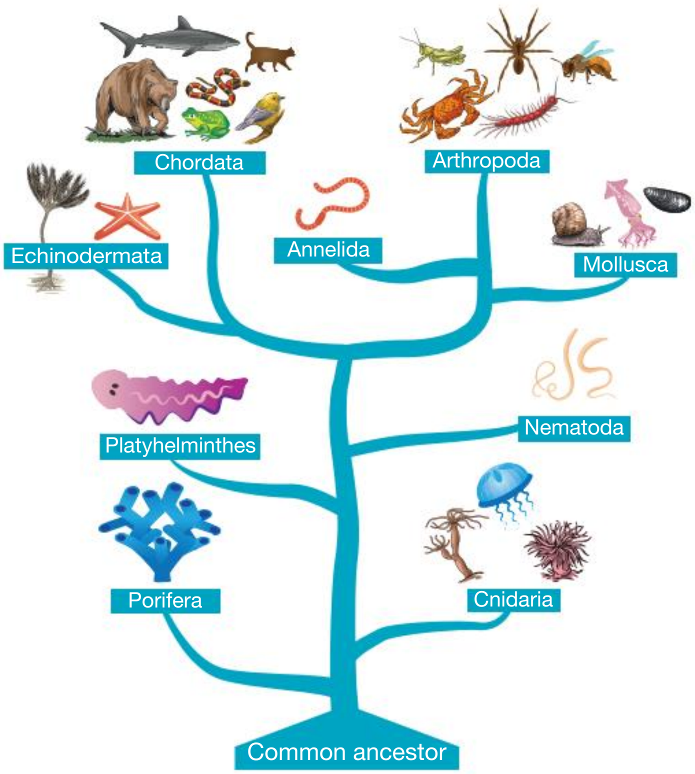
Symmetry refers to how an animal's body parts are arranged around a central axis or point. Symmetry can help scientists identify similarities and differences between groups of organisms.

Symmetry means the body can be divided into two equal halves along one plane. Most animals, including humans, dogs and butterflies, have **bilateral symmetry** (the right and left sides are mirror images of each other). This type of symmetry is often associated with movement and directional sense.

Radial symmetry refers to the body being arranged in a circular pattern around a central point, like the spokes of a wheel. Examples of animals with radial symmetry include jellyfish and sea anemones. Radial symmetry is common in animals that are stationary or move slowly.

Asymmetry refers to animals with no symmetry at all. Their body shapes are irregular, such as sponges found in the phylum Porifera.

FIGURE 2.28 Animals can be classified into one of nine phyla.

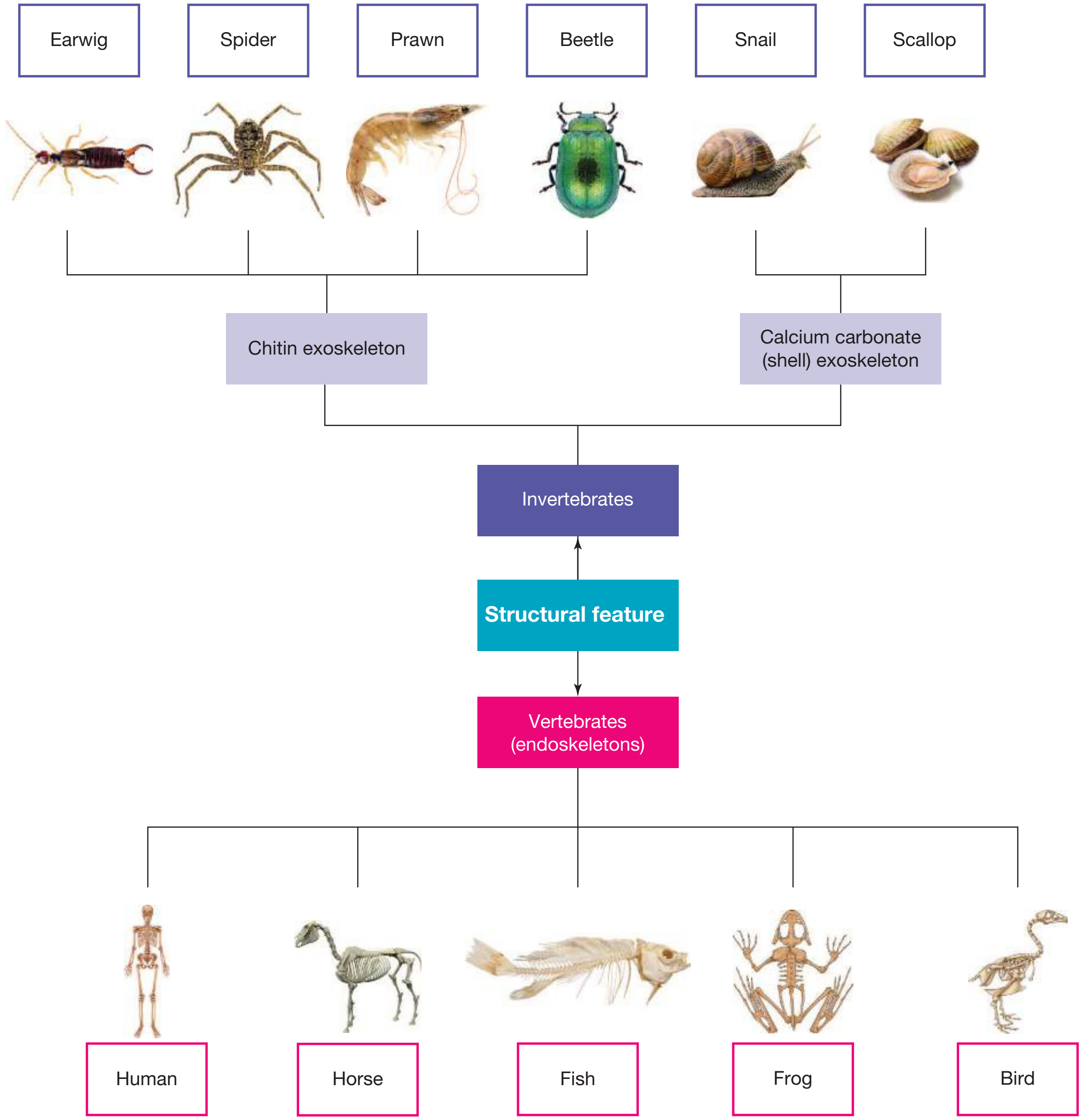


2.6.2 Vertebrates and invertebrates

Animals that have internal skeletons or backbones are called **vertebrates**, whereas animals with external or no skeletons are referred to as **invertebrates**. More than 95 per cent of the animals on our planet are invertebrates.

Vertebrates, such as humans, dogs, fish, birds, frogs and snakes, possess an internal skeleton called an endoskeleton. Invertebrates, such as spiders, flies, snails and grasshoppers, have an external skeleton called an exoskeleton. Different vertebrates and invertebrates are shown in figure 2.29.

FIGURE 2.29 Examples of animals with endoskeletons and exoskeletons



Endoskeletons and exoskeletons

Approximately 75 per cent of all animals in the world have exoskeletons. They may be thick and hard like those of crabs and lobsters, or thin and tough like those of ants and centipedes. As these animals grow, they may moult or discard their old exoskeletons before growing a bigger one. Having an exoskeleton, however, can restrict the size that you can grow. Think about the small size of animals with exoskeletons (such as spiders, flies, snails and grasshoppers), compared to the larger size of those with internal skeletons (such as humans, fish, birds, frogs and snakes).

Unlike exoskeletons, endoskeletons can support a larger body size compared to that of an exoskeleton. Table 2.5 shows some other differences between endoskeletons and exoskeletons.

TABLE 2.5 Differences between endoskeletons and exoskeletons

Feature	Endoskeleton	Exoskeleton
Location	Inside the body	Outside the body
Composition	Cartilage and bone	Chitin or calcium carbonate
Muscle attachment	Muscles attached outside skeleton	Muscles attached inside skeleton
Blood supply	Bone with blood supply	Exoskeleton with no blood supply
Flexibility	More flexibility	Less flexibility
Growth	Grows with body	Does not grow with body
Support of body size	Can support large body size	Cannot support large body size

Animals with no skeleton

Some invertebrates, such as worms and jellyfish, have no skeleton at all. The pressure of fluid in their bodies supports them.

As well as being a type of invertebrate, earthworms belong to the phylum Annelida. Annelids are often found around aquatic and land environments and consist of segmented worms. Each of their segments have **setae**, which they use to help them to grip the soil.

DISCUSSION

1. What do you know about earthworms?
2. What do you think would happen if they lost a lot of fluid?
3. What holds them together?
4. Without a skeleton, how can these animals move?
5. What might the advantages or disadvantages of not having a skeleton be?

FIGURE 2.30 Worms are invertebrates with no skeleton.

Earthworms expand and contract their bodies to burrow through the soil. They use two sets of muscles (**circular muscles** and **longitudinal muscles**) to do this. Contraction of the circular muscles results in the stretching of the earthworm so that it becomes long and thin, which enables it to poke into crevices in the soil. Once stretched out, it can use its setae to anchor itself. Then the worm can pull its body forward by contracting its longitudinal muscles to make it short and fat.

SCIENCE AS A HUMAN ENDEAVOUR: Safeguarding the diversity of the Great Barrier Reef

The Great Barrier Reef in Queensland is one of the most remarkable ecosystems on the planet, hosting more than 1600 species of fish, 600 species of coral and countless other marine creatures, including six of the world's seven species of marine turtles. This vibrant underwater world offers unforgettable experiences like swimming with turtles, snorkelling with manta rays, and exploring its bustling marine life.

FIGURE 2.31 The Great Barrier Reef

Biodiversity, the variety of life within an ecosystem, is essential for the reef's resilience and ability to thrive despite challenges like climate change. Each species has a critical role: hammerhead sharks keep prey populations in check, sea cucumbers recycle sand to combat ocean acidification, and clownfish clean anemones and support their growth. These interactions create a balanced and stable ecosystem that supports all life on the reef.

The Great Barrier Reef's biodiversity is not only vital for its survival but also for the livelihoods of local communities and the global environment. Conservation efforts are underway to protect and restore this natural wonder, from innovative restoration projects to partnerships with local communities and scientists. Measuring and monitoring biodiversity helps researchers identify threats, assess the effectiveness of interventions and guide investments to scale up conservation efforts.

This unique and complex ecosystem is a global treasure. Protecting it is not just an environmental challenge, but a responsibility to ensure its beauty and benefits are preserved for future generations.

1. How do different animals and plants on the Great Barrier Reef help each other and keep the reef healthy?
2. Why is it important to check how many different species live on the reef? How can this help protect it?

Proposed scientific responses to socio-scientific issues impact on society and may involve ethical, environmental, social and economic considerations (VC2S8H03)

INVESTIGATION 2.4

Classifying animals into phyla

Aim

To investigate the characteristics used to classify animals based on features such as body symmetry and type of skeleton, and to identify each animal's species accordingly

Materials

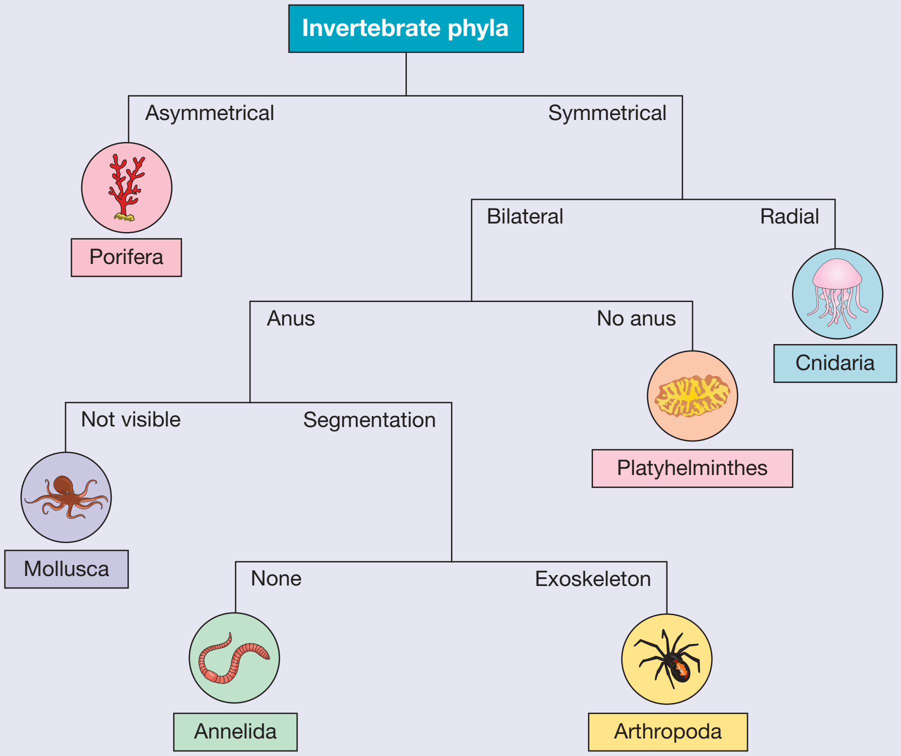
- preserved specimens or photos of animals from a range of phyla
- hand lens

Method

1. Observe each specimen carefully. Use a hand lens if necessary.

CAUTION: Some specimens are preserved in a liquid called formaldehyde, which is toxic and possibly carcinogenic. If you are provided with specimens in jars that contain liquid, do not open the jars. Look at the specimen through the sealed jar.

2. Use the key to decide which phylum each animal belongs to.



Results

Complete a table like the one below using the dichotomous key.

Classification of animal specimens based on their characteristics

Specimen	Name of animal		Characteristics		Phylum
	Common name	Scientific name	Type of skeleton	Type of symmetry	
1					
2					

Discussion

1. Evaluate whether any characteristics in the key were difficult to identify in the specimens.
2. Identify which phyla were the most difficult to distinguish and explain why.
3. Design a tabular key to classify the invertebrate phyla observed in this investigation.

Conclusion

Summarise your findings in three to four sentences, highlighting the main characteristics used to classify the specimens into their correct phyla.

2.6 Activities

learnon

2.6 Quick quiz on	2.6 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
2, 3, 5, 8, 13	1, 6, 7, 9, 12	4, 10, 11, 14

Remember and understand

1. a. **Identify** whether the statements are true or false.
   i. The type of skeleton and their body symmetry are two structural features that can be used to classify animals.
   ii. Animals that have internal skeletons are called invertebrates.
   iii. Skeletons on the outside of the body are called exoskeletons.
   iv. More than 95 per cent of all animals on our planet are vertebrates.
   v. Humans possess an exoskeleton.
   vi. In an animal with an endoskeleton, muscles are connected to the outside of the skeleton.
   b. Rewrite any false statements to make them accurate and true.
2. Do humans possess an endoskeleton or an exoskeleton? **Explain** your response.
3. Complete the following sentence.
   The two most commonly used structural features to classify animals into phyla are their type of _________ and their ___________
4. **Outline** the blood supply of an animal with an endoskeleton.
5. MC **Identify** which phyla possess bodies that show radial symmetry.
   A. Annelida
   B. Arthropoda
   C. Chordata
   D. Cnidaria
6. MC **Identify** which groups of animals have radial symmetry.
   A. Jellyfish and sea anemones
   B. Humans and earthworms
   C. Earthworms and jellyfish
   D. Lobsters and humans
7. MC **Identify** which groups of animals have bilateral symmetry.
   A. Humans and sea anemones
   B. Humans and earthworms
   C. Earthworms and jellyfish
   D. Jellyfish and lobsters
8. **Identify** which group, vertebrates or invertebrates, is more abundant on Earth.

Apply and analyse

9. Complete the table by identifying the type of skeleton and type of body symmetry for each phylum.

Features of phyla

Phylum	Type of skeleton	Type of body symmetry
a. Porifera		
b. Platyhelminthes		
c. Mollusca		
d. Annelida		
e. Arthropoda		
f. Chordata		
g. Cnidaria		

10. Worms have no skeleton and no legs. **Describe** how they are able to move.
11. **Describe** the difference between the way in which muscles are attached in animals with endoskeletons and those with exoskeletons.

Evaluate and create

12. Observe the organisms in the following images.

i.

ii.

iii.

iv.

   a. **Identify** the type of skeleton and type of body symmetry for each animal.
   b. Label features that you consider useful as criteria to classify and **identify** the organisms.
   c. **Construct** a dichotomous key that would enable each of these organisms to be identified.
   d. **Convert** your dichotomous key to either a tabular or circular key.
   e. Use your key to try to classify two other animals not shown in the provided images. **Suggest** modifications that would enable you to identify them using your key.
13. **Construct** Venn diagrams to show the similarities and differences between:
   a. vertebrates and invertebrates
   b. endoskeletons and exoskeletons.
14. Carefully observe the features of the animals figure 2.28.
   a. **Construct** a mind map to record as many features of each animal as you can.
   b. Research additional features online (or share ideas with classmates) and add these to your mind map.
   c. Based on the features recorded in your mind map, **construct** a tree map or a dichotomous key that would enable the identification of each animal group.

Answers and sample responses are available in your digital formats.

LESSON 2.7 Classifying vertebrates

LEARNING INTENTION

In this lesson you will be able to:
- define what makes an animal a vertebrate
- distinguish the features used to classify vertebrates into five main groups and provide examples from each group.

2.7.1 Common features of vertebrates

What do you have in common with a jawless fish like a lamprey? The answer is that you both have a backbone. Lampreys represent one of the earliest vertebrates.

Although there are many different groups of vertebrates, they all share some common features. This similarity is because they shared common ancestors at some point in their evolution. Some scientists study structural similarities to determine how recently groups of vertebrates may have shared common ancestors. One such study focuses on the similarity of vertebrate forelimbs (known as the **pentadactyl limb**).

FIGURE 2.32 Lampreys are eel-like vertebrates.

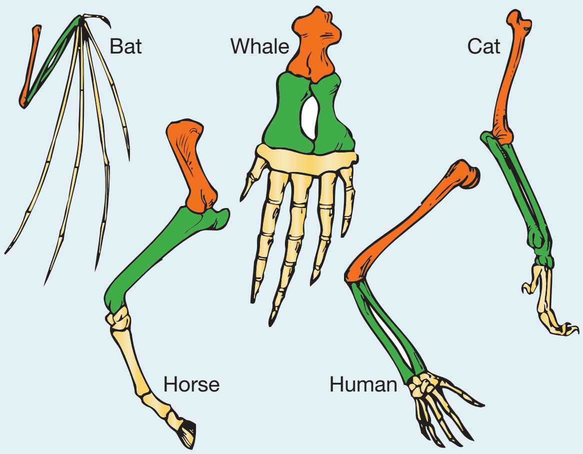
ACTIVITY: Comparing vertebrate forelimbs

Carefully observe the diagrams of the structure of the forelimbs of the bat, horse, whale, human and cat in figure 2.33. These vertebrates possess forelimbs that share the same basic arrangement (pentadactyl limb) because they are derived from a common ancestor.

The forelimbs in figure 2.33 share the same basic structure, showing a common evolutionary origin.

1. List and explain the structural differences between the bat, horse, whale, human and cat forelimbs.
2. Explain how each forelimb is adapted for its specific function (e.g. flying, swimming, walking).
3. Construct a summary poster with clear headings for similarities, differences and adaptations. Include diagrams and labels to illustrate your findings.

FIGURE 2.33 The forelimbs of vertebrates share the same basic arrangement. The colours show equivalent bones.

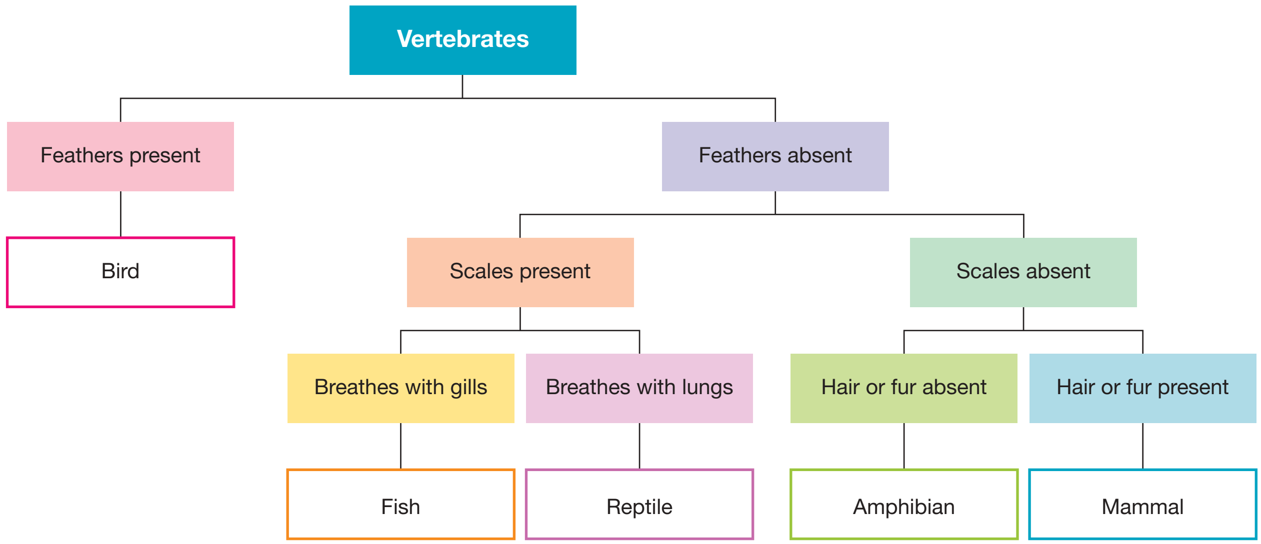


2.7.2 Five main groups of vertebrates

Vertebrates are animals that have a backbone made of bones called vertebrae. The five main groups of vertebrates are:
- fish
- amphibians
- reptiles
- birds
- mammals.

A distinguishing feature across the five vertebrate groups is the ability to regulate their body temperature. Birds and mammals have a relatively constant body temperature and are referred to as **endotherms**. Reptiles, amphibians and fish have a changing body temperature that depends on the external environment and are referred to as ectotherms.

FIGURE 2.34 A dichotomous key can be used to help classify different types of vertebrates.



EXTENSION: Vertebrae and vertebrates

Did you know that the term ‘vertebrate’ is derived from the Latin word *vertebra*, which means ‘joint’? You are classified as a vertebrate because your backbone is made up of many small bones that are stacked on top of one another to form your vertebral column.

Humans have 33 vertebrae. We divide our vertebral column into five sections. From the top of the column, these are:

- Cervical: seven vertebrae (C1–C7)
- Thoracic: 12 vertebrae (T1–T12)
- Lumbar: five vertebrae (L1–L5)
- Sacrum: five fused vertebrae
- Coccyx (tailbone): four fused vertebrae.

Only the cervical, thoracic and lumbar vertebrae are movable.

FIGURE 2.35 Your backbone is made up of many bones called vertebrae (singular, vertebra).

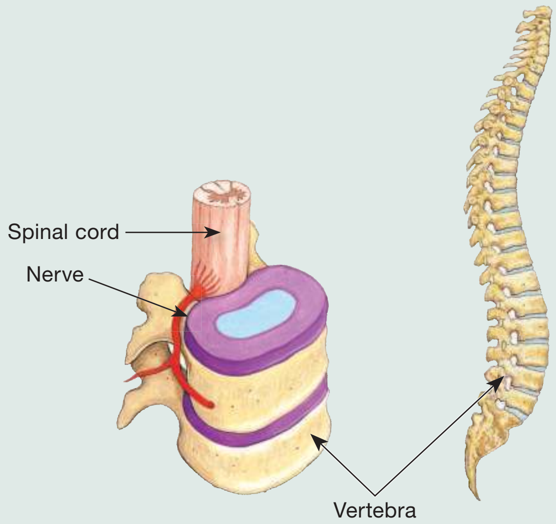
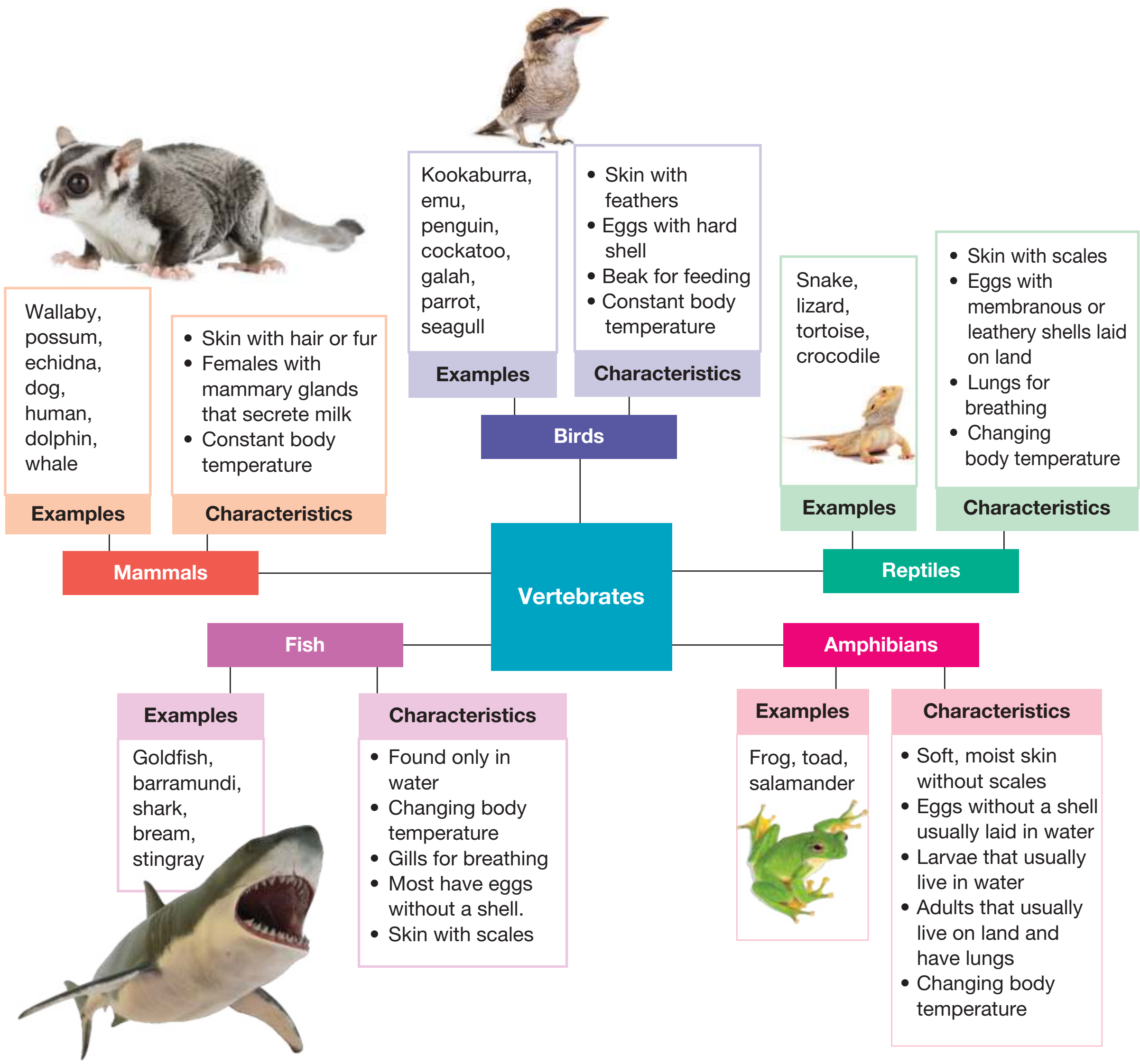


FIGURE 2.36 The five main groups of vertebrates are fish, amphibians, reptiles, birds and mammals.



ACTIVITY: *Flash 'n' mind*

Make a set of *Flash 'n' mind* cards for yourself or for your team to help you learn the characteristics of the different vertebrate groups. Each card is about one-eighth of an A4 page in size and made of coloured cardboard. You will need about 50 cards.

How to make the cards:

1. Write the following terms on five separate cards: mammals, birds, reptiles, amphibians, fish.
2. On 21 separate cards, write each dot point from the characteristics sections of figure 2.36.
3. Using the internet, magazines or other sources, find as many pictures as you can of the animals listed in figure 2.36. Paste these images onto separate cards.
4. Shuffle your cards and, without looking at the diagram, try to arrange them into a similar mind map. As you are laying each card down, say aloud why you are putting it in that place. If you are doing this as a team, discuss any differences of opinion. Once completed, check figure 2.36 to see how you did.
5. As a team, use your cards to design and play as many games as you can to help you learn the characteristics and examples of each vertebrate group.

SCIENCE AS A HUMAN ENDEAVOUR: FrogID

Do you want to discover a new vertebrate species? If so, an interactive app called FrogID may help your quest. Although about 246 species and subspecies of frogs have been confirmed in Australia, Dr Jody Rowley, the Australian Museum's curator of amphibian and reptile conservation biology, believes that about 20 per cent of our frog species are yet to be discovered. She is one of the driving forces behind FrogID, one of Australia's most successful citizen science projects.

FrogID uses the unique calls of each frog species to distinguish them. It records the frog's call and its location. When the information is sent to the museum, an identification is sent back to the sender. Will the frog call that you record belong to a previously undiscovered species of frog? Will your name be incorporated into its scientific name?

FIGURE 2.37 FrogID is a national citizen science project that you can take part in to discover new species of frogs.

1. How does the FrogID app help scientists discover and learn more about different frog species? Why might this be important for protecting frogs in Australia?
2. What makes a frog's call unique? How could recording frog calls help find new species that haven't been discovered yet?

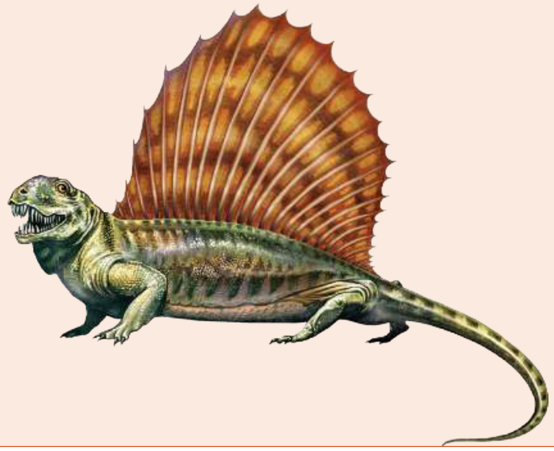
Communication of scientific knowledge has a role in informing individual viewpoints, and community policies and regulations (VC2S8H04)

CASE STUDY: The dimetrodon

Dimetrodon was a meat-eating pelycosaur. The pelycosaurs were the most successful reptiles of the Permian period. They looked like big lizards with huge sail-like fins on their backs. It was once thought that pelycosaurs used this 'sail' to regulate their body temperature, by standing in the early morning sunlight with the sail arranged towards the sun to warm up or turning it into the wind to cool off. However, it is no longer believed that pelycosaurs were **poikilothermic**.

Poikilothermic animals have body temperatures that vary with their environment, while homeothermic animals maintain a relatively constant body temperature. The fin arrangement on pelycosaurs is now considered likely to have been an early stage in the development of temperature regulation of mammals.

FIGURE 2.38 Dimetrodon — a mammal-like reptile



2.7 Activities

learnon

2.7 Quick quiz on	2.7 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3, 4, 5, 9, 18	6, 7, 8, 10, 11, 14, 15, 19	12, 13, 16, 17, 20

Remember and understand

1. a. **Identify** whether the following statements are true or false.
   i. Vertebrates are animals that have a backbone made up of bones called vertebrae.
   ii. The word 'vertebrate' is derived from the Latin word vertebra, which means 'muscle'.
   iii. Vertebrates share some common features because they shared common ancestors at some point in their evolution.
   iv. The forelimbs of vertebrates have similar functions, but do not share any similar structural features.
   v. Lampreys do not possess a backbone.
   vi. Pelycosaurs possessed a huge sail-like fin on their backs to body surf large ocean waves.
   vii. The five main groups of vertebrates are fish, amphibians, reptiles, birds and mammals.

   b. Rewrite any false statements to make them accurate and true.
2. MC **Identify** which pair of animal groups does not possess a skeleton.
   A. Humans and sea stars
   B. Humans and earthworms
   C. Earthworms and jellyfish
   D. Sea stars and lobsters
3. MC **Identify** which group of animals represents one of the earliest types of vertebrates.
   A. Bats
   B. Lampreys
   C. Horses
   D. Whales
4. MC **Identify** which two groups of animals are endotherms.
   A. Lampreys and snakes
   B. Humans and horses
   C. Bats and sharks
   D. Dinosaurs and birds
5. Match each vertebrate group with its skin feature.

Vertebrate group	Skin feature
a. Amphibians	1. Feathers
b. Birds	2. Skin with hair or fur
c. Fish	3. Slimy scales
d. Mammals	4. Dry scales
e. Reptiles	5. Soft, moist skin

6. Match each vertebrate group with its reproductive feature.

Vertebrate group	Reproductive feature
a. Amphibians	1. Eggs with hard shell
b. Birds	2. Eggs with membranous or leathery shells laid on land
c. Fish	3. Eggs without shell, usually laid in water
d. Mammals	4. Females with mammary glands that secrete milk
e. Reptiles	5. Most have eggs without a shell

7. Match each vertebrate group with its example.

Vertebrate group	Example
a. Amphibians	1. Frog
b. Birds	2. Dolphin
c. Fish	3. Penguin
d. Mammals	4. Shark
e. Reptiles	5. Snake

8. Consider what you have learned about vertebrates.
   a. **List** the five main groups of vertebrates.
   b. **Identify** which groups have a changing body temperature and which have a constant body temperature.
   c. **State** an example of each vertebrate group.
9. **Identify** the vertebrate group that each of the following animals belongs to.
   a. Snake
   b. Cane toad
   c. Goldfish
   d. Whale
   e. Emu
   f. Shark
   g. Lamprey
   h. Crocodile

Apply and analyse

10. **Suggest** why vertebrates all share some common features.
11. **Describe** the relationship between vertebrae and your backbone.
12. **Suggest** the function of the huge sail-like fins on the backs of pelycosaurs.
13. **Suggest** why it is thought that the pelycosaurs are a link between reptiles and mammals.
14. **Identify** the vertebrate group that each of the following animals belongs to.
    a. I have lungs but no legs. My offspring are found in membranous-shelled eggs and use lungs to breathe.
    b. I have moist skin but no scales, and two pairs of legs. Although I have lungs and live on land, my young usually live in water and use gills to breathe.
    c. I have a constant body temperature and feathers, and lay eggs with a hard shell.
    d. I have a changing body temperature, gills and fins.
15. Use the following table to **identify** which classification group each of the vertebrates shown in images a–f belong to.

Vertebrate classification groups

Latin or Greek word	English translation	Classification group
Amphis + bios	Double, both sides + life	Amphibia
Marsypos	Pouch	Marsupialia
Osteon + icthyes	Bone + fish	Osteichthyes
Chondr + icthyes	Cartilage + fish	Chondrichthyes
Rodere	To gnaw	Rodentia
Siren	A kind of mermaid	Sirenia

a. Hamster

b. Stingray

c. Quokka

d. Dugong

e. Eel

f. Newt

16. Use this key to classify the following native Australian vertebrates. (You may wish to find photos of each animal to help you.)

1A.	Feathers present	Birds
B.	Feathers absent	Go to 2
2A.	Scales present	Go to 3
B.	No scales present	Go to 4
3A.	Breathe with gills	Fish
B.	Breathe with lungs	Reptiles
4A.	Hair or fur present	Mammals
B.	Hair or fur absent	Amphibians

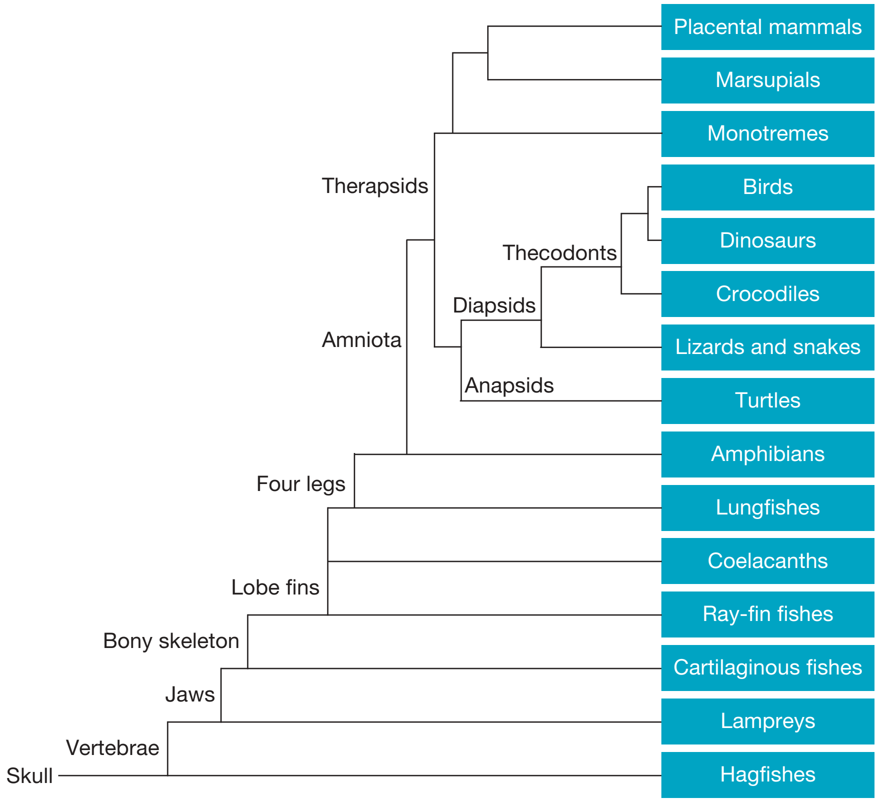
a. Goanna
b. Koala
c. Wombat
d. Emu
e. Dingo
f. Murray cod
g. Kookaburra
h. Little penguin

Evaluate and create

17. a. Copy and complete the following table.
b. Are the answers to the questions in the table the same throughout the life cycle of the organism?

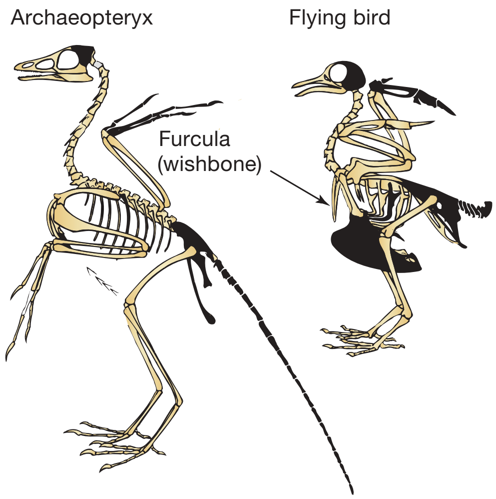
Feature	Mammals	Birds	Reptiles	Amphibians	Fish
a. Is body temperature constant or does it change?					
b. What type of body covering does it have?					
c. Does it lay eggs? If so, what type of shell do they have?					
d. Does it have lungs or gills?					
e. Does it feed its young milk?					
f. Give two examples.					

18. Goldfish and sharks are fish. Research each of these and **construct** a Venn diagram to **summarise** your findings of the structural and behavioural similarities and differences.
19. Use the figure to answer the following questions.



a. MC Which of the following pairs shared the most recent common ancestor?
   A. Birds and dinosaurs
   B. Hagfishes and monotremes
   C. Marsupials and hagfish
   D. Turtles and lampreys
b. MC Which of the following pairs shared the most recent common ancestor?
   A. Marsupials and monotremes
   B. Placental mammals and marsupials
   C. Birds and monotremes
   D. Lampreys and birds
c. MC Which group is most likely to share the most features with placental mammals?
   A. Amphibians
   B. Birds
   C. Marsupials
   D. Monotremes

20. Carefully observe the diagrams of the skeleton of Archaeopteryx and a modern flying bird.
   a. **Describe** at least three similarities between the skeleton and backbone of a modern-day bird and that of the extinct *Archaeopteryx*.
   b. Would you agree with the suggestion by some scientists that *Archaeopteryx* provides a link between dinosaurs and birds? **Justify** your response.



Answers and sample responses are available in your digital formats.

LESSON 2.8 Classifying mammals

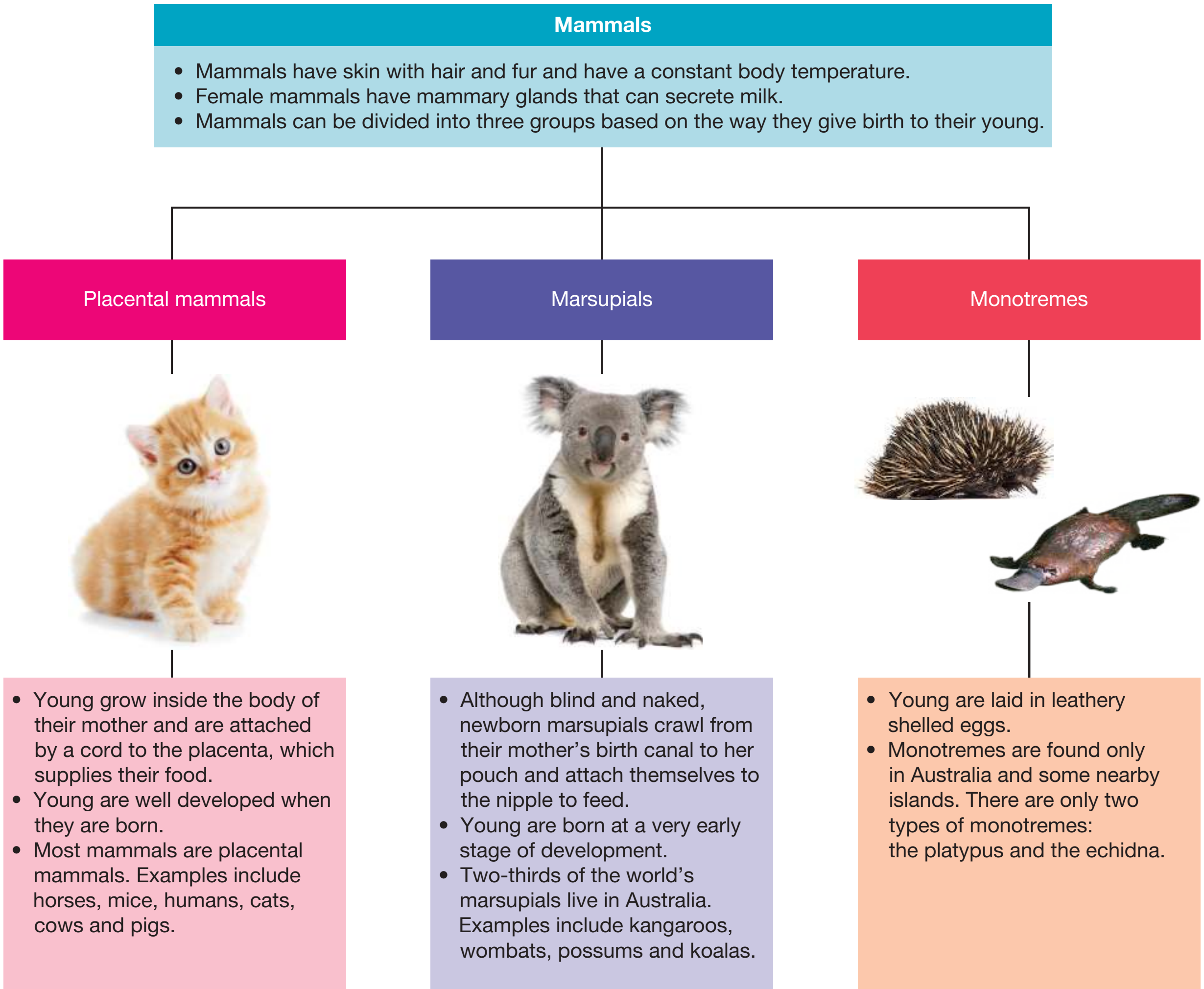
LEARNING INTENTION

In this lesson you will be able to:
- describe the features shared by all mammals
- identify the distinguishing features of placental mammals, marsupials and monotremes.

2.8.1 Types of mammals

Do you have skin with hair or fur and have a constant body temperature? If you do, you could be one of the three types of mammals! The key criterion used to classify mammals is the way in which they give birth to their young.

FIGURE 2.39 Classifying mammals

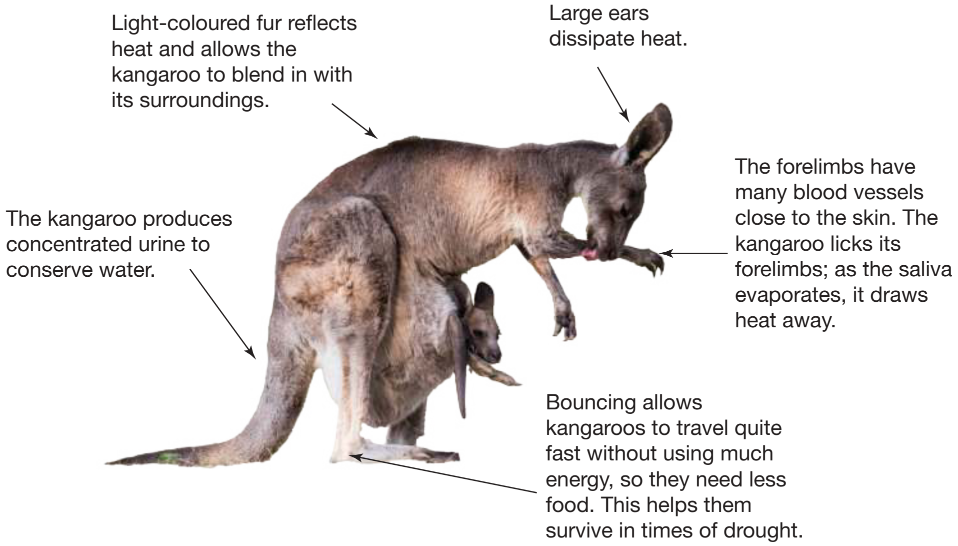


- You are classified as a **placental mammal** because you grew inside your mother, receiving your needs via a placenta, and were born at a well-developed stage.
- **Marsupials** are born at a very early stage of development and then grow inside their mother's pouch.
- **Monotremes** are laid in leathery shelled eggs.

2.8.2 Australian mammals

Australia is unique in the diversity of mammals that live here. Two-thirds of the world's marsupials live in Australia, and monotremes are only found naturally in Australia and on nearby islands. Australia's isolation from the other continents, separated millions of years ago, is considered the reason for the existence of Australia's unique animals, such as the kangaroo and platypus. Australia's native mammals have evolved over time to be particularly well adapted to their harsh Australian environments.

FIGURE 2.40 An adaptation is a feature that helps an organism to survive and reproduce in its environment. This figure identifies adaptations that help a kangaroo survive in the hot, dry Australian environment.



What kind of creature is this?

When European explorers returned from Australia with stories of 'strange' animals such as kangaroos, wallabies, koalas and wombats, people were surprised. Australian animals seemed so different from those common in Europe and other countries.

Imagine their disbelief when the platypus was first described to them. This strange animal had webbed feet and a bill like a duck, but it had no feathers. It laid leathery eggs like lizards and crocodiles, but it did not have scales on its skin. It also had fur and a large tail like that of an otter but, like a reptile, it had only one opening for ejecting faeces and urine.

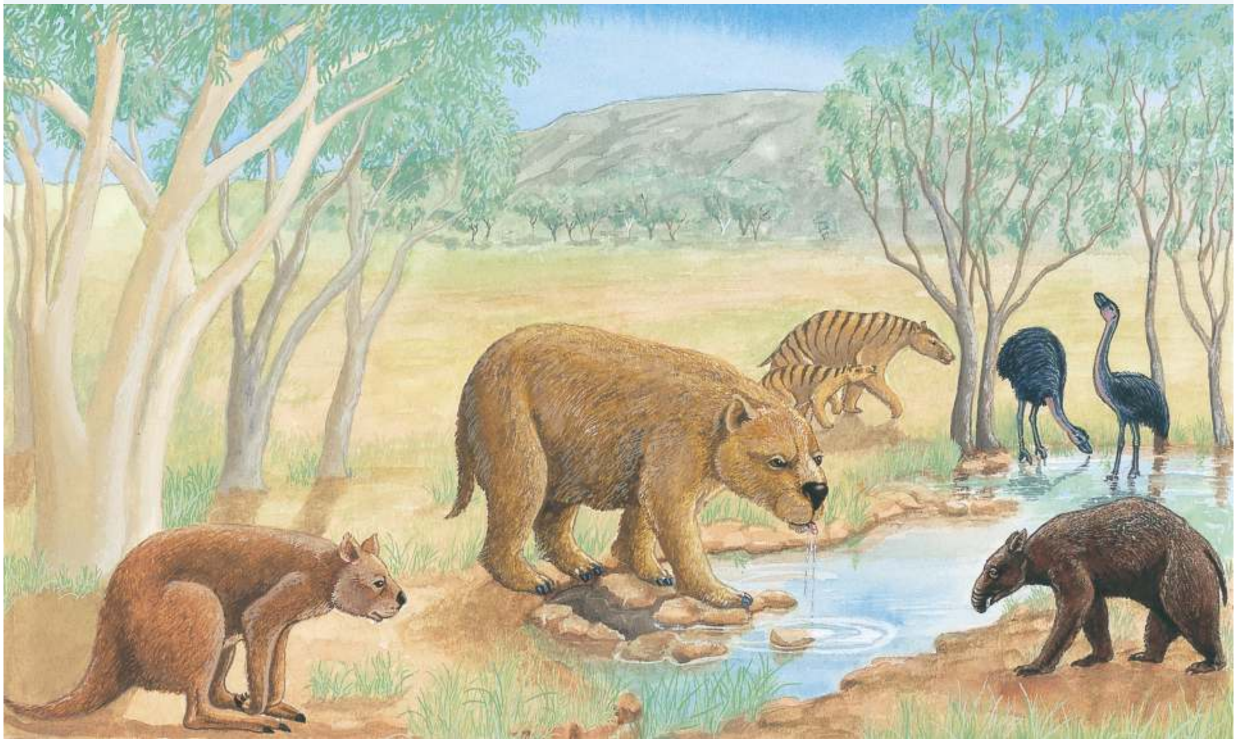
In London in 1799, an Australian sailor presented a platypus specimen to English botanist and zoologist Dr George Shaw. Shaw considered it a hoax and tried to cut off the duck-bill. The scissor-marks are still visible on the preserved platypus skin in the Natural History Museum in London.

FIGURE 2.41 The platypus is a unique, egg-laying mammal native to Australia, combining features of birds, mammals and reptiles.

2.8.3 Ancient megafauna of Australia

If you could travel back in time, you would be amazed by the types of megafauna (giant animals) that roamed the Australian continent. Imagine 'wombats' the size of cars (*Diprotodon optatum*), giant flightless birds (*Genyornis*) and lizards 7-m long (*Megalania*). You might face fearsome lion-like marsupials (*Thylacoleo*) and wolf-like *Thylacinus*, not to mention having giant kangaroos (*Procoptodon*) bounding past.

FIGURE 2.42 This illustration shows some of the animals that inhabited Australia millions of years ago. Others included marsupial lions, koalas, possums, wallabies, kangaroos, goannas and long-beaked echidnas.



Giant kangaroo

The extinct giant kangaroo, *Procoptodon*, was very muscular and stood about 2.5 m high. *Procoptodon* may have weighed about four times as much as the largest kangaroos of today. They had a short face and deep skull with huge molar teeth. Their molars may have helped them to eat tough plant foods. *Procoptodon* may have used their very long forelimbs to pull down the branches of trees and shrubs.

Ancient koala

Lumakoala blackae, an ancient relative of today's koala, had a diet that consisted mostly of soft leaves, but may have occasionally eaten insects. This is different from today's koalas, which eat only tough eucalyptus leaves. The ancient koalas were also much smaller, weighing about 2.5 kilograms — similar to a small domestic cat.

Diprotodons

Diprotodons were the largest marsupials known to have ever existed. All members of this group are now extinct. Among them, *Diprotodon optatum* holds the record for being the largest marsupial ever. Its skeleton suggests that it was about the size of a rhinoceros, measuring approximately 3 m in length and potentially weighing around 2000 kilograms.

Marsupial mammals have existed in Australia for about 35 million years and, due to Australia being isolated from the other continents, many different types have evolved. The story of the history of our mammals is told in our fossil records.

FIGURE 2.43 A timeline of some marsupial fossil finds and major mammal events

Some marsupial fossil finds and events	Time (millions of years ago)	Major mammal events
Present	0.01–present	Humans investigate Earth's history.
Most of the large marsupials became extinct about 15 000–30 000 years ago.	1.64–0.01 mya	There is evidence of Aboriginal and Torres Strait Islander Peoples at least 65 000 years ago.
Many giant browsing marsupials became extinct; there were grazing kangaroos and lots of diprotodons.	5.2–1.64 mya	*Homo habilis,* the earliest known human, appeared in East Africa.
Primitive marsupial 'mice' and 'tapirs' were found at Lake Eyre, South Australia, and diprotodons at Bullock Creek, Northern Territory.	23.5–5.2 mya	Lots of marsupial mammals were living in Australia and South America.
First Australian marsupials occurred about 23 million years ago. Fossils of diprotodons and a relative of the pygmy possum were found in Tasmania.	35.5–23.5 mya	The first marsupials appeared in Australia. The first primates appeared.
Lots of marsupial fossils of this age were found in South and North America.	56.5–35.5 mya	Swimming and flying mammals appeared.
Dinosaurs became extinct about 65 million years ago.	65–56.5 mya	More mammals appeared after dinosaurs became extinct.

ACTIVITY: Questions of the past in the future

Archaeologists and other scientists in a variety of fields are working together to answer questions such as 'Why did the megafauna become extinct?' and 'How is gender determined in a platypus?'

Theories that have been suggested as to why the megafauna became extinct include the following.

- Aboriginal and Torres Strait Islander Peoples may have hunted them as a food source.
- Aboriginal and Torres Strait Islander Peoples may have unknowingly introduced or spread diseases that affected or killed native animals.
- Land management practices such as fire management may have led to a change in the types of vegetation present.
- The climate became drier and vegetation changed so that food sources became scarce.

In May 2013, an international team of experts published research findings stating that, of 90 megafauna, only 8–14 still existed when humans appeared and Aboriginal and Torres Strait Islander Peoples and megafauna coexisted for thousands of years. The lighting of fires and subsequent vegetation change is currently the most supported theory for megafauna extinction. The debate, however, continues.

1. Discuss the theories suggested for the extinction of megafauna.
2. Put forward your own theory (which may include some of the suggestions provided) for the extinction of Australia's megafauna. Justify your thoughts.

EXTENSION: The unique platypus

The platypus is a strange animal with unique features. By mapping its genome (genetic information), researchers hoped to learn more about this peculiar mammal. The platypus (*Ornithorhynchus anatinus*) genome was published in 2008 and has brought new insights into mammalian evolution.

Sex is determined in most mammals by the X and Y **chromosomes** — XX (two X chromosomes) will result in a female and XY (one X and one Y chromosome) will result in a male. In platypuses, however, it gets really interesting! Instead of having a single pair of sex chromosomes, platypuses have ten chromosomes to determine sex. So a female has XXXXXXXXXX and a male has XYXYXYXYXY!

FIGURE 2.44 A platypus eating a worm

Monotreme milk

Teams of Australian scientists at the University of Melbourne, Deakin University and the Australian National University have been studying the milk produced by various mammals. Their research suggests that the milk from monotremes is very different from the milk of other mammals. This supports the theory that placental and marsupial mammals are more closely related to each other than they are to monotremes.

Venom

Platypus venom contains a cocktail of more than 50 different substances. Studies have suggested that some of these substances may be useful in the future as new painkillers. It will be exciting to see what new medicines may result from these findings.

2.8 Activities

learnon

2.8 Quick quiz (on)	2.8 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 5, 9, 10, 12, 14	3, 4, 8, 11, 13, 15, 19	6, 7, 16, 17, 18, 20

Remember and understand

1. a. **Identify** whether the following statements are true or false.
   i. Kangaroos and koalas are examples of placental mammals.
   ii. Monotremes are only found in Australia and on some nearby islands.
   iii. Two-thirds of the world's marsupial species live in Australia.
   iv. The platypus and the echidna are the only two types of marsupials in Australia.
   v. Mammals have skin with hair and a changing body temperature.
   vi. Male mammals possess mammary glands that can secrete milk.
   vii. Mammals can be divided into groups on the basis of how they give birth to their young.
   b. Rewrite any false statements to make them accurate and true.

2. Match the type of mammal with the features of their young.

Type of mammal	Features of their young
a. Marsupials	1. Young are well-developed when they are born
b. Monotremes	2. Young are born at a very early stage of development
c. Placental mammals	3. Young are laid in leathery shelled egg

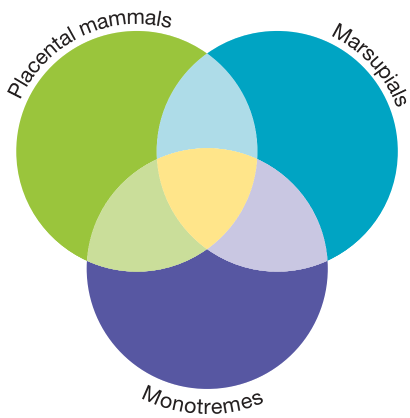
3. Determine the group (placental mammal, marsupial or monotreme) of each of the following animals.
   a. Platypus b. Echidna c. Possum
   d. Cat e. Koala f. Pig
4. **Construct** a table to **summarise** the main characteristics of each of the three groups of mammals.
5. **Outline** how marsupials are different from all other animals.
6. **Explain** how we know that marsupials have existed in Australia for millions of years.

Apply and analyse

7. **Outline** the importance of the findings related to the genome of the platypus.
8. **Suggest** why Australian mammals are so different from those found in other countries.
9. **Explain** what taxonomists in museums do and why their work is important.
10. **Suggest** how placental mammals got their name.
11. Use the timeline in figure 2.43 to answer the following questions.
    a. About how many years ago did dinosaurs become extinct?
    b. How long ago did fossils of swimming and flying mammals appear?
    c. How long ago did fossils of the first marsupials appear?
    d. Evidence suggests that Aboriginal and Torres Strait Islander Peoples were in Australia how many years ago?
12. Write a report on one placental mammal, marsupial or monotreme.
13. a. How are present-day wombats different from their ancient ancestors?
    b. **List** features of each of the following and **suggest** which living animal it is most similar to today.
       i. *Procoptodon*
       ii. *Diprotodon optatum*
14. Look at the prehistoric animals in figure 2.42. **Identify** which animals alive today they are most similar to, and **justify** your answer with evidence.

Evaluate and create

15. **Construct** a triple Venn diagram like the one shown, and complete it to show the similarities, differences and examples of the three mammal groups.



16. SI Adult hedgehogs have 5000 spines. So that the birth canal is not damaged when the mother is giving birth, the initial spines of a newborn are covered with a layer of skin. The spines pop through hours after birth. Although hedgehogs are mammals and they look a little like echidnas because of their spines, they are not classified as monotremes.
    a. Determine whether hedgehogs are placental mammals or marsupials.
    b. **Compare** the differences between hedgehogs and echidnas.
    c. **Identify** what type of mammal a porcupine is, given that it has spines.
    d. **Explain** how porcupines differ from hedgehogs and echidnas.
17. SI Answer the following.
    a. **List** theories that have been proposed as to why Australia's megafauna became extinct.
    b. **State** which theory you support and **justify** your response with evidence.
18. Refer to the timeline in figure 2.43.
    a. **Identify** when marsupials first appeared in Australia and **explain** using the evidence that supports this.
    b. **State** when Earth's greatest ice age occurred. **Describe** other significant events that took place around that time.

19. Select one of Australia's prehistoric marsupials and **summarise** what you know about them. Present your summary in a poster, poem or story.
20. a. How many chromosomes decide the sex of a platypus?
    b. **Compare** this number of sex-determining chromosomes to other mammals.
    c. **Propose** a reason for this difference.

Answers and sample responses are available in your digital formats.

LESSON 2.9 Classifying invertebrates

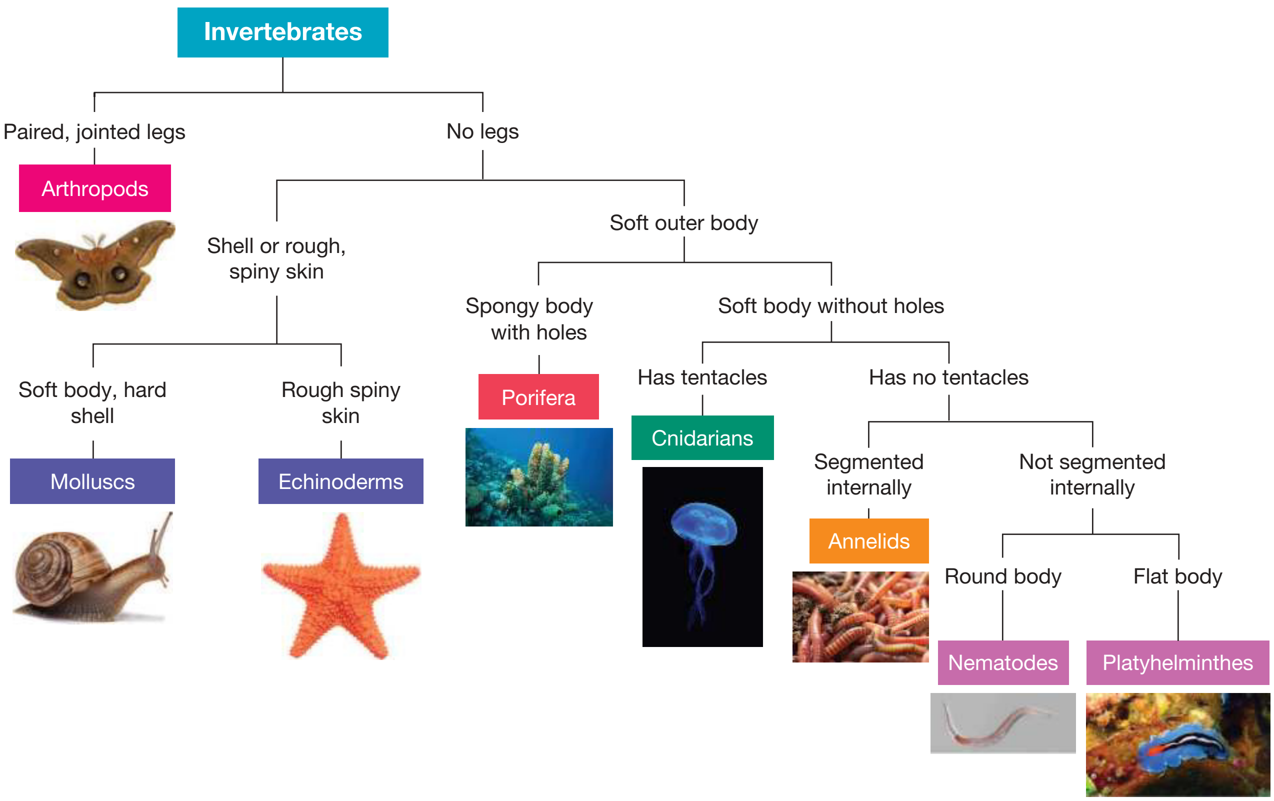
LEARNING INTENTION

In this lesson you will be able to:
- recall the features used to classify invertebrates into eight major phyla
- provide examples from each phylum and explain how their features are adapted to specific functions.

2.9.1 Common features of invertebrates

Feel a little itchy? Did you feel something in your sleep — or were you awake? Was it a flea, an insect, a worm or a louse? Did it burrow its way inside you to feed or did it get its food while crawling on your skin? Chances are it might have been an invertebrate — a creature with no backbone. About 95 per cent of animals are invertebrates. Look at figure 2.45 — how many groups and examples can you recognise?

FIGURE 2.45 The eight major phyla of invertebrates — Arthropoda, Mollusca, Echinodermata, Porifera, Cnidaria, Annelida, Nematoda and Platyhelminthes — shown in a dichotomous key



EXTENSION: Scientific language

The term *platys* comes from the Greek word meaning 'flat'; *helminth* comes from the Greek word for 'worm'; *nema* comes from the Greek word for 'thread'; and *mollusc* comes from the Latin word *mollis*, meaning 'soft'.

Parasites

A variety of invertebrate groups contain organisms that may consider humans to be a food source. Several well-known human parasites belong to these invertebrate groups.

- Arthropods (e.g. head lice, mosquitoes, fleas, ticks and mites)
- Nematodes (e.g. threadworms, hookworms and pinworms)
- Platyhelminthes (e.g. liver flukes and tapeworms)
- Annelids (e.g. leeches).

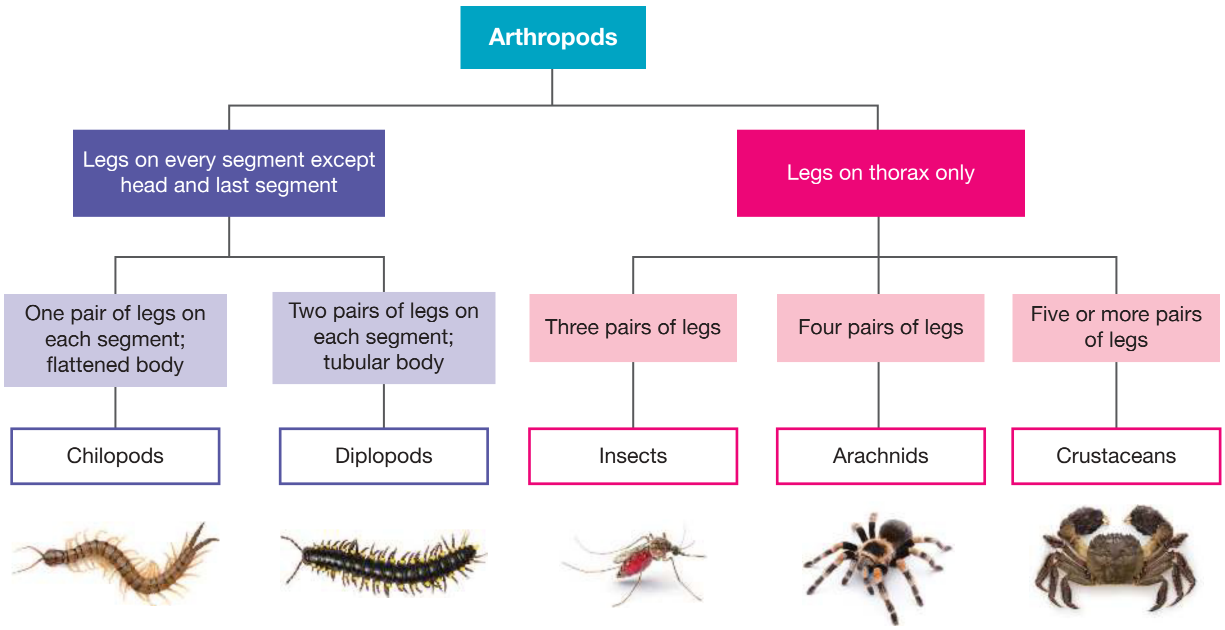
Some organisms obtain their nutrients by feeding on other living organisms. These are:

- parasites
- **endoparasites** and **ectoparasites**
- **vectors**.

2.9.2 Arthropods

About 80 per cent of invertebrates are **arthropods**. Arthropods can be classified on the basis of the organisation and number of their legs.

FIGURE 2.46 The classification of arthropods



ACTIVITY: Create a local arthropod field guide

1. Go outside in your local area (backyard, park or school grounds) and find at least ten different arthropods (insects, spiders or crabs). Take clear photographs of each arthropod you find. Write down where you found them and any interesting behaviours.
2. Use an arthropod identification guide or key to figure out the name of each arthropod in your photos. Write down the name and a few features (how many legs it has, colour or size) for each one.
3. Using your photos and information, make a mini field guide that others can use. For each arthropod, include a photo, its name and any interesting features, where you found it and a short description of its habitat.

2.9.3 Insects

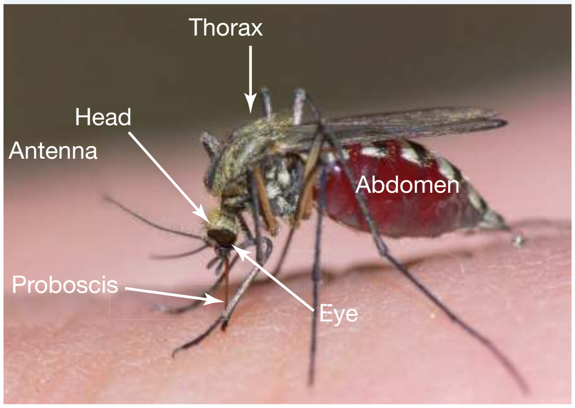
The bodies of insects are divided into three parts:

- head
- thorax (chest)
- abdomen (stomach).

Insects have three pairs of legs. Most have either one or two pairs of wings, a characteristic that separates them from any other invertebrate animal.

These components of an insect can be seen in the mosquito (figure 2.47). Because there are three pairs of legs attached to the thorax, it is classified as an insect. All mosquitoes have a **proboscis**. Only the female mosquito requires a blood meal in order to produce eggs; the proboscis (part of the mouth) pierces the skin of the victim to suck out the blood. Male mosquitoes cannot do this because their proboscis is not strong enough to pierce the skin. They feed on the nectar of plants.

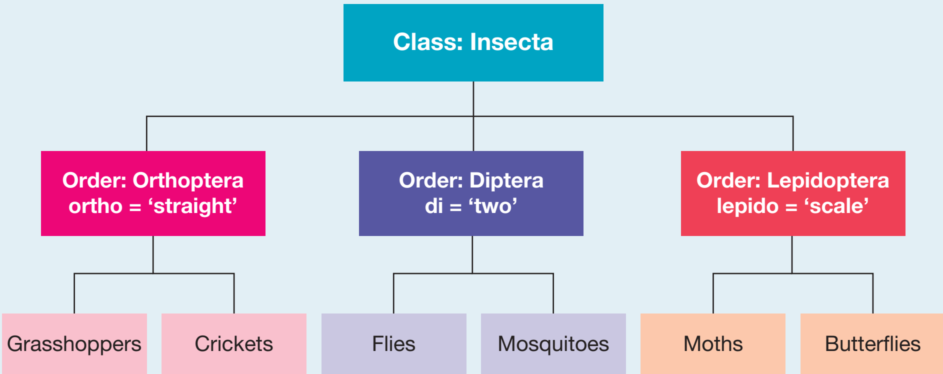
FIGURE 2.47 The proboscis of a female mosquito is like a sharp needle that pierces the skin of its victim in order to suck out a blood meal.



DISCUSSION

Using the knowledge that *pteron* is Greek for 'wing', and the prefix translations in figure 2.48, can you suggest a feature that these insects all share, and one that can be used to separate them? Compare your chosen feature with those of other students. Were there features suggested by others that were better choices?

FIGURE 2.48 Examples of different insects



2.9.4 Functional features of insects

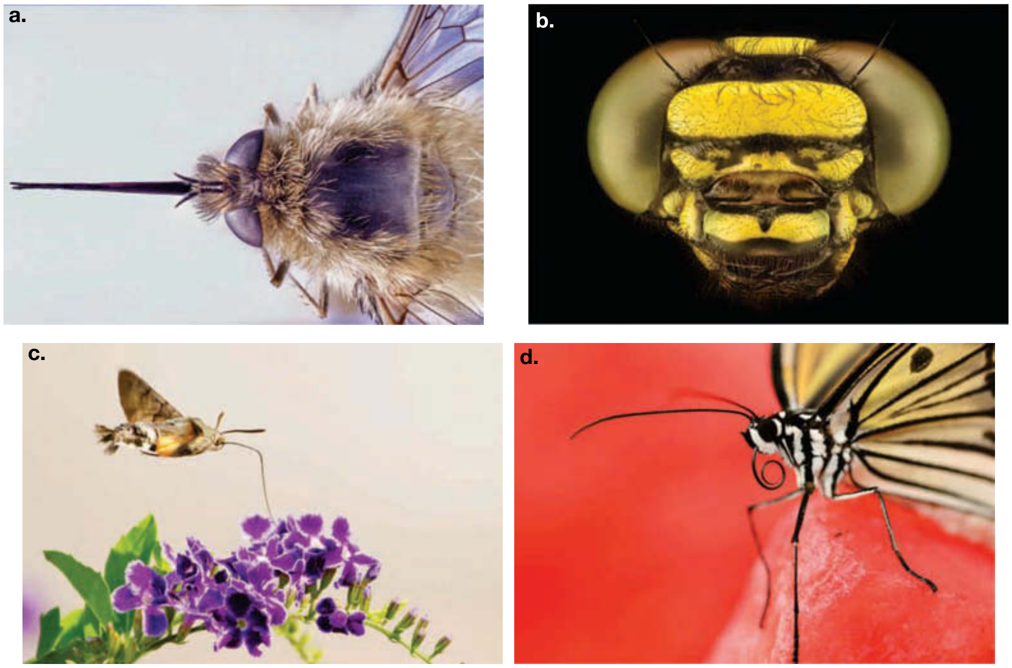
All insects have the same basic mouth parts, but over millions of years, depending on their particular diet, they have developed in different ways. Most insects either bite off pieces of food and chew them, or suck up liquids such as nectar or blood.

Sap- and nectar-sucking insects

Some insects may obtain their food by sucking sap from plants. The shape of an insect's head can often indicate the sort of food it eats. A sap-sucking insect usually has a tiny head with a long, pointed tube (such as a proboscis) extending from its mouth. The shape of this tube is well suited to sucking up sap.

Moths and butterflies have a long, tubular proboscis that unrolls to reach the nectar within a flower. They use muscles that act like an elastic rod to coil it up under their head when they are not feeding. A hawk moth has an unusually long proboscis — it is often longer than its body.

FIGURE 2.49 a. Bee fly proboscis **b.** Dragonfly mouth **c.** Hawk moth proboscis **d.** Butterfly proboscis



EXTENSION: The danger of mosquitoes

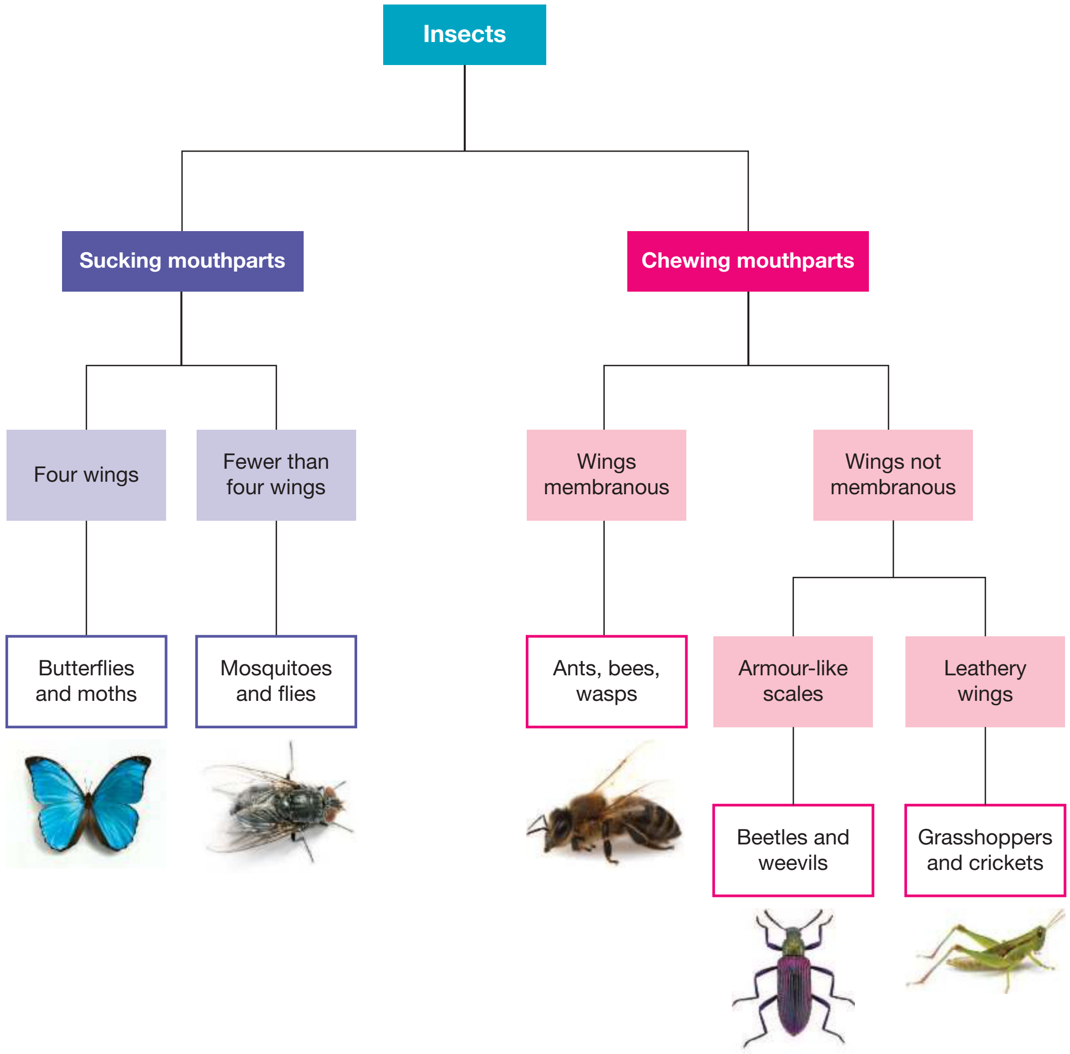
Although adult mosquitoes feed on the sugar in plants, the females in some species must have one or more blood meals to produce eggs. In most species of mosquito, the female has a sharp, tubular proboscis well suited to piercing and sucking. Male mosquitoes never suck blood. Female mosquitoes may pass on malaria, yellow fever, elephantiasis and filariasis while obtaining blood, because they inject saliva containing a parasite into their hosts.

FIGURE 2.50 A mosquito's head as it is seen through a microscope lens

Biting and chewing insects

Some insects have feeding structures that are designed for biting and chewing. They usually eat plants and have a large head to support the strong muscles and jaws that are needed to get through the tough plant tissue.

FIGURE 2.51 Categorising insects that suck and insects that chew



2.9 Activities

learnon

2.9 Quick quiz on	2.9 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 8, 11, 14, 15, 19	3, 4, 5, 9, 13, 16, 21	6, 7, 10, 12, 17, 18, 20

Remember and understand

1. a. **Identify** whether the following statements are true or false.
   i. Animals without backbones are called invertebrates.
   ii. About 80 per cent of invertebrates are molluscs.
   iii. Annelids can be classified on the basis of the organisation and number of their legs.
   iv. Invertebrates without legs include molluscs, echinoderms, porifera, cnidarians, annelids, nematodes and platyhelminthes.
   b. Rewrite any false statements to make them accurate and true.
2. Match each invertebrate phylum with its example.

Phylum	Example
a. Annelids	1. Threadworms
b. Arthropods	2. Slugs
c. Cnidarians	3. Tube sponges
d. Echinoderms	4. Sea urchins
e. Molluscs	5. Grasshoppers
f. Nematodes	6. Tapeworms
g. Platyhelminthes	7. Earthworms
h. Porifera	8. Jellyfish

3. **List** two features shared by the members of each invertebrate phylum.
   a. Arthropods
   b. Molluscs
   c. Echinoderms
   d. Porifera
   e. Cnidarians
   f. Annelids
   g. Nematodes
   h. Platyhelminthes
4. a. **State** the three parts into which an insect's body can be divided.
   b. **State** the number of legs you would expect an insect to possess.
   c. **Describe** what a proboscis is used for.
5. **Identify** each arthropod group by its number of legs and give an example.
   a. Arachnids
   b. Chilopods
   c. Crustaceans
   d. Diplopods
   e. Insects
6. **Outline** how the types of heads and mouth parts of insects can tell you about the way that they live and feed.

Apply and analyse

7. Read the following information about bedbugs and answer the question that follows.
Bedbugs (*Cimex lectularius*) come out at night and feed on the blood of mammals and birds. Their mouth parts are well suited to piercing their host's skin. They have barbed structures for piercing and sawing. The bugs have a pair of tubes, one of which injects saliva containing a substance that stops the blood from clotting, while the other sucks up the blood and saliva mixture. They usually feed just before dawn if the temperature is above 13 °C and may take 5 minutes or more to extract their meal before scurrying off to digest it and rest.

   In your own words, **explain** how bedbugs are able to effectively feed on humans, using the relevant bedbug information from the passage.
8. **Distinguish** between endoparasites and ectoparasites and provide an example of each.
9. Use figure 2.45 to **identify** the invertebrate groups to which the following belong.
   a. I have paired and jointed legs and my body is in sections.
   b. I have a spongy body with many holes, but no shell or legs.
   c. I have no legs, shell or tentacles, but I have a soft, round, segmented body.
   d. I have rough, spiny skin, but no legs.
10. Use figure 2.45 to **identify** the shared features between each of the following pairs.
   a. Nematodes and platyhelminthes
   b. Molluscs and annelids
   c. Arthropods and cnidarians
   d. Arthropods and annelids
11. MC Use figure 2.45 to **identify** which of the following pairs has the most in common.
   A. Arthropods and annelids
   B. Echinoderms and molluscs
   C. Poriferans and platyhelminthes
   D. Cnidarians and echinoderms
12. SI
   a. In a table, **list** the features of slugs, earthworms and snails.
   b. Highlight or circle features that they all have in common.
   c. Which two appear to have most in common?
   d. Use figure 2.45 to see if your data are supported by their classification group.
   e. **Discuss** your findings.
13. **Construct** a table to show examples of arthropods, nematodes, platyhelminthes and annelids that can be human parasites.
14. Use figure 2.46 to **identify** the group that contains arthropods with:
   a. legs on the thorax only and three pairs of legs
   b. legs on every segment except the head and last segment, two pairs of legs on each segment and a tubular body
   c. legs on the thorax only and five or more pairs of legs.
15. Use figure 2.51 to **identify** the group that possesses:
   a. chewing mouth parts and membranous wings
   b. sucking mouth parts and four wings
   c. chewing mouth parts and leathery wings.
16. Use figure 2.51 to **identify** features that differentiate:
   a. mosquitoes from butterflies
   b. mosquitoes from bees
   c. beetles from grasshoppers.

Evaluate and create

17. a. Use figure 2.51 to classify a variety of insects into their groups.
   b. **Describe** any difficulties you encountered while using the key and **suggest** any changes that could make it easier to use.
18. SI Use a magnifying glass or stereomicroscope to observe and sketch the heads of a range of insects. Pay special attention to the parts that may be involved in feeding. **Suggest** what types of food each of the insects might eat and how they might obtain these.

19. Use the alien 'insect' circular key shown to answer the following questions.

a. **Identify** the following 'insect' creatures from another planet.
   i. Green with antennae and one wing
   ii. Three wings and a square head
   iii. Sharp proboscis, one wing and no antennae
   iv. Round head, a stinger and three wings

b. **Describe** the characteristics of a trisee, a peeler and a bitpart.

c. Draw a sketch of a gazer and a bozo.

d. Which of the following are most similar: a bisharp, a noner or a peeler? **Justify** your response.

20. SI **Describe** how you would design a mask to model the feeding parts of several different insects.

21. SI Answer the following.

a. **List** the similarities and differences between locusts and grasshoppers, and present your findings in a Venn diagram.

b. **Identify**, research and report on a question or problem related to locust plagues.

Answers and sample responses are available in your digital formats.

LESSON 2.10 Classifying plants

LEARNING INTENTION

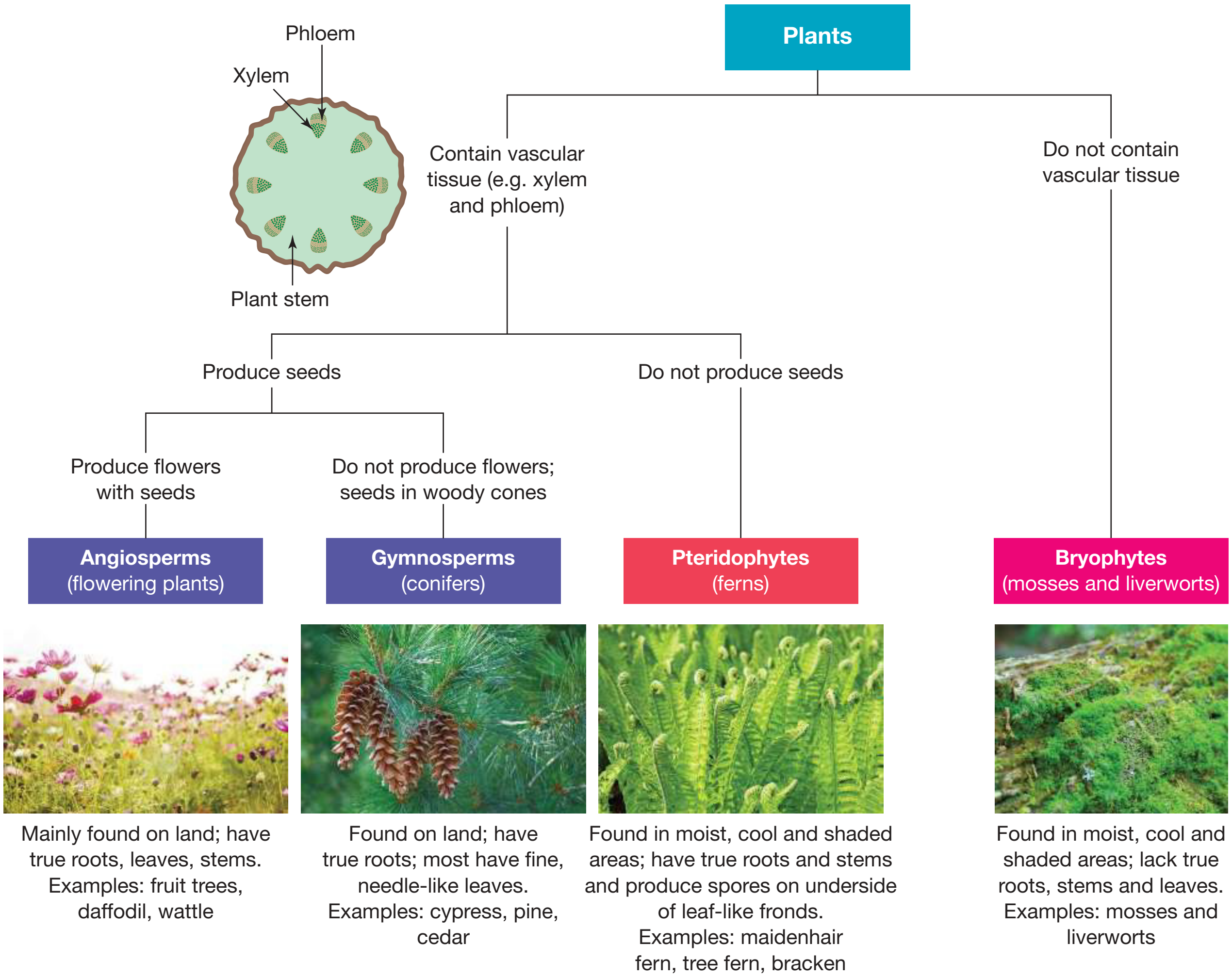
In this lesson you will be able to:

- explain how the presence, absence or patterns in structural or reproductive structures can be used to classify plants
- explain how specific adaptations in plants can enhance their chances of survival.

2.10.1 Using patterns to classify plants

Greek philosopher Aristotle developed one of the first widely used classification schemes (see figure 2.52). He divided plants into groups on the basis of their type of stem. Although this is still a useful system, like most classification systems, it has limitations.

FIGURE 2.52 Classification of plants



Biologists often use the presence, absence or patterns in structural features or reproductive structures to group, classify and identify different types of plants.

1. Plants that contain **vascular tissue** belong to a group called **tracheophyta** ('windpipe' + 'plant'), also referred to as plants with stems.
2. Ferns (**pteridophytes**), conifers (**gymnosperms**) and flowering plants (**angiosperms**) all contain vascular tissue. Mosses and liverworts do not.

Vascular tissue consists of cells that make up tube-like structures that conduct (or transport) materials along the stem of a plant. **Xylem** and **phloem** are two types of conducting tissues. Xylem transports water and minerals from the roots up to the leaves, whereas phloem carries mainly sugars throughout the plant.

FIGURE 2.53 The scientific name for this bottlebrush tree is *Callistemon citrinus.*

2.10.2 The language of plants

Plants can be described using different words, depending on a person's purpose. For example, in describing a bottlebrush tree:

- a scientist would refer to its correct botanical name (*Callistemon citrinus*) and say it belonged to the angiosperm or flowering plant group
- a gardener might say 'I planted a new tree called a bottlebrush'
- a horticulturalist would tend to use both scientific and common names.

Gardeners use common names like 'tree', 'shrub', 'herb' and 'grass' to describe groups of plants, while scientists classify plants based on specific characteristics such as flowers, seeds and fruit. Scientific names are more specific than common names.

KEY IDEA

The prefix *gymno* comes from the Greek word *gymnos*, meaning 'naked'; *angio* comes from the word *angios*, meaning 'vessel'; *phyton* comes from the word *phyton*, meaning 'plant'; and *pterido* comes from the word *pteron*, meaning 'feather'.

2.10.3 Herbs

Have you ever grown a herb garden? Many believe that the use of herbal remedies to treat simple ailments is as old as the human race itself. From early hunting and gathering times, humans have had a close relationship with plants as sources of both food and medicine. Ancient civilisations of Egyptians, Chinese, Persians, Greeks and Romans all practised herbalism.

The herbs (and spices) in your kitchen could have medicinal properties — do you know what effects they might have on you?

CASE STUDY: Uses of herbs

- Thyme can be used to make tea for treating stomach cramps, indigestion, colic and gas retention.
- Lemon thyme smells and tastes like lemon. A few sprigs of lemon thyme in boiling water can make refreshing herbal tea. It is also useful for treating asthma and coughing, and is considered great for boosting your immune system.
- Sweet basil (such as Greek basil) has tiny leaves with a spicy fragrance. Basil is best eaten fresh rather than dried, and goes well with tomato-based dishes. It also helps digestion and relieves constipation.
- Dill is valued for its leaves in spring and its seed in autumn. Its flowers are pale yellow and its stems are grey-green. Dill is added to soups and fish dishes to enhance their flavour. It has also been used as a hair restorer, and as a tea for digestive ailments and to help relieve flatulence.
- Lemon balm is fabulous in salads and refreshing in iced tea. Its healing properties include promoting the relief of tension and restlessness. It also soothes toothache and headaches, and relieves stomach-aches, indigestion and heartburn. Freshly crushed leaves have been used to soothe and cleanse wounds.
- Rosemary can be added to roast potatoes and garlic for a tasty feast. Oil extracted from the leaves and flowers is also used for stomach complaints, gas retention and cramping muscles and limbs — and for aromatic baths.
- Parsley is rich in vitamins A and C. A brew made from the roots is recommended in all ailments of the digestive and urinary tracts. Freshly crushed leaves are also used as a compress for insect bites. Although parsley is often used as a garnish, tabouli is an example of a food made mainly from parsley.

FIGURE 2.54 Common garden herbs you might try growing at home.

ACTIVITY: Your school's gardens — a field guide

1. In pairs, walk around your school grounds and select ten plants.
2. Draw a sketch of each and add as many details as you can next to your diagram.
3. Construct a key to organise these plants into groups.
4. Use field guides and the internet to find out the identity of these plants.
5. Combine your data with that of other groups in your class and use it to construct a plant field guide and key for your school grounds.

2.10.4 Plants beware

History is full of myths and stories about the 'magical' — and sometimes supernatural — properties and uses of plants, and about plants that carry out unusual 'un-plant-like' activities. Some of these stories contain elements of truth.

Witchcraft, superstition and customs

For hundreds of years, some plants have been associated with witchcraft and superstition. For example, the four-leaf form of clover (*Trifolium repens*) that is occasionally found has been considered a token bringing good luck. Another type of clover, *Trifolium pratense*, was thought to guard against witchcraft. In some cultures, people used garlic (*Allium sativum*) to protect them against witchcraft and sorcery; some even added it to animal foods to protect them against evil.

FIGURE 2.55 A four-leaf clover

Stinging hairs

A type of plant with a sting is the giant stinging tree (*Dendrocnide excelsa*), which has large heart-shaped leaves covered with fine stinging hairs. It is commonly found in the rainforests of Queensland and New South Wales. Merely brushing against its leaves can result in a severe burning sensation that may persist for several months. Some people suggest that the juice of cunjevoi lilies (*Alocasia brisbanensis*), squeezed over the stings, will relieve the stinging.

FIGURE 2.56 Stinging hairs covering the leaves of a giant stinging tree

Plants of prey

Some plants found in nitrogen-deficient soil 'eat' insects to supplement their nitrogen. Attracted by the smell of food and a safe landing place, insects can be lured into plants that are not what they seem.

- The Venus flytrap (*Dionaea muscipula*), for example, has a special trap with a hinged lid. As soon as an insect touches the trigger bristles on the trap's upper surface, the trap springs shut. The insect is then trapped in a cage-like prison. Acids and special substances called enzymes are secreted from the plant. These slowly break down the soft parts of the insect's body. It may take the Venus flytrap 2 weeks to fully digest a damselfly. When the trap reopens, the insect's hard exoskeleton, including its wings, is blown away by the wind.
- Sundews (*Drosera* spp.) are another group of insect-eating plants, of which there are more than 50 different species in Australia. The upper part of the leaf is covered with thin red tentacles that are covered in a sticky substance. If an insect touches the tentacles, they bend inwards and trap it. The body of the trapped insect is then digested.

FIGURE 2.57 A Venus flytrap

FIGURE 2.58 Sundews covered in a sticky substance

DISCUSSION

Don't get edible parsley mixed up with fool's parsley, which may look similar but can be poisonous. It can be distinguished from parsley by crushing its leaves, which give an offensive, nauseating odour resembling the stench of mouse droppings!

1. What are some other examples of plants that you need to be wary of?
2. Do some people have bad reactions to plants that others don't?
3. Have you ever had a negative reaction to a plant — either by coming into contact with it or eating it?

FIGURE 2.59 Fool's parsley

2.10 Activities

learnon

2.10 Quick quiz on | **2.10 Exercise**

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 4, 9, 10, 15	3, 5, 7, 11, 14	6, 8, 12, 13, 16

Remember and understand

1. a. **Identify** whether the following statements are true or false.
   i. Aristotle was a Greek philosopher who developed one of the first widely used classification schemes.
   ii. Biologists often use the presence, absence or patterns in structural or reproductive structures to group, classify and identify different types of plants.
   iii. Plants that contain vascular tissue (e.g. xylem and phloem) belong to the group Bryophyta.
   iv. In vascular plants, the phloem transports water and minerals from the roots up to the leaves, whereas the xylem carries sugars throughout the plant.
   v. Flowering plants, conifers and ferns possess vascular tissue, whereas mosses and liverworts do not.

   b. Rewrite any false statements to make them accurate and true.
2. Match each scientific term with its common name and an example.

Scientific term	Common name	Example
a. Angiosperms	1. Flowering plants	i. Maidenhair fern
b. Bryophytes	2. Ferns	ii. Cypress tree
c. Gymnosperms	3. Conifers	iii. Sphagnum moss
d. Pteridophytes	4. Mosses and liverworts	iv. Fruit tree

3. a. **List** two features shared by angiosperms and gymnosperms.

   b. **Identify** a feature that distinguishes angiosperms from gymnosperms.

4. **Identify** whether vascular tissue, flowers or seeds are present or not for each of the following plant groups.
   a. Angiosperms b. Bryophytes c. Gymnosperms d. Pteridophytes
5. Match the scientific name of each plant to its common name.

Scientific name	Common name
a. *Allium sativum*	1. Four-leaf clover
b. *Dendrocnide excelsa*	2. Garlic
c. *Dionaea muscipula*	3. Giant stinging tree
d. *Trifolium repens*	4. Venus flytrap

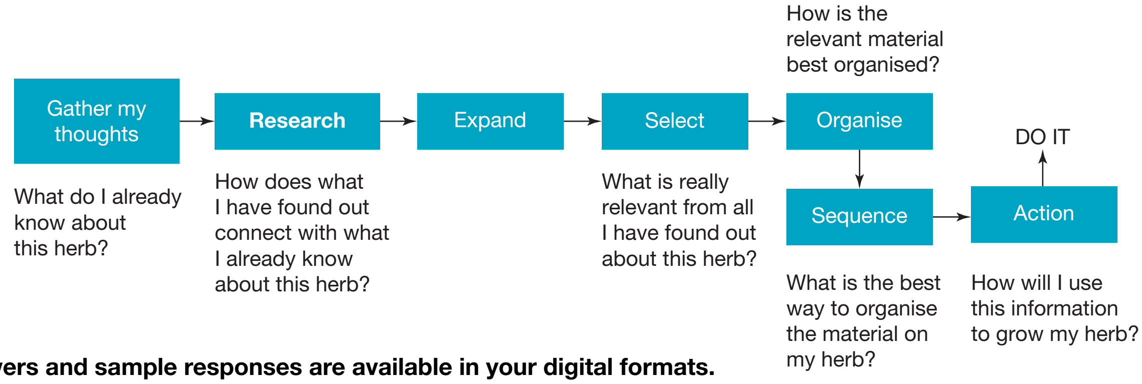
6. **Describe** the advantages to plants of being able to catch and digest animals as well as to photosynthesise.
7. **Recall** which of the following herbs, (i) rosemary (ii) sweet basil, (iii) parsley or (iv) lemon balm, can be used:
   a. as a compress for insect bites
   b. to soothe headaches and help relieve tension and restlessness
   c. for stomach complaints, gas retention and cramping muscles and limbs
   d. to help digestion and relieve constipation.

Apply and analyse

8. **Suggest** why the inner surface of the leaves of a Venus flytrap has both nectar-producing glands and digestive glands.
9. Use figure 2.52 to **identify** the group of plants that:
   a. do not contain vascular tissue
   b. contain vascular tissue and produce flowers with seeds
   c. contain vascular tissue and do not produce flowers, but have seeds in woody cones
   d. contain vascular tissue, but do not produce seeds.
10. **Explain** the role of a taxonomist in a herbarium and why this job is important.
11. **State** the meaning of 'toxicology' and examples of Australian plant toxicology research.
12. a. **Identify** three examples of a tree, shrub, herb and grass. Observe and record five characteristics of each of these plants.
    b. Using your observations, decide which scientific plant group each example belongs to.
    c. Use field guides or keys to **identify** the plants you observed.
13. You may have picked dandelions, blowing off the seeds and watching them be scattered by the wind. **Explain** why dandelions are classified as weeds.

Evaluate and create

14. Design a key that uses the following features, in the order given, to separate ferns, mosses and liverworts, conifers and flowering plants.
    - Seeds or no seeds
    - Seeds in cones or seeds in flowers
    - Stem or no stem
15. SI Design a key to help a gardener tell the difference between trees, shrubs, herbs and grasses.
16. SI Design an investigation about a herb. A flowchart has been provided to help guide you.



Answers and sample responses are available in your digital formats.

LESSON 2.11 The unique flora of Australia

LEARNING INTENTION

In this lesson you will be able to:
- describe the variety of unique and diverse Australian plants
- identify the floral emblem for each Australian state and territory.

2.11.1 Snugglepot and Cuddlepie

When many of your grandparents, or even your great-grandparents, were young, they may have read about the adventures of the Gumnut Babies, Snugglepot and Cuddlepie. They lived in the Australian bush and were constantly bothered by the Big Bad Banksia Man. The characters were based on real Australian plants.

DISCUSSION

Cecilia May Gibbs was born in England in 1877 and moved to Australia in 1881. She grew up in Perth, fascinated by native Australian plants and animals from a young age. Gibbs' family was creative — her father was an artist and cartoonist — and she began drawing the flora and fauna she saw around her from a very young age. She published her first Snugglepot and Cuddlepie story in 1916 under the name May Gibbs.

FIGURE 2.60 May Gibbs was inspired by our Australian bush.

1. What other artists and writers were inspired by Australia's natural environment?
2. Can you think of any other characters in books, film or television that are based on Australian animals or plants?
3. Discuss in groups what Australian animals or plants you would include if you wrote a story and explain why you would include them.

2.11.2 Genus: *Eucalyptus*

The genus *Eucalyptus* includes gums, stringybarks, peppermints, boxes, mallees, ironbarks and ashes. Of the 800 species, all but 13 are native to Australia. Snugglepot and Cuddlepie, the Gumnut Babies, were inspired by the flowers of this group of plants, as shown in figure 2.61.

FIGURE 2.61 The Gumnut Babies Snugglepot and Cuddlepie were based on the flowers of a eucalypt.

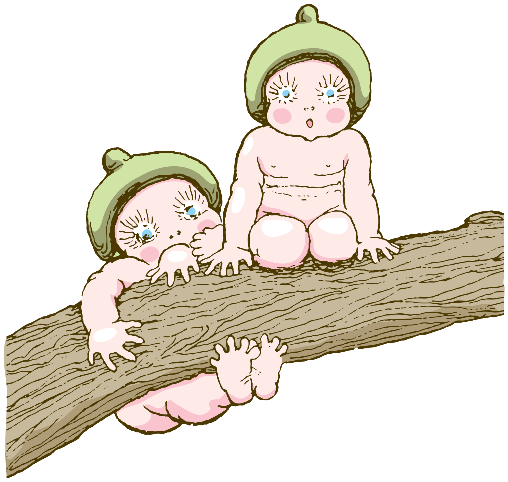


FIGURE 2.62 The flowers of a eucalypt

2.11.3 Family: Proteaceae

Not all flowers have soft, bright, ribbon-like petals. You may not even recognise the flowers of many of our native Australian plants.

The early landmass, Gondwana, was the centre of the origin of the family Proteaceae, and it is in Australia that this family has the greatest diversity. This group includes banksias, grevilleas, hakeas, macadamias and waratahs. Many of these have roots that are very efficient at absorbing water and nutrients, and they are often able to grow in soil that may be deficient in nitrogen and phosphorus.

FIGURE 2.63 There are more than 360 species of *Grevillea*.

FIGURE 2.64 A *Hakea*

FIGURE 2.65 Macadamia flowers

FIGURE 2.66 *Telopea*, commonly known as waratah

Genus: *Banksia*

Of the 76 species of *Banksia*, all but one is native to Australia. All members of this genus have distinctive flower clusters or spikes. Each of these spikes is made up of hundreds (sometimes thousands) of tiny individual flowers with long, stiff, projecting styles. Once fertilised, the outer parts of the flower die off and the fruit body develops into a hard, woody, cone-like structure called a follicle. The seeds within these fruits are protected from foraging animals and fire. In many species, the seeds are not released until they are completely dried out or burnt.

FIGURE 2.67 The Banksia Man is based on the *Banksia* follicle, which is a woody, cone-like structure that develops after a *Banksia* flowers.

FIGURE 2.68 A *Banksia* flower

SCIENCE AS A HUMAN ENDEAVOUR: Joseph Banks (1743–1820)

In 1782, the genus *Banksia* was named after English naturalist Sir Joseph Banks (1743–1820). Banks travelled to Australia with Captain James Cook on a voyage from 1768 to 1771. During this expedition, Banks collected and recorded many plants that were new to Europeans, including Banksia and Eucalyptus. His discoveries were among the first scientific records of Australia's unique flora.

Banks's passion for plants played a big role in making the world appreciate Australia's amazing biodiversity. His collections helped create Kew Gardens in London, which became one of the most famous botanical gardens in the world. Swedish naturalist Carl Linnaeus the Younger was so impressed by Banks's work that he even suggested Australia should be named 'Banksia' instead!

In Victoria, several species of Banksia are native, such as *Banksia marginata* (Silver Banksia), which grows in woodlands and coastal areas. These plants are not just beautiful but also important for wildlife because they provide food and shelter for birds like honeyeaters and small mammals such as possums.

1. Why was Sir Joseph Banks such an important figure in helping the world learn about Australia's unique plants?
2. What do you think it would have been like for Sir Joseph Banks to discover and document plants in Australia that no-one in Europe had ever seen before?

FIGURE 2.69 Sir Joseph Banks

ACTIVITY: Floral emblems of Australia

Did you know that each state and territory of Australia has its own floral emblem? Table 2.6 shows the floral emblems of each Australian state or territory. Which of these flowers have you seen before? Discuss possible reasons for the selections of each of these flower emblems.

TABLE 2.6 Floral emblems of Australian states and territories

	
State Australian Capital Territory	**State** New South Wales
Common name Royal bluebell	**Common name** Waratah
Scientific name *Wahlenbergia gloriosa*	**Scientific name** *Telopea speciosissima*

TABLE 2.6 Floral emblems of Australian states and territories *(continued)*

State Northern Territory
Common name Sturt's desert rose
Scientific name *Gossypium sturtianum*

State Queensland
Common name Cooktown orchid
Scientific name *Dendrobium phalaenopsis*

State South Australia
Common name Sturt's desert pea
Scientific name *Swainsona formosa*

State Tasmania
Common name Tasmanian blue gum
Scientific name *Eucalyptus globulus*

State Victoria
Common name Common heath
Scientific name *Epacris impressa*

State Western Australia
Common name Red and green kangaroo paw
Scientific name *Anigozanthos manglesii*

2.11 Activities

learnon

2.11 Quick quiz	2.11 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 4, 6	3, 5, 7	8, 9

Remember and understand

1. a. **Identify** whether the following statements are true or false.
   i. Stringybarks, gums, mallees and ironbarks are all members of the *Banksia* genus.
   ii. Of the 800 species in the *Eucalyptus* genus, all except 13 are endemic to Australia.
   iii. The Proteaceae family includes banksias, grevilleas, hakeas, macadamias and galahs.
   iv. Of the 76 species of *Banksia*, all but one is native to Australia.
   b. Rewrite any false statements to make them accurate and true.
2. a. **List** four Australian members of the Proteaceae family.
   b. **List** four Australian examples of the *Eucalyptus* genus.
3. a. **Recall** who the *Banksia* genus is named after.
   b. **Describe** the fruit and flowers of the *Banksia*.
4. Which type of plant were Snugglepot and Cuddlepie, from May Gibbs' stories, inspired by?
5. Match the floral emblem of the states and territories of Australia to their common names.

Australian state or territory	Common name of floral emblem
a. Australian Capital Territory	1. Common heath
b. New South Wales	2. Cooktown orchid
c. Northern Territory	3. Red and green kangaroo paw
d. Queensland	4. Royal bluebell
e. South Australia	5. Sturt's desert rose
f. Tasmania	6. Tasmanian blue gum
g. Victoria	7. Waratah
h. Western Australia	8. Sturt's desert pea

Apply and analyse

6. Who was May Gibbs? **Explain** why she included Australian plants in her stories.
7. SI Select two examples of Australian plants. **Explain** their history and **discuss** their importance.
8. **Propose** a report on the importance of native flora in your life.
9. Each Australian state and territory has its own floral emblem. Research:
   a. the key features of each plant
   b. why these plants were selected
   c. any scientific research or interesting information.

Answers and sample responses are available in your digital formats.

LESSON 2.12 Algae, fungi and lichens

LEARNING INTENTION

In this lesson you will be able to explain why algae, fungi and lichens are no longer classified as members of the plant kingdom.

2.12.1 Changing classification

Algae, fungi and **lichen** were once considered the most primitive plants on Earth. These organisms do not produce flowers or seeds, nor do they have roots, stems or leaves. On the basis of current information, many biologists no longer consider them plants. The classification of these is shown in figure 2.70.

FIGURE 2.70 This key can be used to separate algae, fungi and lichens from plants.

1	No roots, stems, leaves or flowers ………..………………………	Algae, fungi and lichens
	Distinct leaves: with or without roots or flowers ………………..	Go to 2
2	No true roots or flowers ……………………………………………	Bryophytes
	True roots: with or without flowers ……………………………….	Go to 3
3	No flowers or seeds, reproduce by spores ……………………….	Pteridophytes
	Seed-bearing plants ……………………………………………….	Go to 4
4	Seeds in cones …………………………………………………….	Gymnosperms
	Seeds produced in an ovary/flower ……………………………….	Angiosperms

While most of these organisms are harmless to humans and other animals, some are not. For example, some fungi can cause disease, and blue-green algae can poison water supplies.

Algae

Characteristics of algae include:

- all live in water
- often unicellular
- no true roots, stems, leaves or flowers
- no special tissue for transporting food or water
- divided into groups depending on their colour
- make their own food using photosynthesis.

Examples of algae are diatom, Neptune's necklace and seaweed (see figure 2.71).

FIGURE 2.71 Neptune's necklace (seaweed) is an alga.

Fungi

Characteristics of fungi include:

- no true roots, stems, leaves or flowers
- usually multicellular; some unicellular
- no chlorophyll and unable to make their own food
- usually obtain their food from other living or dead organisms
- produce enzymes that break down food outside their cells
- broken-down food is absorbed through their cell walls.

Examples of fungi are yeast, mould, mushrooms (see figure 2.72) and toadstools.

FIGURE 2.72 Not all mushrooms are safe to eat! Some can be poisonous.

FIGURE 2.73 Better dry between your toes or you may get the fungal infection athlete's foot (*Tinea pedis*).

FIGURE 2.74 Mushrooms are fungi we eat, and yeasts are very important in making bread and wine.

Lichens

Characteristics of lichens include:

- found on bare rocks (see figure 2.75), the bark of trees, in cold polar regions and on mountain tops
- no true roots, stems, leaves or flowers
- made up of two different organisms: an alga and a fungus
- algal cells live among tiny fungal threads
- algal cells photosynthesise and supply the fungus with food
- fungus provides protection and anchorage for the algal cells
- grow very slowly and are extremely long-lived
- often responsible for breaking down rocks, allowing other organisms to grow.

FIGURE 2.75 Several types of lichen may grow together.

ACTIVITY: Lichens, fungi and algae in Biology books

Look up lichens, algae and fungi in at least three different Biology textbooks and record whether they are classified as belonging to the plant kingdom or to a different group. Try to find at least one Biology book published before 1980. Why have ideas about the classification of lichens, algae and fungi changed? Use your data to complete table 2.7.

TABLE 2.7 Lichens, fungi and algae in textbooks

Reference title	Date published	Lichens grouping	Fungi grouping	Algae grouping
e.g. Text A	1983	Plant kingdom	Plant kingdom	Plant kingdom
e.g. Text B	1990	Fungi kingdom	Fungi kingdom	Protoctista kingdom

2.12 Activities

learnon

2.12 Quick quiz	2.12 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 6, 10	3, 4, 8, 9	5, 7, 11, 12

Remember and understand

1. a. **Identify** whether the following statements are true or false.
   i. Algae, fungi and lichens do not produce flowers and seeds.
   ii. All algae live in water.
   iii. Algae are made up of a fungus and a lichen.
   iv. Although some fungi are multicellular, most are unicellular.
   v. Fungi contain chlorophyll.
   vi. Fungi produce enzymes that break down food outside their cells.
   vii. Lichens grow very slowly and are extremely long-lived.
   viii. Lichens may be found on bare rocks, the bark of trees and mountain tops.

   b. Rewrite any false statements to make them accurate and true.
2. **Recall** the group (algae, fungi, lichens or plants) to which the following belong:
   a. diatoms
   b. giant kelp (seaweed)
   c. toadstools
   d. the cause of athlete's foot (tinea)
3. **Construct** a table that summarises the characteristics of lichens, algae and fungi.

Apply and analyse

4. Lichens are mutualistic symbiotic relationships between a fungus and an alga. **Outline** how each of these organisms benefit in this relationship.
5. SI **Investigate** and report on the features used to classify fungi into groups. Include labelled diagrams or sketches to support your report.
6. **Describe** the symptoms of tinea, **explain** how it is contracted and **outline** methods for its prevention and treatment.
7. Based on what you have learnt about why some organisms are reclassified, answer the following questions.
   a. **Suggest** reasons why lichens, algae and fungi were once classified as plants.
   b. **Identify** which, if any, of these groups you believe are most like plants. **Justify** your reasoning.
   c. If you were a biologist, would you classify any of these groups as plants? **Explain**.
8. a. **Define** slime moulds.
   b. **Describe** their characteristics.
   c. Which kingdom do slime moulds belong to?

Evaluate and create

9. **Construct** a dichotomous branching key that could be used to classify lichens, algae and fungi.
10. Use a Venn diagram to **compare** angiosperms and fungi.
11. SI Design an investigation using slices of bread to find out which conditions are best suited to growing moulds.
12. SI **Discuss** the discovery of penicillin and **explain** its impact on medicine and the treatment of diseases.
    - Include reference to the mould penicillium and the research contributions of Howard Florey, Ernst Chain and Alexander Fleming.
    - Present your findings in a format of your choosing.

Answers and sample responses are available in your digital formats.

LESSON 2.13 Review

2.13 Success criteria

Tick the column to indicate that you have completed the lesson and how well you think you have understood it using the traffic light system.

(**Green:** I understand; **Yellow**: I can do it with help; **Red**: I do not understand)

Lesson	Success criteria	Green	Yellow	Red
2.2	I can identify similarities and differences within and between groups of organisms.			
	I can recognise that biological classification has changed over time, including systems used by Aboriginal and Torres Strait Islander Peoples.			
2.3	I can explain how language patterns can provide hints about the meaning of scientific terminology.			
2.4	I can name and classify species using scientific conventions from the Linnaean hierarchical classification system, such as kingdom, phylum, class, order, family, genus and species.			
2.5	I can create, modify and use a dichotomous key to classify organisms into groups and subgroups.			
2.6	I can observe and identify similarities and differences of particular features within and between groups of organisms.			
2.7	I can define what makes an animal a vertebrate.			
	I can distinguish the features used to classify vertebrates into five main groups and provide examples from each group.			
2.8	I can identify the distinguishing features of placental mammals, marsupials and monotremes.			
	I can identify the distinguishing features of placental mammals, marsupials and monotremes.			
2.9	I can provide examples from each phylum and explain how their features are adapted to specific functions.			
	I can provide examples from each phylum and explain how their features are adapted to specific functions.			
2.10	I can explain how the presence, absence or patterns in structural or reproductive structures can be used to classify plants.			
	I can explain how specific adaptations in plants can enhance their chances of survival.			
2.11	I can describe the variety of unique and diverse Australian plants.			
	I can identify the floral emblem for each Australian state and territory.			
2.12	I can explain why algae, fungi and lichens are no longer classified as members of the plant kingdom.			

learnon

Post-test	Topic 2 Post-test
eWorkbook	Topic 2 eWorkbook
Digital document	Key terms glossary

2.13 Activities

learnon

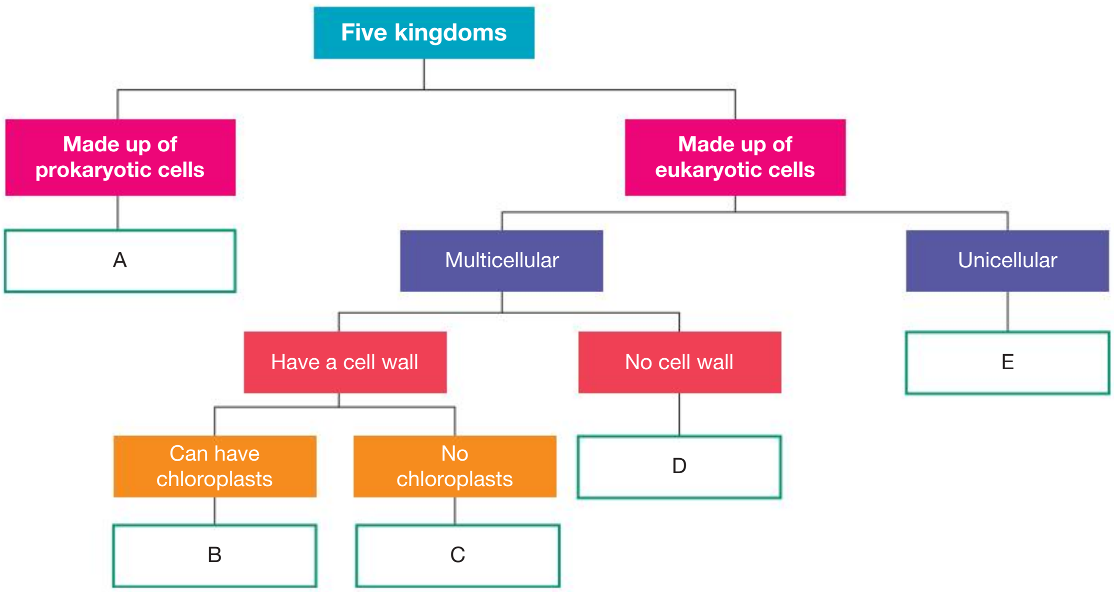
2.13 Review questions

LEVEL 1	LEVEL 2	LEVEL 3
1, 3, 4, 7, 10, 13, 15	2, 5, 6, 8, 9, 11, 12, 16, 19	14, 17, 18, 20, 21

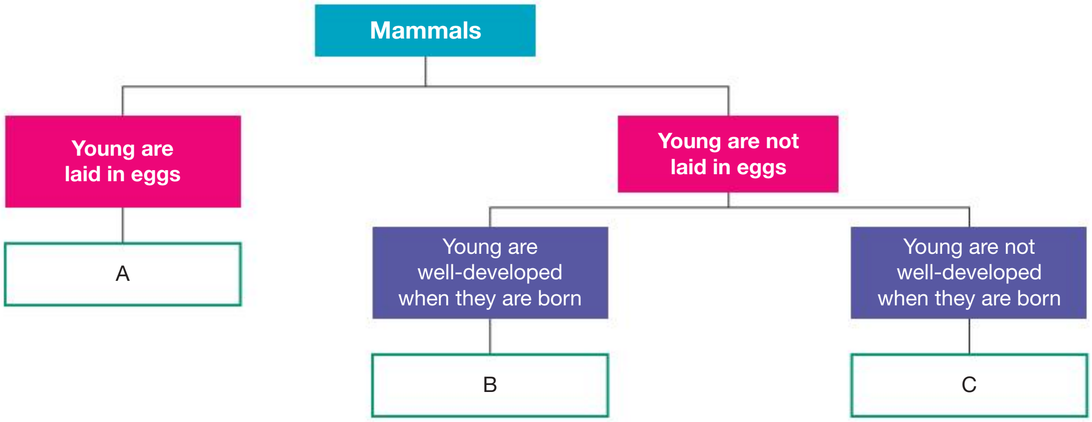
Remember and understand

1. a. **Identify** whether the following statements are true or false.
   i. Plants don't need energy because they make their own.
   ii. All living things are made up of cells.
   iii. Classifying things into groups can make them easier to remember, describe and identify.
   iv. Cell structure can be used to classify organisms into the five different kingdoms.
   v. The order of the classification hierarchy is: kingdom, phylum, order, family, class, genus, species.
   vi. Binomial nomenclature is a naming system in which each species has a name made up of two words; the first is its genus name and the second is the descriptive name.

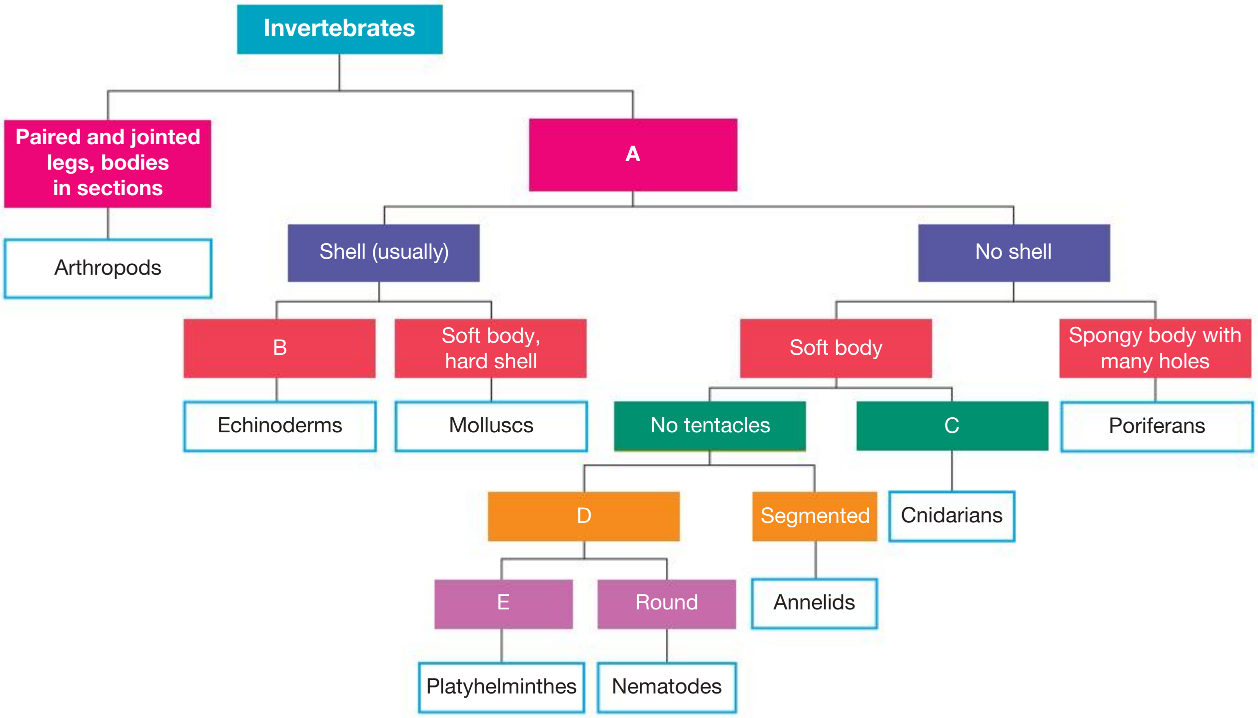
   b. Rewrite any false statements to make them accurate and true.
2. a. **Describe** the system of binomial nomenclature.
   b. **State** the species name for humans.
   c. **List** the seven levels of classification hierarchy in order from kingdom to species.
   d. **Identify** which group contains more living things: the kingdom 'Animalia' or the order 'Primate'.
   e. As you move from kingdom to species, do its members have more or less in common?
3. **Suggest** the identity of kingdoms A–E in the following key.



4. **Suggest** the identity of the type of mammals A–C in the following key.



5. **Suggest** the identity of the missing features A–E in the following key.



6. **Identify** an example for each of the following plant phylums.
   a. Bryophytes
   b. Pteridophytes
   c. Angiosperms
   d. Gymnosperms
7. Using the information in figure 2.34, **identify** the following:
   a. I have no hair, scales or feathers.
   b. I have scales and gills, but not feathers.
8. Using the information in figure 2.46, **identify** the following:
   a. I have four pairs of legs on my thorax.
   b. My tubular body has two pairs of legs on each segment.

Apply and analyse

9. **Describe** how clues in the prefixes and suffixes of scientific words can help you predict their meanings. Give an example.
10. **Explain** why scientists classify living things.
11. **Distinguish** between:
    a. radial symmetry, bilateral symmetry and asymmetry
    b. endoskeletons and exoskeletons
    c. invertebrates and vertebrates.
12. a. **List** the kingdom, phylum, class, order, family, genus and species of humans.
    b. **Describe** what organisms in the same class have in common.
13. Use figure 2.46 to **identify** the group to which each of the following arthropods belongs.

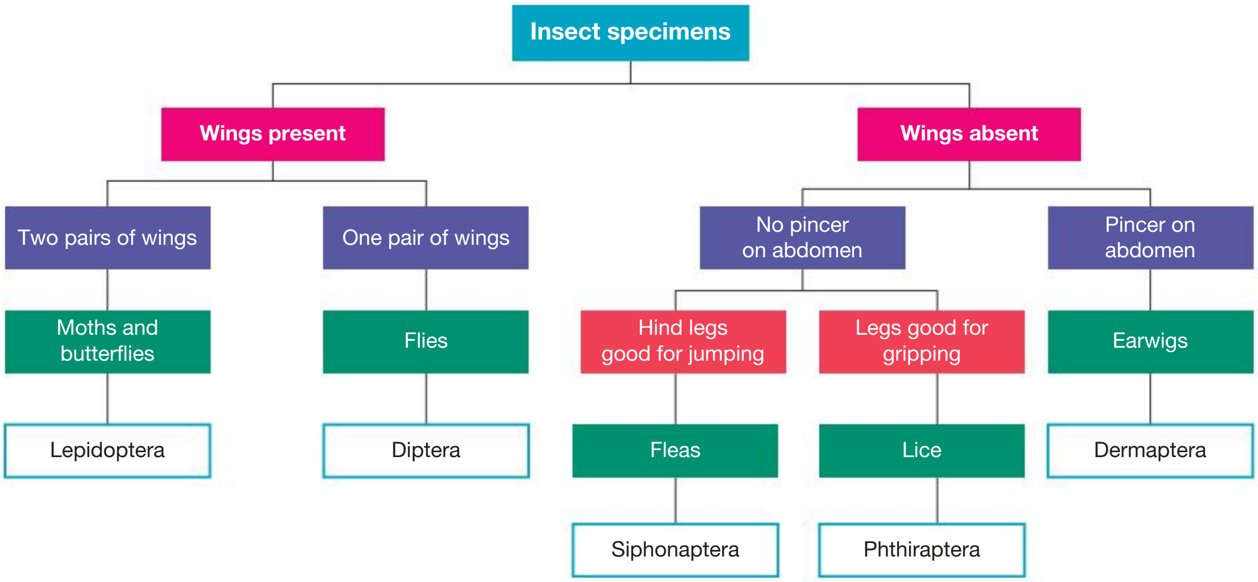
a.


b.


c.


d.


14. Use the information in the dichotomous key to complete the following questions.



a. **Identify** an example of an animal that fits each of the following descriptions.
   i. I have two pairs of wings.
   ii. My legs are good for gripping and I don’t have wings or a pincer.
b. **List** the features of an insect belonging to the Siphonaptera order.
c. **Identify** the order to which the following specimens belong.

i.


ii.


iii.


iv.


Evaluate and create

15. Use the information in figure 2.34 to **construct** Venn diagrams to show the similarities and differences between each of the following pairs.
   a. Fish and reptiles
   b. Amphibians and mammals
16. Use the information in figure 2.46 to **construct** Venn diagrams to show the similarities and differences between each of the following groups.
   a. Chilopods and diplopods
   b. Insects, arachnids and crustaceans
17. Use the information in the dichotomous key in question 14 to **construct** Venn diagrams to show the similarities and differences between each of the following pairs.
   a. Lepidoptera and Diptera
   b. Siphonaptera and Phthiraptera
18. **Investigate** branching, circular and tabular dichotomous keys.
   a. **Describe** these keys and the potential usefulness of each.
   b. Rank these keys from most useful to least useful. **Justify** your ranking.
   c. **Identify** one way in which each key could be improved.
19. SI Answer the following.
   a. **Construct** a table with the following headings.
      - Genus or species
      - Description of useful plant part
      - Beneficial effects
      - Other details
   b. Complete the table with details on the following herbs, using the information in this topic and your own research. In the Description column, you could insert a photo or drawing of the herb.
      i. Peppermint (*Mentha piperita*)
      ii. Sweet basil (*Ocimum basilicum*)
      iii. Borage (*Borago officinalis*)
      iv. Thyme (*Thymus serpyllum*)
      v. Rosemary (*Rosmarinus officinalis*)
      vi. Parsley (*Petroselinum sativum*)
   c. Reformat your table into a visual map.
   d. Select one of your herbs and find a recipe that uses it.
20. **Construct** a dichotomous key that would distinguish between these insects and enable their identification.

a. **Earwig** (Dermaptera)
b. **Dragonfly** (Odonata)
c. **Thrips** (Thysanoptera)
d. **Thysanuran** (Zygentoma)

21. Use Venn diagrams to **summarise** the five-kingdom classification system.

Answers and sample responses are available in your digital formats.

on To test your understanding and knowledge of this topic, go to your learnON title at jacplus.com.au and complete the **post-test**.

3 Ecosystems

CONTENT DESCRIPTION

Matter and energy flow through ecosystems and can be represented using models, including food webs and food pyramids; populations will be affected by changing biotic and abiotic factors in an ecosystem including habitat loss, climate change, seasonal migration and introduction or removal of species (VC2S8U04)

Source: Victorian Curriculum F–10 Version 2.0

LESSON SEQUENCE

LESSON 3.1 Overview

3.1.1 Introduction

Ecosystems are made up of living things that interact with each other as well as with their non-living surroundings.

Look at the picture of the coral reef in figure 3.1. It is just one example of an ecosystem. There are many interactions that are occurring between the different types of **organisms**. For example, you can see different types of fish swimming close to each other among the many forms of coral.

Humans can affect these interactions between different organisms. The scuba diver could swim into the area and might knock the coral with a flipper or catch some of the fish to eat for dinner.

FIGURE 3.1 A coral reef is one example of an ecosystem.

The picture also shows living things (**biotic factors**) interacting with non-living things (**abiotic factors**). There is some light shining from the Sun above that is warming the water. The sunlight also enables the plant life to grow.

Some interactions between organisms in this ecosystem involve feeding **relationships**. Larger marine animals might eat small fish; small fish might eat plants or **microorganisms** in the water.

In this topic, you will explore how organisms interact with each other, sometimes in a harmful way and sometimes in a beneficial way.

DISCUSSION

1. How many different species of living organism do you interact with or encounter in a normal day?
2. How might the types of food people eat have changed Australia's environment in the last 300 years?
3. Which species would you eradicate (remove) from Australia if you could? Why?
4. Would you consider your house or your classroom an ecosystem?
5. What are some ways that you affect different ecosystems?
6. How do living and non-living things interact in an ecosystem?

SCIENCE INQUIRY: Connected threads

Ecosystems are areas where living things (plants, animals and microorganisms) interact with non-living things (e.g. sunlight, water, air and soil). These interactions help all parts of the ecosystem to survive and stay in balance.

For example:

- Plants need sunlight, water and soil to grow.
- Animals need plants or other animals for food and water to drink.
- Non-living things like water, temperature and light can affect where animals and plants live.

Everything in an ecosystem is connected. If something changes, like there being less water or more pollution, it can affect not just one part of the ecosystem but the whole system. For example, if a plant that animals eat dies out, the animals might also struggle to survive.

1. What do you think will happen to the plants that get no water? Why?
2. How might too much water affect the plants compared to the right amount?
3. What patterns do you notice in the growth of plants with different amounts of water?
4. How does this example show the connection between living things (plants) and non-living things (water)?
5. What other questions could you ask about how non-living things like light or temperature affect plants?

Investigable questions, reasoned predictions and hypotheses can be developed in guiding investigations to identify patterns, test relationships and analyse and evaluate scientific models (VC2S8I01)

INVESTIGATION 3.1

Modelling interactions

Aim

To use a model to determine the impact of organism removal on ecosystem stability

Materials

- one large label per student
- ball of string

Method

1. Select a part of the environment and write it on a large label. Examples you could use are the Sun, temperature, wind, soil, water, light, a bee, a worm, a bird, a plant or a human. Make sure that you don't have the same part as someone else!
2. Organise yourselves into a circle.
3. Decide who is to go first. This person holds on to one end of the string and passes the ball of string to another student in the circle, while explaining their relationship to what that student represents. For example, a 'plant' may pass the string to 'light' and say, 'I need light in order to photosynthesise'.
4. Repeat the last step until you can't think of any more relationships.
5. Have someone record your string pattern on paper or the board.
6. What do you think might happen if one part of your 'circle ecosystem' is removed? Try this and discuss what happens.
7. While standing in the circle, discuss which parts of the environment you would not let go of. Include reasons for suggestions given.
8. In your circle, get all of those parts that are non-living (abiotic) to sit down. Discuss your observations.

Results

1. Draw your string pattern. Remember to give your diagram an appropriate title.
2. Note down any observations you made during this investigation.

Discussion

1. Comment on the string pattern. Are there multiple connections between each organism or only one?
2. Comment on what happened when one part of the circle was removed.
3. Which parts were considered biotic (living)? What reasons were given for these? Do you agree? What is your opinion?
4. What happened when all of the abiotic (non-living) parts sat down? What do you think would happen in a real ecosystem?

Conclusion

Summarise your findings of this investigation by completing the following.

a. Answer the research question, outlining the effect the removal of organisms had on ecosystem stability.
b. State whether your hypothesis was supported or refuted.
c. Evaluate the methodology. Are the results a reasonable representation of an ecosystem?

learnon

Pre-test	Topic 3 Pre-test
eWorkbooks	Topic 3 eWorkbook Student learning matrix
Practical investigation eLogbook	Topic 3 Practical investigation eLogbook
Digital document	Key terms glossary

LESSON 3.2 What are ecosystems?

LEARNING INTENTION

In this lesson you will:

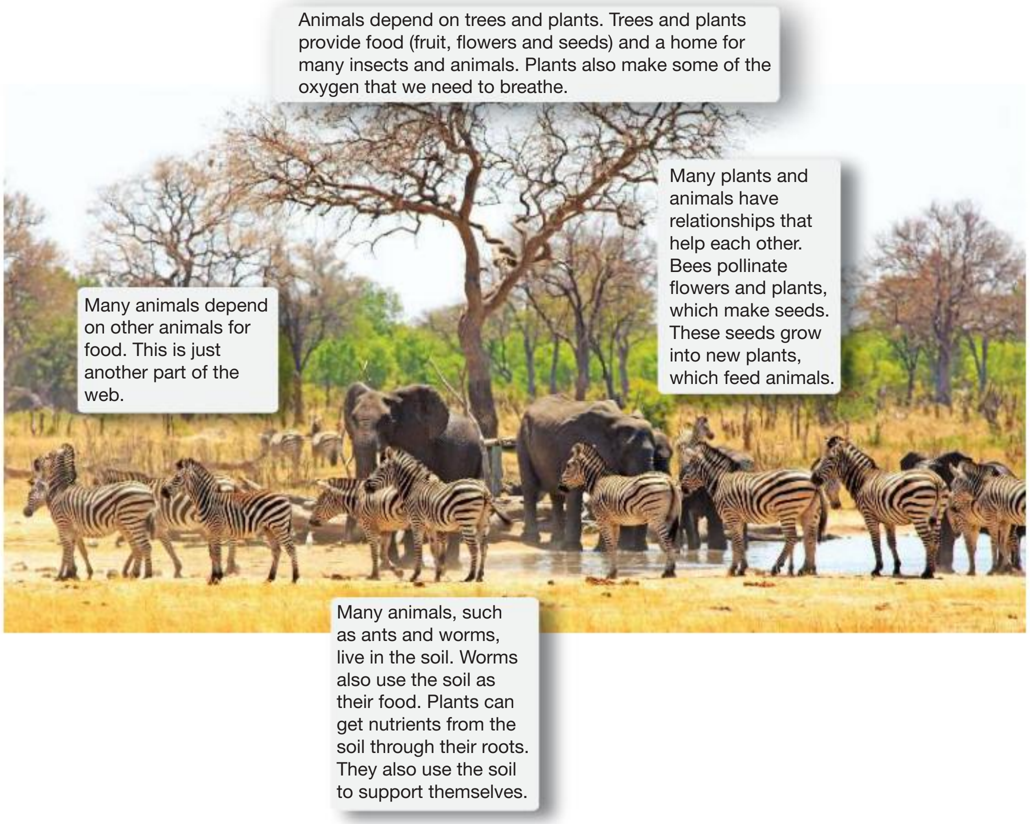
- describe ecosystems, including the way that living and non-living things interact
- describe the conditions that are best suited to specific living and non-living things.

3.2.1 Ecology

The world around you is filled with amazing diversity. Next time you go to the zoo, the beach, an aquarium or just walk outside, have a look at how many different living things there are around you. Differences between these organisms provide clues about how they survive in the environments in which they live. Whatever the differences between the organisms, they depend on each other and their environment for their survival.

The study of the interactions between these components is known as **ecology**.

FIGURE 3.2 Organisms in an ecosystem depend on each other.



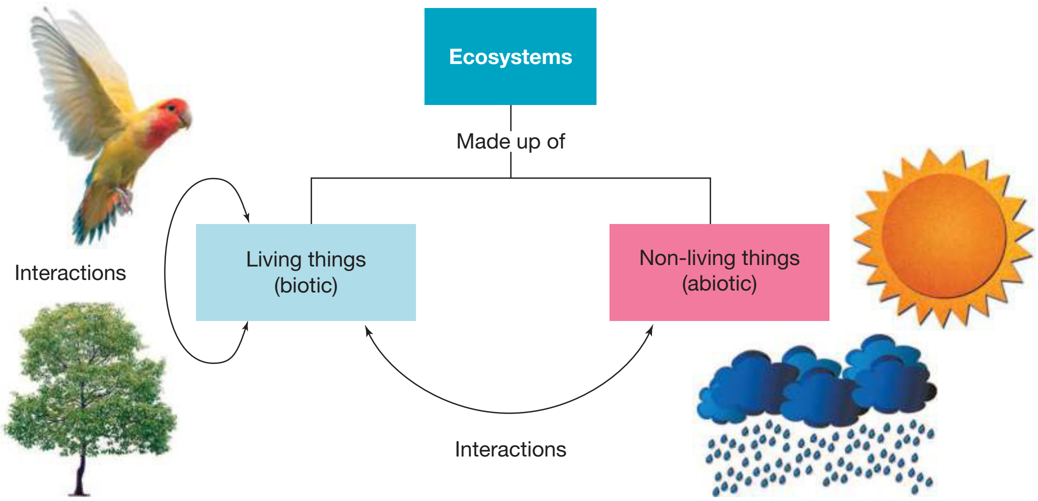
3.2.2 Ecosystems

Ecosystems are made up of living things (biotic factors) and non-living things (abiotic factors) that interact with each other. Within an ecosystem, there are interactions between the biotic factors, and between the biotic and abiotic factors. These relationships are shown in figure 3.3.

Examples of biotic factors include:
- bacteria
- worms
- plants
- snakes.

Examples of abiotic factors include:
- water
- temperature
- salt levels (salinity)
- light intensity
- oxygen levels
- pH (acidity).

FIGURE 3.3 Biotic and abiotic factors in an ecosystem interact with each other.

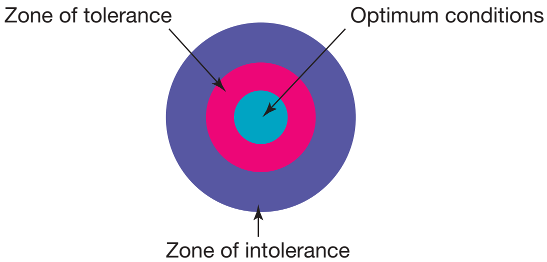


3.2.3 Abiotic factors

Abiotic factors are non-living factors that affect the conditions in a particular environment of an ecosystem. These environmental conditions can affect which types of organisms can survive. Examples of abiotic factors include salinity (amount of salt), temperature, pH (acidity), humidity, sunlight and oxygen levels. For example, the temperature of the air and water affect animals and plants living in an ecosystem. A particular animal would die if the temperature increased above 50 °C in that particular ecosystem.

Each **species** has a **tolerance range** for a particular abiotic factor. Within this tolerance range, the **optimum range** is the range in which the organism functions best. This can be thought of as a target, as shown in figure 3.4.

FIGURE 3.4 Organisms want to live in the centre of the target: the optimum conditions.



For example, a sloth's optimum temperature is in a hot climate; it cannot survive in cold conditions. Similarly, a polar bear's optimum temperature is in a cold climate; it cannot survive in hot conditions.

FIGURE 3.5 Sloths rely on the warmth of their surroundings to regulate their body temperature.

DISCUSSION

What is a human's tolerance range and optimum range for different abiotic factors?

Abiotic factors within **habitats** can influence:

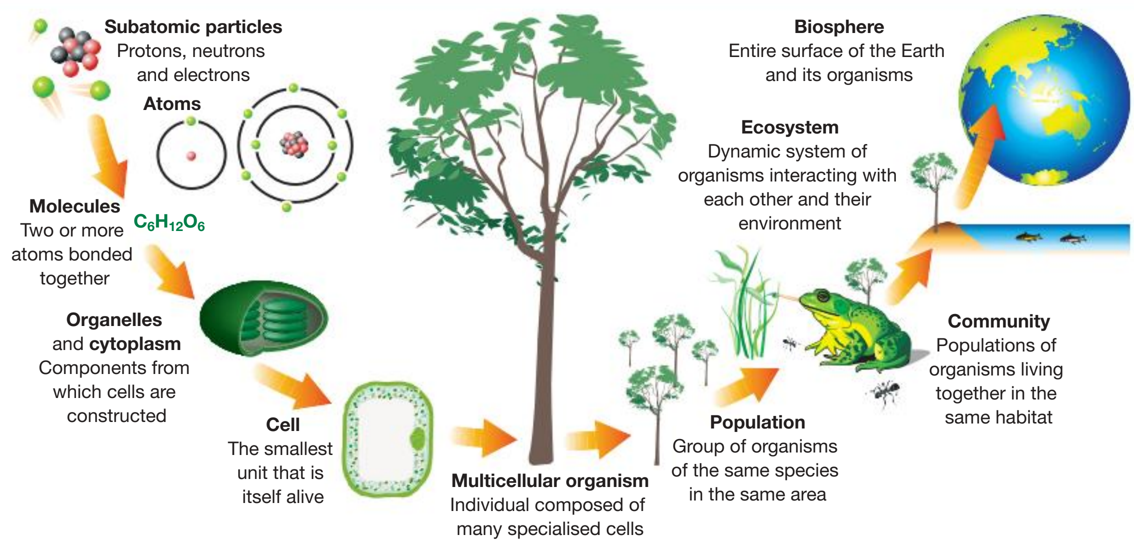
- the types of organisms living there
- where each type of organism is found within the habitat
- how many of each different kind of organism are in the habitat.

3.2.4 Biotic factors

Biotic factors are the living organisms, such as animals, plants and bacteria, that are present in an ecosystem. An example might be a **population** of zebras, which are a biotic factor (prey) for lions (predator) that hunt them for food. Some other biotic factors include **parasites**, pathogens (disease-causing organisms) and **decomposers** such as bacteria and fungi.

The biotic factors within an ecosystem can be grouped in a number of different ways. One way is in terms of their complexity, which can be seen in figure 3.6. All biotic factors are living organisms and thus are made up of cells. Organisms of the same species (those that can interbreed) can group together in different ways to form populations and communities.

FIGURE 3.6 Levels of biological organisation



Within ecosystems, the members of a **community** can be identified as being either **producers** (**autotrophs**) or **consumers** (**heterotrophs**). The feeding relationships between these groups can be shown in flow charts called **food chains**, and in diagrams showing interacting food chains, which are called **food webs**. These will be explored in lesson 3.4.

FIGURE 3.7 Members of a community

ACTIVITY: More than one school community?

How many different habitats and ecosystems are there on your school grounds? Does your school have a pond or wetlands?

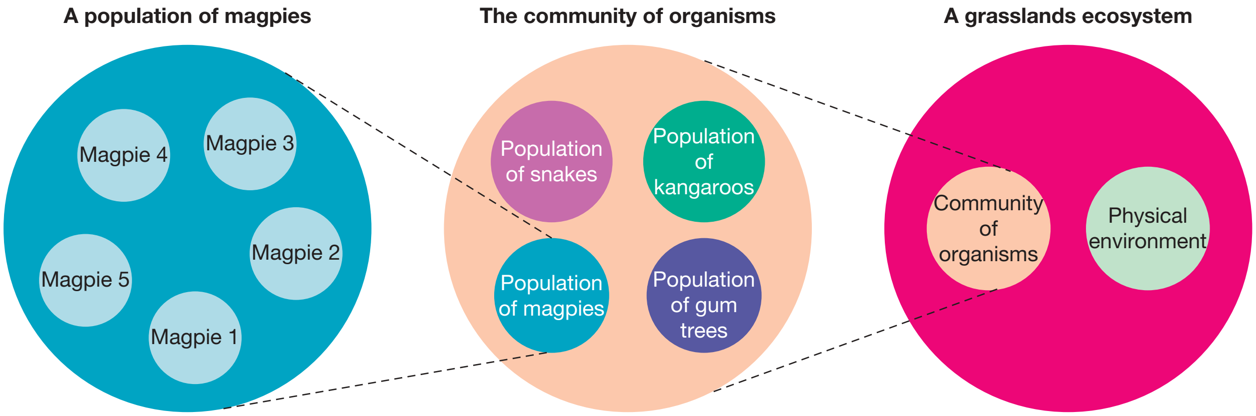
List, draw and briefly describe the different habitats and ecosystems. Ensure you include information about abiotic and biotic factors.

Levels of organisation within ecosystems

In order to explore these feeding relationships, you need to be able to distinguish between the terms ‘organism’, ‘species’, ‘population’ and ‘community’, as shown in figure 3.8. An organism is the simplest form of life. It may be made up of a single cell (unicellular) or many cells (multicellular). Organisms that can interbreed and produce fertile offspring are members of the same species. Organisms of the same species living in the same place at the same time are called populations. A group of populations that live and interact with each other in the same area is called a community. Basically, an ecosystem is made up of a community and its physical environment (biotic and abiotic factors), as shown in figure 3.9.

FIGURE 3.8 An ecosystem is a complex level of organisation.

FIGURE 3.9 Within an ecosystem, communities of organisms interact with the physical environment and abiotic factors. These communities are made up of populations of organisms. Each of these organisms is made up of at least one cell.



INVESTIGATION 3.2

Ecosystem in a bottle

Aim

To determine whether a closed ecosystem is self-sustaining

Materials

- 1 L clear plastic bottle
- scissors or knife
- masking tape
- soil or potting mix
- small plants or seedlings
- grass clippings or ground mulch (including small organisms)

Method

1. Cut the top off the bottle.
2. Pour the soil or potting mix into the bottom of the bottle.
3. Plant the seedlings into the potting mix.
4. Place the ground mulch or grass clippings over the potting mix and around the seedlings.
5. Add sufficient water to moisten the soil.
6. Put the top back on the bottle and seal it with masking tape. The bottle should be completely sealed so that no air, nutrients, animals or plants can be added or removed from the mini ecosystem for the duration of the experiment.

Results

Record your observations in a table like the one below for a duration of 2 weeks. Remember to give the table a title, such as 'Observations of ecosystem over 2 weeks'. In the 'Other comments' column, record any events such as a location or environment change, or incidents with the bottle.

Day	Observations	Other comments	Self-sustaining (Y/N)
1			
2			

Discussion

1. Comment on something that you found interesting or learned throughout your observations.
2. The living things in your mini ecosystem need oxygen to survive. Suggest why.
3. If the bottle was sealed, where did the organisms in your ecosystem get the oxygen from?
4. If you didn't add food to your bottle ecosystem throughout the investigation, where did the organisms get energy from?
5. If the ecosystem inside your bottle is balanced, the organisms within it could continue to survive for a long time without the need for you to add extra water and food.
   a. Suggest possible reasons for this.
   b. What is meant by the term 'balanced ecosystem'?
   c. Suggest events that could unbalance your ecosystem.
6. Repeatability is a measure of whether the test can be repeated under the same conditions to get similar results. Identify if this experiment was repeatable and give a reason for your response.
7. Reproducibility is a measure of whether doing the same experiment under different conditions will give the same trend in the results. Suggest a way that you could make this experiment reproducible.

Conclusion

Write a conclusion for this experiment that answers the research question, refers to whether the hypothesis was supported or refuted, and outlines whether there is confidence in the results.

3.2.5 Habitat

An ecosystem contains many habitats. A habitat is the place or location within the ecosystem where an organism lives. For example, the habitat of a frog may be a pond, for a scorpion it may be the desert and for a fish it may be the ocean. An organism's habitat provides it with appropriate environmental conditions (such as light intensity and temperature) and essential resources, such as food, water, oxygen and shelter.

FIGURE 3.10 The different habitats of three organisms: **a.** a frog **b.** a scorpion **c.** coral.

3.2 Activities

learnon

3.2 Quick quiz on | **3.2 Exercise**

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 4, 7	3, 6, 11	5, 8, 9, 10

Remember and understand

1. Match each term with its meaning.

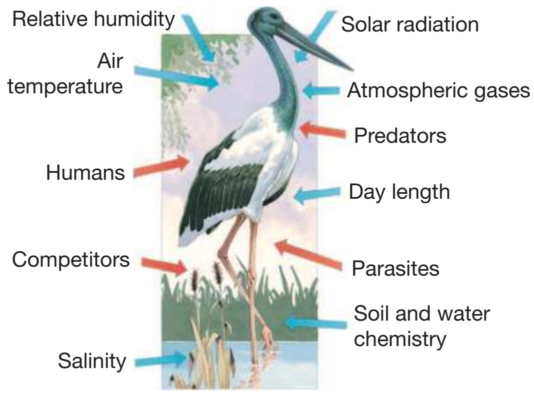
Term	Meaning
a. Ecology	**1.** The location of a population and its spread across an area
b. Ecosystem	**2.** Non-living things
c. Biotic factors	**3.** Populations of organisms living together in the same habitat
d. Abiotic factors	**4.** Groups of organisms of the same species in the same area
e. Population	**5.** The study of how living things interact with their environment
f. Habitat	**6.** Organisation made up of living things and non-living things interacting
g. Community	**7.** The range in which the organism functions best
h. Tolerance range	**8.** Living things
i. Optimum range	**9.** Place where an organism lives
j. Distribution	**10.** The number of particular organisms in an area
k. Density	**11.** The range in which the organism can survive

2. For each of the following terms, **identify** whether it is an abiotic factor, a biotic factor or a habitat.
   a. Mangrove **b.** Humans **c.** Wind **d.** Pond
   e. Rain **f.** Temperature **g.** Desert **h.** Headlice

3. Complete the following sentences that **explain** the difference between key terms.
   a. Abiotic factors are ______________; biotic factors are ______________.
   b. Distribution refers to the ______________ of organisms; density refers to the ______________ of organisms.
   c. Optimum range is the range in which an organism functions ______________; tolerance range is the range in which an organism can ______________; the range of intolerance is the range in which an organism ______________ survive.
4. Order the following in terms of their complexity, from simplest to most complex.
   organism, ecosystem, population, species, cell, atom, community
5. **Outline** the relationship between ecosystems, abiotic factors and biotic factors.

Apply and analyse

6. a. **List** three biotic and three abiotic factors that are part of the ecosystem in which you live.
   b. Select one of these biotic or abiotic factors and **explain** the possible consequences if it changed.
   c. **Suggest** how any negative consequences might be minimised.
7. Draw an animal and use two different-coloured arrows, one for abiotic factors and one for biotic factors (as shown in the figure), to add examples of factors that can affect its survival.



8. Select one of the following abiotic factors and find out more about how it affects the survival of a particular organism.
   - pH (acidity)
   - salinity
   - temperature

Evaluate and create

9. SI Secondary salinity is rising salinity due to human activity.
   a. What human actions lead to secondary salinity?
   b. **Investigate** examples of research that Australian scientists are undertaking in their search for possible solutions to the threat of rising salinity within many of our ecosystems. **Outline** two examples of these. Make sure to include the source of your information.
   c. **Compare** and **contrast** these two research responses to the salinity problem and **explain** which you think is more likely to help with rising salinity.
10. SI a. **Suggest** a question related to your local habitats or ecosystems that you could research using what you have learned in this lesson.
   b. **List** the materials and **outline** the method for your investigation. Submit your proposal to your teacher for approval.
   c. Perform your investigation (or research expected results), presenting your data in appropriate formats.
   d. **Discuss** and **explain** your results, relating them back to your research question.
11. SI Human activity can result in changes to the abiotic factors in habitats, which can affect the survival of other organisms. For example, burning wood and fossil fuels (such as coal) releases oxides of sulfur and nitrogen that can react with water in the atmosphere, forming sulfuric and nitric acid, which can then fall back to Earth's surface as acid precipitation, such as acid rain. Acid rain can decrease the pH of aquatic ecosystems and affect organisms living within it.
   What do you think is the impact of acid rain on aquatic ecosystems? **Explain**.

Answers and sample responses are available in your digital formats.

LESSON 3.3 Relationships in ecosystems

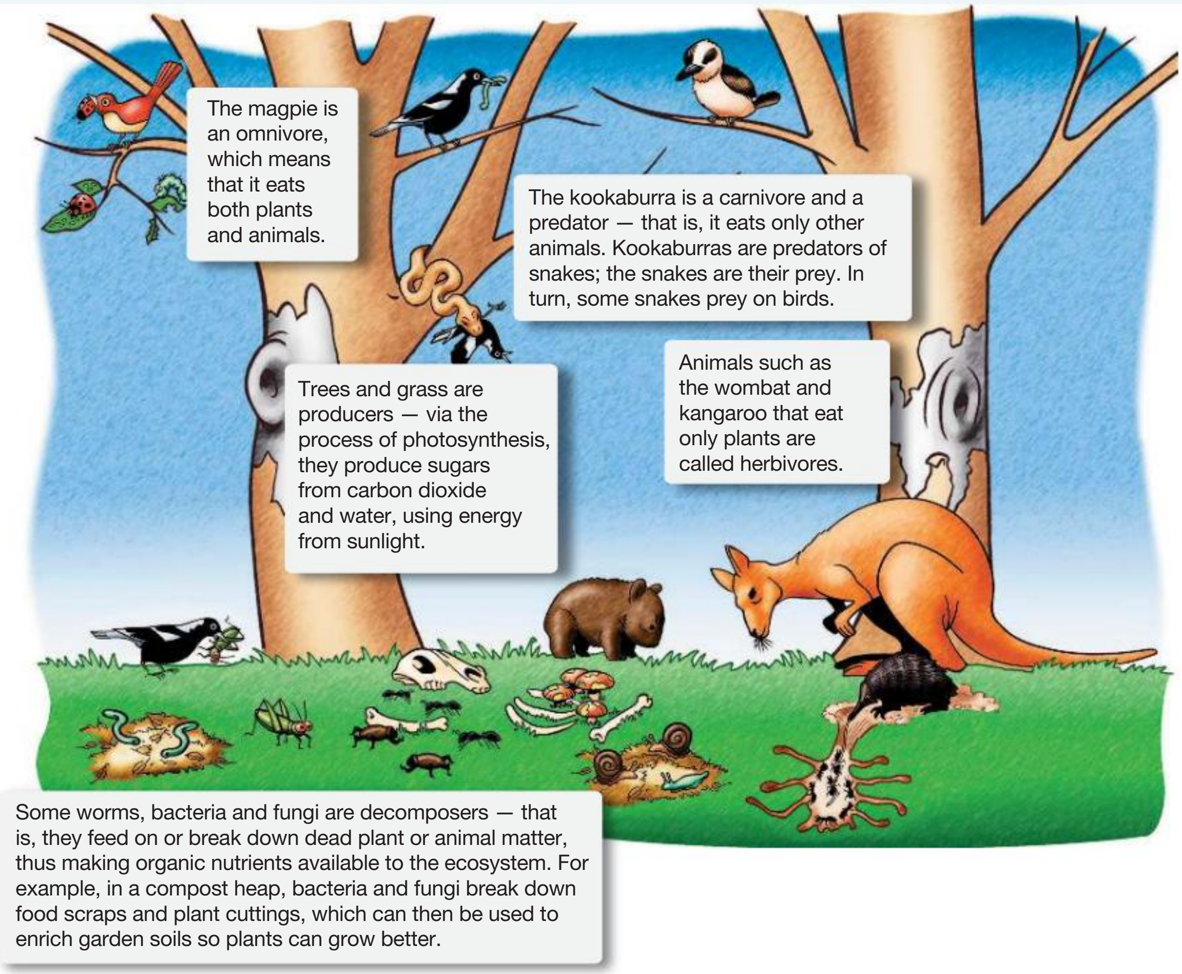
LEARNING INTENTION

In this lesson you will:
- understand that ecosystems are made of living things interacting with each other through feeding relationships
- identify and classify producers, consumers and relationships.

3.3.1 Interacting through feeding relationships

If you want to get into the 'zone' to effectively think and learn about ecosystems, you need to focus on relationships and interactions. To get started, carefully observe figure 3.11. How many different types of interactions can you see occurring?

FIGURE 3.11 Within an ecosystem, organisms interact with each other and with their non-living environment.



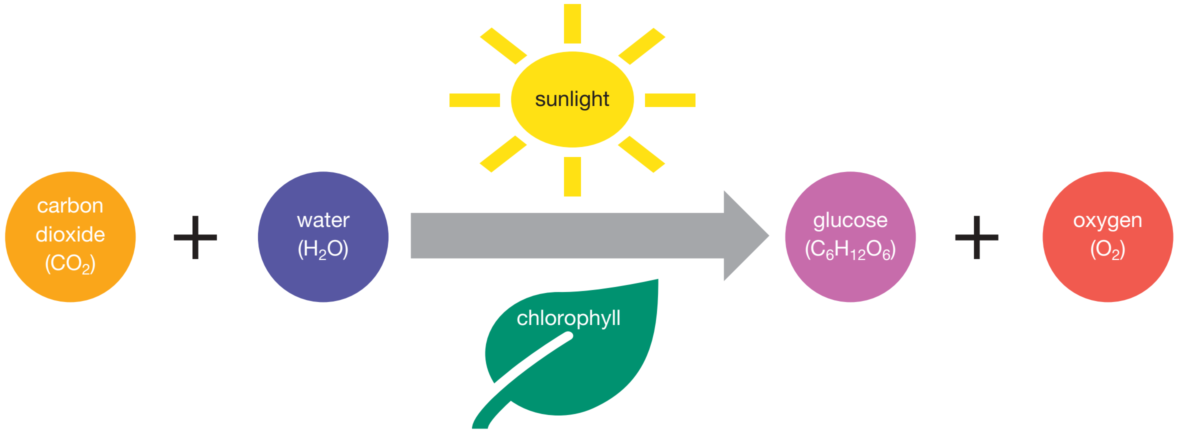
Ecosystems are made up of living and non-living things that interact with each other. For example, plants use energy from the Sun, some animals eat the plants and some animals eat other animals. It is through feeding relationships that energy flows through ecosystems and matter can be recycled.

3.3.2 Producers

Producers within ecosystems are essential because they are at the base of the food chain. They are organisms such as plants that can make their own food from their non-living environment. Many producers achieve this by using a process called **photosynthesis**. This process is summarised in figure 3.12.

Did you know that life on Earth is solar-powered? The source of energy in all ecosystems on Earth is sunlight. Producers, such as plants and algae, are green because they contain the green pigment **chlorophyll**. Plants are responsible for capturing light energy using chlorophyll (or other light-capturing pigments). They then use this light energy to convert carbon dioxide and water into glucose. Carbon dioxide and water are examples of **inorganic** matter. Glucose is described as being **organic** because it contains carbon bound to hydrogen.

FIGURE 3.12 The inputs and outputs of photosynthesis



Plants can convert glucose produced by photosynthesis into other essential organic substances. This means that they do not need to feed on other organisms. This is why they are often referred to as autotrophs ('self-feeders'). Glucose is vital for organisms. It is broken down in our cells to release energy through a process known as **cellular respiration**.

INVESTIGATION 3.3

Do all leaves contain the same pigments?

Aim

To determine whether all leaves contain chlorophyll

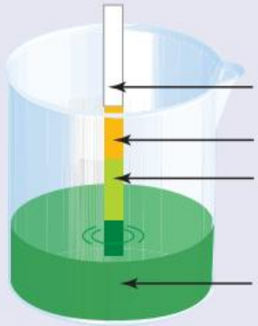
Materials

- large beaker
- hotplate
- at least three different types of leaves (geranium, hydrangea, lettuce, spinach and silverbeet cuttings are excellent)
- metal tongs
- large test tube or small beaker
- methylated spirits
- test tube holder
- stirring rod
- clear plastic wrap
- medium-sized beaker
- filter or chromatography
- paper
- coloured pencils
- digital camera, tablet or smartphone
- ruler

CAUTION: Methylated spirits is toxic and extremely flammable.

Method

1. Half-fill the large beaker with water and bring to a gentle boil on the hotplate. This large beaker will serve as a water bath.
2. Soften two or three leaves by dipping them with tongs into the hot water for 10 seconds.
3. Place the leaves into a test tube or small beaker and cover them with 30–40 mL of methylated spirits. Use a test tube holder to hold the test tube or small beaker upright in the water bath, so that its contents do not spill into the water.
4. When the leaves turn pale and the methylated spirits deepens in colour, remove the test tube or small beaker from the water bath.



5. Decant the coloured methylated spirits into the medium-sized beaker. Allow the liquid to cool for 10 minutes.
6. Suspend a long, narrow strip of chromatography paper or filter paper in the beaker so that just 2–5 mm sits in the liquid, as shown in the diagram. Fold the paper over the side of the beaker to hold it in place.
7. Remove the strip of paper from the methylated spirits before the colours reach the top of the paper.

Results

1. Construct a table like the one below to summarise your detailed observations.

Chromatography strip observations	Leaf A	Leaf B	Leaf C
Colours observed and distance each colour moved up strip			
Total number of colours observed			

2. For each leaf, observe the colours produced and measure their distances along the strip. Record these detailed observations and summarise them in your table. Refer to the photos in the results.
3. Identify which observations can be graphed and construct a graph to display a summary of your results. Remember to give the graph a title.

Discussion

1. Use specific examples from your observations to answer the following questions.
   a. How many different colours did you identify? What were they?
   b. Which colour was the most dominant? Did all the leaves contain it?
   c. Was there any pattern between the distance that a colour moved on the strip and its colour? If so, what was it?
   d. Did all of the leaves contain the same coloured pigments?
2. Answer the following questions about your leaf pigment investigation.
   a. Identify the independent variable of the investigation.
   b. Identify which variables were controlled (kept constant or the same) for all leaf samples.
   c. A valid test is one where only one variable changes. Was this test valid?
   d. Suggest two ways in which the investigation could be improved.
3. a. Suggest a hypothesis or research question that you could use this equipment (with possible modifications) to investigate.
   b. Outline the procedure you would use to investigate your hypothesis.
4. Find out possible names for the pigments that you have separated.
5. Discuss what safety concerns you considered in this investigation.

Conclusion

Write a conclusion for this investigation, remembering to include:

a. an answer to the research question
b. whether your hypothesis was supported or refuted
c. the confidence you have in your results.

3.3.3 Consumers

Consumers lack the chlorophyll required for photosynthesis; animals are unable to make their own food and are called heterotrophs ('other-feeders'). Because they obtain their nutrition from consuming or eating other organisms, they are called consumers. Consumers are divided into different types on the basis of their food source and how they obtain it.

- **Herbivores** eat plants and are often described as being **primary consumers** because they are the first consumers in a food chain; for example, koalas (see figure 3.13).
- **Carnivores** eat other animals and are described as **secondary consumers** or **tertiary consumers** in food chains or webs; for example, Tasmanian devils (see figure 3.14).
- **Omnivores** eat both plants and animals; for example, humans.
- **Detritivores** feed on the tissue of dead or decaying organisms; for example, dung beetles.

FIGURE 3.13 Koalas are herbivores.

FIGURE 3.14 Tasmanian devils are carnivores.

Decomposers

While producers convert inorganic materials into organic matter, decomposers convert organic matter into simple inorganic materials. This is an example of how matter can be recycled within ecosystems so that they remain sustainable.

Fungi and bacteria are common examples of decomposers within ecosystems. These heterotrophs obtain their energy and nutrients from dead organic matter. As they feed, they chemically break down the organic matter, converting it into simple inorganic forms or mineral nutrients. Their wastes are then returned to the environment to be recycled by producer organisms.

FIGURE 3.15 Detrivores, such as **a.** dung beetles, and decomposers, such as **b.** fungi and **c.** bacteria, play an important role in ecosystems.

3.3.4 Interactions between species

The **ecological niche** of each species is its specific role in the ecosystem. This niche includes its:

- habitat (where it lives within the ecosystem)
- nutrition (how it gets its food)
- relationships (interactions with both its own species and other species within the ecosystem).

Competition, predator–prey and symbiotic relationships are all examples of different types of interactions between organisms.

Competition

Organisms in a similar niche within an ecosystem compete when their needs overlap. Competition can be between members of different species (**interspecific**) for the same resource (such as food, mates or shelter), or between members of the same species (**intraspecific**).

FIGURE 3.16 a. Male peacocks compete for mates with other peacocks using their colourful tails. **b.** Seals compete for mating territory. **c.** Plants in a rainforest compete for space and sunlight.

Predator–prey relationships

In a predator–prey relationship, one species kills and eats another species. The predator does the killing and eating, and the prey is the food source. Examples of predator–prey relationships include those between eagles and rabbits, between fish and coral polyps, between spiders and flies, and between snakes and mice.

FIGURE 3.17 Domestic cats, owls and crocodiles all act as predators by preying on other animals.

Symbiotic relationships

Some organisms of different species can have a very close relationship, with at least one of them benefiting; sometimes, their survival depends on it. This type of relationship is called **symbiosis**. A symbiotic relationship is an ongoing relationship between members of different species. The different types of symbiotic relationships, shown in table 3.1 and figure 3.18, are grouped on the basis of whether one of the species is harmed (**parasitism**), both species benefit by the association (**mutualism**), or one species benefits and the other is neither harmed nor benefits (**commensalism**).

TABLE 3.1 Types of symbiotic relationships

Interaction	Species 1	Species 2
Parasitism	✓ (Parasite)	✗ (**Host**)
Mutualism	✓	✓
Commensalism	✓	0

✓ = benefits by the association; ✗ = harmed by the association; 0 = no harm or benefit

FIGURE 3.18 Different types of symbiotic relationships **a.** Parasitism: parasites such as tapeworms harm their host. **b.** Mutualism: oxpeckers eat ticks and other parasites living on the skin of a hippopotamus, which benefits both species. **c.** Commensalism: a remora hitches a ride on a shark and thus travels without burning energy.

Parasite–host relationships

Parasites are organisms that live in or on a host, from which they obtain food, shelter and other requirements. Although the host may be harmed in this interaction, it is not usually killed. Some parasites are pathogens, meaning organisms that cause disease. This means that the functioning of their host is in some way impaired or damaged, resulting in disease.

Mutualism

A relationship in which both species benefit is called mutualism. In a lichen, fungi and algae grow together, as seen in figure 3.20. While the fungi provide water and protection for the algae, the algae provide food for the fungi.

FIGURE 3.19 A non-pollinating fig wasp parasitoid

FIGURE 3.20 Fungi and algae form a mutual relationship to create lichen.

Commensalism

Commensalism is a relationship in which one organism benefits and the other is unaffected. Clownfish, for example, get food and protection from the sea anemone, as seen in figure 3.21.

FIGURE 3.21 Commensal clownfish and host anemone

3.3 Activities

learnon

3.3 Quick quiz on	3.3 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 3, 5, 7, 10	2, 4, 8, 11	6, 9, 12, 13

Remember and understand

1. Match each term with its meaning.

Term	Meaning
a. Producers	**1.** Organisms that break down dead organisms
b. Omnivores	**2.** Animals that eat only plants
c. Herbivores	**3.** Consumers that eat both plants and animals
d. Carnivores	**4.** Organisms that can produce their own food
e. Decomposers	**5.** Animals that eat other animals

2. **Identify**:
   a. the source of all energy in ecosystems
   b. the name of the green pigment that captures light energy
   c. which organisms trap the energy from sunlight.

3. Provide two examples of each of the following.
   a. Herbivores
   b. Carnivores
   c. Decomposers
4. **Distinguish** between the following.
   a. Autotroph and heterotroph
   b. Predator and prey
   c. Producer and decomposer
   d. Parasitism, mutualism and commensalism
5. **Construct** a sentence that uses each of the following lists of terms. (You may use the plural or singular term.)
   a. Producer, light energy, chlorophyll, carbon dioxide, water, glucose, oxygen, plant
   b. Organism, species, population, community, ecosystem, physical environment
6. **Describe** the relationship between each of the following pairs.
   a. Consumers and heterotrophs
   b. Producers and consumers
   c. Herbivores, carnivores and omnivores
   d. Predator and prey

Apply and analyse

7. **Explain** the difference between producers and consumers. Provide at least five examples of each.
8. **Identify** each of the following relationships as competition, predator–prey, mutualism, parasitism or commensalism.
   a. Cats hunt and eat mice.
   b. Aphids suck the sap from a rose bush.
   c. Male kangaroos fight each other for the attention of females.
   d. Termites contain a fungus in their stomach that digests the wood they eat. The fungus cannot live anywhere else. Without the fungus, the termites would not survive.
   e. Lampreys are fish that attach themselves to sharks. They feed on scraps of the shark's food and the shark is unaffected.
9. a. **List** three examples of predators and then match them to their prey.
   b. **Suggest** structural, physiological and behaviour features that may assist:
      i. predators in obtaining food (e.g. webs, teeth, senses, behaviour)
      ii. prey in avoiding being eaten (e.g. camouflage, mimicry, behaviour, chemicals).
10. In the interaction between a clownfish and a sea anemone, which is the commensal?

Evaluate and create

11. **Construct** a Venn diagram or summary table to show some of the similarities and differences between carnivores and herbivores.
12. **Construct** a mind map to show the links between and key points about the following: producers, consumers, carnivores, herbivores, omnivores, decomposers, predators, prey.
13. Some clovers (*Trifolium*) produce cyanide. **Suggest** how this may protect them against being eaten.

Answers and sample responses are available in your digital formats.

LESSON 3.4 Food chains and food webs

LEARNING INTENTION

In this lesson you will explain how energy flows into and out of an ecosystem through the feeding relationships that can be described in food chains and food webs.

Feeding relationships between organisms within an ecosystem can be described in food chains and food webs.

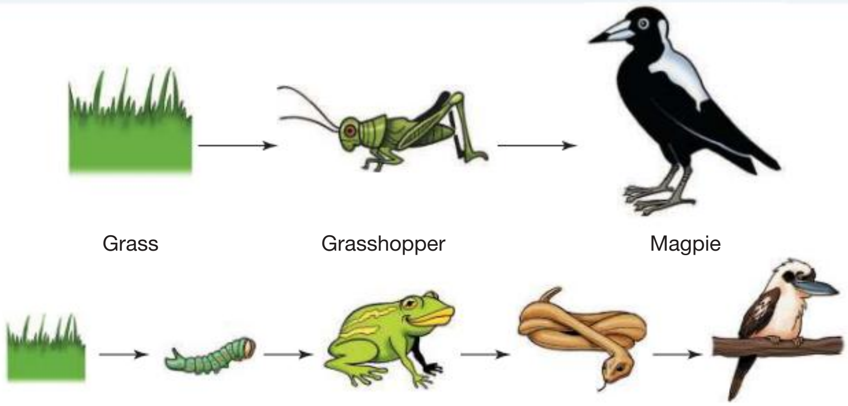
3.4.1 Food chains

A food chain is a linear chain that starts with a producer and ends with a decomposer. It represents 'who eats whom'. To demonstrate a food chain, the names of these organisms are linked by arrows. The arrow in a food chain indicates 'is eaten by' and describes the direction of the flow of energy. The arrow points to the animal that will be eating it. In figure 3.22, the arrow between the grasshopper and magpie points to the magpie, because it is the magpie that eats the grasshopper and gains energy from it.

3.4.2 Order in chains

Each member of a food chain can be described as a consumer or producer. The type of consumer an organism is depends on the organism it eats.

FIGURE 3.22 Two examples of food chains



In the food chains in figure 3.22:
- grass is the producer
- the consumer that eats the producer is called a primary consumer (e.g. the grasshopper)
- the consumer that eats a primary consumer is called a secondary consumer (e.g. the frog)
- the consumer that eats the secondary consumer is a tertiary consumer (e.g. the snake).

The relationship between producers, primary, secondary and tertiary consumers can be seen in figure 3.23. We can also use the term first-order, second-order and third-order to describe primary, secondary and tertiary consumers.

FIGURE 3.23 The food chain runs from producer through to tertiary consumer.

Producers → Primary consumer → Secondary consumer → Tertiary consumer

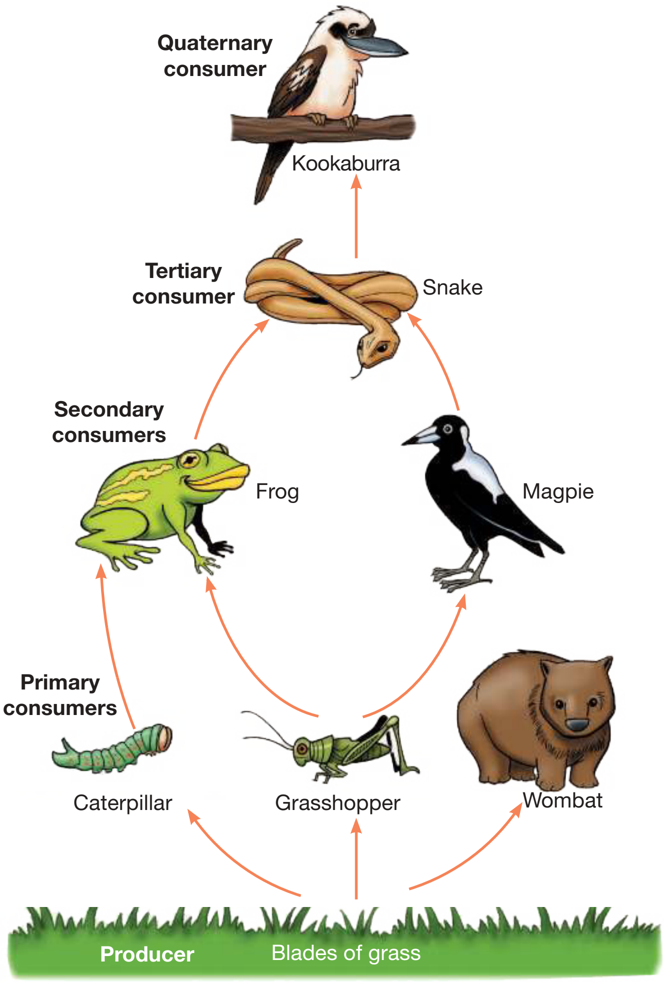
Note that primary consumers can also be called secondary producers, because they produce **biomass** for their predators, the secondary consumers. These secondary consumers can in turn also be called tertiary producers, because they also produce biomass for their predators (the tertiary consumers). The term 'producer' is only used for primary producers, which use photosynthesis to produce their own food.

3.4.3 Food webs

Interconnecting or linked food chains make up food webs. Each step in a food chain is called a **trophic level**. In the food web in figure 3.24:

- grass blades are producers
- the caterpillar, grasshopper and wombat are all primary (first-order) consumers
- the frog and magpie are secondary (second-order) consumers
- the snake is a tertiary (third-order) consumer
- the kookaburra is a quaternary (fourth-order) consumer.

FIGURE 3.24 Multiple food chains result in a food web.



Depending on the feeding relationships within a food web, organisms can hold more than one position. For example, if the kookaburra ate the caterpillar, it could also be considered as a secondary consumer.

If one of the organisms in a food web is removed, or a new organism is introduced, other organisms in the food web may be affected.

For example:

- What do you think the effect might be if the grasshoppers were removed from this ecosystem?
- What if all of the kookaburras died?
- What do you think might happen to the numbers of snakes?
- What implications might this have on the other organisms in this food web?

DISCUSSION

Consider the feeding relationships between the organisms in the food web in figure 3.24. How many different food chains can you see between the organisms in this ecosystem?

3.4.4 Visiting a rock pool

Carefully study the rock pool in figure 3.25. There are many different feeding relationships within this ecosystem. Two examples of food chains are shown in figure 3.26.

FIGURE 3.25 Different relationships in a rock pool

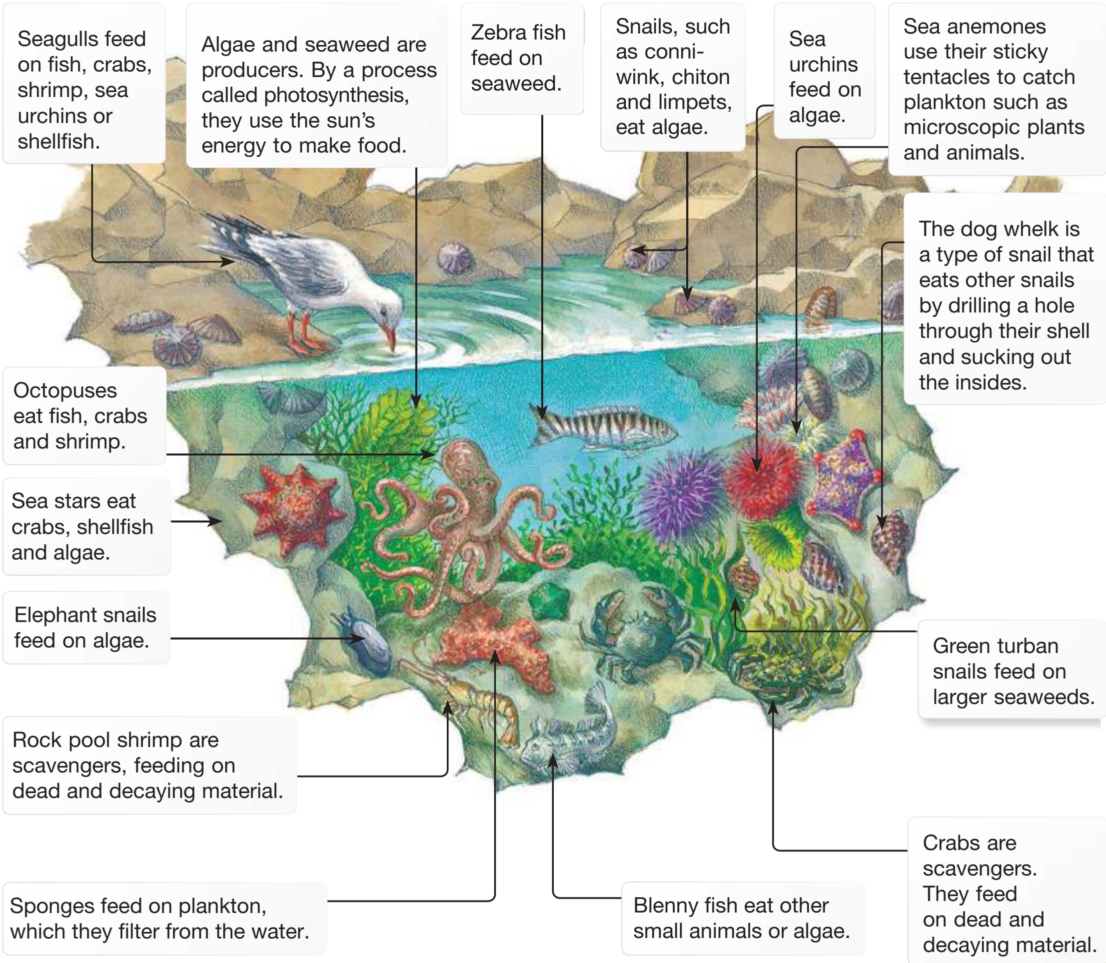
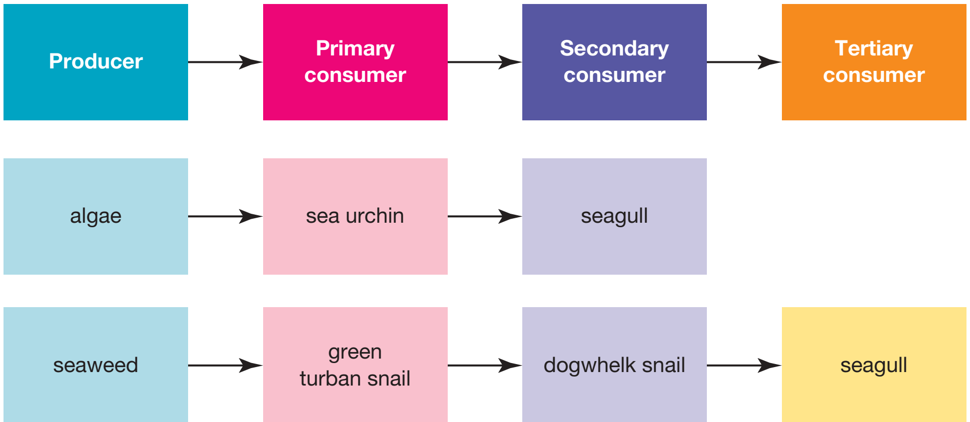


FIGURE 3.26 Two examples of food chains in a rock pool



ACTIVITY: Make a food web

Construct a food web using students connected by pieces of string. Make up one of your own by discussing it in a group and planning it out on a large piece of paper.

Pull on one string and see how it affects other organisms. If you feel a tug on a string you are holding, then pull on all the other strings you are holding.

1. Explain why some of the organisms felt the tug.
2. Explain why the other organisms did not feel the tug.
3. List two strengths in the design of this investigation.

3.4 Activities

learnon

3.4 Quick quiz on | **3.4 Exercise**

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3, 8, 11, 18	4, 5, 7, 12, 15, 16, 17	6, 9, 10, 13, 14, 19

Remember and understand

1. Match each term with its meaning.

Term	Meaning
a. Food chain	**1.** A herbivore (eats plants or algae) in an ecosystem
b. Food web	**2.** An animal that eats primary consumers
c. Primary producer	**3.** Shows the interconnected feeding relationships within an ecosystem
d. Primary consumer	**4.** An autotroph, such as plants or algae, which collectively make up the first trophic level in an ecosystem
e. Secondary consumer	**5.** A pathway along which food is transferred from producers to the next trophic level, and so on

2. **State** the alternative term used for:
   a. primary consumer
   b. secondary consumer
   c. tertiary consumer.
3. Provide an example of each of the following.
   a. Food chain
   b. Food web
   c. Primary producer
4. **Distinguish** between each of the following pairs.
   a. Primary producer and primary consumer
   b. Food chain and food web

Apply and analyse

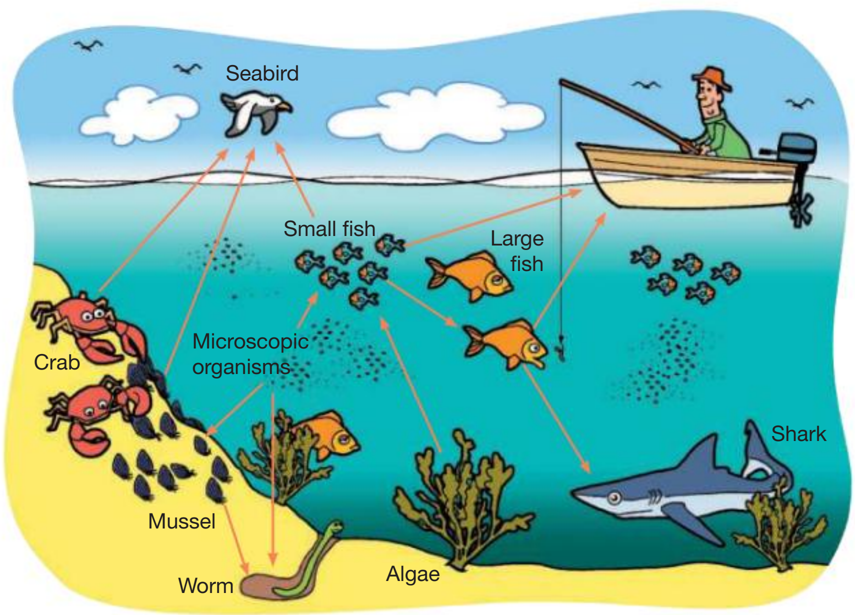
5. Copy and complete the following sentences:
   a. The feeding relationship of an _______________ is shown in a food _______________, and the feeding relationships in the community of an _______________ is displayed in a food _______________.
   b. A plant is a _______________ producer and passes 10 per cent of its energy to the caterpillar, a primary _______________.
6. Write a short response to each of these 'what if' statements.
   a. The Sun stopped shining.
   b. All plants died.
   c. There were no decomposers.
   d. There were no carnivores.
   e. There were no herbivores.
   f. There were no pollinators.
7. Write down a food chain in which you are:
   a. a primary consumer
   b. a secondary consumer
   c. a tertiary consumer.
8. Give an example of each of the following.
   a. Competition between two carnivores of different species
   b. Competition between two herbivores of different species
   c. A predator and its prey
9. Why do food chains rarely contain more than three levels of consumer?
10. **Describe** a situation in which an organism can be both a second-order (secondary) consumer and a third-order (tertiary) consumer in a food web.

Evaluate and create

11. Use information from figure 3.25 to:
    a. **identify** a primary producer
    b. **identify** two secondary consumers
    c. **identify** two tertiary consumers
    d. **identify** a detritivore or scavenger
    e. **construct** two food chains
    f. **construct** a food web.
12. Draw a food chain that contains a fifth-order consumer.
13. SI Genevieve and Callum made some observations over a period of a week about the feeding habits of a number of organisms in a small pond. Their results are listed here.
    - Snails eat water plants and algae.
    - Tadpoles eat algae.
    - Small fish eat snails, algae and water plants.
    - Larger fish eat snails, small fish and tadpoles.

a. **Construct** a food web using the information provided. Start with the producers at the bottom and work upwards. Make sure your arrows face the right way.
b. Which organisms are the producers?
c. Which organisms are primary consumers?
d. Which organisms are both secondary and tertiary consumers?
e. Which organism is an omnivore?
f. Which organisms are predators of the snail?
g. Which organisms are competitors of the tadpoles?
h. What would happen to the water plants and the larger fish if the snails increased in number?
i. What would happen to the snails and the larger fish if the small fish disappeared?

14. Draw a diagram representing a food chain in a parasite–host feeding relationship. How is it different from the predator–prey food chain examples in figure 3.26?
15. Draw a diagram to show the role of decomposers in a food web.
16. Use a mind map, flowchart or another visual tool to **describe** how energy flows through an ecosystem. Add colour and diagrams to your map.
17. For the food web shown below:
    a. **construct** three different food chains
    b. **identify** a producer
    c. **identify** a primary consumer
    d. **identify** a secondary consumer
    e. **identify** a tertiary consumer
    f. **identify** a decomposer.



18. Create a food web using the following organisms: lion, zebra, hyena, grass, snake, bug, grass, meerkat. You may wish to research what each organism consumes.
19. Draw a food web for a community of organisms in one of the following: your own garden, a forest, a desert, a river or a marina.

Answers and sample responses are available in your digital formats.

LESSON 3.5 Energy flows

LEARNING INTENTION

In this lesson you will:
- explain how energy flows into and out of an ecosystem via the pathways of food webs
- explain how ecosystems have their own system of recycling.

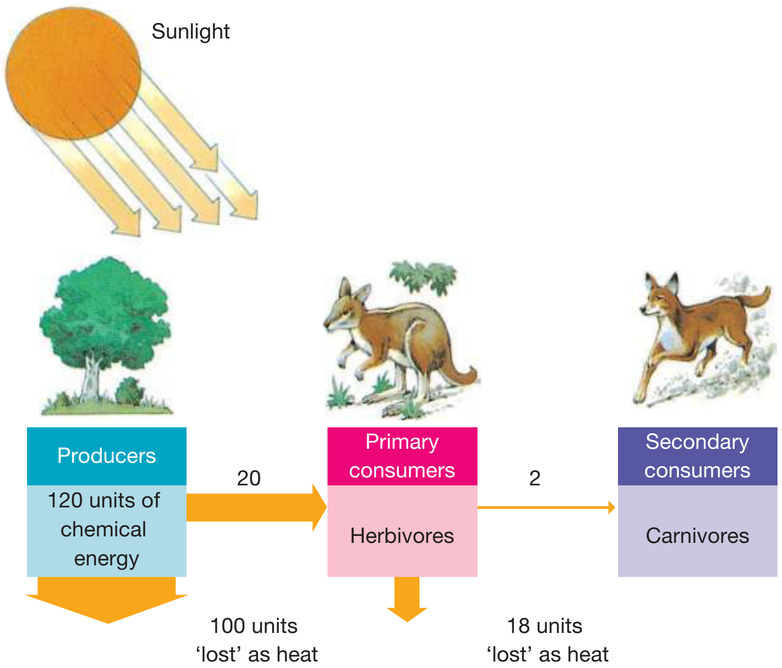
Energy flows through an ecosystem and, as it moves, it changes from one form to another. No new energy is created.

3.5.1 Energy flow in an ecosystem

Living things need energy to grow, reproduce and move. Energy cannot be created but it is transferred through the ecosystem.

The Sun is the initial source of energy for our ecosystems. Producers, such as plants, capture some of this light energy and convert it into chemical energy using the process of photosynthesis. When consumers eat producers, some of this energy is passed along the food chain. Therefore, energy flow is unidirectional (one direction) in any ecosystem.

FIGURE 3.27 Energy flow in an ecosystem. The values of units of energy flowing through the food chain are examples only, but show how the amount of energy decreases through a food chain.



KEY IDEA

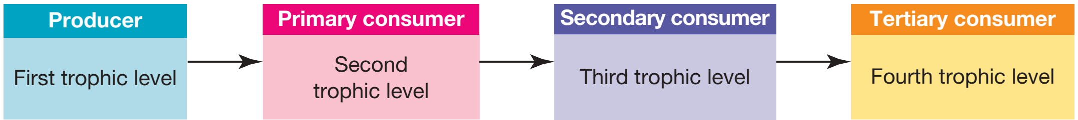
The Sun is *not* part of the food chain. It is the original source of energy for life on Earth. Producers use light energy from the Sun to undergo photosynthesis.

3.5.2 Trophic levels

A food chain can be defined as a pathway along which food is transferred from producers to consumers. Producers and consumers can be arranged into different feeding levels called trophic levels.

For example, producers make up the first trophic level and the consumers (herbivores) that eat them make up the second trophic level. Consumers eating these herbivores make up the third trophic level and consumers eating these consumers make up the fourth trophic level.

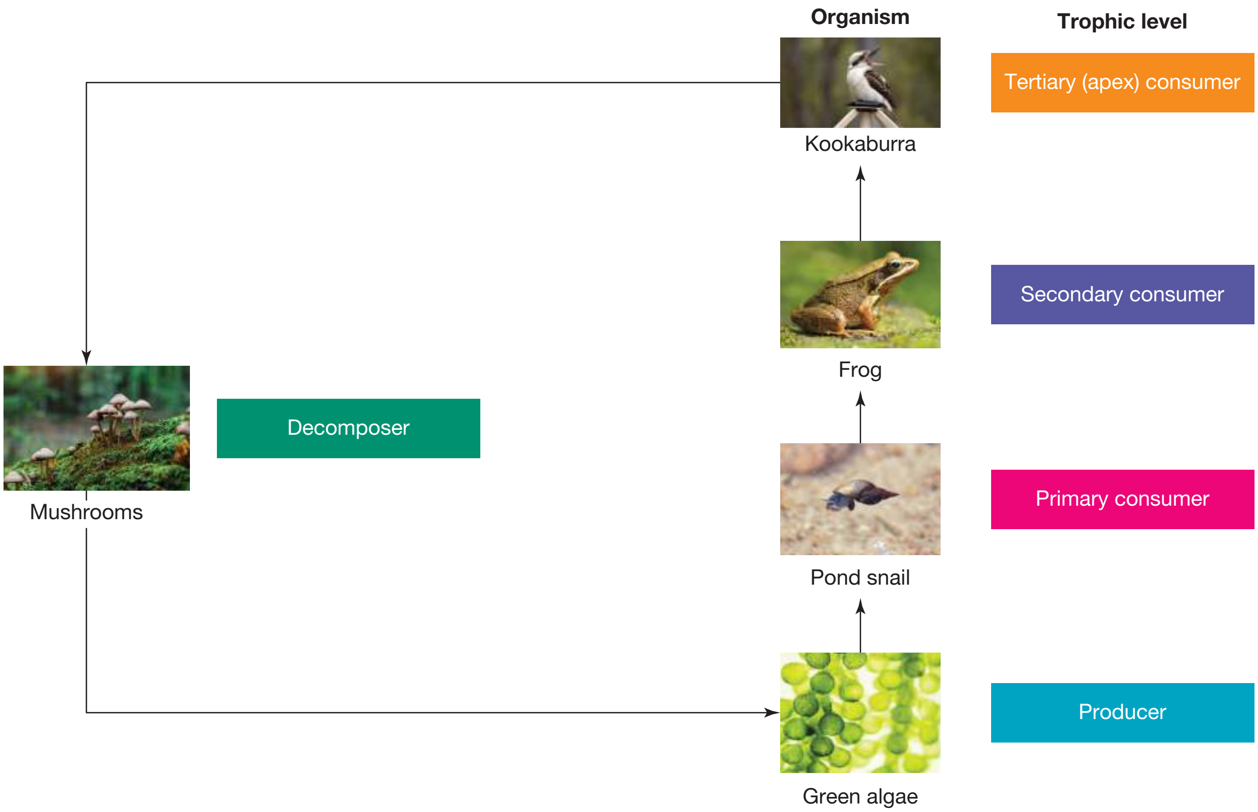
FIGURE 3.28 Trophic levels in ecosystems



Organisms can occupy more than one trophic level. These categories are not fixed because many organisms feed on several trophic levels.

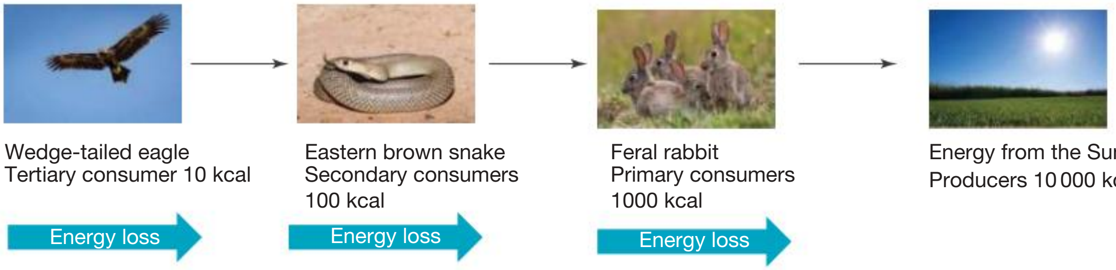
Figure 3.29 shows an example of trophic levels. Algae occupy the first trophic level because they are producers. Pond snails feed on the algae, so they occupy the second trophic level and are primary consumers. The snails are eaten by frogs, which are secondary consumers occupying the third trophic level. The kookaburra eating the frogs occupies the fourth trophic level.

FIGURE 3.29 An example of trophic levels in a pond



One important factor that limits the number of trophic levels in a food chain is energy. Energy is not recycled, nor can it be created or destroyed. Energy is transformed from one form to another. At each level in the food chain, some energy is also released to the environment in other forms (such as heat, kinetic and sound energy), as shown in figure 3.30. Because only about 10 per cent of the chemical energy is passed from one trophic level to the next, most food chains do not usually contain more than four trophic levels. There is also a limit to the number of organisms that can exist at each level.

FIGURE 3.30 An example of energy flow and trophic levels



3.5.3 Decomposition and nature's recycling

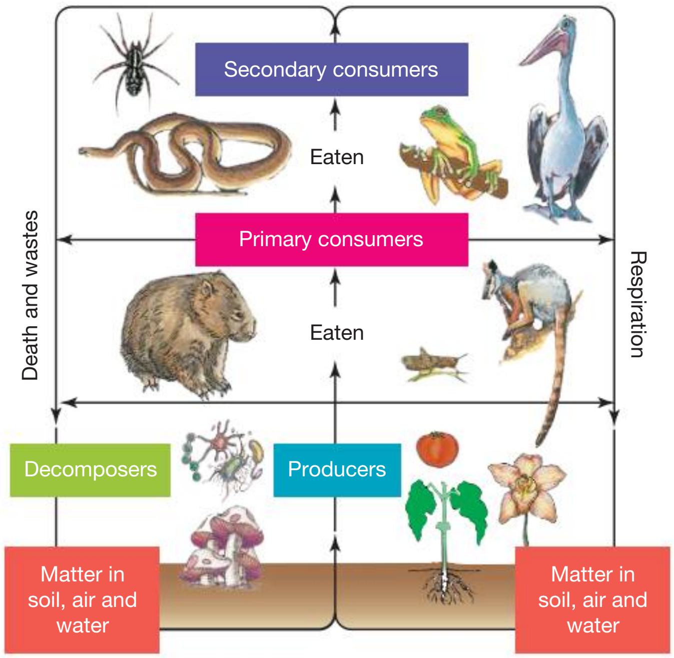
Tyrannosaurus rex lived on Earth over 65 million years ago. We have found the bones, but what happened to the atoms that made up its flesh? What will happen to the atoms in your body when you die?

Borrowing atoms

All living things contain atoms. They make up our body cells, are in the food that we eat and are involved in essential chemical reactions that keep us alive. The set of all of these chemical reactions is called **metabolism**. Throughout these reactions, atoms are rearranged; some are used or retained for a time, and some are returned to the environment as wastes.

These atoms and molecules are not just rearranged within one organism, but recycled through various organisms in a food web, as shown in figure 3.31. There is a cycle between the production of food through producers, the consumption of organisms by consumers and the release of wastes. These wastes can in turn be used by producers or decomposers. Life on our planet relies on the recycling of atoms between the biotic and abiotic parts of ecosystems.

FIGURE 3.31 Various components are recycled through ecosystems.



SCIENCE INQUIRY: Atoms within ecosystems

Atoms are constantly recycled within ecosystems. For example:

- Carbon cycle: Carbon atoms move from the atmosphere (CO_2) into plants during photosynthesis, through animals as food, and back to the environment via respiration or decomposition.
- Nitrogen cycle: Nitrogen atoms are converted by bacteria into forms plants can use, then pass through food webs before being released back into the atmosphere or soil by decomposers.
- Water cycle: The hydrogen and oxygen atoms in water are cycled through organisms and returned to the atmosphere via processes such as transpiration or evaporation.

This constant movement of atoms connects all living things to their environment, emphasising the interdependence of organisms within ecosystems.

1. What happens to the atoms in an animal's body when it dies? How are these atoms reused in the ecosystem?
2. Why are decomposers so important for recycling atoms in ecosystems? What would happen if decomposers were removed?
3. How might human activities, such as deforestation or pollution, disrupt the recycling of atoms in ecosystems?

Investigable questions, reasoned predictions and hypotheses can be developed in guiding investigations to identify patterns, test relationships and analyse and evaluate scientific models (VC2S8I01)

Decomposers — nature's recyclers

Decomposers (as introduced in section 3.3.3) are heterotrophs, so they cannot make their own food through photosynthesis.

The two main groups of decomposer organisms are bacteria (microorganisms) and fungi. These decomposers are also called **saprophytes**. They obtain their energy and nutrients from dead organic material. This includes dead organisms and their wastes (such as faeces and skin flakes). As they feed, they use enzymes to chemically break down the matter into simpler forms or mineral nutrients. Their wastes are then returned to the environment to be recycled by producer organisms. This recycling of matter from one form to another within ecosystems is key to their sustainability.

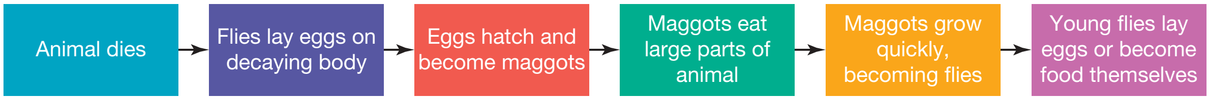
Other larger organisms, such as earthworms and maggots, are called detritivores because they feed on detritus (dead and decaying material). By breaking detritus down into smaller pieces, they increase its surface area, which increases the efficiency of further breakdown by bacteria and fungi.

FIGURE 3.32 Mushrooms and other fungi are decomposers.

FIGURE 3.33 Detritivores help decomposers break down organic material.

The products of decomposition are inorganic molecules that can then be used by other organisms. For example, plants can use these inorganic molecules in reactions such as photosynthesis to produce organic molecules. These organic molecules are then eaten by other organisms (such as consumers) and passed along food chains. If it were not for decomposers, carbon, nitrogen, phosphorus and other elements essential to life would be locked in the organic molecules of dead organisms and their wastes. Decomposers play a key role in the recycling of atoms within ecosystems.

FIGURE 3.34 The role of decomposers in breaking down organic matter



INVESTIGATION 3.4

Looking at decomposers

Aim

To determine if sterilisation and freshness of grass affects microbe growth

Materials

- safety glasses
- six nutrient agar plates
- fresh grass
- grass that has recently died
- decomposing grass
- three paper bags
- forceps
- oven
- Bunsen burner
- heatproof mat and matches
- stapler and marking pen
- tape
- incubator
- stereo microscope or hand lens

Method

1. Sterilise the forceps by holding them in a Bunsen burner flame for 1 minute.
2. Using the forceps, place a sample of the fresh grass in a paper bag. Fold the edge over several times and staple the fold securely closed. Label the bag ‘fresh’.
3. Resterilise the forceps and repeat the procedure for the other two samples of grass. Label them ‘dead’ and ‘decomposing’ respectively.
4. Place all three bags in a hot oven for 15 minutes.
5. While the bagged samples are sterilising in the oven, use sterile forceps to gently wipe a sample of fresh grass over the surface of an agar plate, taking care to use the correct technique. Label this plate ‘fresh U’. (U means unsterilised.)
6. Resterilise the forceps and repeat the procedure for the other two samples of grass, labelling them ‘dead U’ and ‘decomposing U’ respectively.
7. Using the correct technique (see previous instructions) gently wipe a sample of each of the three types of sterilised grass over an agar plate. Use a new plate for each sample. Label the three samples ‘fresh S’, ‘dead S’ and ‘decomposing S’. (S means sterilised.)

CAUTION: Tape the lid of the agar plate. *Do not* open the lid of the agar plate.

8. Incubate all six plates for 24 hours at about 37 °C.
9. Use a stereo microscope or hand lens to observe any growth of microorganisms.

Results

1. Record your observations in a table.
2. Photograph the results. Number and label each photograph.

Discussion

1. Which plate had the greatest amount of microbe growth?
2. Why were samples of each of the grasses sterilised?
3. Which type of microbe was more prevalent on the plates: bacteria or fungi? (Bacteria make smooth, shiny and usually round colonies, whereas fungi make fuzzy, irregularly shaped growths.)

Conclusion

Write a conclusion for this investigation.

Are people biodegradable?

If something can be broken down by decomposers, it is said to be **biodegradable**. This is very useful because it means that some decomposers can also break down not just dead and decaying organisms, but also some of the rubbish that humans produce. If the material cannot be broken down, it is described as **non-biodegradable**. Paper and food scraps are examples of biodegradable materials, whereas plastic and foam are examples of non-biodegradable materials.

INVESTIGATION 3.5

Preserving apples

Aim

To test substances for their effectiveness as food preservatives

Materials

- small apple cubes (peeled)
- test tubes
- range of solutions to test for their effectiveness as food preservatives (e.g. water, sugar solutions of different concentrations, vinegar, salt solutions of different concentrations)

Method

1. Place one apple cube in each test tube.
2. Do not add anything to test tube 1.
3. In each of the other test tubes, pour one of the solutions you are testing. For example, you could put water in test tube 2 and ethanol in test tube 3.
4. Write an aim for this experiment.
5. Design a table to record your results. You will be recording your observations for each apple cube each lesson for the next 2 weeks.

Results

1. In each lesson, record whether each piece of apple has changed. Take note of the colour, the presence of mould and any other signs of decay.
2. Record the results in your table. Give your table a title.

Discussion

1. Give the order of best preservative to worst preservative using your results to support your order.
2. There are a number of ways substances can slow decomposition — the first is to coat the surface so bacteria or fungi cannot decay the apple or the substance can create an environment where it is hard for microorganisms to grow. Using this information, can you explain why some substances prevented decomposition and why others did not?

3. Did your results support or refute your hypothesis?
4. Do you believe your test was fair and therefore valid? Explain your reasoning.
5. Was the experiment repeatable? Give evidence to support your answer.
6. Design an experiment to determine if there is bacterial growth on your samples of apple.

Conclusion

Write a conclusion that includes:
a. an answer to the research question
b. whether the hypothesis was supported or refuted
c. the confidence you have in your results.

3.5 Activities

learnon

3.5 Quick quiz on | **3.5 Exercise**

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 5, 9, 11	3, 7, 8, 12	4, 6, 10, 13

Remember and understand

1. Match each term with its meaning.

Term	Meaning
a. Metabolism	1. Release enzymes to break down complex organic matter into simple inorganic material to be absorbed
b. Detritivores	2. Organisms that feed off dead and decaying matter (detritus)
c. Saprophytes	3. Heterotrophs that consume the remains of dead organisms and their wastes
d. Decomposers	4. The set of all of the chemical reactions that keep organisms alive

2. **Identify** the term used for:
   a. organisms that eat only plants
   b. the process that plants use to convert light energy into chemical energy
   c. a material that can be broken down by decomposers and used to feed some animals.
3. Provide two examples of:
   a. decomposers
   b. detritivores
   c. scavengers.
4. **Distinguish** between:
   a. biodegradable and non-biodegradable
   b. decomposer and producer.
5. **Construct** a sentence that uses each of the following lists of terms.
   a. Decomposer, heterotroph, consumer, dead organisms, ecosystems, recycle
   b. Producers, herbivores, carnivores, decomposers, nutrient pool, matter, ecosystem
6. **Outline** or **describe** the relationship between:
   a. photosynthesis and respiration
   b. death and decomposition.
7. An entomologist may be called upon when a dead body is found. **Explain** how an entomologist may be able to help the investigation.

Apply and analyse

8. **Explain** the role played by photosynthesis in an ecosystem.

Evaluate and create

9. **Suggest** why some of the bones of the dinosaurs were not decomposed by microorganisms.
10. SI Things that can be broken down by decomposers, such as paper and food scraps, are described as biodegradable. Plastic bags and foam packaging are described as non-biodegradable.
    a. Find out why non-biodegradable items are not broken down by decomposers.
    b. Create an advertisement that may influence people to use fewer non-biodegradable items.
    c. **Suggest** advantages and disadvantages of using paper bags instead of plastic bags.
    d. Design your own biodegradable carry bag. **Summarise** your design, **explaining** any important features.
11. **Identify and explain** the primary source of energy in a food web. How does this energy flow from one organism to another?
12. Create a diagram that shows the flow of energy through a food web, including the role of decomposers. Make sure to include at least five different organisms.
13. **Compare** the flow of energy in a natural ecosystem versus a human-modified ecosystem (e.g. a farm). **Explain** how human activities affect these energy pathways.

Answers and sample responses are available in your digital formats.

LESSON 3.6 Ecological pyramids

LEARNING INTENTION

In this lesson you will identify and describe the different ecological pyramids used to represent relationships between organisms at different trophic levels.

3.6.1 What are ecological pyramids?

An ecological pyramid is a diagrammatic representation of the relationships between the different living organisms at different trophic levels.

The three main types of ecological pyramids are:

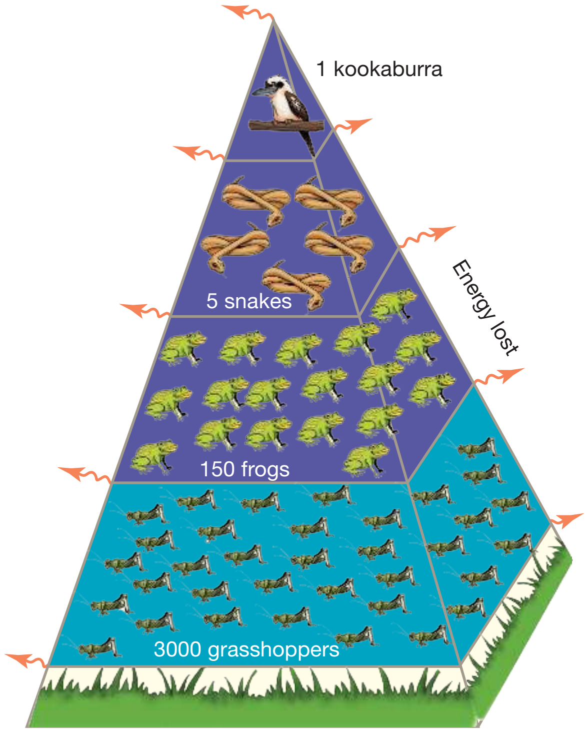
- pyramids of number, showing the number of organisms and the relationships between them at each trophic level
- pyramids of energy, showing the flow of energy from one trophic level to another
- pyramids of biomass, showing the biomass at different trophic levels.

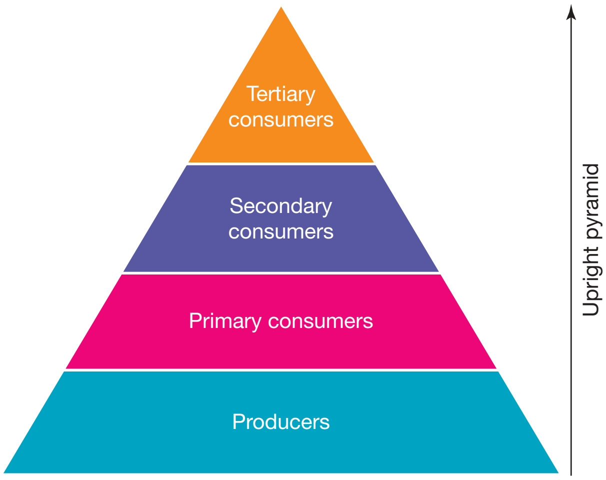
These pyramids are constructed by stacking boxes that represent feeding (or trophic) levels within a particular ecosystem. The size of the box indicates the number or amount of the feature being considered.

Pyramid of number

A pyramid of number (see figure 3.35) is an ecological pyramid showing the number of organisms at each trophic level. This pyramid is always upright in shape because there is a decrease in the number of organisms from the second trophic level to the final trophic level.

FIGURE 3.35 Pyramids showing the number of organisms in a food web and the general shape of a pyramid of numbers

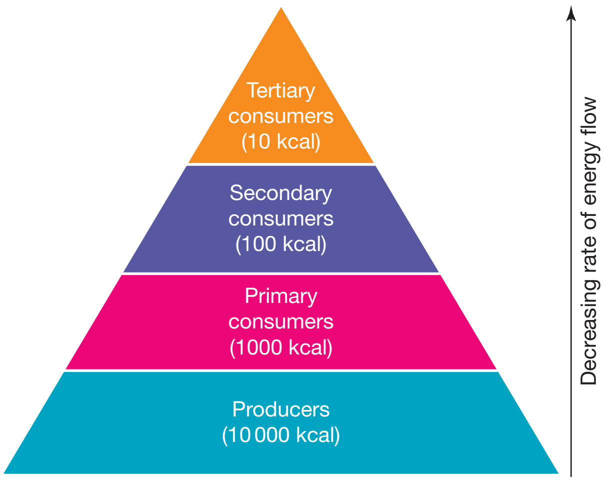




Pyramid of energy

A pyramid of energy (see figure 3.36) represents the total energy available at each trophic level of the food chain. Because only about 10 per cent of the chemical energy is passed from one trophic level to the next and the remaining 90 per cent is lost as heat, the pyramid of energy is always upright.

FIGURE 3.36 A pyramid of energy, showing the total energy available at each trophic level



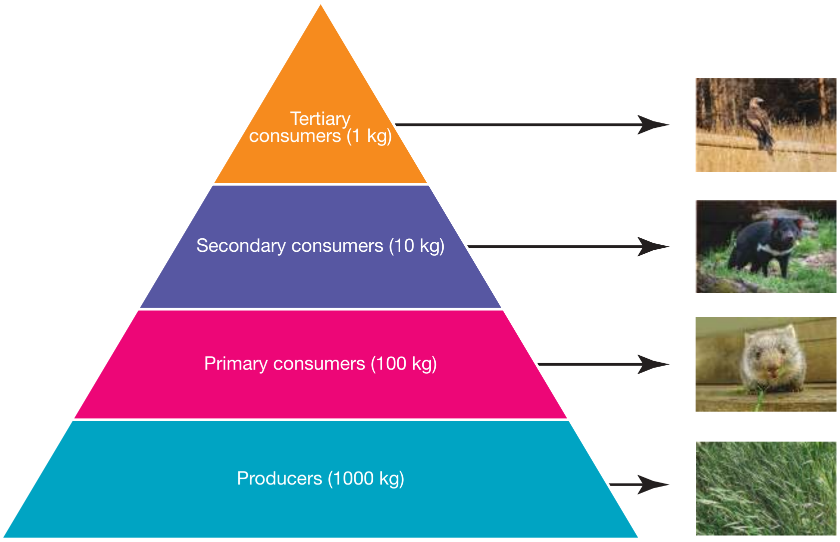
Pyramid of biomass

A pyramid of biomass represents the total mass of living organisms at each trophic level. Biomass is defined as the total mass of all living matter in a particular trophic level at any given point in time.

There are two main types of biomass pyramids:
- inverted pyramids of biomass
- upright pyramids of biomass.

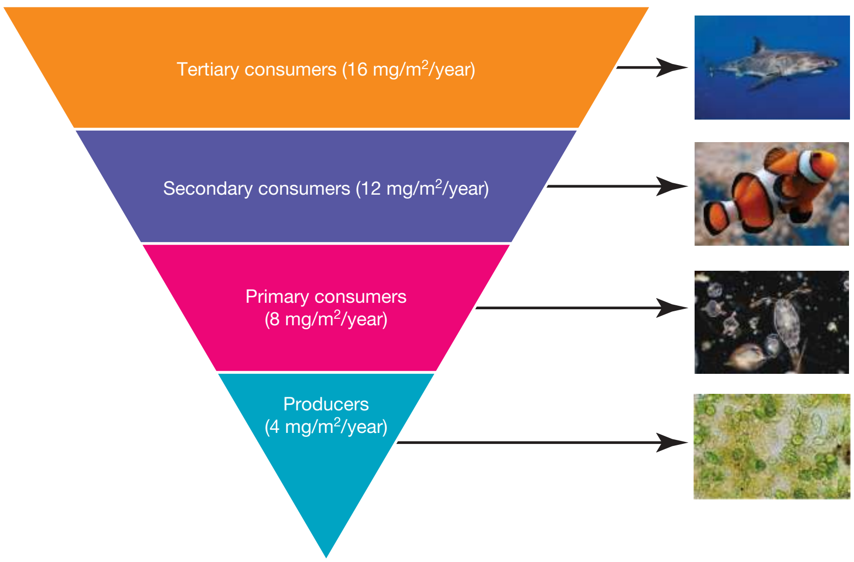
Terrestrial biomass pyramids are usually upright because the biomass decreases as we move up from the second trophic level to the final trophic level. Terrestrial ecosystems have much more biomass in plants, such as trees and grass. If you have less biomass you move up the trophic levels.

FIGURE 3.37 An example of an upright pyramid of biomass



However, the pyramids of biomass of aquatic ecosystems such as ponds, lakes, rivers and oceans are inverted because there is increase in the biomass of organisms as we move up the trophic levels. In aquatic ecosystems, producers are large in number, but their biomass is less than that of primary consumers. Similarly, the biomass of secondary consumers is more than the biomass of primary consumers.

FIGURE 3.38 An example of an inverted pyramid of biomass



3.6 Activities

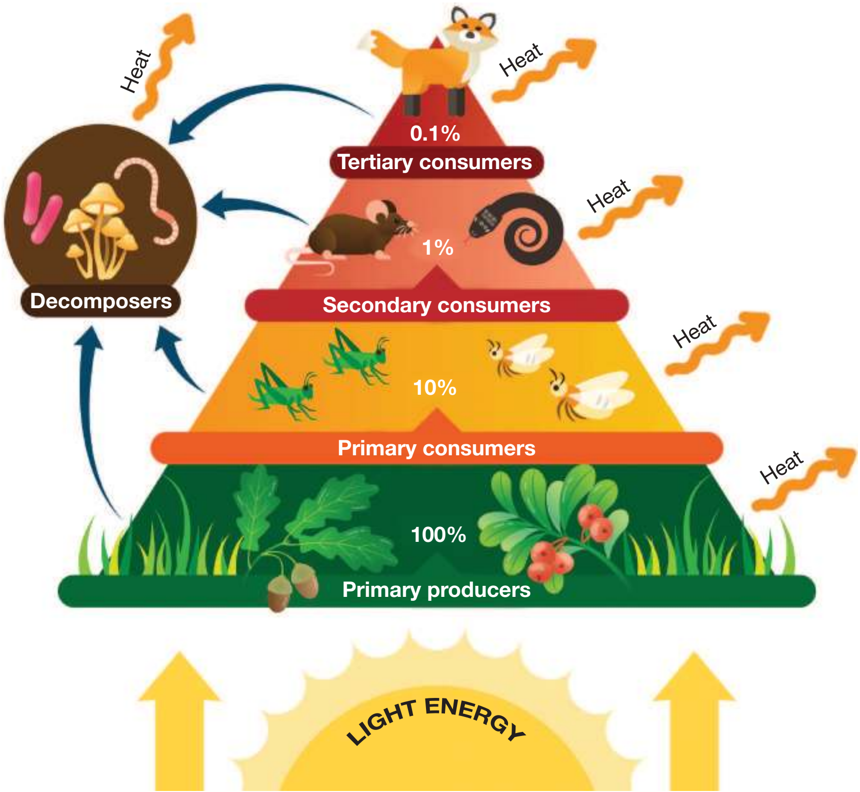
learnon

3.6 Quick quiz on	3.6 Exercise

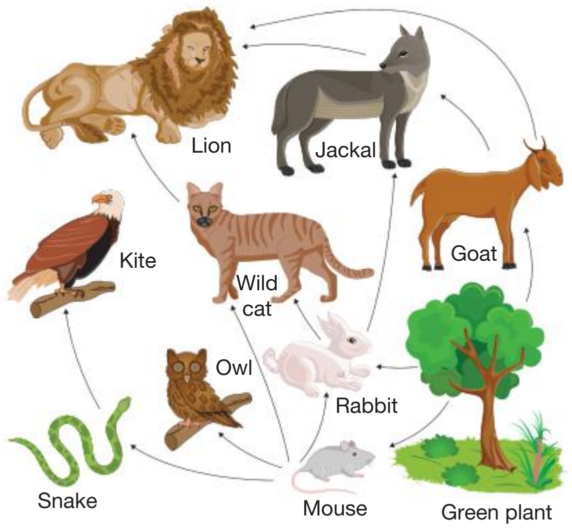
LEVEL 1	LEVEL 2	LEVEL 3
2, 3, 4, 5	1, 6, 9	7, 8, 10, 11

Remember and understand

1. **Explain** what an ecological pyramid is.
2. **Identify** the three main types of ecological pyramids.
3. MC Which of the following terms is used to describe each feeding level within a food chain?
   A. Food web
   B. Pyramid of biomass
   C. Pyramid of numbers
   D. Trophic level
4. **Identify** the type of pyramid shown.



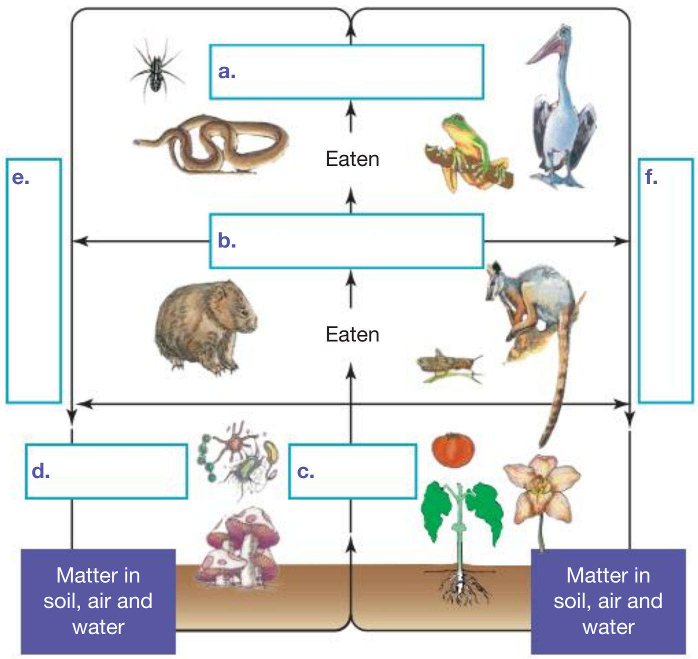
5. **MC** The image shown is an example of which one of the following?
A. Food chain **B.** Food web **C.** Pyramid of biomass **D.** Trophic level



6. **MC** Which type of ecological pyramid indicates that, as you move up the food chain, there is only about 10 per cent of the food energy received at each level, which is then passed through to the next level?
A. Energy pyramid
B. Pyramid of biomass
C. Pyramid of numbers
D. Pyramid of weight

Apply and analyse

7. **Suggest** why food chains rarely contain more than four trophic levels.
8. Label the flowchart shown with the following terms.
producers, decomposers, secondary consumer, death and wastes, respiration, primary consumer



9. Complete the following table.

Features of each trophic level		
Trophic level	**Organism**	**Food source**
First		Convert inorganic substances into organic matter using sunlight energy and the process of photosynthesis
	Primary consumer (herbivore)	Plants or other producers
Third		
	Tertiary consumer (carnivore)	

10. **Construct** a food chain that contains these four organisms: quail, grass, owl, lion. **Identify** the tropic level each belongs to.
11. **Construct** a pyramid of biomass for a pond containing algae and phytoplankton, zooplankton, snails and tadpoles, newts and goldfishes.

Answers and sample responses are available in your digital formats.

LESSON 3.7 Changes in ecosystems

LEARNING INTENTION

In this lesson you will explain how events such as seasonal changes, destruction of habitat or introduction of a species impact abiotic and biotic factors, and cause changes to populations.

3.7.1 Seasonal changes

Seasonal changes can affect the timing of many life-cycle events, such as when flowers bloom or when **pollinators** emerge. They also affect the type and amount of food available.

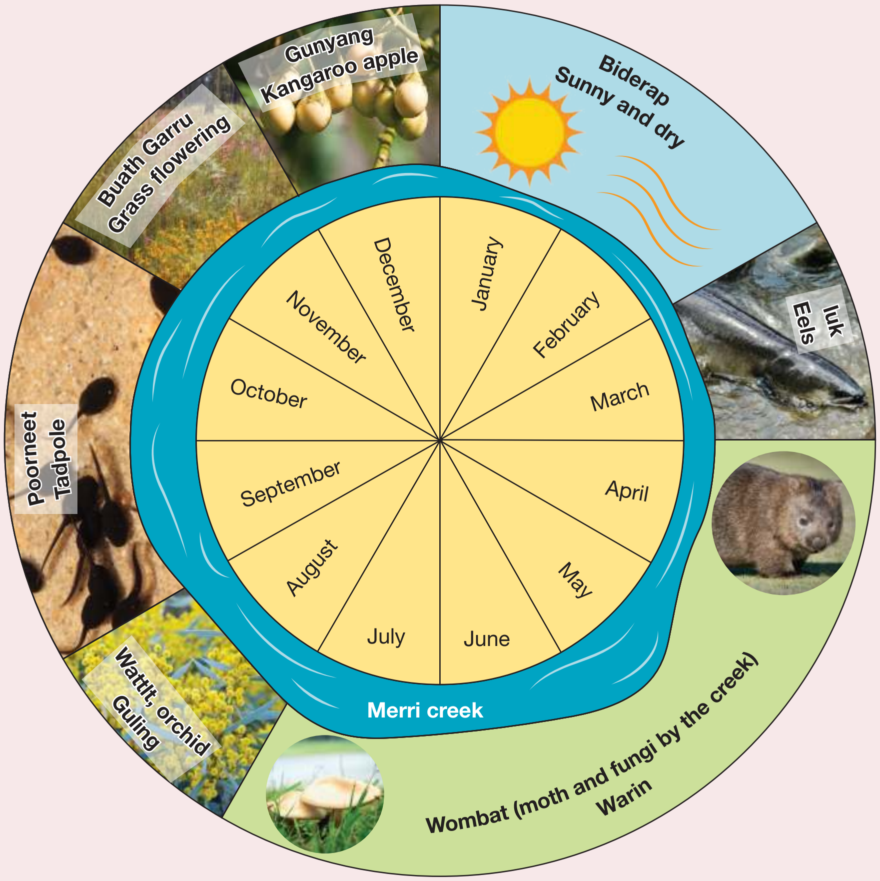
SCIENCE AS A HUMAN ENDEAVOUR: A seasonal calendar

Aboriginal and Torres Strait Islander Peoples have their own seasonal calendars based on observational changes in the landscape and skyscape. These observations are based on how plants and animals reacted to the changing climate rather than mapping and following the position of Earth from the Sun (as is the case with the calendar system widely used today, called the Gregorian calendar). For example, fish migrating up the river for spawning could indicate a change to warmer weather, or flowers dropping seeds could indicate the beginning of cooler weather. These calendars differ for different regions. Varying Aboriginal and Torres Strait Islander groups developed their own seasonal calendars based on their surrounding environment (you can explore Aboriginal and Torres Strait Islanders Peoples' weather knowledge on the Bureau of Meteorology website). The Kulin People in south central Victoria observe seven seasons, which help them know what is good to eat.

The seasons that the Wurundjeri Woi Wurrung people of the Kulin Nation observe are:

- Biderap — Dry season (Jan–Feb)
- Iuk — Eel season (March)
- Waring — Wombat season (April–July)
- Guling — Orchid season (Aug)
- Poorneet — Tadpole season (Sept–Oct)
- Buarth Gurru — Grass-flowering season (Nov)
- Garrawang — Kangaroo apple season (Dec).

FIGURE 3.39 The seasonal calendar of the Wurundjeri Woi Wurrung people around Merri Creek



Source: Based on the seasonal calendar observed by the Wurundjeri Woi Wurrung of the Kulin Nation.

Multidisciplinary endeavours to advance scientific knowledge make use of people's different perspectives and worldviews (VC2S8H02)

Plants that produce flowers are called angiosperms. These flowering plants have their male and female reproductive structures located in their flowers. For a **seed** to be produced, **pollination** must occur.

Pollination — biotic and abiotic interactions

Both biotic and abiotic factors can contribute to successful pollination. While some plants may be able to pollinate themselves, many plants rely on either animals (such as bees, butterflies and birds) or the wind to transport their **pollen** from one plant to the **stigma** of another (cross-pollination). The structure of these flowers is often well suited to the biotic or abiotic factor assisting them.

FIGURE 3.40 Cross-pollination by a bee

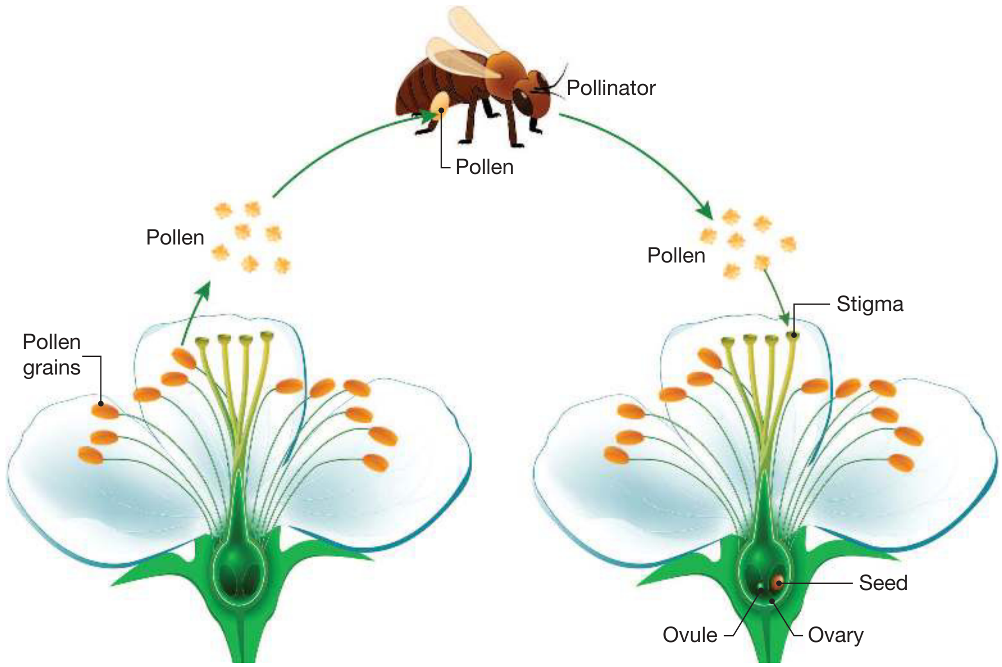
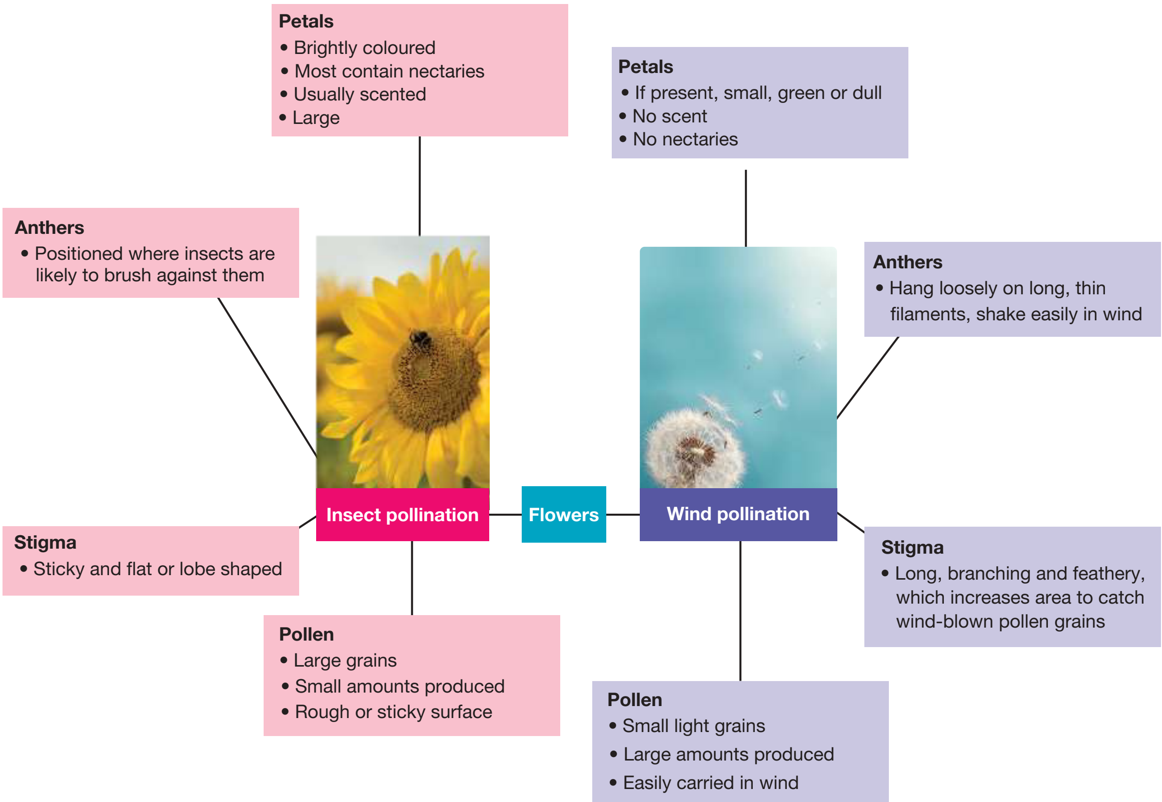


FIGURE 3.41 Some plants can pollinate themselves, while others rely on animals or the wind for successful pollination.



Flowers — feeding relationships

Organisms that assist plants in pollination are called pollinators. They are doing so because it supplies them with food! Birds and insects such as honey bees and butterflies feed on the nectar of flowers and, in the process, they become covered with pollen. This pollen can then be transferred to other plants when they go to feed on them. Examples of this feeding relationship can be seen in figure 3.42.

Flowering plants (angiosperms) are one type of primary producer. All producers are positioned at the first trophic level in their food chains. As well as supplying a food source to many different animals through the production of glucose during photosynthesis, angiosperms also provide the raw materials for bees to make honey, which other animals can eat.

FIGURE 3.42 Two examples of feeding relationships between animals and plants

Dispersal — biotic and abiotic interactions

The fruit of a plant contains its seeds. These are actually the swollen ovaries of the plant. One of the main jobs of fruits is to help with dispersal or spreading of the seeds. A variety of biotic or abiotic factors may also be involved in dispersal of the seeds.

Some Australian plants, such as *Banksia* and mountain ash (*Eucalyptus regnans*), require high temperatures to burst their fruit so that the seeds may be released. This adaptation gives these plants an excellent chance of survival in regions prone to bushfires.

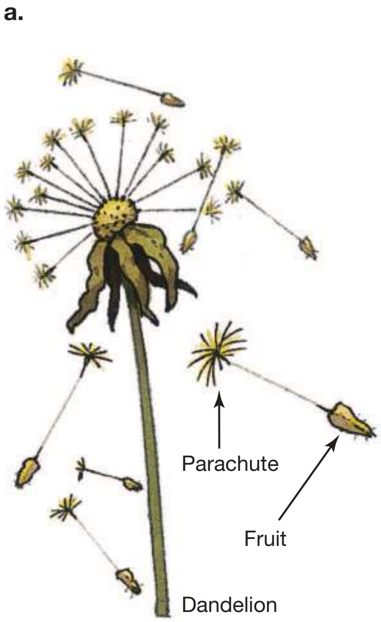
Dispersal (spreading seeds) may happen in a variety of ways. Biotic factors may be involved, such as animals eating the plants' fruit (e.g. tomatoes, grapes and apples) and dispersing the seeds.

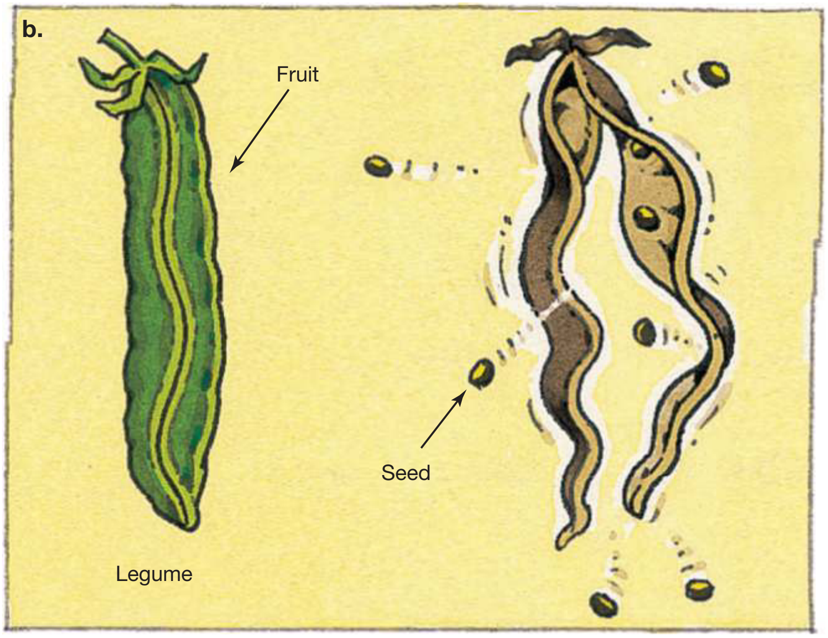
Abiotic factors may also help with dispersal, including:

- water (such as coconuts)
- wind (such as grasses and dandelions).

Some plants, including some legumes, split open when ripe, throwing their seeds out long distances and dispersing their seeds themselves.

FIGURE 3.43 a. Dispersal of fruit from a dandelion b. Seeds dispersing from a legume





Fruits and seeds — feeding relationships

Fruits that attract animals are often brightly coloured. When a fruit is eaten by an animal, usually only the soft parts of the fruit are digested. The seeds that are not broken down inside the animal are passed out in its faeces. So, by eating the fruit, animals assist in the dispersal of the seeds.

FIGURE 3.44 Animals consume brightly coloured fruits and help disperse the seeds.

DISCUSSION

What is your favourite fruit? Describe its appearance and which animals it would attract to disperse its seeds. Did you know that you are eating the swollen ovary of a plant when you eat fruit?

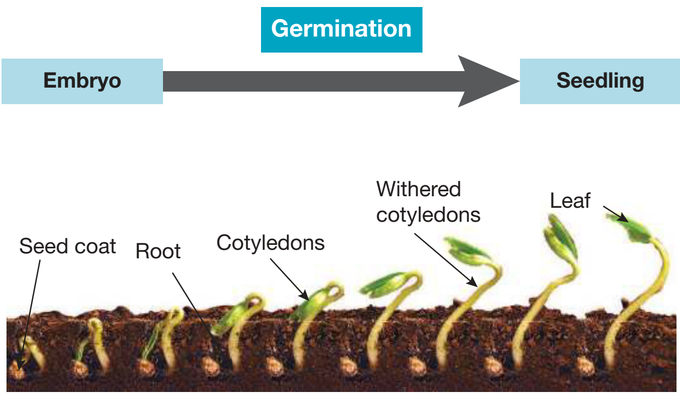
Germination — biotic and abiotic interactions

Germination is a process in which a seed bursts open and the embryo plant becomes a young plant called a seedling (as shown in figure 3.45).

Germination depends on three key abiotic factors.

1. Water:
   - necessary for the seed to swell and burst open
   - transports food to the growing embryo
2. Oxygen:
   - required for cellular respiration (breaking down glucose, which converts energy into a form that the plant cells can use to grow and develop)
3. An optimum temperature (remember the key terms: tolerance range and optimum range).

FIGURE 3.45 The germination process



Although light is not necessary for the germination of most seeds, it is needed once the young shoot breaks through the soil surface. Plants use light energy, and carbon dioxide and water from their environment, to make their own food using the process of photosynthesis.

3.7.2 Destruction of habitat

About 5000 years ago, when **agriculture** (farming) began, humans learned how to control the growth of other organisms in order to maximise their own food supply. These humans began to create artificial ecosystems.

The purpose of agriculture is to turn as much of the Sun's light energy as possible into chemical energy in particular crops or pasture plants for animals. To do this, it is necessary to interfere with the food web of which the selected organism is part. This often also requires the clearing of forests, or removal of other organisms that may compete for resources, and hence lower the yields. Such activities have led to the destruction of many natural ecosystems. The development of agriculture has led to drastic environmental changes in many ecosystems on our planet.

SCIENCE AS A HUMAN ENDEAVOUR: Laboratory-grown meat

Increased meat consumption around the world is of great concern because it impacts the ecosystems. Beef production is considered to be one of the major sources of methane and nitrous oxide emissions in the environment.

Laboratory-grown meat may help to solve some of the serious environmental issues of methane emissions related to the beef industry; however, some doubts still prevail. Around the world, many companies are moving quickly to bring lab-grown meat or cultured meat onto the market. In Singapore, on 2 December 2020, lab-grown meat was approved for sale by a regulatory authority for the first time.

Cultivated meat, also known as cultured meat, is animal meat that is produced by cultivating animal cells directly in the laboratory.

FIGURE 3.46 Would you be willing to eat meat grown in a lab?

Lab-grown meat production uses significantly less water and land, emits few greenhouse gases and decreases eutrophication, which is the excessive production of algae and plants in waterways. It is predicted that this industry will reduce the agriculture-related clearing of land, biodiversity loss and animal slaughter.

Even though reduced animal suffering is the main reason to support the production of lab-grown meat, there are some concerns raised about it. It can have a negative effect on animal farmers. The price of lab-grown meat could create inequality among large cultured-meat-producing companies and the animal farmers.

Lab-grown meat is considered to be unnatural, and it replaces the interdependence of species within nature; that is, we do not have to rely on nature for our survival, but can instead make our own nutrients.

1. How might the adoption of lab-grown meat reduce environmental issues such as greenhouse gas emissions and land use associated with traditional livestock farming?
2. What potential challenges could lab-grown meat present to traditional animal farmers? How might society address these challenges to ensure fair economic opportunities?

Proposed scientific responses to socio-scientific issues impact on society and may involve ethical, environmental, social and economic considerations (VC2S8H03)

Monocultures

Farms usually grow very large areas of only one type of plant. For example, in some regions there are thousands of hectares planted only with wheat, while in other regions thousands of hectares are covered with grapes, sugar cane or some other single crop. Such crops are called **monocultures** and can lead to reduced **biodiversity**.

FIGURE 3.47 Areas planted with only one crop are called monocultures.

At the end of each growing season, the crops are harvested, processed and delivered to shops and supermarket shelves for the consumer. There is little natural decomposition of dead material, and the soil may be exposed to the effects of wind and rain for a certain period of the year. These factors combine to remove valuable nutrients from the soil.

The use of fertilisers

Nitrogen and phosphorus atoms are required by organisms so that they can make proteins (organic molecules contain carbon). These organic molecules can play many key roles in both the structure and functioning of organisms. A supply of these atoms is essential for an organism's survival.

The harvesting and removal of crops can reduce the amount of organic material available for decomposers to feed on. This results in reduced levels of nutrients (such as nitrogen and phosphorus) on agricultural land. Because this would reduce the future production of crops, **fertilisers** are often added to replace these 'lost' nutrients.

FIGURE 3.48 Modern agriculture provides large amounts of food, but at a cost to the environment.

Eutrophication

Some fertilisers may end up in waterways and result in unnaturally high levels of nitrogen and phosphorus in the water. This can lead to a rapid increase in populations of blue-green algae that block light from reaching producers in the water. Increased death of plants and algae provide increased organic matter for bacteria to decompose. This leads to an increase in the bacterial populations, which then use up more oxygen in the water. This process is called **eutrophication**. Reduced availability of oxygen can kill fish and other organisms.

FIGURE 3.49 High levels of phosphorus from fertiliser in water can lead to eutrophication.

Carefully observe figures 3.50 and 3.51. The diagram in figure 3.50 shows how phosphorus is normally cycled within ecosystems. The diagram in figure 3.51 shows the effect of excess phosphorus on populations of organisms. Eutrophication is like the suffocation of a waterway. It can result in the death of organisms, and so it creates an imbalance in the food chains and webs.

FIGURE 3.50 A simplified view of how phosphorus is cycled within an ecosystem

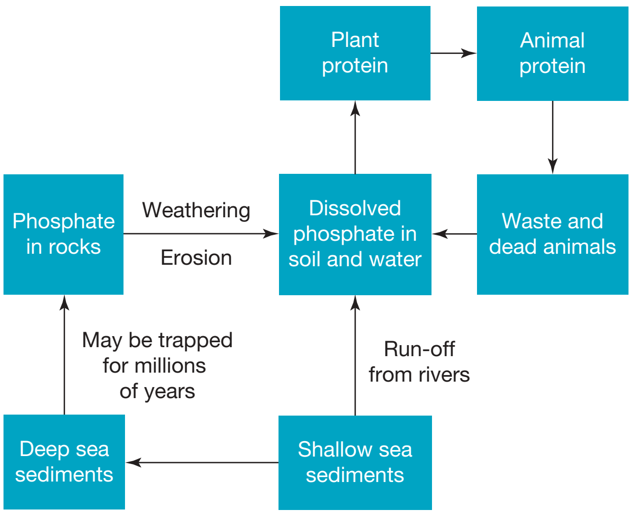
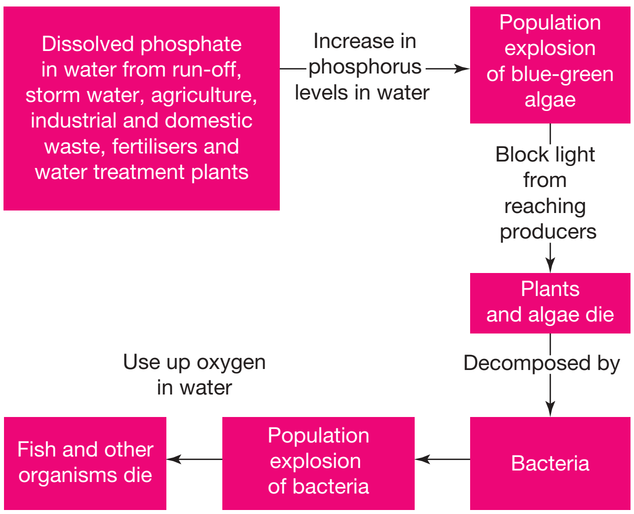


FIGURE 3.51 Eutrophication can result in the death of organisms within the ecosystem.



SCIENCE AS A HUMAN ENDEAVOUR: Desalination plants

Over the past few decades, significant growth in the human population and industries has increased the demand for fresh water. Reductions in water quality and quantity have negative impacts on ecosystems. Therefore, to meet the demands of fresh water, desalination can be considered as an option.

Desalination is the process of removing salts and other minerals from undrinkable water to produce fresh water for human consumption and other uses. Desalination plants take in large amounts of seawater through large pipes and remove all the salts and minerals, known as brine, from it.

It is assumed that desalination can have considerable environmental impacts on ecosystems. Brine has a high salt concentration, which creates disposal issues. Brine is usually disposed of in the ocean, which can kill marine organisms and cause damage to the marine population.

FIGURE 3.52 Brine rejected into the Mediterranean Sea in Hadera, Israel

FIGURE 3.53 The desalination process

Also, significant energy consumption in the desalination process — in order to produce electricity and heat — would lead to increased greenhouse gas emissions into the atmosphere.

Further, desalination can be a threat to marine life. Mature fish, larvae and other marine life could be significantly injured or killed if they become trapped in open-ocean surface intake pipes.

1. How can desalination be used to address fresh water shortages while minimising its negative impacts on marine ecosystems and greenhouse gas emissions?
2. What are some alternative methods to desalination for providing fresh water? What are their respective environmental, social and economic advantages and disadvantages?

Proposed scientific responses to socio-scientific issues impact on society and may involve ethical, environmental, social and economic considerations (VC2S8H03)

Deforestation

Some of the biggest impacts humans have on the planet and its ecosystems are through deforestation. Deforestation involves the removal of large numbers of trees to clear land for other uses, not just for agricultural use, but also for urban and residential use.

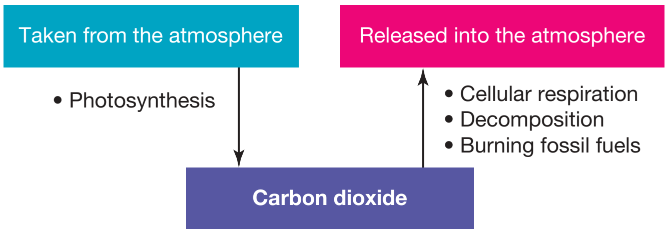
Deforestation greatly harms ecosystems. It severely impacts, or even destroys, the food chains and food webs that are in delicate balance, and many organisms lose their food source with the loss of important producers. The habitat of numerous organisms is also changed or lost completely.

FIGURE 3.54 The deforestation and clearing of huge parts of an ecosystem

Carbon dioxide and climate change

If producers are reduced in number or removed from ecosystems through deforestation, less carbon dioxide will be removed from the atmosphere, as shown in figure 3.55. The increase in carbon dioxide contributes to air pollution and a rise in Earth's surface temperature. This explains why cutting down trees can contribute to the enhanced greenhouse effect and a changing climate. This climate change then further affects the various fragile ecosystems in various ways. There are many links between climate change and the impact on living things.

FIGURE 3.55 Deforestation and removing trees can result in more carbon dioxide in the atmosphere because less is absorbed for use in photosynthesis.



Our way of life also adds greenhouse gases into the environment, resulting in the enhanced greenhouse effect. Human activities including deforestation have seen a rise in the release of carbon dioxide, which is a greenhouse gas, into the atmosphere. This contributes to global warming.

The trapping of greenhouse gases leads to an increase in Earth's temperature due to trapped heat. Examples of the negative effects of this can be seen globally:

- Over time, the polar ice caps have been melting due to increased temperatures, wiping out much of the habitat of polar bears.
- The increased temperature and dryness of ecosystems has greatly increased the bushfire risk, particularly in Australia, where severe bushfires affected the country in late 2019 and early 2020.

FIGURE 3.56 Polar bears surrounded by melting polar ice

3.7.3 Introduced species

An **introduced species** is one that has been released into an ecosystem in which it does not occur naturally. The food webs in ecosystems are very delicate and can be easily unbalanced, especially when new organisms are introduced. These introduced organisms compete with other animals for food, provide predators with a new source of prey or may act as predators themselves.

CASE STUDY: Northern Pacific sea star

History

The Northern Pacific sea star (*Asterias amurensis*) is a marine pest, accidentally brought to Australia on the hulls of boats and ships and in ballast water. This foreign sea star was first discovered in the Derwent estuary near Hobart in 1986. Since then, it has spread to Port Phillip Bay, with its population now estimated at around 100 million. The population is likely to continue to increase because it has no natural predators or competitors in our ecosystem, and the female sea star can produce up to 10 million eggs a year.

Ecological impact

1. Potentially causing great harm to our marine ecosystem and to marine industries
2. Threatening biodiversity and shellfish aquaculture in south-eastern Tasmania and Port Phillip Bay
3. Acting as a voracious predator; some of our native marine species, such as scallops and abalone, don't recognise it as a predator, so do not try to escape it

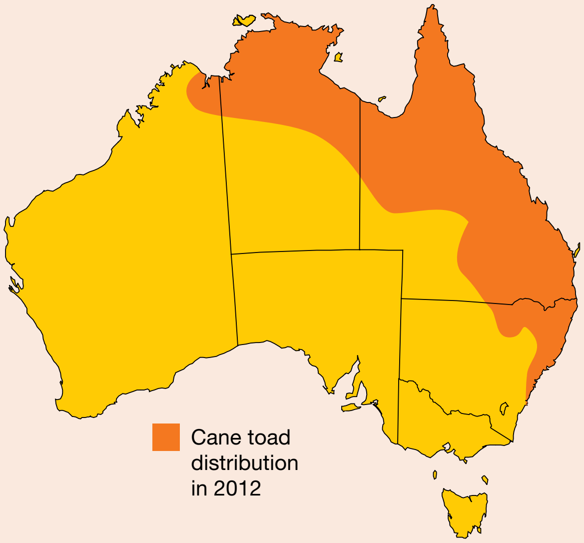
CASE STUDY: Cane toads

History

The cane toad (*Bufo marinus*) was introduced into Australia in 1935 to control the sugarcane beetle, which was destroying sugar cane in Queensland. Unfortunately, the cane toad preferred other insects and the sugarcane beetle was not greatly affected. Cane toads are poisonous and kill the animals that eat them. They need little water for breeding. In one season, the female toad can lay up to 40 000 eggs, which take only 3 days to hatch.

Ecological impact

1. Occupying water habitats so that native tadpoles cannot live there
2. Killing fish that eat the tadpoles, and other animals that eat the adult toads
3. Eating our natural wildlife including frogs, small lizards, birds, fish and insects



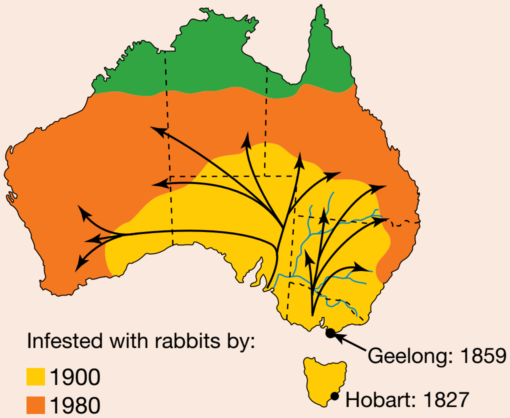
CASE STUDY: Rabbits

History

In 1859, 24 rabbits were introduced from Europe and released in Geelong, Victoria. With few predators, they multiplied rapidly and thrived. By 1890, there were 600 million rabbits in New South Wales alone, all of which had descended from the first 24 rabbits introduced into Victoria.

Ecological impact

1. Competing for food with the native animals such as kangaroos, wallabies, wombats and bandicoots
2. Disrupting food webs and unbalancing ecosystems
3. Building extensive underground warrens
4. Stripping most of the vegetation in their area, causing another problem: erosion. Without plant roots to hold the soil, wind and rain carry the soil into creeks, rivers and lakes, causing further problems for the organisms that live there.



Preserving ecosystems

There have been some exciting developments in preserving ecosystems. There is increasing collaboration between governments, communities, scientists and farmers to work together to:

- meet the demand for food for the world's increasing populations
- reduce damage to and preserve natural ecosystems
- reduce the risks of disease to crop plants
- develop strategies to deal with the possible effects of climate change and natural disasters such as droughts, floods and fires. This includes monitoring climate change and temperatures in places such as Antarctica.

Saving endangered species

The intimate interactions that link us all together can also sometimes break us apart.

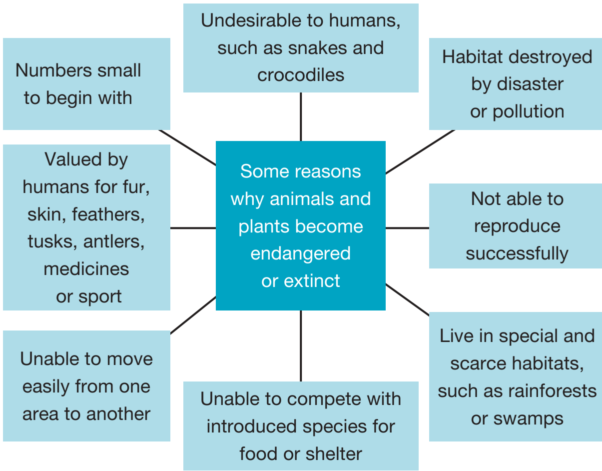
In the 200 years since the European colonisation of Australia, more than 125 different species of Australian native plants and animals have become extinct. This includes over 10 per cent of all native mammals. Many more species are in danger of extinction.

Why should we be so concerned about endangered species? After all, there are many plants and animals on Earth and it may become overcrowded in the future.

Some of the reasons to be concerned about endangered species are that:

- their disappearance affects all other species in the food web
- all species have a right to live on and share Earth
- they may be useful in the future for food, medicines, etc.
- future generations should have the same chance to see a diverse world.

FIGURE 3.57 Reasons for extinction

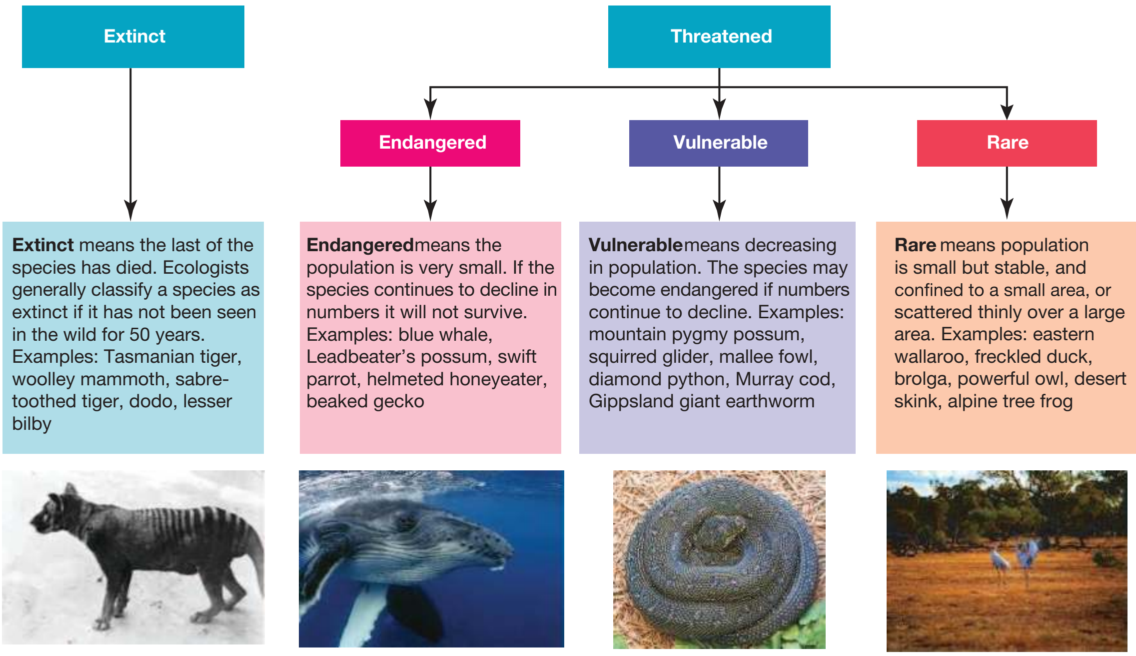


Some of the solutions put into practice to reduce the threat to endangered species include:

- declaring areas as national parks, where plants and animals are protected
- setting up fauna and flora reserves, wetlands and other specialised habitats
- placing quotas (limits) on hunting and exports
- culling (reducing numbers) of overpopulated species, such as western grey kangaroos in some national parks, to allow native plants to survive.

Australia is not the only place where organisms are in danger. All around the world, humans are threatening the survival of other inhabitants of our planet. Threatened species can be rare, vulnerable or endangered (refer to figure 3.58).

FIGURE 3.58 Extinct and threatened species



3.7 Activities

learnon

3.7 Quick quiz on	3.7 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 7, 9, 16	3, 4, 5, 6, 8, 10, 17	11, 12, 13, 14

Remember and understand

1. Match each term with its meaning.

a.

Term	Meaning
a. Angiosperms	1. The fusion (joining together) of male and female sex cells
b. Pollen	2. When pollen grains attach to the stigma
c. Pollination	3. Produced in the anthers of a flowering plant
d. Seed dispersal	4. The process in which the seed bursts open and the embryo plant becomes a seedling
e. Fertilisation	5. Plants that produce flowers
f. Germination	6. The spreading of seeds

b.

Term	Meaning
a. Monoculture	1. A chemical used to kill plants other than the planted crop so that they don't compete with crop plants for nutrients, water and light
b. Fertilisers	2. A chemical used to kill insects that compete with humans for food crops
c. Eutrophication	3. The control of plant or animal pests through the use of chemicals
d. Insecticide	4. Results from the addition of very high levels of phosphorus in waterways, which can reduce the levels of oxygen available in the water
e. Herbicide	5. A crop that contains only one species
f. Chemical control	6. A species that has been released into an ecosystem in which it does not occur naturally
g. Introduced species	7. Chemicals that are added to the soil to replace nitrogen and phosphorus

2. MC What is the best definition of a pollutant?
   A. Anything added to the environment that harms living things
   B. Anything added to the environment that helps living things
   C. Chemicals added to the environment that harm living things
   D. Anything added to the environment that harms people
3. **Identify** whether plants with the following features are more likely to be pollinated by insect or wind.
   a. Flowers with large, scented, brightly coloured petals and nectaries
   b. Flowers with very small, green and unscented petals
   c. Flowers with anthers hanging loosely on long, thin filaments and shaken easy in the wind
   d. Flowers that produce small amounts of large, sticky pollen

4. Copy and complete the sentences using words from the list supplied.
   a. germination, seed, embryo, seedling, abiotic factors, water, oxygen, temperature
      Abiotic factors such as __________, __________ and available __________ impact on the __________ of a seed into an __________ plant and __________.
   b. pollination, nectar, honey, bee, flower, food, plant, pollen, stigma, anther
      A plant uses _______ to attract a bee for _______. The ________ transfers pollen from the __________ of a flower to the _________ of another and uses nectar for __________.
5. Give examples of three:
   a. species that have been introduced into Australia
   b. ways in which biological control may be used
   c. reasons why rabbits, Northern Pacific sea stars and cane toads are not wanted in Australia
   d. things that commonly make up household rubbish
   e. pollutants.

Apply and analyse

6. **Describe** the relationships between:
   a. flowers of flowering plants and bees
   b. fruits of flowering plants and animals.
7. If an animal, such as a bird, eats the seeds of fruit, **describe** how the seeds can be dispersed and why this is important.
8. **Identify** which conditions are necessary for germination. **Explain** why they are needed.
9. **Explain** whether all introduced species are pests.
10. Look at the image of deforestation in figure 3.54. Should forests be protected? If so, how many of them? If not, why not? Give reasons for your answers.
11. SI Population statistics of several animals were collected in two areas over 5 years. One area contained only native animals, while the other area contained native animals with an introduced species: the rabbit.
    The feeding habits of the animals were also studied:
    - Bandicoots eat roots, seeds, leaves and insects.
    - Dingos eat bandicoots, wallabies and rabbits.
    - Wallabies eat grasses and leaves.
    - Rabbits eat grasses and leaves.
    - Insects eat roots, seeds, leaves and grasses.

Area 1: populations of native animals over 5 years

Year	1	2	3	4	5
Bandicoot	310	488	505	505	505
Dingo	5	11	11	12	10
Wallaby	90	197	281	293	290

Area 2: populations of native animals over 5 years

Year	1	2	3	4	5
Bandicoot	310	475	495	500	505
Dingo	5	11	11	12	10
Wallaby	90	199	72	72	73
Rabbit	6	412	5122	5114	5120

   a. Draw two separate food webs: one of the native animals only, and the other one including the introduced species.
   b. Plot two population graphs from the two tables, using a different colour for each animal. Join the points with straight lines.
   c. i. Which native animal was most affected by the introduction of the rabbit into the second area?
      ii. Which animals were least affected?

d. i. What happened to the number of rabbits in the first 2 years?
ii. What happened to the number of rabbits after the first 2 years?
iii. Can you explain why this happened?
e. i. What effect did the introduction of the rabbits have on the wallaby population?
ii. Why do you think the rabbits had this effect?
f. Did the rabbits have any effect on the dingo and bandicoot populations? **Explain** your answer.
g. In your own words, **describe** any differences in the food webs of the two areas and how the populations of each of the native animals changed.

12. SI **Suggest** projects that governments, communities, scientists and farmers can work collaboratively on.

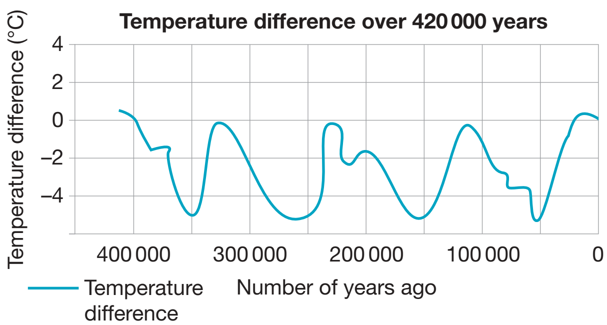
Evaluate and create

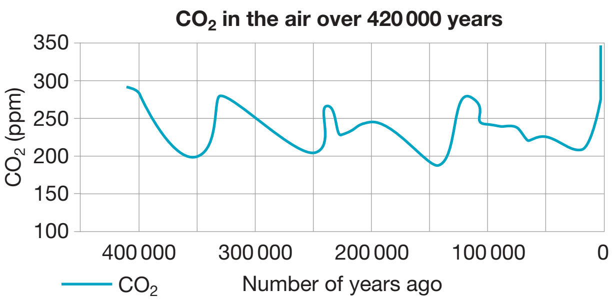
13. SI Not all plants are welcome in Australia; some plants have been identified as Australian 'weeds of national significance'. Features shared by these plants relate to their invasiveness, their potential to spread and their effect on primary production and the environment.
a. Find out the names of five plants on the Australian government's list of 'weeds of national significance'.
b. Select any plant on this list and either write a report or create a brochure about it with the following information.
i. **State** the common and scientific names of the plant.
ii. **Describe** the plant (include size, shape, structures and colour).
iii. **Describe** the distribution of this plant in Australia.
iv. **Outline** some interesting points about this plant.
v. **Suggest** why this plant is considered a weed.
vi. **Suggest** ways to control or eliminate this weed in Australia.
vii. **Suggest** possible consequences of removing this weed from Australian ecosystems.

14. SI Imagine that you are involved in each of the following situations. Prepare a report for both to promote your profession (or viewpoints), activities and any effects on the environment.
a. Woodchipping, deforestation or land clearing
b. An environmental protection group, such as Greenpeace

15. Horses were introduced to Australia by European settlers for transportation, agriculture and recreation. Feral horses, or brumbies, now cause significant ecological damage, such as degrading waterways, compacting soil, spreading non-native plants and altering vegetation. Efforts are ongoing to manage their populations and reduce their environmental impact on Australia's ecosystems.
Describe how feral horses negatively affect Australia's ecosystems, and what measures can be taken to reduce these impacts.

16. SI Scientists have drilled into ice in Antarctica and collected samples at very deep levels. Ice cores can provide information about the Earth and its atmosphere over hundreds of thousands of years. The Earth's temperature and the levels of carbon dioxide in the air can be tracked using these ice cores. Carefully study the graphs shown.





a. **Describe** the pattern shown for temperature differences over 420 000 years.
b. **Describe** the pattern shown for carbon dioxide levels over 420 000 years.
c. Do these graphs support the theory that global warming is due to increased levels of carbon dioxide in the air? **Explain** your answer.

Answers and sample responses are available in your digital formats.

LESSON 3.8

Aboriginal and Torres Strait Islander Peoples' connection to their ecosystem

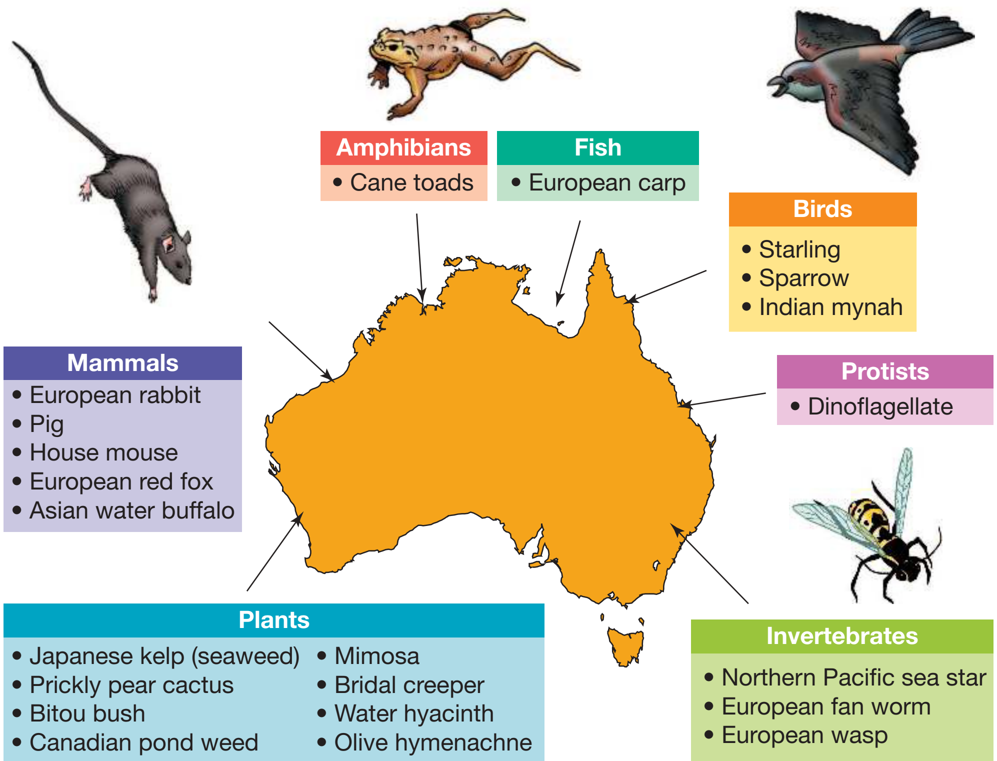
LEARNING INTENTION

In this lesson you will explain how Aboriginal and Torres Strait Islander Peoples have responded to invasive species and how they manage the land using fire.

3.8.1 Impact of invasive species

Many plants and animals have been introduced into Australia since European colonisation. Some of these foreign plants and animals are invasive, and they have had a significant impact on Aboriginal and Torres Strait Islander Peoples' resource access and cultural practices. **Invasive species** are those plants and animals that are introduced into a certain area and then spread to the point that they damage the environment.

FIGURE 3.59 Some of the many introduced species in Australia that have become pests



For example, the cane toad (*Bufo marinus*) was introduced into Australia in 1935 to control the sugarcane beetle, which was destroying sugar cane in Queensland. Unfortunately, the cane toad preferred other insects, and the sugarcane beetle was not greatly affected. Cane toads are poisonous and kill the animals that eat them. They need little water for breeding. In one season, the female toad can lay up to 40 000 eggs, which take only 3 days to hatch. As a result, the cane toad population quickly increased throughout Australia. The increase in the cane toad population has significantly affected the food chains and food webs of Australian ecosystems, including those that were in harmony under the management of Aboriginal and Torres Strait Islander Peoples.

ACTIVITY: Investigating the impact of invasive species on the local ecosystem

Research three invasive species (animal or plant) in Australia and copy and complete the following table with your findings.

Name of the invasive species	Areas affected	Main problems caused	Control measures taken by the government

Biodiversity decline

It is estimated that indigenous peoples, who represent approximately 6 per cent of the world's population, protect around 80 per cent of the remaining biodiversity.

Australia's unique biodiversity, which resulted from the continent's separation from other land masses millions of years ago, is facing major threats. These include loss and fragmentation of habitats, water pollution, diseases, uncontrolled bushfires, and the introduction and spread of non-native invasive species, which compete with Australia's native flora and fauna.

SCIENCE AS A HUMAN ENDEAVOUR: Endangered species

Policies and regulations related to hunting and fishing catch limits

The rainbow colours of the paradise parrot or the stripes of the Tasmanian tiger will never be seen again. Do you know why? They are extinct. These two animals are among 100 other species of Australian animals that are now extinct or extinct in the wild since European colonisation.

At present, Australia's biodiversity is decreasing. Upwards of 1700 species and ecological communities are known to be threatened and at risk of extinction. The key threats to native species include the destruction of habitats, invasive species, the variation in fire regimes (pattern, frequency and intensity of fires), the lack of sustainable management of natural resources, and alterations to aquatic ecosystems and the climate as a whole.

Endangered species are listed in the *Environment Protection and Biodiversity Conservation Act 1999.* The Threatened Species Strategy is the Australian government's chief mechanism for prioritising action and investment, guiding efforts to recover our threatened plants, animals and ecological communities from 2021 to 2031.

Australian animals such as turtles, dugongs and wombats are legally hunted under Federal native title laws, even though they are considered to be endangered species. Wildlife environment conservationists Bob Irwin and Colin Riddell started a campaign supported by Elders from Aboriginal and Torres Strait Islander communities to protect these endangered species. The Queensland government swiftly decided to protect turtles and dugongs under the *Animal Care and Protection Act 2001*.

The Queensland government has also developed the Queensland marine and turtle conservation strategy 2021–31 to address the conservation of six threatened marine turtle species only found in Australia. This strategy was developed with a number of stakeholders, including Aboriginal and Torres Strait Islander Peoples, recognising their current efforts and proposing to support them in maintaining healthy marine turtle numbers through their management of their land and sea Country. Additionally, the Australian Fisheries Management Authority (AFMA) is responsible for the management of Commonwealth fisheries.

There are several types of fishing regulations. Limits on the number of fish that can be caught are meant to keep people from catching too many fish at one time. Size limits are also meant to protect fish of spawning size before they are caught. Ultimately, fishing laws are meant to protect fish and make sure that everyone can fish sustainably. In Victoria, most people who wish to remove any species of fish (including yabbies, prawns and pippies) require a licence. This licence covers what you can use to fish as well as how much and what you can take.

FIGURE 3.60 The threatened green sea turtle has important nesting sites in and around the Great Barrier Reef.

1. Should endangered species like turtles and dugongs be hunted under native title laws, even if they are at risk of extinction? What ethical and environmental considerations need to be balanced when making such decisions?
2. How do policies like the Queensland marine and turtle conservation strategy aim to protect endangered species while involving Aboriginal and Torres Strait Islander Peoples? Why is it important to consider social and cultural factors in conservation efforts?

Proposed scientific responses to socio-scientific issues impact on society and may involve ethical, environmental, social and economic considerations (VC2S8H03)

Aboriginal and Torres Strait Islander Peoples, who have relied on Australia's biodiversity for thousands of years and have a vast knowledge of their environment, are developing innovative techniques that combine traditional land management/practices and western solutions to address the problem of biodiversity decline.

SCIENCE AS A HUMAN ENDEAVOUR: Invasive plant management in Australia

Gamba grass and salvinia

The ecosystems of northern Australia are changing quickly because of invasive species such as gamba grass (see figure 3.61), which can feed hotter and more intense bushfires. Some areas of Aboriginal and Torres Strait Islander Peoples' lands have not been notably affected, while other areas are now considered at risk of losing their biodiversity because more intense bushfires could transform the vegetation there and thus affect the ecosystems in those lands.

FIGURE 3.61 Gamba grass, which was introduced in Australia as a pasture grass, is now a serious threat to the savannas of northern Australia.

On the Daly River of the Northern Territory, Ranger coordinator Rob Lindsay has listed gamba grass as one of the **Weeds of National Significance (WONS)**.

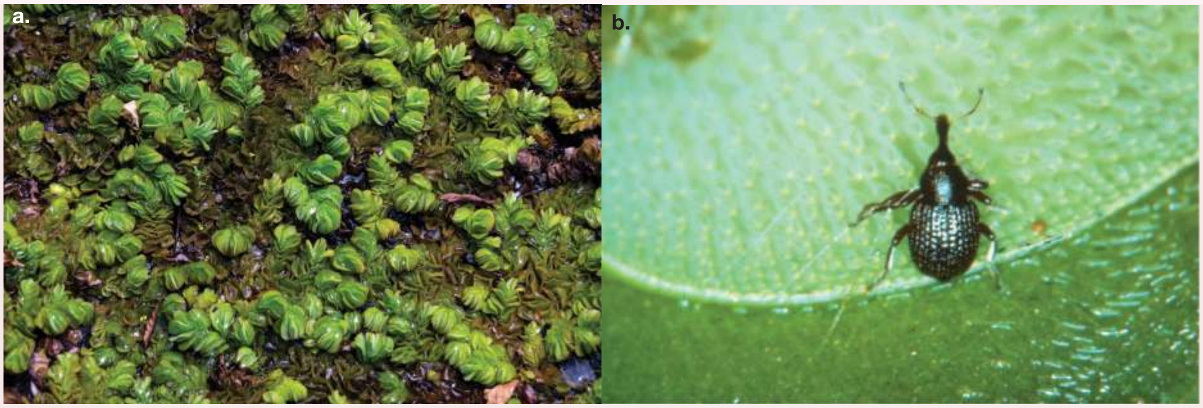
According to Lindsay, weed management is part of caring for Country. However, it also takes up a lot of resources and time, which are already scarce, because caring for Country also involves fire management, feral animal control and cultural obligations.

As a result, chemical spraying is often used to control WONS, but Aboriginal and Torres Strait Islander Peoples are also involved in other management techniques, such as biocontrol.

Salvinia, which was introduced into Australia as an ornamental plant for fishponds and aquariums, is another example of a plant that has been identified as a WONS.

The salvinia weevil, a small (2–3 mm), dark, sub-aquatic weevil, is a successful biological control agent for salvinia in Australia. While the adults feeding on the plant are harming it, most of the damage comes from the larvae tunnelling into the plant's rhizome to feed, causing it to rot and sink.

FIGURE 3.62 a. Salvinia, a pretty plant used in fishponds and aquariums, is a highly invasive species. **b.** The salvinia weevil, originating from Brazil, was selected as a biological control agent to combat salvinia.



This method of control was used with resounding success in Lake Moondarra in Queensland 50 years ago. Before the introduction of this little weevil, the whole surface of the lake was covered by the highly invasive salvinia, but in just over 1 year the lake was completely rid of it.

In the Kimberley region (Western Australia), which is now 93.5 per cent native title land, ranger programs have been developed so that Aboriginal Peoples can care for their Country. These programs use a combination of traditional knowledge, western science and modern technology. This sector of conservation and land management offers opportunities for long-term careers for Aboriginal and Torres Strait Islander People in remote communities.

1. How do gamba grass and salvinia affect both the environment and the cultural practices of Aboriginal and Torres Strait Islander communities?
2. What are the advantages and disadvantages of using chemical spraying versus biological control methods, such as introducing the salvinia weevil, in managing invasive species?

Proposed scientific responses to socio-scientific issues impact on society and may involve ethical, environmental, social and economic considerations (VC2S8H03)

3.8.2 Land management by Aboriginal and Torres Strait Islander Peoples

Bushfires have always been a common part of the Australian environment because of its dry and arid climate. Bushfires can be deliberately or accidentally started by humans, but they can also happen naturally (e.g. due to lightning strikes).

Aboriginal and Torres Strait Islander Peoples have deep connections to the lands, waterways and seas they have been caring for for more than 65 000 years. They have made frequent and planned use of fire for effective land management. Burning the land was considered a cleaning process to remove all the dead matter. It was also used to clear tracks for easy movement, to facilitate hunting, to promote biodiversity, and for signalling, cooking and providing warmth.

Firestick farming

Firestick farming involves controlled burning of parts of the bush. It reduces the risk of uncontrolled and damaging bushfires by clearing the land (reducing the amount of fuel available), while also enabling animals to escape. Further, it promotes plant growth and increases the amount and diversity of food available. This abundance of new vegetation then attracts animals such as wallabies and kangaroos, which enables people to hunt more easily.

FIGURE 3.63 Controlled burning in Kakadu National Park, Northern Territory

Firestick farming is also used for burning invasive weeds to allow native species a chance to regrow.

Cool burning, often known as cultural burning, involves lighting small fires in small areas with firesticks to clear the underbrush (the small flames burn the grasses but not trees). These fires are controlled and closely monitored.

Aboriginal and Torres Strait Islander Peoples' knowledge of the seasons and local conditions enable them to produce the most effective cool burns, determining when and where to burn to prevent the fire from spreading.

SCIENCE AS A HUMAN ENDEAVOUR: Fire management in northern Australia

Aboriginal and Torres Strait Islander Peoples' community-based ranger groups leading the way

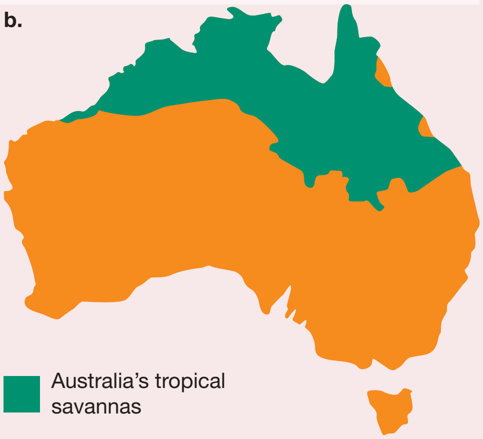
For thousands of years, Aboriginal and Torres Strait Islander Peoples have carefully managed the use of fire across Australia. The Cultural protocols that developed over this course of time are still being used today. By way of collaboration with Aboriginal and Torres Strait Islander Peoples, Elders oversee the process of controlled burns.

The fire management that was implemented led to fewer, larger trees. In between, grasses and vegetables grew, animals grazed and travel was easy. The loss of this fire has led to a greater density of smaller trees. When a bushfire starts, this density makes it much easier for fire to spread and harder for us to stop it. In northern Australia, the tropical savannas (see figure 3.64) are considered the most fire-prone areas of the world. Bushfires are a major issue across Australia, but 70 per cent of the country's affected areas are in northern Australia. Over the past two decades, responsible fire management has greatly reduced the annual average area burned. Due to Aboriginal and Torres Strait Islander Peoples' community-based rangers' efforts, the fire management protocol has paved the way for one of the most successful greenhouse gas emission reduction practices in Australia.

The comprehensive principles of fire management in northern Australia involve low-intensity burning early in the dry season, when fires are manageable, and proactively preventing the occurrence of uncontrolled fires in the late dry season, which are usually caused by lightning or other non-human sources. In doing so, firebreaks are created to prevent larger fires from burning later in the dry season.

The 2019 fire season was especially challenging in northern Australia, but following this traditional practice — as opposed to the post-colonial practice of burning later in the dry season — greatly reduced the severity of the fires that year. Satellite monitoring has revealed that this practice reduced dry season wildfires over an area of 115 000 square kilometres, and reduced all fires by 88 000 square kilometres. Overall, this proactive approach has led to greenhouse gas emission reductions by upwards of seven million tonnes of carbon dioxide. Climate change will continue to impact regions of northern Australia and across the country. However, the resounding success of this initiative based on traditional knowledge has shown that there is a way forward.

FIGURE 3.64 a. Savanna landscape in the Kimberley region, Western Australia **b.** The tropical savannas in northern Australia, which cover approximately 17 per cent of the land, but on average account for 70 per cent of the areas affected by fire each year



1. How does combining traditional fire management practices of Aboriginal and Torres Strait Islander Peoples with modern scientific methods help reduce the severity of wildfires and greenhouse gas emissions?
2. Why is it important to incorporate the knowledge and cultural protocols of Aboriginal and Torres Strait Islander Peoples when developing effective fire management strategies?

Multidisciplinary endeavours to advance scientific knowledge make use of people's different perspectives and worldviews (VC2S8H02)

3.8.3 Bush medicine

Archaeological studies have shown that prehistoric humans practised medicine, using medicinal herbs and shamanism (a system of religious practice). All over the world, different communities discovered, by trial and error, how certain plants could be used to treat specific ailments.

The Aboriginal and Torres Strait Islander Peoples are no exception. They studied their environment over thousands of years and developed treatments and remedies using native plants.

SCIENCE AS A HUMAN ENDEAVOUR: Aboriginal and Torres Strait Islander Peoples' medicine

Medicinal and endemic plants

Aboriginal and Torres Strait Islander Peoples' traditional practices for treating wounds and infections, using well-developed scientific knowledge and skills, predated western science's germ theory. The information was passed down over thousands of years through generations in their oral history. Plants were the source of most treatments.

Aboriginal and Torres Strait Islander Peoples used crushed tea tree leaves for wounds. Scientists in the 1920s found that tea tree oil (see figure 3.65a) was far more effective than their current disinfectant, carbolic acid. Tea tree oil was also found to have antimicrobial, antifungal, antiviral and anti-inflammatory properties, and it is now added to many therapeutic medications, including those for fungal toenail infections and acne. The aromatic oil also stimulates the production of lubricating fluids in the throat, easing irritations that result in coughs.

Like all medications, bush medicines should be taken under the care and guidance of trained health Kangaroo apples (see figure 3.65b) can be used to treat achy and swollen joints to decrease pain, but it should be noted that while the ripe orange fruit is good to eat, the green fruit is poisonous.

FIGURE 3.65 a. Tea tree oil has antimicrobial, antifungal, antiviral and anti-inflammatory properties.
b. The kangaroo apple (*Solanum laciniatum*), which is so common people think it is a weed, is a natural anti-inflammatory steroid.

a. b.

There is great potential to make many more therapeutic discoveries based on the knowledge obtained from thousands of years of scientific experimentation and applications by Aboriginal and Torres Strait Islander Peoples.

1. How did the traditional use of tea tree leaves by Aboriginal and Torres Strait Islander Peoples influence modern medicine's understanding and application of tea tree oil?
2. Why is it important for contemporary medicine to consider and incorporate traditional practices, such as those using kangaroo apples, while ensuring treatments are safe and effective?

Scientific knowledge, including models and theories, can change because of new evidence (VC2S8H01)

3.8.4 Bush tucker

Bush tucker, or bush food, refers to the food native to Australia that Aboriginal and Torres Strait Islander Peoples have used to feed themselves. Different communities will rely on different food sources that are present in their specific environment. For instance, bush tomatoes (desert raisins) are traditionally picked up during the autumn and winter months in the central deserts of Australia, while in northern Australia, Kakadu plums are harvested in January and February.

Ancient knowledge

Managing food sources and ecosystems is an important part of Aboriginal and Torres Strait Islander Peoples' cultures.

Before the European colonisation of Australia, there were hundreds of diverse groups of peoples, with their own languages and cultures, living sustainably and eating a balanced diet from the plants and animals of their Country.

Whether they lived by the sea, on the banks of a river, high in the mountains or in the desert, they understood the seasonal changes and local foods, gaining a balanced diet from 'bush tucker'.

FIGURE 3.66 Bush tucker includes a range of plant energy storage organs such as nuts, fruits and roots.

To live from the land, people knew the habits of local animals, and kept a close watch on changes in the weather and how they affected plant growth. They also used controlled burning and other techniques to manage the land and the food it produced. Their knowledge and skill allowed them to hunt and harvest food very successfully. Aboriginal and Torres Strait Islander Peoples also collected shellfish, nuts, berries, fruits, waterlily stems and roots, ants, and many other types of food from the environment. They knew which foods were poisonous, and were able to prepare some of these so that they could be eaten safely. In many communities, they also cultivated specific plant crops and created systems to manage food sources such as fish.

Some of the early European settlers and explorers learned some bush tucker skills, but most didn't. The explorers Burke and Wills died of starvation in central Australia on their return journey to Melbourne in 1861, even though seeds, roots and grubs eaten by the local people were available.

Finding water in the bush

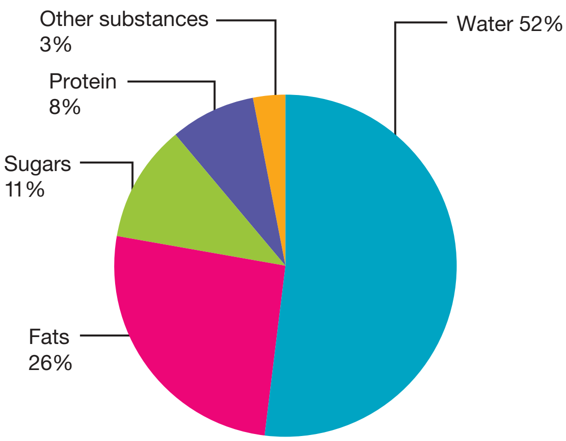
Water is scarce in many areas of Australia. Many Aboriginal and Torres Strait Islander Peoples knew how to obtain water in even the most arid parts of their Country. They knew where to dig in dry creek beds and were able to obtain water from tree roots, tree stems, frogs and other animals. They also cut tree roots into small sections and sealed the ends with clay to store water.

Witjuti tucker

Witjuti grubs (*Endoxyla leucomochla*) are the white larvae of beetles and were regarded as a delicacy in drier areas (see figure 3.67). They are very nutritious and rich in protein, fat and sugars, and are good sources of iron, calcium and water (see figure 3.68). Witjuti grubs can be obtained from the roots and stems of trees, especially the witjuti bush they are named after, and live off the sap in the trees. They can be up to 13 cm long.

FIGURE 3.67 A witjuti grub — regarded as a delicacy in drier areas

FIGURE 3.68 The average body composition of a witjuti grub



Impacts of European colonisation: Dugongs

Dugongs are marine animals, with a flattened tail and cow-like appearance. They feature in many of the creation stories across northern Australia.

For some coastal Aboriginal or Torres Strait Islander Peoples, dugongs have been a highly prized source of meat. In the past, everyone was allowed to hunt dugongs for food, hide and oil. However, it is now legal only for Aboriginal and Torres Strait Islander Peoples to hunt them, and only if they use traditional methods of hunting. Even with these restrictions, dugong populations in some regions are still at very low levels.

Healthy tucker

Plants contain complex mixtures of chemicals, including those that humans can use for nutrition, such as proteins, fats and carbohydrates. Plants also produce bioactive compounds that can be beneficial for human health, including antioxidant and anti-inflammatory properties. These compounds are known as phytochemicals (from the Greek word *phyto*, meaning 'plant').

In 2009, the CSIRO produced a research report on the presence of 'health-enhancing compounds' in a variety of native Australian herbs, spices and fruit samples. They reported that the foods sampled were exceptionally rich sources of antioxidants, folate, iron, and vitamins C and E.

TABLE 3.2 Some of the findings of a 2009 CSIRO report on Australian native foods

Bush food	High in antioxidants	High in vitamin C	High in folate	High in iron
Kakadu plum	✓	✓	✓	
Quandong	✓		✓	✓
Tasmanian pepper leaf	✓		✓	✓
Lemon myrtle	✓		✓	
Australian desert lime		✓	✓	

As of November 2024, there was no publicly available information indicating that CSIRO has published an updated report specifically on the presence of health-enhancing compounds in native Australian herbs, spices and fruits since their 2009 study. However, other organisations and researchers have conducted studies in this area. For instance, AgriFutures Australia has explored the health benefits of Australian native foods, evaluating health-enhancing compounds in various native fruits and herbs.

While CSIRO's report may not have been updated, ongoing research by CSIRO and other institutions continues to investigate the health properties of native Australian plants.

Grow your own

Interest in Australian native foods has been increasing in the past years. You can now more easily find nurseries that sell native plants so that you can grow your own midyim berries, bush tomatoes, quandongs or finger limes, depending where you live. However, care should always be taken to make sure you are not consuming parts of the plant or fruits that are poisonous. For example, the unripe bush tomato (*Solanum centrale*) contains high levels of the toxin solanine, as do the leaves and bark of the tree. Once the tomato ripens, the solanine dissipates. This is true for common foods that also belong to the *solanaceae* family, such as tomatoes (*Solanum lycopersicum*), potatoes (*Solanum tuberosum*) and eggplant (*Solanum melongena*), none of which should be eaten when unripe.

3.8 Activities

learnon

3.8 Quick quiz on	3.8 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 5, 6, 10	3, 7, 9, 12	4, 8, 11, 13

Remember and understand

1. Briefly **outline** the knowledge and skills that Aboriginal and Torres Strait Islander Peoples traditionally used to achieve a balanced diet.
2. **State** where witjuti grubs may be found and what they look like, and **suggest** why they are described as being very nutritious.
3. **Describe** how Aboriginal and Torres Strait Islander Peoples' communities living in arid areas find enough water to survive.
4. SI **Discuss** dugongs, and write a small paragraph answering the following questions.
   a. **Suggest** reasons for why dugongs are endangered.
   b. Which groups of people in Australia are allowed to hunt dugongs and why?

Apply and analyse

5. Bush tucker can provide a balanced diet. Give examples of bush foods that contain:
   a. protein b. carbohydrates c. fats and oils.
6. SI Refer to figure 3.68.
   a. **Identify** the percentage of each of the following in the average body composition of a witjuti grub.
      i. Sugars ii. Protein iii. Fats iv. Water
   b. Which substance makes up the highest proportion of witjuti grubs? Why might this be important for people living in dry environments?
7. Use the information in table 3.2 to **identify**:
   a. which bush food is high in iron
   b. which bush food is not high in antioxidants
   c. which bush foods are high in vitamin C.
8. **Identify** two Australian native plants as a source of food or medicine. **State** the species name and its use.

Evaluate and create

9. **Construct** a table to show the similarities and differences between potatoes, carrots, rhubarb, celery and onion.
10. **Construct** a Venn diagram to compare the following.
    a. Kakadu plums and quandongs b. Lemon myrtle and Tasmanian pepper leaf
11. What do you think about hunting dugongs? Who should be allowed to hunt them? How many should be taken, when and why? **Justify** your opinions.
12. Dugongs feature in the creation stories of many Aboriginal and Torres Strait Islander Peoples' cultures across northern Australia. Write a short story that features a dugong.
13. SI Aboriginal and Torres Strait Islander Peoples may use fire to manage their Country and feed their community. Well-managed fires promote new plant growth. This attracts animals, which makes hunting much easier. **Discuss** how Aboriginal and Torres Strait Islander Peoples recognised relationships in ecosystems in your area.

Answers and sample responses are available in your digital formats.

LESSON 3.9 Review

3.9 Success criteria

Tick the column to indicate that you have completed the lesson and how well you think you have understood it using the traffic light system.

(**Green:** I understand; **Yellow:** I can do it with help; **Red:** I do not understand)

Lesson	Success criteria	Green	Yellow	Red
3.2	I can describe ecosystems, including the way that living and non-living things interact.			
	I can describe the conditions that are best suited to specific living and non-living things.			
3.3	I can understand that ecosystems are made of living things interacting with each other through feeding relationships.			
	I can identify and classify producers, consumers and relationships.			
3.4	I can explain how energy flows into and out of an ecosystem through the feeding relationships that can be described in food chains and food webs.			
3.5	I can explain how energy flows into and out of an ecosystem via the pathways of food webs.			
	I can explain how ecosystems have their own system of recycling.			
3.6	I can identify and describe the different ecological pyramids used to represent relationships between organisms at different trophic levels.			
3.7	I can explain how events such as seasonal changes, destruction of habitat or introduction of a species impact abiotic and biotic factors, and cause changes to populations.			
3.8	I can explain how Aboriginal and Torres Strait Islander Peoples have responded to invasive species and how they manage the land using fire.			

learnon

Post-test	Topic 3 Post-test
eWorkbook	Topic 3 eWorkbook
Digital document	Key terms glossary

3.9 Activities

learnon

3.9 Review questions

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 4, 9	3, 5, 6, 8, 11	7, 10, 12, 13

Remember and understand

1. Match each term to its meaning.

Term	Meaning
a. Herbivores	1. Organisms that produce their own food
b. Producers	2. Animals that eat plants
c. Consumers	3. Organisms that live in or on other organisms and obtain their food from them
d. Parasites	4. Organisms that break down dead plants and animals
e. Decomposers	5. Animals that eat other organisms

2. Copy and complete the puzzle, using the clues provided.

a. _ _ _ _ E _ _ _ _ _ _
b. _ _ _ _ N _ _ _ _ _
c. _ _ _ _ _ V _ _ _ _
d. _ _ _ I _ _ _
e. _ _ R _ _ _ _ _ _
f. _ _ O _ _ _ _ _ _
g. _ _ _ _ N _ _
h. _ _ _ _ M _ _ _ _ _ _
i. _ _ _ _ _ E _
j. _ _ N _ _ _ _
k. _ _ T _ _ _ _ _ _

Clues

a. Animals that eat the same sort of food and live in the same area
b. Animals that are close to extinction
c. Meat-eating animals
d. A place where an organism lives
e. Plant-eating animal
f. A stable system made up of living and non-living things
g. Describes species that no longer exist
h. Organisms such as bacteria and fungi that break down plant and animal remains
i. A diagram that shows the feeding relationships of organisms in an ecosystem
j. Information about number and closeness of organisms determined by sampling
k. The interaction between members of two species that benefits both species

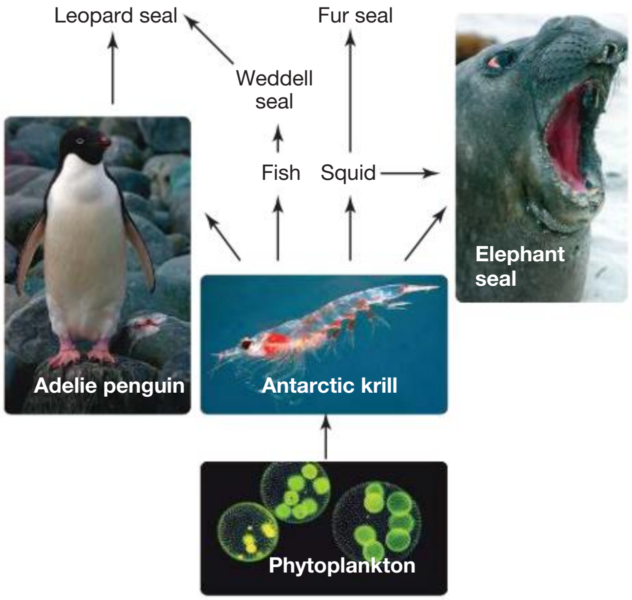
3. **Describe** similarities and differences between the following terms.
   a. Producer and consumer
   b. Food chain and food web
   c. Mutualism and parasitism
   d. Population and community
4. **Outline** the importance of decomposers in an ecosystem.

Apply and analyse

5. a. **Explain** how atoms and matter are recycled through an ecosystem.
   b. There is a connection between the food you put into your stomach and the air you breathe into your lungs. **Explain** the connection.
6. a. **Identify** the key source of energy in ecosystems.
   b. **Describe** how energy moves through ecosystems.
7. **Describe** three ways in which Aboriginal and Torres Strait Islander Peoples use the ecosystem around them.
8. Many Australian species are endangered, including mammals, fish and birds.
   a. **Describe** the term *endangered*.
   b. **Explain** how this differs from the term *vulnerable*.
   c. **Outline** three ways in which humans may cause a species that is endangered to become extinct.
9. **Explain** how humans can live more sustainably and better protect our ecosystems.

Evaluate and create

10. **Construct** a pyramid that represents the transfer or transformation of materials and energy in food chains and webs.
11. **Construct** a food web that includes organisms in a local ecosystem.
12. a. **Construct** three food chains from the food web shown.
    b. In the food web, **identify** the:
       i. producer
       ii. primary consumer
       iii. secondary consumer
       iv. tertiary consumer.
    c. In the food web, **identify** which organism is both:
       i. a secondary and a tertiary consumer
       ii. a tertiary and a quaternary consumer.
    d. **Suggest** the effect of reduced numbers of Antarctic krill on the ecosystem.



13. SI Select one of the introduced organisms shown in figure 3.59. Find out and report on:
    a. where they came from and how they arrived in Australia
    b. the effects they have had on Australian ecosystems.

Answers and sample responses are available in your digital formats.

on To test your understanding and knowledge of this topic, go to your learnON title at jacplus.com.au and complete the **post-test**.

4 States of matter

CONTENT DESCRIPTION

The particle and kinetic theories of matter can be used to describe the arrangement and motion of particles in a substance, including the attraction between particles, and to explain the properties and behaviour of substances, including melting point, boiling point, density, compressibility, gas pressure, viscosity, diffusion, and expansion and contraction (VC2S8U05)

Source: Victorian Curriculum F–10 Version 2.0

LESSON SEQUENCE

LESSON 4.1 Overview

4.1.1 Introduction

Everything around you and in you is made of matter. Your school bag, your desk, the clothes you are wearing, the food that you eat and the air that you breathe are substances that are made of **matter**. Generally, anything that has **mass** and takes up space is matter. Different types of matter have different properties. A precious and essential form of matter is water — we cannot exist without it. Most of Earth is covered in water, which exists naturally on Earth in three states: **solid**, **liquid** and **gas** (or vapour). The North and South poles are covered in ice, which is solid water. Between the poles there are liquid oceans and seas, and in the atmosphere immediately above Earth's surface, there is **water vapour**.

FIGURE 4.1 Water naturally occurs on Earth in three states: solid (ice), liquid and gas (vapour). Water vapour is not visible. The clouds consist of tiny droplets of liquid water.

In this topic you will investigate the various properties of the solid, liquid and gas states. In order to explain the behaviour of solids, liquids and gases, the particle model and kinetic theory will be introduced. When heated or cooled, the state of substances can be changed, and the particle model will be used to explain what is happening during this change of state.

DISCUSSION

1. Why does ice melt?
2. Why do droplets form on the outside of a cold soft drink can?
3. Why do car windows fog up in winter?
4. What are clouds made of?
5. What is the difference between hail and snow?
6. In which state of matter do particles have the most energy?

SCIENCE INQUIRY: Bathroom science

When you take a hot shower, the water heats up and produces water vapour. This vapour spreads through the bathroom and comes into contact with cooler surfaces, like the mirror, causing condensation. Condensation occurs when warm water vapour in the air cools and turns back into tiny liquid droplets. The movement of air during a shower can also create unusual effects, like the shower curtain moving inward. These behaviours are influenced by the interaction of heat, pressure and the states of matter.

1. Why does the mirror fog up in the bathroom after someone has had a hot shower?
2. On really hot days, you may have a cold shower to cool down. Does the bathroom mirror fog up when you do this?
3. Some showers have shower curtains rather than glass shower screens. When people have warm showers, the curtain tends to move in towards the person and stick to them. Give possible explanations for why this happens.

FIGURE 4.2 Bathroom mirrors often fog up when you have a shower.

4. When you have a hot shower, the bathroom fills with water vapour. Is this water vapour a gas or a liquid or both? Explain your reasoning.
5. At what temperature does water become too hot to touch?
6. Does water vapour always rise?
7. Are water vapour and steam the same thing?
8. Can you see water vapour or steam?

Investigable questions, reasoned predictions and hypotheses can be developed in guiding investigations to identify patterns, test relationships and analyse and evaluate scientific models (VC2S8I01)

INVESTIGATION 4.1

Investigating the properties of solids, liquids and gases

Aim

To investigate the properties of solids, liquids and gases

Hypothesis

If the properties of the three states of matter are investigated, then a solid, a liquid and a gas will have distinctive properties.

Materials

- ice cube
- plastic syringe
- spatula
- balloon
- beaker of water
- balance
- 250 mL beaker (empty)

Method

Copy the table in the Results section of this investigation and use your observations to complete it.

Ice

1. Weigh the ice cube and record the mass.
2. Pick up an ice cube and place it on the bench. Using a spatula, try to squash it or compress it to make it smaller.

Water

1. Take the beaker of water and draw a small amount into the syringe. Place your finger over the opening at the end of the syringe and press down on the plunger.
2. Place the beaker on the balance and zero the balance, release the water back into the beaker and record the mass.

Gas

1. Partially inflate a balloon with air and hold the opening tightly closed. Try to squeeze the balloon.
2. Release your hold on the opening of the balloon.
3. Place the 250 mL beaker on the balance and zero the balance. Add the deflated balloon and record the mass. Blow the balloon up and tie it, and sit it on the beaker to hold it still and record the mass again.

Results

Use a table like the one below to record your findings.

Substance	State of substance	Can the shape be changed easily?	Does it take up space?	Can it be compressed?	Does it have mass?
Ice	Solid				
Water	Liquid				
Air	Gas				

Discussion

1. How do you know that air takes up space?
2. How do you know that air has mass?
3. Where did the air in the balloon go when you released the opening?
4. Which state(s) can be compressed?
5. Which state(s) can change shape depending on the container?

Conclusion

Summarise your findings about the properties of solids, liquids and gases. Remember that you must only include the findings of this experiment and not include any other properties that were not tested. Your conclusion should be no longer than three or four sentences.

learnon

Pre-test	Topic 4 Pre-test
eWorkbooks	Topic 4 eWorkbook Student learning matrix
Practical investigation eLogbook	Topic 4 Practical investigation eLogbook
Digital document	Key terms glossary

LESSON 4.2 Different states of matter

LEARNING INTENTION

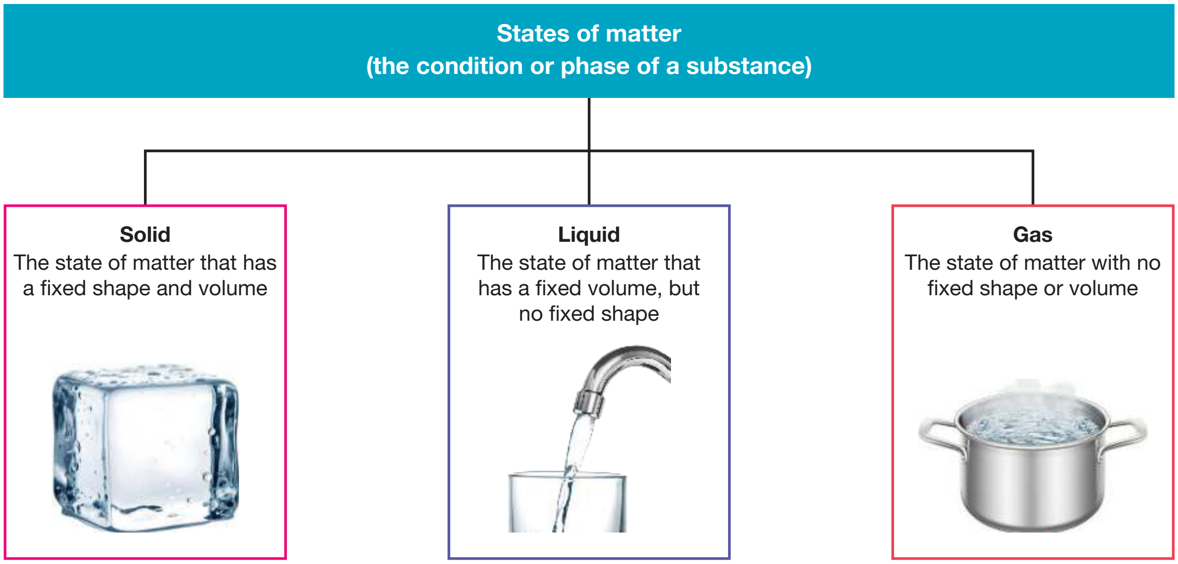
In this lesson you will compare the properties of different states of matter.

4.2.1 Solids, liquids and gases

Every substance in the universe is made up of matter that can exist in a number of different forms called states. Almost all matter on Earth exists in three different states: solid, liquid or gas. These states of matter have very different **properties**. That is, they are different in the way they behave and appear. Note that there is also a fourth state of matter, known as **plasma**, which is when a gas is heated at extreme temperatures and becomes electrically charged, as in a neon sign.

FIGURE 4.3 The aurora borealis (northern lights) are a form of plasma.

FIGURE 4.4 States of matter



Solids

Solids, such as ice, have a very definite shape that cannot easily be changed. They take up a fixed amount of space and are generally not able to be compressed.

FIGURE 4.5 Common solid objects

Liquids

Liquids, such as water, do not have a fixed shape. The shape of a liquid changes to that of the container in which it is kept. Like solids, liquids take up a fixed amount of space.

If a liquid is poured into a glass, it will take up the shape of the glass. If you continue to pour, it will eventually overflow onto the bench or floor.

FIGURE 4.6 Liquid overflowing in a cup

Gases

Gases spread out and will not stay in a container unless it has a lid. Gases move around, taking up all of the available space; for example, when a roast is cooking, the smell can drift from the kitchen throughout the house. This movement is called **diffusion**. In figure 4.7, iodine gas is being formed and is spreading, or diffusing, throughout the gas jar.

FIGURE 4.7 The iodine gas will diffuse to take up the space inside the glass jar.

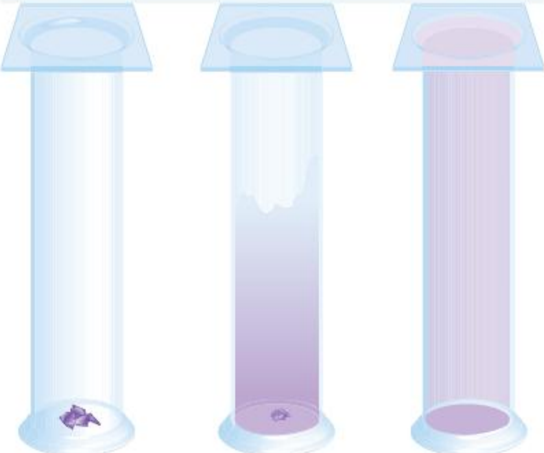


FIGURE 4.8 For safety, iodine gas is being diffused in a fume cupboard.

Gases, unlike solids and liquids, exhibit **compressibility**, allowing them to occupy less space when pressure is applied. For example, the compressibility of an inflated balloon can be observed when it is squeezed.

DISCUSSION

Salt crystals are able to be poured and also take up the shape of their container. Are salt crystals liquid or solid?

INVESTIGATION 4.2

Ranking substances

It is useful to refer to the properties of substances to decide if substances are solids, liquids or gases. Examples of properties include appearance, colour, shape, how they feel or smell, if they are heavy, if they can be poured, and their melting point and boiling point.

Aim

To investigate whether materials are solids, liquids or gases based on their properties

Hypothesis

If the properties of the three states of matter are investigated, then a solid, a liquid and a gas will have distinctive properties that enable us to classify them.

Materials

- a brick
- Vegemite
- playdough
- green slime
- orange cordial
- tomato sauce
- salt
- sugar
- steam
- air

Green slime — is it solid or liquid? How do you know?

Method

1. Prepare a table as shown in the results section of this investigation to fit all of the materials.
2. Working in small groups, make accurate and detailed observations of the properties of each of the materials and record them in the results table.

Results

Use a table like the one below to record your findings.

Substance	Properties	Solid, liquid or gas
Brick	Hard Feels rough Heavy Cannot be poured	
Playdough		

Discussion

1. Based on your observations, decide whether to classify each material as a solid, liquid or gas.
2. Rank the substances in order from most solid-like to most liquid-like to most gas-like.
3. Compare your rankings with those of other groups. Comment on any differences between the rankings.
4. Which properties were most useful in classifying the materials?
5. Suggest further investigations that might assist you in relating properties to different states of matter.

Conclusion

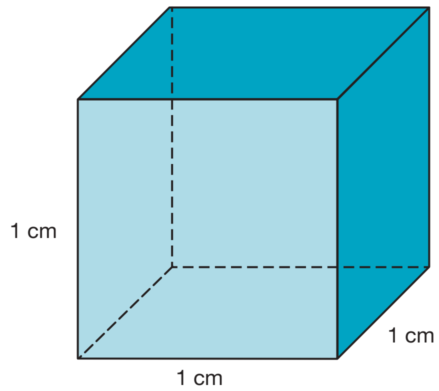
Which substances were most difficult to classify as solid, liquid or gas? Explain why they were difficult to classify. Your conclusion should be no longer than three or four sentences.

4.2.2 Measuring matter

The amount of matter in a substance, whether solid, liquid or gas, is called mass. The most commonly used unit of mass is the kilogram (kg), which is equal to 1000 grams (g). Mass is measured with an electronic scale or balance.

The amount of space taken up by a substance is called its **volume**. The volume of solids is usually measured in cubic metres (m^3) or cubic centimetres (cm^3). The volume of fluids is measured in millilitres (mL). One millilitre occupies the same volume as 1 cm^3. A **fluid** is a substance that can flow. All liquids and gases are fluids.

FIGURE 4.9 This cube has a volume of 1 cm^3 and can hold 1 mL of a fluid.



KEY IDEA

Some basic volume conversion equivalents to keep in mind include:

$$1 \text{ mL} = 1 \text{ cm}^3$$
$$1 \text{ L} = 1000 \text{ cm}^3$$
$$1000 \text{ L} = 1 \text{ m}^3$$

ACTIVITY: Water bottle

You are designing a water bottle for a marathon runner. The bottle needs to hold exactly 500 mL of water, but you want to ensure it is light and compact. To test your design, you need to think about both mass and volume.

If the bottle holds 500 mL of water, what is the mass of the water in kilograms?

(*Hint:* Remember that 1 mL of water has a mass of 1 g.)

As a class, discuss the following:
1. Why is it important to measure both mass and volume in science and engineering?
2. How does the relationship between mass and volume (e.g. density) help us understand the difference between solids, liquids and gases?

4.2 Activities

learnon

4.2 Quick quiz (on)	4.2 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3, 6, 11	4, 7, 8, 9, 12, 13	5, 10, 14

Remember and understand

1. MC **Identify** the term for anything that has mass and takes up space.
   A. Solid
   B. Liquid
   C. Gas
   D. Matter
2. MC **Identify** the state that cannot flow.
   A. Solid
   B. Liquid
   C. Gas
   D. Matter
3. **List** as many solids, liquids and gases that you can remember coming into contact with before leaving for school today. Organise them into a table under the headings Solids, Liquids and Gases, or into a cluster, mind or concept map. You can list items in multiple columns if they displayed properties of both states.
4. a. MC **Identify** three properties from the list below that most solids have in common.
      A. Retain their shape
      B. Do not retain their shape
      C. Have a changing volume
      D. Have a constant volume
      E. Have mass
      F. Do not have mass
   b. Would liquids have the same three properties? If not, what differences might be expected?
5. a. **Identify** the unit used to measure small volumes, such as for liquid medicines.
   b. **Suggest** how you could measure such a volume.

Apply and analyse

6. **Describe**, in terms of their properties, how gases differ from liquids.
7. Both steel and chalk are solids. **Describe** what properties of steel make it more useful than chalk for building bridges.
8. Are plasticine and playdough solids or liquids? **Explain**.
9. What is diffusion? Give two examples of this occurring around your house.
10. Is it possible for a solid to behave like a fluid? **Explain** your answer.

Evaluate and create

11. At a petrol station, safety signs ask for the car engine to be switched off before you fill the petrol tank. Use your knowledge of diffusion to **explain** why this is necessary.
12. SI Different liquids pour or flow in different ways. Test this by pouring honey, shampoo, cooking oil and water from one container to another. Write your hypothesis first and make sure it is a fair test by considering the variables. Record the time each liquid takes to pour. Record the results in a table and write a conclusion based on your observations and results.
13. Create a short poem about the properties of solids, liquids and gases.
14. SI Olivia says that when a candle burns, it is a solid that burns; Henry says it is a liquid that burns and Zahra says it is a gas. Write a hypothesis about what you think is occurring and then observe a candle burning (you could do it yourself or find a video online). Decide who is correct and write a summary of your findings.

Answers and sample responses are available in your digital formats.

LESSON 4.3 Changing states

LEARNING INTENTION

In this lesson you will describe how the state of a substance is affected by properties such as melting and boiling point and the amount of heat energy absorbed or released.

4.3.1 Changing states

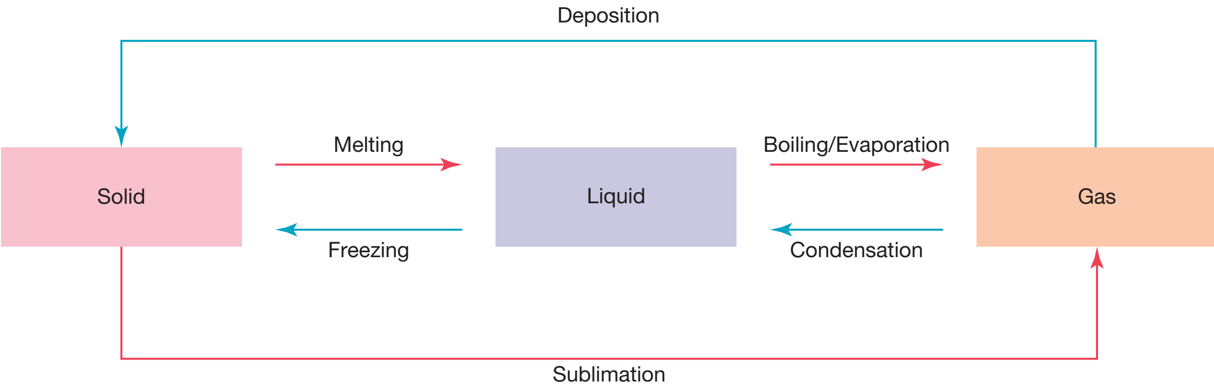
Water is the only substance on Earth that exists naturally in three different states at normal temperatures. It is in the oceans, in the polar ice and in the air as water vapour. Water is constantly moving and changing states. You can observe water changing states in the kitchen.

KEY IDEA

To change the state of any substance, including water, it must be heated or cooled, or the pressure must be changed.

FIGURE 4.10 Unfortunately, the ice sculpture in this photograph won't last for very long. Even as the sculptor works, it is melting as heat moves into it from the warmer air around it.

FIGURE 4.11 The processes involved in changing states



Melting point and boiling point

The **state of matter** of any substance depends on **pressure** and its **temperature**. The temperature at which a substance changes from a solid into a liquid (**melts**) is called its **melting point**. A liquid changes into a solid (**freezes**) at the same temperature. Water has a melting point of 0 °C, so to melt ice it has to be heated to a temperature of 0 °C. To freeze water it has to be cooled to a temperature of 0 °C.

Melting and boiling points change with the height above sea level. This is because the air gets thinner and the air pressure gets lower as you move away from Earth's surface. If you were climbing Mount Everest and made a cup of coffee near its peak, you would find that the water boiled at about 70 °C instead of 100 °C.

The **boiling point** is the temperature at which a substance boils. At this temperature, the substance changes from liquid into gas (**evaporates**) quickly. At the same temperature, a gas changes into a liquid (**condenses**). The melting and boiling points of some common substances are shown in table 4.1.

TABLE 4.1 Melting and boiling points of some common substances at sea level

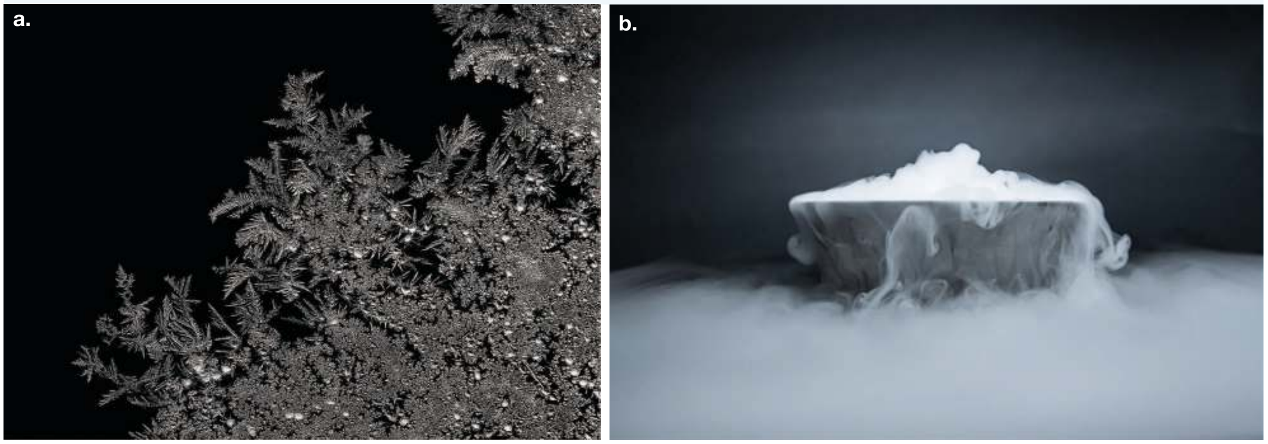
Substance	Melting point (°C)	Boiling point (°C)
Water	0	100
Table salt	804	1413
Iron	1535	2750
Aluminium	660	1800
Oxygen	–218	–183
Nitrogen	–210	–196

Sublimation and deposition

Carbon dioxide (the gas you breathe out) has some interesting properties. For instance, it cannot form a liquid under atmospheric pressure, but if cooled to below –78.5 °C, it can change directly from a gas into a solid without going through the liquid state. This change of state is called **deposition**. When dry ice changes back into a gas, it is called **sublimation**. Dry ice is often used in the medical industry (e.g. to remove warts) and in the food industry, for food conservation. Note that dry ice can cause burns and **asphyxiation** if handled without protective equipment or used in a poorly ventilated room.

If you blow warm moist air on a very cold window, you will probably observe tiny ice crystals forming; this is another example of deposition. Frost formation occurs as water vapour changes into ice without first condensing into a liquid.

FIGURE 4.12 a. Frost formation is an example of deposition. **b.** Sublimation can be observed as frozen carbon dioxide turns from a solid directly into a gas.



DISCUSSION

Dry ice and frost formation show us examples of sublimation and deposition in action. Consider their uses and potential dangers.

Can you think of situations where sublimation or deposition might cause problems, like frost on an aeroplane wings?

FIGURE 4.13 The changing states of water in the kitchen

KEY IDEA

The state of an object depends on its temperature and the pressure surrounding the object.

4.3 Activities

learnon

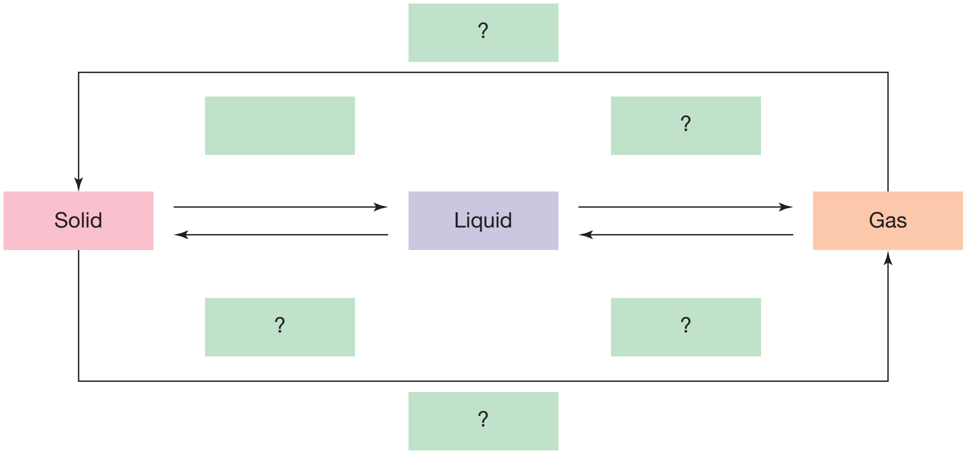
4.3 Quick quiz on	4.3 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 4, 6	2, 3, 8	5, 7, 9

Remember and understand

1. **State** the name given to the change of state from liquid water to steam. What happens to make this occur?
2. **Describe** what happens to liquid water when it is cooled below 0 °C. Has heat moved into or out of the liquid?
3. MC At higher altitudes, why does water boil at a temperature less than 100 °C?
   A. Because the temperature at higher altitudes is low
   B. Because atmospheric pressure is low
   C. Because the temperature at higher altitudes is higher
   D. Because atmospheric pressure is high

4. Complete the diagram by labelling the changes of state.



5. When water evaporates it can change state from a liquid to a gas in the form of either steam or water vapour. **Explain** the difference between steam and water vapour.

Apply and analyse

6. Give two examples of how dry ice could be harmful to humans.
7. **Explain** the difference between evaporation and boiling.

Evaluate and create

8. SI **Examine** the data recorded in the table below.

Melting and boiling points of some common substances at sea level

Substance	Melting point (°C)	Boiling point (°C)
Water	0	100
Table salt	804	1413
Iron	1535	2750
Aluminium	660	1800
Oxygen	–218	–183
Nitrogen	–210	–196

a. At what temperature would you expect table salt to melt? At what temperature would it freeze?
b. Would you expect aluminium to be found as a solid, liquid or gas at:
   i. 200 °C
   ii. 680 °C
   iii. 1900 °C?
c. **Identify** which substance — oxygen or nitrogen — would freeze first if the temperature were gradually lowered.

9. Imagine you are at home and you leave a very cold bottle of water or carton of milk on a table or bench for 10 minutes.
   a. What change would occur on the outside of the bottle/carton?
   b. Where does the water come from?
   c. What change of state has occurred?

Answers and sample responses are available in your digital formats.

LESSON 4.4 The state of the weather

LEARNING INTENTION

In this lesson you will:
- describe the differences between different forms of precipitation such as rain, hail, snow and sleet
- recognise how scientists predict the weather
- examine how global reporting on high-impact weather events has led to the development of warning systems and evacuation policies.

4.4.1 Water and the weather

Rain, hail, snow and sleet are all types of **precipitation**. Precipitation is falling water, whether in solid or liquid form. All precipitation occurs because energy from the sun melts ice and causes liquid water to evaporate to become water vapour in the atmosphere. When the temperature in the atmosphere gets low enough, the water vapour condenses or freezes. That's when we get rain, hail, snow or sleet.

KEY IDEA

The type of precipitation we get depends mostly on the temperature in the clouds and the air around them. It also depends on the amount of water vapour in the air and the air pressure.

Rain

Rain forms when water vapour condenses in cold air, forming tiny droplets of water. These droplets are so small that they are kept up by moving air, forming clouds. As the droplets join together, they become too heavy to remain in the air. They fall to the ground as rain. When air currents are low, very tiny drops of rain might fall as a fine mist known as drizzle.

FIGURE 4.14 Clouds are formed by tiny droplets of water, kept up by air currents.

Hail

If drops of rain freeze, they might form hailstones. Air currents within clouds move raindrops from the bottom of the cloud upwards to the top of the cloud. The top of the cloud is much colder than the bottom and the rising raindrops freeze very quickly. The frozen raindrops fall back towards the bottom of the cloud. If the air currents are strong enough, the frozen raindrops rise again, adding a new layer of ice. They fall again, then rise again to form another layer of ice. This can happen over and over again, each time adding a new layer of ice. When the ice has built up many layers, it gets heavy enough to fall to the ground as a hailstone. Hailstones can be extremely large and can cause extensive damage.

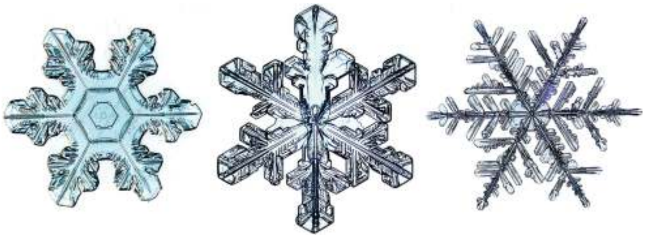
FIGURE 4.15 In summer, warm rising air helps to keep the hailstones in the clouds for longer, forming even more layers of ice than usual. These hailstones can reach masses of over 1 kg before they fall.

Snow

Snow consists of crystals of ice that have frozen slowly in clouds. Many shapes and patterns can be found in snowflakes. The shape and size depend on how cold the cloud is, its height and the amount of water vapour it holds. Crystals of ice form when clouds have temperatures below –20 °C. The crystals join together and fall. As they fall, they become wet with moisture but then refreeze as snowflakes.

FIGURE 4.16 Snow is a form of precipitation consisting of ice crystals that fall from clouds.

FIGURE 4.17 Snowflakes form many shapes and patterns but always have six 'sides'.



If the air between the cloud and the ground is colder than 0 °C, the snowflakes fall as very powdery, dry snow. If the air is warmer, the ice crystals melt and fall as rain or sleet.

Sleet

Sleet is snow that is melting or raindrops that are not completely frozen. Sleet forms when the air between the clouds and the ground is warm enough to melt ice.

4.4.2 Predicting the weather

SCIENCE AS A HUMAN ENDEAVOUR: Studying the weather

The scientists who predict, or forecast, the weather are **meteorologists**. Meteorology is the study of the atmosphere and includes the observation, explanation and prediction of weather and climate. Numerous observations of temperature, precipitation, wind speed, air pressure, humidity and more are needed to make weather forecasts. Humidity is a measure of the amount of water vapour in the air.

FIGURE 4.18 A meteorologist releases a weather balloon in Antarctica

Before the first weather balloon was launched in 1882, observations with instruments such as thermometers, barometers and rain gauges could be made only on land or ships. Not long after the invention of the first 'flying machine' in 1903, weather instruments were attached to the wings of planes, allowing them to be taken higher in the atmosphere.

As new technology becomes available, the number and quality of observations improve. Improved weather balloons, together with radar, satellite images and computer modelling, allow meteorologists to make predictions further ahead and more accurately than ever before.

As a class, discuss the following:

1. How has the invention of new tools, such as weather balloons and satellites, changed the way scientists understand and predict the weather?
2. Before the invention of weather balloons, meteorologists could only make observations from land or ships. How might this have limited their weather predictions compared to today?

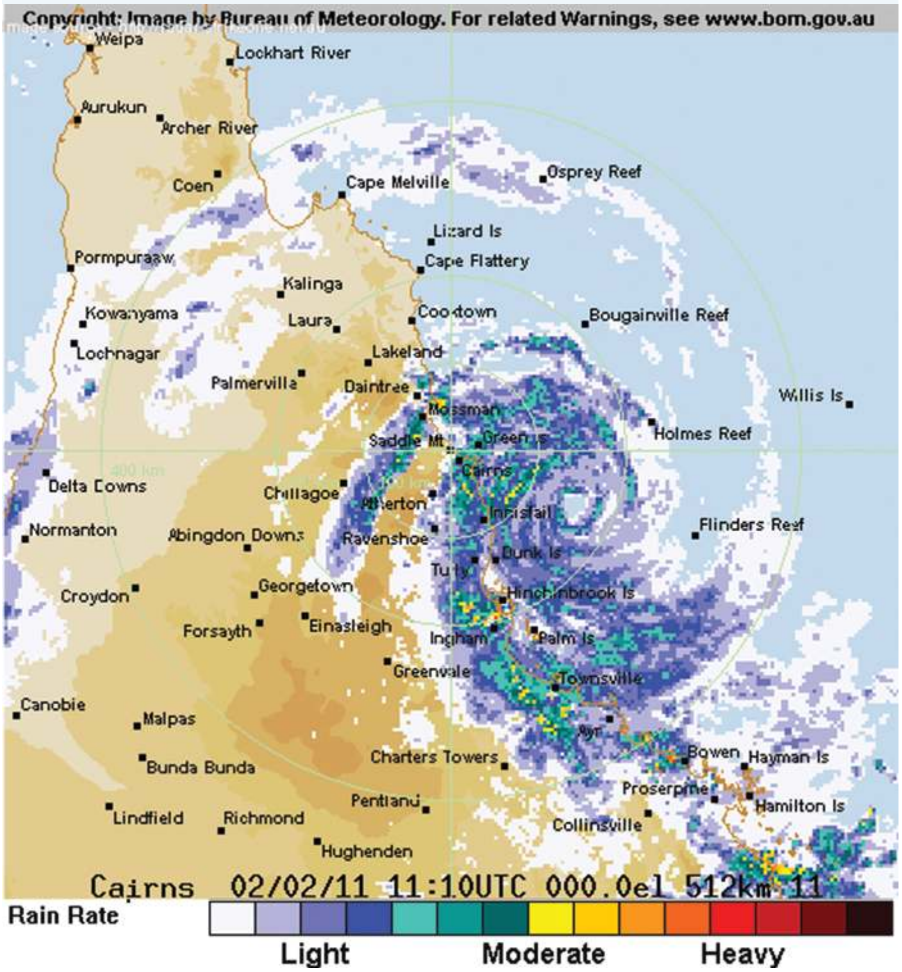
Scientific knowledge, including models and theories, can change because of new evidence (VC2S8H01)

4.4.3 Advances in warning systems for high-impact weather events

Extreme weather events have become increasingly common as Earth's climate changes rapidly due to global warming. This frequently impacts our everyday lives through an increase in the number of events such as floods, droughts, heatwaves, wildfires and cyclones. In response, scientists have been developing early warning systems to alert at-risk communities of incoming dangerous weather events. This allows communities to act immediately, which can minimise the risks that they would otherwise be exposed to. Different technologies have been developed to detect or predict high-impact weather events and these early warning systems, along with adequate evacuation policies, can save lives.

For instance, in Australia, FireWatch uses automatic smoke detection technology as a bushfire early detection system. The Bureau of Meteorology tracks tropical cyclones using satellite imagery, forecasts their trajectory using computer weather models and produces tropical cyclone warnings.

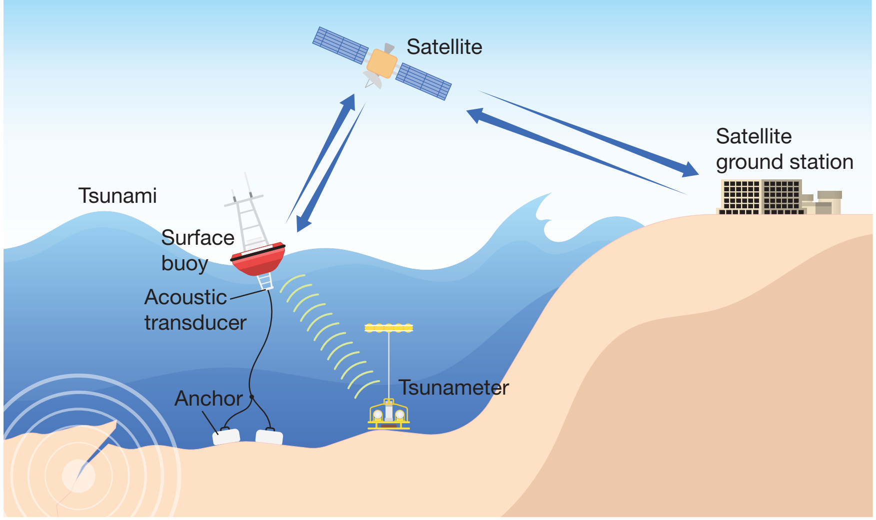
FIGURE 4.19 A Bureau of Meteorology radar image of the severe tropical cyclone Yasi



But it is not just high-impact weather events that are closely scrutinised. Australia also has several deep-ocean tsunami detection buoys deployed to alert us of incoming tsunamis. In the same way that countries prone to earthquakes use earthquake detection technologies, such as seismometers, in their early warning systems, regions prone to urban and river flooding, such as Brisbane (Queensland) or Jakarta (Indonesia), tend to have flood early warning systems and evacuation policies.

Once a danger is established, communication systems such as SMS texts or TV and radio broadcasts are used to immediately alert people. At-risk communities can then evacuate if necessary.

FIGURE 4.20 A tsunami early warning system



Currently, each state in Australia has its own state-level emergency risk assessment projects. These projects analyse the severity of each emergency risk and how to manage and prepare for them.

Disasters such as the Black Summer bushfires of 2019–20 in New South Wales and the 2022 floods in Queensland are recent examples of the importance of disaster risk reduction and community preparedness.

The Australian Warning System, which is a national approach to warnings for high-impact weather events such as bushfires and floods, aims to better prepare Australians for these types of disasters. The Australian Institute for Disaster Resilience aims to create a more disaster-resilient Australia.

4.4 Activities

learnon

4.4 Quick quiz on	4.4 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3, 4, 5, 10	6, 8, 11, 12	7, 9, 13, 14

Remember and understand

1. MC What are clouds made of?
   A. Condensed water
   B. Frozen water
   C. Steam
   D. Condensed ice
2. **Recall** and **describe** what meteorology is concerned with.
3. MC What is humidity a measure of?
   A. Air pressure
   B. Atmospheric temperature
   C. Amount of water in the air
   D. Expected rainfall

4. **Explain** how hailstones are formed.
5. **Identify** the differences between snow and sleet.
6. **Explain** how hailstones can get as large as the one in figure 4.15.
7. **Suggest** why extra-large hailstones are more common in summer than in winter.

Apply and analyse

8. **List** leisure activities that rely on predictions about the weather.
9. Ski resort operators suffer when there is a shortage of snow in some years. **Suggest** what conditions they would look for to predict coming snowfall.
10. In which occupations do each of the following types of weather prevent activity?
    a. Extreme heat
    b. Heavy rain
    c. Thunderstorms

Evaluate and create

11. SI Record the predictions of the maximum temperature of your area made in a 7-day forecast. For each day of the 7-day period, also record the maximum temperature predicted on the day before. These forecasts can be found online using the **Bureau of Meteorology** weblink in the Resources panel.

    Then record the actual maximum temperature for each day as reported on the evening news or the BoM website. Use a table like the one below to record your data.

Daily maximum temperatures (°C)

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Prediction in 7-day forecast							
Forecast the day before							
Actual maximum temperature							

    a. **Compare** the accuracy of the 7-day forecast with the accuracy of the previous day's forecast.
    b. **State** your opinion about the accuracy of the forecast made the day before.
    c. Apart from temperature, **list** other aspects of the weather forecast that are reported in weather apps or on the news.
    d. Graphs make it easier to read and interpret information, find trends and draw conclusions. **Examine** the data in the table and **construct** a graph representing the different temperatures over the week, ensuring you use a different colour for the three temperature measurements.
12. **Explain** the differences between rain, hail, snow and sleet. Provide one characteristic for each type of precipitation.
13. How do scientists predict the weather? **List** two methods they use and **explain** why these methods are effective.
14. How has global reporting on high-impact weather events contributed to the development of warning systems and evacuation policies? Give an example of a weather event and **describe** the response measures that were implemented as a result.

Answers and sample responses are available in your digital formats.

LESSON 4.5 The particle model

LEARNING INTENTION

In this lesson you will:
- use and construct models and diagrams to represent changes in particle arrangement as substances change state, and relate this to the motion, energy and distance between particles
- explain properties of materials such as density, melting point and compressibility in terms of particle arrangement, and explain the process of diffusion in a liquid and a gas in terms of particles.

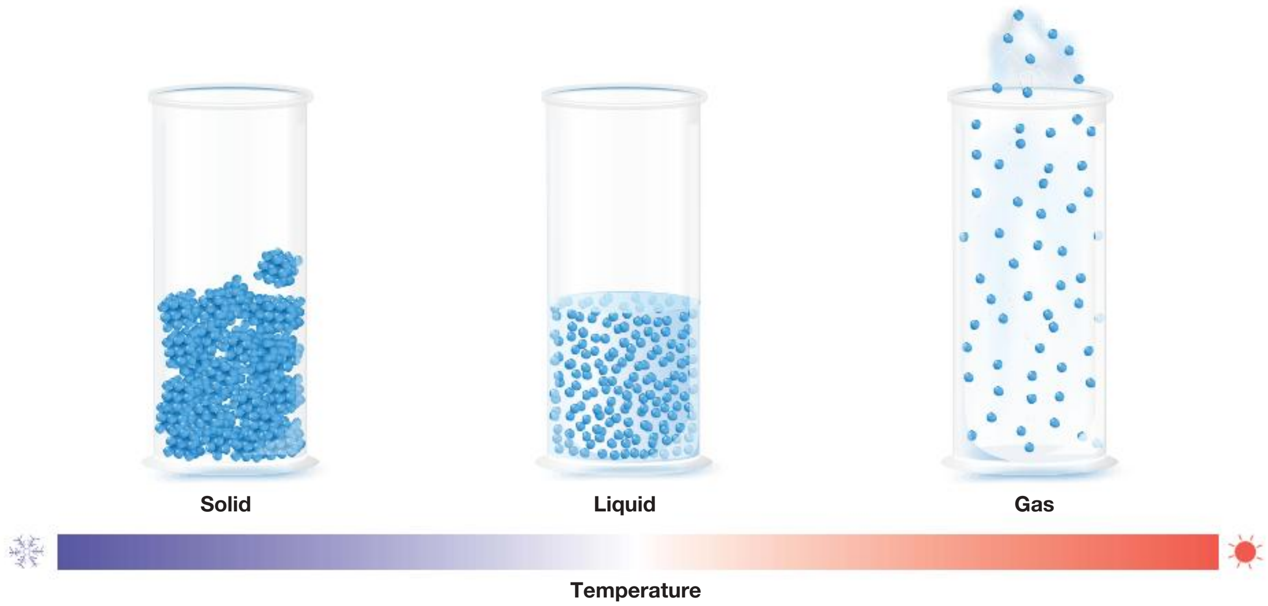
4.5.1 The particle model and kinetic theory

How do you explain why ice has properties that are different from those of water or steam? Scientists use a model to explain the different properties of solids, liquids and gases. A model is a way of representing something that is like the object or idea but not exactly the same as the object or idea. This model is called the **particle model**.

KEY IDEA

According to the particle model:
- all substances are made up of tiny particles
- the particles in liquids and solids are attracted towards other surrounding particles
- the particles are always moving
- the hotter the substance is, the faster the particles move.

FIGURE 4.21 A particle model for different states — solid, liquid and gas



The fact that particles are always moving is due to **kinetic** theory. The kinetic theory of matter states that all matter is made up of small particles that have space between them (even in a solid) and are in random motion. The amount of energy, in the form of motion (i.e. kinetic energy), within the system of particles determines how that matter is organised and what state it is in.

SCIENCE AS A HUMAN ENDEAVOUR: Kinetic theory and scientific advancements

Kinetic theory explains the behaviour of particles in solids, liquids and gases. It helps us understand how temperature, pressure and volume affect matter. Scientists have used this theory to develop technologies like refrigerators, air conditioners and even engines.

Before the nineteenth century, scientists believed that heat was a fluid called 'caloric' that flowed between objects. As new experiments were conducted, evidence showed that heat is actually the movement of particles. This led to the development of the kinetic theory of matter, which explains that particles move faster when heated and slower when cooled.

Technological advancements, like the invention of thermometers and vacuum pumps, helped scientists gather data to refine this theory. Today, we use kinetic theory to create better insulation materials, improve energy efficiency and understand natural phenomena like weather patterns and gas behaviour in space.

As a class, discuss the following:

1. How did new evidence, like experiments on particle motion, change the way scientists understood heat and matter?
2. How does the kinetic theory help us develop technologies like refrigerators or engines?

Scientific knowledge, including models and theories, can change because of new evidence (VC2S8H01)

KEY IDEA

The word 'particle' comes from the Latin word *particula*, meaning 'part'.

4.5.2 Particles in a solid

In solids, the particles are very close together, so they cannot be compressed. The attraction between neighbouring particles in a solid is usually strong. Because there are such strong bonds between the particles, solids usually have a fixed shape and a constant volume. The particles in solids cannot move freely; instead they vibrate in a fixed position.

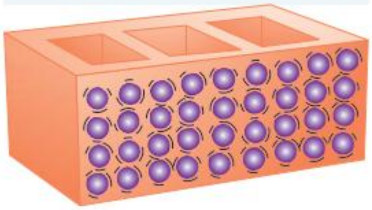


FIGURE 4.22 Particles in a solid

4.5.3 Particles in a liquid

In liquids, the particles are held together by attraction, but the bonds between them are not as strong as those in solids. The weak particle attraction allows the particles to roll over each other, but they can't 'escape'. For this reason, liquids have a fixed volume but the rolling motion of the particles allows them to take up the shape of their container. As in solids, the particles in liquids are still very close together. Liquids cannot be compressed into smaller spaces.

FIGURE 4.23 Particles in a liquid

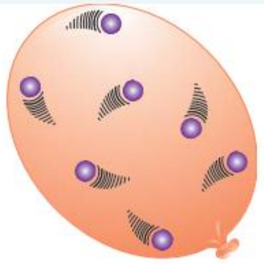
4.5.4 Particles in a gas

The particles in a gas have much more energy than those in solids or liquids, and they are in constant motion. The attraction between the particles in a gas is so weak that they are able to move freely in all directions. They spread out to take up any space that is available. This means that gases have no fixed shape or volume and, because of the large spaces between particles, gases can be compressed.

Spreading out

The spreading of one substance through another is called diffusion. This can happen only when the particles of one substance can spread through the particles of another substance. Diffusion is possible in liquids and gases because the particles move around. You would expect diffusion to happen faster in gases than in liquids because the particles move faster. Particles in a solid vibrate in a fixed position, so diffusion can't occur.

FIGURE 4.24 Particles in a gas

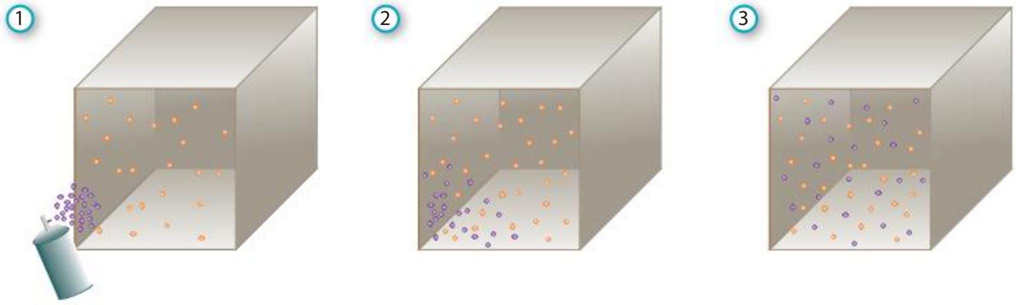


ACTIVITY: PhET simulation

Access the **PhET simulation: States of matter: Basics** interactivity in the Resources panel. Imagine a piece of wax being heated up in a heat-proof bowl. Describe what would happen. Would there be any left in the bowl if it was left to heat for long enough?

There are **forces of attraction** between particles in all states of matter. In a solid, these attraction forces keep the particles packed closely together so the particles do not move past each other. In gases, there are big spaces between the particles, but there are still attraction forces between the particles.

FIGURE 4.25 The particles of two gases spread through each other over time (from 1 through to 3), until they are evenly mixed.



The particle model and balloons

The particle model can be used to explain what happens to a balloon when you inflate it. Particles of air inside the balloon constantly move in all directions. They collide with each other and with the inside wall of the balloon. But the wall is not rigid. It can stretch as more particles are added. The balloon **expands** until it can't stretch any more. When you let some of the air out of the balloon, fewer particles collide with the inside wall of the balloon. It gets smaller, or **contracts**.

INVESTIGATION 4.3

Investigating diffusion

Aim

To investigate diffusion of liquids and gases

Hypothesis

If diffusion is occurring in this experiment, then one will observe the movement and travelling of the particles through sight or smell.

Materials

- 250 mL beaker
- food colouring
- fragrant spray
- water
- eye-dropper

Method

1. Your teacher will release some fragrant spray in one corner of the classroom. Put your hand up when you can notice the smell. Record the time it takes for the smell to get to the students at the back of the room.
2. Place a drop of food colouring into a beaker of water and record your observations for several minutes, making sure the beaker is not moved.

Results

1. Using the recorded times, describe how the fragrant spray travelled across the classroom.
2. Draw a diagram to show the movement of the food colouring through the water.

Discussion

1. What is diffusion?
2. Describe how the fragrant spray moved through the air using the particle model.
3. This investigation shows diffusion in a gas (air) and in a liquid (water).
   a. In which state does diffusion occur faster? Explain why this occurs.
   b. Is it a fair test to compare the two observations? Explain.
   c. How could you make dispersion in water occur faster? Describe an investigation that you could do to test this.
   d. Explain whether you think diffusion occurs in solids.

Conclusion

Summarise the findings of the experiment in three or four sentences.

ACTIVITY: PhET simulation

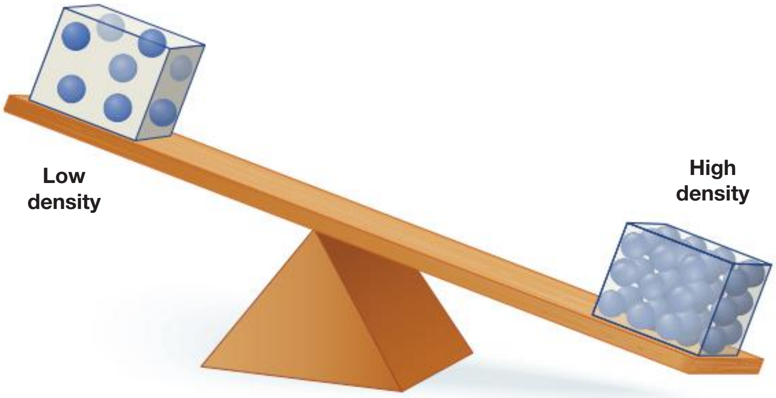
Access the **PhET simulation: Density** interactivity in the Resources panel. Collect three things from outside (e.g. a leaf, a stick and a pebble). Place them in a beaker half filled with water — what floats and what sinks?

The particle model and density

The **density** of a substance refers to its mass per unit volume. We can also, and more simply, think of density in terms of floating or sinking, which is dependent on the density of the liquid an item is placed in. We can further our understanding of the particle theory when explaining density. In a solid, the particles are tightly packed. This means that the density of a solid is greater than a liquid or a gas, in which the particles are more spread out. Hence, a gas would have the least density.

FIGURE 4.26 When placed in water, substances that are more dense than water sink and substances that are less dense than water float.

FIGURE 4.27 Substances are more dense if the particles are tightly packed together.



For any given substance, density generally decreases as the temperature increases. Thus, hot air rises and cold air sinks.

INVESTIGATION 4.4

Investigating density

Aim

To investigate the density of various materials

Hypothesis

If a liquid is denser, then an item's ability to float will increase.

Materials

- two 200 mL beakers
- water
- oil (any type is fine)
- selected materials such as coins, paperclips, marbles or rubber bands

Method

1. Place 150 mL of water in one beaker and 150 mL of oil in the other beaker.
2. Carefully place the first of your selected items into each of the beakers and record your observations.
3. Repeat step 2 using different items.

Results

1. Use a table like the one below to record which items appeared to sink or float in the water or oil.

	Sink		Float	
Item	**Water**	**Oil**	**Water**	**Oil**
Coin				
Paperclip				
Marble				

2. Using a pencil, draw a diagram to show what you observed for *one* item only in the water and the oil.

Discussion

1. What is density?
2. Did one of your items sink in water but float in oil?
3. Were your results what you expected?
4. Can you explain your results in terms of the density of water and oil?

Conclusion

Summarise the findings of the experiment in three or four sentences.

4.5.5 Viscosity

Honey and water are both liquids but water moves more freely than honey. This is because honey is more **viscous**. Viscosity is a measure of the resistance of a **fluid** (liquid or gas) to change shape. The more resistance the matter has, the more viscous it is said to be. Temperature alters a substance's viscosity; at higher temperatures, a substance will be less viscous.

FIGURE 4.28 Lava flows when it is hot. It gains viscosity as it cools, thereby flowing more slowly.

4.5.6 Compressed gases

The fire extinguishers used to put out electrical fires are filled with carbon dioxide gas. This is possible due to the compressibility of carbon dioxide, which allows large amounts of the gas to be squeezed into a container. The compressibility of gases is due to the significant space between their particles. Compressed gases stored in cylinders are commonly used for purposes such as barbecues, scuba diving and fuelling natural gas vehicles, and in aerosol cans.

SCIENCE INQUIRY: How fire extinguishers use compressed gas

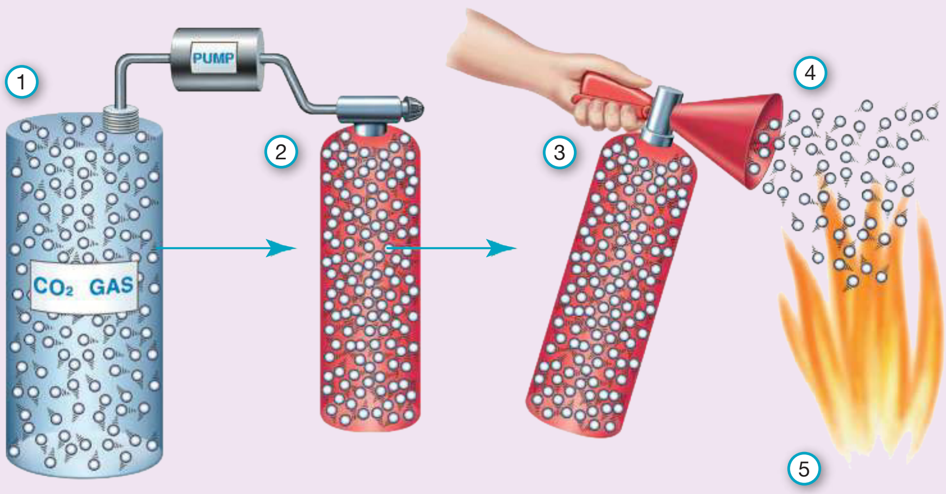
Fire extinguishers are essential safety tools that use compressed gas to fight fires. Inside the extinguisher, a pressurised gas forces out the extinguishing agent (like foam, powder or carbon dioxide) when activated. Each type of extinguisher is designed for specific types of fires.

- Carbon dioxide extinguishers: use compressed CO_2 to displace oxygen, smothering the fire. CO_2 is stored as a liquid under pressure and expands into a gas when released, creating a cooling effect.
- Dry chemical extinguishers: contain a fine powder propelled by compressed nitrogen or air to coat and smother flames, preventing oxygen from feeding the fire.
- Water extinguishers: use compressed air to spray water, cooling the fire and removing heat.

The design of fire extinguishers takes into account the behaviour of gases under pressure and the need for efficient delivery of the extinguishing agent. Compressed gases are critical because they expand rapidly, allowing a controlled release of the extinguishing material when the handle is activated. Imagine you are designing a fire extinguisher for a small kitchen fire. You must decide which type of compressed gas would work best and how much pressure is needed to ensure the extinguisher works effectively.

1. Discuss how compressed gases behave when released and how they help deliver the extinguishing material.
2. Explore the concept of pressure by comparing different types of extinguishers and the gases used. Imagine you are designing a fire extinguisher for a small kitchen fire. You must decide which type of compressed gas would work best and how much pressure is needed to ensure the extinguisher works effectively.

FIGURE 4.29 Carbon dioxide gas under pressure is used to extinguish fires.



1. Gases, including carbon dioxide, have lots of space between their particles.
2. Carbon dioxide is compressed into a cylinder. The particles are squashed closer together.
3. The carbon dioxide particles are now under increased pressure. This means that the particles in the gas collide frequently with the walls of the cylinder and push outwards. The particles are trying to escape, but are held in by the container.
4. When the nozzle is opened, the pressure forces the carbon dioxide gas out very quickly through the opening.
5. The particles of gas quickly spread over the fire. The gas smothers the fire, stopping oxygen in the air from getting to it. Fires cannot burn without oxygen, so the fire goes out.

Reproducible investigations to answer questions and test hypotheses can be planned and conducted, including identifying independent, dependent and controlled variables where applicable, stating assumptions, recognising and managing risks (VC2S8I02)

DISCUSSION

1. How is the particle model different from real particles of solids, liquids and gases?
2. a. Explain why this statement is incorrect: 'The particles of a liquid expand when heated'.
   b. Write the statement correctly.

4.5 Activities

learnon

4.5 Quick quiz on	4.5 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 6, 7	3, 4, 8, 10	5, 9, 11, 12, 13

Remember and understand

1. **List** the states of matter in order from the one with the smallest space between the particles to the one with the most space between the particles.
2. a. What is diffusion?
   b. **Identify** which states of matter are able to diffuse.
3. SI **Explain** why a model is needed to explain the properties and behaviour of different states of matter.
4. **Identify** the four main ideas of the particle model.
5. Use the particle model to **explain** why gases are compressible.

Apply and analyse

6. **Describe** an everyday example of diffusion.
7. a. **Compare** the motion of particles in a liquid with the motion in a gas.
   b. Create a diagram to **compare** the motion of particles in a liquid to those in a gas.
8. What happens to the particles in carbon dioxide gas when they are compressed into a fire extinguisher?
9. Use the particle model to **explain** what keeps car or bicycle tyres in the right shape when they are pumped up to a high air pressure.
10. **Explain** why kinetic theory is important in understanding the behaviour of particles in different states of matter.

Evaluate and create

11. Use the particle model to **explain** why:
    a. perfume can be smelled from a few metres away
    b. steam can be compressed, but ice cannot
    c. water vapour takes up more space than the same amount of liquid
    d. solids do not mix well, but gases and liquids mix easily in most cases.
12. a. Draw labelled diagrams of three containers with solid particles in the first, liquid particles in the second and gas particles in the third.
    b. How does this model of particles compare with the particles in an actual container?
13. Cold water sinks but ice floats on warmer water. **Suggest** why this might be. Write one or two sentences with an explanation relating to density.

Answers and sample responses are available in your digital formats.

LESSON 4.6 Energy matters

LEARNING INTENTION

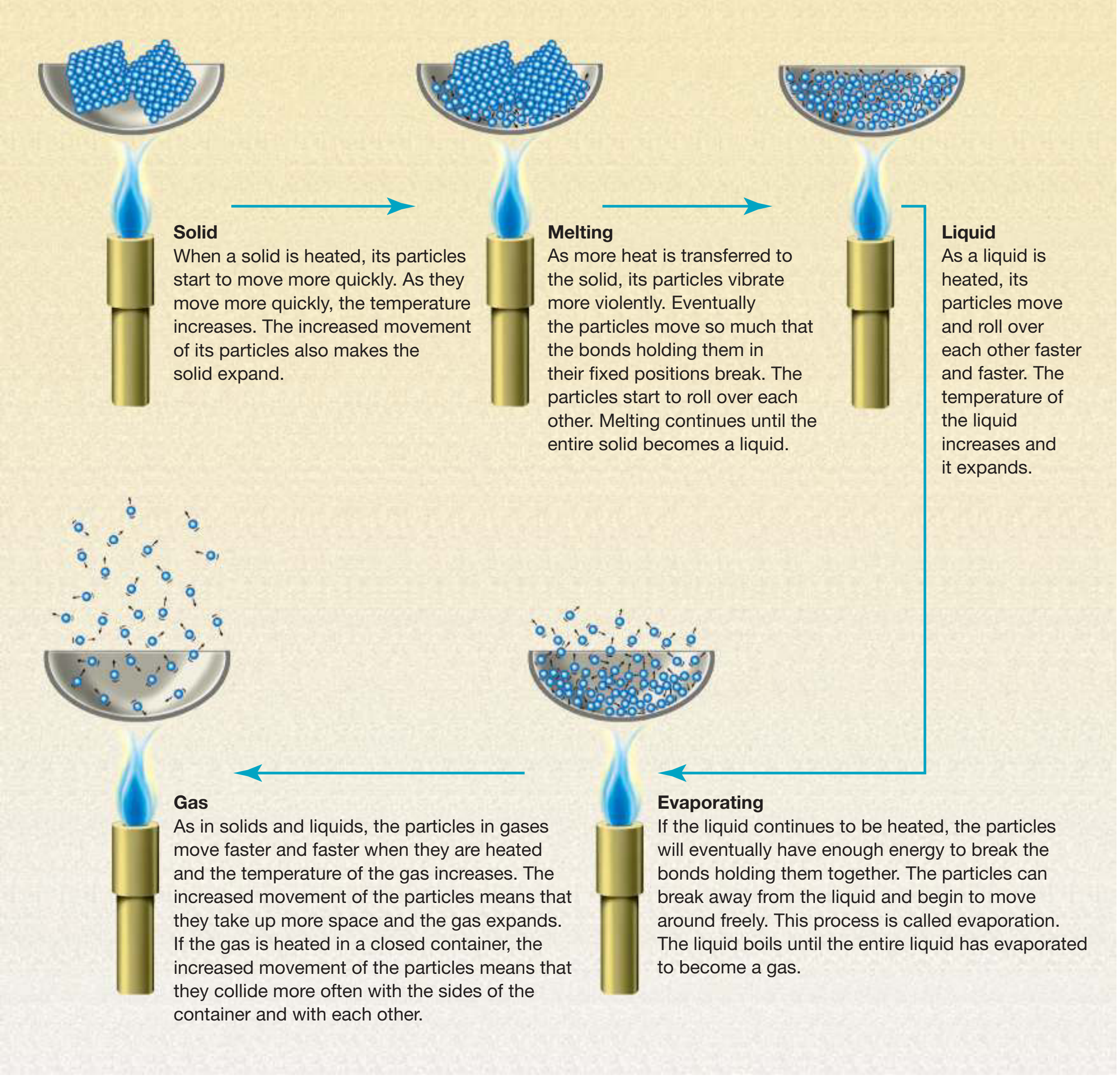
In this lesson you will explain how the changing motion and energy of particles is affected by the amount of heat energy absorbed or released.

4.6.1 Energy in and energy out

A change of state involves the heating or cooling of matter. As a substance is heated, energy is transferred to it. When a substance cools, energy moves away from it to another substance or to the environment. The change in energy causes the particles in the substance to move at different speeds.

An increase in the energy of the particles of a substance results in an increase in the temperature of the substance. A decrease in the energy of particles results in a decrease in the temperature of the substance.

FIGURE 4.30 This flowchart shows what happens to the particles that make up a substance when it changes from a solid state into a gas state. When a gas is cooled, the direction of the flowchart can be reversed as the substance changes from a gas state into a solid state.



INVESTIGATION 4.5

Explaining gases

Aim

To investigate the expansion and contraction of a gas

Hypothesis

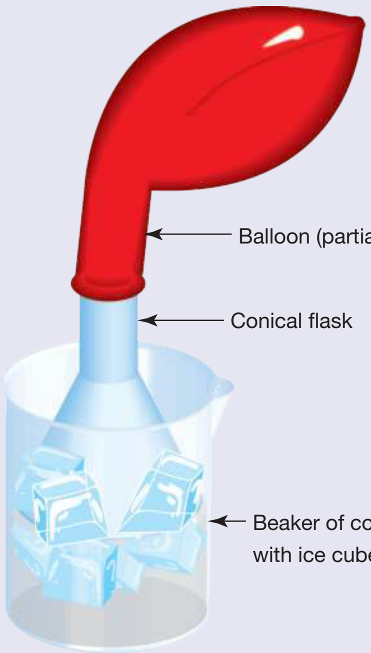
If the temperature of a gas is increased, it will expand because the energy causes the particles in the substance to move faster.

Materials

- balloon
- ruler
- two large beakers
- hot and cold water
- piece of string
- small conical flask
- ice cubes

Method

1. Inflate the balloon to its maximum size. Then deflate it. This makes it easier to stretch.
   - Inflate the balloon again, to a size slightly larger than an orange. Fit the neck of the balloon over the conical flask to seal it.
   - Wrap the string once around the widest part of the balloon to find its circumference. With a ruler, measure the length of the string that encircled the balloon.
   - Record your measurement in a table.
2. Half-fill one of the beakers with ice cubes and a small amount of cold water.
   - Place the conical flask in the ice-water beaker and observe the balloon. After a few minutes, use the string to measure the circumference of the balloon again.
   - Record your measurement in your table.



3. Put some hot water into the second beaker. Take the conical flask from the ice water and place it into the hot water.
   - Leave it for a few minutes, then measure and record the balloon's circumference.

Results

Use a table like the one below to record your findings.

Temperature of surroundings	Circumference of balloon (cm)
Room temperature	
Cold (ice water)	
Hot (hot water)	

Discussion

1. Was any air added to or removed from the balloon after it was placed over the conical flask?
2. After being in ice water and hot water, were there any changes in the size of the balloon?
3. Using the particle model, try to explain what might have made the balloon contract and expand.
4. Identify which quantity was varied or changed in this experiment. What things were kept the same?
5. Describe what happens to the air in the balloon when it gets cold.

Conclusion

Summarise the findings of the experiment in three or four sentences.

4.6.2 Examples of heating and cooling

The tyres on a moving car get quite hot. This makes the air inside expand and may even cause a blowout in extreme circumstances. Heating usually causes gases to expand much more than solids or liquids. Gases expand easily because the particles are spread out and not attracted to each other strongly. Solids, liquids and gases contract when they are cooled because the particles lose energy, slow down, need less space to move in and become more strongly attracted to each other.

KEY IDEA

Kinetic theory explains that when a substance is heated, the particles gain energy, move faster, become further apart and take up more space, and a substance expands as the temperature increases.

Hot air balloons rise when the air inside them expands. The particles in the heated air move faster and take up more space. This makes each cubic centimetre of air inside the balloon lighter than each cubic centimetre of air outside the balloon, so the air inside the balloon rises, taking the balloon with it.

Architects and engineers allow for expansion and contraction of materials when designing bridges and buildings. Bridges have gaps at each end of large sections so that in hot weather, when the metal and concrete expand, they will not buckle. Railway lines also have gaps to allow for expansion. Electrical wires are hung from poles loosely so that when the weather cools, they will not become too tight and break as they contract.

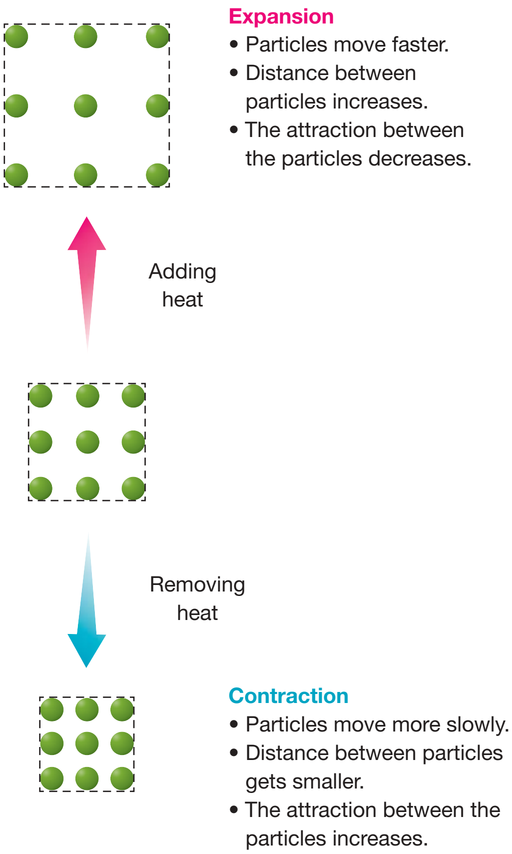
The amount by which a structure will expand or contract depends on the material it is made from, so when choosing a material, it is important to find out how much it will expand or contract. Table 4.2 shows how much some commonly used materials expand when the temperature increases by 10 °C.

TABLE 4.2 Expansion of materials

Substance	Expansion (mm) of 100 m length when temperature increases by 10 °C
Steel	11
Platinum	9
Concrete	11
Glass — soda	9
Glass — pyrex	3
Lead	29
Tin	21
Aluminium	23

FIGURE 4.31 These hot air balloons rise when the air inside them expands. How do they get back down to the ground?

FIGURE 4.32 The volume of a substance changes, expanding as heat is added and contracting as heat is removed.



SCIENCE AS A HUMAN ENDEAVOUR: Designing for expansion and contraction

Gustave Eiffel, the engineer behind the Eiffel Tower, carefully designed the structure to account for the effects of temperature changes on metal. The Eiffel Tower is made of iron, which expands when heated and contracts when cooled. Eiffel's design included allowances for this expansion and contraction, enabling the tower to withstand temperature changes without damaging the structure. On a hot summer day, the tower can expand by up to 15 cm in height due to thermal expansion.

This principle is not only applied to iconic landmarks but also to everyday structures like bridges, railway tracks and buildings. Modern engineers continue to use knowledge of material expansion and contraction when designing infrastructure to ensure safety and durability. The choice of materials and the inclusion of features like expansion joints, gaps and flexible connections are critical for handling these temperature-induced changes.

As a class, discuss:

1. Why is it important for engineers and architects to account for thermal expansion and contraction when designing large structures like bridges or railway tracks?
2. What might happen if these factors were ignored?
3. How does designing structures that account for expansion and contraction contribute to public safety and long-term economic sustainability?
4. Should engineers and architects be held accountable if they fail to account for these changes and their structures fail?

Proposed scientific responses to socio-scientific issues impact on society and may involve ethical, environmental, social and economic considerations (VC2S8H03)

An exception to the model

According to the particle model, the spaces between the particles in a liquid get smaller as the liquid is cooled, and the particles are closest once the liquid has become a solid. However, water is one of the few substances that does not behave exactly as the particle model predicts.

When the temperature of water is cooled from 100 °C to 4 °C, the particles behave as expected, with the spaces between them growing smaller. As water temperature drops below 4 °C, however, something strange happens — the spaces between the particles start to get larger again. By the time water freezes at 0 °C, the particles are further apart than they were at 4 °C! In general, the volume taken up by water particles increases by nearly 10 per cent when it becomes ice; you may have noticed this if you have ever put a full bottle of water in the freezer.

FIGURE 4.33 Oops! The reason why you should not put a bottle full of water in the freezer.

ACTIVITY: The scientist

Imagine a scientist who has only studied other substances, like metal or oil, tries to use the particle model to predict what happens to water as it freezes. How might this lead them to the wrong conclusions?

As a class, discuss the following:
1. If the scientist assumes water behaves like metals or oils when freezing, what incorrect conclusions might they make about the density or behaviour of ice? For example, how might they explain whether ice sinks or floats?
2. How could the scientist's misunderstanding of water's behaviour cause problems in real-world scenarios, such as predicting how freezing temperatures might affect lakes, pipes or infrastructure?

4.6.3 Thermometers

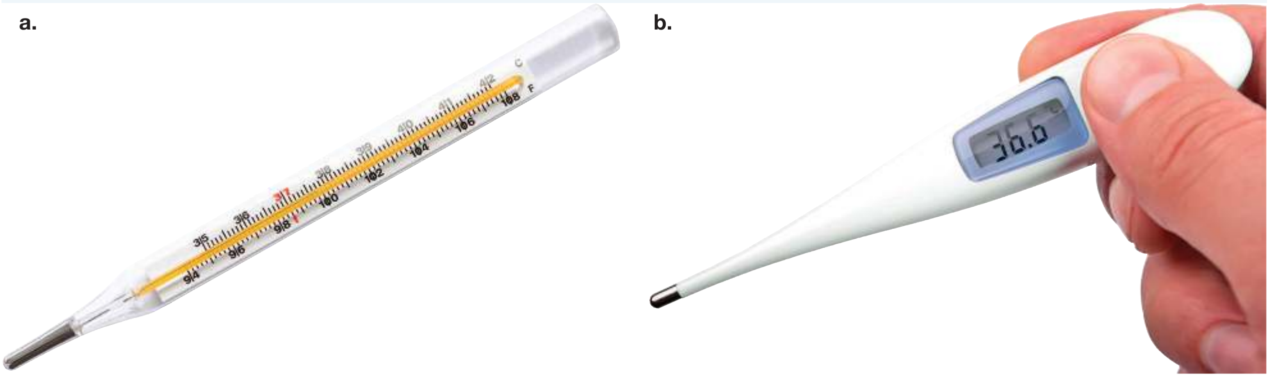
Bulb thermometers, like the one pictured in figure 4.34a, use the expansion of liquids when they are heated to measure temperature. Most bulb thermometers consist of a thin tube and a bulb that contains a liquid. As the temperature rises, the liquid expands, moving up the tube, which is sealed at the top.

The two most commonly used liquids in thermometers are mercury and alcohol. Mercury has a low freezing point (−39 °C) and a high boiling point (357 °C). Alcohol, however, is much more useful in very cold conditions because it does not freeze until the temperature drops to −117 °C. On the other hand, alcohol boils at 79 °C, so it cannot be used for measuring higher temperatures.

The temperature of the human body ranges between 34 °C and 42 °C; it is normally about 37 °C. A clinical thermometer is designed to measure this range.

The tube of the bulb thermometer in figure 4.34a narrows near the bulb. Once the mercury has expanded, this narrowing prevents the mercury contracting and moving back into the bulb before the temperature can be read. Once a reading has been taken, the mercury has to be shaken back into the bulb before the thermometer can be reused.

FIGURE 4.34 a. Bulb thermometer **b.** Digital thermometer. Digital thermometers are easier to read than bulb thermometers.



Bulb thermometers are gradually being replaced by digital thermometers, which don't rely on expansion and contraction of mercury or any other liquid. Digital thermometers contain a thermostat, which is a sealed solid, embedded inside. The thermostat's resistance to electric current depends on temperature. A tiny computer measures the thermostat's resistance and calculates the temperature, which is displayed on a small screen, making them easier to read.

INVESTIGATION 4.6

Expansion of liquids

Aim

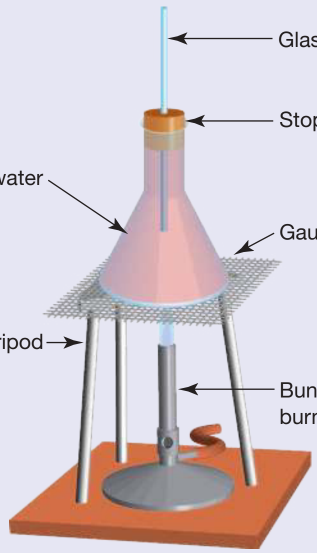
To investigate the expansion of a liquid

Hypothesis

If a liquid is heated, it will expand and rise.

Materials

- 500 mL conical flask
- tripod and gauze mat
- eye-dropper
- narrow glass tube
- food colouring
- marking pen
- rubber stopper with one hole to fit the tube
- Bunsen burner, heatproof mat and matches



Method

1. Use an eye-dropper to place two or three drops of food colouring in the flask, then fill it with water right to the top.
2. Place the stopper in the flask with the glass tube fitted. Some coloured water should rise into the tube. Mark the level of the liquid in the tube with the marking pen.
3. Place the flask on the tripod and gauze mat, light the Bunsen burner and gently heat the liquid.
4. After about 5 minutes of heating, turn off the Bunsen burner and watch what happens to the liquid level in the tube. Measure and record the change in height.

Results

Use a table like the one below to record your findings.

	Change in water level (cm) from initial height
After heating for 5 minutes	
After cooling	

Discussion

1. Describe what happened to the level of the liquid while it was being heated.
2. Describe what happened to the level of the liquid while it was cooling.
3. Use the particle model to explain your responses to questions 1 and 2.

Conclusion

Summarise the findings of the experiment in three or four sentences.

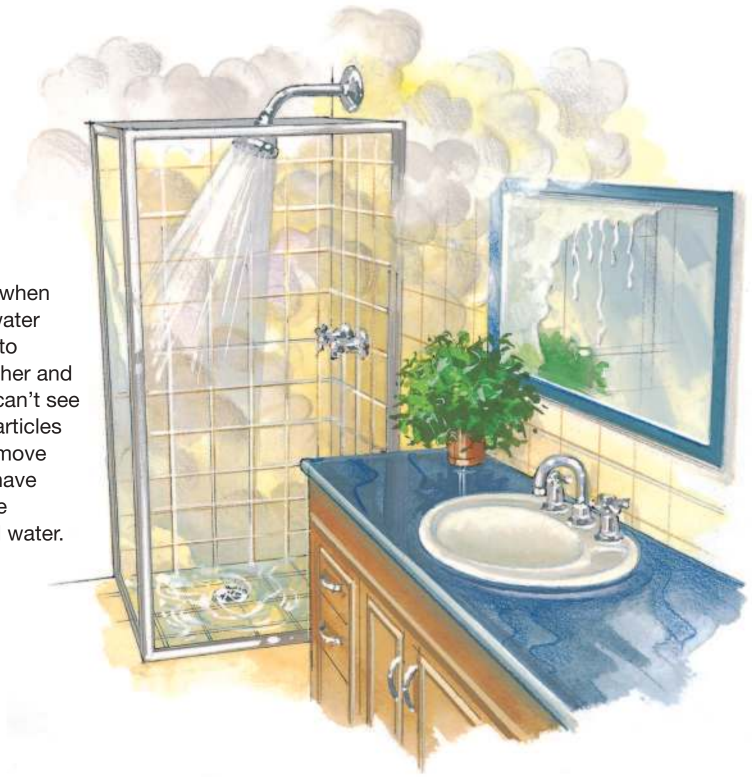
4.6.4 Foggy mirrors

Have you noticed how the mirror in the bathroom fogs up after a hot shower? The 'fog' is actually formed by invisible water vapour in the air cooling down when it contacts the cold glass. It condenses to become water.

DISCUSSION

In movies, you sometimes see a mirror being held up to the mouth and nose of someone who is unconscious to check whether they are breathing. Explain why this would work.

FIGURE 4.35 Different states of water found in your bathroom



4.6 Activities

learnon

4.6 Quick quiz on	4.6 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 4, 7, 10	2, 5, 8, 11, 12, 13, 16	3, 6, 9, 14, 15, 17, 18

Remember and understand

1. MC What happens to the movement of particles as a substance changes its state from a gas to a liquid?
   A. Particles speed up, gain energy and move closer to each other.
   B. Particles slow down, lose energy and move closer to each other.
   C. Particles speed up, lose energy and move away from each other.
   D. Particles slow down, gain energy and move closer to each other.
2. **Describe** two changes in the properties of a substance when its particles move faster.

3. When a substance changes state from a solid to a liquid:
   a. **describe** what happens to the bonds between the particles
   b. **explain** how the motion of the particles change.
4. **Explain** why solids generally expand when they are heated.
5. The following statements are incorrect. Rewrite them correctly.
   a. Heating a liquid might make its particles stick closer together.
   b. Solids have a definite shape because their particles are free to move around.
   c. You can compress a gas because its particles are close together.
   d. When you heat a liquid, the particles expand.
6. a. **Describe** what change you expect to see when hot metal objects are cooling.
   b. Why does this happen? **Explain** using the particle model.

Apply and analyse

7. **List** two examples of structures that contain gaps to prevent them buckling in hot weather.
8. Give one reason for why overhead electric power lines are not hung tightly.
9. SI Refer to table 4.2 to answer the following questions.
   a. If a steel rod 10 m in length was heated so that its temperature rose by 10 °C, how long would the rod become?
   b. **Explain** why pyrex, rather than soda glass, is used in cooking glassware such as casserole dishes and saucepans.
   c. Concrete is often reinforced with steel bars or mesh to make it stronger. **Explain** why steel is a better choice than another metal, such as aluminium or lead.
10. For each of the following changes of state of a substance, **identify** whether it involves adding energy to the particles or transferring energy away from the particles.
    a. Melting
    b. Condensation
    c. Boiling
    d. Freezing
    e. Sublimation
    f. Evaporation
11. **Construct** a flowchart like the one in figure 4.30 to show how a gas changes state to become a liquid and then a solid. Include the names and descriptions of the two changes of state that take place.
12. Use the particle model to **predict** what will happen to the length and width of a solid substance if it is heated (without melting).
13. Hot air balloons have a gas heater connected to them.
    a. **Describe** what happens to the particles inside the balloon when the heater is turned on.
    b. **Explain** why the balloon rises.

Evaluate and create

14. SI **Suggest** why icebergs float in Arctic and Antarctic waters. Do you think much of the iceberg is under the water, or is it mostly above? How could you test your hypothesis? Design a suitable experiment.
15. A jar with the lid jammed on tightly can be hard to open. If hot water is run over the lid, it becomes easier to open. **Explain** why.
16. The mercury thermometer was invented by a German scientist named Daniel Gabriel Fahrenheit (1686–1736). A different set of markings is used to scale Fahrenheit thermometers. At what temperatures does water boil and freeze on this scale?
17. Under what conditions might you use an alcohol thermometer rather than a mercury thermometer?
18. SI **List** the advantages of digital thermometers over mercury bulb thermometers for measuring human body temperature.

Answers and sample responses are available in your digital formats.

LESSON 4.7 Review

4.7 Success criteria

Tick the column to indicate that you have completed the lesson and how well you think you have understood it using the traffic light system.

(**Green:** I understand; **Yellow:** I can do it with help; **Red:** I do not understand)

Lesson	Success criteria	Green	Yellow	Red
4.2	I can compare the properties of different states of matter.			
4.3	I can describe how the state of a substance is affected by properties such as melting and boiling point and the amount of heat energy absorbed or released.			
4.4	I can describe the differences between different forms of precipitation such as rain, hail, snow and sleet.			
	I can recognise how scientists predict the weather. I can examine how global reporting on high-impact weather events has led to the development of warning systems and evacuation policies.			
4.5	I can use and construct models and diagrams to represent changes in particle arrangement as substances change state, and relate this to the motion, energy and distance between particles.			
	I can explain properties of materials such as density, melting point and compressibility in terms of particle arrangement, and explain the process of diffusion in a liquid and a gas in terms of particles.			
4.6	I can explain how the changing motion and energy of particles is affected by the amount of heat energy absorbed or released.			

learnon

Post-test	Topic 4 Post-test
eWorkbook	Topic 4 eWorkbook
Digital document	Key terms glossary

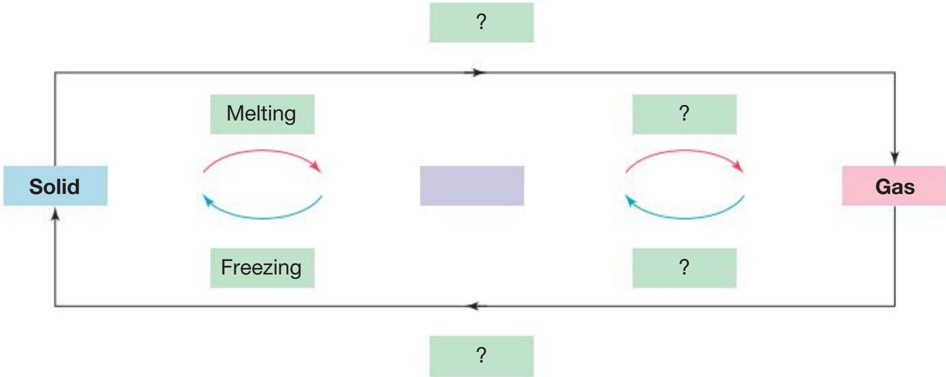
4.7 Activities

4.7 Review questions

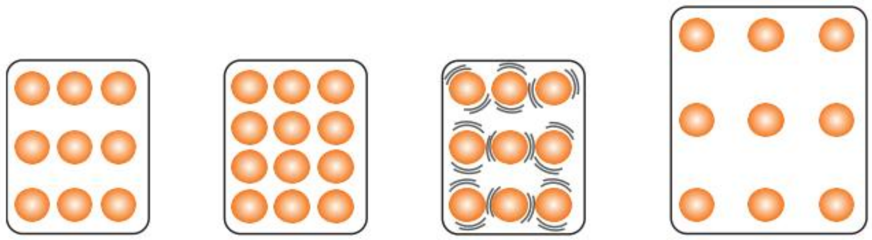
■ LEVEL 1	■ LEVEL 2	■ LEVEL 3
1, 2, 6, 7, 9, 13	3, 4, 8, 10, 11, 14	5, 12, 15, 16

Remember and understand

1. Complete the diagram, labelling the missing state and changes of state.



2. **MC** What happens during a change of state?
   A. Heat energy is always absorbed.
   B. The temperature remains constant until the change is complete.
   C. The temperature increases at a constant rate as the heat energy is absorbed.
   D. Heat energy is neither absorbed nor lost.
3. **MC** What happens when a substance sublimes?
   A. It changes from a liquid to a solid on cooling.
   B. It changes from a liquid to a gas on heating.
   C. It changes from a liquid to a solid on cooling.
   D. It changes from a solid to a gas on heating.
4. **Identify** in which state — solid, liquid or gas — particles have:
   a. the most energy
   b. the least energy.
5. **Identify** in which state the forces of attraction between particles are likely to be greatest.
6. **Describe** the changes of state involved in the formation of rain and hail.
7. Which of the diagrams below (A, B or C) best represents the particles of a solid after heating?

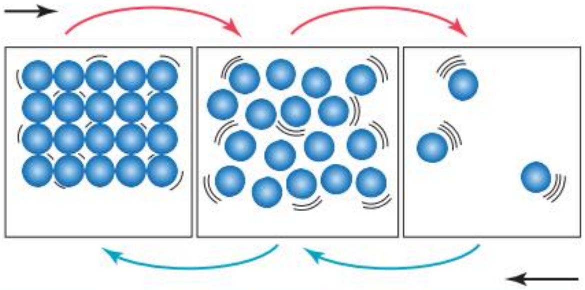


Original solid A B C

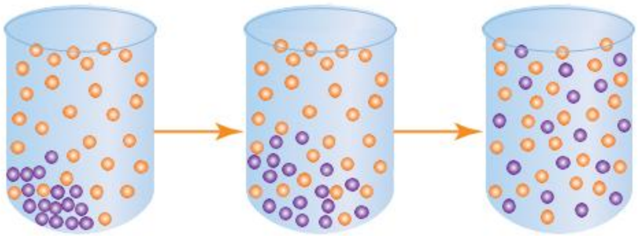
8. Use the particle model to **explain** why steam takes up more space than liquid water.

Apply and analyse

9. Label the boxes in the diagram to show which represents a solid, liquid and gas. Label the black arrows to **identify** whether energy is added or removed. **State** which properties are shown by each of the substances.



10. **Name** the process that is taking place in the following diagram and **explain** why it occurs only in liquids and gases.

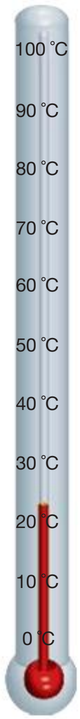


11. Complete the table below to summarise the properties of solids, liquids and gases. Use a tick to indicate which properties each state *usually* has.

Properties of solids, liquids and gases

Property	Solid	Liquid	Gas
Has a definite shape that is difficult to change			
Takes up a fixed amount of space			
Can be poured			
Takes up all of the space available			
Can be compressed			
Is made of particles that are strongly attracted to each other and can't move past each other			
Is made of particles that are not held together by attraction			

12. **Explain** why perfume or aftershave lotion evaporates more quickly than water.
13. a. To the nearest degree, **state** the temperature shown on the thermometer.
    b. **Explain** how mercury and alcohol thermometers are able to provide a measure of temperature.
14. Snow and hail are water in a solid state. **Describe** the difference between snow and hail, and **explain** how each of them is formed.



Evaluate and create

15. SI Beatrice and Sam performed an investigation to find the volume of a cork stopper. The measuring cylinder was filled to the 80.0 mL level. A cork stopper was dropped into the measuring cylinder and the volume rose to 83.5 mL as the cork floated on the surface.
    a. **Describe** how to accurately read the initial measure of the volume on a measuring cylinder.
    b. **Explain** whether this is a fair test to find the volume of the cork.
    c. What could you suggest to these students to improve the design of the experiment?

16. SI Julia and Chris performed an investigation about the rate of evaporation of ethanol in three different pieces of equipment. The containers used were a flat Petri dish, a 100 mL beaker and a 100 mL conical flask. In each container, 10.0 mL of ethanol was used.
The volume in each container after 45 minutes was:
- Petri dish 9.3 mL
- beaker 9.8 mL
- conical flask 9.6 mL.

a. **State** the aim of this investigation.
b. **Propose** a hypothesis for this investigation.
c. **State** the dependent variable.
d. **State** the independent variable.
e. **State** at least one variable that would need to be controlled.
f. **List** the equipment and chemical required.
g. **List** the steps of the method.
h. Prepare a table to place the results showing initial and final volumes.
i. In the discussion, **suggest** an explanation of your results.
j. **Suggest** a way to improve this investigation.
k. Write a conclusion.

Answers and sample responses are available in your digital formats.

on To test your understanding and knowledge of this topic, go to your learnON title at jacplus.com.au and complete the **post-test**.

5 Separating mixtures

CONTENT DESCRIPTION

Matter can be classified as pure substances such as elements and compounds or impure substances such as mixtures (including solutions), and can be modelled using the particle model; mixtures may have a uniform (homogeneous) or non-uniform (heterogeneous) composition and can be separated based on the properties of their components using techniques including filtration, decantation, evaporation, crystallisation, magnetic separation, distillation and chromatography (VC2S8U06)

Source: Victorian Curriculum F–10 Version 2.0

LESSON SEQUENCE

LESSON 5.1 Overview

5.1.1 Introduction

Think about your school bag on the first day of school. It probably had some pens, pencils, a ruler, highlighters, books and your lunch. In this example, the graphite in the pencils could be referred to as a **pure substance**, whereas all of the other objects combined could be described as a **mixture**.

FIGURE 5.1 Are the objects in your school bag pure substances or mixtures?

What else might be in your school bag? You might have a bottle of water. While water is a pure substance, the water you get from a tap also contains small amounts of minerals, creating a mixture. A special type of purified water, called distilled water, is referred to as a pure substance because it only contains water. If you have a soft drink, it is a mixture, because it contains more than one substance. As well as containing water, flavours and colours, carbon dioxide gas is partly dissolved in the water, which makes it fizzy.

In this topic you will be investigating pure substances and mixtures, and you will also learn about different ways of separating the components of mixtures. One example of separation, called chromatography, can be shown with coloured markers. Coloured markers, food dyes and watercolours are made of lots of different colours. Mixtures are found in everyday life.

DISCUSSION

1. What makes a fizzy drink fizz?
2. How does the Red Cross separate the red and white blood cells from the blood of donors?
3. How can you get fresh water from sea water?
4. What do a vacuum cleaner and tea strainer have in common?
5. What happens to your waste after you flush the toilet?
6. Where is the cream in homogenised milk?
7. Why is being able to separate mixtures important?

SCIENCE INQUIRY: A world of mixtures

Mixtures are everywhere — in the ground, the air and the water. A mixture is made up of two or more substances that are physically combined but not chemically bonded.

Mixtures can be separated into their components by physical means, such as filtration, evaporation or distillation.

- Air is a mixture of gases, including about 78 per cent nitrogen, 21 per cent oxygen, and trace amounts of carbon dioxide, argon and other gases. Each gas keeps its own properties and can be separated, as in the process of fractional distillation.
- Ocean water contains pure water, dissolved salts and other substances such as minerals and microscopic organisms. The salt can be separated from water through evaporation.
- Even though it appears pure, fresh water from rivers and lakes contains dissolved minerals, gases and microscopic organisms.

FIGURE 5.2 Mixtures can be found in the air.

These mixtures are essential for life. Oxygen in the air supports breathing, minerals in ocean water sustain marine ecosystems, and substances in fresh water help plants and animals survive.

As a class, compile data on the composition of air, ocean water and fresh water.

Create pie charts or bar graphs to visually represent the proportions of substances in each mixture (e.g. percentage of nitrogen, oxygen and carbon dioxide in air).

Discuss the following:

1. How do the components of air, ocean water and fresh water vary? Why is it important that each mixture contains specific substances in specific amounts?
2. What methods could you use to separate the components of air, ocean water or fresh water? Why might separating these mixtures be useful in real-life applications?

Separating mixtures

Unlike pure substances, mixtures are usually easy to separate into their different parts. For example, imagine that a few small iron nails have been dropped into a child's sandpit and have sunk into the sand so that they cannot be seen. One way of separating the nails from the sand is to use a magnet. This works because the nails and sand have different properties. The nails are made from iron, a substance that is attracted to magnets.

What if plastic beads had been dropped into the sandpit instead of nails? They cannot be separated from the sand with a magnet. The key to separating them is recognising the different properties of the plastic beads and the sand. An obvious difference is size. The plastic beads are much bigger than grains of sand. A child's sand sieve would do the trick. Sand grains pass through but the plastic beads do not.

FIGURE 5.3 Nails can be separated from sand with a magnet.

Data and information can be organised and processed by selecting and constructing representations including tables, graphs, keys, models and mathematical relationships (VC2S8I04)

INVESTIGATION 5.1

Experimental design for separation of mixtures

Aim

To investigate a method of separating the four parts of a mixture

Hypothesis

If a mixture contains materials with different properties, then the materials can be separated by using a variety of techniques.

Materials

- sand (about 250 mL)
- used matches
- small pebbles (about 500 mL)
- steel paperclips
- water as required

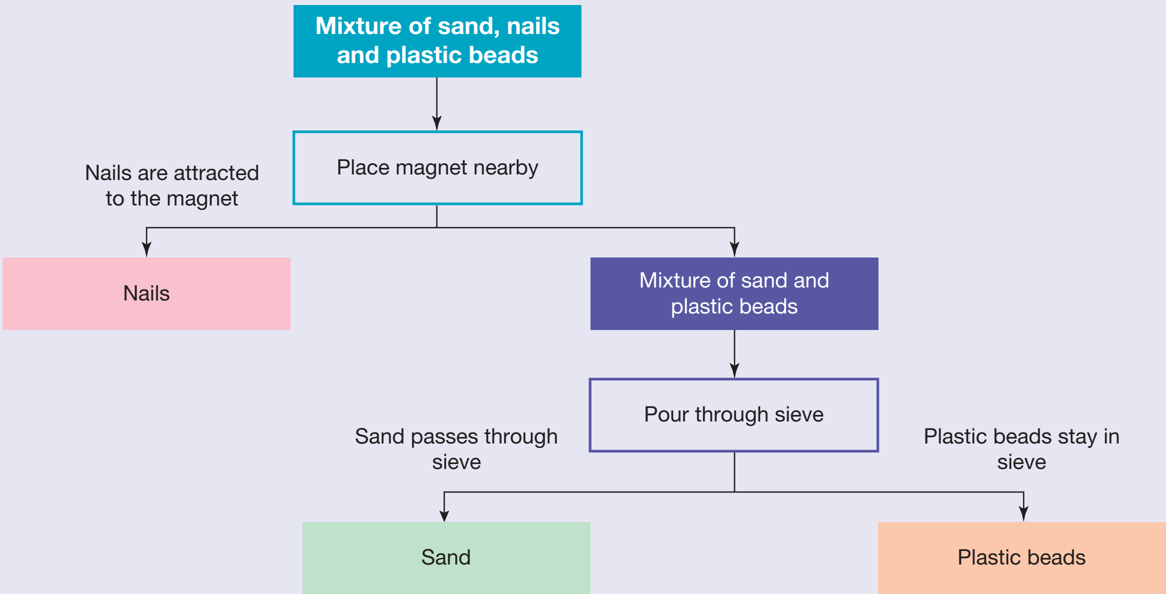
Method

Your task is to separate the four parts of a mixture of dead matches, pebbles, steel paperclips and sand.

1. Mix the matches, pebbles and paperclips evenly in a plastic container of sand.
2. Devise and write a step-by-step plan of a method to separate the four parts. You will need to think about the properties of each part of the mixture that will make separation possible.
3. Make a list of all the extra equipment that you will need.
4. Check your plan with your teacher, then gather the equipment and perform the separation.

Results

1. The flowchart shows one way of separating the parts of a mixture of sand, nails and plastic beads.



2. On A3 paper, draw a similar flowchart to show how each part was separated from the mixture in this investigation.

Discussion

1. Describe any difficulties that you had when performing this separation.
2. Explain whether the order of separation was important to the process.

Conclusion

Summarise the findings of the investigation in three or four sentences and link them back to the aim and hypothesis.

learnon

Pre-test	Topic 5 Pre-test
eWorkbooks	Topic 5 eWorkbook Student learning matrix
Practical investigation eLogbook	Topic 5 Practical investigation eLogbook
Digital document	Key terms glossary

LESSON 5.2 Mixtures and solutions

LEARNING INTENTION

In this lesson you will:
- use representations of particles to show the difference between samples of pure substances and mixtures, and identify examples of each
- examine different solutions, identify the solvent and solute, and describe the difference between concentrated and dilute when referring to solutions.

5.2.1 Pure substances and mixtures

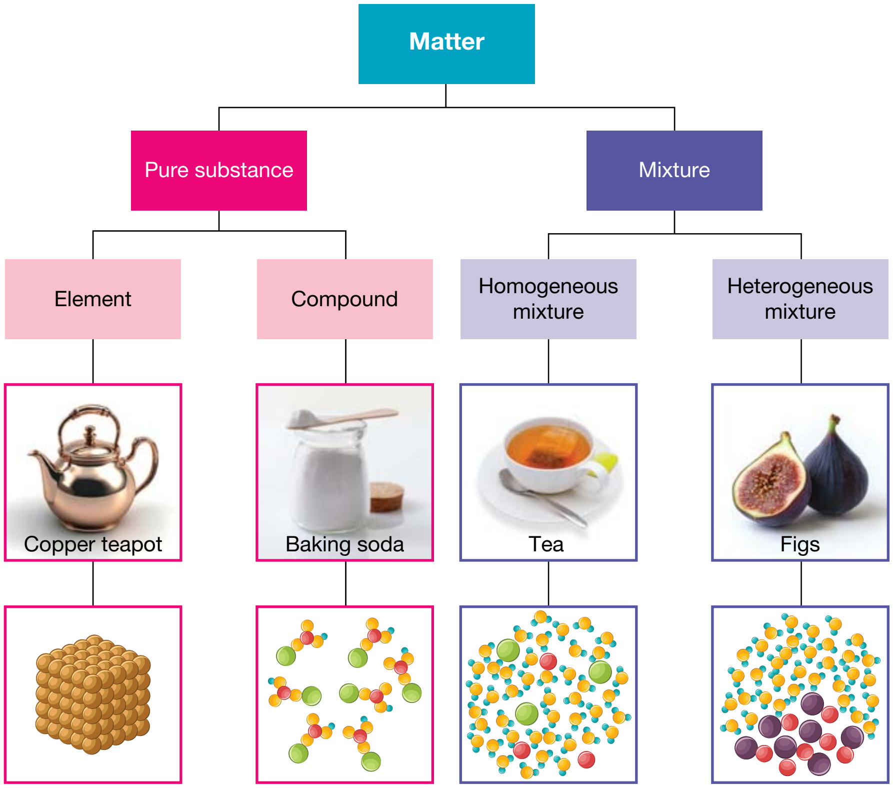
Matter makes up everything in our universe. It is any substance that has mass and volume, whether it be miniscule, like that of an atom, or vast, like the entire volume of the Pacific Ocean.

Matter can be split into two main components:
- pure substances
- mixtures.

KEY IDEA

- A pure substance is a material made of only one type of particle with a uniform composition, like an element or compound.
- A mixture is a combination of two or more substances that are physically combined and can be separated with each substance retaining its own properties.

FIGURE 5.4 Comparing pure substances and mixtures



Pure substances include compounds and elements. An important feature of pure substances is that they are very difficult to break down into their individual parts. For example, pure salt (sodium chloride) would be very difficult to split it into sodium and chlorine.

Mixtures, on the other hand, are much easier to separate. The components that make up a mixture can have much more variation than the components that make up a pure substance.

KEY IDEA

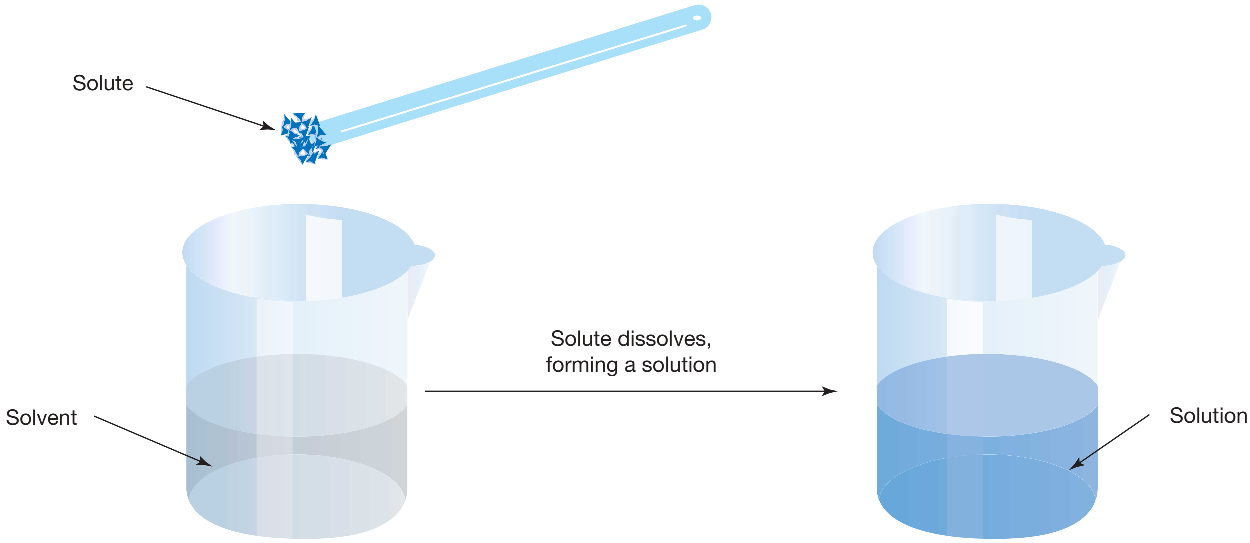
- **Homogeneous mixtures** are those in which particles are spread evenly throughout the mixture; they appear as a single state. Air, for example, is a homogeneous mixture, because the different gas particles are distributed uniformly.
- **Heterogeneous mixtures** are those in which different components are scattered unevenly throughout the mixture; they appear as more than one state. An example is a mixture of oil and water or sand and water.

In this topic, we will explore these types of mixtures and different ways that they can be separated.

5.2.2 What is a solution?

The 'fizz' in fizzy drinks is the carbon dioxide gas that is dissolved in the flavoured liquid. Carbon dioxide is pumped into bottles or cans at high **pressure**. The bottles and cans are then sealed to keep the carbon dioxide **dissolved** in the water. When you open the container, the pressure is reduced and the carbon dioxide bubbles out.

FIGURE 5.5 Adding a soluble substance to liquid



Like most substances, fizzy drinks are mixtures of other substances. If you look at the label on a bottle or can of soft drink, you will see that, as well as carbon dioxide, it also contains sugar, food colouring, flavouring and preservative. Preservatives stop the substances in soft drinks from going off. Flavourings are added to make the drink taste more pleasant and food colouring is added to make the drink look more attractive.

All of these substances are dissolved in water. A mixture of one substance dissolved in another is called a **solution**, which is a homogeneous mixture. The substance that dissolves is called the **solute**. The substance that the solute dissolves in is called the **solvent**. Solutions in which water is the solvent are called **aqueous solutions**. Water is a good solvent because many chemicals can dissolve in it. Fizzy soft drinks are aqueous solutions, in which water is the solvent, and sugar, food colouring, flavouring, preservative and carbon dioxide are all solutes.

5.2.3 'Do-it-yourself' fizz

Substances that dissolve in a liquid are said to be **soluble**. The particles of the solute are too small to be seen, so the resulting solution is **transparent**. Substances that do not dissolve are said to be **insoluble**.

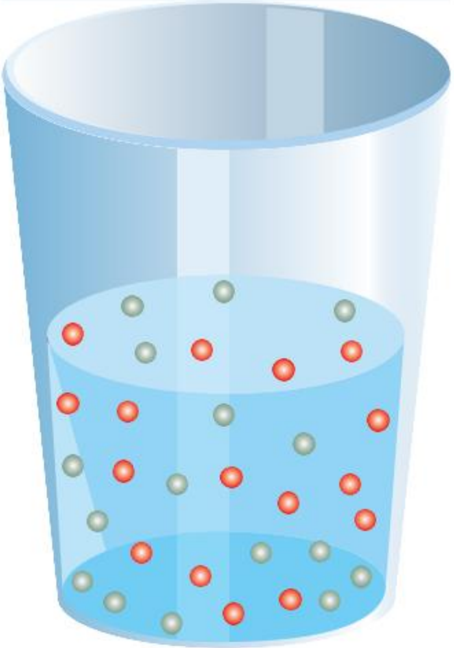
At higher pressures, carbon dioxide is soluble in water. In soft drink, such as that shown in figure 5.6, the carbon dioxide cannot be seen in a bottle of soft drink until the bottle is opened and the pressure is reduced.

You can make carbon dioxide gas using two chemicals found in your kitchen: vinegar and bicarbonate of soda. When these two chemicals are mixed, a **chemical reaction** takes place. The vinegar and bicarbonate of soda change into new substances. One of these new substances is the gas carbon dioxide, which is a pure substance, and is the same gas that is in fizzy drinks.

ethanoic acid (vinegar) + sodium bicarbonate → sodium ethanoate + carbon dioxide + water

FIGURE 5.6 When you open the bottle, dissolved carbon dioxide is visible.

FIGURE 5.7 In a solution, the particles of one substance (the solute) are spread evenly throughout the other (the solvent).



INVESTIGATION 5.2

Froth and bubble

Aim

To investigate the separation of carbon dioxide from fizzy drinks

Hypothesis

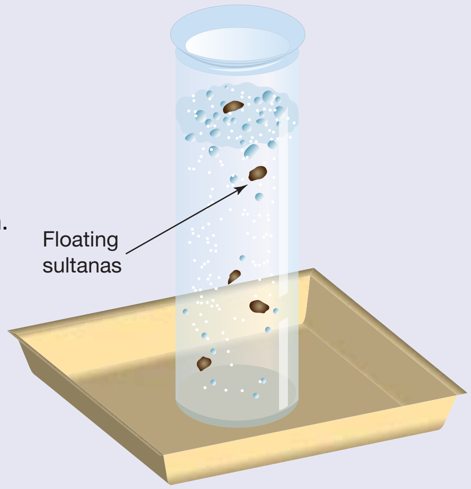
If carbon dioxide gas is dissolved in a solution, then it will form bubbles that rise to the surface of the liquid and disperse.

Materials

- vinegar
- bicarbonate of soda
- spatula
- plastic tray
- stirring rod
- gas jar
- sultanas

Method

1. Stand the gas jar on a plastic tray and pour the vinegar into the gas jar until it is 2 cm from the top.
2. Add a spatula of bicarbonate of soda and several sultanas.
3. Stir the vinegar and remove the stirring rod.
4. Watch the sultanas in the gas jar.



Results

1. Make notes recording the movement of the sultanas in the solution.
2. Examine the sultanas and describe their appearance.

Discussion

1. Explain how the sultanas rise to the surface.
2. Explain why the sultanas drop back to the bottom after reaching the surface.
3. Investigate other items in the jar to determine if they can be carried to the surface.

Conclusion

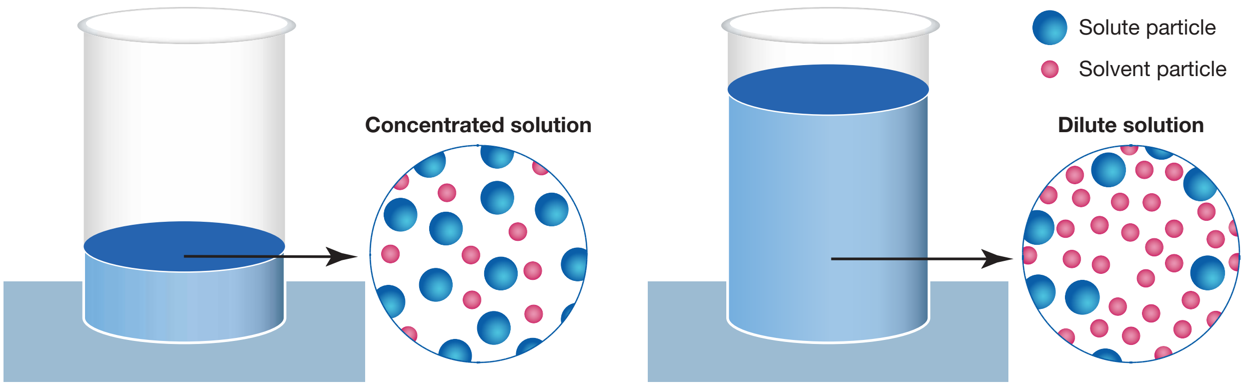
Summarise the findings of the investigation in three or four sentences.

5.2.4 Concentration

When more solute is dissolved in a solvent, the solution is said to be more **concentrated**. For example, by adding more and more sugar to a cup of hot water, you are making the solution more and more concentrated. Eventually the solution gets so concentrated that no more sugar will dissolve in it. When no more solute can be dissolved in a solvent, the solution is **saturated**.

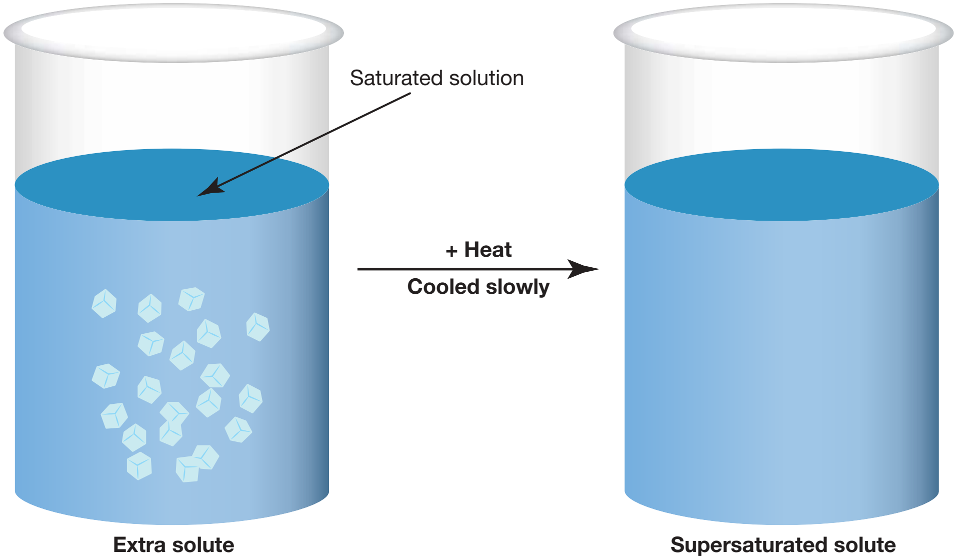
FIGURE 5.8 The cordial in these glasses is a coloured solution. Can you tell which has the greatest concentration of cordial syrup?

FIGURE 5.9 A concentrated solution contains a relatively large amount of solute particles, while a dilute solution contains a relatively large amount of solvent particles.



There is a limit to how much sugar (the solute) you can dissolve in water (the solvent) at a certain temperature. When you heat a saturated solution of sugar in water, the water molecules move faster, allowing you to dissolve even more sugar than usual — it is like pushing the limits! A **supersaturated** solution is when it has more solute (such as salt or sugar) that dissolves than it normally could at that temperature. However, these solutions are unstable, meaning if you disturb them or let them cool, that extra solute can suddenly come out of the solution and form crystals.

FIGURE 5.10 Creating a supersaturated solution



You could make a solution of sugar and water less concentrated by adding more water. This process, where more solvent is added, is called **dilution**. When you add water to cordial, you are diluting it.

SCIENCE INQUIRY: Solutions

Aim

To construct representations for supersaturated, saturated, concentrated and dilute solutions

Construct

Use your knowledge of solutions to construct a representation to illustrate the difference between supersaturated, saturated, concentrated and dilute solutions. You can use a physical representation on paper, a 3D model, or presentation software such as PowerPoint, Google Slides, Canva or coding platforms such as Scratch.

Evaluate

Once you have constructed your representation, test the understanding of the different types of solutions by having other students classify solutions based on your visual representation or program.

Conclusion

As a class, reflect on how the constructed representation aided in visualising the behaviour of solutes in solvents and their significance in real world applications (e.g. crystallisation in industry — sugar production, pharmaceuticals, salt production, metal recovery, food and beverages industry, water treatment, and mineral extraction).

Data and information can be organised and processed by selecting and constructing representations including tables, graphs, keys, models and mathematical relationships (VC2S8I04)

ACTIVITY: PhET simulation

Access the **PhET simulation: Concentration** interactivity in the Resources panel and use the simulation to investigate the relationships between volume and the amount of solute to solution concentration.

5.2 Activities

learnon

5.2 Quick quiz on	5.2 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
2, 3, 4, 7, 11	1, 5, 9, 10, 14	6, 8, 12, 13, 15

Remember and understand

1. Consider the following substances: carbon dioxide, cup of tea, copper and pasta sauce.
   a. Categorise the substances according to whether they are pure substances or mixtures.
   b. **State** what homogeneous means.
   c. **State** which mixture is homogeneous.
2. MC **Identify** which of the following best describes a soft drink.
   A. Solution B. Solvent C. Solute D. Pure substance
3. MC **Identify** which of the following is *not* a solute likely to be found in a bottle or can of fizzy soft drink.
   A. Flavours (natural or artificial)
   B. Water
   C. Carbon dioxide
   D. Sugar
4. MC **Identify** what escapes from a fizzy drink, causing it to go flat.
   A. Water B. Sugars C. Carbon dioxide D. Solvents
5. MC **Identify** the substance added to cordial to dilute it.
   A. Water B. Sugars C. Carbon dioxide D. Solutes
6. MC **Identify** which of the following statements is false.
   A. Water is the solvent in an aqueous solution.
   B. Water is a common solvent.
   C. Many types of solutes dissolve in water.
   D. All clear solutions are aqueous solutions.
7. **Identify** which of the following solutions are solvents and which are solutes.
   a. Soft drink b. Sea water c. Swimming pool water d. Cup of coffee

Apply and analyse

8. Complete the following passage using the words from the list. (You will not need to use all of the words.)

   large, *small*, *saturated*, *maximum*, *minimum*, *dissolved*, *undissolved*

   A concentrated solution has a ____________________ amount of solute dissolved. A ____________________ solution has the ____________________ amount of solute that can dissolve at that temperature. Excess solute will then remain ____________________.
9. a. **Name** the substance you could add to salt water to make it:
      i. more concentrated
      ii. less concentrated.
   b. **Explain** how you would create a supersaturated solution.
   c. **Describe** what happens to a supersaturated solution if you cool it down or disturb it.
10. A bottle of soft drink left lying in sunlight may burst open. Complete the passage using the following terms to explain why. (You will not need to use all the terms.)

    higher, *lower*, *temperature*, *carbon dioxide*, *solute*, *solution*, *pressure*, *liquid*, *bottle*, *lid*, *tighter*, *off*

    The ____________________ ____________________ causes the ____________________ to leave the ____________________, increasing the ____________________ in the space between the surface of the ____________________ and the top of the ____________________. Sometimes this pressure is enough to force the lid ____________________.

11. Is a box jellyfish a pure substance or a mixture? **Explain** why.
12. Think about what would happen if you placed an unopened can of soft drink and an unopened can of diet soft drink of the same type in a sink of water.
    a. **Suggest** which would float.
    b. **Suggest** which would sink.
    c. **Infer** what this might tell you about the sugar content in regular soft drinks compared to diet soft drinks.

Evaluate and create

13. SI **Evaluate** the claim made by manufacturers that some washing powders are equally effective in cold water as in hot water. Design an experiment to **investigate** whether washing powders dissolve better in cold water compared to hot water. Include the following components: aim, materials, method, and definitions of the dependent and independent variables.
14. SI Develop an experiment to **investigate** whether a fizzy drink loses its carbonation more quickly at cold or warm temperatures. Ensure you conduct a fair test by controlling all variables except the one you are testing.
15. SI Determine the maximum amount of sugar that can be dissolved in 200 mL of water at room temperature, and **examine** the effect of a 10 °C increase in temperature on solubility. Record your observations and formulate a conclusion based on your findings.

Answers and sample responses are available in your digital formats.

LESSON 5.3 Separating solids from mixtures

LEARNING INTENTION

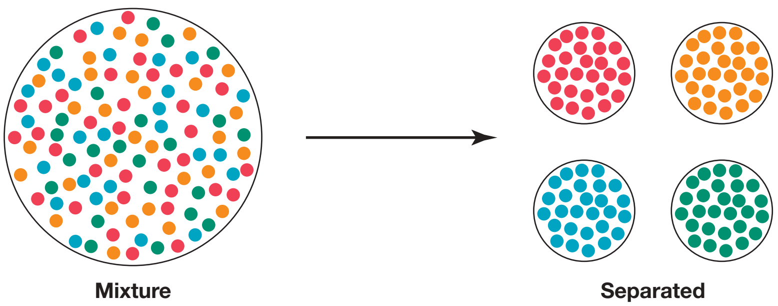
In this lesson you will describe a range of physical separation techniques, including decanting, sieving, filtration and magnetic separation, based on differences in physical properties.

5.3.1 Physical properties

Pure substances have unique physical **properties**, such as density, state (solid, liquid or gas), melting point, boiling point and solubility. Scientists need to understand these properties to distinguish between different pure substances.

To separate mixtures, various techniques are used based on the differences in these physical properties. There are many ways to separate mixtures in a laboratory; some methods are simple and quick, while others require expensive equipment and take more time. We will explore a variety of important separation techniques.

FIGURE 5.11 There are various techniques used to separate mixtures.



KEY IDEA

- Pure substances have unique physical properties (density, state, melting point, boiling point, solubility) that help scientists differentiate between them.
- Techniques for separating mixtures are selected based on the differences in their physical properties.

5.3.2 Decanting

There are several methods for separating mixtures that are not solutions. When insoluble materials are mixed with a solvent, they will settle at the bottom of the container if the mixture is allowed to stand. The insoluble material that collects at the bottom is known as **sediment**. If sediment sinks to the bottom of a container and the solvent (i.e. water) can be poured off, this process is called **decanting**. This is the simplest method for separating a mixture of a liquid and an undissolved solid.

FIGURE 5.12 Sedimentation of muddy water

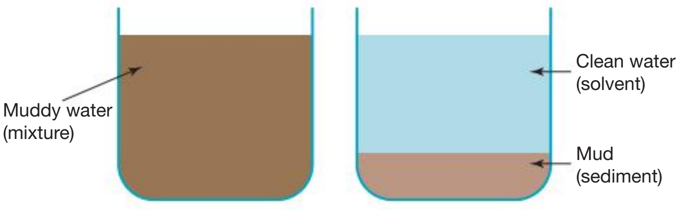
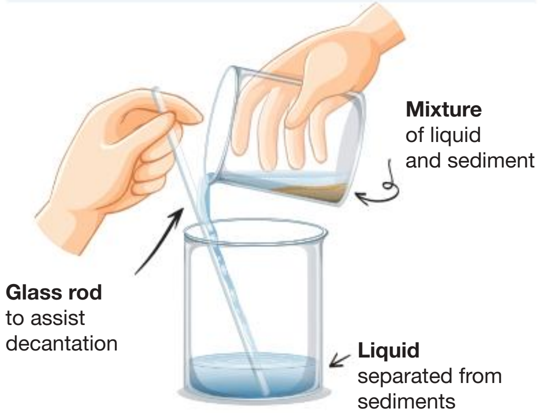


FIGURE 5.13 Separating a mixture by decanting

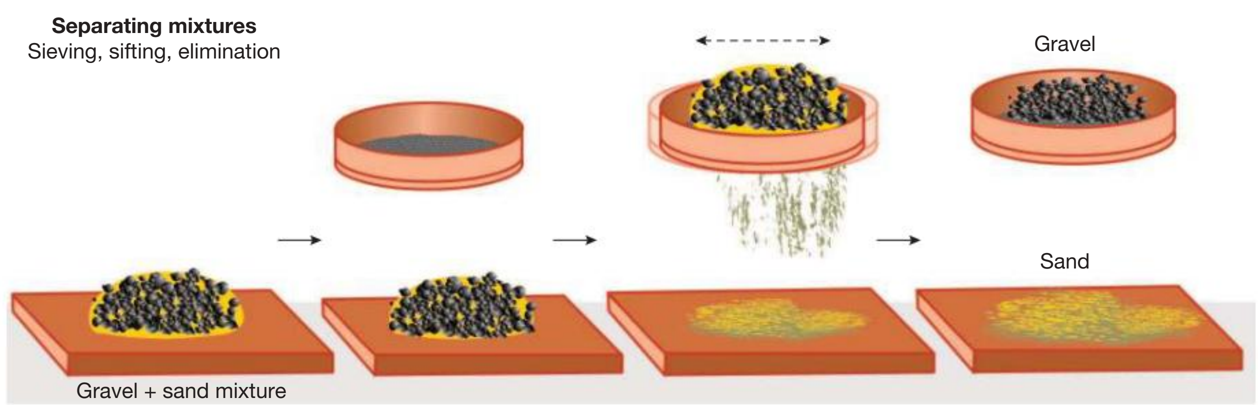


To decant a mixture, the solid is allowed to settle to the bottom of the container, forming a sediment. The liquid is then carefully poured off the top. Decanting can be used to separate most of the mud from muddy water. After the mud has settled to the bottom, the water can be poured off. If the water is still cloudy, it can be filtered to remove the remaining undissolved particles.

5.3.3 Sieving

Sieving is frequently used in the home. This happens when water is separated from vegetables, rice, pasta or lentils using a colander, when flour is sifted, and when a strainer keeps the tea leaves from going into a cup of tea. Sieving is efficient at separating larger particles from finer particles, as seen in figure 5.14. It involves passing a mixture of solids through a sieve or mesh that allows finer (smaller) particles to pass through while retaining larger particles on the surface. Sieving separates mixtures based on differences in particle size.

FIGURE 5.14 Sieving can be used to separate gravel from sand.



KEY IDEA

- Decanting is a separating technique used to separate mixtures based on differences in density and solubility.
- Sieving is a separation technique used to separate solid particles based on their size.

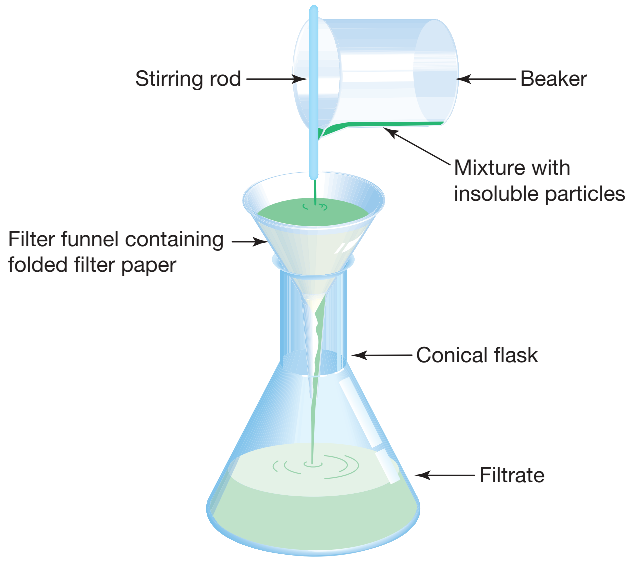
5.3.4 Filtration

What do a vacuum cleaner, tea strainer and protective face mask have in common? They are all devices for separating particles from mixtures by **filtration**. Filtration is a very fine sieving process. In the laboratory, filtration is carried out using filter paper, but there are many other useful methods of filtration that are used in the home and in industry.

FIGURE 5.15 Common household items that are filters: **a.** vacuum cleaner **b.** tea strainer **c.** face mask

In filtration, solutions, solvents or gases pass through the **filter** but particles that cannot fit through the filter are trapped by it; the filter is like a sieve. Insoluble particles can be separated from a mixture using filter paper in a funnel as shown in figure 5.16. The insoluble particles that remain in the filter paper are referred to as the **residue**. The liquid that is able to pass through the filter is referred to as the **filtrate**.

FIGURE 5.16 Equipment used to filter a mixture that contains insoluble particles



KEY IDEA

Filtration is a separation technique used to separate solid particles from a liquid or gas based on their particle size and solubility.

INVESTIGATION 5.3

Filtration in the laboratory

Aim

To investigate filtration to separate substances in a mixture

Hypothesis

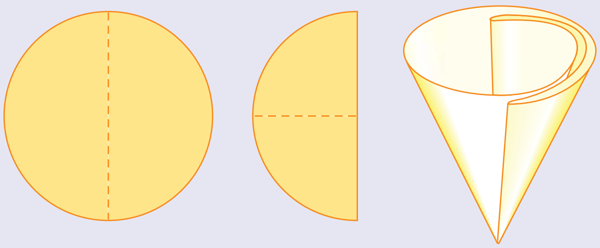
If a substance is insoluble in water, then it can be filtered out.

Materials

- 100 mL beaker
- funnel
- filter paper
- glass stirring rod
- conical flask
- insoluble substance, such as soil, chalk dust or charcoal

Method

1. Half-fill your 100 mL beaker with water.
2. Add your insoluble substance to the water and stir with the stirring rod.
3. Set up the equipment for filtering as shown in figure 5.16.
4. Fold the filter paper as shown.
5. Place the filter paper in the funnel and moisten with clean water to hold the filter paper in place.
6. Pour your mixture into the filter paper.



Results

1. Describe the appearance of your mixture in the beaker before filtration. Did it form a suspension or sediment, or float on top?
2. The liquid passing through the filter into the conical flask is called the filtrate. Describe your filtrate.
3. Examine your filter paper. The material trapped by the filter paper is called the residue. Describe your residue.

Discussion

1. Filter paper is like a sieve with small holes in it. Explain how the filter paper worked like a sieve in this experiment.
2. What results would you expect if there was a small hole at the bottom of the cone? Explain why.

Conclusion

Summarise the findings of the investigation in three or four sentences using correct scientific terms.

5.3.5 Magnetic separation

Recycling often uses magnetic separation to sort metals from other waste materials. In recycling plants, magnets help to separate metals such as iron and steel from non-magnetic items, making the recycling process more efficient. Magnetic separation works because some materials (e.g. iron, nickel and cobalt) are attracted to magnets while others are not. This technique is useful for separating metals from mixtures.

KEY IDEA

Magnetic separation is a technique used to separate magnetic materials from non-magnetic ones based on their magnetic properties.

FIGURE 5.17 Industrial magnets at work in a metal recycling facility

INVESTIGATION 5.4

Exploring magnetic separation

Aim

To investigate how magnetic separation can be used to separate a mixture of magnetic and non-magnetic materials

Materials

- iron filings
- sand
- bar magnet
- plastic spoon
- paper towel
- plastic snaplock bag
- clear plastic container or tray
- electronic balance

Hypothesis

Write a hypothesis to predict how effective magnetic separation will be in removing iron filings from a sand and iron mixture.

Method

1. Prepare the mixture by mixing equal amounts of sand and iron filings in a plastic container.
2. Use a spoon to stir the mixture. Record observations about the appearance and texture of the mixture.
3. Place the bar magnet into a plastic snaplock bag and hold the magnet above the mixture without touching it, and slowly move it across the surface. Observe what happens.
4. Once the iron filings are attracted to the magnet, gently remove them from the sand by lifting the magnet and placing it over a paper towel. Remove the plastic snaplock bag to separate the iron filings from the bar magnet.
5. Continue the process until most of the iron filings are separated from the sand.
6. Look at the remaining sand and collected iron filings. Using the electronic balance, record how much of each substance has been separated.

Results

Record your observations, including how much of the iron filings were separated and how much sand remained.

Discussion

1. Describe how the appearance of the mixture changed after using the magnet.
2. Identify any challenges you faced during the separation process.
3. Explain how the size and strength of the magnet might affect the separation results.
4. Discuss real-life situations where magnetic separation is important.
5. Investigate how understanding magnetic separation can help us with recycling and waste management.

Conclusion

Based on your results, describe how effective magnetic separation was in separating iron filings from sand. Explain why this process worked and whether your hypothesis was correct.

ACTIVITY: Making mnemonics

Thinking tools that are used to help us remember are called *mnemonics* (pronounced 'nemonics'). Rhymes, such as nursery rhymes, songs or advertising jingles, are often used as mnemonics. Individually or in small groups, create a short rhyme or song to help you remember some of the terms used in this topic so far. Share your rhymes with the class.

Consider the following groups of words as a starting point:
- filtration, sieving, decanting, magnetic separation
- solute, solvent, solution.

5.3 Activities

learnon

5.3 Quick quiz on	5.3 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 4, 7	3, 8, 9	5, 6, 10, 11

Remember and understand

1. Match each of the following terms with their descriptions.

Term	Description
a. Sediment	1. A process in which liquid is carefully poured off the sediment
b. Filtration	2. Liquid passing through filter paper
c. Residue	3. Material deposited on a filter
d. Filtrate	4. An insoluble substance that sinks to the bottom
e. Decanting	5. A process of separating suspended particles using a filter
f. Magnetic separation	6. A process that uses a magnet to separate magnetic materials from non-magnetic ones in a mixture

2. **Identify** the materials that can be separated using magnetic separation.
   a. Iron filings
   b. Plastic
   c. Aluminium cans
   d. Tin cans
   e. Steel
   f. Copper

3. Complete the following sentences using terms from the list.

decanting, *filtering*, *magnetic separation*, *sieving*, *physical properties*, *mixtures*, *separate*, *size*, *density*, *magnetism*

Pure substances have unique __________ that distinguish them from other materials. When dealing with __________, we can use different methods to __________ the components based on their specific properties. For example, __________ is used to separate solid particles from liquids based on __________, while __________ can remove materials that are attracted to a magnet. Additionally, __________ allows us to separate mixtures based on the __________ of the particles.

Apply and analyse

4. Think of two more filters or sieves used in the home. **Construct** a table like the following to **describe** the filters.

Filters and sieves in the home

Filter	Mixture	Residue	Filtrate
Vacuum cleaner	Air and dust	Dust	Air
Food strainer	Chips and hot oil	Chips	Oil

5. **Explain** why the air filter and oil filter in a car engine have to be replaced occasionally.
6. The following steps in a recipe are examples of separating mixtures in the kitchen. **Identify** each step with the separating method being used — is it filtration, sieving or decanting?
   a. Strain the boiled rice with a colander.
   b. Pour the hot water from the boiled potato.
   c. Remove the excess oil from the top of the simmering soup.
   d. Pour sauce into a jug, ensuring that the spice sediment is left behind in the pot.
   e. Place the filter into your coffee machine.
7. **Explain** why filtering is preferable to decanting when separating solid particles from a mixture.
8. **Describe** a situation where magnetic separation might not be effective. What factors contribute to its ineffectiveness?
9. Imagine you are camping at the beach when a strong wind disturbs your dinner preparation. You need to separate the following substances (in italics) from mixtures that the wind has created. **Explain** how you would separate each of the accidental mixtures and still be able to eat your dinner. Include which property of each substance would help you to remove it.
   a. The *salt* spills into the uncooked (dry) pasta.
   b. *Sand* blows into the jug of lemonade.
   c. *Water* spills into the container of raw sausages you are about to cook.

Evaluate and create

10. Filters are often included in face masks (such as those worn during pandemics). **Explain** why these are important and **outline** the advantages and disadvantages of these filters.
11. **Evaluate** the effectiveness of magnetic separation in recycling aluminium cans versus other materials.

Answers and sample responses are available in your digital formats.

LESSON 5.4 Other separating techniques

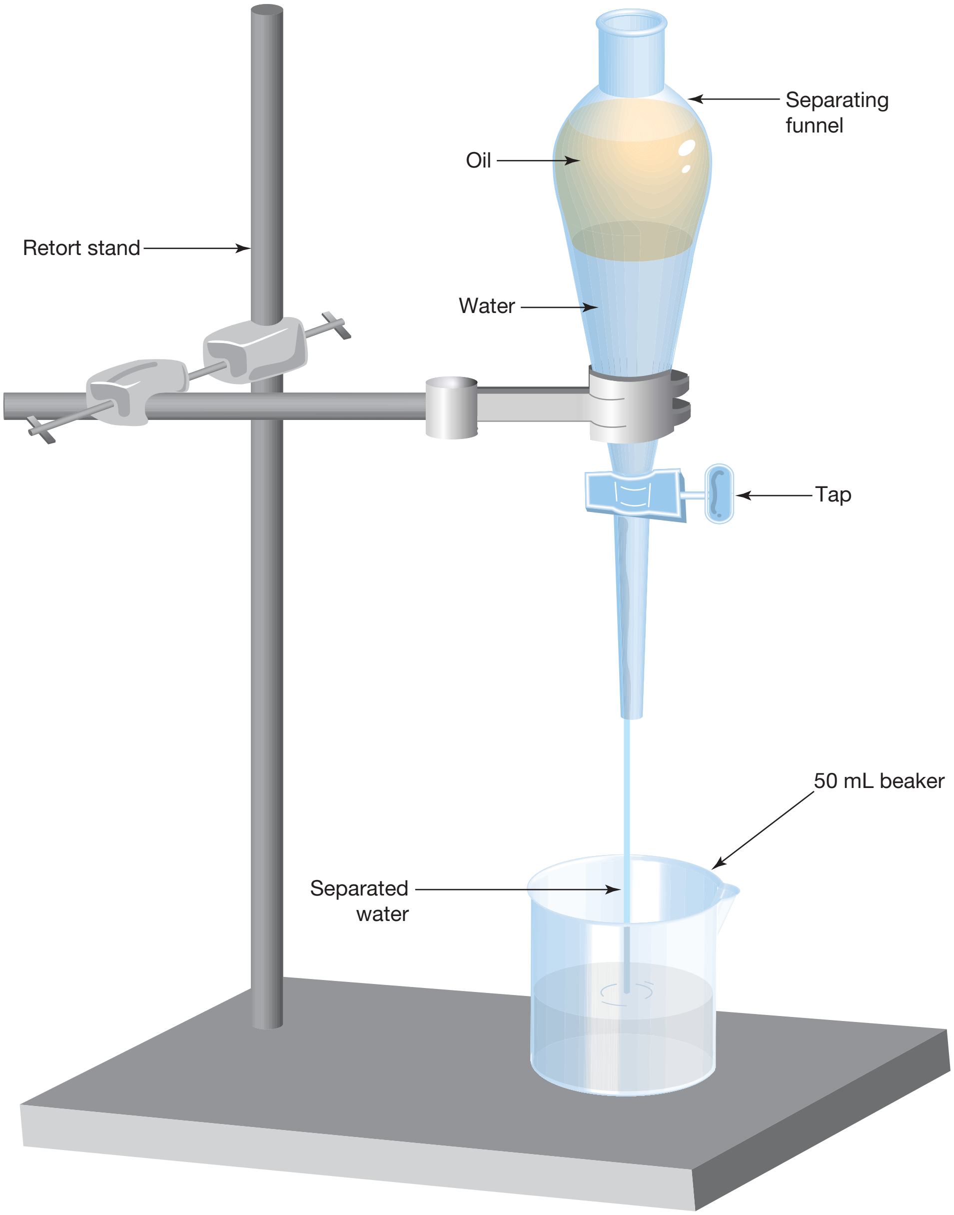
LEARNING INTENTION

In this lesson you will explain how a separating funnel and centrifuge separate mixtures, and the type of mixtures they are used to separate.

5.4.1 The separating funnel

When one liquid does not mix with another but floats on top of it, a **separating funnel** can be used to separate the two liquids. Oil floats on water because oil is less dense than water. This mixture can be separated using a separating funnel as shown in figure 5.18.

FIGURE 5.18 Using a separating funnel to separate oil from water



5.4.2 Centrifuging

A mixture can be separated by spinning it very quickly. This method is called **centrifuging**. The spin-dry cycle of a washing machine acts as a centrifuge and a filter. As the machine spins at high speed, the clothes are forced to the sides of the tub and the water passes out through the holes in the tub. The clothes cannot fit through the holes, and so much of the water is removed from them.

In the laboratory, centrifuging is used to separate solid or liquid substances from liquids. The mixture is placed in special test tubes that are spun in a circle at high speeds. The heavier substances are forced to the bottom of the tube and the lighter substances are left near the top.

Decanting can be used to pour off liquid after substances have been centrifuged. You can also decant by pouring off a liquid, like an insoluble oil layer on top of water, if a separating funnel is not available.

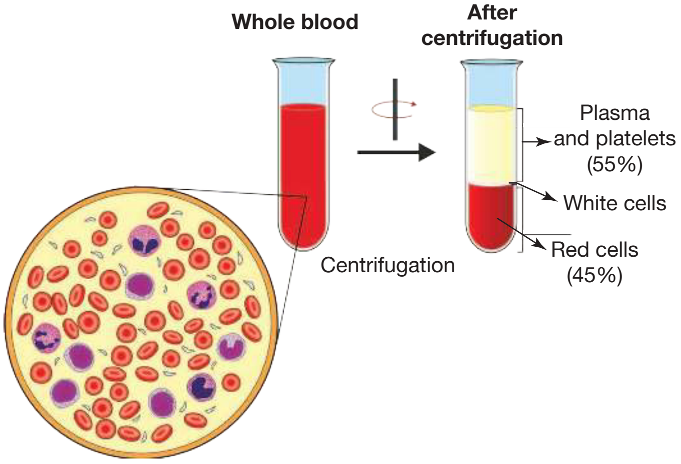
FIGURE 5.19 A centrifuge uses centrifugal force (force due to rotation) to separate components of a mixture.

Using centrifuging and filtering to separate blood

About one million donations of blood are made in Australia each year. Some of the donations are given to people who have lost blood during surgery, accidents or disasters. Blood is also given to people during the treatment of many diseases, including cancer. These people need to be given a regular supply of blood.

Blood is a life-giving mixture. It can be separated into four parts: plasma, a clear, yellowish liquid; red blood cells, which carry oxygen; white blood cells, which fight disease; and platelets, which clot blood, as shown in figures 5.20 and 5.21.

FIGURE 5.20 Centrifuging blood



Blood cells are **suspended** in plasma. Like other suspensions, blood donations can be separated into parts by spinning (centrifuging). Red and white blood cells are heavier than plasma and platelets, so they are forced to the outside edges of the containers in the centrifuge. Further centrifuging separates the platelets and different types of blood cells.

Some donors give only the plasma from their blood, as outlined in table 5.1. As the blood is taken out of the donor, it passes through a machine that separates the plasma from the rest of the blood. The blood cells are then pumped back into the donor.

Because each part of the blood has a special job to do in our bodies, different problems can be treated with different parts of the blood. In Australia, blood is collected and separated by Australian Red Cross Lifeblood. Separation allows doctors to treat a larger number of patients and save many lives.

FIGURE 5.21 Blood is collected and separated by the Australian Red Cross Lifeblood.

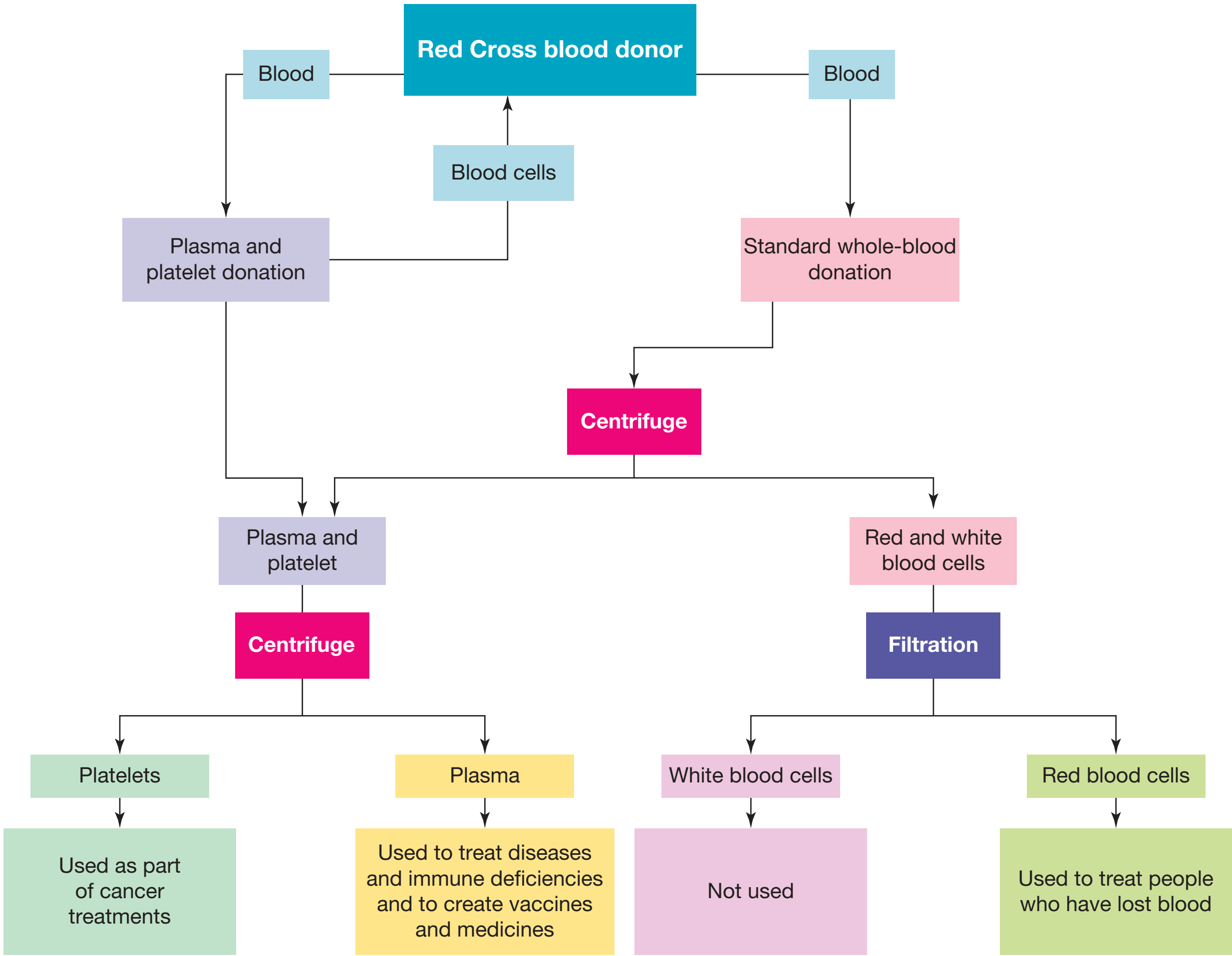


TABLE 5.1 Blood types and main uses

Blood type	Percentage of population	Most useful donations	Main uses
AB	5%	Plasma	AB plasma can be given to people with any blood type.
A	38%	Whole blood, plasma or platelets	A is a common blood type, so there is a high demand for these products.
B	14%	Plasma	B-type blood is particularly useful for people with blood diseases, severe burns or trauma.
O–	7%	Whole blood or platelets	All products from O– blood can be given to people with any blood type.
O+	38%	Whole blood, plasma or platelets	O+ is the most common blood type. There is a high demand for these products.

Once blood is separated, each part has to be stored differently.

- Red blood cells can be stored for 42 days at 2–6 °C.
- Plasma can be frozen for 12 months at –40 °C.
- Platelets are stored for 5 days at 20–24 °C. During this time they have to be moved at least every 12 hours to stop them clumping together. (Platelets seal wounds in our bodies by sticking together.)

5.4.3 Aboriginal and Torres Strait Islander Peoples' separating techniques

Separation techniques have been used by Aboriginal and Torres Strait Islander Peoples for thousands of years to help with their everyday needs for food, water and medicine. Some of the techniques include hand picking, winnowing, yandying, sieving and decanting, filtration, cold pressing, and steam distilling.

Hand picking

Hand picking is a separating technique that is simply using hand and eye coordination to select a desirable product by distinguishing it by its shape, colour, size and so on. It is used for harvesting desert raisins (also known as bush tomatoes) by the Alyawarre, Anmatyerre, Warlpiri and Pitjantjatjara peoples in the Australian central desert region (see figure 5.22).

FIGURE 5.22 Australian desert raisin, also known as kutjera or bush tomato. Observe the different elements of the plant. Which visual characteristics would you use to pick ripe bush tomatoes?

Winnowing

Winnowing is a method used to separate seeds from their outer layers and debris. The seeds and debris are tossed into the air, and the wind blows away the lighter parts, while the heavier seeds fall back into a **coolamon**, which is a type of vessel for carrying objects (see figure 5.23).

FIGURE 5.23 An assortment of native bush foods (Kakadu plums, acacia seeds, desert quandong, bush coconuts) in coolamons.

Yandying

Yandying is similar to winnowing and is used to separate denser seeds from lighter debris. A shallow wooden dish called a yandy is used. The contents are shaken gently, causing the denser seeds to sink to the bottom while lighter materials remain on top.

FIGURE 5.24 Yandying kalaru seeds

ACTIVITY: Hand picking scavenger hunt

Explore an outdoor area utilising the hand picking technique. As you search for a variety of natural materials such as seeds, leaves, stones, flowers and sticks, decide what to look for based on specific physical properties. Consider the shape (e.g. round, flat, long), colour (e.g. green, brown, yellow) and size (e.g. small, medium, large) of the items you collect. Gather those that meet your criteria in a bag or container. Once back in the classroom, share your findings with your classmates and discuss how you used hand picking to select your items.

ACTIVITY: Winnowing

With a mixture of lightweight materials (e.g. dry leaves, feathers) and heavier materials (e.g. small stones, seeds), use a fan or outdoor space to demonstrate winnowing by tossing the mixture in the air and observing how the lighter materials are carried away by the wind while the heavier materials fall back down.

Discuss how this method is used in agriculture.

Sieving and decanting

Some Aboriginal and Torres Strait Islander Peoples combine the techniques of sieving and decanting to prepare native yams, which can be toxic if not cooked properly.

The yams are boiled and then placed in a dilly bag (woven from plant fibres). When the bag is squeezed, the soft parts of the yam strain through the bag into water. The bag acts like a sieve, letting some substances pass through while keeping others inside. Afterward, the water is decanted and washing helps remove toxins. The yam is hung up overnight before it is ready to eat.

Filtering

Flowering banksia (honeysuckle) cones can be used to filter muddy water. This technique has been used by the Gunditjmara peoples in Victoria to obtain drinking water.

SCIENCE INQUIRY: Filtering water

Aim

To explore filtering techniques

Construct

Build a simple filtration system using a plastic bottle, sand, gravel and charcoal. Cut the bottom off the bottle and layer the materials inside. Justify your choices for the order of materials based on their physical properties and filtering capabilities.

Evaluate

Collect and pour muddy water into your filtration system and observe how it passes through the layers. Collect the filtered water and compare its appearance and clarity to unfiltered water.

1. Discuss your observations regarding the effectiveness of the filtration system.
2. Consider the cultural significance and discuss the importance of clean water in Aboriginal and Torres Strait Islander Peoples' culture. Include its significance for health, traditional practices and the deep connection to the land.

Reproducible investigations to answer questions and test hypotheses can be planned and conducted, including identifying independent, dependent and controlled variables where applicable, stating assumptions, recognising and managing risks, considering ethical issues and following protocols when accessing cultural sites and artefacts on Country and Place (VC2S8I02)

Cold pressing

Cold pressing is a technique used to extract oils from plants. The plant material is ground into a pulp and then pressed to release watery and oily components. Oil, which is less dense than water, rises to the top. For instance, macadamia nuts can be cold pressed to extract oil.

Steam distillation

This technique is used to extract aromatic oils from plants, often for medicinal purposes. The plant materials are boiled in hot water to release oils. The steam carries the aromatic components, which can be inhaled or applied to the body. For example, eucalyptus oil is used to help treat sore throats.

5.4 Activities

learnon

5.4 Quick quiz on	5.4 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 3, 7	2, 5, 8, 10	4, 6, 9

Remember and understand

1. MC Using a separating funnel:
   A. sand can be separated from water.
   B. oil can be separated from salad dressing.
   C. red blood cells can be separated from blood.
   D. salt can be separated from sea water.

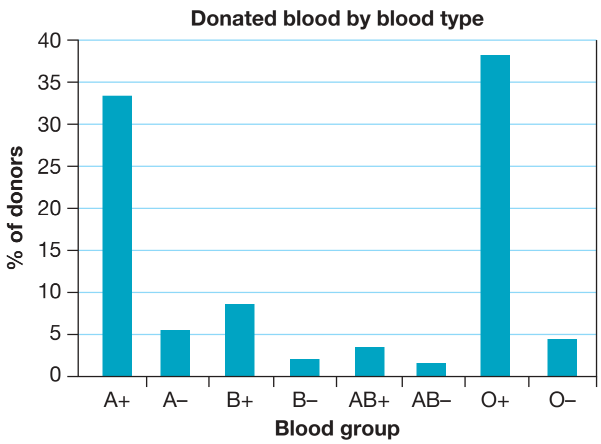
2. MC **Identify** which techniques are used to separate different parts of blood.
A. Centrifuging and decanting
B. Decanting and filtration
C. Filtration and centrifuging
D. Filtration and desalination
3. From the following terms, **identify** the four components (or parts) of blood that blood donations are separated into.

plasma, *white blood cells*, *filters*, *dishlets*, *blood type*, *red blood cells*, *aqueous blood cells*, *platelets*

4. **Explain** why donated blood is separated into different parts.
5. MC **Identify** the property of plasma and red blood cells that allows them to be separated with a centrifuge.
A. Red blood cells are lighter solids suspended in heavier liquid plasma.
B. Red blood cells are light liquids dissolved in plasma.
C. Red blood cells are heavier solids suspended in lighter liquid plasma.
D. Red blood cells attach to the white blood cells, making them larger than the plasma.
6. MC Which of the following best explains why blood is separated in a centrifuge rather than being left to settle by itself?
A. It is faster.
B. Blood does not settle by itself.
C. It is slower and more precise.
D. It is safer for the donor.
7. **Explain** the following separation techniques used by Aboriginal and Torres Strait Islander Peoples. For each technique, **identify** an example of its use.
a. Cold pressing
b. Winnowing
c. Yandying
d. Steam distilling

Apply and analyse

8. **Explain** how blood is separated into different parts. Ensure you use the correct scientific terminology.
9. **Analyse** the bar graph and respond to the following questions.
a. **Identify** the type of blood with the highest percentage of donors.
b. **Identify** what the vertical axis represents.
c. **State** a title for this graph.
d. **State** the total percentage of donors who have B group blood.
e. **Explain** why there is a high demand for O+ blood group.



Evaluate and create

10. In an average week, Australian Red Cross Lifeblood needs about 33 000 blood donations to meet the need for blood and blood products.
a. **Propose** some reasons for why people may not want to donate blood.
b. What is the minimum body weight required of blood donors?
11. SI Create an advertisement to encourage people to donate blood. Briefly **describe** how the blood is obtained, how the blood is separated into its components and how each part is used.

Answers and sample responses are available in your digital formats.

LESSON 5.5 Separating solutions

LEARNING INTENTION

In this lesson you will explain the physical separation techniques such as evaporation, distillation, crystallisation and chromatography, and outline examples of where they are used.

5.5.1 Reviewing solutions

Imagine being stranded on a small, sandy island with no fresh water to drink. You are surrounded by the sea. But you cannot drink the sea water; it would dehydrate you even further. You have to find a way of separating the water from the salt dissolved in it. What can you do?

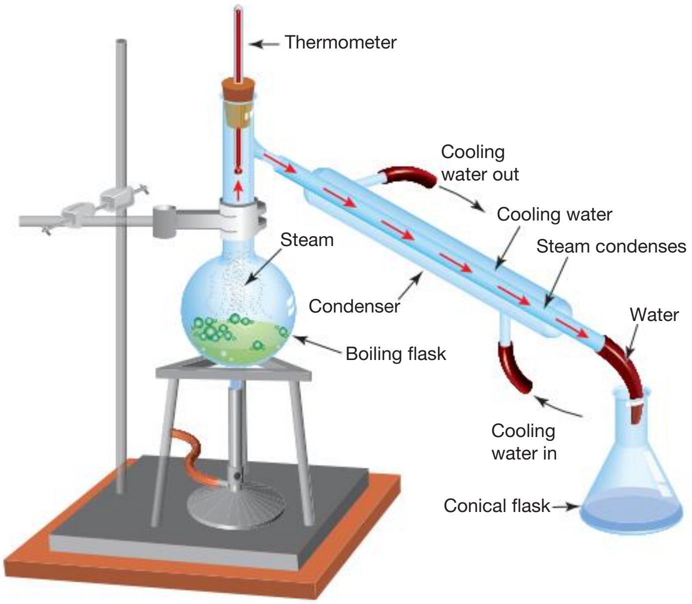
FIGURE 5.25 How would you survive on a sandy island surrounded by undrinkable salt water?

Sea water is a solution. Separating the solute from the solvent in a solution is usually more difficult than separating undissolved substances from a liquid. Filtration will not work — the dissolved particles are too small. Neither will decanting nor centrifuging. You cannot even see the dissolved particles. The answer lies in the fact that the solvent and solute have different properties. In the case of salt water, when heated to 100 °C, the water evaporates, leaving the salt behind as solid crystals. This process is called evaporation, a physical separation technique that takes advantage of the different boiling points of water and salt.

5.5.2 Distillation

In the laboratory, pure water can be produced by a process called **distillation**. Tap water is poured into a boiling flask (see figure 5.26) and heated to the boiling temperature for water, 100 °C. The water boils, **evaporates** and becomes steam. The steam travels along the water condenser. The steam inside the condenser is cooled to below 100 °C and **condenses** to form liquid water. The condenser is kept cool by running cold water through its outer jacket.

FIGURE 5.26 Equipment used for distillation in the laboratory



The pure water collected in the conical flask is called the **distillate** and can be rightly labelled **distilled water**. The impurities in the water are left behind in the boiling flask.

KEY IDEA

Distillation is a separating technique that uses differences in boiling points to separate components of a mixture. It can be used to separate pure water from sea water. It can also be used to separate a mixture of two liquids as long as they boil at different temperatures.

In order to separate liquids, the liquids must have different boiling points or **volatility**. Volatility means how readily a substance can evaporate or become a vapour. Liquids with a high volatility have a low boiling point and can easily turn to vapour. Liquids with a low volatility have a high boiling point and cannot easily become a gas. In distillation, the liquid with the lower boiling point (or higher volatility) turns to steam first, and is collected as liquid after moving through the condenser.

5.5.3 Slow evaporation

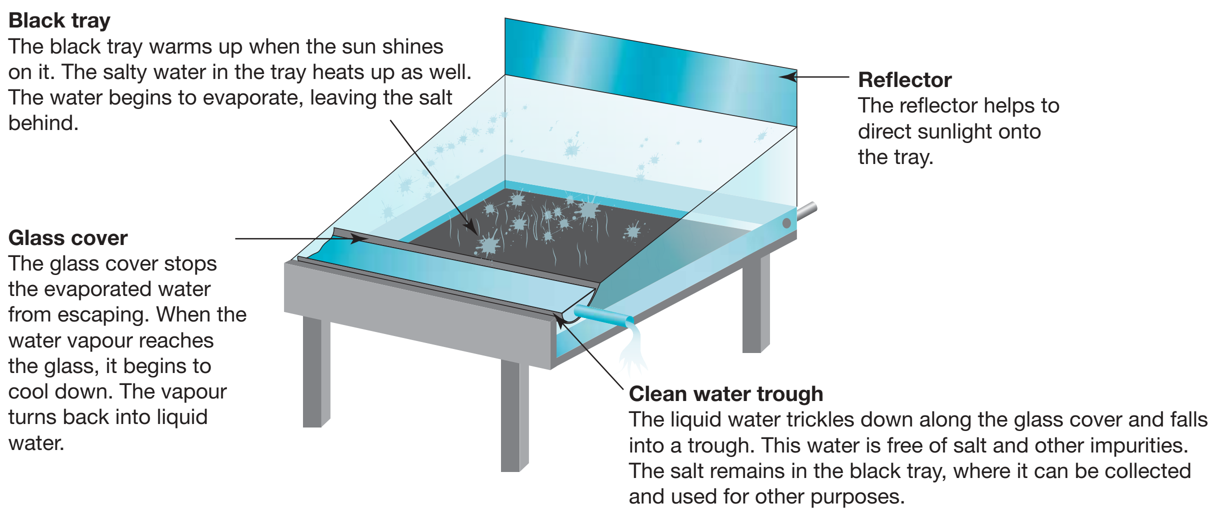
Pure water can be separated from salty water without boiling it. The salt and other impurities are left behind. The process takes longer, but the energy of the Sun can be used to evaporate the water. Solar distillation, as shown in figure 5.27, could be used to produce small amounts of pure water from salt water.

When evaporation is used to separate pure water from salt water, the salt is left behind as crystals. If it is more important to collect the solute than the solvent, this process of separation is called **crystallisation**. Table salt is produced by the process of crystallisation, using energy from the Sun to evaporate sea water or water from salt lakes.

KEY IDEA

- Evaporation is a separating technique that removes the solvent from a solution by turning it into vapour, based on the difference in boiling points between the solvent and solute, leaving the solid behind.
- Crystallisation is a separating technique that forms solid crystals from a dissolved substance as the solvent evaporates. This process is based on the solubility of the solute, which crystallises as the solution becomes saturated.

FIGURE 5.27 In solar distillation, the Sun's energy can be used to distill sea water.



The desert island solution

In places where fresh water is scarce, a simple water still could be used to evaporate and collect pure water. If the water is muddy or not clear, it should be filtered first to separate the undissolved particles. On a desert island, clothing, like a T-shirt, could be used as a filter.

INVESTIGATION 5.5

Making a simple water still

Aim

To investigate a simple still to separate salt from salt water

Hypothesis

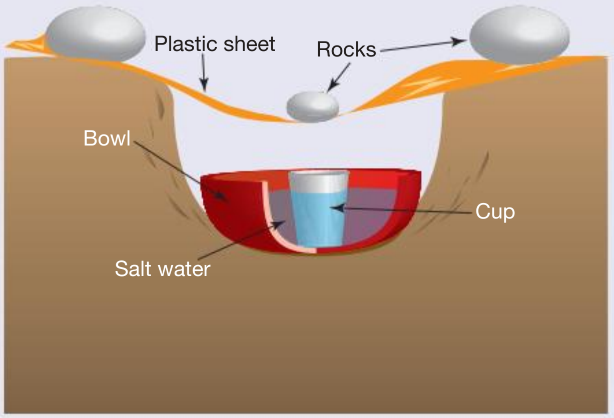
If a solution of salt water is distilled using a simple water still, then the salt and water will be separated, with water falling into the cup and salt remaining in the bowl.

Materials

- trowel
- bowl
- scissors
- some small rocks
- cup
- saltwater solution
- plastic bag

Method

1. Dig a shallow hole in the ground outside. The hole should be in a spot that gets a lot of sunlight.
2. Put the bowl in the bottom of the hole and put the cup in the middle of the bowl.
3. Pour the salt water into the bowl. Don't allow any salt water to get into the cup.
4. Cut the side seams of the plastic bag and open it up so that it forms a flat sheet of plastic. Place the plastic over the hole, using small rocks to anchor it in place. Make sure that the hole is completely covered.
5. Place a small rock in the middle of the plastic sheet, just above the mouth of the cup.
6. Leave undisturbed for a couple of hours.



Results

Examine the contents of the bowl and the cup and record your observations.

Discussion

1. Identify how the water level in the bowl has changed.
2. Observe if there is any residue on the walls of the bowl and determine what you expect this residue is composed of.
3. Describe the differences between the water in the cup and the water in the bowl.

Conclusion

Summarise the findings of the investigation in three or four sentences.

5.5.4 Crystallisation

Crystallisation is the formation of crystals from a saturated solution. It can be used to purify an impure solid by making a warm saturated solution. Crystals will form as this solution cools. This is because more of the solid is able to dissolve in the warmer saturated solution, so when the solution cools down, the extra solid that can no longer dissolve forms crystals.

FIGURE 5.28 A saturated solution of manganese sulfate crystallising

INVESTIGATION 5.6

Crystallisation

Aim

To investigate separation by crystallisation

This investigation must be done in class with your teacher.

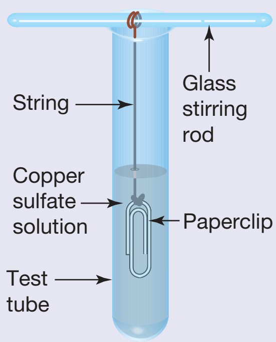
Materials

- test tube
- solid copper sulfate (or alum)
- a balance
- 150 mL beaker
- glass stirring rod
- hot water
- string
- test tube rack
- piece of filter paper
- filter funnel
- conical flask or beaker
- paperclip

CAUTION: Wear gloves and protective clothing for this investigation.

Method

1. Weigh 28 g of copper sulfate and add to the beaker.
2. Prepare a hot concentrated solution of the copper sulfate by pouring 20 mL of hot water into the beaker. Stir the solution until no more solid will dissolve.
3. Pour the blue copper sulfate solution through the filter paper into the conical flask or beaker. The undissolved copper sulfate will remain on the paper.
4. Quickly pour the solution into a test tube.
5. Tie the string to the glass rod. Attach the paperclip to the end of the string and arrange it as shown in the diagram.
6. Leave to cool overnight in the test-tube rack.



Results

Describe the changes that have taken place in the test tube.

Discussion

1. Identify the solid substance that has formed.
2. Explain why warm water was used.
3. What do you think was the purpose of the paperclip?
4. Identify the term used to describe a solution in which no more solid will dissolve.
5. List the variables in this experiment.
6. Write a hypothesis to suggest a factor that could be changed to increase the size of the crystal.

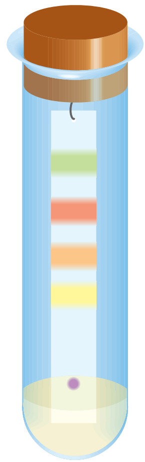
Conclusion

Summarise the findings of the investigation in three or four sentences.

5.5.5 Chromatography

Paints, inks, dyes and food colourings are often mixtures of substances that have different colours. You can separate a mixture of different colours using **paper chromatography**, as shown in figure 5.29. Chromatography relies on the differences in solubility of substances in a mixture.

FIGURE 5.29 Filter paper being used in the process of chromatography



An example of the process of paper chromatography:

1. A small amount of the solution is placed on a strip of filter paper 2 cm from its end.
2. The filter paper is hung so that the sample is just above the level of the solvent.
3. The colours dissolve as the solvent soaks up the paper strip.
4. The more soluble colours move more quickly and travel further up the strip than the less soluble colours.

KEY IDEA

Chromatography can separate parts of mixtures according to their different solubilities in a particular solvent.

INVESTIGATION 5.7

Separating colours

Aim

To investigate the use of paper chromatography to separate substances in food colouring

Hypothesis

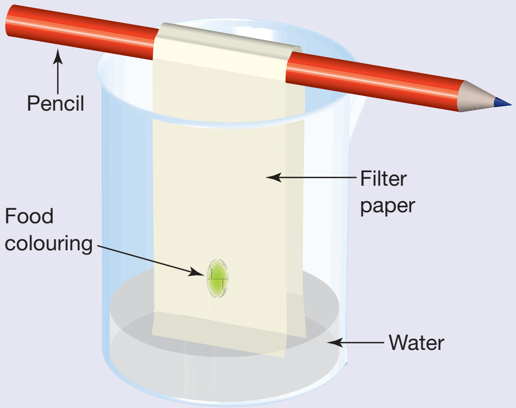
If a sample of water-soluble food colouring is made of a mixture of different dyes, then these will be separated using paper chromatography, because some colours will move further up the paper than others.

Materials

- food colouring
- toothpick
- filter paper
- scissors
- 250 mL beaker
- pencil
- ruler

Method

1. Cut a piece of filter paper approximately 10 cm by 3 cm.
2. Rule a pencil line 2 cm from the end of the paper.
3. Use the flat end of a toothpick to place a small dot of food colouring in the centre of the pencil line on the filter paper.
4. Pour tap water into the beaker to a depth of 1 cm.
5. Stand the filter paper so that the end just dips into the water. Make sure that you keep the dot of food colouring out of the water.
6. Fix the filter paper to a pencil to hold it in the beaker.
7. Leave the filter paper to stand until the water has risen almost to the top.
8. Repeat the experiment with different food colourings.



Results

Record your observations of the colours for the different food colours in a table (you could also draw diagrams or take photos).

Discussion

1. Describe how the colours are separated using this method.
2. Explain whether you think the colours would separate in the same way if a different solvent were used.
3. **a.** State if any of the separated colours are the same distance from the pencil line. For example, was the yellow in different food colours the same distance from the pencil line?
   b. Analyse what this suggests about the specific food colour.

Conclusion

Summarise the findings of the investigation in three or four sentences.

SCIENCE AS A HUMAN ENDEAVOUR: Where is chromatography used in industry?

The principles of chromatography are used in complex instruments to separate and identify a huge range of substances. Chromatography is used in the food industry to detect more than just food colours. Food scientists can tell us what other ingredients have been added to food.

Chromatography can also identify pesticides and harmful chemicals that have entered our food from the water in creeks and dams, or from soil **pollution**.

Forensic scientists use gas chromatography to detect a range of substances, including traces of illegal drugs. They can also use chromatography to compare mixtures found at crime scenes with those found on suspects. Many mixtures contain a unique combination of substances. For example, ink from different pens varies, even if the colours look the same.

The separating technique of chromatography is used to detect substances in blood and urine. In medical laboratories, samples of blood or urine are tested for drugs and alcohol. Abnormal levels of vitamins and hormones in a person's blood can also be detected using chromatography.

FIGURE 5.30 A high-performance liquid chromatography (HPLC) machine automatically separates mixtures by chromatography.

Chromatography is a powerful technique used across many scientific fields to separate and identify substances in mixtures. Its applications are vital for addressing health, safety and environmental challenges. Here are more examples of its uses:

- Environmental science: Chromatography helps monitor pollution levels in air and water. It can detect minute traces of harmful substances, such as heavy metals or microplastics, ensuring public health and environmental safety.
- Pharmaceutical industry: Drug manufacturers use chromatography to ensure the purity of medications and confirm their chemical composition. This ensures that drugs are safe and effective before they are sold.
- Sports science: Chromatography is used to detect performance-enhancing drugs in athletes. Anti-doping agencies rely on this technique to ensure fair competition in sports.
- Art and history: Art restorers use chromatography to analyse pigments in ancient paintings and documents. This helps preserve cultural heritage and detect forgeries.

Chromatography is used in fields as diverse as food safety, forensics and sports.

1. Why do you think a single scientific method can be applied to so many areas? What does this tell us about the importance of cross-disciplinary knowledge?
2. Chromatography can detect drugs in blood or urine, ensuring safety in workplaces and sports. However, it also raises privacy concerns. How can we balance the need for safety with respecting people's privacy?

Multidisciplinary endeavours to advance scientific knowledge make use of people's different perspectives and worldviews (VC2S8H02)

5.5 Activities

learnon

5.5 Quick quiz (on)	5.5 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3, 8, 13	4, 6, 10, 12, 14	5, 7, 9, 11

Remember and understand

1. MC **Identify** the separating technique used to produce crystals from a saturated solution.
   A. Crystallisation
   B. Centrifuging
   C. Filtering
   D. Decanting
2. MC **Identify** the property used to separate mixtures in distillation.
   A. Particle size
   B. Boiling point/volatility
   C. Solubility
   D. Colour
3. MC **Identify** the property used to separate mixtures in chromatography.
   A. Particle size
   B. Boiling point/volatility
   C. Solubility
   D. Colour
4. Complete the table by adding the correct names for each piece of equipment used in the distillation process.

Distillation equipment

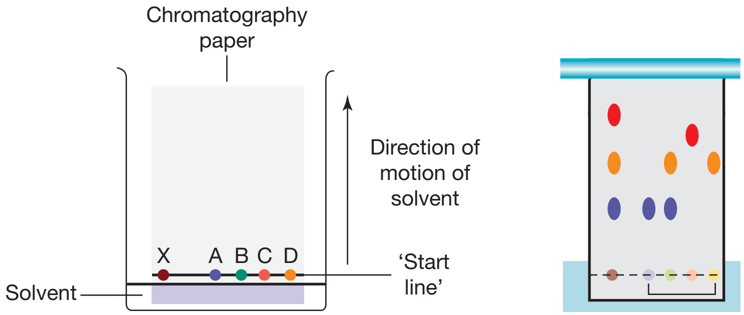
Description	Equipment
a. Heats the liquid in the boiling flask	
b. Measures the temperature of the evaporated liquid	
c. Cools the vapour after it leaves the boiling flask	
d. The container that collects the pure liquid	

5. MC **Identify** the purpose of a glass cover on a solar still.
   A. Stops the evaporated water escaping into the air
   B. Prevents bystanders from interfering with the process
   C. Keeps bugs out
   D. Stops the black tray from fading in the sunlight
6. **Outline** three uses of chromatography in industry.
7. SI A solution was made by dissolving a white solid in water. The solution was boiled in an evaporating dish until all the water had evaporated. The following measurements were obtained:
   - Mass of evaporating dish = 27.3 g
   - Mass of evaporating dish + solution = 49.8 g
   - Mass of evaporating dish after boiling = 32.3 g

   a. **Calculate** the mass of the solid.
   b. **Calculate** the mass of the water.

Apply and analyse

8. **Explain** how evaporation and crystallisation are different from each other.
9. **Explain** why cool, running water is passed through distillation equipment.
10. A dot of a black marker pen was placed on a pencil line 2 cm from the bottom of a strip of filter paper, and then the strip was placed in a beaker with 1 cm of water. The water rose, and after 5 minutes, the colours had separated into yellow, blue and purple, followed by a brown section at the top of the paper.
    a. **List** the coloured dyes from the fastest moving to the slowest moving.
    b. **List** the dyes from the most soluble to the least soluble.
    c. **Explain** why a pencil line was used and not an ink or marker pen at the point where the dot was placed.
    d. How could you tell if another black marker pen contained the same dyes?
11. SI Dots from five different coloured pens were marked on a pencil line and placed in a solvent.



    a. **Identify** the colour of the dyes that were present in the black pen (marker X).
    b. Why do you think the red spot from the black pen is at a different distance from the start than the red spot from the red pen?
    c. **Explain** if you would expect the order of the spots to be the same if a different solvent was used.
    d. **Summarise** the variables that affect the position of the spots obtained in paper chromatography.
12. **Explain** why crystallisation is not suitable to purify water.

Evaluate and create

13. SI Zoe performs a paper chromatography experiment on waterproof markers, using water as a solvent. Will her experiment work? **Explain** your answer.
14. SI Design a separating machine that will separate a mixture of three substances, such as nails, beans and sand. **Outline**:
    - the name of your separating machine
    - a diagram of the machine
    - information on what mixture your machine will separate
    - instructions for how to use it
    - an explanation of why it works
    - the advantages that your machine has for its particular use.

Answers and sample responses are available in your digital formats.

LESSON 5.6 Separation in industry

LEARNING INTENTION

In this lesson you will describe how important separation processes are in the mining and dairy industries, and how they are used to clean up oil spills.

5.6.1 Separating mixtures in industry

Separating the useful material from a mixture is often a problem in industry. In mining, the mineral ores that are needed are mixed with useless rock called gangue. In the dairy industry, the cream has to be separated from the milk before it can be put into containers for sale. Separation is also important in cleaning up after oil spills in the ocean.

Separating mixtures in mining

Copper

The metal copper is used in hot water pipes, electrical wiring and even in the coins we use. Copper is found in rocks in Earth's crust in the form of mineral ores. Before the copper can be purified, the copper ore has to be separated from the gangue. The gangue is the waste rock that is mixed with the ore containing the copper.

The mixture of gangue and copper ore that is dug out of the ground is in solid lumps. These lumps have to be crushed into a fine powder before the copper ore and gangue can be separated. Crushing takes place in a ball mill, which is a long barrel containing lots of heavy steel balls. As the barrel is rotated, the steel balls crush the lumps into a fine powder.

Once the copper ore and gangue are crushed, the copper ore is separated from the gangue by a process called **froth flotation**. The crushed mixture is mixed with water and some special chemicals, and stirred. Bubbles of air are blown into the bottom of the container and the copper ore is carried to the surface by the bubbles. The gangue sinks to the bottom of the tank and the copper ore is skimmed off the top of the liquid. The copper ore is treated to extract the pure copper, which can then be used to manufacture the many copper products we use.

Gold

Gold obtained from the ground is also mixed with unwanted rock. After grinding in a ball mill, the mixture of crushed rock and gold is mixed with water. The gold can be separated from the mixture using **gravity separation** because the gold is heavier than the rock. The mixture is spun and the gold sinks to the bottom.

In the same way, panning for gold by swirling the pan allows the heavier gold to settle in the pan (see figure 5.31) while the lighter gravel and sand swirl out of the pan with the water.

FIGURE 5.31 Gold separated from unwanted rock

Separating mixtures in the dairy industry

SCIENCE AS A HUMAN ENDEAVOUR: Separating mixtures in the dairy industry

Cow's milk is a mixture of watery milk and fatty cream. If fresh milk straight from the cow is left to stand, the cream floats to the top of the milk. The milk that you buy as homogenised full-cream milk contains both the milk part and the cream mixed together. Very fine droplets of cream are dispersed evenly throughout the watery milk.

Skim milk is the watery milk part without the cream. Milk is separated from the cream at the dairy using a centrifuge. The cows' milk is fed continuously into the centrifuge at one end; as the milk is spun in the centrifuge, the lighter cream separates from the heavier skim milk and each part is continuously collected at the other end.

FIGURE 5.32 Milk is separated using a variety of techniques to create many different products.

Skim milk powder is made by evaporating about half of the water from the skim milk. A fine mist of this skim milk is then sprayed into a current of hot air, so that more water evaporates. The powdery, dry milk is collected from the bottom of the chamber.

Communication of scientific knowledge has a role in informing individual viewpoints, and community policies and regulations (VC2S8H04)

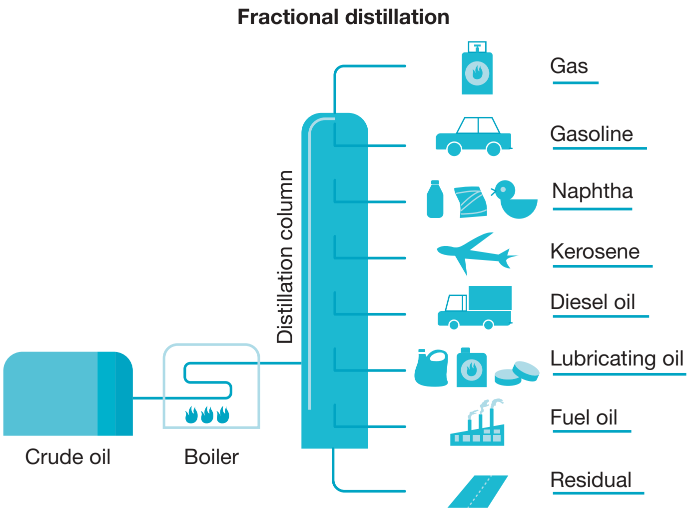
Separating crude oil

Crude oil is a natural mixture made up of lots of different substances. We find it deep underground. To use it, we need to separate these substances. Each part of the oil can be used for different things, such as making fuel for cars or plastic for toys. The process of separating crude oil is called fractional distillation. This is how it works:

- The crude oil is heated until it turns into a gas.
- As the gas cools, the different parts of the mixture turn back into liquids at different temperatures.
- These liquids are collected separately. The lighter parts (e.g. gas) come out first, while the heavier parts (e.g. diesel) come out later.

This process works because each substance in crude oil has a different boiling point, which means it turns from liquid to gas at a different temperature.

FIGURE 5.33 The process of separating crude oil



INVESTIGATION 5.8

Separation by flotation

Aim

To investigate modelling the separation of the gangue from mineral ore

Materials

- jar and lid
- sand
- sawdust
- teaspoon

Method

1. Half-fill the jar with water.
2. Add a teaspoon of sand and a teaspoon of sawdust.
3. Place the lid on the jar firmly and shake vigorously.
4. Allow the jar to stand.
5. Use a spoon to remove the sawdust.

Results

Describe the appearance of the contents of the jar immediately after shaking and then after settling.

Discussion

1. In this experiment, which substance represented the gangue?
2. Which substance represented the mineral ore?
3. How is the method of separation in this experiment different from the froth flotation method used to separate copper ore from the gangue?
4. Suggest how the method for this investigation could be improved.

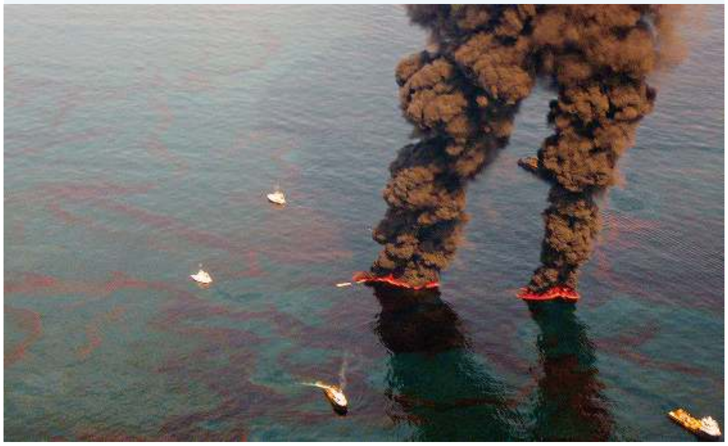
Conclusion

Summarise the findings of the investigation in three or four sentences.

5.6.2 Cleaning up oil spills in the ocean

On 20 April 2010, an explosion on the BP Deepwater Horizon drilling rig caused a huge oil spill in the Gulf of Mexico, covering thousands of square kilometres of ocean. In 2018, a similar spill occurred in the East China Sea when an oil tanker collided with a cargo ship. In February 2023, the sinking of the *MT Princess Empress* off the coast of the Philippines resulted in another major spill, threatening marine biodiversity in the region. These spills cause significant harm to birds, fish and marine ecosystems. Various clean-up techniques are used based on the properties of oil and sea water.

FIGURE 5.34 Controlled burns of oil gathered from the surface of the Gulf of Mexico following the BP Deepwater Horizon oil spill disaster

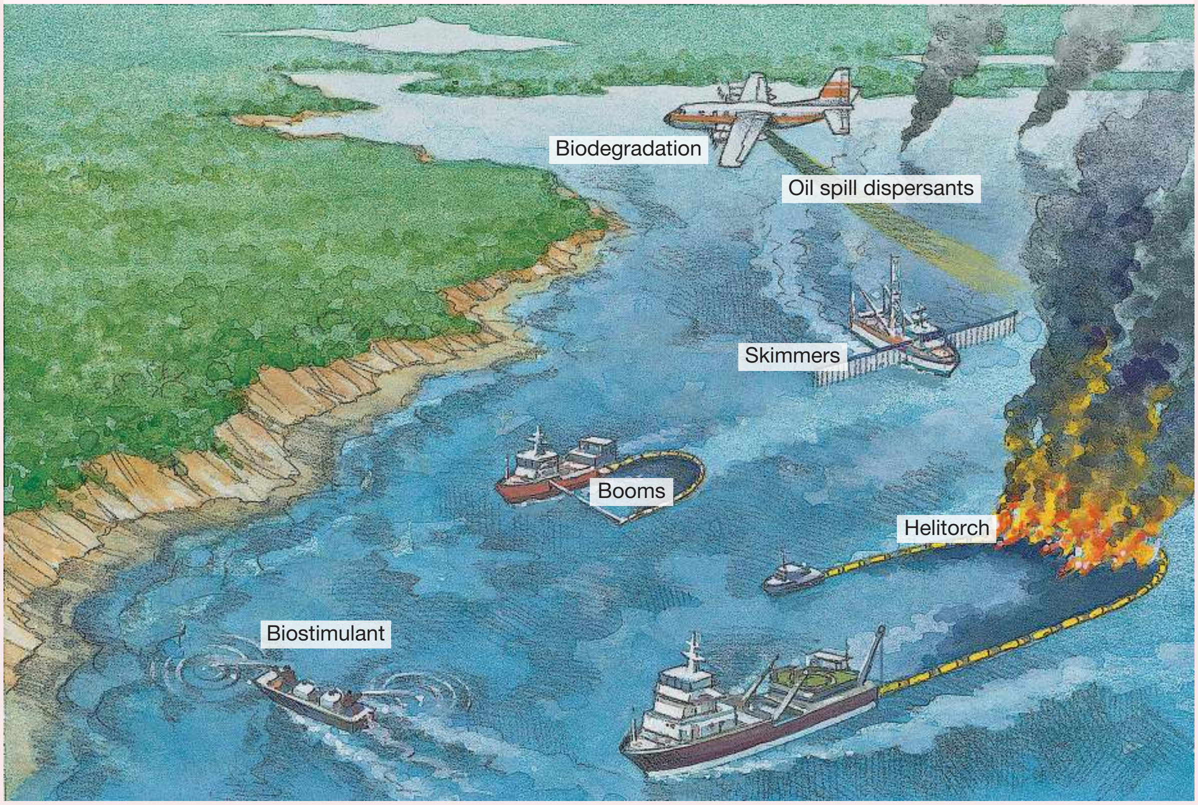


SCIENCE AS A HUMAN ENDEAVOUR: Oil spills and clean-up technologies

Oil spills have devastating environmental, social and economic impacts, particularly on marine ecosystems and coastal communities. Cleaning up these spills requires a multidisciplinary approach that combines chemistry, engineering, biology and environmental science.

Figure 5.35 shows some of the main techniques used to address oil spills.

FIGURE 5.35 How to clean up an oil spill



Biodegradation: Microorganisms in the ocean naturally break down the oil over time, but this can take many years.

Dispersants: Chemicals called **surfactants** are sprayed from helicopters or boats to break the oil into smaller droplets, which are easier for bacteria and algae to decompose.

Controlled burning: Fresh oil can be burned off the water surface using a **helitorch**, but this produces smoke that may release pollutants into the air.

Biostimulants: Fertilisers can be added to boost microorganism growth, speeding up the natural breakdown of oil.

Booms: Floating barriers made of materials like neoprene prevent oil from spreading by trapping it in one area.

Skimmers: Boats equipped with devices that scrape oil from the surface and store it for removal.

These methods, though effective, vary in how quickly they work and may have environmental impacts of their own. Use the interactive image in the Resources panel to learn more.

1. Which oil spill clean-up method do you think is the most effective? Why? What factors should scientists and governments consider when choosing a method?
2. Some clean-up methods, such as chemical dispersants and controlled burning, can harm marine life or release pollutants. Do you think these methods should be used despite their negative impacts? Why or why not?

Proposed scientific responses to socio-scientific issues impact on society and may involve ethical, environmental, social and economic considerations (VC2S8H03)

SCIENCE INQUIRY: Ethical responses to oil spills

Aim

To explore how mixtures are separated in oil spill clean-up methods and justify an ethical response to this environmental issue

Part 1: Research and analysis

Form small groups within the class. Each group will be assigned a different clean-up method: biodegradation, dispersant, controlled burning, biostimulants, booms and skimmers.

Research the effectiveness, environmental impact and limitations of your assigned method. Analyse the pros and cons. Address the following questions:

- How effective is it at cleaning up oil?
- What are the short-term and long-term environmental impacts?
- Does it harm marine life or ecosystems?

Part 2: Ethical evaluation

Evaluate the ethical considerations of your clean-up method:

- Does it cause harm to marine ecosystems while separating the oil?
- Does it prioritise short-term results or long-term environmental health?
- Is it fair to prioritise one species or ecosystem over another (e.g. protecting fish versus birds)?
- Should companies be allowed to use cheaper methods that may cause more harm in the long run?

Part 3: Presentation and justification

Present how your method separates oil from water, connecting it to the scientific principles of mixture separation. Justify the method's ethical use, considering environmental and social impacts.

Part 4: Class debate

Defend your method by focusing on both the scientific process of separating oil from water and the ethical implications.

Discuss which method provides the most effective separation of mixtures, considering the ethical costs.

Part 5: Reflection

Individually, write a reflection discussing which method is best, both scientifically (as a way to separate mixtures) and ethically. Use the principles of separation and ethical reasoning in your response.

Evidence-based arguments can be constructed to support conclusions or evaluate claims, including consideration of ethical issues and protocols associated with using or citing secondary data or information (VC2S8I07)

5.6 Activities

learnon

5.6 Quick quiz on	5.6 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 7	3, 4, 5, 8	6, 9, 10

Remember and understand

1. MC **Identify** the type of separation method used when panning for gold.
   A. Crystallisation
   B. Gravity separation
   C. Centrifuging
   D. Distillation

2. MC **Identify** the correct words to complete the following sentence: Froth flotation is used when the impurities are ____________________ the ore particles.
   A. similar to
   B. lighter than
   C. heavier than
   D. mixed in with
3. Complete the following passage to describe how copper ore is separated from unwanted rock. The copper ___________ is crushed to a fine __________. The mixture undergoes __________ and the unwanted rock forms the __________. The copper ________ is recovered from the __________ and is converted to crude copper in a furnace. If pure copper is required then it is further purified.
4. MC **Determine** which statement is true regarding homogenised milk.
   A. It does contain cream. The cream is dissolved into the aqueous part of the milk.
   B. It does contain cream. The cream is present as small colloidal particles spread through the aqueous part of the milk.
   C. It does not contain cream. All cream particles are removed during the homogenisation process.
   D. It does not contain cream. Homogenised milk is only made from fat-free milk.

Apply and analyse

5. **Describe** how copper ore is carried to the surface during froth flotation.
6. **Describe** how skim milk and skim milk powder are separated from whole milk.
7. **Explain** the difference between booms and skimmers.

Evaluate and create

8. **Explain** how separation processes used in the dairy industry ensure the quality and safety of milk products. Provide at least two examples to support your evaluation.
9. Imagine you are an environmental scientist tasked with cleaning up an oil spill. **Construct** a step-by-step plan to effectively clean up the spill. **Explain** which separation methods you would use and why, and how you would address the environmental impact on marine life and ecosystems.
10. Design an innovative separation process that could be used in either the mining or dairy industry, or for cleaning up oil spills. **Describe** how your process would work, the scientific principles behind it, and how it improves upon existing methods. Consider factors such as efficiency, environmental impact and cost-effectiveness in your design.

Answers and sample responses are available in your digital formats.

LESSON 5.7 Removing contamination from water

LEARNING INTENTION

In this lesson you will outline the contaminants in water, describe separation methods used to purify water for drinking from sea water on a large scale and understand methods to maintain safe water supplies for everyone.

5.7.1 Contamination: harmful substances in water

Water used for drinking and washing needs to be clean and free of harmful substances. Water supplies can be **contaminated** by dissolved substances or substances suspended in the water. Besides clay, there are a number of other contaminants.

- Human and other animal body wastes contain disease-causing microorganisms.
- Algal blooms can release poisonous substances into the water. They can also affect the taste and cause odour problems.
- Pesticides or detergents can be washed into rivers and contaminate water supplies.
- Poisonous chemicals may also be washed into rivers.
- Salt dissolved in water can make it unfit for drinking.

- Iron dissolved in water can contaminate it. This is common in bore water.
- High levels of calcium and magnesium salts can cause water to be 'hard', making it difficult to lather. This causes problems in laundries, bathrooms and kitchens.

FIGURE 5.36 a. Algal blooms can release poisonous substances into waterways. **b.** Pesticides can contaminate water supplies. **c.** Industrial waste can wash into waterways.

KEY IDEA

Clean water is essential for drinking and hygiene, requiring the use of separation techniques to remove harmful pollutants from water supplies.

DISCUSSION

Would you like your water to come out of the tap looking like the water in the glass in figure 5.37? Would you bathe or shower in it? Imagine your clothes after washing them! Do you think it would be safe to drink this water?

FIGURE 5.37 Would you drink this water?

5.7.2 Flocculation

If you live in a country town, your water probably comes from a nearby river or lake. It is quite likely you would not want to drink that water unless it had been purified. Many country towns have their own water treatment plants. Water is pumped from the river or lake into the treatment plant. The cloudy water contains mud and other substances in suspension, which can be settled out of the water by a process called **flocculation**.

The suspended particles would take a long time to settle if the water were just left standing, so the chemical aluminium potassium sulfate is added to the cloudy water to make the small particles clump together. These clumps are called **floc**. The floc is heavy enough to settle to the bottom of the tank and form a sediment. The water above the sediment is clear and flows off to the filtering stage.

After flocculation, the clear water is filtered through sand and gravel to remove any leftover suspended substances in the water. Chlorine is added to kill harmful bacteria. The purified water is pumped to the local water tower, which then supplies the town with drinking water.

INVESTIGATION 5.9

Treating your own dirty water

Aim

To investigate separating clean water from dirty water

Hypothesis

If the processes of flocculation, decanting and filtering are applied to a sample of muddy water, then clean water will be produced.

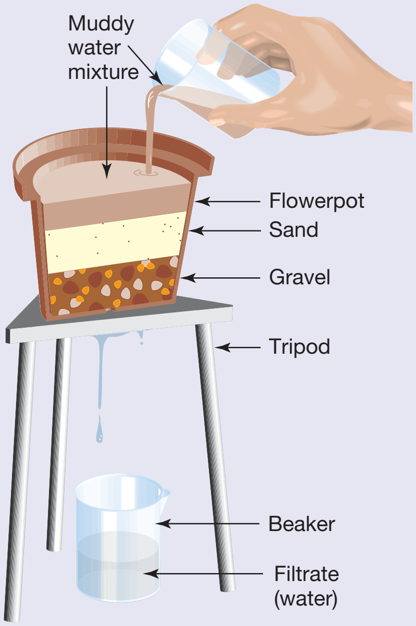
Materials

- muddy water (muddy water made with clay is best)
- alum (aluminium potassium sulfate)
- flowerpot and tripod
- limewater
- two 250 mL beakers
- bleach
- stirring rod
- sand
- gravel

CAUTION: Safety glasses should be worn while conducting this investigation and extra care should be taken when handling bleach.

Method

1. Pour 150 mL muddy water into the beaker.
2. Add half a teaspoon of alum and 10 drops of limewater.
3. Stir the water to mix the chemicals and allow the floc to form.
4. Once you can see the floc forming, allow the water to stand and the floc to settle to the bottom.
5. Decant the water from the beaker into your water filter. Collect the filtrate in a clean beaker, as shown in the figure.
6. Add two drops of bleach (which contains chlorine) to your filtrate.



Results

1. Use a table like the one below to record your findings.
2. Describe the water at each stage of the process. Include the appearance and odour of the water.

Treatment stage	Description of water
Untreated water	
Water after flocculation	
Water after filtration	
Water after chlorination	

Discussion

1. Identify which separation technique you used to purify the water.
2. State the step you feel was the most effective.
3. Prepare a series of picture diagrams to explain the steps you have taken to purify the water.
4. Explain if you think the treated water would be suitable to drink.
5. Suggest modifications or additions that would improve the purity of the water.

Conclusion

Summarise the findings of the investigation in three or four sentences.

5.7.3 Desalination: making the sea safe to drink

Distillation and evaporation are not effective for large-scale purification of sea water for drinking. Instead, desalination plants in Victoria, New South Wales, Western Australia and South Australia use **reverse osmosis**, a process that applies the principles of **osmosis** in reverse, to separate salt from sea water. In this process, sea water is pumped under high pressure through thin membranes, allowing pure water to pass while leaving behind concentrated salt, which is returned to the ocean.

Desalination plants have been built in Australia to help secure water supply during drought conditions and periods of low rainfall, ensuring long-term water security. However, the use of desalination plants raises concerns due to their high energy consumption, often sourced from coal-fired power plants, which contributes to pollution and sustainability issues. Additionally, the salty, warmer water returned to the ocean can threaten marine life, necessitating careful planning and scientific studies to mitigate these effects, such as ensuring the discharge outlet is located offshore. In the case of the Wonthaggi plant in Victoria, the outlet is around 1 km offshore.

KEY IDEA

Desalination is a process that separates salt from sea water, providing clean drinking water by using techniques such as reverse osmosis to filter out salt particles.

FIGURE 5.38 The processes of osmosis and reverse osmosis

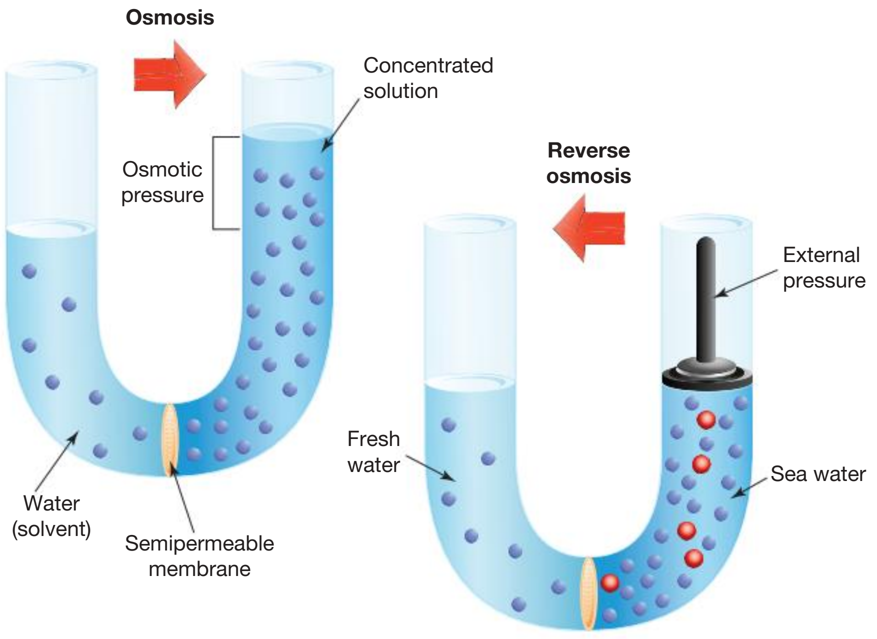
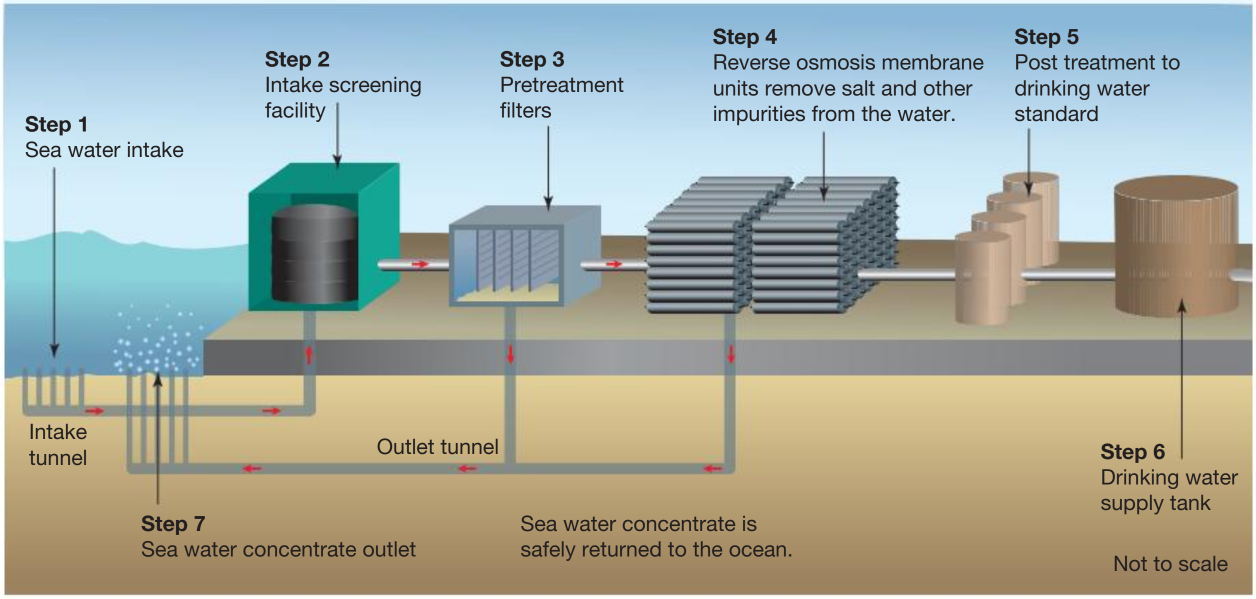


FIGURE 5.39 Example of a desalination plant



SCIENCE INQUIRY: Investigating desalination and its impact

Aim

To investigate how desalination works and evaluate its ethical, environmental, social and economic impacts

Part 1: Research the desalination process

Investigate how reverse osmosis is used to remove salt from sea water. Focus on understanding the scientific principles of separating salt from water.

Part 2: Investigate environmental impacts

Research the effects of desalination on marine life and ecosystems. Consider what happens to the leftover salty water that is pumped back into the sea.

Part 3: Explore social and economic factors

Examine the cost of running desalination plants and how this impacts access to clean water. Look into the social benefits of desalination in regions where fresh water is scarce.

Part 4: Analyse ethical considerations

Reflect on the long-term sustainability of desalination. Consider whether using large amounts of energy for desalination is ethically justifiable, especially in places that rely on non-renewable energy sources.

Part 5: Written reflection

Write a one-page summary of your findings, answering the following.
- Explain how reverse osmosis works to separate salt from water.
- Outline the main environmental concerns associated with desalination.
- Justify if we should prioritise desalination over other methods for obtaining clean water. Why or why not?

Reproducible investigations to answer questions and test hypotheses can be planned and conducted, including identifying independent, dependent and controlled variables where applicable, stating assumptions, recognising and managing risks, considering ethical issues and following protocols when accessing cultural sites and artefacts on Country and Place (VC2S8I02)

5.7 Activities

learnon

5.7 Quick quiz on	5.7 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2	3, 5	4, 6

Remember and understand

1. MC **Identify** what process is used to separate salt from sea water in Australian desalination plants.
   A. Osmosis
   B. Reverse osmosis
   C. Centrifuging
   D. Evaporation
2. MC **Identify** which of the following substances would contaminate drinking water. Select all that apply.
   A. Human body waste
   B. Animal body waste
   C. Algal blooms
   D. Pesticides
   E. Detergents
   F. Chlorine
3. Various substances, including the following, are added to drinking water supplies. **Explain** the reasons for their inclusion.
   a. Lime (calcium)
   b. Chlorine
   c. Fluoride

Apply and analyse

4. Among the swimming pool products that are claimed to clarify pools or make them 'crystal clear' are Super-Floc and Power Floc.
   a. Use the names to deduce the process used by these products to assist in the separation of unwanted particles from the pool water.
   b. Which process of separation takes place after the product has done its job?
5. The building of desalination plants is controversial. **Explain** two reasons for this.

Evaluate and create

6. SI Home swimming pools are vacuumed using a pool vacuum cleaner. **Suggest** how this type of vacuum cleaner works. Draw a diagram to show this.

Answers and sample responses are available in your digital formats.

LESSON 5.8 Separating waste

LEARNING INTENTION

In this lesson you will describe how human wastewater is treated and how materials in household waste are separated to be recycled.

5.8.1 Wastewater treatment

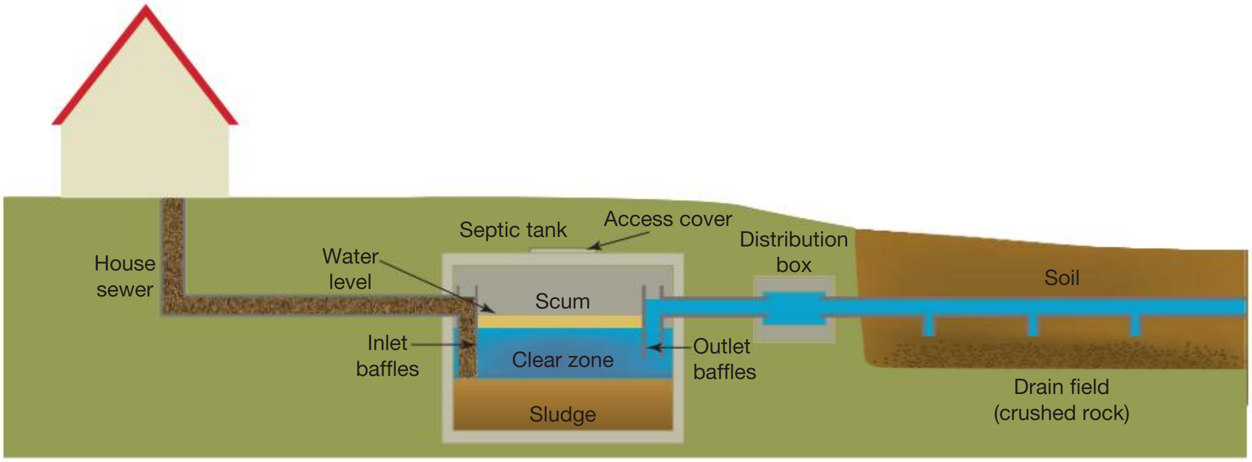
When you flush the toilet, shower or wash dishes, wastewater enters an underground sewer system, consisting mainly of water mixed with human waste, detergents and other substances. This **sewage** flows through drains to a treatment plant, where it is processed and cleaned before being released back into the environment.

The design of treatment plants typically involves consultations between state or territory governments, engineers, scientists (including biologists and environmental scientists), and local community groups. In rural areas, treatment plants are often situated on the outskirts of towns.

In areas without a local treatment plant, wastewater is managed through a personal sewage treatment system known as a **septic tank**, usually located in the backyard as shown in figure 5.41. Septic tanks are an essential part of wastewater **sewerage** systems, providing on-site treatment. Within the septic tank, bacteria break down the sewage, producing a thick sludge that settles at the bottom, while clearer water is released into the surrounding soil. The sludge needs to be removed from time to time.

FIGURE 5.40 Soapy water from your kitchen sink washes down the drain and into the underground sewer system.

FIGURE 5.41 A typical septic tank system, where bacteria breaks down the sewage



KEY IDEA

Wastewater sewerage systems collect and treat sewage from homes and industries to protect the environment and public health by removing harmful substances before returning clean water to the ecosystem.

5.8.2 The separation process

Wastewater contains solids like bacteria, dirt and large items that don't break down easily, as well as many dissolved substances. When it reaches a sewage treatment plant for primary treatment, it first passes through a screen that removes larger items. Then, it flows into settling tanks for about 2 hours, allowing solids to settle at the bottom and **floatable** materials, like oil and plastic, to rise to the top for removal.

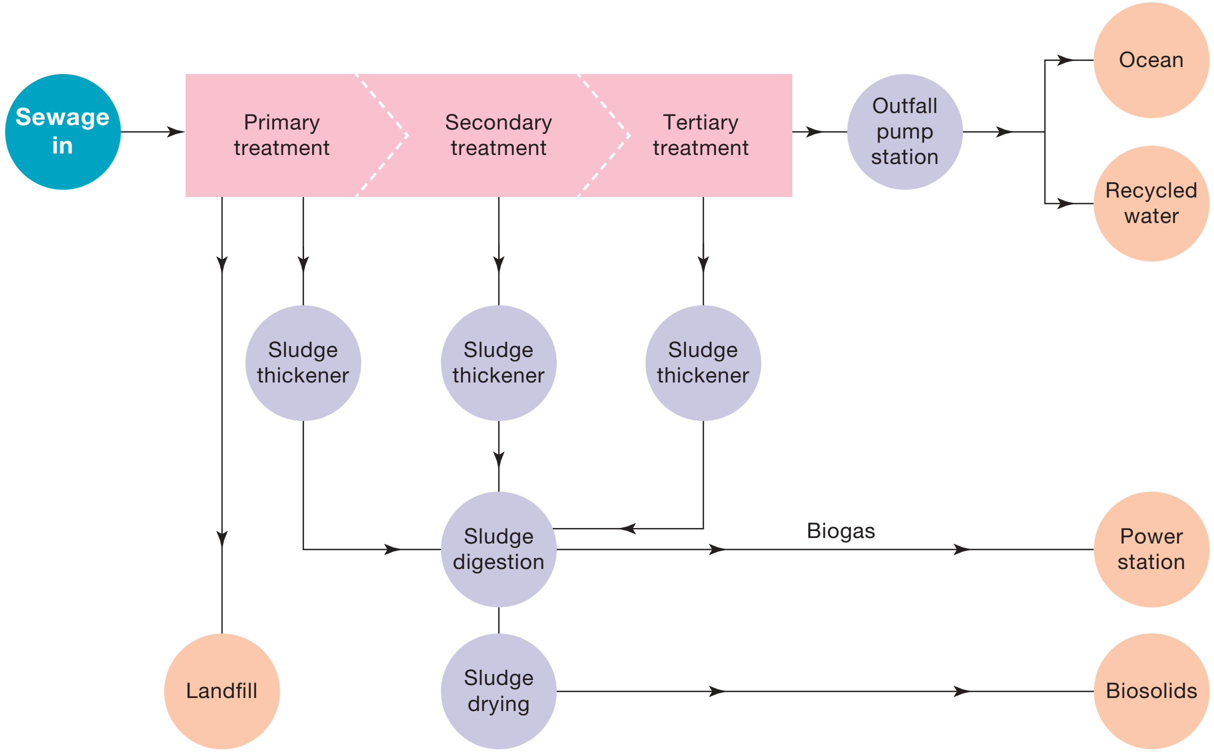
The remaining water moves to secondary treatment, where it is filtered through soil and grass or stored in lagoons for 2–4 months. During this time, bacteria further break down dissolved substances, and sedimentation occurs. Although the treated water looks clear, it is still unsafe to drink.

The advanced lagoon treatment system, like the one at Melbourne Water's Western Treatment Plant shown in figure 5.42, covers a large area and recycles some treated water for agricultural use. However, many materials should not be disposed of down sinks because the sewage system is not designed to handle them. Chemicals, fats and oils can pollute the sea and harm marine life. Small objects like cotton buds and baby wipes can block filters, leading to significant plumbing and sewer issues.

FIGURE 5.42 The lagoon system at Melbourne Water's Western Treatment Plant in Werribee

Figure 5.43 shows a more detailed diagram of the Western Treatment plant sewage treatment process.

FIGURE 5.43 Melbourne Water's sewage treatment process



ACTIVITY: Treatment plant processes

Go behind the scenes of the Werribee Western Treatment Plant. In groups, research different aspects of the processes at the treatment plant and present your findings to the class. Reflect on what you have learned and consider how it can influence your actions at home.

Play it safe

The best policy at home is to avoid putting anything solid or oily, or that you suspect may be poisonous or harmful to living things, down the sink. Some things that can go down the sink at home in small amounts are:

- drain cleaners
- window cleaners
- kitchen and bathroom cleaners
- disinfectants (but not if you have a septic tank).

At school, you should not tip anything down the sink except water, unless your teacher instructs you to.

5.8 Activities

learnon

5.8 Quick quiz on	5.8 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 4, 5, 8	2, 6, 9, 11	3, 7, 10, 12, 13

Remember and understand

1. MC **Identify** which of the following substances is likely to be found in wastewater.
   A. Human waste
   B. Food scraps
   C. Cleaning products
   D. All of the above
2. Reorder the stages of how sewage is broken down in a septic tank from beginning to end.
   I. Bacteria in the tank breaks the sewage down.
   II. Clean water flows out of the tank.
   III. The sewage becomes a thick, smelly sludge.
   IV. The sludge sinks to the bottom of the tank.
   V. Sewage enters the septic tank.
3. **Identify** the correct words from the list to complete the following passage, which describes the processes involved in the primary and secondary treatment of sewage. (*Hint*: You won't need to use all of the words.)

   algae, *bacteria*, *floatables*, *lagoons*, *purify*, *screen*, *sediment*, *settling*, *sediment*, *suspended*

   Sewage is first passed through a __________ (filter) to remove larger items. It then flows into __________ tanks, where __________ solids settle to form a __________, and __________, such as oil and plastic, collect on the top and are removed. Wastewater may be stored in a series of 1-m-deep __________ for 2–4 months, where suspended solids can __________. Bacteria in the water break down dissolved substances and __________ the water further.
4. **List** some substances that should not be tipped down the kitchen sink.
5. **List** at least two reasons why recycling is good for the environment.
6. MC **Identify** why the same type of magnet cannot be used for separating both aluminium and steel cans.
   A. Aluminium is not attracted to magnets.
   B. Neither steel or aluminium are magnetic.
   C. Steel is not attracted to magnets.
   D. This is not true. The same magnet can be used for aluminium and steel.

Apply and analyse

7. **Describe** how paper and cardboard are separated from other recyclable materials.
8. **Explain** what happens to recycled glass after it is separated from other materials in a recycling plant.
9. **Suggest** why disinfectants that kill bacteria should not be poured down a septic system.
10. **Explain** why some recycling mixtures are manually separated by people instead of machines.
11. Complete the table below about separating recyclable rubbish. For each method, **identify** the:
    i. material removed from the flow of rubbish
    ii. properties of the recycled material that allow it to be separated from the mixture.

Properties of recyclable rubbish

Method	What is removed	Properties
a. Sorting by hand		
b. Magnet		
c. Air classifier		
d. Lasers		
e. Electricity		

12. **Explain** what roles engineers, biologists and environmental scientists might play in the development of a sewage treatment plant. Write a short paragraph **describing** some of the tasks each person might have to complete.

Evaluate and create

13. SI Design a poster or summary that explains which plastics can be recycled, including an explanation of symbols and images.

Answers and sample responses are available in your digital formats.

LESSON 5.9 Review

5.9 Success criteria

Tick the column to indicate that you have completed the lesson and how well you think you have understood it using the traffic light system.

(**Green:** I understand; **Yellow:** I can do it with help; **Red:** I do not understand)

Lesson	Success criteria	Green	Yellow	Red
5.2	I can use representations of particles to show the difference between samples of pure substances and mixtures, and identify examples of each.			
	I can examine different solutions, identify the solvent and solute, and describe the difference between concentrated and dilute when referring to solutions.			
5.3	I can describe a range of physical separation techniques, including decanting, sieving, filtration and magnetic separation, based on differences in physical properties.			
5.4	I can explain how a separating funnel and centrifuge separate mixtures, and the type of mixtures they are used to separate.			
5.5	I can explain the physical separation techniques such as evaporation, distillation, crystallisation and chromatography, and outline examples of where they are used.			
5.6	I can describe how important separation processes are in the mining and dairy industries, and how they are used to clean up oil spills.			
5.7	I can outline the contaminants in water, describe separation methods used to purify water for drinking from sea water on a large scale and understand methods to maintain safe water supplies for everyone.			
5.8	I can describe how human wastewater is treated and how materials in household waste are separated to be recycled.			

learnon

Post-test Topic 5 Post-test

eWorkbook Topic 5 eWorkbook

Digital document Key terms glossary

5.9 Activities

learnon

5.9 Review questions

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 4, 5, 7, 10, 12, 17, 20, 22	3, 6, 9, 13, 14, 16, 18, 23	8, 11, 15, 19, 21

Remember and understand

1. **Identify** whether the following substances are pure substances or mixtures.
   a. Freshly made apple juice
   b. Tap water
   c. Soft drink
   d. Cake batter
   e. Sterling silver
   f. Distilled water
   g. Gold nugget
   h. Glass
   i. Cornflakes
   j. Oxygen
2. Black instant coffee is a mixture of coffee powder and hot water. **Identify** what ingredients in a cup of coffee form each part of the mixture.
   a. Solute
   b. Solvent
   c. Solution
3. MC **Identify** which of the following substances is a mixture.
   A. Silver
   B. Distilled water
   C. Smoke
   D. Nitrogen gas
4. **Outline** how you would separate the sand from a mixture of sand and sawdust. Choose one option for each of the boxes in the flowchart to show how you would do this in four steps.

A. Place mixture in an oven on a metal tray.
B. Place mixture in a test tube of oil.
C. Place mixture in beaker of water.
D. Place mixture in the freezer.

↓

A. Stir
B. Freeze
C. Mash
D. Blend

↓

A. Add salt.
B. Scoop sawdust from surface and allow to dry.
C. Place in a separating funnel.
D. Tip into a colander.

↓

A. Filter
B. Crystallise
C. Distil
D. Centrifuge

5. MC **Identify** which of the following are separating processes done by sight in a recycling plant.
A. Separating different coloured glass
B. Removing other household rubbish from recyclables
C. Separating the steel cans from the aluminium cans
D. All of the above

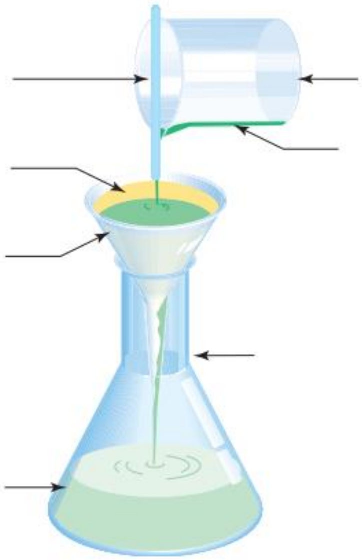
6. Match the separation techniques to their description and examples.

Method of separation	How it works	Example of how it is used
a. Filtration	1. Particles mixed in a liquid are made to clump together so that they settle to the bottom of a mixture more quickly.	i. In making fruit juice
b. Distillation	2. A device or substance allows some substances to flow through but prevents others from flowing through.	ii. Tea strainer
c. Crystallisation	3. Two liquids that do not mix are poured through a funnel with a tap. The liquid that floats on the other is left in the funnel, while the other liquid is allowed to flow out.	iii. In cleaning pools in which animals are kept; in separating sewage from water
d. Flocculation	4. A mixture is spun so that the heavier particles move further to the outside than the lighter particles.	iv. Leaving the sediment at the bottom of a glass of muddy water
e. Decanting	5. A liquid mixture is soaked up through paper to separate substances that have different colours.	v. In the manufacture of table salt
f. Separating funnel	6. A liquid is poured off after a sediment has formed at the bottom of the container.	vi. Analysing stains, dyes and inks
g. Centrifuging	7. A solution is heated to leave a solid dissolved in a solvent behind as crystals.	vii. Separating blood cells from plasma
h. Chromatography	8. A mixture of two liquids that have different boiling points is heated. The liquid with the lower boiling point evaporates first and is collected.	viii. Separating oil from water

7. MC A separating funnel works when two substances have different:
A. melting points.
B. colours.
C. boiling points.
D. densities.

Apply and analyse

8. During an experiment, a teacher accidentally drops some steel drawing pins into a bowl of sugar. **Outline** two methods that could be used to remove the drawing pins from the sugar. Briefly **explain** each method.
9. Imagine you dropped plastic nails in the sawdust in woodwork class. **Propose** three reliable, safe ways of separating the nails from the sawdust.
10. The diagram shows a mixture being filtered.
    a. Add the missing labels.
    b. MC What is the purpose of the stirring rod?
        A. Pouring the mixture along a stirring rod creates splashing that helps to agitate the mixture.
        B. The stirring rod prevents the gases from escaping the funnel.
        C. Pouring the mixture along a stirring rod prevents splashing and ensures that all of the mixture is filtered.
        D. The stirring rod goes through a hole in the middle of the filter so it stays in place.



11. You have been asked to analyse some salt-contaminated soil and to propose a method for separating the salt from the soil.
    a. SI **Outline** the method that you would use to obtain pure dry salt and pure dry soil.
    b. Draw a labelled diagram showing how your equipment would be set up for each stage of your separation.
    c. **Suggest** possible errors that might affect the outcome of this experiment.
12. Pasta is cooked by boiling it in water. It sinks to the bottom of the saucepan when it is left to stand.
    a. **Describe** two methods that could be used to separate the pasta from the water.
    b. Which of the two techniques is better for separating the pasta and water?
13. **Identify** the properties that allow the following substances to be separated from a mixture.
    a. Peas from a mixture of peas and water
    b. Oil from a mixture of oil and water
    c. Gold particles from a mixture of sand and creek water
    d. Cream from cows' milk
14. SI You are out in the bush and the only water available to drink is in a muddy waterhole. You have an empty bottle and a cup. **Explain** how you would remove the dirt from the muddy water so that you could drink the water.
15. **Explain** the difference between froth flotation and flocculation.
16. **Explain** why chlorine is added in small amounts to the water supplies of many cities.
17. **State** one good reason why each of the following objects or substances should not be tipped down the sink or flushed in a toilet.
    a. Fat or oil
    b. Cotton buds
    c. Oven cleaner

Evaluate and create

18. Use a labelled diagram to illustrate the differences between the processes of osmosis and reverse osmosis used in desalination plants.
19. SI Blue-green algae has grown in a lake. It forms a fine, green suspension in the water. The local council wants to make the water clear again so that fish and other living organisms can safely inhabit the lake. **Propose** a method that you would use to solve the local council's problem. Remember that your method should not harm the fish already in the lake.
20. How does flocculation make the particles in a suspension settle out?
21. **Explain** why blood collected by Australian Red Cross Lifeblood needs to be separated before it is used.
22. SI Design a mixture that cannot be separated by the methods described in this topic. **Explain** the basis for your design.

23. Read the following story 'An ocean of salt' and use the information to answer the questions that follow.
   a. Write down what you think Marco would have said to his son. **Explain** the two methods clearly.
   b. **Propose** three questions that Flavius would have asked in return.
   c. **Construct** a flowchart that shows the steps involved in each salt harvest process using appropriate scientific terminology to describe changes of state and separation techniques.

An ocean of salt

Salt has been used by civilisations for centuries to preserve meats, cure hides, make cheese and other foods, and as flavouring in cooking. Salt was essential for life. Some communities even used salt instead of money as a form of payment. A community grew wealthy from its ability to produce salt.

Salt was mined from the ground, in the form of rock salt, or collected from seawater. The seawater, sometimes called brine, was evaporated and the salt collected. The brine was either heated over a wood fire or collected in shallow pools and left to heat in the sunlight.

'There's a whole ocean out there — full of salt — we just need to get it out of the water!', Marco remembered his grandfather saying. Marco lived during ancient Roman times. He lived in a town off the coast of the Mediterranean Sea. Marco himself now worked in the business his grandfather had started. He, too, marvelled at how he used the Sun and winds to separate salt from seawater.

This day was special; it marked the day his son, Flavius, would first work at the salt business. As they reached the hill, they smelled smoke from the wood fires and looked out over the flat natural basin where salty water collected in shallow pools. Flavius saw that the smoke was from fires burning under large rectangular lead pans. Marco turned to his son and explained the two ways they separated salt from seawater.

Answers and sample responses are available in your digital formats.

To test your understanding and knowledge of this topic, go to your learnON title at jacplus.com.au and complete the **post-test**.

6 Precious resources

CONTENT DESCRIPTION

The sustainable use of Earth's resources is influenced by whether the resources are renewable or non-renewable; the processes involved in resource extraction and energy production come with both benefits and risks to sustainability (VC2S8U09)

Source: Victorian Curriculum F–10 Version 2.0

LEARNING SEQUENCE

LESSON 6.1 Overview

6.1.1 Introduction

When people describe Australia as being rich in resources, they are talking about useful materials such as iron, copper, nickel, uranium, coal and a host of precious minerals. Gold and diamonds are examples of precious minerals found in Australia. All these resources are used in the production of items that are part of our daily lives. They are also sources of energy (fuel) needed to operate some of these items.

FIGURE 6.1 Gold is a valuable resource, so when gold was discovered in the 1850s, Victoria's population grew dramatically.

All resources require time to renew, and these timescales can vary greatly. Resources are considered non-renewable when the time it takes to replenish them is much slower than the rate of consumption. Therefore, it is necessary to use precious minerals, fuels and water wisely to ensure that our future is sustainable and that these resources remain available for generations to come.

DISCUSSION

1. Why does it matter if a resource is renewable or non-renewable?
2. How do geologists know where to mine for precious minerals?
3. How does coal form from a damp, green swamp?
4. What makes underground coal mining so dangerous?
5. How many homes can be powered by a single wind turbine?
6. What makes a fuel sustainable?

SCIENCE INQUIRY: Renewable and non-renewable resources

Renewable resources are those that are not depleted (used up) when used, or are naturally replaced within a human lifetime. For example, solar energy is a renewable energy resource that can be used for heating water or generating electricity. It is never 'used up' because it is constantly replaced by the sun. Oil is a **non-renewable resource** because it takes millions of years to be replaced. **Sustainable resources** are renewable and can be replenished at the same rate that they are consumed, or faster.

1. Copy and complete the table. Identify if each natural resource is renewable or non-renewable.

TABLE 6.1 Determining if natural resources are renewable or non-renewable

Natural resource	Renewable or non-renewable?	Reason for your decision
Coal		
Diamonds		
Hydro-electricity		
Natural gas		
Water		
Wood		

2. The materials in the following table are all made from natural resources. Copy and complete the table with your own knowledge. Identify the gaps using your own research.

TABLE 6.2 Comparing different materials made from natural resources

Material	Natural resource it is made from	Renewable or non-renewable?	Why is it useful?
Plastic			
Steel			
Nylon			
Wool			
Paper			
Glass			
Electrical wire			

3. The demand for many metal resources is increasing around the world. This includes the rising demand for iron ore, copper and nickel, and emerging metals such as lithium.
   a. World demand for refined copper in 2023 was 26.5 million tonnes. That is enough copper to fill 7000 Olympic-sized swimming pools. The estimated demand for 2030 is 30.3 million tonnes. Calculate how many more tonnes are required to meet the increased demand.
   b. Why do you think there is an increased demand for copper?
   c. i. Identify a resource problem that will accompany the increased demand for copper.
      ii. Suggest a solution to the above problem and create a brochure or poster to show this solution.

Information and processed data can be analysed to show patterns, trends and relationships, and to identify anomalies (VC2S8I05)

learnon

Pre-test	Topic 6 Pre-test
eWorkbooks	Topic 6 eWorkbook Student learning matrix
Practical investigation eLogbook	Topic 6 Practical investigation eLogbook
Digital document	Key terms glossary

LESSON 6.2 Earth's mineral resources

LEARNING INTENTION

In this lesson you will be able to describe why most of Earth's mineral resources are considered non-renewable and explain the steps involved in removing metal resources from Earth's crust.

6.2.1 Natural resources

When looking out a window during a storm, have you ever thought about where the glass protecting you might have come from? Most glass is made from liquid sand, a product of melting ordinary silica sand (like the sand you see on the beach) to a very high temperature of 1700 °C.

Earth provides a vast range of resources, like sand, that allow us to live healthily and to make things that we take for granted every day. Buildings, furniture, cars and plastics (including nylon and polyester found in your sport uniform) are all made from natural resources that are sourced from Earth.

ACTIVITY: Engaging with sources and resources

Natural resources are materials that come from Earth and are used in various ways. For example, we use them for making products, providing energy and even for keeping us alive.

These resources include:

- **fossil fuels** such as coal, oil and natural gas
- minerals
- timber.

Some natural resources are essential for life, including:

- water
- sunlight
- gases such as oxygen in the air.

Natural resources can be grouped into two main types:

- renewable resources: these can be replaced over time (e.g. sunlight and timber)
- non-renewable resources: these are limited and can run out (e.g. fossil fuels and minerals).

1. Aboriginal and Torres Strait Islander Peoples utilise a vast array of natural resources, including those for medicine, tools and paint.
   a. Brainstorm the natural resources used for each of these purposes.
   b. Suggest other purposes for which these natural resources were used.
2. To mine or not to mine? Imagine it is the year 2070 and the last deposit of oil that humans can get to is deep beneath the Great Barrier Reef. If the oil is extracted, there will be enough oil products to keep cars on the road for another 10 years. However, to reach the oil, the Great Barrier Reef would be destroyed and would never reform. What would you do? Justify your answer.

FIGURE 6.2 What if oil were found beneath the Great Barrier Reef?

6.2.2 Metal resources in Earth's crust

Earth can be pictured like an apple with a layer of skin on the outside, flesh on the inside and a core at the centre. The thin surface layer of Earth is called the **crust** and is made mostly of solid rock.

The metals used in buildings, vehicles, trams and trains, all electronic devices (such as a computer or smartphone) and countless other products are obtained from **minerals** found in Earth's crust. Minerals are the individual natural and solid crystals of matter that very slowly collect to form rocks, which can contain one or more types of mineral. Not all minerals are useful for humans, but when these minerals contain a metal, such as aluminium in bauxite, it can become a valuable **ore mineral**. Table 6.3 outlines some of these ore minerals and the metals they may contain.

The majority of mineral resources are non-renewable because when they are mined and used they are not naturally replenished within a human lifetime. It can take millions of years for mineral resources to renew through Earth's natural processes.

TABLE 6.3 Some ore minerals commonly mined in Australia and they metals they contain

Ore mineral	Metal
Bauxite	Aluminium
Galena	Lead
Sphalerite	Zinc
Haematite	Iron
Pentlandite	Nickel
Chalcopyrite	Copper
Gold	Gold

ACTIVITY: Understanding Earth's crust

To get an idea of how thin Earth's crust is, take a medium-sized apple and cut it in half. Now imagine that the apple is Earth — the crust, by comparison, is as thin as the apple skin.

1. Measure the width of the apple skin compared to the width of the entire apple (at the widest part of the cut surface). What total percentage of the skin makes up the diameter of the apple?
2. With the crust representing such a small portion of Earth, why are we limited to using the minerals found in the crust?
3. Draw a labelled diagram of how each feature of the apple can be compared to Earth. You may need to research some of the layers of Earth to help you do this.

FIGURE 6.3 Earth's crust is like the skin of an apple.

6.2.3 Finding ore minerals

Locating ore minerals is like finding a needle in a haystack, because metals only make up a tiny portion of the entire Earth's crust. Scientists usually want to find areas where metals have gathered (concentrated), rather than finding small pieces of metal scattered across a large area.

The task of scientifically locating ore minerals usually occurs in the following steps.

1. High above the Earth, satellites with cameras and sensors look for features on the surface that provide clues to what lies beneath.
2. Planes and helicopters look for further clues by measuring gravity and magnetic changes across the surface. Some ore minerals, such as those that contain iron and nickel, can be found because they are magnetic.
3. Geologists walk and explore the surface, identifying and collecting rock and mineral samples.

FIGURE 6.4 The last step in finding minerals is exploring the surface of Earth to collect samples that give clues to what lies beneath.

DISCUSSION

Geologists spend a lot of time looking for minerals without disturbing the environment. Why do you think they do this, rather than starting by digging up Earth?

6.2.4 Mining ore

Once the ore has been found, the process of removing it from the ground is **mining**. The method used for mining depends on several factors, including:

- estimated amount (quantity) of ore
- how close the mineral ore is to the surface
- what type of rock lies around the mineral ore.

Open-cut mining is a method of removing ore that is close to the surface. A large hole is made to expose the rocks containing the ore. Explosives are used to break up the rock and huge trucks are used to transport the broken pieces out of the open pit.

FIGURE 6.5 The Super Pit in Kalgoorlie, Western Australia, is one of Australia's largest open-cut gold mines. In 2020 it was approximately 1.55 km across, 3.7 km long and 600 m deep.

If the ore is deep below the surface, underground mining is used. Tunnels and vertical shafts are dug deep into the ground to reach the ore. The deepest underground mine is more than 4 km down, where temperatures reach around 66 °C. All mining is dangerous, but underground mining is more dangerous and expensive than open-cut mining. Some reasons for this include:

- temperatures are higher and air quality is poorer
- tunnels can flood
- tunnels or shafts can collapse.

INVESTIGATION 6.1

Comparing renewable and non-renewable resources

Aim

To investigate the rate at which renewable and non-renewable resources are replenished and how this impacts their sustainability

Materials

- two sponges (representing renewable resources such as water)
- a cup of marbles or small stones (representing non-renewable resources such as coal or minerals)
- two large bowls or trays
- timer or stopwatch
- measuring cup
- water

Method

1. Place one sponge in a bowl of water (representing a renewable resource).
2. Place the cup of marbles or stones in a separate bowl (representing a non-renewable resource).
3. Squeeze the sponge completely into a measuring cup to simulate extracting water. Record the amount extracted. Refill the bowl with water.
4. After extracting water from the sponge, allow it to reabsorb water for 30 seconds and then extract again. Repeat for three cycles.
5. Transfer as many marbles as possible to a separate container in 30 seconds. Do not refill the bowl.
6. Repeat steps 1–5 for three trials, recording the amount of water extracted and the number of marbles collected each time.

Results

Use a table like the one below to record your findings.

Trial	Sponge water extracted (mL)	Marbles collected
1		
2		
3		

Discussion

1. What patterns do you observe in the extraction and replenishment of the renewable resource (water) compared to the non-renewable resource (marbles)?
2. How might the method be improved to better represent real-world extraction and replenishment processes?
3. What other renewable or non-renewable resources could you model using this investigation?
4. Based on the results, why are renewable resources generally more sustainable than non-renewable resources?

Conclusion

Summarise the findings of the investigation in three or four sentences and link them back to the aim.

6.2.5 Extracting the metal

After the rock containing an ore mineral is removed from the ground, the valuable part of it, the metal, is extracted. The method of extraction (or separation) varies from metal to metal, but most methods involve **concentration**, **reduction** and **purification**.

The processes that occur in these stages are:

- *Stage 1: Concentration of the ore mineral*
  The useful rock taken from the ground is a mixture of wanted ore minerals and unwanted material. The unwanted material is called **gangue**, or more commonly, 'waste'. To concentrate the ore minerals,

the rock is physically crushed into smaller pieces and put through a series of tests that help to separate the ore mineral from the gangue. The gangue is generally placed into waste piles called mullock heaps or tailings (see figure 6.6).

- *Stage 2: Reduction of the ore mineral to the metal*
  This involves a number of chemical reactions that separate the metallic portion from the non-metallic portions. The reduction process often involves **smelting**, in which the ore is melted (see figure 6.6). The reduction of aluminium ore requires additional and expensive processes, which is one of the reasons why recycling aluminium cans is so important.
- *Stage 3: Purification of the metal*
  Most metals obtained from the reduction process still contain impurities. These are removed using various chemical processes to produce the pure metal.

FIGURE 6.6 a. Waste piles (mullock heaps) containing gangue **b.** Hot liquid iron being poured from a melting pot during smelting

a.

b.

ACTIVITY: Traditional mining of ochre

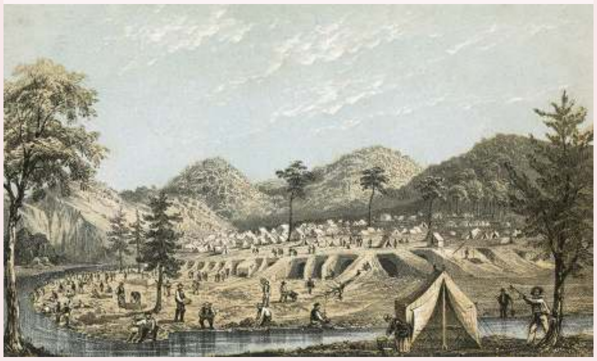
Long before the big mining companies began exploring for and extracting minerals, Aboriginal and Torres Strait Islander Peoples were extracting a type of mineral called **ochre** from the ground (ochre is a natural clay pigment). Investigate traditional ochre mining and how ochre can be used by Aboriginal and Torres Strait Islander Peoples. Create a poster to summarise this information.

SCIENCE AS A HUMAN ENDEAVOUR: The Victorian Gold Rush and identifying contaminants

Victoria was the heart of the Australian Gold Rush in the 1850s. The Gold Rush attracted people from around the globe, with many from Europe and China. The miners were known as 'diggers'.

The landscape dramatically changed during this time as diggers altered stream beds, removed trees, dug shafts and piled tailings. Today, there are thousands of abandoned former mine sites, including shafts and mullock heaps, as well as a few abandoned small open-cut pits. Many of these sites are protected for their important heritage. However, they may also raise environmental issues.

FIGURE 6.7 Diggers' huts on the goldfields were basic bark huts.



Mining during the Gold Rush was targeted towards extracting gold, but there were other minerals present in the waste rocks, which were left behind in mullock heaps on the surface. With no environmental rules in place, this waste material has been exposed to air and water for the last 150 years. Some of the minerals have chemically changed into dangerous contaminants such as arsenic. This can pose a public health risk.

FIGURE 6.8 A scientist takes notes in the field and takes soil samples for testing.

Scientists such as agronomists and geochemists try to identify and evaluate the health risk by sampling soils and water around the abandoned mine sites. If contaminants are found, there are several options, including:

- leave it and avoid using any sands or tailings from the site
- shift the contaminated material to a toxic waste dump
- put microorganisms into the polluted site, with the hope that they eat and break down the contaminants.

Mining is an ongoing and economically important activity, and it will continue because we need the natural resources it extracts, such as the ore minerals. However, we recognise that mining operations have a big environmental impact. The study of and advancements in science mixed with improved government guidelines have helped us reduce this impact.

1. Mining is essential for resources such as gold and minerals, but it can also harm the environment. How do you think scientists and governments should balance the economic benefits of mining with the need to protect the environment?
2. There are several ways to manage contaminants like arsenic at old mining sites: leaving them alone, moving them to a toxic waste dump or using microorganisms to break them down. Which method do you think is best and why? Consider factors such as cost, safety and environmental impact.

Proposed scientific responses to socio-scientific issues impact on society and may involve ethical, environmental, social and economic considerations (VC2S8H03)

DISCUSSION

What are some of the positive effects of mining? What are some of the negative effects of mining? Discuss, with reference to sustainability, whether you think the positives outweigh the negatives, or the negatives outweigh the positives.

How might decisions about mining have an impact on people in other places in Australia or around the world?

6.2 Activities

learnon

6.2 Quick quiz on	6.2 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3, 5	4, 7, 8, 11	6, 9, 10

Remember and understand

1. **Outline** why minerals in Earth's crust are classified as non-renewable resources.
2. MC Which of the following statements about ore minerals is correct?
   A. Valuable metals can be extracted for profit.
   B. They are minerals from which liquid sand comes.
   C. All rocks are made from them.
   D. All of the above are correct.
3. **Explain** why underground mining is more dangerous than open-cut mining.
4. Create a two-column table on extracting a metal from its ore.
   a. In the first column, **list** the three stages involved in extracting a metal from its ore, with the first at the top and the last at the bottom.
   b. In the second column, **describe** the purpose of each stage.

TABLE The different stages in extracting metals from ore

Stage	Purpose

Apply and analyse

5. **Explain** why exploration for mineral resources could be likened to 'finding a needle in a haystack'.
6. SI A geologist has been hired to find a new iron ore mine site. Their procedure of exploration was that they:
   i. used satellite images to circle potential areas, identified by red/dark-coloured soils
   ii. walked around the area collecting samples for analysis
   iii. used a plane equipped with a magnetometer to identify areas with higher magnetism
   iv. overlapped the results from steps ii. and iii. to find common ground with positive data and propose the new mine site for drilling.
   a. **Identify** an error they made in their procedure.
   b. **Identify** two proper applications in their exploration.
7. **Identify** three advantages and three disadvantages of open-cut mining.
8. SI **Suggest** why the temperature in underground mining tunnels would be greater than the temperature on the surface.

Evaluate and create

9. SI You are given a chocolate chip cookie but you only want the chocolate chips. How could you extract the chocolate chips? Relate your process to one or more of the three metal extracting stages.
10. **Explain** why each step in locating areas where metal is concentrated is important in the process of finding ore minerals.

11. Fosterville mine in Bendigo, Victoria, is an underground gold mine. In 2024, more than 6000 kg of gold was extracted from the mine. The mine is scheduled to close in 2033 and restoration will need to occur. **Suggest** why underground mining has a greater risk than open-cut mining.

Fosterville mine in Bendigo, Victoria

Answers and sample responses are available in your digital formats.

LESSON 6.3 Fossil fuels

LEARNING INTENTION

In this lesson you will be able to describe how fossil fuels are formed, what they are used for and the global impacts of their use.

6.3.1 What are fossil fuels?

Among the natural resources within Earth's crust is a reserve of energy in the form of fossil fuels. The energy stored in fossil fuels originally came from the sun, captured by once-living ancient plants and animals. These plants and animals died, and their remains were buried under layers of **sediments** that have built up over tens or hundreds of millions of years.

Fossil fuels have a high energy density. When we burn fossil fuels — coal, oil and natural gas — the stored energy is converted to other forms of energy, including heat, movement and light. In the same way that we burn wood to release energy that trees capture from the sun, we burn fossil fuels to release the captured energy of these ancient plants and animals.

6.3.2 How coal is formed

Coal is formed from the remains of ancient plants that grew in swamps. Millions of years ago — even before the peak of dinosaurs — much of the land on Earth was covered with warm, humid forests and swamps. There are four key stages in the process of forming coal from ancient swamps.

Stage 1: Plant matter to peat

Trees and plants die and are buried by layers of other dead plants before they can decompose (rot). Over hundreds to thousands of years, more layers of material build up. The older layers at the bottom are compressed under the weight of younger layers on top. The compression drives some of the moisture out of the material, like squeezing water out of a sponge. This lightly compacted plant matter is known as **peat**. The shapes of leaf and wood are still visible in peat.

Stage 2: Burial by sediments

Over time, areas were flooded by rivers or rising sea levels, which covered the peat with sediments of gravel, sand or mud. Over millions of years, the peat continued to be buried by sediments.

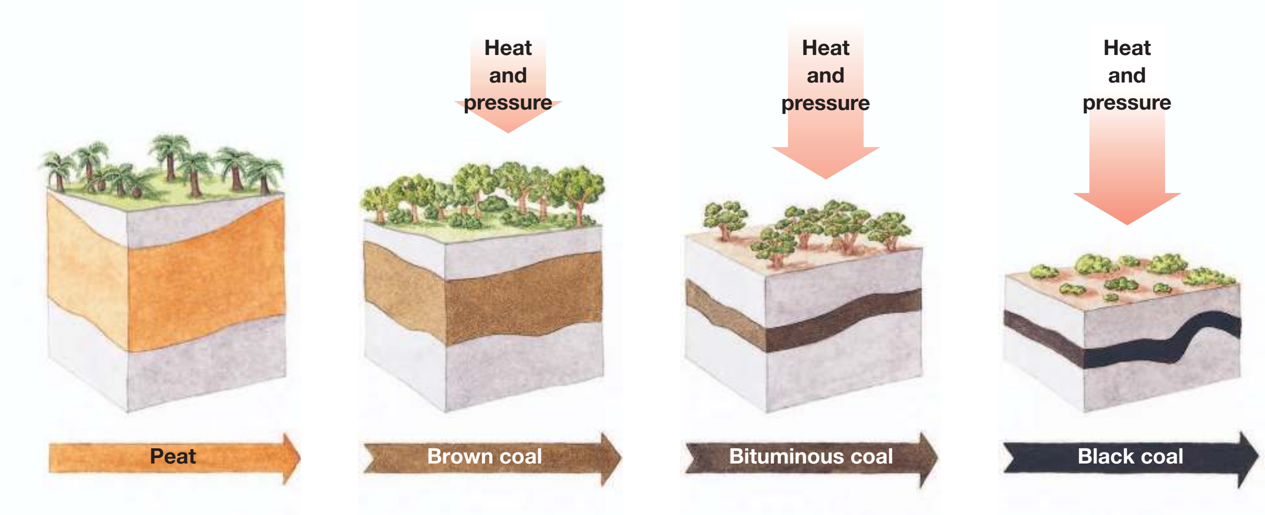
Stage 3: Production of brown coal

When buried deep enough, the compression from the overlying materials and heat from Earth push out more moisture, concentrating the plant matter. This forms **brown coal** (lignite), which only has some plant fossils still visible.

Stage 4: Concentration into black coal

With even more time, compression and heat, nearly all moisture is removed, concentrating the plant matter into harder **black coal** (bituminous and anthracite). Anthracite is the most condensed and energy-rich form of black coal. At this stage, the fossils are no longer visible.

FIGURE 6.9 The process of coal formation



Using coal as a fuel

The concentrated plant remains of either brown or black coal can be burned as fuel. Black coal provides more energy than the same amount of brown coal, mainly because it contains less water. In some countries, peat is used as a fuel. However, it must be dried first. In Ireland, where there is very little coal or oil, peat is used to generate electricity.

The majority of Australia's brown coal mines are in Victoria, with major reserves found in the Latrobe Valley. The location of these mines, and the black coal mines, can be seen in figure 6.10. In 2017, one of the largest brown coal stations (Hazelwood, near Morwell) was closed, and the local open-cut mine is undergoing rehabilitation (being returned to a more natural state). The closure of more coal stations and mines will likely follow as we try to move towards 'cleaner' energy. Australia's coal consumption fell by 4 per cent in 2022–23. In fact, since 2009, Australia's coal consumption has dropped by 25 per cent.

FIGURE 6.10 Locations of Australian brown and black coal mines

DISCUSSION

Almost one-quarter of the crust that makes up the Australian continent contains coal of one type or another. Australia has approximately 5 per cent of the world's known reserves of black coal and approximately 23 per cent of the world's recoverable reserves of brown coal. More than three-quarters of the black coal mined in Australia is exported to other countries.

1. Why do you think Australia exports so much of its coal?
2. What positive or negative effects might result from Australia exporting so much of its coal?

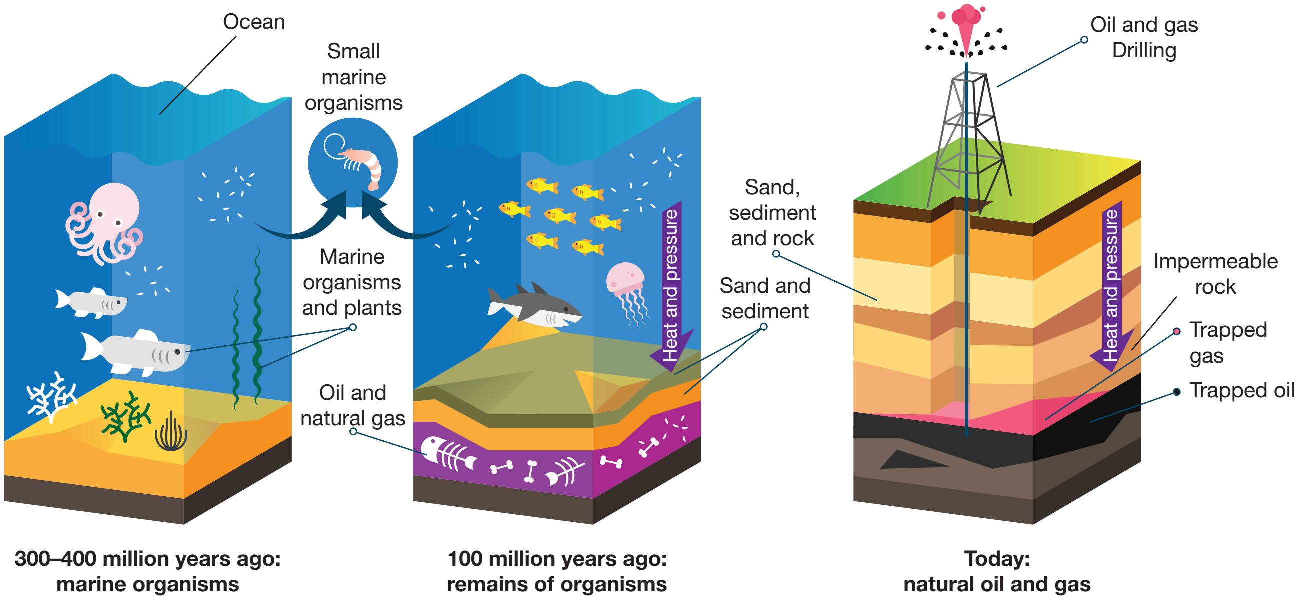
6.3.3 Oil and natural gas

Oil and **natural gas** have formed from the remains of ancient tiny animals and plants that lived in shallow seas. The process of forming oil and natural gas involves the following four key stages.

Stage 1: The death of tiny organisms

Millions of years ago, tiny organisms died and sank to the sea floor, where they were buried by sediments. As these animal and plant remains slowly decomposed, they were compressed by the water and new layers of sediment that formed above them. The decomposition and burial caused chemical reactions that gradually changed the remains into a waxy substance called **kerogen** and a black tar (bitumen).

FIGURE 6.11 Summarising the process of natural gas and oil production



Stage 2: Hydrocarbon conversion

The death and burial of more organisms adds more compression over time. This compression and the heat from Earth convert kerogen into the **hydrocarbons** we call crude oil. If temperatures become even hotter, the kerogen becomes the smaller hydrocarbons we call natural gas. If the temperature gets too hot, the kerogen is destroyed.

Stage 3: Migration

The hot oil and gas are less dense than the rocks around them. This encourages them to move upwards through the overlying layers of sedimentary rocks. Sediments and rocks that allow fluids and gas to move through them (or migrate) are described as **porous**, because the spaces in between sediments (pores) link together, like hallways in a building.

Stage 4: Trapped

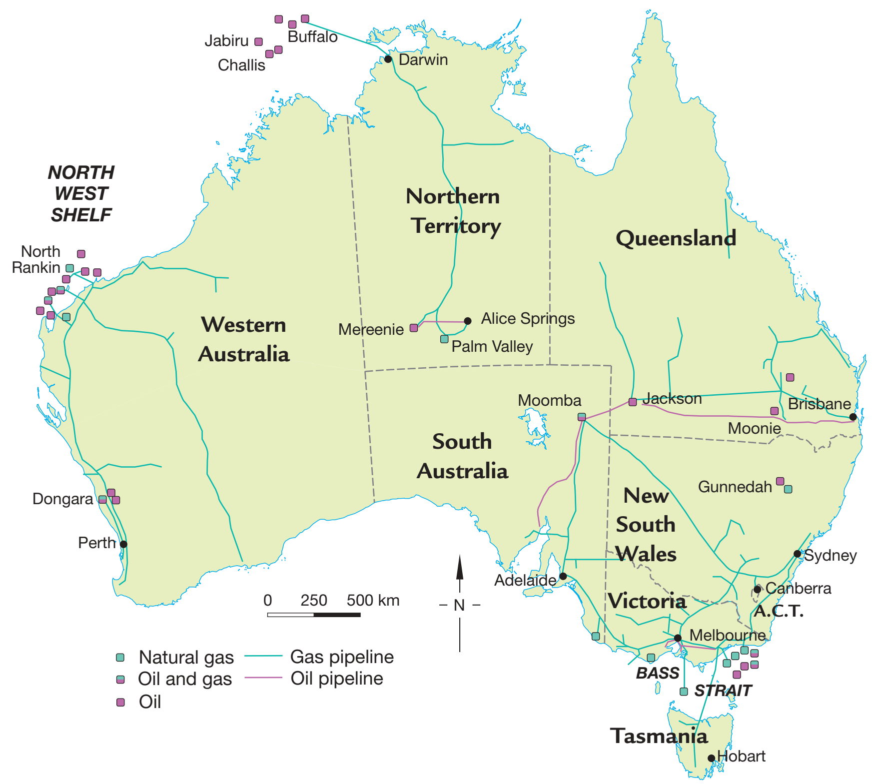
The upward-moving oil and gas can be trapped by a non-porous rock layer above, which does not allow them to move through. The best locations for oil and gas to concentrate are where the rock layers have bent or cracked. Generally the gas pools above the oil.

The trapped oil and/or gas is taken from beneath Earth's surface by the pumping of an oil rig, and then transported to oil refineries and converted into a number of different products, including gas, diesel fuel, petrol and petrochemicals. We use these products for many purposes: to operate cars, trains and machinery; heat buildings; cook food; make plastics; and create fibres that we weave into polyester and nylon fabrics. They are even used in cosmetics.

Using natural gas and oil in Australia

Australia's biggest oil and natural gas reserves lie under the seabed in the Bass Strait off the coast of Victoria, and on the North West Shelf off Western Australia. The use of oil and natural gas currently supplies 64 per cent of Australia's energy.

FIGURE 6.12 Australia's oil and gas reserves



6.3.4 The impact of using fossil fuels

Fossil fuels are hundreds of millions of years old, but in the last 200 years consumption has increased rapidly, leaving fossil fuel reserves depleted. When will they run out? No one really knows the absolute answer to that, because advancing science and technology has allowed us to continue accessing more reserves.

KEY IDEA

Fossil fuels are non-renewable resources. To say that they are being used up more quickly than they are replaced is an understatement.

There will be a point when all reserves are gone, especially with ever-increasing populations and demand. This is a problem to consider, as is the important question, 'What are the environmental impacts of using fossil fuels?'

SCIENCE AS A HUMAN ENDEAVOUR: Global impact

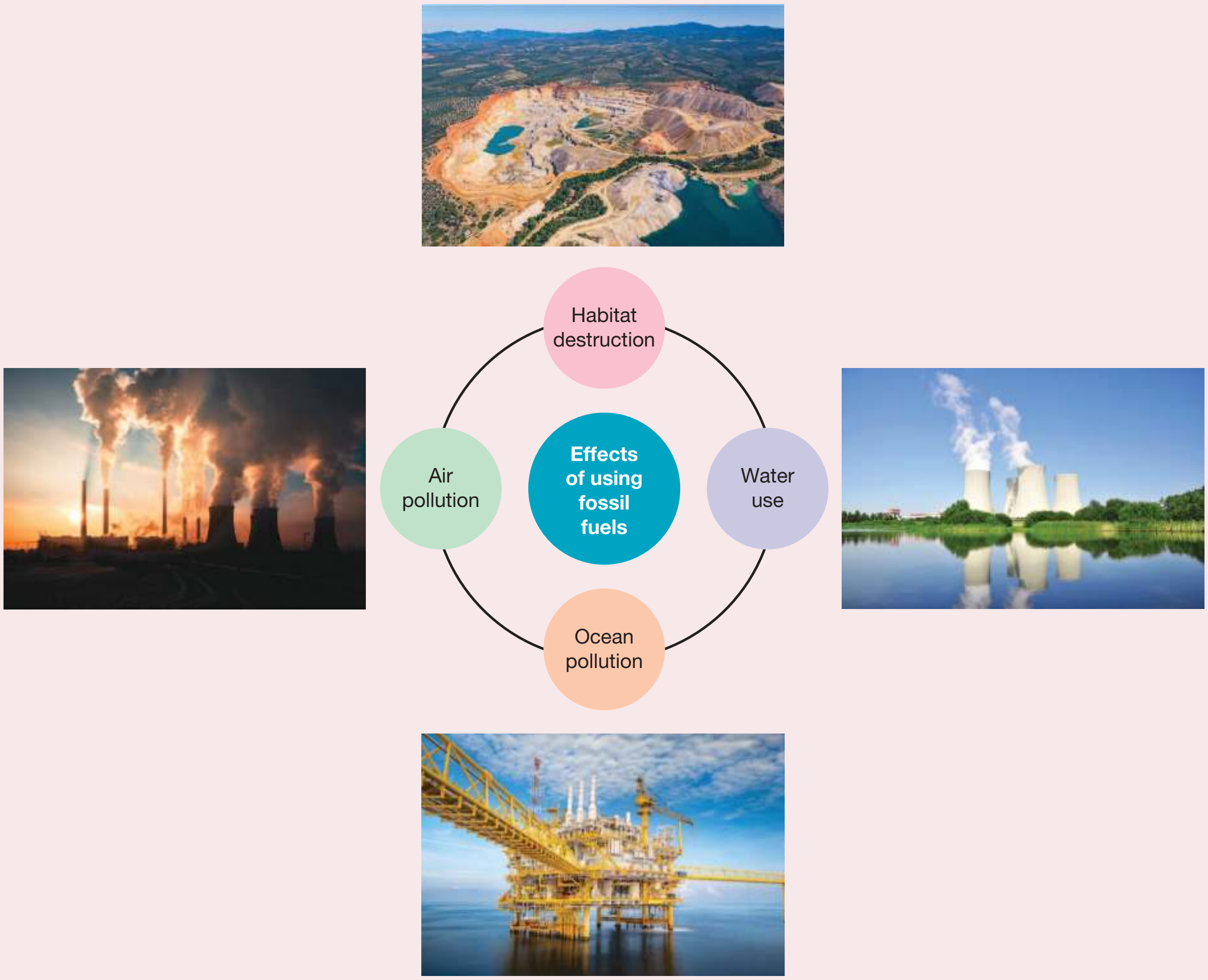
The use of fossil fuels has changed and advanced the way we live our lives, but at what cost? Unfortunately, there are several environmental downsides to the use of fossil fuels.

The four main negative effects fossil fuels have on the environment are:

1. *Air pollution:* The burning of fossil fuels releases carbon dioxide, methane and other harmful gases into the atmosphere. Some of these gases contribute to climate change and global warming.
2. *Water demands:* Most fossil fuels use conventional steam technologies to generate electricity. Steam plants require large amounts of water for both the creation of steam and cooling. This demand can negatively impact local water resources and aquatic habitats.

3. *Habitat destruction:* A vast amount of land has been disturbed to provide space for mining, drilling wells, pipelines and processing facilities.
4. *Ocean pollution:* The pollution of the coastline is often blamed on oil from offshore oil rigs, oil spills and natural seepage. In oil rigs, oil companies drill through layers of undersea rock to tap oil reserves. However, most pollution comes from the oil and oil products that are dumped down our drains.

FIGURE 6.13 The four main negative effects of fossil fuels on the environment



Most developed nations, including Australia, have encouraged the use of more renewable energy resources such as solar and wind energy. However, fossil fuels are used for more than just producing energy. Plastics and many other products include fossil fuels in their recipes. Scientists and engineers will have to come up with environmentally friendly replacements for all those products if society chooses to reduce its current reliance on fossil fuels.

1. Fossil fuels are used for energy and products like plastics. How can scientists and engineers create solutions to reduce our dependence on fossil fuels while still meeting society's energy and product needs?
2. Many developed nations are moving towards renewable energy sources like solar and wind. What are some of the challenges of replacing fossil fuels with renewable energy? How might these challenges be overcome to ensure a smooth transition?

Proposed scientific responses to socio-scientific issues impact on society and may involve ethical, environmental, social and economic considerations (VC2S8H03)

DISCUSSION

Giving up fossil fuels entirely won't be easy, at least in the near future, because they supply over 80 per cent of the world's total primary energy. Imagine a world in which mining fossil fuels was banned. What are the top ten everyday 'necessities' and luxuries we rely on that you would miss if the world's supply of fossil fuels ran out? Think about objects (e.g. plastic bottles) and processes (e.g. electricity production) that would be affected.

For the objects you listed, can you think of renewable resources that would be able to replace them?

6.3 Activities

learnon

6.3 Quick quiz on	6.3 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 4, 7, 9	3, 5, 8, 10, 12, 13	6, 11, 14, 15

Remember and understand

1. **Identify** where the energy stored in fossil fuels comes from.
2. When fossil fuels are burned, the stored energy is converted to which three forms of energy?
   a. Head
   b. Wind
   c. Movement
   d. Light
3. MC Apart from its colour, how is black coal different from brown coal? Select all the options that apply.
   A. It contains more moisture.
   B. It contains more carbon dioxide.
   C. It is harder.
   D. It is drier.
4. MC Why is peat generally not used as a fuel in most countries of the world?
   A. It is harder to find.
   B. It is too heavy.
   C. It has to be dried first.
   D. It produces greenhouse gases.
5. Peat and the varieties of coal can all be burned as an energy source. However, they are not all equal in the amount of energy released for the same volume of material.
   Order these fuels from the one that provides the most energy to the least:
   peat, anthracite coal, brown coal, bituminous coal
6. **Explain** how oil and natural gas get trapped underground.
7. MC Where are Australia's biggest oil and natural gas reserves? Select all the options that apply.
   A. North West Shelf, off the coast of Western Australia
   B. Coral Sea, east of Cairns
   C. Darwin Harbour
   D. Bass Strait, off the coast of Victoria
8. MC When we burn fossil fuels — coal, oil and natural gas — the stored energy is converted to other forms of energy, including heat, movement and light. Which of these is also produced?
   A. Carbon dioxide
   B. Methane
   C. Water vapour
   D. All of the above

Apply and analyse

9. Apart from the threat of the supply running out, **describe** two other major downsides to the use of fossil fuels.
10. SI Black coal is sometimes mined underground but brown coal is not, even though there are reserves that could be mined in that way. **Suggest** why underground mining of brown coal is avoided.
11. **Explain** why it is correct to describe fossil fuels as 'stored solar energy'.
12. MC Brown coal is used to generate electricity in Victoria rather than black coal, even though brown coal contains more moisture. Based on figure 6.10, why is this the case for Victoria?
    A. Victoria contains large deposits of brown coal.
    B. Victoria does not have factories that can break down black coal.
    C. Black coal pollutes the air more.
    D. Brown coal is easier to use.
13. Using words from the following list, complete the paragraph to explain why increasing temperature will change crude oil hydrocarbons into natural gas, and can eventually destroy all hydrocarbons if it gets too hot.
    smaller, larger, more, less, increases, decreases
    Natural gas is a __________ hydrocarbon that results from the break-down of ___________ crude oil hydrocarbons. This breakdown occurs when temperature increases, forcing the hydrocarbon structure to vibrate ___________. If it gets too hot, the hydrocarbons can break apart completely.

Evaluate and create

14. SI You are a scientist working for an oil company and your team has found a rock layer super-rich in natural gas. Unfortunately, the rock properties have not allowed the gas to migrate and concentrate.
    a. **Suggest** ideas about how to solve this problem.
    b. Are there any downsides to your solution? **Justify** your answer.
15. SI The table shown lists each Australian state in order of energy consumption share (percentage) for the 2022–23 financial year and their population share as of March 2024.
    a. With the given data, **construct** a chart to help you evaluate the relationship between energy consumption and population size.
    b. **Analyse** the data and **describe** the relationship.
    c. **Suggest** a hypothesis as to why the relationship may or may not be perfect.

TABLE The differences in energy consumption across various states and territories in Australia

Australian state/territory	Energy consumption share (2022–23) (%)	Population share (March 2024) (%)
New South Wales and Australian Capital Territory	24.5	33.1
Victoria	19.9	25.6
Queensland	24.5	20.5
South Australia	5.1	7.0
Western Australia	22.0	10.8
Tasmania	1.8	2.2
Northern Territory	2.2	1.0

Source: Department of Climate Change, Energy, the Environment and Water, Canberra.

Answers and sample responses are available in your digital formats.

LESSON 6.4 Renewable energy

LEARNING INTENTION

In this lesson you will be able to describe the different types of renewable energy and their positive and negative features.

6.4.1 Reducing our fossil fuel use

Over 80 per cent of the world's total energy needs are supplied by fossil fuels. This includes fuel used for transportation and heating, as well as generating electricity.

In 2017–18, the main sources of electricity generation in Australia were:

- 60 per cent coal
- 21 per cent gas
- 17 per cent renewable sources (with approximately 6 per cent hydro, 6 per cent wind, 4 per cent solar).

However, in the past few years, the percentage of electricity supplied by renewable sources has steadily increased. In 2023, 35 per cent of Australia's total electricity generation came from renewable energy sources. By 2030, the federal government is aiming for 82 per cent of Australia's electricity to come from renewable sources. This is an ambitious target and a significant increase from the current percentage.

KEY IDEA

Renewable sources are those that are not depleted when used, or are naturally replenished within a human lifetime.

Australia's energy needs are still largely met by fossil fuels, in that most power stations rely on coal and steam to drive **turbines** that are used to generate electricity. Coal is still used because of its abundance and low cost. The problems caused by using coal, including pollution and climate change, give us no choice but to look for alternative sources of energy.

Governments, industry and power companies all have a responsibility to seek renewable alternatives. Even you and your parents/guardians, as consumers, have a responsibility to make sensible choices about your energy use.

6.4.2 Renewable energy options

Solar energy

High solar radiation levels over large areas provide Australia with some of the best solar resource opportunities in the world and make it one of the fastest growing alternative sources for home energy. **Solar energy** is renewable because the sun rises every day, providing continual sunlight.

Solar energy uses many photovoltaic cells placed on solar panels to absorb sunlight and use the light energy to create an electrical current that can be used immediately or stored in rechargeable batteries. The photovoltaic cells can also be used to power domestic hot water systems.

FIGURE 6.14 Many buildings in Australia now have panels of photovoltaic cells on the roof to generate electricity.

Solar panels can be installed onto individual house roofs to help reduce energy costs, or set up in large grids called solar 'farms'. Relatively high costs, panel sizes and power fluctuations have limited the use of solar energy resources, but recent and significant investments in research and development are helping to increase the efficiency and cost-effectiveness of solar power.

Solar thermal power stations use curved mirrors that reflect sunlight onto tubes filled with oil. The hot oil is used to heat water to form steam, which drives the turbines that generate electricity.

EXTENSION: Victoria's goal

The Victorian government hopes to meet a goal of supplying 65 per cent of the state's electricity from renewables by 2030. Across 2023–24, rooftop solar produced more than 9 per cent of Victoria's electricity generation, with 4847 megawatts (MW) of small-scale rooftop photovoltaic capacity, and Victoria reached 537 MW of commissioned battery storage capacity — more than any other state.

Wind energy

Wind 'farms' dotted with wind turbines can be found in many countries throughout the world, including Australia. **Wind energy** is renewable because wind is continually created by the uneven heating of Earth and its oceans by energy from the sun. Wind is continuous, but the strength of wind can fluctuate, and some locations, such as the coast, are known for having more consistently strong winds.

Wind energy technology is relatively old, with the first windmills used almost 2000 years ago. Today's wind turbines use the wind to turn propeller-like blades around a rotor, which spins a generator, creating electricity.

FIGURE 6.15 Wind farms are an important way to provide energy in Australia.

The size of a wind turbine determines its energy potential — the bigger the turbine, the more energy it can produce. Most land-based wind farms in Australia display turbines that are 110 m in height to a horizontal rotor with three blades around 70 m long — a blade upright would be the height of a 20-storey building. A single wind turbine of this size can provide enough energy to supply more than 2000 average homes with the electricity they need.

Wind power is expanding rapidly and, as of 2024, is Australia's second-largest source of renewable energy behind hydro-electricity.

SCIENCE INQUIRY: Investigating the efficiency of renewable energy

Your community is considering renewable energy. To help decide, your class will simulate energy generation using heat (solar energy), airflow (wind energy) and water flow (hydropower).

Materials

- heat source (e.g. lamp or hair dryer) and a thermometer for solar energy
- fan, pinwheel or small windmill for wind energy
- small container, water and plastic cups for hydropower
- stopwatch
- ruler
- data recording sheets

Investigable question

Which simulated renewable energy source (heat, wind or hydro) generates the most measurable effect in a controlled setup?

Method

Heat simulation (solar energy)

1. Place a thermometer under a lamp or hair dryer and measure how much the temperature increases over 5 minutes.
2. Record temperature readings every minute.

Wind simulation (wind energy)

1. Use a fan to spin a pinwheel or windmill. Measure the number of spins in 5 minutes at a consistent fan speed.
2. Record spin counts every minute.

Water flow simulation (hydropower)

1. Use a stream of water from a container to turn a small water wheel made from plastic cups.
2. Measure the time it takes to lift a small weight or move a cup.
3. Record the time and weight moved during each trial.

Variables

- *Independent variable:* Type of renewable energy simulation (heat, wind or hydro)
- *Dependent variable:* Measurable effect (temperature rise, pinwheel spins or weight moved)
- *Controlled variables:* Time of measurement, intensity of lamp/fan/water flow and experimental conditions.

Data collection

1. Record the results in a table for each simulation.
2. Plot the results on bar graphs for comparison.

Analysis

1. Compare the results to determine which energy simulation showed the highest measurable effect. Discuss the implications for real-world renewable energy solutions.
2. Based on your results, which renewable energy simulation produced the most measurable effect? How might this compare to the real-world efficiency of solar, wind and hydroelectric power?
3. If your school had to choose one renewable energy source to implement based on these simulations, which would you recommend and why?

Investigable questions, reasoned predictions and hypotheses can be developed in guiding investigations to identify patterns, test relationships, and analyse and evaluate scientific models (VC2S8I01)

Biomass

Bioenergy is another potential renewable energy resource in Australia. **Biomass** is renewable because it is sourced from edible food crops or any other organic matter.

When producing bioethanol, plant material is exposed to an anaerobic environment in the presence of yeast, producing ethanol as a by-product. This is purified and can be used in cars — such as E10 fuel that is available at most petrol stations.

In Europe, biogas produces approximately 6 per cent of the renewable energy electricity generation. In Australia, there are now more than 200 biogas plants, but they are still considered an emerging technology because over half of the gas produced is not transformed into usable energy.

FIGURE 6.16 A biogas plant at a pig farm in the Czech Republic producing renewable energy from biomass

Ocean waves

Ocean waves are both clean and renewable sources of energy with a tremendous worldwide potential of generating electricity. **Ocean wave energy** is renewable because waves are common, produced by the effect of the wind blowing over the ocean surface. The up and down movement of the waves is used to drive motors on floating devices that generate electricity.

Australia has a world-class wave energy resource along its western and southern coastline, especially in Tasmania. Research by the CSIRO shows wave energy could contribute up to 11 per cent of Australia's energy (enough to power a city the size of Melbourne) by 2050, due to the Southern Ocean winds generating consistently large waves. The large consistent swell provides ideal conditions for wave energy production.

FIGURE 6.17 Part of a wave-powered electricity generator on the shore. Notice the fins inside the turbines that are caught by the waves.

Hydrogen energy

Hydrogen power can generate energy that could help reduce pollution and reliance on fossil fuels. It involves using hydrogen gas (H_2) as a fuel to produce electricity or energy. Because hydrogen is the most abundant element in the universe, it is seen as a potential clean energy source for the future.

One of the main ways **hydrogen energy** works is through **hydrogen fuel cells**. These devices convert hydrogen gas into electricity by combining hydrogen with oxygen from the air. The only waste product from this process is water (H_2O), making it an environmentally friendly option.

Another way hydrogen can be used is by burning it like traditional fuels to produce heat or power engines. But unlike fossil fuels, burning hydrogen does not release harmful gases like carbon dioxide (CO_2), which contributes to global warming.

FIGURE 6.18 A modern hydrogen production plant

Hydrogen is important because it has the potential to be a renewable energy source. It can be produced from water through a process called **electrolysis**, which splits water into hydrogen and oxygen. If the electricity used in electrolysis comes from renewable sources like wind or solar power, the hydrogen is completely clean. Furthermore, since hydrogen produces only water as a by-product, it does not contribute to air pollution or climate change. Hydrogen also serves as an energy storage solution, allowing excess electricity from renewable sources to be converted into hydrogen and stored for later use. However, generating hydrogen through electrolysis using renewable electricity can be costly.

Hydro-electricity

In 2024, 5–7 per cent of Australia's electricity was generated by **hydro-electric** power plants. This is a renewable energy source because it uses the ever-moving water cycle, driven by solar energy and gravity. Heat from the sun evaporates water from the oceans, clouds are formed and it eventually rains. Water then flows over the surface as rivers, trying to make its way back to the ocean.

Hydro-electric plants are generally associated with high dams along rivers, which concentrate water into a reservoir. Water from the reservoir is released into steep pipes, where falling water rotates turbines and generates electricity.

Hydro-electric energy resources were developed early in Australia and are currently the largest source of renewable electricity. The hydro-electric plants are located within areas of highest rainfall and elevation, and are mostly in New South Wales and Tasmania. A dry climate coupled with high evaporation rates and highly variable rainfall over much of Australia limits substantial expansion of hydro power. Droughts and bushfires can reduce the energy potential.

FIGURE 6.19 In a hydro-electric power station, the turbines are driven by water falling through pipes from a high dam.

- *Ecosystems and wildlife:* Building dams can flood large areas, which disrupts local habitats and forces wildlife to move. Changing the river's flow can affect fish migration and breeding, causing a decline in fish numbers and variety. Reservoirs can also change the vegetation and lead to habitat loss for many species.
- *Water quality and availability:* Dams and reservoirs can change how rivers flow, reducing water quality downstream and affecting water availability for both nature and people. The reduced flow can impact wetlands and estuaries, which need regular fresh water to stay balanced. Additionally, water evaporation from reservoirs can increase salinity levels, which can harm aquatic life.
- *Land and soil:* The weight of the water in reservoirs can change Earth's crust, sometimes causing earthquake-like activity. Building dams can also lead to soil **erosion** and sediment build-up, affecting both upstream and downstream areas. Moreover, changing river dynamics can affect the shape and stability of riverbeds and surrounding landscapes.

By looking at how hydro-electric plants affect the environment, we can see why using our resources wisely is important. It helps keep nature balanced and ensures we have a sustainable future for everyone.

6.4.3 Nuclear energy

Nuclear power stations use energy released from the radioactive metals of uranium or plutonium to boil water and produce steam to drive turbines. **Nuclear energy** is technically a non-renewable energy source because it comes from a mineral.

There are positive and negative effects of using nuclear energy.

TABLE 6.4 The effects of using nuclear energy

Positive	Negative
Stable and consistent amount of energy	Radioactive waste
Higher energy density	Risks of accidents
Less air pollution produced	

Most of the world's nuclear power plants can be found in the United States, Europe, Japan and Canada. Australia exports large volumes of uranium oxide, which is enriched overseas for use in nuclear power plants. In 2022, Australia supplied 11 per cent of the world's uranium and is one of the world's largest exporters.

DISCUSSION

In 1986, in Chernobyl, Ukraine, radiation from a nuclear power plant accident resulted in the death of between 15 000 and 30 000 people. Many people who argue against nuclear power use nuclear accidents like Chernobyl as evidence for how dangerous its production can be.

Another nuclear disaster occured at the Fukushima Daini nuclear power plant in Japan in 2011, caused by an earthquake and a tsunami that soon followed. Due to flooding of parts of the plant and damage to equipment, multiple nuclear meltdowns occurred and radioactive material was released. This led to the evacuation of more than 100 000 nearby residents.

How common are such accidents? Do you think the benefits outweigh the risks? Would you be happy living in an area that was near a nuclear power plant?

FIGURE 6.20 The entire city of Pripyat in Ukraine near the Chernobyl power station had to be abandoned after the nuclear accident.

ACTIVITY: Risks and benefits

In groups, create an infographic that illustrates the risks and benefits of different forms of energy production. Each group should present their infographic to the class.

6.4 Activities

learnon

6.4 Quick quiz on	6.4 Exercise

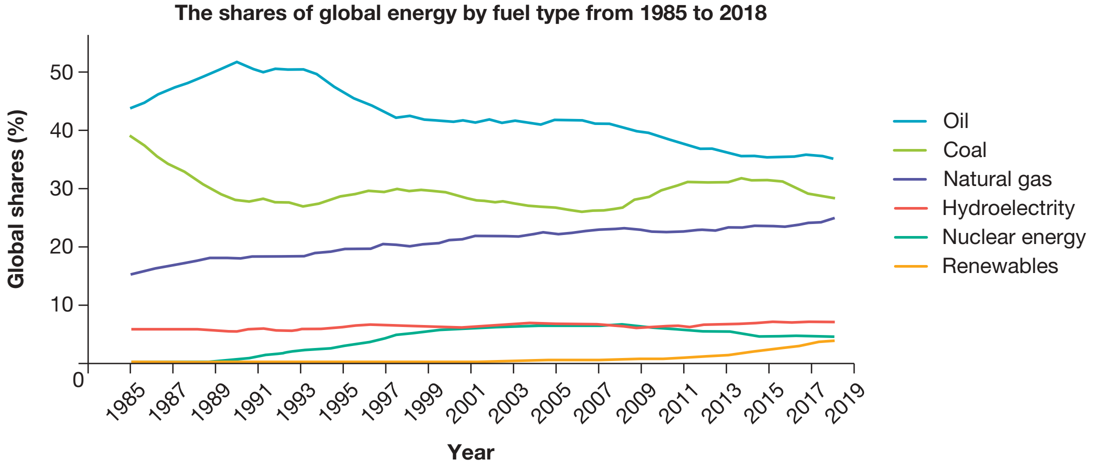
LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3, 8	5, 6, 9, 10	4, 7, 11

Remember and understand

1. What percentage of Australia's energy is aimed to be supplied by renewable energy sources by 2030?
2. MC Which two of the following are ways of protecting Earth's supply of non-renewable energy resources?
   A. Using less coal
   B. Reducing use of solar power
   C. Increasing use of renewable energy
   D. Banning wind farms
3. **Outline** why hydrogen energy is classified as renewable.
4. **Describe** two ways in which solar energy can be used to generate electricity.
5. Of the following, **identify** which two non-renewable fuels are not fossil fuels: wind energy, uranium, plutonium, geothermal energy, coal.

Apply and analyse

6. SI The following graph displays the shares (per cent) of global energy consumption by fuel type.



a. MC Which option best describes the pattern of oil consumption for the last 30 years?
   A. Decreasing overall
   B. Increasing overall
   C. Unchanging
   D. Less than renewables

b. MC Which option best describes the pattern of coal consumption over the last 30 years?
   A. Decreasing overall
   B. Increasing overall
   C. Unchanging
   D. Less than renewables

c. MC Which span of years saw the greatest increase in renewable energies?
   A. 1985–1987
   B. 1989–1992
   C. 1997–1999
   D. 2015–2017

d. MC Which non-renewable energy resource dropped the most to compensate for the rise in renewable energy?
   A. Nuclear
   B. Coal
   C. Hydro-electricity
   D. Natural gas

e. What do you predict the future lines for the next ten years will look like?

7. The turbines in coal-fired and hydro-electric power stations rotate in only one direction. **Explain** why the turbines in tidal power stations rotate in two directions.

8. Nuclear energy is a non-renewable energy source.
   a. **Explain** why nuclear energy is classified as non-renewable
   b. Is nuclear energy a fossil fuel? **Justify** your answer.

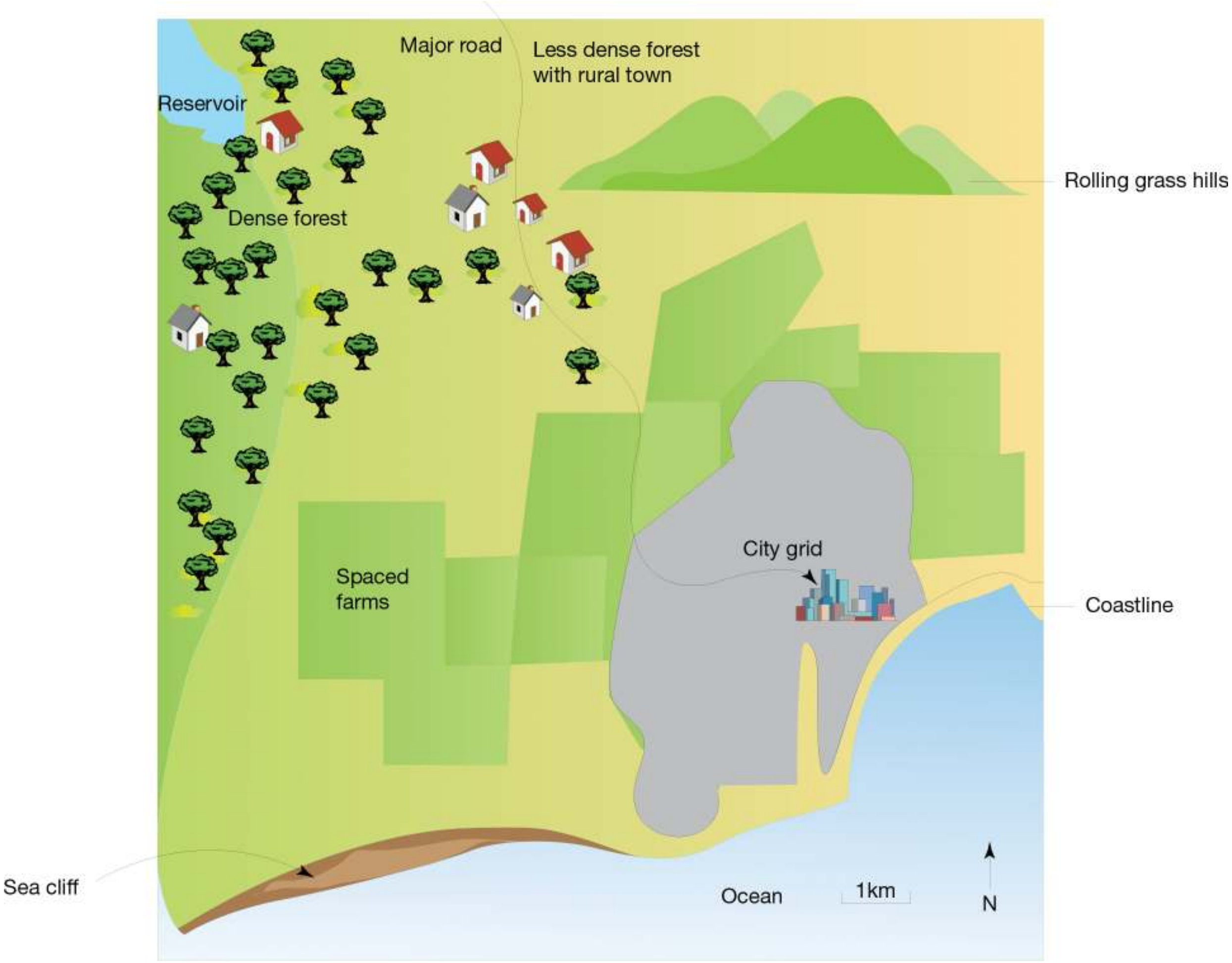
Evaluate and create

9. SI Each of the renewable energy options for generating electricity solves some of the problems caused by burning fossil fuels. However, each of them also has disadvantages or limitations. **Describe** at least one disadvantage for each of the renewable energy options.

TABLE Disadvantages of different renewable energy souces

Renewable energy source	Disadvantage(s)
a. Solar	
b. Wind	
c. Biomass	
d. Ocean waves	
e. Hydrogen	
f. Hydro-electricity	

10. **SI** **Identify** where on this map you would place a wind farm and **explain** your reasons for not selecting the other locations.



11. **SI** At present, to provide all of an average home's electrical needs with solar energy, 28–35 solar panels would be required.
    a. **Propose** why there is a range in the number of required solar panels.
    b. **Calculate** whether a medium-sized house with a roof area of 150 m^2 can fit 35 standard residential panels (approximately 164 cm by 99 cm with 60 cells) on its roof.
    c. **Suggest** what might stop people from using solar energy to supply 100 per cent of their electrical needs.

Answers and sample responses are available in your digital formats.

LESSON 6.5 Mining and the environment

LEARNING INTENTION

In this lesson you will be able to evaluate the environmental impact of extracting and using resources, and document your findings in a written scientific report.

6.5.1 The decision to mine

FIGURE 6.21 An open-cut mine

Mining supplies essential metals and fuels for electricity generation, contributing significantly to the wealth and high living standards of some Australians. It provides many jobs and brings income to the country. However, certain types of mining can create large holes in the ground, remove vegetation, and harm animal and plant habitats. Additionally, mining can pollute water and air and leave piles of waste soil and rock.

Mining companies, just like individuals, are required to be good citizens and responsible members of the community. The economic benefits of mining must be balanced against the social and environmental responsibilities. The development of mines to extract natural resources from below Earth's surface often leads to debate. The decision about whether mining should take place, or how it should take place in a particular location, is never a simple one.

INVESTIGATION 6.2

The environmental impact of resource extraction

Aim

To investigate the effect of resource extraction on the environment by simulating the removal of resources from Earth's surface and observing changes to the landscape

Materials

- a large tray filled with sand (representing Earth's surface)
- small pebbles or beads (representing valuable resources such as minerals or coal)
- a plastic spoon or small scoops
- a ruler
- water spray bottle
- timer

Method

1. Bury the pebbles or beads evenly within the sand in the tray.
2. Level the sand to represent a natural landscape.
3. Use the plastic spoon to scoop out as many pebbles as possible in 30 seconds. Repeat this for three trials.
4. Measure the depth of the holes left in the sand using a ruler.

5. Spray water lightly over the sand to simulate rain. Observe how the sand behaves around the holes created.
6. Refill the tray and conduct a second round of extraction using a slower, more controlled method (e.g. using a sieve to minimise disturbance).

Results

Use a table like the one below to record your findings.

Trial	Number of pebbles extracted	Average depth of holes (cm)	Observations of landscape changes
1			
2			
3			

Discussion

1. What differences did you observe between the two extraction methods in terms of landscape disturbance?
2. How does rainfall affect the disturbed areas compared to the undisturbed areas?
3. What variables could you control to ensure a fair comparison between extraction methods?
4. How could this model be adjusted to better reflect real-world mining or drilling practices?
5. Based on your observations, how can mining practices be modified to reduce environmental impact?

Conclusion

Summarise the findings of the investigation in three or four sentences and link them back to the aim.

6.5.2 Benefits and environmental risks

The processes involved in resource extraction and energy production come with both benefits and risks to sustainability. When evaluating the mining industry in Australia, it is essential to consider these factors.

Benefits

The benefits of mining in Australia are:

- *economic contribution:* mining plays a crucial role in Australia's economy, generating significant revenue
- *job creation:* the mining industry provides employment opportunities for thousands of Australians, both directly in mining operations and indirectly through related industries
- *export revenue:* Australia exports a large quantity of minerals and fuels to other countries, bringing in substantial foreign exchange earnings
- *technological innovation:* the mining sector often drives technological advancements and innovation, leading to improved mining techniques and equipment
- *infrastructure development:* mining companies invest in infrastructure such as roads, railways and ports, which benefits the broader community
- *resource utilisation:* the resources extracted during mining, such as metals and fuels, are important for various industries and daily life.

Environmental risks

Sulfur dioxide

Sulfur dioxide gas is one of the pollutants released during the extraction of metals, such as copper and zinc, from their mineral ores. Sulfur dioxide can also to released during the burning of coal. Modern extraction facilities often employ technologies to capture and process some of this sulfur dioxide, converting it into sulfuric acid for other industrial uses, such as manufacturing fertilisers.

The remainder of the gas is released into the atmosphere from towers up to 400 m high. The high towers are used to spread the gas more widely into the atmosphere. The release of sulfur dioxide at ground level would endanger wildlife, people and property.

Sulfur dioxide can react with moisture in the air to produce sulfurous acid and sulfuric acid. When rain falls to Earth carrying the acid with it, it is called **acid rain**. Acid rain collects in streams, rivers and lakes, causing harm to animals and plants. It also damages buildings, bridges, statues and other structures.

Waste

The waste products of metal extraction are called **tailings**. They can be composed of crushed rock, water, trace amounts of metals and potentially toxic chemicals used during the extraction process. The tailings are stored in tailings dams until they can be dried out and chemically treated to remove toxic chemicals. The tailings often contain small amounts of other valuable minerals that can sometimes be removed.

Tailings dams are essential for mine safety and environmental sustainability. However, they can be unstable and may leak, particularly older tailings dams that are no longer used or are poorly maintained. This leaking process is called **leaching**, and occurs when elements in the tailings form acids that can dissolve in rainwater and leak into the ground. These liquids can cause major damage to the surrounding environment and watercourses, endangering animals and plants.

SCIENCE AS A HUMAN ENDEAVOUR: Reducing the environmental impact of mining

Mining companies are required to act as responsible members of the community, balancing economic benefits with their social and environmental responsibilities.

New technologies and stricter regulations are helping reduce the environmental impact of mining, such as capturing sulfur dioxide for industrial use and better managing tailings dams to prevent leaks.

The decision to mine involves careful consideration of the benefits and risks. Communities, governments and mining companies must collaborate to ensure mining practices are sustainable and equitable.

1. How can mining companies and governments work together to reduce the negative impacts of mining while maintaining its benefits?
2. Should mining be allowed in areas with high environmental or cultural value, such as near rainforests or sacred sites for Aboriginal and Torres Strait Islander Peoples? What factors should be considered when making these decisions?

Proposed scientific responses to socio-scientific issues impact on society and may involve ethical, environmental, social and economic considerations (VC2S8H03)

CASE STUDY: Queenstown's barren landscape

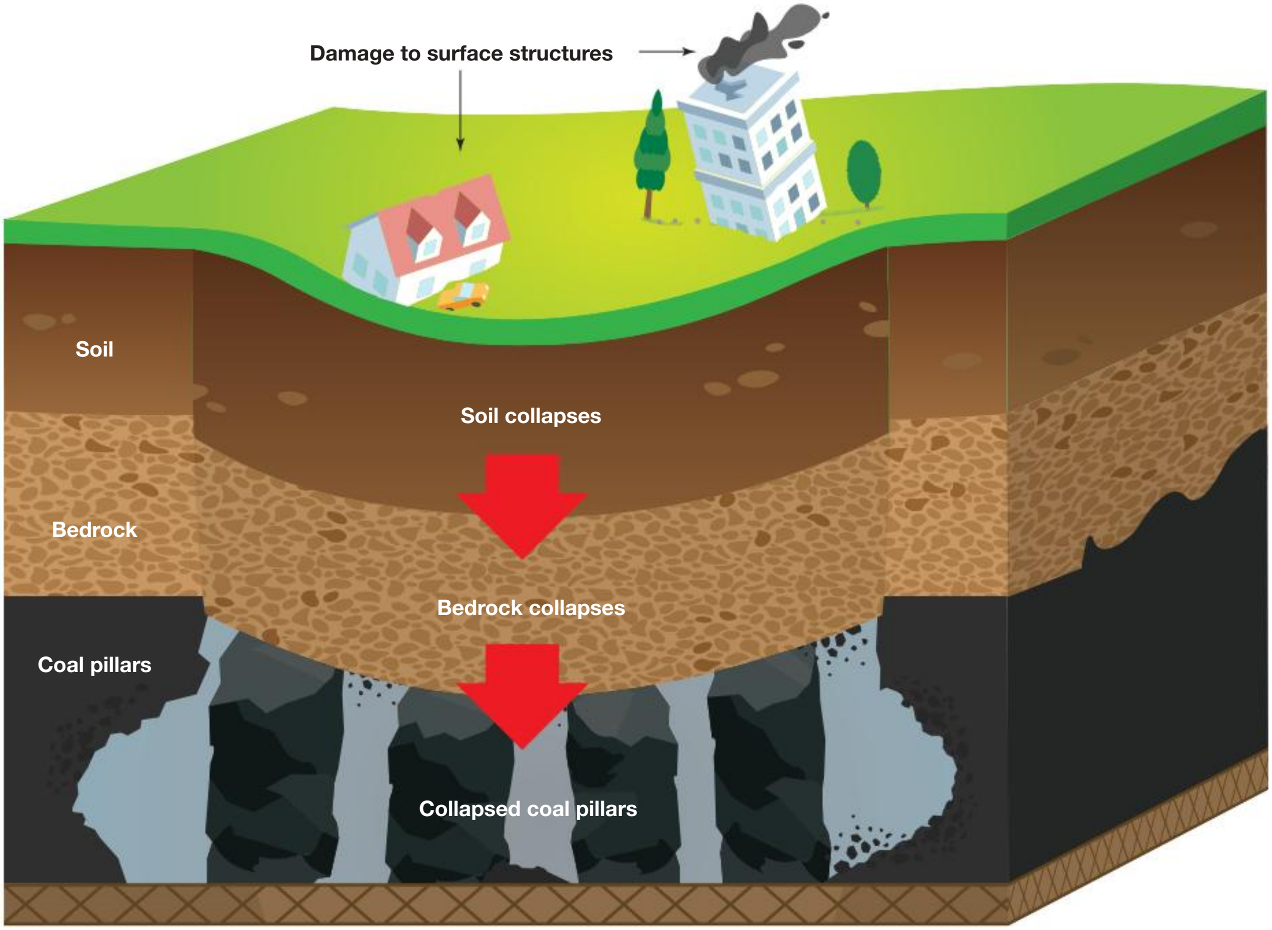
The consequences of mining can still be seen in Queenstown, on the west coast of Tasmania. Copper mining and smelting began in the area in 1902. Pollutants were released into streams and the surrounding air. During the same period, extensive tree felling and bushfires almost cleared the land of vegetation. The polluted air prevented most new plant growth and rain washed away much of the topsoil. The entire site became barren and desolate. Although smelting ceased in the 1960s, mining continued until 1994. Since then, Copper Mines of Tasmania has undertaken a major rehabilitation program to restore natural vegetation and minimise further damage to the environment. The most difficult task is to contain the leaching of tailings to protect waterways.

FIGURE 6.22 Queenstown, Tasmania

Subsidence

After coal has been extracted during underground coal mining, the land above can sink and fill the old, hollow mine workings. This can cause the surface above to drop, which is known as **mine subsidence**. This can cause damage to buildings and other structures, ranging from small problems like jammed doors and cracks in walls, to major structural damage or the opening of sinkholes.

FIGURE 6.23 Mine subsidence occurs when the ground above the cavities left behind by underground mining collapses.



DISCUSSION

You bought a new house in a recently opened housing estate but, suddenly, huge cracks started appearing in the walls inside and outside the house. Half of the doors do not close properly and there are gaps around the windows. Lots of other houses near you have the same problems. You find out that the housing estate was built over a closed underground coal mine and that there has probably been subsidence where the mine caved in.

It will be extremely expensive to fix the house, but who should pay: you (the homeowner), the building company that built the house, the estate developers who bought the land from the mining company, the mining company or the government?

CASE STUDY: Regenerating an old mine in Australia

Mining is an important industry in Australia, providing valuable resources such as coal, gold and iron ore. However, when a mine is no longer used, it can leave behind damaged land, polluted water, and lost plant and animal life. Scientists and environmental experts work to regenerate old mines to restore ecosystems and make the land useful again.

This case study explores how an old open-cut coal mine in Queensland, Australia, was successfully rehabilitated.

The issue: abandoned coal mine in Queensland

The mine, originally opened in the 1980s, provided coal for more than 30 years. When it closed, it left behind:

- a large open pit, which filled with polluted water
- bare, rocky land where plants could no longer grow
- lost animal habitats, making it difficult for local species to survive
- dust and soil erosion, affecting nearby communities and farmland.

The solution: steps to regenerate the mine site

1. Water treatment and management

- The pit was tested for dangerous chemicals, such as heavy metals.
- A water treatment system was installed to remove pollutants.
- Clean water was slowly released into nearby rivers to restore the natural water flow.

2. Soil improvement and land restoration

- Layers of fresh soil were brought in to cover the rocky ground.
- Nutrient-rich compost and fertilisers were added to improve plant growth.
- Native grass and small plants were planted first to stop soil erosion.

3. Planting trees and rebuilding habitats

- Large areas were planted with native Australian trees, such as eucalyptus and acacia.
- Scientists studied which plants were best for attracting native animals back to the area.
- Wetlands were created to help filter water and provide homes for frogs and birds.

4. Monitoring and protecting the area

- Environmental scientists checked the site regularly to ensure plant and animal life was returning.
- Fences were put up to stop invasive species such as wild rabbits from damaging new plants.
- Local communities and schools were invited to help plant trees and learn about conservation.

The results: mine transformation

- After 10 years, the old mine site was transformed.
- The water in the mine pit was safe, and native fish returned to nearby rivers.
- Trees and plants grew, creating a new forest where wildlife thrived.
- Kangaroos, birds and reptiles were seen living in the regenerated area.
- The land was stable, and the risk of soil erosion and dust storms was reduced.
- Some parts of the site were turned into a nature reserve and others into farmland.

Conclusion

This case study shows that science and environmental management can help repair damage caused by mining. By treating polluted water, restoring soil and planting native species, an abandoned mine can become a thriving ecosystem once again.

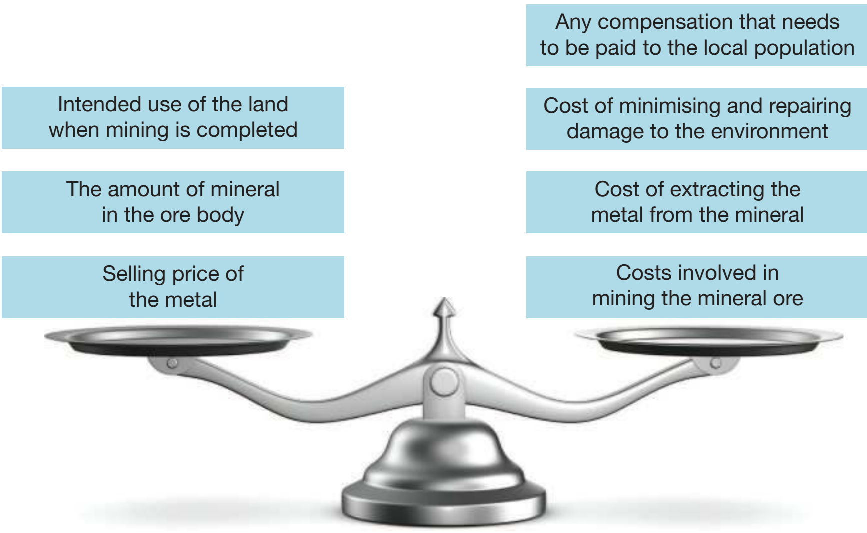
1. Why is it important to regenerate old mine sites?
2. What are some of the biggest challenges in restoring mined land?
3. How do native plants and animals help rebuild an ecosystem?
4. What other human activities might damage the environment? How can they be repaired?
5. If you were in charge of a mine rehabilitation project, what steps would you take?

6.5.3 Weighing up the issue

In the past, mining was often carried out without considering its long-term effect on the environment and the people who live and work in the area. Today, an **environmental impact statement (EIS)** must be prepared before a mining operation can commence. This statement outlines how the mining company intends to manage all environmental aspects of the proposed mine. It also outlines how the land will be **rehabilitated** or reconstructed, so that it can be used again after the completion of the mining. The EIS, along with any other relevant information, is studied by the government before permission to proceed is granted. The EIS reports on:

- existing flora, fauna and soils
- existing towns and roads in the area
- proposed new towns, roads and other developments
- how the new development might affect the local community and environment
- alternative plans to complete the development that might have less impact on the environment
- measures that will be put in place to monitor and control air, water and noise pollution during the project and while rehabilitation is undertaken
- rehabilitation proposals for the area.

FIGURE 6.24 To decide whether it will be profitable to mine and extract a metal, a mining company must consider many different factors.



6.5.4 Rehabilitation

Before mining of a new site begins, seeds of the natural vegetation of the area are collected so that seedlings may be cultivated at a later stage. The seedlings are grown in special nurseries until they are mature enough to return to the site of the mine. During open-cut mining, the overburden (the material removed from the site to expose the mineral ore or coal) is used to fill holes left from earlier stages of the mining operation. Fresh topsoil is used to cover the overburden to ensure that new vegetation will grow.

FIGURE 6.25 Progressive rehabilitation of a rock waste dump

The soil surface is shaped to fit in with the surroundings, fertilised and sown with seeds or planted with seedlings. Care is taken to shape the new surface to prevent the newly sown soil from being eroded or washed away by wind or rain.

FIGURE 6.26 The progress of rehabilitation at Sunnyside mine in north-west New South Wales can be seen here. This mine was decommissioned in 2019.

ACTIVITY: Engaging with the environment

In this lesson, we have seen how the decision to mine a resource can have an enduring impact on the environment that must be balanced against the benefits that the resource provides to our lives.

At present, Australia is the world's biggest provider of lithium, a metal used to produce rechargeable batteries for so much of our technology, including electric scooters and cars, laptops, and mobiles. It is also used for the batteries that store electricity generated by solar panels and wind turbines.

However, the lithium mining and refining process causes the same problems as the mining of other metals, including disruption of communities, damage to the environment and the need to control pollutants. There is also the issue of what to do with the tons of e-waste that the batteries contribute to once they are no longer able to store electricity. Some critics have stated that the damage that lithium causes to the environment is worse than that from coal.

Your task is to write a scientific report that either supports or refutes the hypothesis that lithium causes more damage to the environment than coal.

Use the library and the internet to research the advantages and disadvantages of lithium and coal. You will need to consider how they are mined and processed, the effect that mining and processing has on the environment, and the long-term effects the use of these resources has on the environment.

6.5 Activities

learnon

6.5 Quick quiz on	6.5 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2	3, 4, 6	5, 7

Remember and understand

1. MC **Identify** the major air pollutant released during the extraction of metals from their ores.
   A. Water vapour
   B. Carbon dioxide
   C. Sulfur dioxide
   D. Nitric acid

2. Match these terms with their definitions.

a. Tailings	1. Restoration of an environment to its previous condition before mining
b. Leaching	2. The sinking of ground caused by the collapse of soil and rock into underground cavities
c. Subsidence	3. Occurs when sulfur dioxide and nitrogen react with moisture in the air to produce acid
d. Acid rain	4. Study of the possible effects of a planned project on the environment
e. EIS	5. Solid waste products from metal extraction
f. Rehabilitation	6. The movement of contaminants from solid wastes dissolved in water downward through soils

Apply and analyse

3. **List** the benefits and disadvantages of mining.
4. Australian coal is mainly black coal. **Explain** why this means that Australian coal is sometimes described as a 'clean' variety of coal.
5. The recycling of metals, especially aluminium, is encouraged because of the amount of energy that can be saved. **Propose** some other arguments to support the recycling of metals.
6. **Describe** what factors should be considered by a mining company when deciding whether to begin a mining project.

Evaluate and create

7. **Identify** some of the environmental impacts of extracting and using natural resources, such as minerals or fossil fuels. Choose one example of a resource and **explain** how its extraction and use affect the environment. Include suggestions for how these impacts could be reduced.

Answers and sample responses are available in your digital formats.

LESSON 6.6 Aboriginal and Torres Strait Islander Peoples' use of resources

LEARNING INTENTION

In this lesson you will be able to explain how Aboriginal and Torres Strait Islander Peoples use minerals and resources for a wide range of purposes.

Aboriginal and Torres Strait Islander Peoples are renowned for having a great sense of interconnectedness with their environment, more so than the European settlers in Australia. For more than 60 000 years, Aboriginal and Torres Strait Islander Peoples have worked with the environment and used a complex system of land management to care for Country. Their traditional use of resources is sustainable and provides everything needed to survive.

6.6.1 Ochres and pigments

Ochre is the term used to describe pigments made from naturally occurring iron ore. It is valued by many Aboriginal and Torres Strait Islander Peoples as a pigment for painting and ceremonial body decoration, and for medicine. It has been mined by Aboriginal and Torres Strait Islander Peoples for thousands of years. There are more than 400 recorded ochre pit mining sites across Australia.

Most ochre mines are open-cut, with the coloured ochres being chipped away from cliffs of exposed iron ore using sharpened stone or wooden tools.

After the ochre is mined from the rock, it is ground into a fine powder using shaped and hollowed rocks. This powder is then turned into a paint by mixing it with plant gums, water and — in some ceremonial uses — with blood.

FIGURE 6.27 These ochre pits in the MacDonnell ranges are sources of yellow and red ochre.

Ochre ranges in colour with yellows, reds and browns being the most common. The various shades of ochre are caused by differences in their iron content and the trace elements present in the rock from which it is extracted:

- yellow ochre is mainly made up of goethite — a form of yellow iron oxide that has a high-water content that it has absorbed from the clay that binds it
- red ochre is naturally formed in areas with high concentrations of the mineral haematite, a type of red iron oxide with little water content.

In regions where red pigment is not readily available from a red ochre source, yellow ochre is heated, causing the water in the ochre to be removed and turning the goethite into red-brown haematite. In chemistry, this process of heating a mineral is called **calcination**.

In some regions, an ochre formed from magnetite (black iron oxide) is used instead of charcoal for black pigment.

FIGURE 6.28 Ochres, charcoal and kaolin are traditional pigments used in the rock paintings of Aboriginal and Torres Strait Islander Peoples.

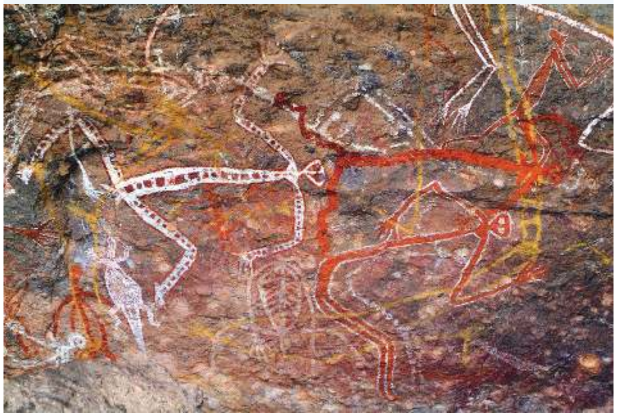


FIGURE 6.29 Ochres are primarily iron oxide and used as yellow, orange, red and brown pigments. Charcoal is often used for black pigment and kaolin clay is widely used for white pigment.

Ochre is also widely used as a traditional medicine. When swallowed, some ochres work as antacids, reducing the effect of rising stomach acid into the oesophagus.

Red ochre, which is rich in iron, can be swallowed as a treatment for anaemia. It can also be rubbed on the skin to protect from insect bites and ticks and patted into wounds to help healing.

6.6.2 Stone and natural glass

Aboriginal and Torres Strait Islander Peoples have not traditionally used metals for tools and weapons. Instead, these are made from stone and fire-hardened wood. Axe heads and cutting and scraping tools can be made from hard, brittle stones such as greenstone, silcrete, quartz, quartzite, basalt and chert. Rocks and stones of appropriate size and shape are quarried from outcrops of bedrock or collected as rounded stones from stream beds and beaches.

FIGURE 6.30 Knapped silcrete in a Wangkumara stone quarry in Sturt National Park

FIGURE 6.31 Grinding grooves at Ku-ring-gai Chase National Park

Sharp edges can be produced by **knapping** (also called 'percussive flaking'). In this process, the stone (called a 'core') is struck sharply at an angle with a smaller, harder rock (called a 'hammerstone') or a hardened piece of wood, causing flakes of the stone to be removed. The flake could be large enough to use as a tool on its own or the core stone could be shaped by repeated removal of flakes from one edge. The edges of these tools can be very sharp but also very brittle, and can easily become dull. Stone cutting tools can be reshaped and sharpened by knapping them again or by using **honing**, a technique in which the stone is repeatedly ground through grooves in a coarse rock such as sandstone.

6.6.3 Resin gums

While many modern adhesives and resins are the result of refining crude oil, Aboriginal and Torres Strait Islander Peoples traditionally use resins that are derived from plants such as porcupine grass and grass trees. These resins become soft when heated, so they can be shaped and moulded by hand. When the resins cool, they are very hard. This resin is used for a variety of purposes, such as attaching stone axe heads to wooden handles and for waterproofing bark canoes. Gum adhesives are also obtained from a number of trees including wattles and eucalypts.

FIGURE 6.32 Grass trees (*Xanthorrhea*) are a source of natural resin.

FIGURE 6.33 Two axes made of a sharpened and shaped stone head bonded to wooden handles with resin tar

6.6 Activities

learnon

6.6 Quick quiz on	6.6 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2	3, 5	4, 6

Remember and understand

1. Match the pigment colour with the substance that can be used to produce it.

a. Black	**1.** Kaolin clay
b. Brown	**2.** Haematite
c. Red	**3.** Charcoal
d. White	**4.** Heated yellow ochre
e. Yellow	**5.** Goethite

2. MC What process is used to remove the water from yellow ochre to make it into a form of red ochre?
   A. Calcination
   B. Knapping
   C. Leaching
   D. Honing

Apply and analyse

3. **Explain** how Aboriginal and Torres Strait Islander Peoples make axes despite not having a tradition of using metal.
4. Anaemia is a common condition in which the blood does not contain enough red blood cells to carry sufficient oxygen to the body. This makes the person with the condition feel tired and weak. It is usually caused by not having enough iron in your diet. **Explain** how Aboriginal and Torres Strait Islander Peoples' consumption of red ochre to treat tiredness and fatigue could work as a treatment for anaemia.

Evaluate and create

5. The painting shown is in the Lascaux Cave in France, and was created approximately 15 000 years ago. **Account for** the similarity in the colours used by these artists with those used by Aboriginal and Torres Strait Islander Peoples.

6. **Describe** how Aboriginal and Torres Strait Islander Peoples have traditionally used minerals and resources for various purposes. Include examples to **explain** how these resources can be used in everyday life and how this knowledge reflects the deep connection to Country.

Answers and sample responses are available in your digital formats.

LESSON 6.7 Review

6.7 Success criteria

Tick the column to indicate that you have completed the lesson and how well you think you have understood it using the traffic light system.

(**Green:** I understand; **Yellow:** I can do it with help; **Red:** I do not understand)

Lesson	Success criteria	Green	Yellow	Red
6.2	I can describe why most of Earth's mineral resources are considered non-renewable.			
	I can explain the steps involved in removing metal resources from Earth's crust.			
6.3	I can describe how fossil fuels are formed, what they are used for and the global impacts of their use.			
6.4	I can describe the different types of renewable energy and their positive and negative features.			
6.5	I can evaluate the environmental impact of extracting and using resources and document my findings in a written scientific report.			
6.6	I can explain how Aboriginal and Torres Strait Islander Peoples use minerals and resources for a wide range of purposes.			

learnon

Post-test Topic 6 Post-test

eWorkbook Topic 6 eWorkbook

Digital document Key terms glossary

6.7 Activities

learnon

6.7 Review questions

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 6, 12, 13	3, 4, 5, 8, 9, 14, 15, 18	7, 10, 11, 16, 17

Rememember and understand

1. MC Which of the following statements about precious minerals obtained from mines is correct?
   A. They are renewable because they are in unlimited supply.
   B. They are non-renewable because they are in unlimited supply.
   C. They are renewable because they cannot be replaced in a human lifetime.
   D. They are non-renewable because they cannot be replaced in a human lifetime.
2. MC What are the solid wastes of metal extraction called?
   A. Sediment B. Gangue C. Smelt D. Ore

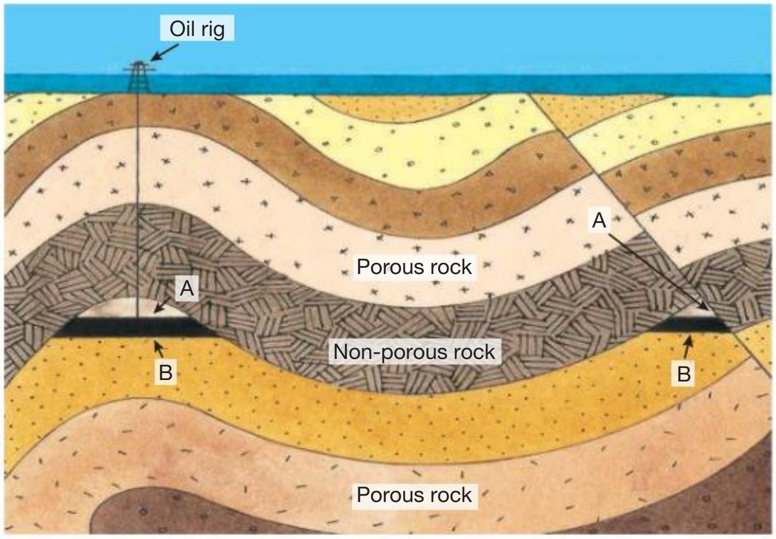
3. Complete the table to match the metals with their ore minerals.

Mineral ore	Metal
a. Bauxite	1. Lead
b. Galena	2. Aluminium
c. Haematite	3. Copper
d. Chalcopyrite	4. Iron

4. MC Which of the following is NOT used to decide whether an ore is extracted by open-cut mining or underground mining?
   A. How close the mineral ore is to the surface
   B. The temperature of the atmosphere
   C. How much rock lies above the mineral ore
   D. What type of rock lies above the mineral ore
5. **Describe** what happens to the rock taken from the ground during the first stage of extraction of its precious metal.
6. **State** the three most commonly used fossil fuels.
7. **Outline** what happens to most of Australia's coal after it is mined.
8. **Explain** the difference between:
   a. ochres and pigments
   b. calcination and knapping
   c. honing and leaching.

Apply and analyse

9. **Identify** the differences between brown coal and black coal (apart from the colour).
10. Examine the diagram.



   a. **Identify** the two substances labelled A and B.
   b. What property must the layer of rock directly above A and B have?
11. Complete the following sentences to **outline** the differences between the way in which coal is formed and the way in which oil and natural gas are formed.
   - Coal is formed _____________ and oil and natural gas are formed __________.
   - _____________ formation requires chemical processes, whereas ____________ formation requires high temperatures.

12. **Explain** why it is so important for Australia to reduce its dependence on fossil fuels.
13. Our huge dependence on non-renewable energy sources is not sustainable. What is meant by the term 'sustainable'?
14. **Expain** why biomass is considered a renewable energy source.
15. a. What role does carbon dioxide play in global climate change?
    b. How does cutting down trees in forests increase the amount of carbon dioxide in the air?
16. Why does the use of fossil fuels make a difference to Earth's atmosphere and surface?

Evaluate and create

17. Why do you think uranium-fuelled nuclear energy is not used to generate electricity in Australia even though we have more uranium reserves than any other country in the world? **Justify** your response.
18. Draw a flowchart to show how oil and gas are believed to have formed.

Answers and sample responses are available in your digital formats.

on To test your understanding and knowledge of this topic, go to your learnON title at jacplus.com.au and complete the **post-test**.

7 Earth in space

CONTENT DESCRIPTION

Cyclic changes in the relative positions of Earth, the Sun and the Moon can be modelled to show how these cycles cause eclipses and influence predictable phenomena on Earth, including seasons and tides (VC2S8U12)

Source: Victorian Curriculum F–10 Version 2.0

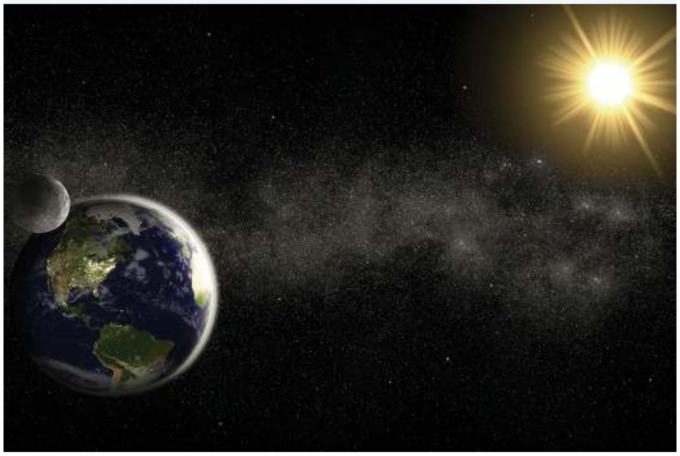
LESSON SEQUENCE

LESSON 7.1 Overview

7.1.1 Introduction

Earth is just a tiny speck in a vast **universe**. It is one of eight planets in the **solar system**, and the Sun is one of more than a billion, billion stars in the universe. But life on Earth is very much controlled by events in our own 'neighbourhood'. The seasons, day and night, the tides and the phases of the Moon are the results of Earth's orbit around the Sun, the rotation of Earth and the orbit of the Moon around Earth.

FIGURE 7.1 The Moon is a natural satellite that orbits Earth. Earth is one of eight planets that orbits the Sun.



DISCUSSION

1. What causes the seasons?
2. Why is there more daylight in summer than winter?
3. Why does the same side of the Moon always face Earth?
4. Which step was 'one giant leap for mankind'?
5. What causes the phases of the Moon?
6. Why do coastal communities experience high and low tides?
7. Why are total solar eclipses so rare?
8. Which famous scientist was imprisoned for arguing that the planets revolved around the Sun?
9. How does our current knowledge of Earth, the Moon and the Sun differ from historical ideas?

SCIENCE INQUIRY: Understanding the phases of the Moon

The Moon's phases are a result of its motion around Earth and its changing position relative to the Sun. Over time, we see different portions of the Moon's illuminated surface, creating patterns known as the phases of the Moon.

How do the phases of the Moon work?

The Moon does not produce its own light; it reflects sunlight. As the Moon orbits Earth, the Sun illuminates different portions of its surface. From Earth, we see varying amounts of the Moon's illuminated side, which creates the phases: new moon, crescent, first quarter, gibbous, full moon, and back again.

Observing the Moon

Scientists and students study the Moon to understand its motion and phases. By observing the Moon at regular intervals, we can gather data to explain the patterns of its changing shape in the night sky.

Observing the Moon over one full lunar cycle (approximately 29.5 days) helps us identify the sequence of its phases. Recording the percentage of the illuminated surface visible from Earth shows the repeating pattern.

Tracking the Moon's phases

1. Look at the Moon every three to four nights over at least two weeks. Record its shape and the time, and note the Sun's position.
2. Estimate the percentage of the Moon's illuminated surface and create a graph to visualise changes over time.
3. Analyse the data to explain how the Moon's orbit causes its phases and predict its appearance in the future.

Understanding the Moon's phases helps explain natural phenomena such as tides and eclipses. This knowledge has practical uses in navigation, agriculture and even cultural events, which have historically been tied to lunar cycles.

Data and information can be organised and processed by selecting and constructing representations including tables, graphs, keys, models and mathematical relationships (VC2S8I04)

learnon

Pre-test	Topic 7 Pre-test
eWorkbooks	Topic 7 eWorkbook Student learning matrix
Practical investigation eLogbook	Topic 7 Practical investigation eLogbook
Digital document	Key terms glossary

LESSON 7.2 Explaining the night sky

LEARNING INTENTION

In this lesson you will describe how new evidence from historical and current day astronomers have changed people's views of the solar system.

7.2.1 Developments in astronomy

Our scientific understanding of astronomy comes from ancient Greek, Roman, Egyptian, Chinese and Syrian astronomers. Astronomers have been recording observations of the night sky for at least 4000 years. They have been trying to explain their observations for the same length of time.

Ask someone to cite a famous astronomer, and they will probably name one of the well-known European astronomers, such as Copernicus or Galileo. However, major contributions to astronomy have been made by people from vastly different cultures over thousands of years.

FIGURE 7.2 Galileo Galilei is considered the father of modern astronomy.

ACTIVITY: Contributions to astronomy

1. Using the internet or other resources to research, match each of the following individuals with their major contribution to astronomy.

Individual	Contribution to astronomy
Abd al-Rahman al-Sufi	Discovered how to use the brightness of stars to determine how far away they are
Galileo Galilei	Discovered Saturn's largest moon, Titan
Aristarchus of Samos	Rejected the Ptolemaic theory
Henrietta Swan Leavitt	Discovered that Earth and the other planets travel about the Sun in elliptical orbits
Christiaan Huygens	Showed the orbits of comets to be elliptical and periodic
Zhang Heng	Discovered the gap in the ring system of Saturn
Annie Jump Cannon	Was the first astronomer to use a telescope to observe the night sky
Johannes Kepler	Made the earliest recorded observation of the Andromeda Galaxy
Hipparchus of Nicaea	Recognised that the Moon was not a light source but reflected the light of the Sun
Giovanni Cassini	Developed a classification system for stars and classified approximately 350 000 stars
Nicolaus Copernicus	Proposed the first known heliocentric model
Edmond Halley	Discovered the precession of the equinoxes

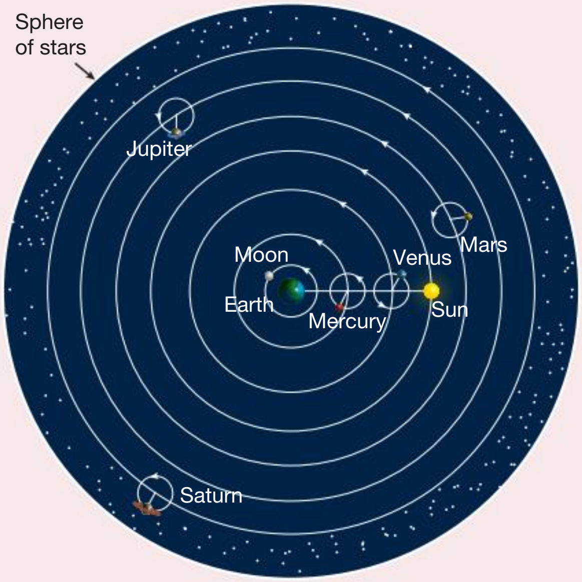
2. Select one of the individuals in the table and write a short paragraph about their contribution to astronomy.

SCIENCE AS A HUMAN ENDEAVOUR: Modelling the universe

Ptolemy's theory

In about 150 CE, the early Greek astronomer Ptolemy used his own observations and the ideas of other Greek astronomers to develop a model of the universe. The universe is the whole of space and everything in it. In Ptolemy's model, Earth was the centre of the universe. The universe was surrounded by a sphere called the celestial sphere, to which all of the stars were attached. The Moon, the Sun and the planets orbited Earth, which did not move at all. Ptolemy's model was generally accepted as correct for almost 1500 years.

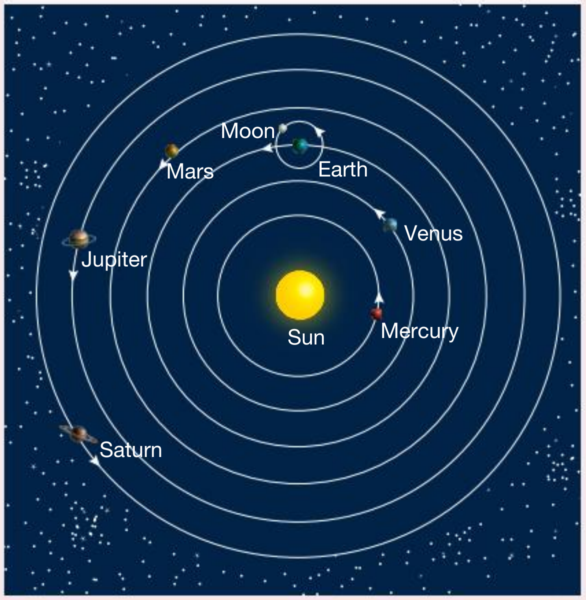
FIGURE 7.3 Ptolemy's model of planetary motion



Aristarchus's heliocentric model

In the following century, Aristarchus developed a model of the universe in which the Sun was fixed and all the planets, including Earth, orbited it along circular paths (see figure 7.4). This is a heliocentric model, with *helio* meaning 'sun', and *centric* meaning 'centre'. He also noted that, once a day, the Moon revolved around Earth and Earth rotated on its axis. Aristarchus's model did not gain wide acceptance at the time. However, this is the model we currently use. This Sun-centred theory would have defied common sense at the time because we do not feel Earth spinning or moving through space.

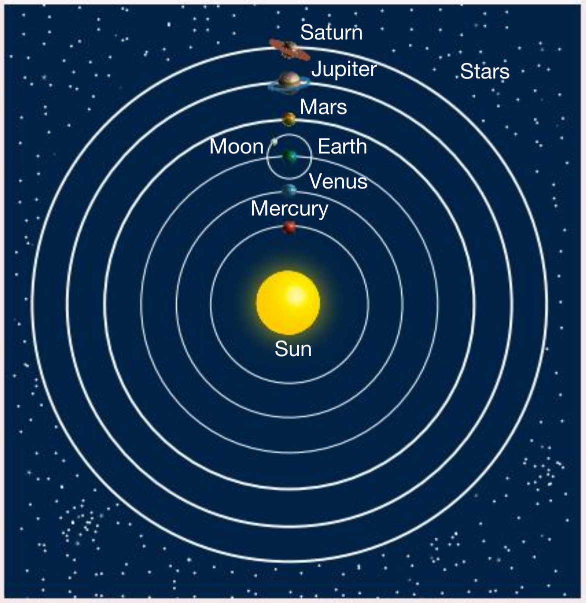
FIGURE 7.4 Aristarchus's heliocentric model



Copernicus's heliocentric model

Nicolaus Copernicus, born in Poland in 1473, was a mathematician with a keen interest in astronomy. He was unhappy with Ptolemy's model and, although it explained the circular movement of the stars, it did not fully explain the movement of the planets across the sky. Copernicus was convinced that the planets revolved around the Sun. The movement of the stars could be explained if Earth spun on its own axis once a day. Copernicus wrote a book in which he used mathematics to explain his ideas. He died in 1543 on the day that his book, *On the Revolutions of Heavenly Spheres*, was published. The book was then banned because it disputed the teachings of the Roman Catholic Church and was considered to be morally wrong. According to the Roman Catholic Church at that time, Earth had to be at the centre of the universe.

FIGURE 7.5 Copernicus's heliocentric model



The heliocentric model is confirmed

Galileo Galilei (1564–1642) was the first astronomer to use a telescope to observe the night sky. His discovery in 1610 of four moons orbiting the planet Jupiter showed that not all heavenly bodies revolve around the Earth. Galileo, despite strong opposition from the Church, actively supported the ideas of Copernicus. In 1616, he was ordered by the Roman Catholic Church not to defend the Copernican model. However, he defied the order and in 1632 published a book in which he showed that the ideas of Copernicus were far more sensible than the Earth-centred model of Ptolemy. The following year Galileo was forced, under threat of torture, to deny his beliefs in public. His book was banned and he was sentenced to life imprisonment. Old, sick and losing his sight, Galileo was allowed to serve his sentence locked in his own home. He was totally blind during the last four years of his life.

It was not long after Galileo's death that the observations of other astronomers, and the theories of English scientist Sir Isaac Newton, confirmed that the Sun was at the centre of the solar system. Newton died in 1727 knowing that he had finally convinced most astronomers that Earth was not the centre of the solar system or the universe.

1. What made scientists change their minds about Earth being the centre of the universe? Why did it take so long for people to accept this new idea?
2. Why do you think some people didn't believe the heliocentric model at first? Can you think of other times when new ideas were hard to accept?

Scientific knowledge, including models and theories, can change because of new evidence (VC2S8H01)

More than 2000 years ago, the Ancient Greeks discovered that Earth was spherical. Eratosthenes, an Ancient Greek mathematician, used the length of shadows in different places at exactly the same time to accurately calculate the circumference of Earth.

During the seventh century, Indian mathematician and astronomer Brahmagupta developed methods to calculate the paths of astronomical objects through the sky, and predicted the timing of solar and lunar eclipses. Numerous astronomers from other countries and cultures also made significant contributions.

SCIENCE AS A HUMAN ENDEAVOUR: Early astronomers

Al-Battānī

During the tenth century, Al-Battānī, an Islamic astronomer and mathematician, made astronomical observations for more than four decades. He determined the length of the solar year with incredible precision (less than three minutes off) and explained how annular eclipses occur, by noticing that the distance between Earth and the Sun varies throughout the year.

Al-Battānī also made considerable contributions to mathematics, and centuries later astronomers such as Copernicus, Kepler and Galileo were still using his work.

Wang Zhenyi

Wang Zhenyi (1768–1797) was one of the famous Chinese scientists from the Qing dynasty (1644–1912). Wang was born during a time when girls were prevented from receiving an education. However, her family encouraged and supported her in her love for learning.

Wang studied astronomy and mathematics, especially trigonometry, and became interested in lunar eclipses. During a time when Chinese scholars thought that the movement of the planets, the Sun and the Moon was a sign of angry gods, Wang successfully used her knowledge of sciences and mathematics to explain that lunar and solar eclipses occur due to the relative position of the Sun, the Moon and Earth.

Wang conducted many experiments at home to explain celestial phenomena such as eclipses. In one exhibit, she demonstrated that the Moon obscuring the Sun is the explanation for a solar eclipse. To do this, she built a model, using a mirror to represent the Moon, a hanging lamp to represent the Sun and a round table to represent Earth. By moving the relative position of the three objects, she showed that the passing of the Moon (the mirror) between Earth (the round table) and the Sun (the hanging lamp) caused a solar eclipse. Can you use the same model to show that the passing of Earth between the Sun and the Moon causes a lunar eclipse?

FIGURE 7.6 A modern artist's impression of Wang Zhenyi's home experiment to explain a lunar eclipse

1. Al-Battānī and Wang Zhenyi made significant contributions to our understanding of eclipses. How do their discoveries show the importance of diverse cultural perspectives in advancing scientific knowledge?
2. Wang Zhenyi used a simple model with a mirror, lamp and table to explain eclipses. Why do you think models are useful in helping us understand complex scientific ideas? How could you use this model to demonstrate both solar and lunar eclipses?

Multidisciplinary endeavours to advance scientific knowledge make use of people's different perspectives and worldviews (VC2S8H02)

Developments in astronomy have been driven by passionate scholars for thousands of years, but newly invented technology has also been important. The development of the first telescopes in the seventeenth century allowed people to make more accurate observations, which led to rapid advancements in astronomy. Modern telescopes, including NASA's James Webb Telescope launched in 2021, allow us to use the full light spectrum (and not just visible light) to study the universe, and to determine such things as the composition of stars.

The quest for knowledge and for the understanding of the universe that started long ago is not over yet. Astronomers are still making new discoveries, often leading to more questions than answers. In astronomy, as in many other areas (such as traditional medicine or land management), indigenous knowledge from around the world is now being recognised and incorporated into research. In Australia, as seen in lesson 7.7, Aboriginal and Torres Strait Islander Peoples possess specific knowledge and understanding of astronomy.

SCIENCE AS A HUMAN ENDEAVOUR: Promoting astronomy knowledge and understanding

Karlie Noon

Astronomer, astrophysicist and science communicator Karlie Noon, a Gamilaraay woman, is the first female Aboriginal or Torres Strait Islander person in New South Wales to graduate with a double degree in maths and physics.

Noon is on a mission to explore the knowledge Aboriginal and Torres Strait Islander Peoples have about the link between the land and the sky. She wants to show that they have been doing science for a long time and that this knowledge and understanding has been passed down through rock art and stories.

Based on her experiences in her education and upbringing, Noon is interested in inspiring people from minorities and lower socioeconomic groups to engage in STEM (science, technology, engineering and mathematics).

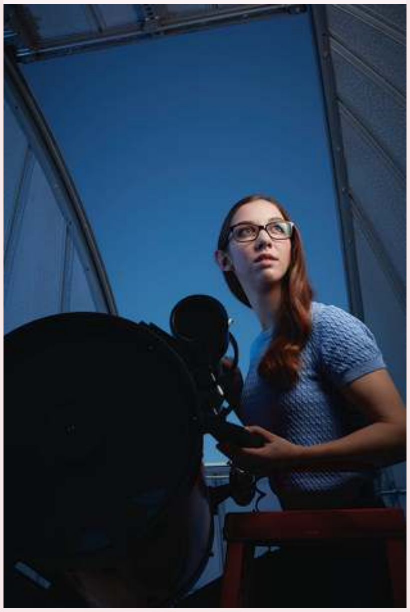
FIGURE 7.7 Astrophysicist Karlie Noon at the Murchison Radio-astronomy Observatory in Western Australia

Kirsten Banks

Kirsten Banks is a Wiradjuri woman who is an astrophysicist and science communicator at Sydney Observatory. Kirsten launched her career in astrophysics with a Bachelor of Science at the University of New South Wales. She is currently studying galactic archaeology, which involves studying the stars of the Milky Way galaxy and looking at its history and formation.

As a science communicator, Kirsten educates people about the links between Aboriginal and Torres Strait Islander Peoples' astronomy and western astronomy. Kirsten wants to bridge the knowledge gap between academia and the general population by making information about space and astronomy easy to understand and accessible by appearing on TV shows, TEDx talks and creating TikTok videos.

FIGURE 7.8 Kirsten Banks at the University of New South Wales



1. Karlie Noon and Kirsten Banks work to connect Aboriginal and Torres Strait Islander Peoples' knowledge with modern astronomy. How do you think this blending of perspectives helps us to better understand the universe? Why is it important to acknowledge both traditional and western knowledge in science?
2. Kirsten Banks uses social media and public talks to make astronomy accessible to more people. Why do you think making science easy to understand and engaging is important? How could you communicate something you've learned in science to a younger audience or your community?

Multidisciplinary endeavours to advance scientific knowledge make use of people's different perspectives and worldviews (VC2S8H02)

7.2 Activities

learnon

7.2 Quick quiz (on)	7.2 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 3, 5, 9	2, 6, 7, 12	4, 8, 10, 11

Remember and understand

1. **Name** the person who first calculated the length of a solar year with incredible precision.
2. **Explain** the contribution to astronomy for which Wang Zhenyi is best known.
3. Who proposed the first known heliocentric model?
4. Give one reason for why an Earth-centred model of the solar system made more sense to early astronomers than a sun-centred one.
5. **Name** the new technology that enabled Galileo to make observations that supported the idea of a sun-centred solar system.

Apply and analyse

6. **Explain** why people rejected Copernicus's ideas for many years.
7. **Describe** the limitations that ancient cultures had in their study of the night sky.
8. **Describe** how Copernicus explained the circular motion of the stars, if Earth was not at the centre of the universe.

Evaluate and create

9. **Suggest** evidence that you would use to argue that Earth is at the centre of the universe.
10. During the lifetimes of Copernicus and Galileo, new theories about our solar system developed rapidly and previous ones were rejected. In science, why are existing theories replaced by new ones?
11. **Explain** how the discovery of new planets and moons by historical astronomers changed people's views of the solar system.
12. Imagine you are a modern-day astronomer who has discovered a new object in the solar system that challenges our current understanding. Write a short article **explaining** your discovery and how it could change people's views of the solar system. Include historical examples of how past discoveries have shifted our perspective.

Answers and sample responses are available in your digital formats.

LESSON 7.3 Earth in orbit

LEARNING INTENTION

In this lesson you will describe how Earth's tilt and its position in space, relative to the Sun, influence the seasons and day/night cycles.

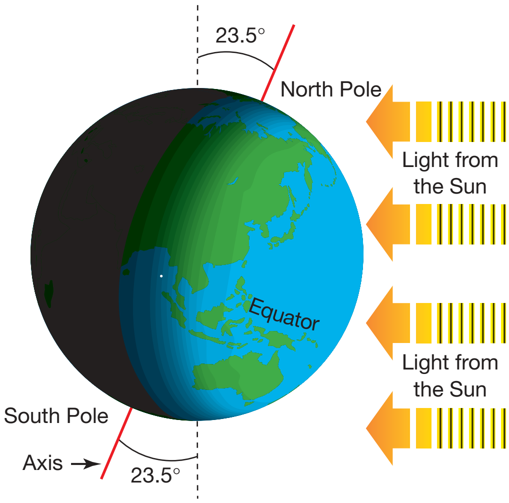
7.3.1 Night and day

Earth rotates continuously on its own **axis**. All other planets, those in our solar system and far off planets in other solar systems, also continuously rotate. Earth's axis is an imaginary straight line between the South Pole and the North Pole. The axis is tilted at an angle of 23.5° from the vertical, as shown in figure 7.9. This **rotation** takes 24 hours to complete and causes day and night on Earth.

Earth rotates in an anticlockwise direction (opposite to the hands on a clock face) when viewed from above the North Pole, or a clockwise direction when viewed from above the South Pole. This means that as you travel west, sunrise will happen later and later in the day. At night, the rotation of Earth makes the Moon and planets appear to move from right to left, or west to east, across the sky.

As Earth rotates, the side facing the Sun receives light from the Sun and experiences daytime (see figure 7.9). The side of Earth facing away from the Sun does not receive any light and experiences night-time. During one rotation, the amount of sunlight one place receives will increase and then decrease, creating dawn, midday and twilight. One full rotation of Earth around its axis takes 24 hours, or 1 day.

FIGURE 7.9 Only one half of Earth can face the Sun at any one time. This diagram shows Australia and part of East Asia in daylight.



KEY IDEA

The rotation of Earth around its axis causes day and night on the surface on our planet.

From the surface of Earth, the Sun appears to rise, move across the sky and set every day. Early astronomers explained day and night by suggesting that the Sun moved around Earth. They couldn't feel the surface of Earth moving, so they believed Earth was stationary and the Sun was moving. As more accurate measurements of the night sky were made, people started believing that Earth was rotating.

INVESTIGATION 7.1

Day and night

Aim

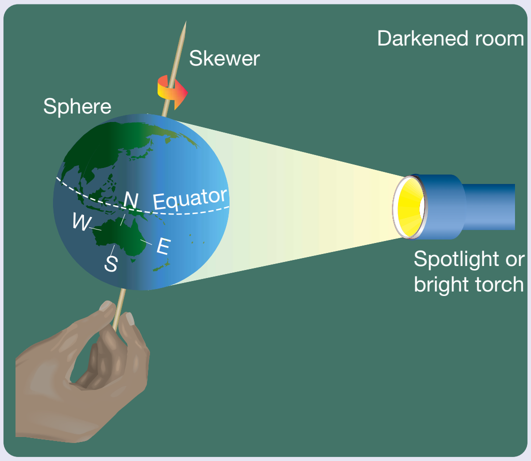
To model the cycle of day and night

Materials

- polystyrene (or similar) sphere
- spotlight or bright torch
- skewer
- marker

Method

1. Your sphere represents Earth. Draw a line around the centre to represent the equator. Label the Northern Hemisphere and Southern Hemisphere and mark the North Pole and South Pole.
2. Draw an outline of the continents on your sphere: Australia, Africa, North America, South America, Europe, Asia and Antarctica. Use an atlas to check the positions and approximate shape of each continent.
3. Draw in a compass and label the directions of north, south, east and west.
4. Gently push a skewer through the centre of your sphere from bottom to top through the North and South poles. This represents Earth's imaginary axis.
5. Turn on the spotlight or torch in a darkened room. Its light represents the Sun's light. Hold the skewer so it leans a little away from the vertical. This represents Earth's tilt.



6. Turn your sphere very slowly in the light, making sure you keep the skewer slightly tilted all the time. Turn it in an anticlockwise direction (as seen from above the North Pole).

Results

1. In which direction is 'Earth' rotating — from east to west or west to east? Check the compass directions you marked on your sphere.
2. In which direction does the 'sun's light' seem to move around 'Earth'?

Discussion

1. Where is Africa located on Earth compared to Australia? When Australia is having day time, what is Africa experiencing? Explain why these continents experience daylight at different times.
2. Explain why the stars appear to move across the sky at night.
3. Use the rotation of Earth to help explain why night falls in Perth about 2 hours later than in Sydney and Melbourne.

Conclusion

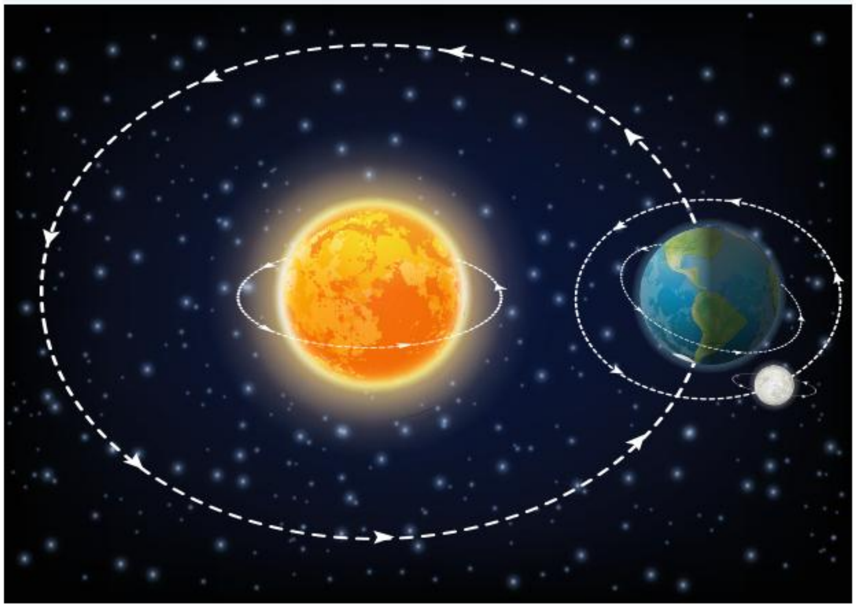
Summarise your findings about Earth's rotation and how it affects us on the surface of Earth.

7.3.2 Paths through space

Earth is also constantly moving through space. It does not move randomly but takes a specific path around the Sun called an **orbit**. It takes the Earth 1 year to complete one orbit of the Sun.

Earth's orbit is **elliptical**; it is almost, but not quite, circular. The Moon also moves in an orbit — it moves in an elliptical orbit around Earth. Other planets in our solar system also orbit the Sun in elliptical orbits. Many of these planets also have moons in elliptical orbits around them. Even the Sun follows a path through space.

FIGURE 7.10 Cyclical motions of Earth, the Moon and the Sun



Earth orbits the Sun because of the Sun's **gravitational force** pulling on Earth. The Sun's gravitational force also acts on other planets in our solar system, making them orbit the Sun too. Earth's gravitational force on the Moon causes the Moon to orbit Earth too. These gravitational forces are always present between the Sun and Earth, and Earth and the Moon, and make the movement of Earth and the Moon **cyclical**. This means there are predictable cycles or patterns that repeat themselves. These patterns and cycles allow us to measure and predict events such as the seasons, the phases of the Moon and the tides.

INVESTIGATION 7.2

Modelling rotations and revolutions

Aim

To model the movement of Earth in space

Materials

- chalk (for drawing on the ground)
- outdoor area (or large indoor area with no furniture)
- hoop

Method

1. Select one student to act as the Sun, a second to act as Earth and a third to act as the Moon.
2. Using the chalk, mark the position of the Sun on the ground. Draw a large elliptical path for Earth to follow around the Sun.
3. The student acting as the Sun should rotate slowly in position. The person acting as Earth should rotate slowly while also moving along the path marked on the ground holding the hoop around them.
4. The student acting as the Moon should slowly rotate while also orbiting Earth, moving around the hoop.
5. Check Earth's rotation and revolution are in the correct directions.

Results

1. Draw a diagram showing the Sun and Earth and their movements.
2. Record the number of Earth rotations needed to complete one 'day'. (Begin by facing the Sun and record the number of Earth rotations until the student is again directly facing the Sun.)

Discussion

1. Compare a 'revolution' to a 'rotation'.
2. Explain why the Moon and the Sun do not crash into each other as they move through space.
3. Explain why Earth needs to do more than one rotation from noon on one day to reach noon the next day.
4. The Sun is not stationary in space, it also moves along a path. Predict the effect of this movement on Earth and the Moon.

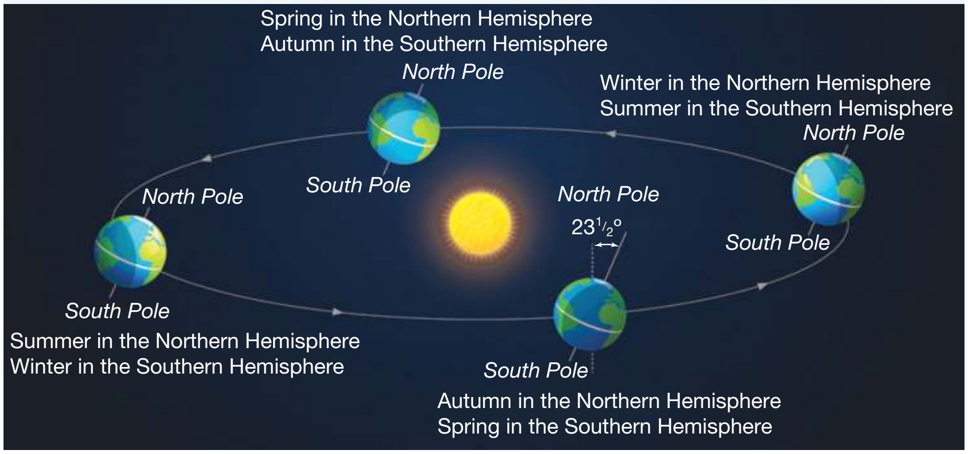
Conclusion

Write a short paragraph describing the motions of Earth, the Moon and the Sun relative to each other.

7.3.3 Earth's seasons

The seasons occur at different times of year in the Northern and Southern Hemispheres. They are caused by the tilt of Earth's axis combined with Earth's orbit around the Sun. Earth's axis always tilts in the same direction. This means that some parts of Earth receive more light than others at different times of year.

FIGURE 7.11 As Earth orbits the Sun, the seasons change. This diagram shows the seasons as they are in the Southern Hemisphere.

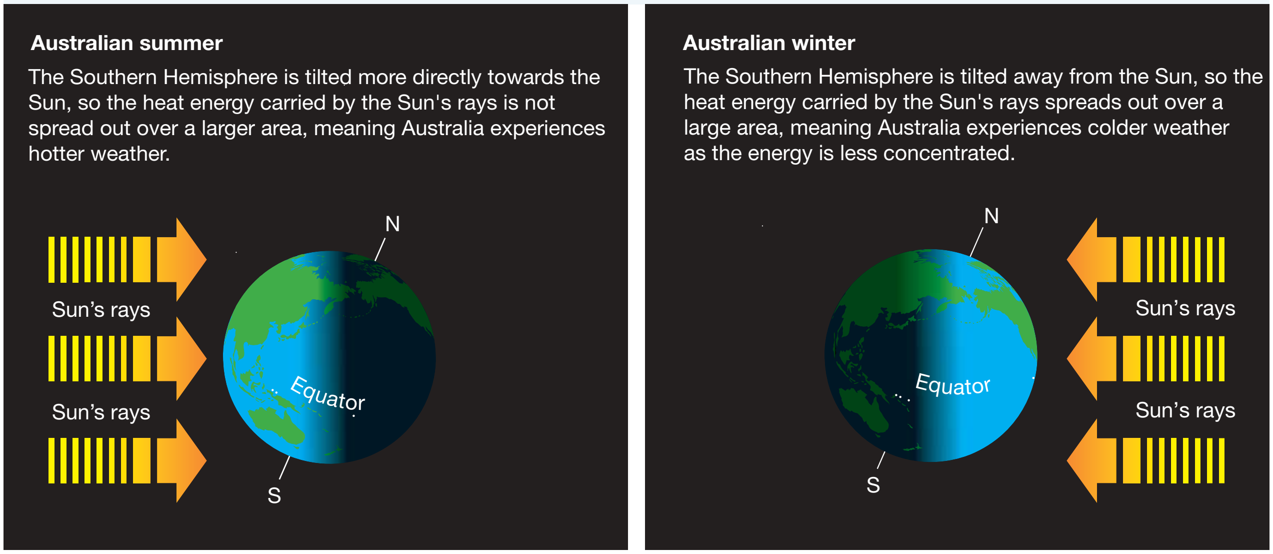


The Southern Hemisphere experiences summer when it is tilted towards the Sun. At that time, light from the Sun hits the Southern Hemisphere 'head-on'. Heat energy from the Sun is more concentrated, leading to an increase in temperature and warmer weather. At the same time, the Northern Hemisphere experiences winter because it is tilted away from the Sun.

The Southern Hemisphere experiences winter when it is tilted away from the Sun. It's cooler than summer because light from the Sun hits the Southern Hemisphere at a large angle, spreading the heat energy over a larger area. Because the heat energy is spread out over a larger area, the temperature is lower. While it is winter in the Southern Hemisphere, it is summer in the Northern Hemisphere.

Between summer and winter, neither hemisphere is tilted towards the Sun. Both hemispheres receive the same amount of sunlight and heat energy, creating similar temperatures in both hemispheres. This happens during autumn and spring.

FIGURE 7.12 The tilt of Earth's axis and the orbit of Earth around the Sun together cause the seasons.



INVESTIGATION 7.3

How does the angle of sunlight hitting Earth affect the seasons?

Aim

To investigate the link between the angle of the sunlight and the temperature on Earth's surface

Equipment

- torch
- white card or bare wall to act as a screen

Method

1. Use the torch to cast light on a white card or a bare wall. Observe the shadow of a student's hand on the wall when the palm is vertical.
2. Measure the height of the shadow.
3. Ask the student to hold the palm in a tilted position, between vertical and horizontal. Measure the height of the shadow.
4. Ask the student to hold their palm horizontal. Measure the height of the shadow.

Results

1. Record your measurements of shadow height in a table like the one below.

Palm position	Height of shadow (cm)

2. Using your results, draw a line graph.

Discussion

1. Describe the change in the shadow's height as the student's palm moved from vertical to horizontal.
2. Describe the change in the amount of light hitting the student's palm as it moved from vertical to horizontal.
3. Link the amount of light hitting the student's palm to the temperature of their palm.
4. Compare the temperature on the surface of Earth at a place receiving direct sunlight to a place angled towards the Sun.

Conclusion

Write a paragraph linking the tilt of Earth's axis and the angle of sunlight hitting Earth to the seasons.

7.3.4 Measuring time

Earth takes just under 24 hours to complete one rotation around its axis. The time between noon one day and noon the next day is 24 hours. This period is called a day. One Earth day is longer than one rotation because Earth is also moving around the Sun. Not all planets complete a rotation around their axis in 24 hours. For instance, a day on Jupiter lasts 9 hours and 55 minutes, while a day on Venus lasts 243 Earth days and 36 minutes.

The Moon takes approximately 27 days to complete one revolution around Earth. Because Earth also moves, it can appear as if the Moon takes longer to complete its orbit: 29.5 days. Historically, this time period of 29.5 days is used to define a month. This time frame of 29.5 days is known as the lunar cycle (the time between one full moon to the next as observed from Earth).

Earth takes 365.25 $\left(365\,\frac{1}{4}\right)$ days to complete one **revolution** around the Sun. This period is called a calendar year. To make the calendar simpler, we make each year 365 days with every fourth year being a leap year, 366 days. Over 4 years, that averages out at 365.25 days.

KEY IDEA

A day is the length of time taken by a planet to rotate on its own axis. A year is the length of time taken by a planet to complete one revolution around a star.

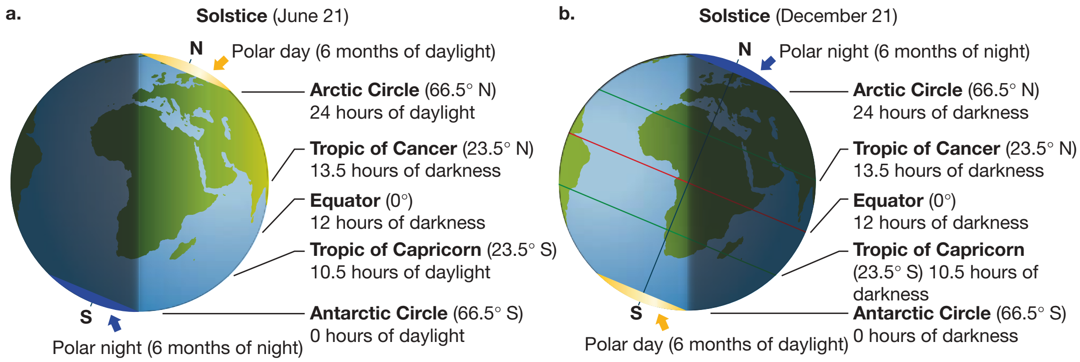
Longest day of the year

The longest day of the year, the day with the most daylight hours, is called the **summer solstice**. In Australia it occurs in late December. Some people think that it occurs because Earth is closer to the Sun on this day, but that is not true. The summer solstice occurs when Earth's tilt towards the Sun is at a maximum and the Southern Hemisphere receives the most sunlight. Therefore, the Sun appears at its highest point in the sky and is above the horizon for the longest period of time in the year.

Just like the seasons, the number of hours of daylight is determined not by the distance of Earth from the Sun, but by the tilt of Earth's axis. In summer, the Southern Hemisphere is tilted towards the Sun and more of the Southern Hemisphere is lit up. This means the Sun rises early and sets late, providing sunlight for many hours.

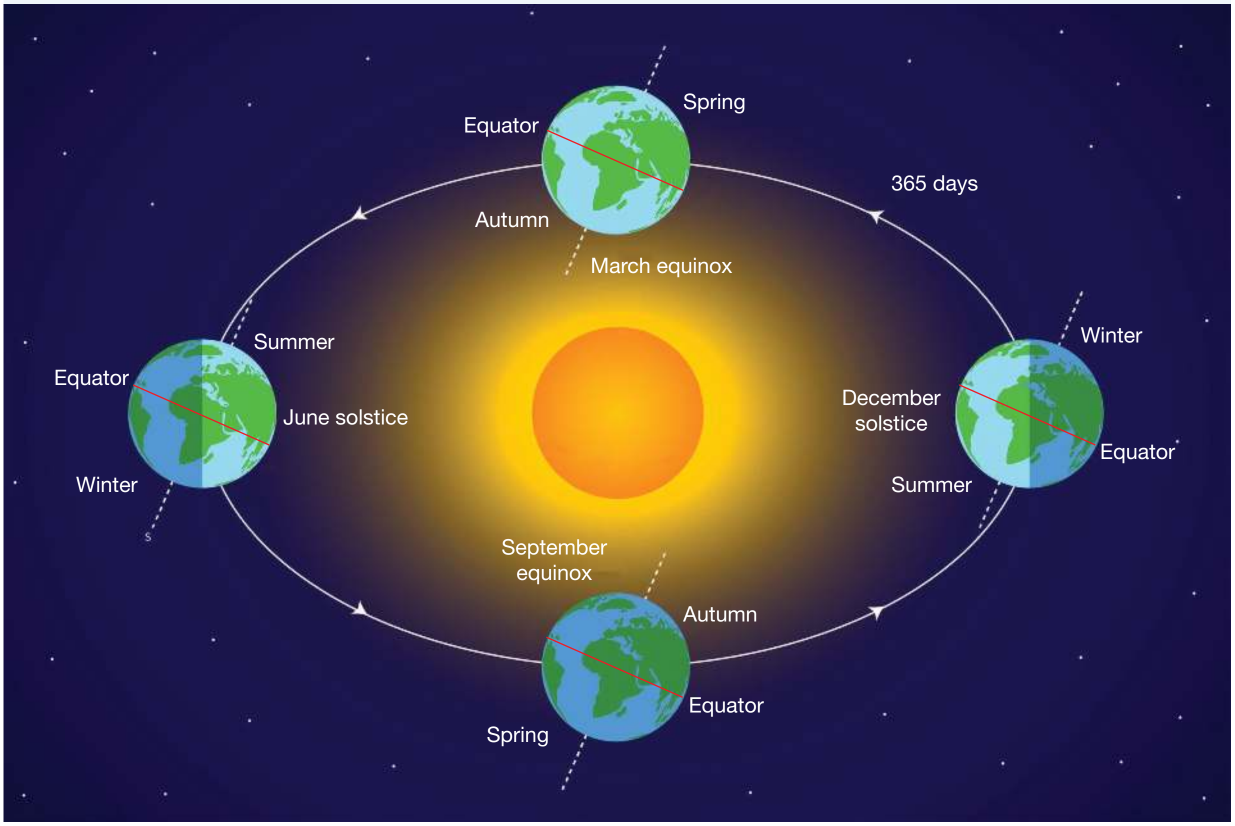
In winter, the Sun is low in the sky, rising late in the morning, then setting early in the afternoon. The day with the fewest hours of daylight is called the **winter solstice**. On this day, Earth's tilt is at a maximum distance from the Sun and the Southern Hemisphere receives the least amount of sunlight. This happens in June in Australia.

FIGURE 7.13 Australia, which is in line with the Tropic of Capricorn, receives approximately **a.** 10.5 hours of daylight on the winter solstice and **b.** 10.5 hours of darkness on the summer solstice.



There are two days during the year with the same number of daylight hours as night hours. These days are called the spring **equinox** (in September in Australia) and the autumnal equinox (in March in Australia). On these days, Earth's axis is tilted neither towards nor away from the Sun. All places on Earth, in both hemispheres, receive the same amount of sunlight.

FIGURE 7.14 During the equinox, which occurs twice a year, there are equal hours of daylight and darkness.



INVESTIGATION 7.4

Long days, short days

Aim

To model and explain the variation in daylight hours

Materials

- polystyrene (or similar) sphere
- spotlight or bright torch
- skewer
- marker
- two pins with coloured heads

Method

1. Push the skewer through the polystyrene sphere. Mark the North and South poles and the equator on the sphere. Draw in continents on the sphere.
2. Hold the skewer vertically. Push two pins into your sphere — one where Sydney approximately is and the other directly above it at the top of the sphere, near the skewer.
3. Set the spotlight up in a central place (such as on a table that you can walk around). Darken the room.
4. Stand to the left of the spotlight. Hold the skewer so it leans to the left from the vertical. The southern half of your sphere should be leaning more towards the light.
5. Slowly turn your sphere in the light, making sure you keep the skewer slightly tilted. Turn it in an east to west direction. Watch what happens from side on. Watch the side of the sphere you can see as you turn it. A partner should watch the other side.
6. Now stand to the right of the spotlight holding your skewer tilted to the left as before. This time, the northern half of your sphere should be leaning more towards the light. Repeat what you did in the previous step.

Results

Summarise your observations and outline which pin moves from the dark to the light first.

Discussion

1. Which pin comes into the light first when the southern half of the sphere leans towards the light? Is it the same when the Northern Hemisphere tilts towards the light?
2. Compare the number of daylight hours in Australia when the Southern Hemisphere is tilted towards the Sun and when the Northern Hemisphere is tilted towards the Sun.
3. Are there places on Earth that do not receive any sunlight when the Southern Hemisphere is tilted towards the Sun? Describe what life would be like for people living in these places.
4. Are there places on Earth that always receive sunlight when the Southern Hemisphere is tilted towards the Sun? Describe what life would be like for people living in these places.

Conclusion

Summarise your findings in three or four sentences to explain how the tilt of the Earth and the number of daylight hours are linked.

7.3 Activities

learnon

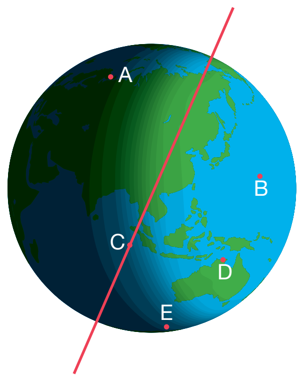
7.3 Quick quiz on	7.3 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
2, 3, 5, 12, 14	1, 7, 8, 11, 15	4, 6, 9, 10, 13

Remember and understand

1. **Describe** the difference between the revolution and rotation of Earth.
2. Give the length of one Earth:
   a. rotation
   b. revolution.
3. **Explain** why we experience day and night.
4. Give a reason for the Sun rising in the east and setting in the west.
5. **Identify** the season in Australia when the Southern Hemisphere is tilted towards the Sun.

Apply and analyse

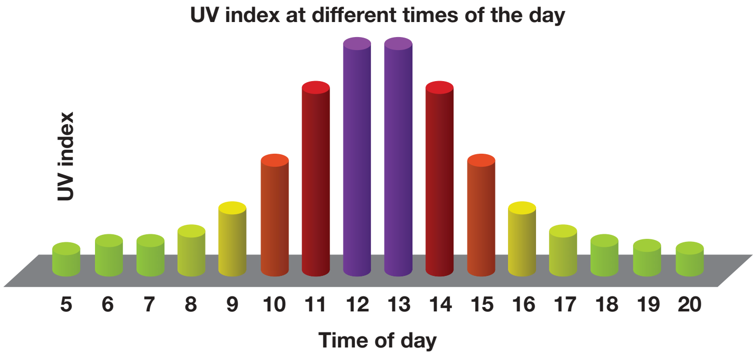


6. Use the diagram to answer the following questions.
   a. **Identify** which of the locations A, B, C, D and E are:
      i. in daylight
      ii. experiencing summer
      iii. experiencing the longest day
      iv. experiencing the shortest day.
   b. In which of the locations that are in daylight will the Sun set first?
7. **Explain** why it is usually warmer on a summer's day than on a winter's day.
8. **Explain** why there are 365 days in most years but 366 days in every fourth year.
9. **Explain**, with the aid of a diagram, why the South Pole experiences very short days during the Southern Hemisphere's winter.
10. **Explain** why both the time and position of sunrise and sunset change every day.
11. A day on Jupiter is less than 10 hours. This means it takes under 10 hours for Jupiter to complete one rotation. But this giant planet, made mostly of gas, is about 13 000 times bigger than Earth. So when it rotates, its outermost clouds move at close to 45 000 km every hour!
    a. **Identify** which planets in the solar system have the shortest and longest days.
    b. How long are these days?
    c. **Identify** which planets in the solar system have the longest and shortest years.
    d. How long are these years?

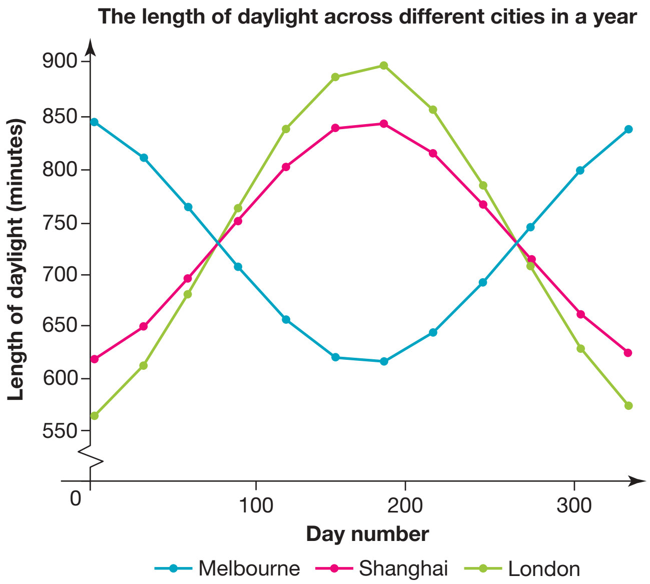
12. Brainstorm to compile a list of occupations in which day-to-day work is affected by seasonal changes. Provide a brief description of how each occupation is affected.

Evaluate and create

13. Observe the position of the shadow of a tree trunk or vertical pole every couple of hours on a sunny day.
    a. **Describe** how the shadow moves during the day from sunrise to sunset.
    b. What does the shadow tell you about the movement of the Sun and Earth?
    c. **Predict** the differences in the shadow between summer and winter.
    d. In ancient times, a vertical stick was used as a daylight clock. It was called a sundial. **Describe** the disadvantages of sundials.
14. SI The graph shows the UV index at different times on a summer day in Melbourne. (*Note:* Hours are shown in 24-hour time.)



    a. At what time is the UV index the highest?
    b. Using this graph, give the approximate time of sunrise and sunset in Melbourne on this day.
    c. **Explain** why the UV index varies throughout the day.
15. SI The graph shows the length of a day in different cities around the world in the Northern Hemisphere versus Southern Hemisphere.



    a. **Explain** why Melbourne has its longest daylight hours at the start and end of the year, while Shanghai and London experience their longest daylight hours in the middle of the year.
    b. London is closer to the North Pole than Shanghai and has a larger variation in its daylight hours. Melbourne is closer to the South Pole than Brisbane. Would Brisbane have more or less variation in its daylight hours compared to Melbourne?

Answers and sample responses are available in your digital formats.

LESSON 7.4 The Moon

LEARNING INTENTION

In this lesson you will:

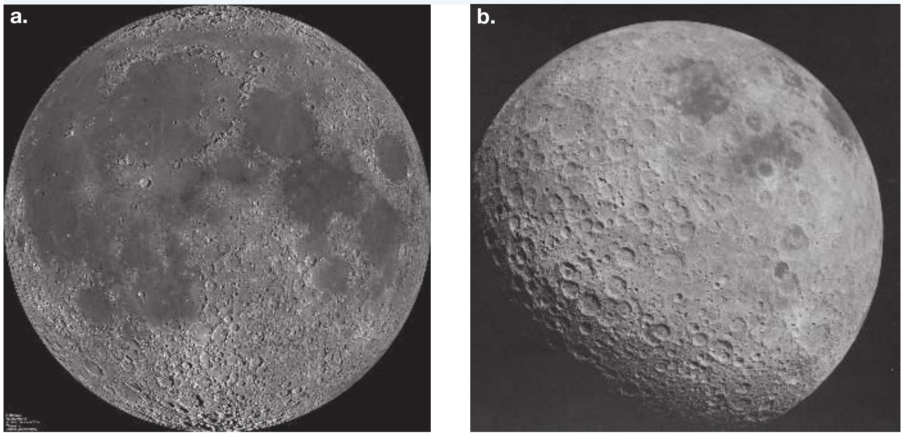
- describe the differences between the surfaces of Earth and the surface of the Moon
- describe the sequence of the phases of the Moon and explain why these phases occur.

7.4.1 Looking up from Earth

From Earth, the Moon is the brightest object in the night sky. The Moon is the only natural **satellite** of Earth. Its presence and changing appearance have raised questions, inspired myths and legends, shaped our calendar and determined the dates of some religious holidays.

The Moon takes the same amount of time to complete one full rotation around its axis as it takes to orbit Earth. For this reason, only one face of the Moon can be seen from Earth. The near side of the Moon always faces towards Earth, while the opposite side — the far side, also often called the dark side of the Moon — always faces away from Earth. The face seen from Earth is much less mountainous and rugged than the other side. Because the Moon wobbles a little during its orbit around Earth, we sometimes get a view of small parts of the far side of the Moon. However, 41 per cent of its surface is never visible from Earth.

FIGURE 7.15 a. The near side and **b.** the far side of the Moon



Unlike Earth, the Moon has no atmosphere or weather. There is no air. There is no sign of water on the surface. There is no wind and no rain, which means that there is no erosion. Therefore, the surface of the Moon has not changed for a very long time.

Profile of the Moon

- Natural satellite of Earth
- Distance from Earth: 385 000 km
- Diameter at equator: 3475 km (Earth's diameter is 12 750 km)
- Period of orbit around Earth: about 27.3 days*
- Period of rotation around its own axis: about 27.3 days
- Surface gravity: about one-sixth that of Earth
- Surface temperature: ranges from –175 °C in darkness to 125 °C in sunlight

*This period of orbit is relative to distant stars.

INVESTIGATION 7.5

Observing the Moon's surface from Earth

Aim

To observe the Moon's surface using a telescope or binoculars

Materials

- binoculars or small telescope

Method

1. Observe the Moon with a pair of binoculars or a small telescope. The best time to observe the Moon is when about half of it is visible. Craters and mountains are difficult to see when there is a full moon because they do not cast shadows.
2. Try to identify the seas (dark, smooth areas), mountainous areas and craters.

Results

Sketch and label what you see.

Discussion

1. Which features were the easiest to locate?
2. How do you think the craters were formed?

Conclusion

Summarise the differences between the surface of Earth and the surface of the Moon.

ACTIVITY: Investigating the surface of the Moon

Research online to find different views of the Moon's surface. For example, you can use the **Earth's Moon** weblink in the Resources panel to access a 3D model of the Moon's surface.

Dark areas on the Moon's surface are large flat areas called 'seas'. Small circles are craters, while non-circular areas are mountains.

1. Locate an image of the Moon showing either the North or South Pole.
2. Draw a diagram of the Moon's surface. Identify any seas, large craters or mountains in your diagram.
3. Locate an image of the Moon showing the poles at the top and bottom.
4. Draw a diagram of the Moon's surface. Label key features of your diagrams.
5. Describe the location of the craters on the Moon. Are they evenly spaced across the surface?
6. Describe the location of the 'seas' on the surface of the Moon. Are they evenly spaced across the surface?
7. Write a couple of sentences about something you found surprising about the surface of the Moon.

7.4.2 Phases of the Moon

The Moon is visible from Earth only because it reflects light from the Sun. The Sun, the Moon and Earth rarely line up in a straight line, which means sunlight can almost always reach the Moon.

When Earth is between the Sun and the Moon, the side of the Moon facing Earth is completely bright. At night, the whole bright side of the Moon is visible. You see a **full moon**.

When the Moon is between the Sun and Earth, the side of the Moon facing Earth is facing away from the Sun and in complete darkness. At night, the Moon is not in the right place to be seen and it does not appear in the sky at all. This is a **new moon**. When the side of the Moon visible from the Earth is partially bright and partially in shadow, only the bright part can be seen. The Moon can look like a crescent, a semi-circle or a lopsided circle. These different shapes of the Moon are called **phases**. Figure 7.16 shows how the phases change during one complete cycle. The time between one full moon and the next is referred to as a **lunar month**.

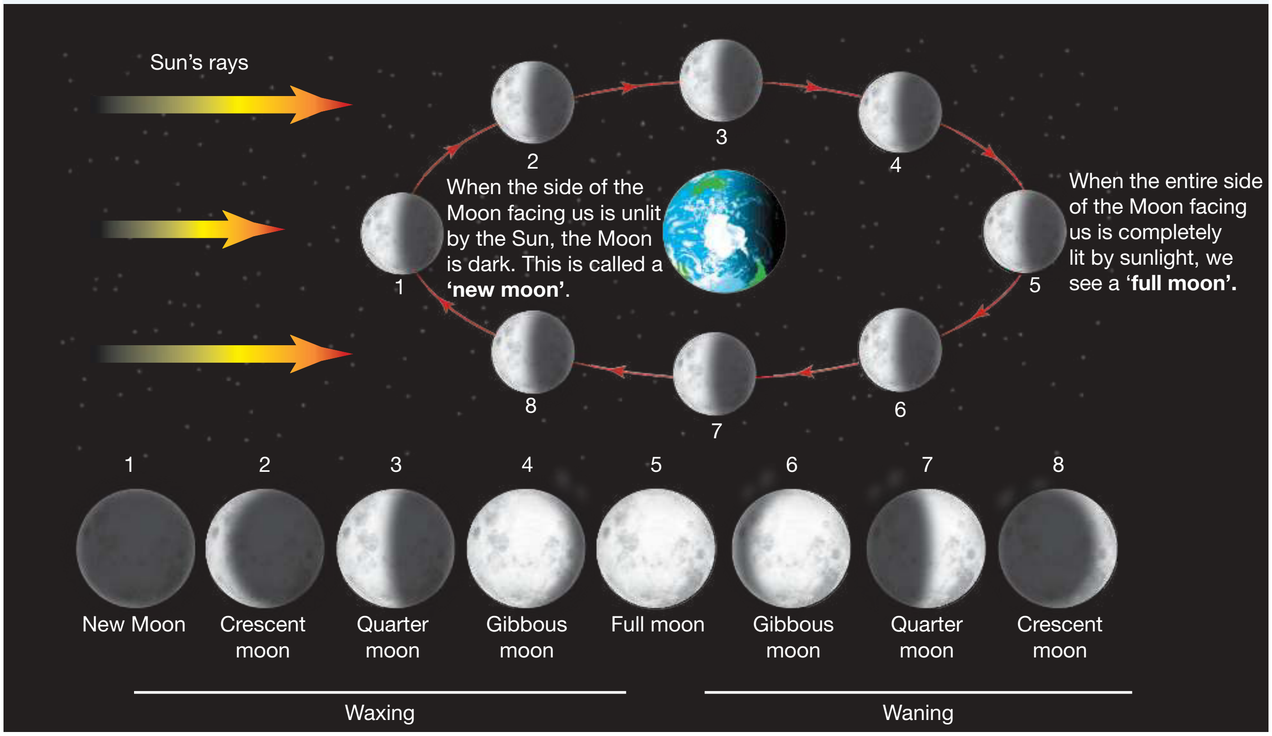
KEY IDEA

The phases of the Moon are caused by the relative positions of the Earth, Sun and Moon.

The actual appearance of the Moon varies a little depending on where exactly in Australia you are. The closer you are to the equator, the more the phases will be like those shown in the diagrams in figure 7.16. Further south, in Victoria or Tasmania for instance, the divide between the bright and dark parts of the first quarter moon and last quarter moon will not be vertical.

During the period between a new moon and a full moon, the Moon is said to be **waxing**. More and more of the bright part of the Moon becomes visible. As the phases change between the full moon and the new moon, it is said to be **waning**. Less and less of the bright part of the Moon is visible.

FIGURE 7.16 As it rotates around Earth, the Moon cycles through different phases.



DISCUSSION

Why can you sometimes see the Moon during the day? Where is the Moon when you can't see it? Discuss this with your classmates.

INVESTIGATION 7.6

Modelling the phases of the Moon

Aim

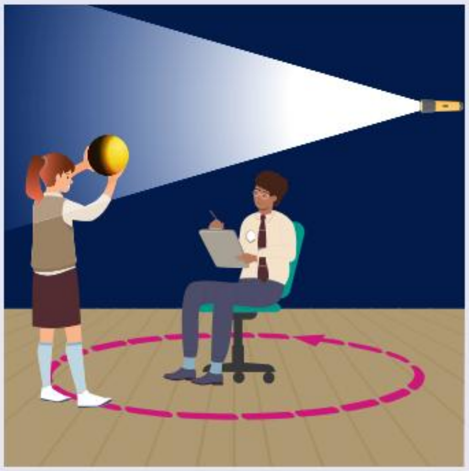
To model the phases of the Moon

Materials

- projector or spotlight
- large, light-coloured ball

Method

1. Select one student to act as Earth and another to hold the ball representing the Moon.
2. Darken the room and aim the projector (the Sun) at the ball (the Moon). The student holding the ball walks around 'Earth' slowly in an anticlockwise direction, holding the same side towards 'Earth'.
3. Try to identify each of the eight phases of the Moon, as they are seen by the person representing Earth. Stop rotating briefly when each of the phases is identified so that the positions of the 'Sun', 'Earth' and 'Moon' can be recorded.



Results

Draw a diagram to show the positions of the 'Sun', 'Earth' and 'Moon' that result in a:

a. full moon
b. gibbous moon
c. quarter moon
d. crescent moon
e. new moon.

There may be multiple options for some.

Discussion

1. Explain why the appearance of the Moon varies when we see it from Earth.
2. Explain why the Moon is not visible at night during a new moon.

Conclusion

Write three or four sentences describing what causes the phases of the Moon.

7.4 Activities

learnon

7.4 Quick quiz (on)	7.4 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 6	3, 5, 9	4, 7, 8

Remember and understand

1. During which phase of the Moon is it:
   a. between the Sun and Earth
   b. on the opposite side of Earth from the Sun?
2. **Define** a lunar month.
3. **Explain**, with the aid of a diagram, how a quarter moon occurs.
4. Sometimes the Moon appears as a semi-circle. **Explain** why this is called a quarter moon.

Apply and analyse

5. Sometimes the Moon is visible during the day.
   a. **List** the phases of the Moon that are most likely to be seen during the day.
   b. Would it be possible to see a full moon during daylight hours? **Explain** your answer.
6. Draw a clear diagram or make a flowchart to show how the phases of the Moon occur.

7. SI a. Using the information in the table, draw a graph of the percentage of the Moon's surface that is visible against the day of the month.

Percentage of the Moon's surface visible from Earth

Day of the month	Percentage of the Moon's surface visible from Earth
1	96
3	100
5	93
8	67
12	23
15	2
16	0
19	10
23	50
25	72
30	100
31	97

b. Using your graph, determine the phase of the Moon on:
  i. day 11
  ii. day 16
  iii. day 25.
c. Using your graph, determine the day on which the Moon would be a:
  i. full moon
  ii. waning gibbous moon
  iii. first quarter moon.

Evaluate and create

8. SI **Define** a blue moon.
9. **Describe** a harvest moon.

Answers and sample responses are available in your digital formats.

LESSON 7.5 Eclipses

LEARNING INTENTION

In this lesson you will describe the cause of solar and lunar eclipses, and draw diagrams showing the relative positions of Earth, the Sun and the Moon during eclipses.

7.5.1 Lunar eclipses

Any object that you cannot see through casts a shadow when the Sun shines on it. Earth and the Moon both cast shadows into space. Most of the time, nothing is in the region of the shadow and, therefore, we do not notice it. A **lunar eclipse** occurs when the Moon passes into Earth's shadow. The Moon no longer receives any light from the Sun and it can't be seen from the surface of Earth. This can happen only during a full moon, when Earth lies between the Sun and the Moon. When the entire Moon passes through the shadow of Earth (also known as the **umbra**), a total lunar eclipse occurs.

A total lunar eclipse is usually called a blood moon, because the Moon has a red tinge (see figure 7.17). This is caused by red light from the Sun bending (or diffracting) around Earth and reaching the Moon. When only a section of the Moon passes through Earth's shadow, a partial lunar eclipse occurs because only a portion of the light is blocked by Earth. During a partial lunar eclipse, the visible part of the Moon will be less bright than normal, because some of the light from the Sun is being blocked, but not all. This area is called the **penumbra**.

FIGURE 7.17 Earth's shadow makes the Moon change shape during a total lunar eclipse. Note the red tinge of the Moon at the height of the eclipse. This looks like the Moon is changing phase but the reason for the different shapes is different from the reason for phase changes.

Lunar eclipses occur more often than solar eclipses. However, the Moon's orbit around Earth is tilted, so it does not pass through Earth's shadow every time there is a full moon (see figures 7.18 and 7.19).

KEY IDEA

Eclipses happen when Earth, the Moon and the Sun line up and the shadow of Earth falls on the Moon, or the shadow of the Moon falls on Earth.

FIGURE 7.18 Total lunar eclipse

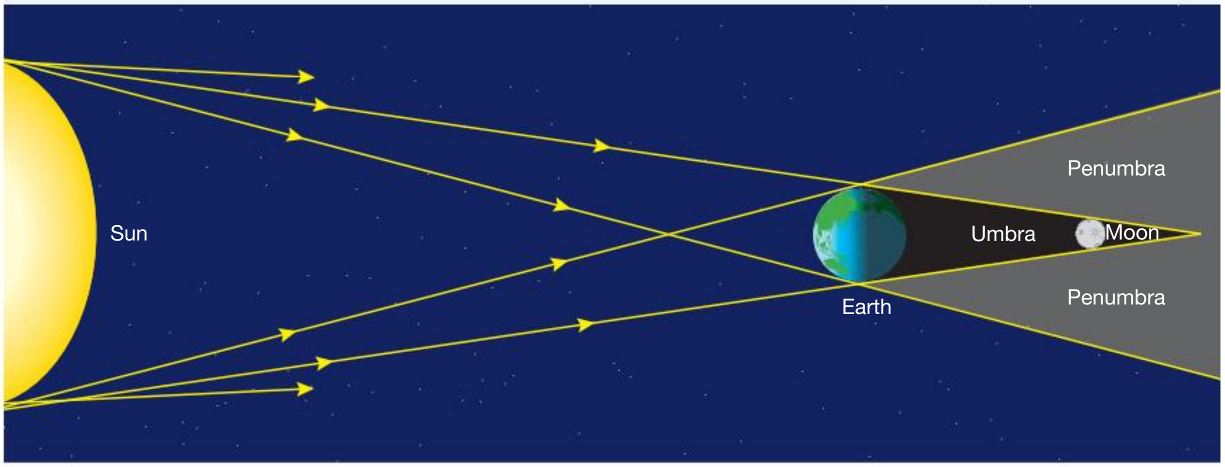
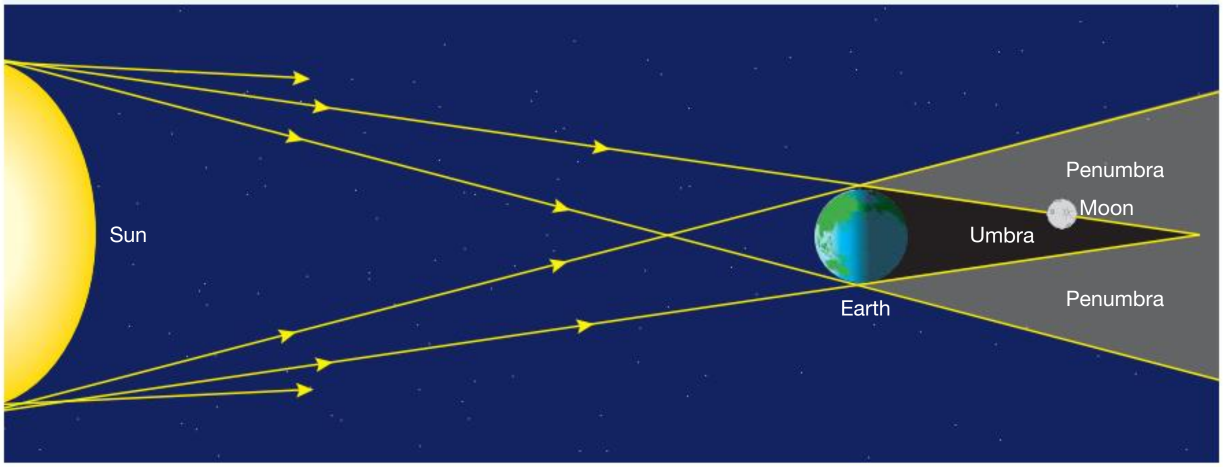


FIGURE 7.19 Partial lunar eclipse



INVESTIGATION 7.7

Modelling a lunar eclipse

Aim

To model a lunar eclipse

Materials

- projector
- globe
- tennis ball attached to string

Method

1. Darken the room and aim a beam of light from the projector onto the globe, to represent the Sun illuminating Earth.
2. Suspend the tennis ball (representing the Moon) on the opposite side of the globe from the projector, so that it is partly within the shadow of the globe (this shadow represents Earth's umbra).
3. Slowly move the tennis ball along a circular path around the globe, to simulate the Moon's orbit around Earth. Observe how the shadow moves across the tennis ball during this motion.
4. *Optional:* Rotate the globe gently as you move the tennis ball, to demonstrate Earth's rotation as part of the system.

Results

1. Draw a diagram showing the initial positions of Earth, the Moon and the Sun in your model of a lunar eclipse.
2. Observe and describe how the shadow moves across the tennis ball as it travels along its orbit. Does the shadow cover the tennis ball completely, or does some light still reach it?
3. Draw a final diagram illustrating the position of the Moon when it is fully within Earth's shadow (a total lunar eclipse).

Discussion

1. Identify the phase of the Moon when a lunar eclipse occurs. Explain your choice.
2. If the Moon (tennis ball) is moved closer to Earth or further away from Earth, would lunar eclipses happen more or less often? Give a reason for your answer.

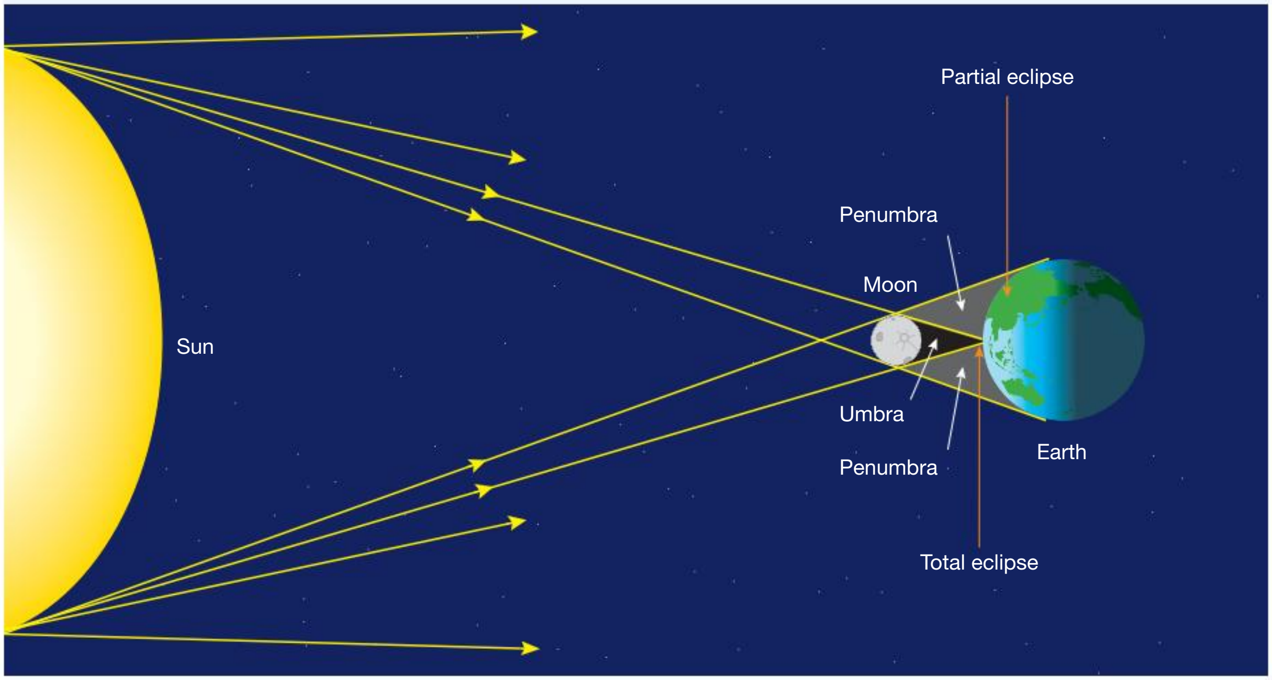
Conclusion

Write a summary explaining how the motion of the Moon and the Sun creates lunar eclipses.

7.5.2 Solar eclipses

Sometimes, when the Moon passes between Earth and the Sun, the Moon's shadow falls on Earth. The part of Earth in the shadow experiences a **solar eclipse** (see figure 7.20).

FIGURE 7.20 Total and partial solar eclipses



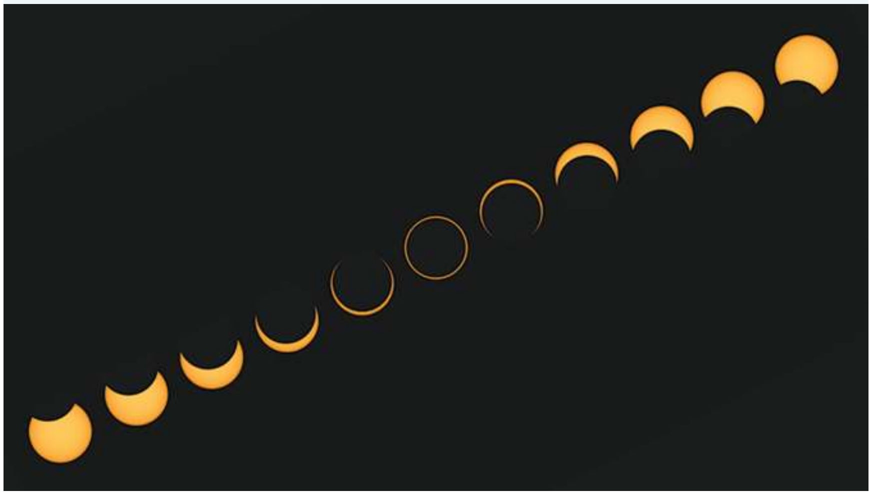
Total solar eclipse

The shadow cast by the Moon during an eclipse is not sharp; it has a fuzzy or partially dark edge. Most of the shadow is only partially dark; only the centre of the shadow is in total darkness. Even though the Moon passes between the Sun and Earth every 29.5 days, solar eclipses do not occur very often. Usually the whole shadow passes above or below Earth. If the dark centre of the shadow falls on Earth, that part of Earth experiences a **total solar eclipse**.

During a total solar eclipse, the area in the dark centre of the shadow becomes completely dark, as if it were night-time. The Sun is completely blocked out, as seen in figure 7.21.

The latest total solar eclipse to affect Australia touched the Western Australian coast at Exmouth in April 2023. The next total solar eclipse will happen in July 2028 and will cross a narrow band from the Kimberley in Western Australia all the way to Sydney.

FIGURE 7.21 A total solar eclipse — the Sun's light is blocked



Partial and annular solar eclipses

Partial solar eclipses (see figure 7.22) and **annular solar eclipses** (see figure 7.23) are much more common than total solar eclipses. A partial solar eclipse is experienced in areas on the surface of Earth where only part of the Sun is blocked out completely. The rest of the Sun will appear less bright than it normally does because it will be in the penumbra of the Moon's shadow. Not enough of the Sun is blocked out to cause darkness. An annular eclipse occurs when the Moon blocks out the central part of the Sun, leaving a ring (called an annulus) of light from the outer part of the Sun, which is visible from Earth.

FIGURE 7.22 A partial solar eclipse

FIGURE 7.23 An annular eclipse

Solar eclipses are extremely useful to astronomers because the outer part of the Sun, known as the corona, can be seen. The corona is normally not visible because of the brightness of the rest of the Sun. However, during a total solar eclipse, the rest of the Sun's light is blocked out by the Moon. The corona can then be successfully photographed and studied.

CAUTION

You must *never* look directly at an eclipse of the Sun — even a partial eclipse. You could permanently damage your eyes. Sunglasses will not protect you; you must use eclipse glasses, which reduce light down to safe levels.

INVESTIGATION 7.8

Fuzzy shadows

Aim

To investigate the creation of sharp and fuzzy shadows

Materials

- torch
- white card or a bare wall to act as a screen
- coin

Method

1. Use a torch to cast light on a white card or bare wall. Observe the shadow of a coin as you move it between the light source and screen.
2. Create sharp shadows and fuzzy shadows.
3. Create a shadow that is dark in the centre and partially dark on the outside. This is the type of shadow cast on Earth by the Moon.

Results

1. Where does the coin need to be to create a sharp shadow?
2. Where does the coin need to be to create a fuzzy shadow?
3. Draw a diagram of the shadow that is dark in the centre and partially dark on the outside. Label the torch, coin, umbra and penumbra on your diagram.

Discussion

1. Describe the position of Earth, the Moon and the Sun during a total solar eclipse.
2. Explain why the shadow is fuzzy. Would you expect this in a partial solar eclipse?

Conclusion

Write a summary to describe what kind of shadow the Moon casts on Earth during a total solar eclipse.

7.5 Activities

learnon

7.5 Quick quiz on	7.5 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2	3, 5	4, 6

Remember and understand

1. **Compare** a solar eclipse and a lunar eclipse.
2. **State** why you must never look directly at a solar eclipse.

Apply and analyse

3. **Explain** why total solar eclipses are much less frequent than partial solar eclipses.
4. **Explain** why a total lunar eclipse occurs only when there is a full moon, and why a solar eclipse occurs only when there is a new moon.

Evaluate and create

5. Is the image showing a lunar eclipse or a solar eclipse? **Justify** your response.

6. Draw diagrams showing the positions of Earth, the Sun and the Moon during a solar and a lunar eclipse. Write a brief explanation for each diagram.

Answers and sample responses are available in your digital formats.

LESSON 7.6 Tides

LEARNING INTENTION

In this lesson you will explain the causes of tides on Earth and describe the relative effect of the Moon's and Sun's gravitational pulls on the size of high and low tides.

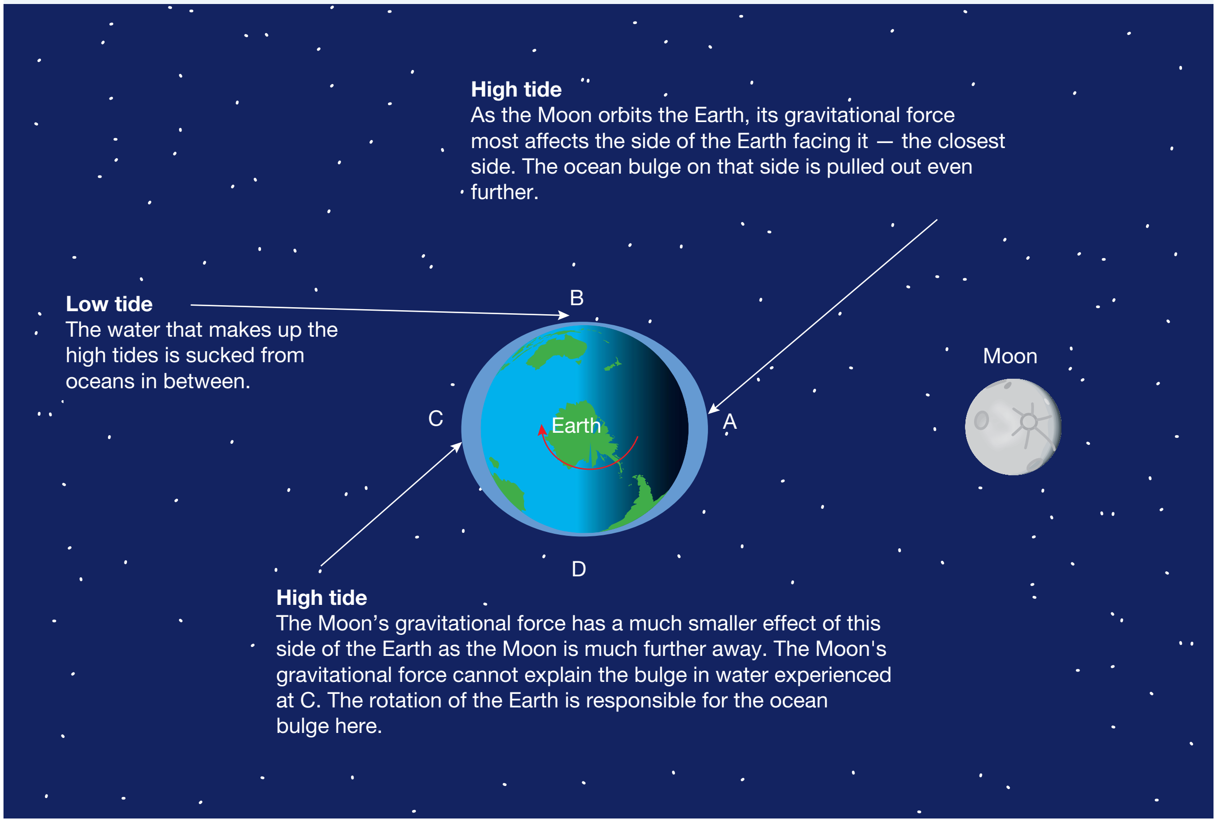
7.6.1 Tides and the Moon

If you have lived near or visited coastal areas, you will know that the level of the water rises and falls. These changes in the water level are called **tides**. These tides occur for a number of reasons, mostly due to the gravitational force of the Moon.

Figure 7.25 shows a view of Earth from above the South Pole. The red arrow shows the direction of Earth's rotation. The oceans at A, closest to the Moon, are pulled more strongly towards it, taking water away from B and D. The result is that A is a region of high tide while B and D are regions of low tide. As Earth rotates, different places on Earth move through A, B and D, and experience a high tide at A and low tides at B and D. However, places on Earth experience two high tides and two low tides a day; the Moon's gravitational force can only explain one high tide.

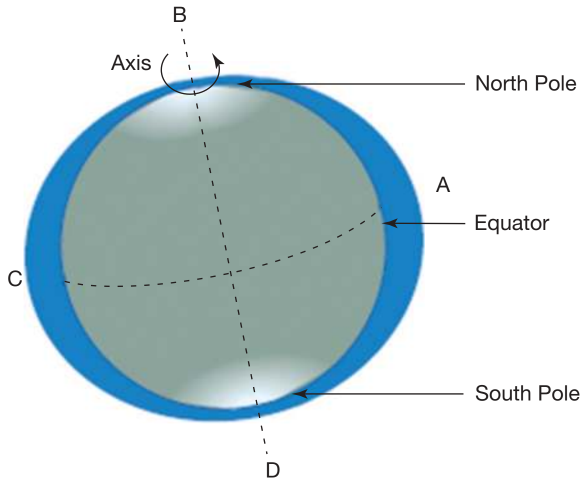
FIGURE 7.24 Low and high tides at Lorne, Victoria. Between these two tides the water level rose vertically by 2.6 m, but stretched horizontally much further along the beach.

FIGURE 7.25 Looking down on Earth from above the South Pole — as Earth rotates once, each place on Earth experiences two high tides and two low tides.



Because the Earth rotates on its axis, the oceans bulge near the equator. This bulge is shown in figure 7.26. This effect is just like that in the spin-dryer of a washing machine. As it spins, the water in the oceans moves away from the surface of Earth. The ocean water doesn't leave Earth's surface because it is pulled back by Earth's gravitational force. This effect is stronger than the effect of the Moon's gravitational force on the side of Earth opposite the Moon (point C in figure 7.25), creating a second high tide.

FIGURE 7.26 The rotation of Earth would cause a permanent bulge all the way around the equator if it were not for the Sun and the Moon.



SCIENCE INQUIRY: Understanding tides and the Moon's influence

Tides are the daily rise and fall of sea levels, primarily caused by the Moon's gravitational pull. Observing and understanding these changes help scientists explain the relationship between celestial forces and Earth's natural cycles

How do tides work?

The Moon's gravity pulls on Earth's oceans, creating bulges of water known as high tides, at the closest and farthest points from the Moon. The areas perpendicular to these bulges experience low tides. As Earth rotates, different locations move through these high and low tide regions, resulting in two high tides and two low tides each day.

The gravitational pull of the Moon explains one high tide, but the second high tide is caused by the Earth being pulled slightly toward the Moon, leaving another water bulge on the opposite side of the planet.

Tides are influenced by other factors as well, such as:

- the Sun's gravity (though less than the Moon's)
- the shape of coastlines and ocean basins
- the relative positions of the Earth, Moon and Sun (spring tides and neap tides occur during specific alignments).

Observing tide data

Analyse tide data from a coastal location over several days and connect it to the Moon's phases:

- Use an online tide chart to gather high and low tide times and heights.
- Record the Moon's phase on each observation day.
- Graph the tide changes alongside the Moon's phases to identify patterns.

Why study tides?

Understanding tides has practical applications, such as:

- predicting tidal patterns for fishing and boating
- managing coastal ecosystems and protecting shorelines
- understanding the impact of celestial forces on Earth.

1. Why do some areas experience larger tidal differences than others?
2. How might the Moon's phases (new moon or full moon) impact the height of tides?

Information and processed data can be analysed to show patterns, trends and relationships, and to identify anomalies (VC2S8I05)

7.6.2 The effect of the Sun

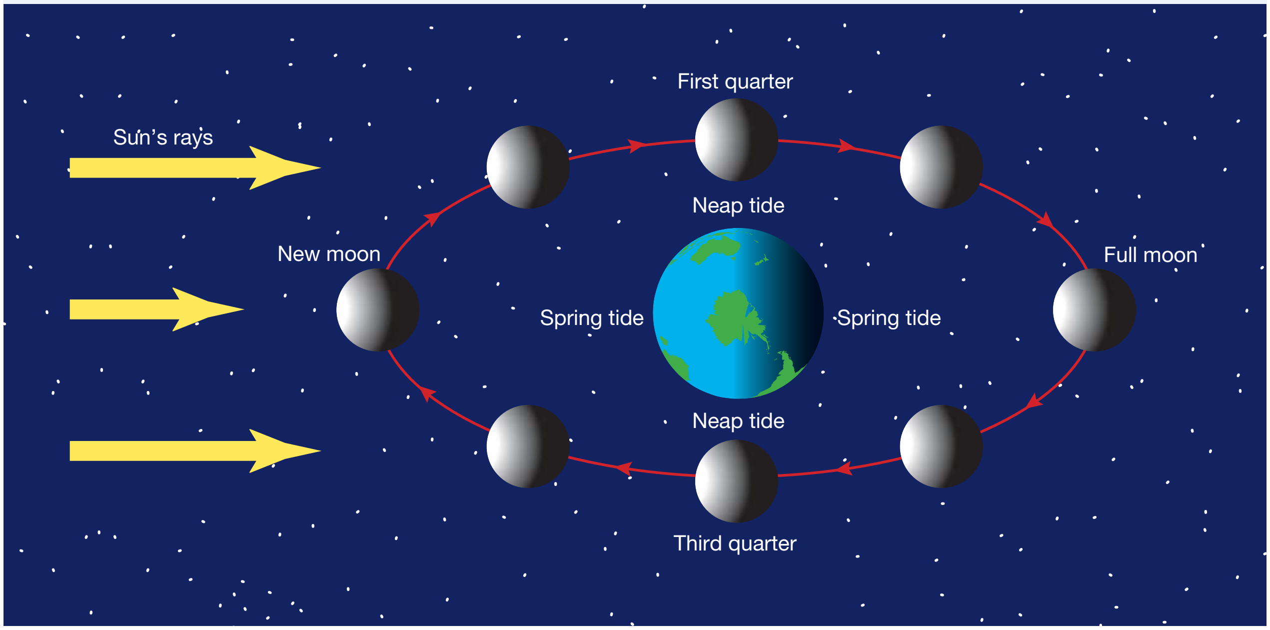
The Sun also influences the tides. However, because it is further away, its gravitational force has much less effect than the Moon's. Even though the mass of the Moon is 27 million times less than that of the Sun, its gravitational force on the water on Earth is greater because it is so much closer to Earth.

When the Sun is on the same side of Earth as the Moon, its gravitational force adds to the gravitational force of the Moon. When it is on the opposite side, its gravitational force assists the rotation of Earth to create the second bulge of water, and higher tides than normal are experienced. These tides are called **spring tides**. They occur when there is a full moon or a new moon when the Sun, Earth and the Moon are lined up.

KEY IDEA

Tides are the result of the gravitational pull of both the Moon and the Sun on water on the surface of Earth.

FIGURE 7.27 During each orbit of the Moon around Earth (29.5 days), there are two spring tides and two neap tides.



About 7 days after a spring tide, the Sun and the Moon are no longer in the same line as Earth. The gravitational pull of the Sun is at right angles to the gravitational pull of the Moon. The gravitational pull of the Sun and the Moon work against each other; this means that the high tides are not as high as usual and the low tides are not as low as usual. These 'weaker' tides are called **neap tides**. They occur when there is a quarter moon.

ACTIVITY: Tides roleplay

In groups of at least four students, create a roleplay to illustrate how the movement of Earth around the Sun, and the Moon around Earth, causes tides. One student can act as a narrator to provide commentary during the roleplay.

7.6 Activities

learnon

7.6 Quick quiz on	7.6 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 5, 9	2, 4, 7, 10	3, 6, 8

Remember and understand

1. **State** the major cause of tides on Earth.
2. **State** the number of high and low tides expected each day.
3. Even though the Sun is much larger than the Moon, it has much less effect on the tides. **Explain** why this is.

Apply and analyse

4. **Explain** why the highest tides (spring tides) occur during a new moon or a full moon.
5. If the Moon did not exist, would there still be tides? If so, how would they be different?
6. **Explain** how the tides would be different if Earth did not rotate.

Evaluate and create

7. Draw a well-labelled diagram that shows one arrangement of the Sun, the Moon and Earth that would cause a neap tide.
8. On any given day, one high tide is higher than the other. **Explain** why this happens.
9. SI Use the information in the table to plot a graph of the high and low tide levels at Portland beach during April 2024.

High and low tide at Portland beach

Date	Highest tide (m)	Lowest tide (m)
Tuesday 2 April	1.24	0.18
Friday 5 April	1.18	0.23
Tuesday 9 April	1.09	0.25
Saturday 13 April	1.09	0.31
Wednesday 17 April	1.29	0.14
Sunday 21 April	1.16	0.23
Thursday 25 April	1.02	0.36
Monday 29 April	1.07	0.27

10. Use the information in the table to answer the questions that follow.

High tide and low tide during July

		High tide 1	Low tide 1	High tide 2	Low tide 2
Monday 1 July	Time	12:32	6.27		18.11
	Height (m)	1.41	0.37		0.62
Friday 5 July	Time	3:59	10:35	16:55	22:49
	Height (m)	1.60	0.51	1.46	0.69
Tuesday 9 July	Time	7:14	1:19	19:39	13:15
	Height (m)	1.52	0.54	1.71	0.51
Saturday 13 July	Time	9:47	3:50	21:53	15:24
	Height (m)	1.41	0.49	1.76	0.61

Wednesday 17 July	Time	12:47	6:45		18:15
	Height (m)	1.28	0.60		0.79
Sunday 21 July	Time	3:48	10:20	16:42	22:41
	Height (m)	1.56	0.49	1.53	0.66
Thursday 25 July	Time	3:59	10:35	16:55	19:56
	Height (m)	1.66	0.32	2.02	0.34
Monday 29 July	Time	11:19	5:14	23:23	16:58
	Height (m)	1.48	0.27	1.95	0.55

a. **Identify** when the first low tide occurred on Thursday 25th July.
b. How long was the period between the first low tide and the first high tide on Saturday 13th July?
c. There was no second high tide on Monday 1st July or Wednesday 17th July. It occurred early the next morning. **Predict** the time of the first high tide on Tuesday 2nd July.

Answers and sample responses are available in your digital formats.

LESSON 7.7 Aboriginal and Torres Strait Islander Peoples' astronomy knowledge and understanding

LEARNING INTENTION

In this lesson you will investigate Aboriginal and Torres Strait Islander Peoples' knowledge systems of astronomy, including phases of the Moon, solar and lunar eclipses, seasonal calendars and tides.

7.7.1 The oldest astronomers in the world

Aboriginal and Torres Strait Islander Peoples have continuously inhabited this continent for at least 65 000 years. Together they are the oldest human civilisation, and the oldest astronomers in the world. They developed different ways of observing and recording the movements of the Sun, the Moon and the stars. This knowledge has been passed down through generations using song, dance, ceremony and storytelling.

FIGURE 7.28 The stars over the Australian outback

Records of Aboriginal and Torres Strait Islander Peoples' beliefs indicate that knowledge and understanding of the night sky varied across Victoria and Australia. Some groups, but not all, had a clear understanding that solar eclipses were caused by the Moon blocking light from the Sun. In some areas, people knew the difference between stars and planets, and carefully recorded the appearance of comets, meteor showers and other changes to the night sky. Some of these observations match records from other countries.

Aboriginal and Torres Strait Islander Peoples were keen observers of the night sky and created many stories to explain what they saw. The Sun appears in many stories as a kind, female creator spirit and the Moon as a bad, male creator spirit. Cultural stories were different in different parts of Victoria and included local animals and events to explain eclipses and the phases of the Moon.

SCIENCE AS A HUMAN ENDEAVOUR: The earliest astronomers

Many ancient cultures have stories about how the universe was created, what it was like and how Earth, the Sun, the Moon, the planets and the stars were made, as well as why the stars form different shapes in the night sky. Aboriginal and Torres Strait Islander Peoples tell stories from thousands of years ago that explain the stars, the Sun and the Moon. The shapes of groups of stars in the night sky and the stories about them are passed on from generation to generation. The stories and the shapes of the groups of stars vary between different peoples.

Magic water and eternal life

The Wurundjeri people from the Melbourne area explain the phases of the Moon through a story about Menyan, the Moon. Menyan wanted to help people live forever and gave them a drink of his magic water when they died. The bronze-winged pigeon, Mongbarra, did not like this and believed that people's lives should stop when they died. Mongbarra's magic was stronger than Menyan's. Mongbarra stopped the magic water from working on people, but it still works on Menyan. Every month when Menyan dies, he drinks his magic water and comes back to life.

Chopped to bits

The Yolŋgu Peoples of Arnhem Land (Northern Territory) explain the phases of the Moon with the story of Ngalindi and his wives. At the time of the full moon, Ngalindi is a fat lazy man. His wives punish him by attacking him with an axe, and he is seen as a waning moon as parts of him are chopped off. Unable to escape his wives, Ngalindi dies of his wounds, and this is the time of the new moon. He rises from the dead after three days and is seen as the waxing moon as he again grows round and fat. Two weeks later, his wives punish him again, and the cycle repeats.

1. How do stories like those of the Wurundjeri and Yolŋgu Peoples provide insight into how ancient cultures explained natural phenomena like the Moon's phases? Why is it important to study these stories alongside scientific explanations?
2. Different groups of Aboriginal and Torres Strait Islander Peoples interpret the stars and the Moon in unique ways. How can learning about these interpretations deepen our understanding of astronomy and human connections to the universe?

Multidisciplinary endeavours to advance scientific knowledge make use of people's different perspectives and worldviews (VC2S8H02)

Many Aboriginal and Torres Strait Islander Peoples' records indicate that different communities had a complex understanding of the movements of Earth, the Sun and the Moon. For instance, several communities understood that solar eclipses were caused by the Moon blocking the Sun, and that tides were linked to lunar phases.

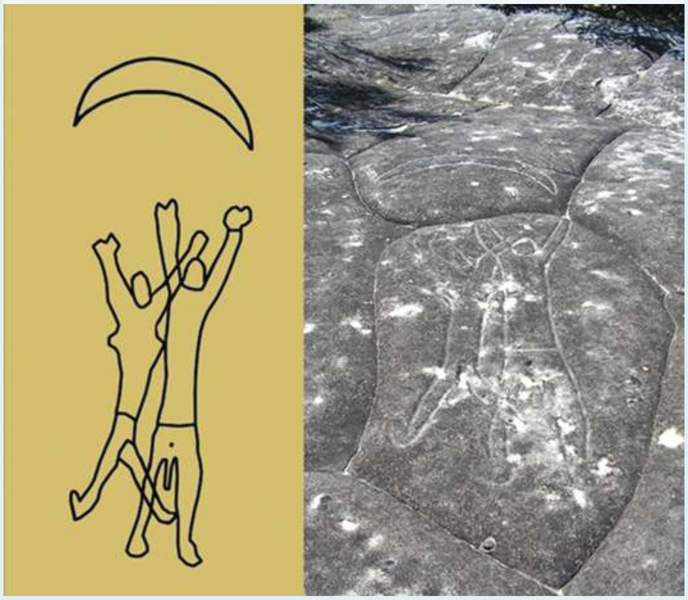
Many other civilisations in the ancient world (such as the Ancient Greeks, or the Incas) viewed eclipses as bad omens. For some Aboriginal and Torres Strait Islander cultures, solar and lunar eclipses were considered negative and linked with disease and death.

Several (but not all) Aboriginal and Torres Strait Islander cultures identify the Sun as a kind female creator spirit — the Sun-woman — and the Moon as a bad male creator spirit — the Moon-man — and different communities have different stories explaining eclipses as well as the phases of the Moon.

ACTIVITY: Working out the meaning of the 'eclipse' rock carving at the Basin Track, Ku-ring-gai Chase National Park, New South Wales

1. Observe the engraving shown in figure 7.29. What do you think the crescent shape represents?

FIGURE 7.29 A rock engraving from the Ku-ring-gai Chase National Park, New South Wales

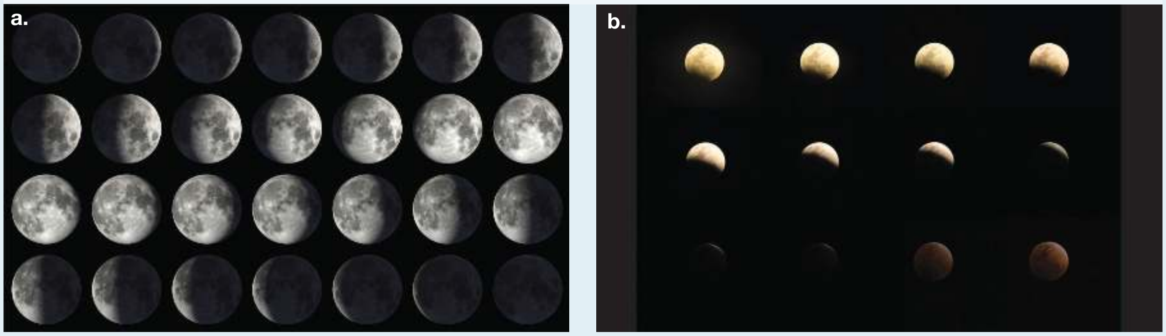


2. Compare and contrast the crescent shape in figure 7.29 with the different boomerang shapes shown in figure 7.30. Does it look like a boomerang? Do you know which shape(s) of boomerang the traditional owners of Ku-ring-gai used?

FIGURE 7.30 Boomerangs come in a variety of shapes.

3. Compare and contrast the crescent shape in figure 7.29 with the appearance of the Moon throughout a lunar cycle (see figure 7.31a) and during a lunar eclipse (see figure 7.31b). Could the crescent represent the Moon?

FIGURE 7.31 a. Appearance of the Moon throughout a lunar month **b.** Timelapse of the 2018 total lunar eclipse from Thailand



4. Research other rock paintings or engravings from Australia that are connected to astronomy. Create a poster for your classroom with the information you found.

7.7.2 Predicting seasonal changes

Aboriginal and Torres Strait Islander Peoples' seasons are organised differently from the traditional four-season calendar used today. By observing the movement and position of stars, Aboriginal and Torres Strait Islander Peoples developed seasonal calendars with many different seasons based on changes to the environment, plant and animal life cycles, and the availability of different foods. The properties of stars, such as their brightness and colour, are also used for predicting weather and seasonal changes. This information has been passed down through the generations and is still being used today.

In many Aboriginal and Torres Strait Islander Peoples' traditions, each season was indicated by the emergence of an important star or a group of stars in the sky. For example, the star cluster known as Seven Sisters, or Pleiades, is linked to whale migrations along the east coast; its first appearance before dawn signals the start of winter and the beginning of whales' migration towards Antarctica, while its last appearance before dawn marks the time when whales will come back with their calves.

Each seasonal calendar has been developed over thousands of years for a specific environment by the community living there. This knowledge is therefore linked to the land. For instance, for communities living in the central desert, the first rise of the Seven Sisters doesn't indicate the start of whale migration but marks the ideal time to look for dingo pups, because it coincides with the peak in dingo breeding season. For Torres Strait Islander Peoples, the Pleiades is known as Baidam, the Shark Constellation, and is associated with the start of the shark mating season.

SCIENCE AS A HUMAN ENDEAVOUR: Origin stories

The availability of ant larvae

The Boorong People of north-west Victoria tell a story about Marpeankurrk, an ancestor who lived during a drought when food was hard to find. Marpeankurrk kicked over a log while looking for food and found some ant larvae. He thought the ant larvae were delicious. The Boorong People called a star marpeankurrk — when the star can be seen in the night sky, they know they can collect ant larvae to eat.

The emu in the sky

Rock engravings carved by the Guringai Peoples of the northern outskirts of Sydney show an emu in the same pose and orientation as the 'emu in the sky' constellation that stretches from its head in a dark patch of the Southern Cross through the cloud-like band of stars that we call the Milky Way. Their story explains that when the real emu in the sky is directly above the engraving, it signals that it is emu egg-laying season and it is time to gather the eggs. Another explanation from the Papunya Peoples in the Northern Territory tells the story of an old blind man who speared the emu and sent it to the Milky Way after it killed his wife while protecting its eggs.

FIGURE 7.32 The 'Emu in the Sky' constellation rising over the Tasman Sea from a beach near Lakes Entrance, Victoria

1. How do the stories of Marpeankurrk and the emu in the sky demonstrate the use of the natural world, like stars and constellations, as a way for Aboriginal and Torres Strait Islander Peoples to understand seasonal changes and resource availability?
2. How might studying these stories and the associated astronomical observations help modern scientists and environmentalists understand and predict natural cycles?
3. Why is it important to respect and incorporate Aboriginal and Torres Strait Islander Peoples' knowledge into science education?

Multidisciplinary endeavours to advance scientific knowledge make use of people's different perspectives and worldviews (VC2S8H02)

7.7.3 Understanding the tides

Aboriginal and Torres Strait Islander Peoples have observed the lunar phases for a long time, and understood the relationship between different phases of the Moon and the tides, and their effect on the environment around them.

Communities living on the coast, such as the Yolŋgu Peoples in north-eastern Arnhem Land, tend to have an evidence-based understanding of how the tides are linked to the Moon phases, and can precisely predict the time and height of the next tide from the position of the Moon. This knowledge is used to inform hunting, fishing and agricultural practices. For example, Torres Strait Islander Peoples know it is safer to dive on reefs to look for lobsters during a neap tide, when the tidal currents are reduced and the visibility is better, than during a spring tide. Spring tides, which occur during full and new moon phases, are better periods to catch fish because they are more active (see lesson 7.6 for more information on tides). However, in estuaries and shallow waters, stronger tidal currents during spring tides also mean more suspended sediments in water, preventing you from seeing the fish, or the fish from seeing your lure if you plan to go spearfishing or lure fishing. For the Bardi Peoples of the Kimberley region (Western Australia), their understanding of the link between the lunar cycle and the tides enables them to successfully determine when to collect shells and when to fish.

ACTIVITY: Stone-walled intertidal fish traps

Use the internet or other resources to research stone-walled fish traps used by Aboriginal and Torres Strait Islander Peoples and write a short paragraph explaining how tides are used to trap fish.

ACTIVITY: Using solunar charts to determine when to go fishing

Solunar charts are based on the relative positions of the Sun and the Moon and their effect on Earth's tides, and are used to predict the best days of the month and times to catch fish. Research online to find solunar information for a location in Victoria. For example, you can use the **Solunar information** weblink in the Resources panel to access current data.

1. Write down the time of moonrise and of the lunar transit (when the Moon reaches its maximum height).
2. Write down the best times for fishing.
3. Compare the times. What do you notice about the movement of the Moon across the sky and the best times to fish?
4. Choose a date 2 or 3 days in the future. Do the same comparison.
5. Write a short paragraph explaining why knowledge of the Moon's movements helped Aboriginal and Torres Strait Islander Peoples go fishing.
6. Create a table showing the phase of the Moon and the solunar theory fishing prediction. Include at least one month of dates in your table. Comment on your results. Is there a link between the Moon phase and fishing?

7.7 Activities

learnon

7.7 Quick quiz on	7.7 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2	3, 6	4, 5

Remember and understand

1. **Describe** the meaning of the emu in the sky to the Guringai Peoples of New South Wales.
2. How do the Yolŋgu Peoples of Arnhem Land explain the phases of the Moon?
3. Besides Dreaming stories that are still told today, **list** evidence that Aboriginal and Torres Strait Islander Peoples studied the night sky.

Apply and analyse

4. Use the following solunar chart for Cairns to answer the following questions.

Cairns solunar chart

Day	Moon phase	Tidal range (m) between 1st tide and 2nd tide	Tidal range (m) between 3rd tide and 4th tide	Type of tide
1	●	2.1	1.9	Spring
9	◐	1.2	0.4	Neap
16	○	2.0	2.1	Spring
23	◑	1.5	1.1	Neap
30	●	1.6	2.1	Spring

a. **Identify** when it would be safer to snorkel near Cairns. **Explain** your reasoning.
b. You can organise a fishing trip either on day 23 or on day 30. If your goal is to catch fish, **explain** which is the better choice.

Evaluate and create

5. Write about other traditional astronomy knowledge of your local Aboriginal Peoples, or a people you have a connection to.
6. **Explain** why it can be difficult to interpret the meaning of Aboriginal and Torres Strait Islander Peoples' rock art or engravings.

Answers and sample responses are available in your digital formats.

LESSON 7.8 Review

7.8 Success criteria

Tick the column to indicate that you have completed the lesson and how well you think you have understood it using the traffic light system.

(**Green:** I understand; **Yellow:** I can do it with help; **Red:** I do not understand)

Lesson	Success criteria	Green	Yellow	Red
7.2	I can describe how new evidence from historical and current day astronomers have changed people's views of the solar system.			
7.3	I can describe how Earth's tilt and its position in space, relative to the Sun, influences the seasons and day/night cycles.			
7.4	I can describe the differences between the surface of Earth and the surface of the Moon.			
	I can describe the sequence of the phases of the Moon and explain why these phases occur.			
7.5	I can describe the cause of solar and lunar eclipses, and draw diagrams showing the relative positions of Earth, the Sun and the Moon during eclipses.			
7.6	I can explain the causes of tides on Earth and describe the relative effect of the Moon's and Sun's gravitational pulls on the size of high and low tides.			
7.7	I can investigate Aboriginal and Torres Strait Islander Peoples' knowledge systems of astronomy, including phases of the Moon, solar and lunar eclipses, seasonal calendars and tides.			

learnon

Post-test Topic 7 Post-test

eWorkbook Topic 7 eWorkbook

Digital document Key terms glossary

7.8 Activities

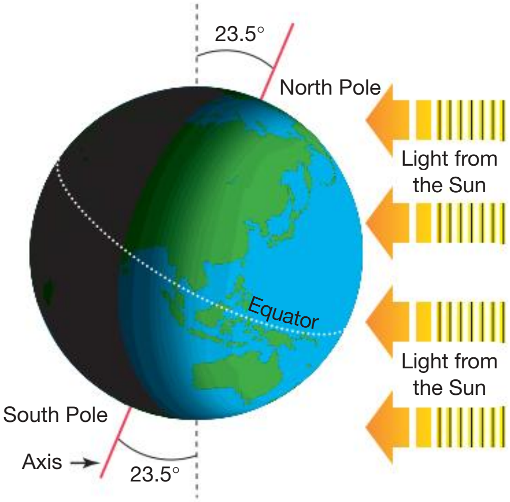
learnon

7.8 Review questions

LEVEL 1	LEVEL 2	LEVEL 3
1, 4, 10, 12	2, 6, 8, 11	3, 5, 7, 9

Remember and understand

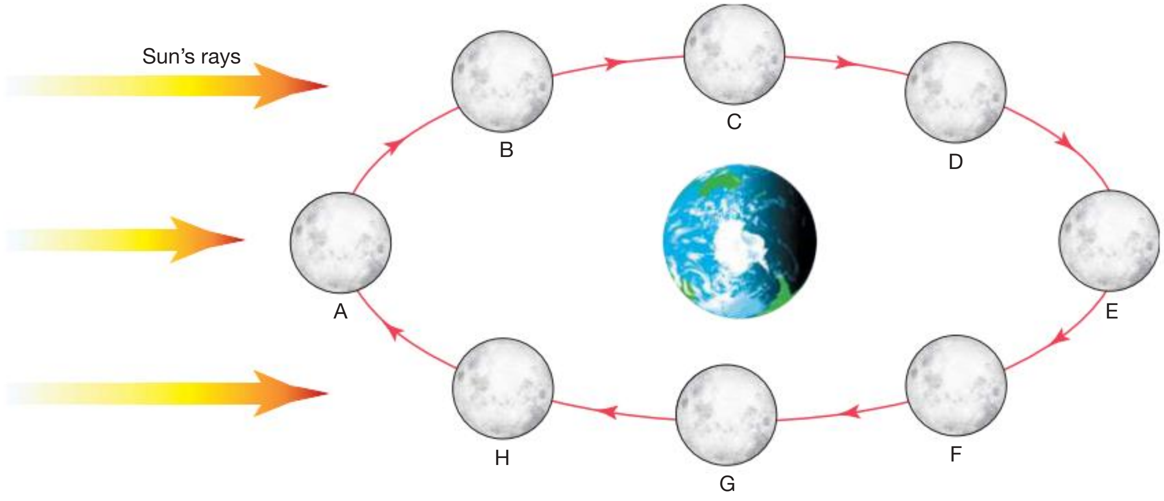
1. **Compare** the rotation and revolution of Earth.
2. The diagram shows half of Earth in sunlight while the other half is in darkness. Which Australian season is represented in this diagram? **Explain** how you know.



3. **Explain** why the position of the Sun in the sky at midday changes from day to day.
4. **Explain** the cause of a partial solar eclipse. **Compare** it to a total solar eclipse.

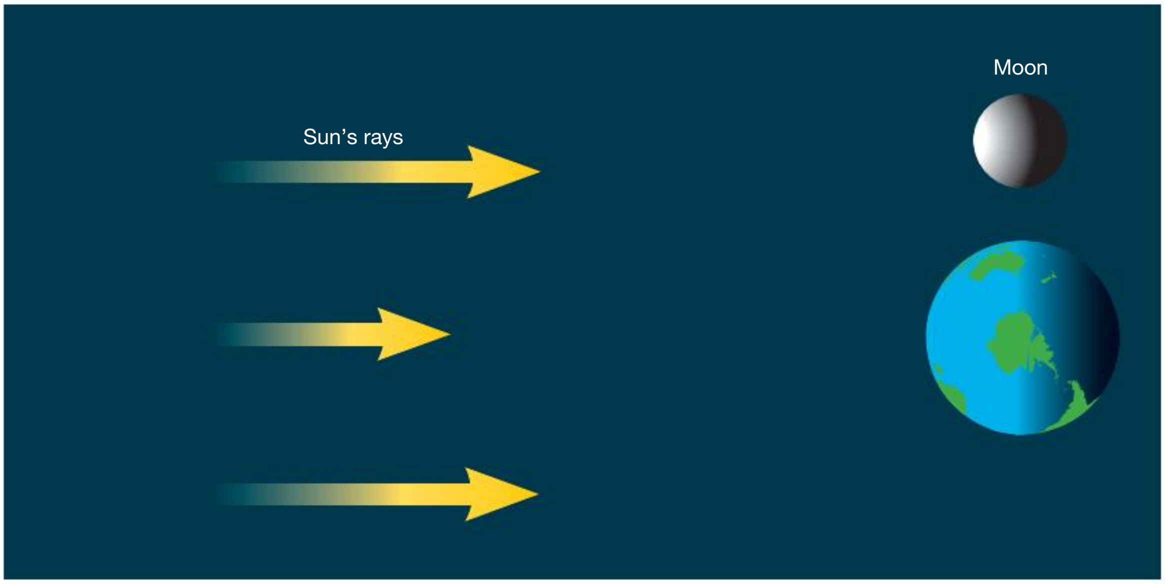
Apply and analyse

5. The diagram shows the Moon in eight different positions during an orbit around Earth.



a. Copy the diagram of the Moon in the eight different positions and shade the parts of Earth and the Moon that are in darkness.
b. **State** the length of one complete lunar orbit.
c. Give a reason for the new moon not being visible during daytime.
d. **Describe** the position of the Moon relative to Earth that results in a quarter moon.
e. **Describe** the position of the Moon relative to Earth that results in a gibbous moon.
f. **Describe** the position of the Moon relative to Earth that results in a full moon.
g. **State** the number of times the Moon rotates around its own axis while completing a single orbit of Earth. Give a reason for your answer.

6. The length of a day on the planet Venus is 243 Earth days. The length of a year on Venus is only 225 Earth days. **Explain** how it is possible for a day to be longer than a year.
7. **State** the type of tide experienced when a full moon is overhead. **Explain** your answer.
8. The diagram shows Earth from above the South Pole. When the Moon is in the position shown, **state** the type of tide that is being experienced on the east coast of Australia — high tide, low tide or neap tide. Give a reason for your answer.

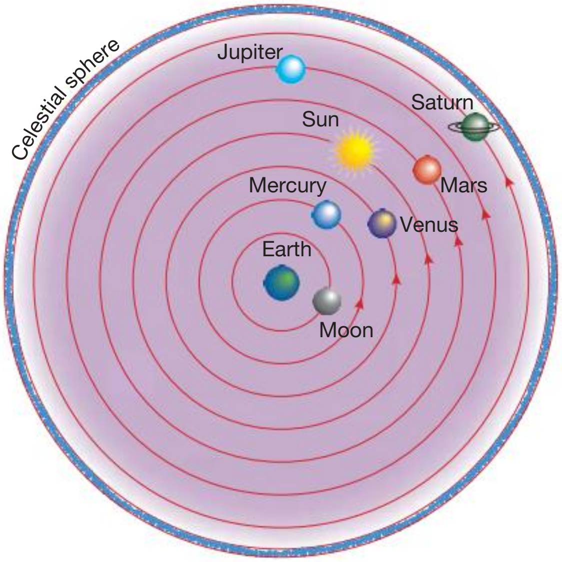


Evaluate and create

9. The image shows Earth as it is seen from the Moon.
   a. Why is Earth visible even though it does not emit its own light?
   b. Would you expect Earth to always be visible from the part of the Moon that faces it? **Explain** your answer.
   c. Would Earth show similar phases to the Moon's phases? Draw some diagrams showing the positions of the Sun, Earth and the Moon to explain your answer.
   d. If you were on the Moon, **predict** the length of time between Earthrise and Earthset. **Explain** your answer.

10. Astronauts have already visited the Moon and may soon land on Mars. Do you think astronauts will ever visit a planet outside our solar system? **Explain** your answer and **describe** what a trip to a distant planet might look like.

11. a. **Name** the astronomer who developed the model of the universe shown in the diagram.
    b. **Identify** the location of the stars on the diagram.
    c. **Explain** why this model of the universe was accepted for almost 1500 years.
    d. **Name** three well-known scientists or mathematicians who developed alternatives to this model. **Describe** their discoveries or theories.



12. Imagine you are given the task of describing your planet and its position in space to an alien from a distant galaxy. You are limited to either 200 words or one image, but you cannot use both words and images. What would you write or draw?

Answers and sample responses are available in your digital formats.

on To test your understanding and knowledge of this topic, go to your learnON title at jacplus.com.au and complete the **post-test**.

8 Forces in action

CONTENT DESCRIPTION

Balanced and unbalanced forces acting on objects, including gravitational force, may be investigated and represented using force diagrams; changes in an object's motion can be related to its mass and the magnitude and direction of the forces acting on it (VC2S8U14)

Source: Victorian Curriculum F–10 Version 2.0

LESSON SEQUENCE

LESSON 8.1 Overview

8.1.1 Introduction

The way objects move depends on the **forces** that are acting on them. A force is an interaction between objects and may be described as a push, pull or twist. While you are reading this, the muscles in your eyes are pulling the lenses in your eyes into the right shape so the words are not blurry.

Many forces are important in everyday life. Earth's **gravitational force** keeps us from floating away into space. Frictional forces allow us to move, speed up, slow down and stop. What would happen without forces?

They say that 'what goes up must come down'. But when a bungee jumper's head is about to reach the water, it is a case of 'what goes down should come up'.

FIGURE 8.1 Forces can be seen in our everyday lives as a push or a pull.

DISCUSSION

1. In what circumstances do forces cause objects to speed up, slow down or travel at a constant speed?
2. Why doesn't gravity cause you to fall through the floor?
3. Would the gravitational force acting on you be the same on Mars as on Earth?
4. Why is it difficult to walk on ice?
5. How does a compass work?
6. Why do you sometimes get a shock when you touch a doorknob after walking on carpet?
7. Why are bicycle helmets necessary?
8. How do seatbelts, airbags and head restraints protect you in a car accident?

SCIENCE INQUIRY: Forces in everyday life

Forces are at work in every part of our daily lives, from walking and playing sports to driving cars and even sitting still. A force can be described as a push or a pull that can cause an object to start moving, stop moving, change direction or change shape.

Forces can be classified into two main types.

- **Contact forces**: Forces that require direct contact between objects.
  - Friction — the force that resists motion when two surfaces rub against each other. For example, friction helps us walk without slipping, but it also slows down moving objects like a rolling ball.
  - Air resistance — a type of friction that slows objects moving through air. For example, a parachute increases air resistance to slow a skydiver's fall.
  - Applied force — any force exerted by a person or object, such as pushing a door open or pulling a rope.
- **Non-contact forces**: Forces that act at a distance without physical contact.
  - Gravity — the most well-known non-contact force, gravity pulls objects toward Earth. Gravity keeps us on the ground and causes objects to fall when dropped. It also keeps planets in orbit around the Sun.

Forces in action

- **Friction and lubrication:** Friction can be helpful (e.g. stopping a car when brakes are applied) or a problem (e.g. causing parts of a machine to wear out). To reduce unwanted friction, lubricants such as oil and grease are used in engines and moving parts.
- **Buoyancy and floating:** Some objects float while others sink because of the buoyant force, which pushes upward on objects in a fluid (e.g. water or air). Ships, boats and hot air balloons rely on buoyancy to stay afloat.
- **Surface tension:** Water molecules stick together, creating a strong surface that allows some small insects (e.g. water striders) to walk on water without sinking.
- **Aerodynamics:** Objects such as planes, cars and bicycles are designed to reduce air resistance so they can move faster and more efficiently.

FIGURE 8.2 Several different forces are acting on these ice-skaters.

Investigating forces

Scientists and engineers study forces to improve technology and solve real-world problems.

- Engineers design sports shoes with the right amount of friction to help athletes run faster.
- Car manufacturers test aerodynamics to make vehicles more fuel efficient.
- Scientists study how forces affect bridges and buildings to make them safer.

By studying forces, we can better understand how objects move and interact with the world around us.

Whether we are running, swimming, flying or floating, forces play a major role in how we experience and navigate our environment.

1. Using a large sheet of paper or a whiteboard, create a table with the terms listed in the left-hand column as shown in table 8.1.

TABLE 8.1 Examples and meanings of different terms relating to forces

Term	Meaning	Real-life examples
a. Force		
b. Friction		
c. Mass		
d. Gravitational force		
e. Gravitational force acting on an object		
f. Lubricant		
g. Buoyancy		
h. Surface tension		
i. Aerodynamic		

2. Discuss each term and what you think it means. Research the meaning of each term and write the meanings in column two of your table.

3. Discuss some real-life examples of each of the terms and write them in column three of your table. Try to come up with at least three examples of each.
4. Compare your answers with those of other groups in the class.
5. Examine the image in figure 8.2. How do you think forces impact the way the skaters are able to move?

Information and processed data can be analysed to show patterns, trends and relationships, and to identify anomalies (VC2S8I05)

learnon

Pre-test	Topic 8 Pre-test
eWorkbooks	Topic 8 eWorkbook Student learning matrix
Practical investigation eLogbook	Topic 8 Practical investigation eLogbook
Digital document	Key terms glossary

LESSON 8.2 Forces

LEARNING INTENTION

In this lesson you will explain what forces are and their effect on different objects.

8.2.1 Forces everywhere

When a tennis ball is hit with a tennis racquet, it is clear that forces are acting on the ball. The ball not only changes its direction of movement, but also, while in contact with the racquet, changes its shape as well.

A force is an interaction that causes an object to accelerate, slow down or change shape. Forces are acting around you all the time and cause changes to occur. Sometimes the effects are obvious and sometimes they are not. At this moment, forces are acting inside your body to pump blood around. When you write, you use a force to push the pen or pencil. The standard unit of force is the **newton** (N).

FIGURE 8.3 Forces act on a tennis ball when it is hit with a tennis racquet.

KEY IDEA

A force is an interaction between objects and may be described as a push, pull or twist.

INVESTIGATION 8.1

Forces

Aim

To investigate the effects of forces on different objects

Materials

- rubber band
- plasticine
- tennis ball
- coin
- plastic ruler or rod
- nylon or wool cloth

Method

Perform each of the following actions and record your observations in the Results table. Take note of any changes in the motion or shape of each object and what caused the change in the motion or shape.

- Stretch a rubber band.
- Squash a lump of plasticine.
- Push down on the floor with one foot.
- Drop a tennis ball. Observe what happens:
  - at the moment that you drop it
  - as it falls
  - as it hits the ground
  - as it bounces up again.
- Flick a coin with one finger so that it slides along the surface of a table. Observe what happens after the coin is flicked.
- Charge a plastic ruler or rod by rubbing it with a nylon or wool cloth. Hold it close to a thin stream of tap water.

Results

Record your observations in a table like the one below.

Action	Change in motion or shape	Cause of change
Stretch a rubber band		
Squash a lump of plasticine		
Push down on the floor with one foot		
Drop a tennis ball — at the moment it is dropped		
Drop a tennis ball — as it falls		
Drop a tennis ball — as it hits the ground		
Drop a tennis ball — as it bounces up		
Flick a coin with one finger so that it slides along the surface of a table		
Hold charged ruler or rod close to a thin stream of tap water		

Discussion

1. When you squash a lump of plasticine and stretch a rubber band, a change in shape is observed. What is different about the behaviour of these two materials?
2. Does the tennis ball change its shape at all when it hits the ground? What would happen to a falling lump of plasticine when it hits the ground? Would it bounce? Check your prediction.
3. Which of the forces that you observed were able to change the motion of objects without making contact with them?

Conclusion

Summarise the observations you made during the investigation and the effect of forces on different objects.

8.2.2 Gravitational fields and gravitational force

You may have heard that gravity is what pulls objects toward Earth, but scientists use the term gravitational force instead. This force acts on everything that has mass, keeping us on the ground and holding planets in orbit around the Sun.

Gravitational force happens because of something called a **gravitational field**. A gravitational field is the invisible area around an object where its gravity can pull on other objects. The stronger the field, the stronger the pull (gravitational force).

Think of it like this: imagine Earth is a giant magnet. The gravitational field is like the invisible area where the magnet's pull can be felt. The closer you are to the magnet (Earth), the stronger the pull. The further away you go, the weaker the pull until, eventually, you do not feel it at all.

8.2.3 Contact or no contact?

The changes in motion shown in figure 8.4 are all caused by contact forces. One object touches another. The tennis racquet strikes a ball, the air pushes against the parachutes to slow down the skydivers, and the tube of toothpaste is squeezed to change its shape and push out the toothpaste.

FIGURE 8.4 Each of these photos demonstrates the action of different forces. Identify as many of these forces as you can.

But the motion and shape of objects can be changed without anything touching them.

When you drop a tennis ball, it speeds up as it falls through the air. The gravitational force pulls it towards the ground. Gravitational force is a non-contact force. An object does not have to be touching Earth to be pulled towards it. Other forces that can work without touching are **magnetic forces** and **electrostatic forces**.

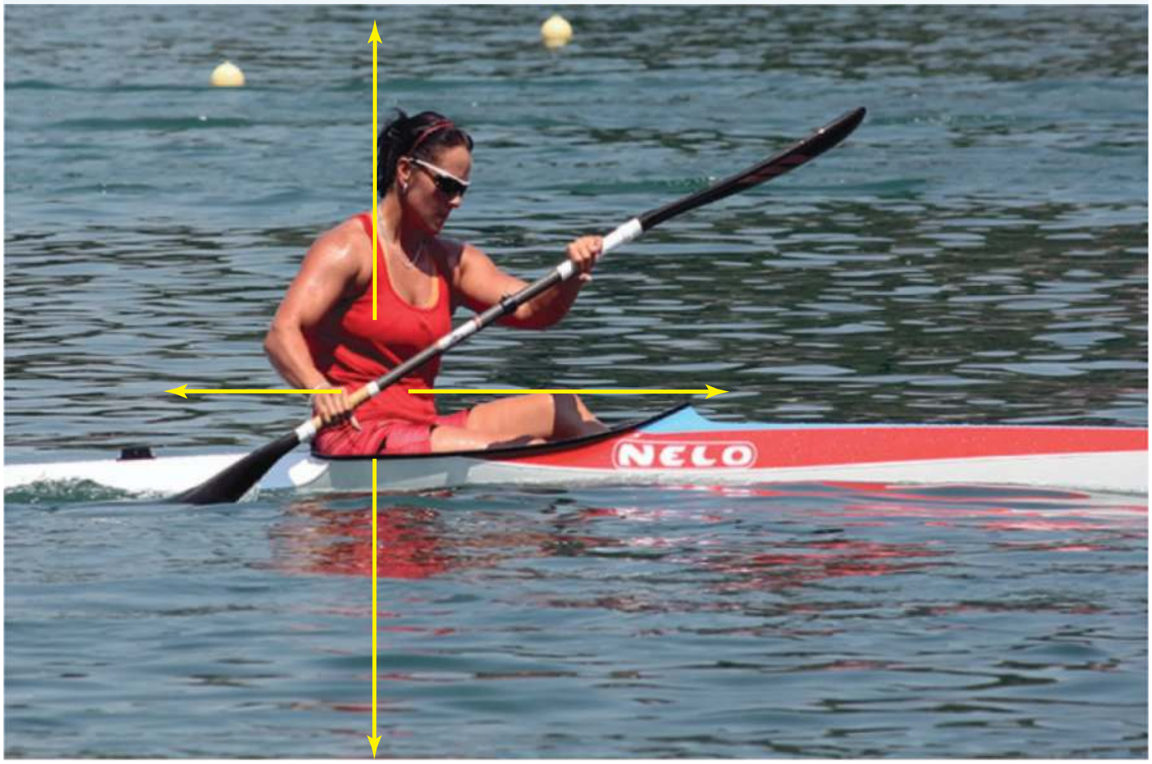
Magnets can attract each other or some metals, such as iron, from a distance. This is an example of a magnetic force. If you rub a pen with a cloth, you can pick up small pieces of paper with an electrostatic force.

8.2.4 Representing forces

Arrows are used to represent the size and direction of forces. The length of the arrow shows how large the force is compared to another force, while the arrowhead shows the direction in which the force is acting. The arrows representing forces are usually drawn from an object's centre of mass, which is the point where all of the object's mass is balanced. For objects near Earth's surface, the gravitational force acting on them is often shown as an arrow pointing downward from the centre of mass.

In the human body, the centre of mass is located near the bellybutton when standing upright. This is the point where the force of gravity pulls down evenly on the body.

FIGURE 8.5 Forces acting on a kayaker who is speeding up



The arrows in figure 8.5 show that the upward and downward forces on the kayaker are the same size but in opposite directions. Gravity pulls the kayaker down and the water pushes the kayak (and the kayaker) up (the upward push of the water is called **buoyancy**). These two vertical forces on the kayaker add up to zero, so there is no change in her upward or downward motion.

The horizontal arrow to the right represents the forward force on the kayaker (provided by using the paddle) and the horizontal arrow to the left represents the backward force (provided by the drag of the water). The forward force is larger than the backward force, so the kayaker and kayak speed up.

8.2.5 More than one force

There is almost always more than once force acting on an object. All forces acting on an object are added together to determine the **net force** acting on the object. It is very important to distinguish that the net force is not a type of force, or an extra force acting on something — it is simply the combination of all forces acting on a specific object. The direction of the force is very important when calculating net force.

KEY IDEA

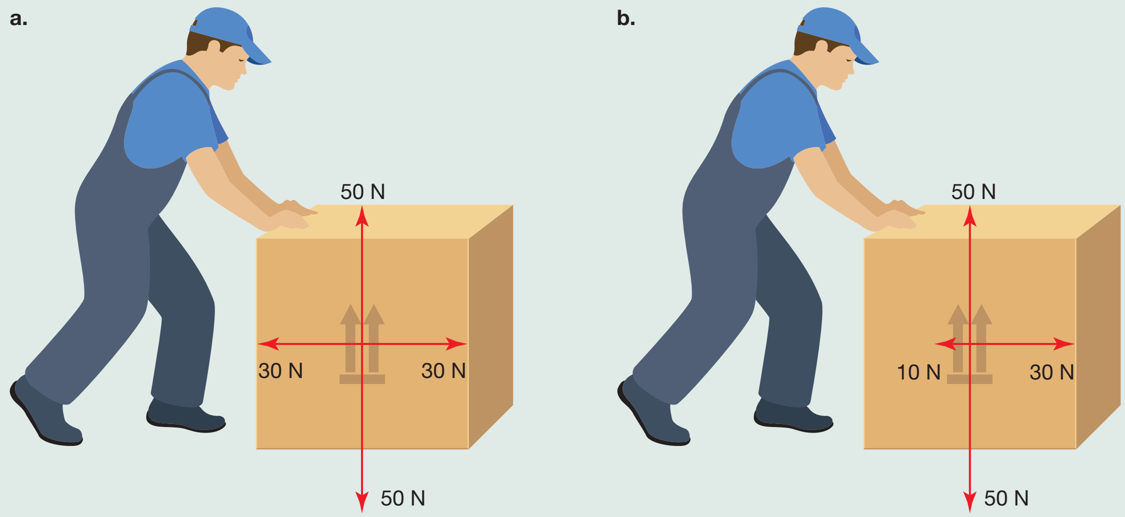
If the net force acting on an object is zero (the forces are in **equilibrium**), then the object's motion will remain unchanged. If the net force is non-zero, the object's speed and/or direction will change.

EXTENSION: Calculating net force

Consider a situation in which a box is being pushed along the floor, as in figure 8.6.

In figure 8.6a, the upward and downward (gravity) forces are both 50 N, and the left (**friction**) and right (push) forces are both 30 N. All forces balance each other, so the net force acting on the box is 0 N. The box will continue to move to the right (because it was already moving) without changing its speed or direction.

FIGURE 8.6 The forces at work when pushing a box across the floor



Now consider the situation shown in figure 8.6b: the upward (contact force) and downward (gravity) forces are both still 50 N, but the left (friction) force is 10 N and the right (push) force is 30 N. The vertical forces balance each other out, so the box will not move up or down. The horizontal forces, however, do not balance. Because the horizontal force on the right is bigger than on the left, the box will move to the right with increasing speed.

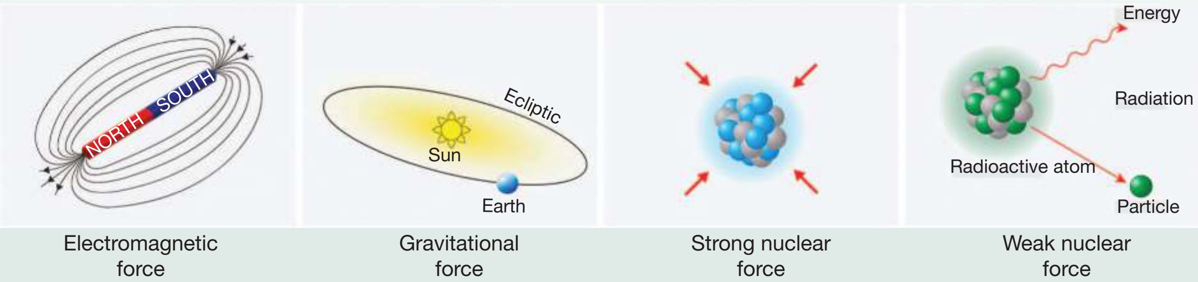
EXTENSION: What's in a name?

In this topic, we explore forces due to gravity, friction, air resistance and buoyancy. However, there are many other names for forces that you may encounter, such as magnetic, electrostatic, tension and compression.

Scientists have shown that there are four main forces in the universe: electromagnetic, gravitational, strong nuclear and weak nuclear.

You will explore these in detail as you learn more about physics.

FIGURE 8.7 The four fundamental forces



8.2 Activities

learnon

8.2 Quick quiz on	8.2 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 4, 7	2, 5, 9	3, 6, 8

Remember and understand

1. MC **Identify** which of the following cannot be used to describe a force.
   A. Force of gravity B. Speed C. Push D. Pull
2. Classify the following forces as either contact forces or non-contact forces.
   a. Friction b. Electrostatic c. Magnetic d. Gravitational
3. **Name** the force that slows down an object moving through water.
4. What keeps us on the ground and holds planets in orbit around the Sun?

Apply and analyse

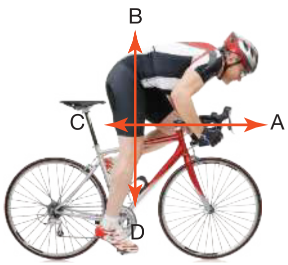
5. Complete the following sentences.
   When the net force acting on an object is zero, the object's motion _______________. When the net force acting on an object is non-zero, the object's motion _________________.
6. Where would you expect to find the centre of gravity of a plastic ruler? **Explain** your response.
7. Copy and complete the following table to list an everyday example of a force for each of the effects of forces given. The first one has been done for you.

Everyday examples of forces

Effect	Example
a. Starting motion	Pushing your hands on the back of a friend on a swing
b. Stopping motion	
c. Speeding up motion	
d. Slowing down motion	
e. Changing the direction of motion	
f. Changing the shape of an object	
g. Having no visible effect	

Evaluate and create

8. When you flick a coin so that it slides across a table, it slows down.
   a. **Name** the force that slows it down.
   b. If your finger is still pushing the coin, there are four forces acting on the coin. **Identify** the direction and relative size of each force.
   c. **Name** the forces acting on the coin after your finger stopped pushing.
   d. SI Do you think that the mass of the coin affects how quickly it slows down? **Construct** an investigation to answer this question, clearly stating any independent, dependent and controlled variables.
9. There are four forces acting on a cyclist, as shown in the diagram.
   a. **Name** which of the four forces represented is a non-contact force.
   b. **Explain** what would happen if forces B and D were not equal.
   c. Is the cyclist's speed increasing, decreasing or remaining steady? **Explain** your answer.
   d. **Describe** what would happen to the cyclist's motion if the size of force C increased to become equal in size to force A.
   e. What would happen if force C became greater in size than force A?



Answers and sample responses are available in your digital formats.

LESSON 8.3 Gravity

LEARNING INTENTION

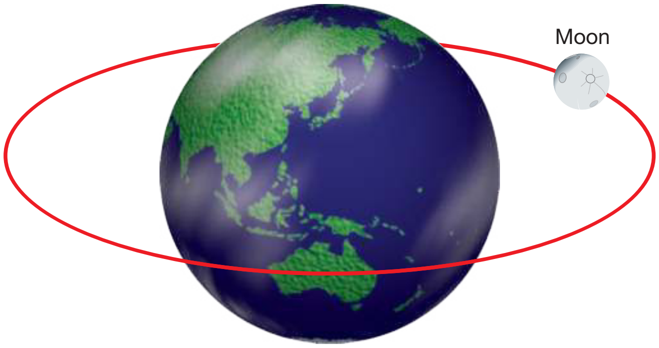
In this lesson you will:
- explain what the force of gravity, mass and gravitational force are
- describe what it means to reach a terminal speed.

8.3.1 Gravity: an attractive force

What causes a ball to fall to the ground after you throw it? Why don't you get flung from the surface of Earth as it spins around? What keeps the Moon in orbit around Earth and the planets in orbit around the Sun? The answer to all of these is the force of gravity. Without Earth's gravitational force, the atmosphere would disperse into space.

Every object with **mass** in the Universe pulls on other objects with a force of gravity. However, this force is only noticeable for objects with very large masses, such as planets and stars. The force of gravity towards an object depends on its mass. Mass is a measure of the amount of material in an object or substance, and its standard unit is the kilogram (kg). The mass of an object is the same wherever it is in the Universe.

FIGURE 8.8 If it weren't for gravity, the Moon would fly past us. The gravitational attraction between Earth and the Moon keeps the Moon in orbit around Earth.



The greater the mass of an object, the greater the force of gravity with which it can attract other objects. Gravity is such a weak force that, unless the object is as large as a star, planet or moon, its pull of gravity is just too small to notice or measure compared to other forces. That is why we can clearly see that we are pulled towards Earth, but we cannot see any noticeable pull between us and everyday objects such as a refrigerator.

8.3.2 Gravitational force

The gravitational force on an object depends on its mass and the strength of gravity on the planet or celestial body.

Gravity depends on two things:
- mass — how much matter an object has, measured in kilograms (kg)
- gravity strength — how strongly gravity pulls on an object, measured in newtons per kilogram (N/kg).

How to calculate gravitational force

We can use a simple rule to find the force of gravity on an object:

$$F = mg$$

where F = gravitational force (how strongly gravity pulls, measured in newtons)

m = how much mass an object has (how heavy it is, measured in kilograms)

g = gravity strength (how strong gravity is in that place, measured in newtons per kilogram).

For example:

- on Earth, gravity pulls with a strength of 10 N/kg. If a person has a mass of 50 kg, the gravitational force is:

$$F = 50 \times 10 = 500\text{ N}$$

  Therefore a 50 kg person feels 500 N of gravity on Earth.
- on Mars, gravity is weaker, only 4 N/kg. For the same 50 kg person, the gravitational force is:

$$F = 50 \times 4 = 200\text{ N}$$

  This means the person experiences only 200 N of gravity on Mars, making them feel much lighter.

KEY IDEA

We can use a simple rule to find the force of gravity on an object:

$$F = mg$$

The more mass something has, the stronger gravity pulls on it. Planets with stronger gravity pull objects down more than planets with weaker gravity.

SCIENCE AS A HUMAN ENDEAVOUR: Sir Isaac Newton and the falling apple

Sir Isaac Newton (1643–1727) was one of the greatest scientific minds in history. He made groundbreaking discoveries in mathematics, physics and astronomy. His most famous contribution is the Law of Universal Gravitation, which describes how gravity affects objects on Earth and in space.

While the popular story claims that Newton 'discovered' gravity after an apple fell on his head, historians believe that he observed an apple falling while he was sitting in a garden. This observation led him to a profound realisation: why do apples (and all objects) always fall straight down, rather than sideways or upwards?

Newton began questioning the nature of this force, wondering if it extended beyond Earth. He eventually connected it to the motion of the Moon, proposing that the same force pulling an apple to the ground also keeps the Moon in orbit. His insights became the foundation for his Law of Universal Gravitation, which states:

> Every object in the universe attracts every other object with a force that is proportional to their masses and inversely proportional to the square of the distance between them.

FIGURE 8.9 Did an apple falling on the head of Newton inspire the discovery of gravity?

This means that:

- larger objects (like planets) exert stronger gravitational forces than smaller objects
- the farther apart two objects are, the weaker the gravitational attraction between them.

Newton's discoveries helped explain why planets orbit the Sun, why the tides move with the Moon's pull, and why objects fall to the ground. His work laid the foundation for modern physics and space exploration, influencing scientists such as Albert Einstein and shaping how we understand the universe.

Newton's lasting impact

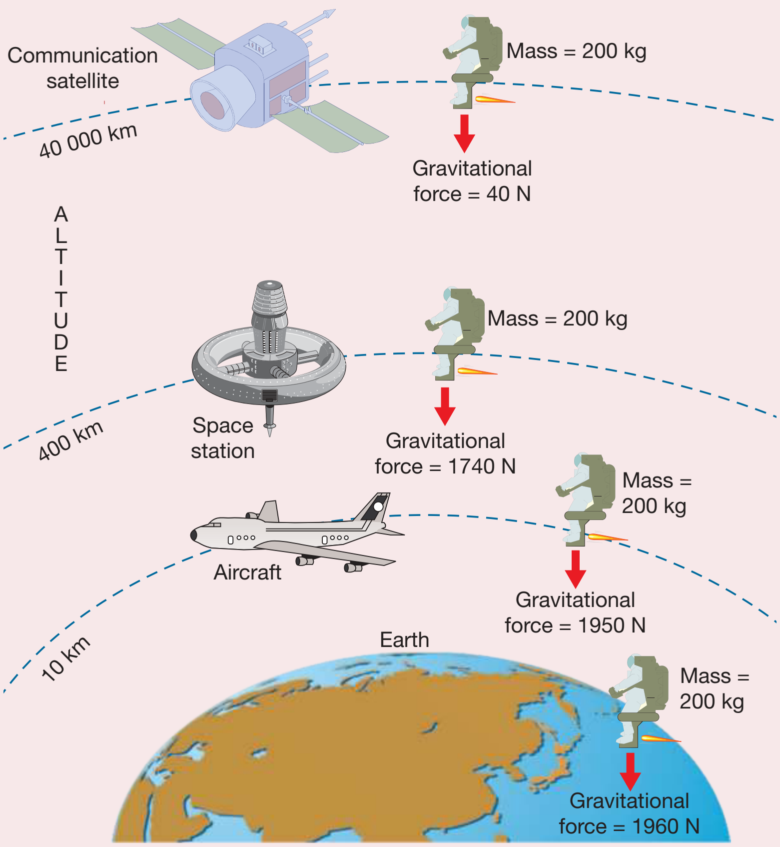
Newton's ideas are still used today in fields such as astronomy, engineering and space science. His laws of motion and gravity help scientists:

- predict planetary motion, which is essential for space missions
- design bridges and buildings, ensuring they can withstand forces acting on them
- understand black holes and gravitational waves, expanding our knowledge of the cosmos.

Although modern physics has advanced beyond Newton's theories — such as Einstein's theory of general relativity, which provides a more detailed explanation of gravity — his work remains a fundamental part of science education and engineering applications.

1. Who was Sir Isaac Newton? What were his major contributions to science?
2. Why do historians doubt that an apple hit Newton on the head?
3. What did Newton's apple observation help him realise about gravity?
4. How did Newton connect gravity on Earth to planetary motion in space?
5. What is the Law of Universal Gravitation? How does it explain the motion of objects?
6. How have Newton's discoveries influenced modern science and technology?
7. How has our understanding of gravity changed since Newton's time?
8. How do astronauts experience gravity differently in space compared to on Earth?

FIGURE 8.10 The gravitational force acting on an object decreases as the object moves further from the centre of Earth. However, the object's mass remains the same regardless of its location.



Scientific knowledge, including models and theories, can change because of new evidence (VC2S8H01)

8.3.3 Measuring mass and gravitational force

The gravitational force you feel (which we often call weight) depends on the gravitational field strength where you are.

On Earth, the gravitational field is strong, so objects feel a strong gravitational pull. On the Moon, the gravitational field is weaker, so objects feel less gravitational force and seem lighter. In deep space, far from planets and stars, the gravitational field is very weak, so objects float freely.

Mass can be measured with a balance. Figure 8.11 shows an old-fashioned measuring scale on which the mass of an object is being compared with a known standard mass. A 2-kilogram bag of flour will balance the two standard 1-kilogram masses, regardless of the strength of the gravitational force acting on it.

A laboratory beam balance measures mass by comparing an object's mass to sliding masses on the other side of the balance.

Gravitational force (often called weight) can be measured using a spring balance like the one shown in figure 8.12. The object is fastened to the hook on the end of the spring. The gravitational force pulls downward, causing the spring to stretch. The amount the spring stretches depends on the strength of the gravitational force acting on the object.

FIGURE 8.11 The 2-kilogram bag of flour will always balance the two 1-kilogram standard masses, regardless of the gravitational force acting on it.

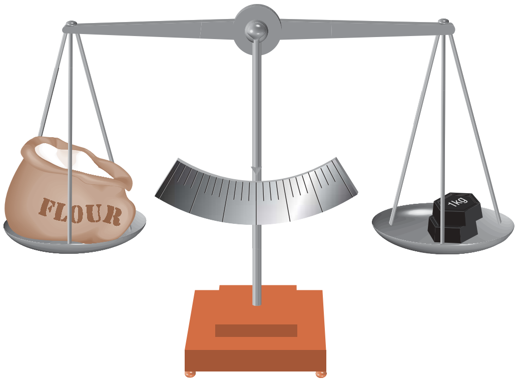


FIGURE 8.12 A spring balance can be used to measure the gravitational force acting on an object.

INVESTIGATION 8.2

Measuring weight

Aim

To investigate the relationship between gravitational force and mass on Earth

Background

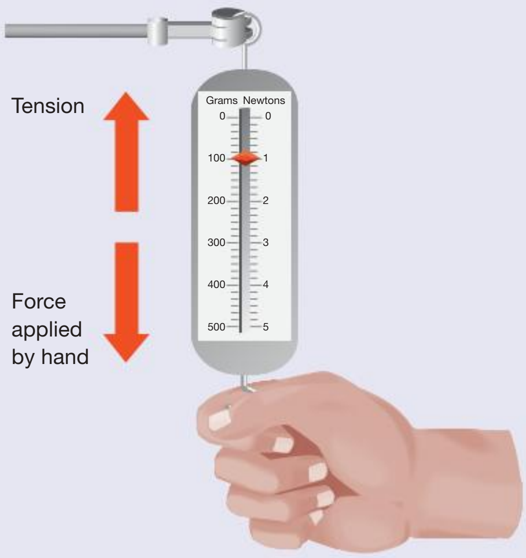
A spring is a useful force measurer because its stretch is proportional to the force applied. If the pulling force doubles, the stretch doubles. If the pulling force triples, the stretch triples. This relationship allows a spring balance to measure the gravitational force acting on an object.

Materials

- 5.0 N spring balance
- set of slotted 50 g masses
- retort stand, bosshead and clamp

Method

1. Pull down on the hook of a 5.0 N spring balance until it reads 1.0 N. There are two forces acting on the hook. As long as the hook is not changing its motion, the upward force of tension is the same as the downward pull of your hand.
2. Pull the hook down until the spring balance reads 2.0 N. The downward pull has doubled.
   - What is the tension in the spring?
   - What has happened to the amount that the spring has stretched?
3. Hang the spring balance from a rod fixed to a retort stand and adjust the pointer so that it reads zero.
4. Attach a 50 g mass to the hook of the spring balance and record the gravitational force acting on it in newtons by reading from the scale on the spring balance. Record your result in the Results table. Calculate and record the mass in kilograms by dividing the mass in grams by 1000.
5. Add 50 g masses, one at a time, until you have a total mass of 400 g. Record the mass in kilograms as you go.
6. Record the gravitational force in newtons (N) as you add each mass.

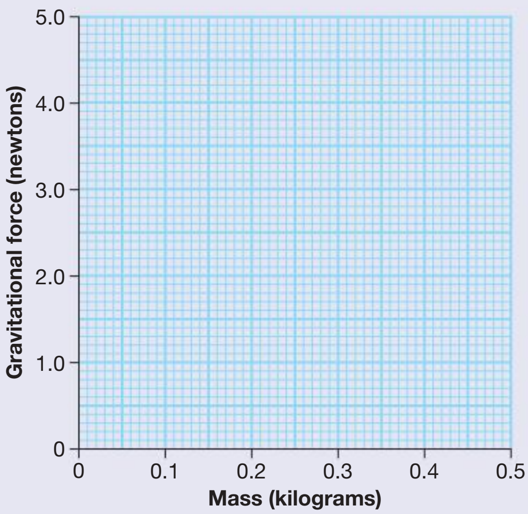


Results

1. Record your results in a table like the one below.

Mass (g)	Mass (kg)	Gravitational force (N)
50	0.05	
100	0.10	
150	0.15	

2. Use your results to plot a graph of gravitational force (N) versus mass (kg), using a grid like the one shown.
3. Draw a line through the points that you have plotted and extend it to estimate the gravitational force acting on a 500 g mass. This extension process is called extrapolation and is used to predict values beyond the measured data.



Discussion

1. Why is it better to hang the spring balance from a rod rather than hold it in your hand?
2. Does the spring increase its stretch by the same amount each time a 50 g mass is added?
3. How would your results be different if you conducted this activity on Mars?
4. Is your line straight? Should it be straight?
5. Use your graph to predict the gravitational force acting on a 500 g mass. Is this prediction accurate? Measure it and see how accurate your prediction is.
6. How could you alter the scale on the spring balance so that you could read the correct mass from it directly?

Conclusion

Summarise your findings and state the relationship between mass and gravitational force on Earth. Explain how this relationship would change on planets with different gravitational field strengths.

8.3.4 Free-fall

An object is said to be in free-fall if the only force acting on it is the force of gravity, although for objects falling near the surface of Earth, gravity is not the only force acting on them.

The way objects fall depends on the net force acting on them, not just on the pull of gravity. Air in the atmosphere pushes against all falling objects. This push is called **air resistance**, which is an example of fluid friction.

INVESTIGATION 8.3

More than one force?

Aim

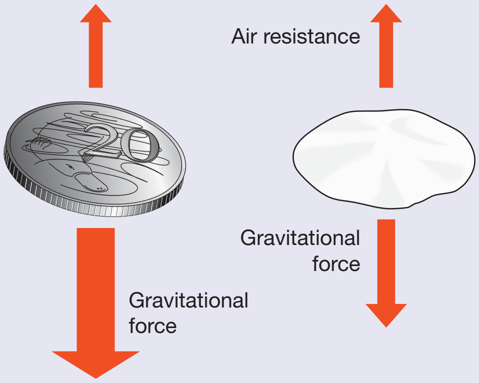
To investigate the effect of air resistance on a disc

Materials

- 20 cent coin
- scissors
- paper

Method

1. Drop a coin from about chest height. The gravitational force acting on the coin pulls it downward. Observe what happens as the coin falls.
2. Cut out a disc of paper about the size of a 20 cent coin.
3. Hold the paper disc in one hand and the 20 cent coin in the other, both at chest height.
4. Predict what will happen if you drop them at the same time.
5. Test your prediction.
6. Place the disc of paper on top of the coin and drop them together from waist height.



Results

1. Which object landed first when you dropped them separately? Was your prediction correct?
2. Which landed first when the paper disc was on top of the coin?

Discussion

1. How many forces were acting on the coin as it fell through the air?
2. What two forces were acting on the paper disc when it was dropped on its own?
3. What was different about the forces acting on the coin?
4. How did dropping the coin and disc together (with the disc on top) differ from when they were dropped separately? Explain why this occurred.

Conclusion

Summarise your findings of what occurred when the coin and disc were dropped separately and together.

Terminal speed

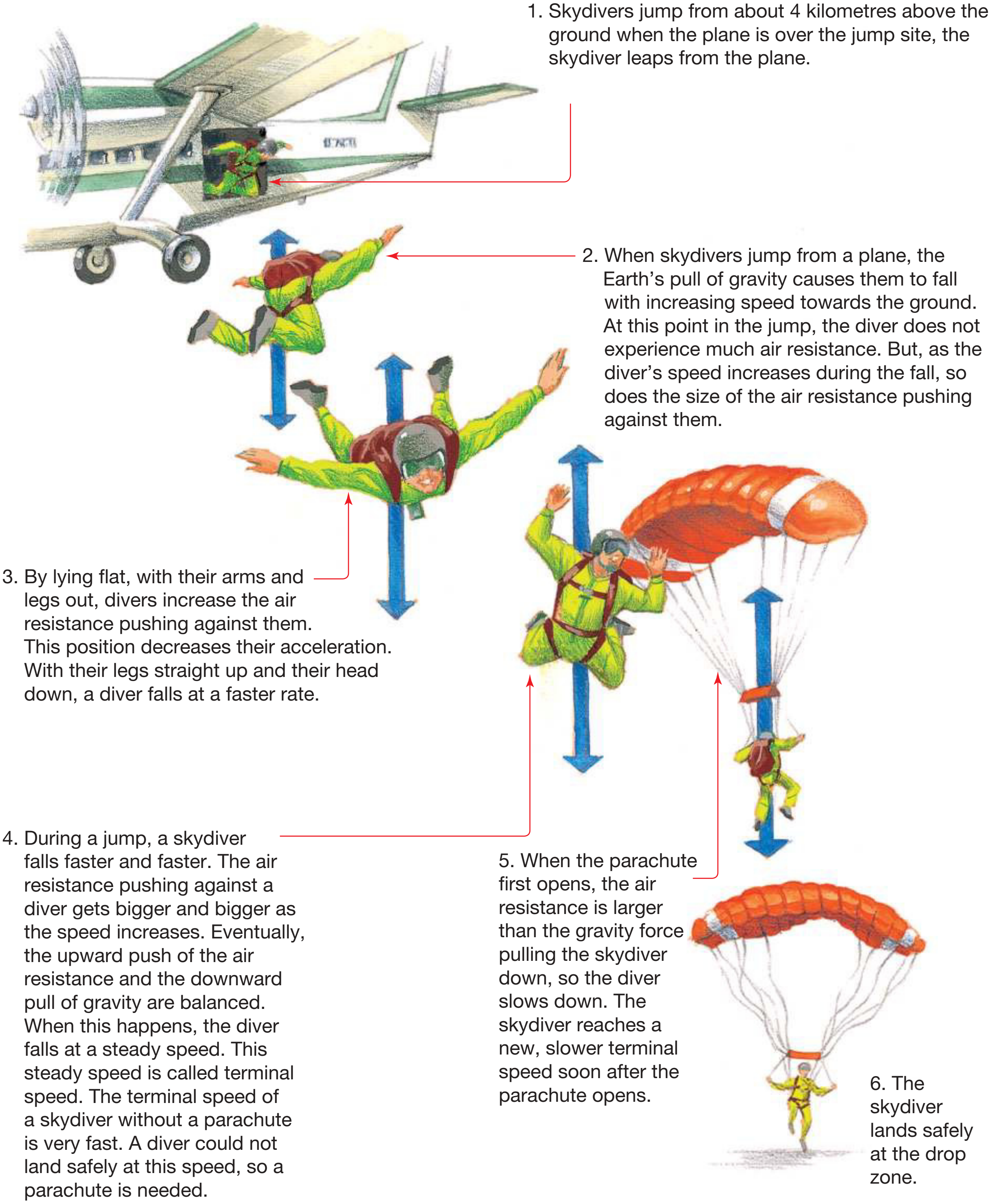
When the paper disc is dropped together with the coin in the second part of investigation 8.3, the coin shields it from the air that would normally push against it.

The air resistance on a moving object increases as the object moves faster. When cycling or running quickly, you feel the air pushing against your face even if there is no wind. When you slow down, you do not feel the same push of air against you. If the object travels fast enough, the air resistance can become as great as the force of gravity on the object. Once the air resistance balances the force of gravity, the net force on the object is zero and it stops speeding up. It has reached its **terminal speed**. It will not fall any faster.

Forces in skydiving

Skydiving is an activity that is enjoyed by thousands of thrill-seekers around the world and is an important part of military and rescue services. The process of skydiving is explored in figure 8.13.

FIGURE 8.13 Forces involved in skydiving



EXTENSION: Resistance in skydiving

Skydivers reach speeds of about 200 km/h before air resistance becomes large enough to balance the gravitational force acting on them. At this point, they stop accelerating and fall at a constant speed, known as terminal velocity.

When the parachute opens, air resistance increases significantly, becoming greater than the gravitational force. This causes the skydiver to slow down until they reach a new, lower terminal velocity of about 20 km/h, allowing for a safe landing.

FIGURE 8.14 There is more than one force acting on these skydivers.

INVESTIGATION 8.4

The landing time of a parachute

Aim

To investigate the effect of a variable on the landing time of a parachute

Materials

- plastic from freezer bags
- scissors
- large paperclips, or plasticine
- stopwatch
- cotton or nylon thread
- metre ruler

Method

Your task is to find out the effect of one of the following factors on the landing time of a parachute.

- Mass of the skydiver
- Size (area) of the canopy
- Shape of the canopy

1. Use plastic from freezer bags to make the canopy. Cotton or nylon thread can be used to hold a model skydiver, which could be represented by paperclips or plasticine.

2. Ensure that you do each of the following:
   - Keep all things constant except the factor that you are deliberately changing, so that your tests are fair. This is called controlling variables.
   - Repeat your measurements of time at least three times and work out an average.
   - Draw up a table in which to record your results. An example is provided, where the variable being investigated is listed in the first column.

Results

Record your results in a table like the one below.

	Time taken to fall (seconds)			
Area of canopy (cm^2)	Trial 1	Trial 2	Trial 3	Average
24 × 24 = 576				
21 × 21 = 441				
18 × 18 = 324				
15 × 15 = 225				
12 × 12 = 144				

Discussion

1. Identify the independent and dependent variables in each part of the investigation.
2. Explain why the mass of the skydiver and the shape and size of the canopy affect the drop time.
3. Evaluate your results and comment on how your design could be improved.

Conclusion

Summarise your findings and state how your chosen variable affects the landing time of a parachute.

Extension

As an extra challenge, after the investigation has been completed, see who can make the parachute that takes the longest to reach the floor with a standard load of five paperclips from a height of 2 metres.

8.3 Activities

learnon

8.3 Quick quiz on | 8.3 Exercise

LEVEL 1
1, 5, 8, 12

LEVEL 2
2, 4, 6, 9, 11

LEVEL 3
3, 7, 10, 13

Remember and understand

1. **Describe** the difference between mass and gravitational force.
2. The force of gravity is not the same on all objects. **Explain** on what property of each object it depends.
3. If you were to land on Mars, would your mass, your gravitational force or both change? **Explain** why.
4. **Name** the gravitational force acting on a person with a mass of 50 kg on Earth.
5. **Describe** terminal velocity and how it affects falling objects.

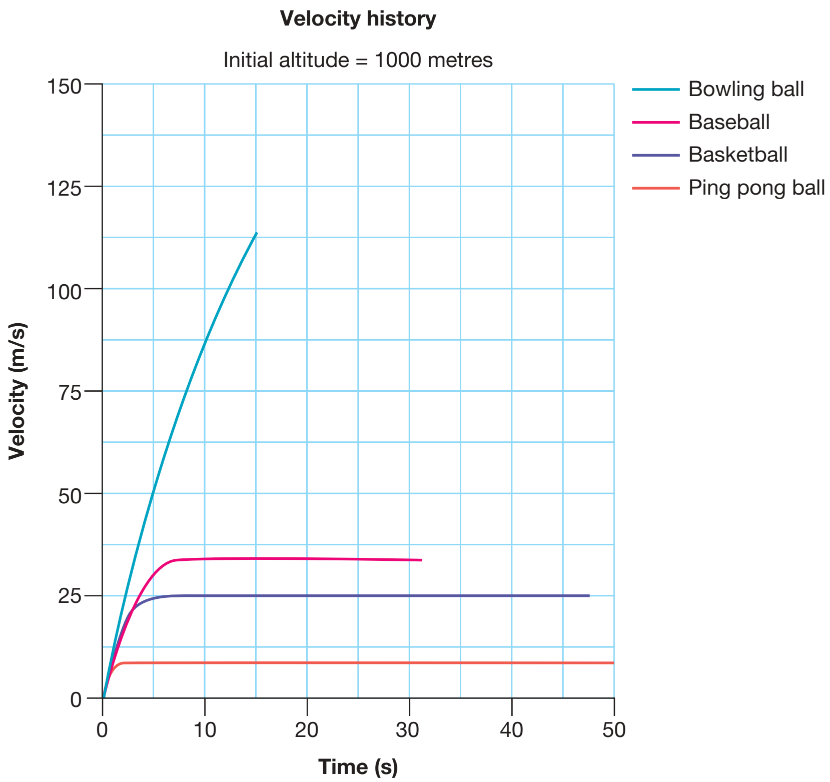
Apply and analyse

6. Objects with mass exert gravitational forces on each other. **Explain** why you do not feel the pull of gravity from nearby objects.
7. a. On Earth, Belinda experiences a gravitational force of 450 newtons. **Calculate** her mass.
   b. On the Moon, the gravitational field strength is about one-sixth that of Earth. **State** what you would expect Belinda's gravitational force to be on the Moon.
8. a. **Identify** and **describe** the forces acting on a bungee jumper just before they reach the bottom of their jump.
   b. Which force is most likely to be the largest? **Explain** your response.

9. When you drop a bowling ball and a feather from the same height in Earth's atmosphere, they reach the ground at different times.
   a. **Explain** why this is the case.
   b. If the bowling ball and feather were falling in a vacuum where there was no air resistance acting on them, **state** which one you think would reach the ground first.

Evaluate and create

10. SI Would a rubber band be as effective as a spring in a force measurer? **Construct** an investigation that would allow you to find this out.
11. SI A number of different balls were dropped from a height of 1000 m above the ground and their velocity recorded over time, as shown in the graph.



   a. MC Of the four balls, which reached its terminal velocity first?
      A. Baseball
      B. Ping pong ball
      C. Basketball
      D. Bowling ball
   b. How long did it take the basketball to reach its terminal velocity?
   c. What was the approximate terminal velocity of the ping pong ball?
   d. **Explain** why some balls reached their terminal velocity faster than others.
12. SI Write a brief report about the impact of Sir Isaac Newton's contributions on the world of science.
13. SI Imagine that you are working in the first space laboratory on Mars. The pull of gravity is a little more than one-third of what it is on Earth. Write a diary entry or summary report for your very first working day in the laboratory. Your response should be an account of your day from 6 am when your alarm rings until 10 pm when you go to bed. Emphasise the effects of less gravity on daily activities.

Answers and sample responses are available in your digital formats.

LESSON 8.4 Friction

LEARNING INTENTION

In this lesson you will:
- explain what friction is
- identify situations where friction is useful and others where it is a nuisance.

8.4.1 The need for friction

Friction is the force applied to the surface of an object when it moves against the surface of another object.

Friction can slow an object, stop it from moving or start it moving. The skater in figure 8.15 could not start moving without friction. He starts rolling by pushing his foot backwards against the path. Imagine what would happen if the path was covered in smooth ice. There would not be enough friction to get him moving forwards. But if the skater is just rolling forwards, the friction applied to the wheels by the path will slow him down and eventually stop him.

FIGURE 8.15 Friction is needed to start skating, and to stop.

CASE STUDY: Crickets

Crickets use friction to make their familiar chirping sound. The sound is made by friction as they rub the back of the left forewing against a row of teeth on the right forewing.

You need friction to do many things. Holding objects in your hand requires friction. Have you ever dropped wet soap in the shower or bath? Wet hands and soap provide little grip. Even walking requires friction. If you have ever slipped on ice or wet floor tiles you'll know why.

When you walk, you push your foot backwards against the ground so that the ground pushes you forward. Without friction your foot would slip backwards as it does on ice. This type of friction, used to assist movement, is called **traction**.

The force of friction is especially important to cars. On a level road, the friction applied by the road when the wheels turn is needed to start a car moving. This friction is another example of traction. Without this friction, the wheels would spin and the car wouldn't start moving. Without friction, cars would not be able to turn corners or stop. The decrease in friction on wet or icy roads makes it very difficult to steer and stop a car.

8.4.2 Friction is sometimes a nuisance

Although friction is necessary for movement and for control of movement of people and vehicles on a surface, it can also be a nuisance. Pushing objects across rough surfaces can be very difficult. You have to push it with a force larger than the friction force acting on it. The heavier the object is, the greater the friction force.

Objects can travel faster if they are smooth. Skis and surfboards are waxed and buffed to reduce friction and make them go faster through snow or water. Bobsled teams smooth and polish the runners of their sleds to maximise their speed down a track.

The smoother the surface on which a vehicle moves, the faster it can go once it gets started. Road surfaces need to be smooth so that vehicles do not waste fuel in overcoming too much friction. However, they need to be rough enough to allow vehicles to turn and brake safely in all types of weather.

Trains and trams run on steel tracks because they produce very little friction. That makes them cheaper to run than vehicles that move on rough surfaces. Imagine how powerful a bus would need to be to carry the same load as a long freight train!

SCIENCE INQUIRY: Reducing and controlling friction in modern transportation

Friction plays an important role in transportation, influencing how efficiently vehicles move and how safely they can stop. While some friction is necessary for grip and control, too much friction can slow movement, waste energy and cause wear and tear on vehicles. Scientists and engineers work to reduce unwanted friction in modern transportation while ensuring that vehicles remain safe and effective.

Modern advances in friction control

Aerodynamic vehicle design

- Cars, trucks and aircraft are shaped to reduce air resistance (drag), allowing them to move more efficiently.
- Formula 1 race cars use special body designs to manage airflow, reducing drag while maintaining enough friction for tyre grip.

FIGURE 8.16 Formula 1 race cars are engineered for speed.

Lubricants in machinery and engines

- To reduce friction inside engines and mechanical parts, scientists develop advanced **lubricants** and synthetic oils that allow moving parts to glide smoothly. This helps extend the life of machines, reduces overheating and improves fuel efficiency.

Low-friction road surfaces

- Engineers design roads using smooth asphalt and concrete mixtures to reduce rolling resistance, improving fuel efficiency.
- Some highways have porous asphalt, which allows water to drain away quickly, preventing hydroplaning and improving tyre grip in wet conditions.

Friction control in high-performance sports

- Athletes in sports such as cycling, speed skating and skiing use equipment designed to minimise friction and maximise speed.
- Ski and snowboard bases are coated with wax to reduce friction with the snow, while Olympic ice skaters wear special suits to cut down air resistance.

Tyre and surface interaction

- Car tyres are designed with different tread patterns to provide the right amount of friction for different conditions.
- Racing tyres are smooth (slick tyres) to maximise grip on dry surfaces, while winter tyres have deep grooves to improve traction on icy roads.

By studying friction and how it interacts with surfaces, engineers continue to develop more efficient and sustainable transportation systems. Reducing unnecessary friction lowers energy consumption, improves speed and extends the lifespan of vehicles and equipment.

1. How does friction affect the movement of different types of vehicles?
2. What are some modern materials and technologies used to reduce unwanted friction?
3. How do race-car designs balance reducing air resistance while maintaining grip on the track?

4. Why do different road surfaces affect vehicle performance?
5. What role do lubricants play in reducing friction in engines and mechanical systems?
6. How do different types of tyres help vehicles adapt to different road conditions?

Information and processed data can be analysed to show patterns, trends and relationships, and to identify anomalies (VC2S8I05)

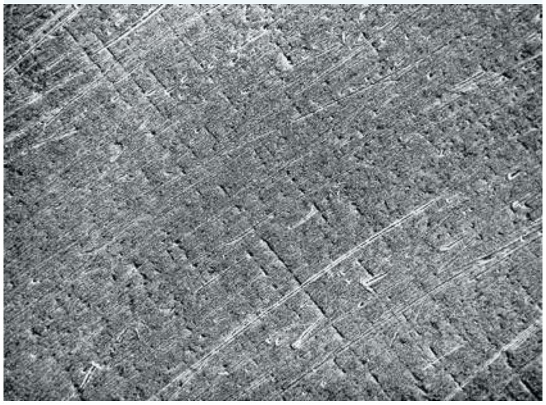
8.4.3 What causes friction?

Even very smooth surfaces are rough when you look at them under a very powerful microscope.

The photograph in figure 8.17 shows a smooth, polished metal surface magnified 300 times. At that magnification, you can see that the surface is actually covered in scratches, making it rough. It is this roughness that causes friction.

Friction is the interaction between surfaces as these scratches and bumps rub against each other.

FIGURE 8.17 A close-up of a 'smooth', polished surface



8.4.4 Reducing friction

Ball-bearings

Ball-bearings (see figure 8.18) are often used to reduce the friction on wheels as they spin around an axle. The ball-bearings act as wheels, allowing the outside ring to 'roll' around the inside ring without sliding. (Rolling friction is much less than sliding friction. Try rolling and sliding an object.) The ball-bearings enable the wheels to turn faster, and reduce wear and tear because they lessen the amount of contact between the surfaces.

FIGURE 8.18 Ball-bearings reduce friction between the axle and wheel hub.

Lubricants

What makes a door squeak? A squeaky door can be silenced with a few drops of oil. The oil reduces the friction within the hinge. Substances like oil, grease and petroleum are called lubricants. They reduce the force of friction produced by the rubbing of solid surfaces.

Lubricants are needed in machines where wear and tear, heat and noise result from surfaces rubbing against each other. Oil and grease are used to lubricate wheel bearings on skateboards, rollerblades and bicycles. Synovial fluid is an example of a lubricant in the human body and is found between your joints to stop your bones from scraping against each other.

FIGURE 8.19 Oil stops the squeak in a door by reducing friction.

8.4.5 Fluid friction

Any substance that is able to take up the shape of its container and can flow is called a fluid. Air and water are both fluids. Objects travelling through air and water experience fluid friction. Like rolling friction and sliding friction, fluid friction acts against the motion of objects. Fluid friction, such as drag and air resistance, limits the speed of objects travelling through air and water. It increases the amount of fuel needed by cars, planes, motorised boats and submarines.

Cars, planes, watercraft and bicycles are **streamlined** to reduce fluid friction. The faster a vehicle needs to travel, the more important streamlining becomes. Some athletes even shave their bodies to streamline them.

Sports scientists at the Australian Institute of Sport and universities throughout the world are constantly searching for ways to reduce friction so that swimmers, short-distance runners and cyclists can move faster through fluids. Tight-fitting and smooth materials such as Lycra® reduce fluid friction through water and air. The design of bicycle helmets is always changing as scientists and engineers find new shapes and materials that reduce fluid friction.

FIGURE 8.20 Scientists use wind tunnels to test the effect of fluid friction on objects with different designs.

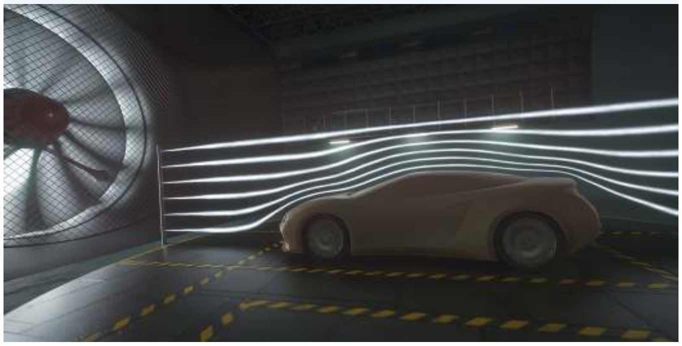


FIGURE 8.21 Racing cyclists' equipment is designed to reduce fluid friction.

ACTIVITY: Reducing friction in sport

Consider a sport or activity where friction is a nuisance. Design a piece of equipment or cloth that will help reduce this friction. Draw a labelled diagram of your design and explain how the various components would reduce friction.

SCIENCE AS A HUMAN ENDEAVOUR: Returning safely from space

When astronauts return from space, one of the most dangerous parts of their journey is re-entry into Earth's atmosphere. As they travel through space there is almost no friction, but when astronauts re-enter the atmosphere at speeds of over 25 000 km/h, they experience extreme fluid friction, generating temperatures greater than 1500 °C. Without proper protection, the spacecraft and its crew would burn up from the intense heat.

Over the years, different spacecraft have been designed to ensure astronauts return safely. Until 2011, NASA's space shuttles were used for astronaut re-entry. These shuttles were covered with thousands of ceramic tiles, which acted as a heat shield by absorbing and releasing heat. To slow down, the shuttles performed zigzagging manoeuvres through the atmosphere before landing like an aeroplane at speeds of about 300 km/h.

Since NASA retired the space shuttles, astronauts have been returning to Earth using the Russian Soyuz capsule, a much smaller, differently shaped spacecraft. The Soyuz capsule is covered in ceramic sheets and has a heat shield that burns away as it absorbs heat. Unlike the space shuttle, which landed on a runway, the Soyuz capsule deploys parachutes to slow down before touching down on the plains of Kazakhstan at speeds of about 5 km/h. Once landed, recovery teams assist the astronauts out of the capsule.

FIGURE 8.22 A recovery team locates the Soyuz capsule after a safe landing.

The evolution of spacecraft re-entry technology highlights how scientific knowledge and engineering designs change over time to improve safety and efficiency. Future spacecraft, such as SpaceX's Dragon capsule and NASA's Orion spacecraft, continue to refine re-entry technology, using advanced heat shields, parachute systems and even controlled rocket landings. Understanding forces such as air resistance, gravity and friction is essential for designing spacecraft that can withstand extreme conditions and bring astronauts safely back to Earth.

1. Why is re-entering Earth's atmosphere dangerous for astronauts?
2. How do space shuttles and the Soyuz capsule protect astronauts from extreme heat?
3. What is the role of friction and air resistance during re-entry?
4. Why do space shuttles land like planes, while the Soyuz capsule uses parachutes?
5. How have spacecraft designs changed over time to improve astronaut safety?
6. What are some modern technologies being developed to improve spacecraft re-entry?
7. How do forces such as gravity, friction and air resistance affect spacecraft as they return to Earth?
8. What would happen if a spacecraft didn't have a heat shield during re-entry?

Scientific knowledge, including models and theories, can change because of new evidence (VC2S8H01)

ACTIVITY: The dangers of spacecraft re-entry

The dangers of the high friction re-entry of spacecraft into the atmosphere were highlighted in 2003 when the space shuttle *Columbia* broke up 16 minutes before it was due to land. All seven crew members were killed. This tragedy is believed to have been caused by minor damage done to some of the ceramic tiles on the shuttle's surface during launch. This left a very small part of the surface unprotected from the high temperatures caused by friction. The resulting fire quickly reached *Columbia*'s fuel tanks, causing a huge explosion.

FIGURE 8.23 Damage to *Columbia*'s ceramic tiles is believed to have caused it to overheat and explode on re-entry in a tragic incident in 2003.

Write and present as a play an account of a discussion between seven astronauts aboard a space shuttle as it leaves orbit, re-enters the atmosphere and lands. The re-entry is not as smooth as it should be, and the temperature inside becomes dangerously hot. Be creative and dramatic, but the play must end with a successful touchdown on Earth.

In what other situations might friction cause a dangerous level of heat?

INVESTIGATION 8.5

Friction

Aim

To compare the friction of a variety of shoes on a floor surface

Materials

- a floor
- a variety of shoes
- equipment used to measure the friction between a shoe and the floor surface

Method

1. Design an experiment to compare the friction of a variety of shoes and a particular floor surface.
2. Collect a variety of shoes to test. Include different types of school shoes and runners.
3. Identify the equipment you will need to measure the friction that exists between each shoe and a particular floor surface.
4. Collect information about each shoe to be tested, such as length, mass, sole material and tread shape.
5. Form testable hypotheses about each variable that you decide to investigate.
6. Write up the method used in your investigation using a scientific report format.

Results

Record your results in a suitable table.

Discussion

1. Identify the variables that you controlled and the variables that you would have liked to control but could not.
2. Explain what shoes had the least friction.
3. Why do you think this is important?

Conclusion

Summarise your findings and outline the differences in friction of various shoes.

8.4 Activities

learnon

8.4 Quick quiz on	8.4 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 4, 7, 10	2, 3, 6, 9	5, 8, 11

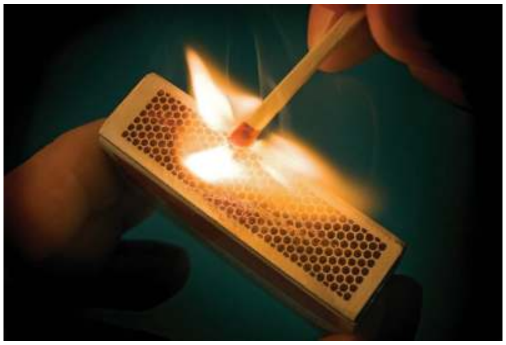
Remember and understand

1. MC **Identify** what friction is.
   A. A force of attraction between two objects with mass
   B. A force applied to the surface of an object when it moves against the surface of another object
   C. A force between charged particles
   D. A force of repulsion between two objects
2. Friction can cause objects to slow down. **Explain** what else it can do.
3. **Explain** how traction is different from other types of friction.
4. **List** three ways in which friction can be reduced. Give an example of each method.
5. **Define** fluid friction. Give some examples of where it happens in everyday life.

Apply and analyse

6. For each of the images below, **explain**:
   a. how the friction force is being helpful
   b. what would happen if the friction force was absent.

i.


ii.


iii.


iv.


7. For each of the images below, **explain**:
   a. how the friction force is being a nuisance
   b. what could be done to reduce the effect of the force of friction.

i.


ii.


Evaluate and create

8. SI Some Olympic swimmers wear smooth, tight-fitting suits, streamlining their bodies to reduce friction. Some of them even shave their heads. **Discuss** how streamlining reduces fluid friction in a racing car or aeroplane.
9. **Discuss** how frictional forces would affect astronauts aboard the space capsule as it leaves the International Space Station, re-enters Earth's atmosphere and lands.
10. SI Imagine a world without friction. Make a list of things that would be:
    a. easier to do
    b. harder to do.
11. Design a concept for a new type of tyre that balances low friction for fuel efficiency and high friction for safety. **Explain** how your design addresses the challenges of different road conditions.

Answers and sample responses are available in your digital formats.

LESSON 8.5 Keeping afloat

LEARNING INTENTION

In this lesson you will describe the upward force known as buoyancy and explain how it is different to surface tension.

8.5.1 Buoyancy

The largest cruise ship in the world, *Icon of the Seas*, has a mass of about 251 million kilograms. The gravitational force acting on this massive ship is enormous — more than 2.3 billion newtons.

Despite this strong downward force, the ship does not sink because there is an equal and opposite upward force acting on it. This upward force, known as buoyancy, is provided by the water the ship is floating on.

Buoyancy is the upward push on an object that is floating on top of or submerged in a fluid. It acts in all liquids and gases. The buoyancy on an object depends on its density (mass per unit of volume). The less dense an object, the more likely it is to experience buoyancy and float. It is the force that keeps helium-filled balloons floating in the air. It is also the force that allows submarines to rise to the surface of the ocean.

Consider figure 8.25. If the buoyancy force acting on the balloons is greater than the gravitational force pulling them down, the balloons will rise into the air when released. If the buoyancy force is also greater than the combined gravitational force of both the woman and the balloons, they will lift her into the air as well.

FIGURE 8.24 The force of buoyancy pushes upwards to keep this huge cruise ship afloat.

FIGURE 8.25 What will happen if she lets go?

The buoyancy force of the water in the Dead Sea is so large that you can lie back and read a book, as shown in figure 8.26. The unusual size of the force is caused by the large amount of salt in the water.

FIGURE 8.26 Buoyancy in the Dead Sea

INVESTIGATION 8.6

Are things really lighter in water?

Aim

To measure buoyancy and its effect on the apparent gravitational force of an object

Materials

- a stone
- length of string
- spring balance
- bucket
- 500 g mass

Method

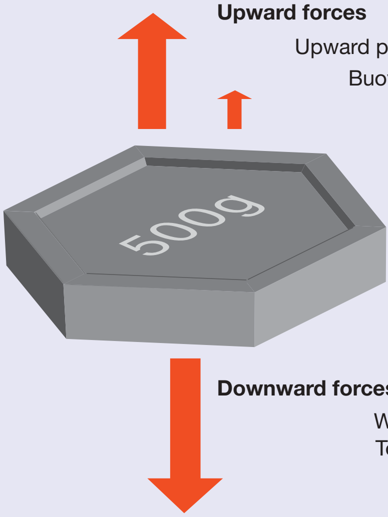
1. Tie some string around a stone. Suspend the stone in a bucket of water without letting it touch the bottom.
2. Use a spring balance to measure the gravitational force (N) acting on a 500 g mass while it is in the air. Record the value.
3. Without removing the mass from the spring balance, carefully lower it into the bucket so that it sits just under the surface of the water.
4. Record the force measured by the spring balance.

Results

1. What did you observe when the stone was lowered into the bucket of water?
2. What was the gravitational force acting on the 500 g mass in air?
3. What was the gravitational force acting on the 500 g mass when submerged in water?

Discussion

1. Does the stone feel any lighter when it is in the water? Why?
2. Use the following diagram to work out the size of the buoyancy force on the 500 g mass. (The total force on the mass is zero while it is sitting still under the surface. That means that the total upward force must be equal to the total downward force.)
3. Is the 500 g mass really lighter? Explain.



Upward forces

Upward pull of spring balance = ________ N

Buoyancy force of water = ________ N

Total upward force = ________ N

Downward forces

Weight of 500 g mass = ________ N

Total downward force = ________ N

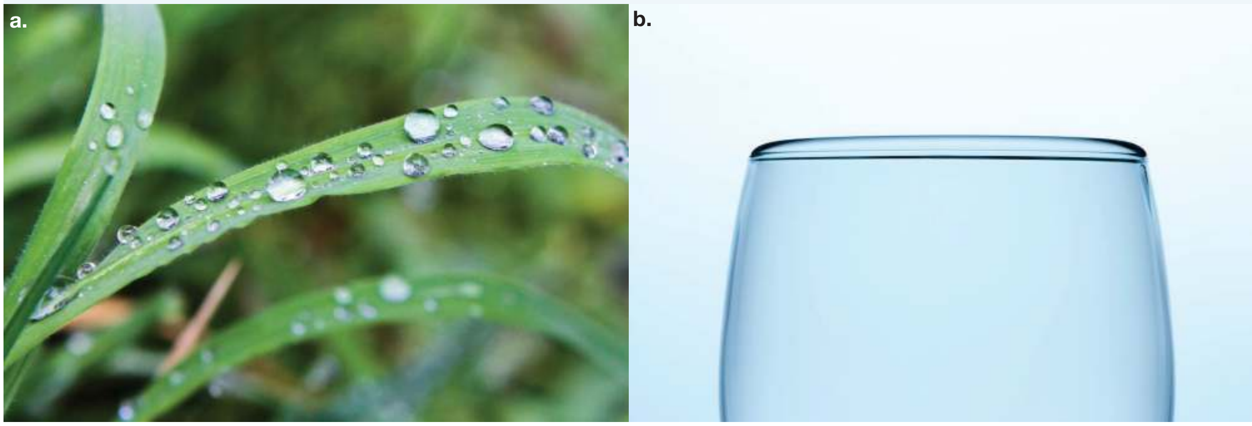
Conclusion

Summarise your findings from this investigation, explaining why an object feels lighter in water, referring to the concept of buoyancy and the forces acting on the object.

8.5.2 Surface tension

Have you ever wondered why water is able to collect as beads on objects? Or why you're able to overfill your glass with water? This is because water is held in shape by **surface tension**. Surface tension is the pulling of particles in a liquid towards each other. How could soaps and detergents affect the surface tension of water?

FIGURE 8.27 a. Water is able to bead on a leaf because of the leaf's waxy surface and the surface tension of the water. **b.** Up to a certain point, you can overfill your glass with water because the surface tension of the water creates a meniscus.



ACTIVITY: Floating matches

Cut a slit in the end of a match and gently open it up a little. Float the match in a bowl of water. Carefully place a drop of dishwashing detergent in the split end of the match and watch what happens. Try to explain your observations.

INVESTIGATION 8.7

Water drops

Aim

To investigate how dishwashing detergent affects the surface tension of water

Materials

- 5 cent coin
- small beaker of water
- eye dropper
- dishwashing detergent

Method

1. Write a hypothesis for your investigation related to the following question: Do you think that adding dishwashing detergent to water will result in you being able to get more drops or fewer drops of water onto a 5 cent coin?
2. With great care, and from a very small height, use an eye dropper to place one drop of water at a time onto the coin. Keep count of the number of drops.
3. Dry the coin thoroughly and try again to see whether you can improve on your first attempt.
4. Compare your result with those of others in your class.
5. Repeat this challenge using water with a few drops of dishwashing detergent added to it.

Results

1. What is the greatest number of drops of water (with no dishwashing detergent added) that you were able to place on the coin?
2. What was the greatest number of drops placed on a 5 cent coin in your class?
3. How many drops of water did you get on the coin after the dishwashing detergent was added?
4. Did the dishwashing detergent make it easier or more difficult to get drops of water to stay on the coin?

Discussion

1. What seems to hold the water on the coin?
2. What difference does adding detergent make to your results?
3. Why do you think the detergent has changed the result?

Conclusion

Summarise your findings from this investigation, explaining how dishwashing detergent affects the surface tension of water.

ACTIVITY: Walking on water

Water spiders can walk on water because of surface tension. While they are light, their ability to stay on the surface is due to the way their weight is spread out, preventing them from breaking the surface of the water.

Surface tension occurs because water molecules pull tightly together at the surface, creating a thin 'skin' that can support small objects or animals with a low enough gravitational force. The water spider's legs are also covered in water-repellent hairs, further helping it stay on top of the water.

FIGURE 8.28 The water spider walks on water. Why can't you?

1. What inventions use the same principle of surface tension to allow humans to move across water?
2. What inventions use different principles (e.g. buoyancy or propulsion) to help humans move across water?

8.5 Activities

learnon

8.5 Quick quiz on	8.5 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 6	4, 5, 7	3, 8

Remember and understand

1. MC **Identify** which two of the following forces act on you when you float on your back in a swimming pool.
   A. Gravitational force
   B. Friction force
   C. Traction force
   D. Buoyancy force
2. **Explain** the difference between buoyancy and surface tension.
3. Would an object float more easily in water or air? **Explain** why.
4. **Identify** the forces that allow a water spider to stand on a still pond.

Apply and analyse

5. **Analyse** the relationship between buoyancy and gravitational force to **predict** what will happen to an object when placed in a fluid:
   a. if the buoyancy force acting on the object is equal to the gravitational force
   b. if the buoyancy force is less than the gravitational force?
6. Why can some small insects walk on water, but humans cannot? Use gravity, buoyancy and surface tension in your explanation.

Evaluate and create

7. SI Different fluids produce different buoyancy forces. What do you think would happen if you dropped a corn kernel or a pea into a glass of water and another into a glass of soda water? Which liquid do you think applies the larger buoyancy force? **Explain** why.
8. SI **Construct** an experiment to compare the buoyancy and surface tension of water, olive oil and vinegar. Write a report using the following headings: aim, hypothesis, materials and method. **Explain** your expected results and conclusion for this investigation.

Answers and sample responses are available in your digital formats.

LESSON 8.6 Staying safe

LEARNING INTENTION

In this lesson you will apply the knowledge of forces to understand how helmets make cycling safer, how airbags and seatbelts make driving safer, and how bending your knees makes landing on the ground safer.

8.6.1 Forces and safety

Understanding forces is extremely important in ensuring health and safety. Regulations around wearing seatbelts in cars and safety helmets while riding a bicycle have all come about from an understanding of forces and motion. These safety measures have drastically reduced deaths and injuries.

SCIENCE AS A HUMAN ENDEAVOUR: The role of helmets in preventing injuries

Every year in Australia, around 1200 people die due to road accidents, and thousands more suffer serious injuries. A significant portion of these accidents involve young bicycle riders aged 10–14, in which the most severe injuries tend to affect the head and face. Research has shown that wearing a helmet greatly reduces the risk of head injuries, making it an essential piece of safety equipment for cyclists.

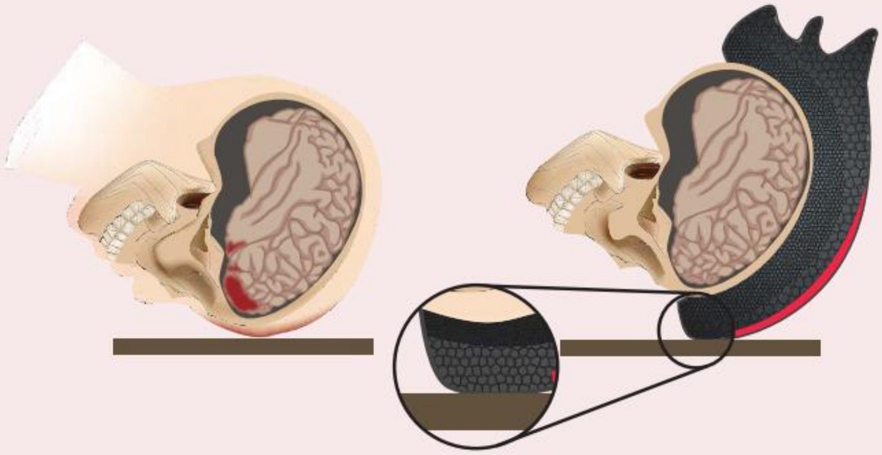
FIGURE 8.29 The law requires that cyclists wear a bicycle helmet.

A bicycle helmet is specifically designed to absorb and distribute impact forces, reducing the risk of severe brain and skull injuries. Helmets are made with two key layers:

- a hard plastic outer shell, which spreads out the force of an impact over a larger area
- a polystyrene foam layer, which compresses upon impact, slowing down the deceleration of the head and reducing the force transferred to the brain.

When a cyclist falls and hits the ground at speeds of up to 20 km/h, a helmet ensures that the head stops more gradually, rather than coming to a sudden halt, which could cause severe brain trauma. The crushing of the foam layer absorbs energy, reducing the overall force that reaches the skull.

FIGURE 8.30 The plastic shell and polystyrene foam of a helmet soften the impact on the head in an accident.



The science behind helmets in other sports

Cycling is not the only activity where helmets are necessary. Helmets are crucial in sports and activities where there is a risk of high-impact collisions or falls.

- Motorcycling: riders travel at high speeds and helmets protect against both impact forces and road debris.
- Horseriding: falls from horses can result in serious head injuries, making helmets essential.
- Contact sports (e.g. rugby and ice hockey): helmets help absorb shock from collisions with other players.
- Skateboarding and rollerblading: helmets protect riders from head injuries in case of a fall.

Scientific advances in helmet design

Over time, scientific knowledge about head injuries has led to improvements in helmet technology. Engineers and scientists use crash testing, material science and biomechanics to create helmets that are stronger, lighter and more effective. Some modern helmets include:

- a multi-directional impact protection system (MIPS), which reduces rotational forces on the brain during angled impacts
- smart helmets with built-in sensors to detect impacts and alert emergency responders
- improved ventilation and comfort designs, ensuring that helmets remain practical for regular use.

By continuously researching and improving helmet designs, scientists and engineers help prevent injuries and save lives. Encouraging helmet use, along with following road safety rules, plays a crucial role in reducing accidents and making activities safer for everyone.

1. Why are head injuries one of the most serious risks in cycling accidents?
2. How does a bicycle helmet protect a cyclist's head from serious injury?
3. What materials are used in helmet construction? How do they absorb impact forces?
4. Why do helmets need both a hard outer shell and a foam inner layer?
5. How have helmet designs changed over time due to scientific advancements?
6. What are the benefits of wearing a helmet in other sports and activities?
7. How do laws and regulations about helmet use impact public safety?
8. What are some modern technologies being developed to improve helmet safety?

Proposed scientific responses to socio-scientific issues impact on society and may involve ethical, environmental, social and economic considerations (VC2S8H03)

INVESTIGATION 8.8

Egghead

Aim

To model a bicycle helmet to observe its effect during a collision

Materials

- hard-boiled egg
- selection of packing materials, such as bubble wrap, foam rubber and newspaper
- sticky tape
- cardboard
- wire

Method

1. Design, build and test a container that will hold a hard-boiled egg. Your aim is to create an egg container that will prevent the shell from cracking when it is dropped from a height of 1.5 metres onto a hard floor.
2. You are actually creating a model of a bicycle accident. The egg represents the head of a cyclist. Your container represents the helmet.

Results

Did your egg survive the fall?

Discussion

1. Draw a neat, labelled diagram of your final egg container.
2. What features of your container were included to protect the shell from cracking?
3. If your 'egg head' was 'injured', suggest how you could improve the effectiveness of your container.

Conclusion

Summarise your findings and relate them to wearing a helmet if cycling.

INVESTIGATION 8.9

Crash test dummy

Aim

To model the effect of a crash on a crash test dummy

Materials

- pencil sharpener or eraser
- toy car
- rubber band
- block of wood
- clamp

Method

1. Clamp a wooden block to the end of a table.
2. Place the pencil sharpener or eraser on the toy car to represent an occupant.
3. Push the toy car towards the wooden block as fast as you can without your 'crash test dummy' falling off.
4. Observe the motion of the crash test dummy after the car collides with the wooden block.
5. Modify this experiment to include 'seatbelts' (by using a rubber band).

Results

1. Describe the motion of both the car and the crash test dummy after the collision without the 'seatbelt'.
2. What difference does the rubber band make to the motion of the crash test dummy during and after the collision?

Conclusion

Summarise your findings and relate them to the importance of wearing a seatbelt in vehicles.

8.6.2 Safety on four wheels

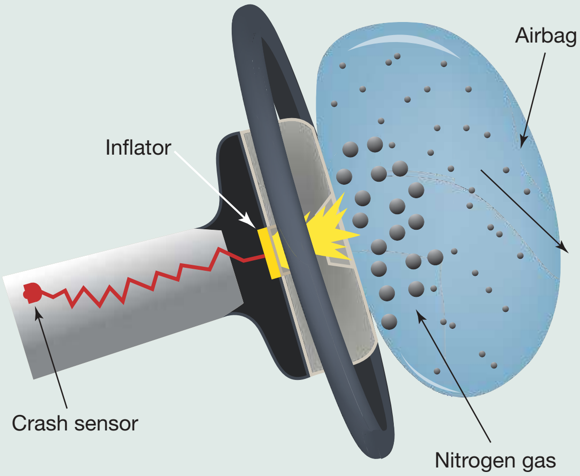
In cars and other motor vehicles, padded dashboards, collapsible steering wheels and airbags reduce injuries by allowing the upper body to slow down more gradually when a car crashes. The addition of various safety features has greatly reduced deaths and fatalities over the years.

EXTENSION: Safety features in cars

Airbags

Airbags inflate when a sensor behind them detects the sudden change in speed or direction that results from a collision, as shown in figure 8.31.

FIGURE 8.31 Deployment of an airbag



Seatbelts

When a car collides head-on with an obstacle or another vehicle, the occupants continue to move forwards after the car stops. In fact, they continue to move forwards at the same speed and direction that the car had before the collision until they are stopped by a force. Without seatbelts, the occupants would fly forwards through the windscreen, or their bodies would be stopped suddenly by the steering wheel, dashboard, roof or other parts of the inside of the car. Most deaths and injuries in car accidents are caused by a collision between the occupants and the inside of the car. With properly fitted seatbelts, car occupants stop as the car stops and are less likely to be killed or injured.

Your body is not the only thing that will keep moving once the car stops as a result of a collision. Any loose objects in the car will continue to move after the car stops. You should therefore never leave any loose objects in the car. They are much safer in the boot! In one accident, a driver was killed by a paperback novel that was sitting on the shelf behind the back seat. It continued to move after the car and driver (with properly fitted seatbelt) stopped. A corner of the book struck the driver in the back of the head, killing her instantly. Unrestrained pets are also dangerous in a collision.

8.6.3 Bend your knees

In some sports, like basketball and volleyball, you need to jump high above the ground. But, of course, what goes up, must come down. When you land on the ground, you stop because the surface provides a large upward force. If you land on your feet with your legs straight and rigid, you stop very, very quickly, even with shoes that cushion. The upward force on your legs is large enough to cause damage. However, if you bend your knees as you land, you stop more slowly and the upward force is less.

FIGURE 8.32 It's best to bend your knees when landing after a high leap.

8.6 Activities

learnon

8.6 Quick quiz on	8.6 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 7	3, 5, 9	4, 6, 8

Remember and understand

1. MC **Identify** how bicycle helmets protect the head in an accident.
   A. They absorb and spread out the impact force to reduce injury.
   B. They increase friction between the helmet and the road to stop your head from moving.
   C. They prevent all forces from acting on your head.
   D. They make your head lighter so gravity affects it less.
2. **Explain** how seatbelts decrease the chance of injury or death during a road accident.
3. **Describe** the likely motion of an unrestrained rear-seat passenger in a car that collides with a tree at 60 k/hour.

Apply and analyse

4. When a stationary car is hit from the rear by another vehicle, it is pushed forwards rapidly. **Describe** the likely motion of a front-seat passenger:
   a. with a head restraint fitted to the seat
   b. without a head restraint fitted to the seat.
5. SI **Explain** how seatbelts protect passengers during a crash, in terms of forces.

Evaluate and create

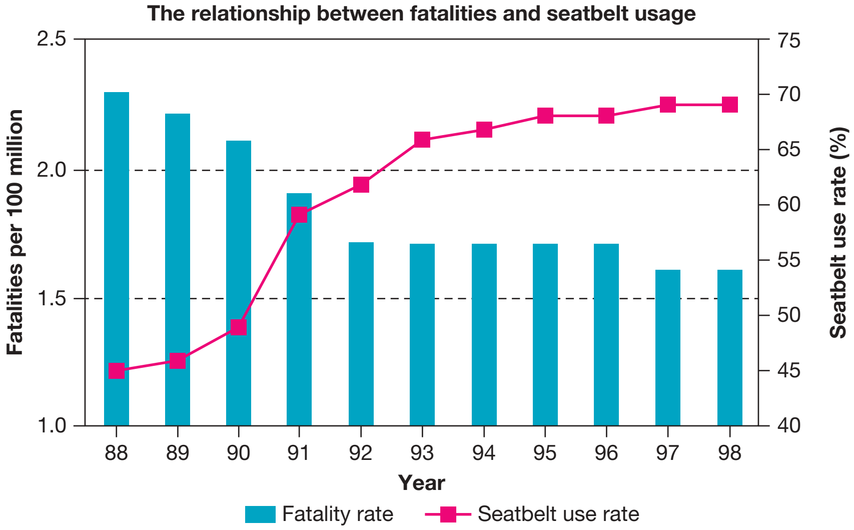
6. SI Not everybody believes that the wearing of bicycle helmets should be compulsory in Australia. **List** the reasons for and against the compulsory wearing of helmets.
7. Imagine you have been tasked with designing a poster with the title 'Don't be an egghead. Wear a helmet.' **Explain** the science behind helmet safety that you need to include on your poster.

8. SI Use the data in the table to answer the following questions.

Comparing the use of seatbelts and no seatbelts in car crash survivals and fatalities			
	Seatbelt	**No seatbelt**	**Total**
Killed	16 001	31 199	47 200
Survived	7 758 634	2 791 887	10 550 521
Total	7 774 635	2 823 086	10 597 721

a. What percentage of car occupants killed were wearing a seatbelt?
b. What percentage of car occupants killed were not wearing a seatbelt?
c. **Construct** a pie graph to display your results from **a.** and **b**.
d. What can you conclude from the data shown in this table?

9. SI Use the graph to answer the following questions.



a. What percentage of car occupants used seatbelts in 1992?
b. In which year was the percentage of fatalities highest?
c. In which years did the fatality rate remain constant?
d. Using the data shown, can you conclude that there is a relationship between seatbelt use and car crash fatalities?

Answers and sample responses are available in your digital formats.

LESSON 8.7 Review

8.7 Success criteria

Tick the column to indicate that you have completed the lesson and how well you think you have understood it using the traffic light system.

(**Green:** I understand; **Yellow:** I can do it with help; **Red:** I do not understand)

Lesson	Success criteria	Green	Yellow	Red
8.2	I can explain what forces are and their effect on different objects.			
8.3	I can explain what the force of gravity, mass and gravitational force are.			
	I can describe what it means to reach a terminal speed.			
8.4	I can explain what friction is.			
	I can situations where friction is useful and others where it is a nuisance.			
8.5	I can describe the upward force known as buoyancy and explain how it is different to surface tension.			
8.6	I can apply the knowledge of forces to understand how helmets make cycling safer, how airbags and seatbelts make driving safer, and how bending your knees makes landing on the ground safer.			

learnon

Post-test	Topic 8 Post-test
eWorkbook	Topic 8 eWorkbook
Digital document	Key terms glossary

8.7 Activities

learnon

8.7 Review questions

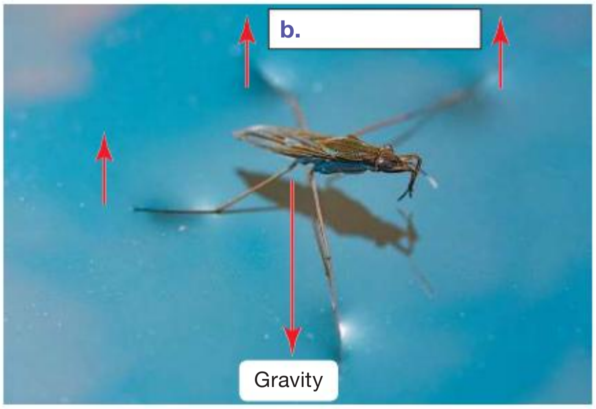
■ LEVEL 1	■ LEVEL 2	■ LEVEL 3
1, 3, 4, 8, 12, 13	2, 6, 7, 9, 11, 13, 14, 16	5, 10, 14, 15, 17

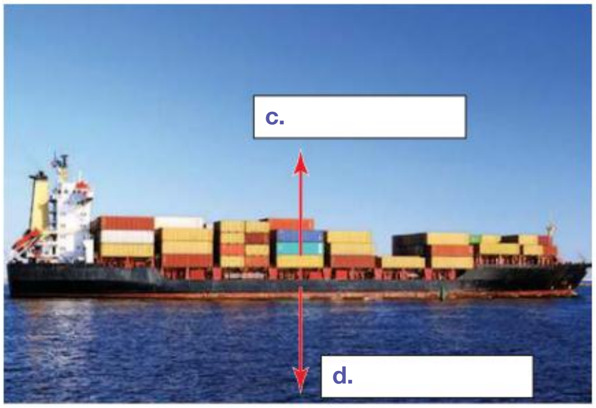
Remember and understand

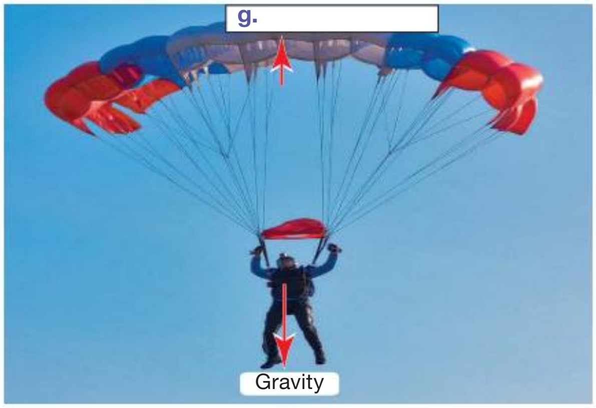
1. Match the force to the effect it creates.

Effect	Force
a. Pushes you up when you are swimming underwater	**1.** Friction
b. Causes all objects with mass to attract each other	**2.** Buoyancy
c. Acts on an object when it moves across the surface of another object	**3.** Surface tension
d. Resists the motion of all objects moving through the air	**4.** Gravity
e. Pushes up on objects on the surface of water, but not on objects below the surface	**5.** Magnetic force
f. Can lift a paperclip from a desktop	**6.** Air resistance

2. **Identify** the forces missing in each of the images.





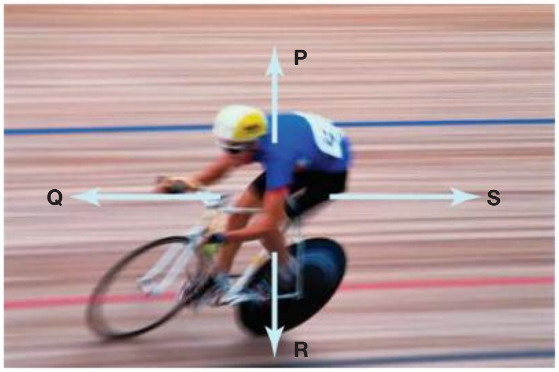


3. **State** the units used to measure:
   a. mass
   b. gravitational force
   c. force.
4. Select the correct option to complete the following sentence.
   Like charges *attract* / *repel* and unlike charges *attract* / *repel*.
5. Draw arrows on the following diagrams to represent the forces acting on the book while it is:
   a. at rest on the desk
   b. falling towards the floor.

a.

b.

6. The arrows in the image of the cyclist represent four forces acting on the cyclist as they ride on a smooth, flat surface. **Identify** these forces and **describe** how each one affects the cyclist's motion.



7. MC The compass needle is not shown in the diagram.

If the needle was included in the diagram, **identify** in which direction it would point.
A. North
B. South
C. East
D. West

Apply and analyse

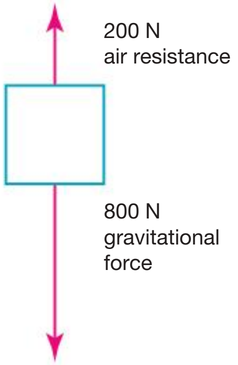
8. **Explain** how streamlining reduces air resistance in vehicles such as cars and aeroplanes.
9. **Explain** why the pull of gravity is less on the Moon than it is on Earth.
10. MC When a package of emergency supplies is first dropped from a plane, it gains speed rapidly. **Identify** why the package eventually stops gaining speed before reaching the ground, even without the use of a parachute.
A. It reaches terminal velocity.
B. Because of gravity.
C. The effect of air resistance is greater than that of gravity.
D. The package gets caught in the wind.
11. **Explain** how lubricants such as grease and oil reduce the production of heat in the moving parts of car engines and other mechanical devices.

Evaluate and create

12. MC **Identify** which of the following are ways that racing cyclists reduce the effect of air resistance on their motion. Select all possible answers.
A. Using an aerodynamic helmet
B. Wearing tight-fitting, streamlined clothing
C. Wearing loose clothing
D. Position their body to become more streamlined
E. Use tyres with more grip
F. Shaving body hair

13. Why do scuba divers wear heavy belts when diving? **Explain** what would happen if they did not, using the terms buoyancy, gravity and net force.

14. SI List some investigations that sports scientists could undertake to improve performance in each of the following sports.
    a. Tennis
    b. Golf
    c. Cricket
15. **Describe** how your body would move if you were a passenger in a car that stopped very suddenly and you were not wearing a properly fitted seatbelt.
16. **Explain** how the thick layer of polystyrene foam or similar material inside the outer shell of a helmet reduces the likelihood of severe head injuries in an accident.
17. a. Determine the size and direction of the net force acting on the object shown in the diagram.



    b. MC If the object is moving downwards, what will happen to its speed?
        A. Its speed will increase.
        B. Its speed will decrease.
        C. Its speed will remain constant.
        D. There is insufficient information to make any judgment on what will happen to its speed.
    c. MC If the object is moving upwards, what will happen to its speed?
        A. Its speed will increase.
        B. Its speed will decrease.
        C. Its speed will remain constant.
        D. There is insufficient information to make any judgment on what will happen to its speed.

Answers and sample responses are available in your digital formats.

on To test your understanding and knowledge of this topic, go to your learnON title at jacplus.com.au and complete the **post-test**.

9 Simple machines

CONTENT DESCRIPTION

Simple machines, including the lever, inclined plane, wedge, pulley, screw, and wheel and axle, alter the direction and magnitude of forces (VC2S8U13)

Source: Victorian Curriculum F–10 Version 2.0

LEARNING SEQUENCE

LESSON 9.1 Overview

9.1.1 Introduction

What do you think of when you hear the word 'machine'? Maybe you think of a car engine. Or a vehicle-building **robot** in a factory, or even a computer. And you would be right — these are all examples of **machines**. But machines are not always complicated things made up of lots of moving parts. As we will see in this topic, a machine can also be something as uncomplicated as a screwdriver or an axe. The earliest machines used by humans were simple ones, such as the **wedge**, the wheel, the boomerang and the spear thrower.

However, it would be a mistake to think that large, complicated machines have only been around for a few hundred years. Figure 9.2 shows a fragment of the Antikythera Mechanism, which was discovered off the coast of Greece in 1902. This device, which calculated when solar and lunar eclipses would occur, was made over two thousand years ago, but x-rays show it contains a complex series of gears.

FIGURE 9.1 The woomera (spear-thrower) is an ancient tool used by humans. It uses leverage to increase a spear's speed and range.

FIGURE 9.2 The Antikythera Mechanism is a machine that was created over two thousand years ago.

The thing that all machines have in common is that they perform specific functions that make our everyday lives easier. For example, they allow us to lift huge rocks in quarries and to travel long distances much faster than walking speed. In this topic, we will see how machines help us by changing the direction in which a force acts, changing the size of a force, or both.

DISCUSSION

1. How could you lift a 200 kg refrigerator off the ground by yourself?
2. Why do bicycles have gears?
3. Why do roads wind around mountains instead of going straight up?
4. What are the hardest types of bathroom taps to use?
5. Why is it harder to open a door when the doorknob is in the centre?
6. What machine has most improved your life?

KEY IDEA

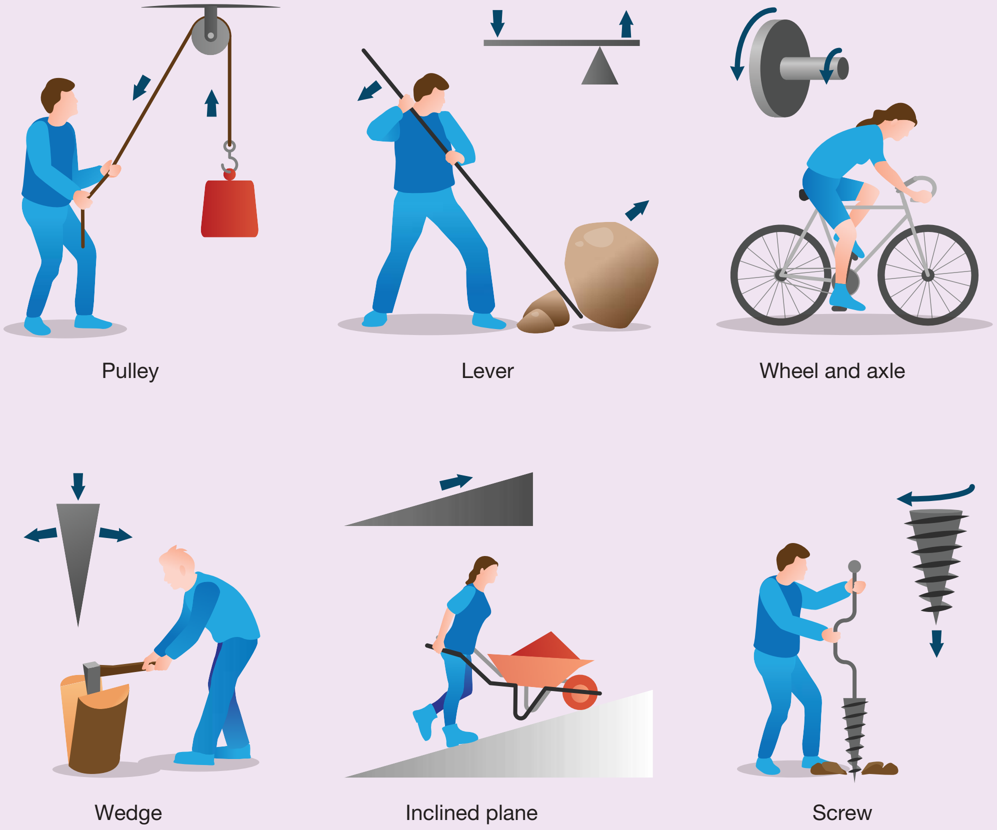
A machine is a device that makes a physical task easier by changing the size, direction or distance of a force. Cars, bikes, cranes and escalators are all machines.

- A **simple machine** is a smaller component that makes up another machine. Examples of a simple machine include a **lever**, **pulley**, **inclined plane**, **screw**, wedge and **wheel-and-axle** system.
- A **compound machine** is two or more simple machines combined.
- A **complex machine** is an advanced system that may include compound machines, electronics or motors.

SCIENCE INQUIRY: Exploring simple machines

Instead of transferring energy, simple machines work by transferring and modifying forces to make tasks easier. They can act as force multipliers (reducing effort required) or speed multipliers (increasing movement speed).

FIGURE 9.3 Some simple machines to make tasks easier



1. What is a machine and what does it do?
2. What are some examples of machines we use in everyday life?
3. What do we mean by ‘simple machines’?
4. How do simple machines help us do work?
5. Can you think of a task that would be difficult without a machine?
6. How do you think a bicycle works as a machine?

Investigable questions, reasoned predictions and hypotheses can be developed in guiding investigations to identify patterns, test relationships, and analyse and evaluate scientific models (VC2S8I01)

INVESTIGATION 9.1

Exploring simple machines

Aim

To explore the function of two simple machines and how they can make tasks easier

Materials

- metal can with lid (a paint, coffee or chocolate-powder tin all work well)
- spoon
- claw hammer
- nail in a block of wood

Method

Part A: Removing the lid from a can

1. Place the lid firmly on the can.
2. Try to remove the lid without using the teaspoon. If you succeed in removing the lid, replace it.
3. Use the teaspoon to remove the lid. Replace the lid again.
4. Use the teaspoon to remove the lid again, but hold the spoon much closer to the end near the lid.

Part B: Removing a nail

1. Try to remove the nail from the block of wood without the hammer. Take care that you don't hurt your hand.
2. Now use the hammer to remove the nail.

Results

Record your observations in a table like the one below.

	Observations without using a simple machine	Observations while using a simple machine (teaspoon/hammer)
Part A		
Part B		

Discussion

1. How does the teaspoon make it easier to remove the lid?
2. Where should you hold the spoon to lift the lid most easily?
3. Would you have been able to get the nail into the block of wood without the hammer?
4. Does the hammer make it easier to remove the nail?
5. Where should you hold the hammer to make it easier to remove the nail?
6. What is another example of something you do every day that uses a simple machine?

Conclusion

Write a clear conclusion for this investigation and write a brief statement about how simple machines can make a physical task easier to do.

learnon

Pre-test	Topic 9 Pre-test
eWorkbooks	Topic 9 eWorkbook Student learning matrix
Practical investigation eLogbook	Topic 9 Practical investigation eLogbook
Digital document	Key terms glossary

LESSON 9.2 Using levers

LEARNING INTENTION

In this lesson you will explain that levers of different types allow you to change the direction, speed or size of a force exerted on an object.

9.2.1 Levers

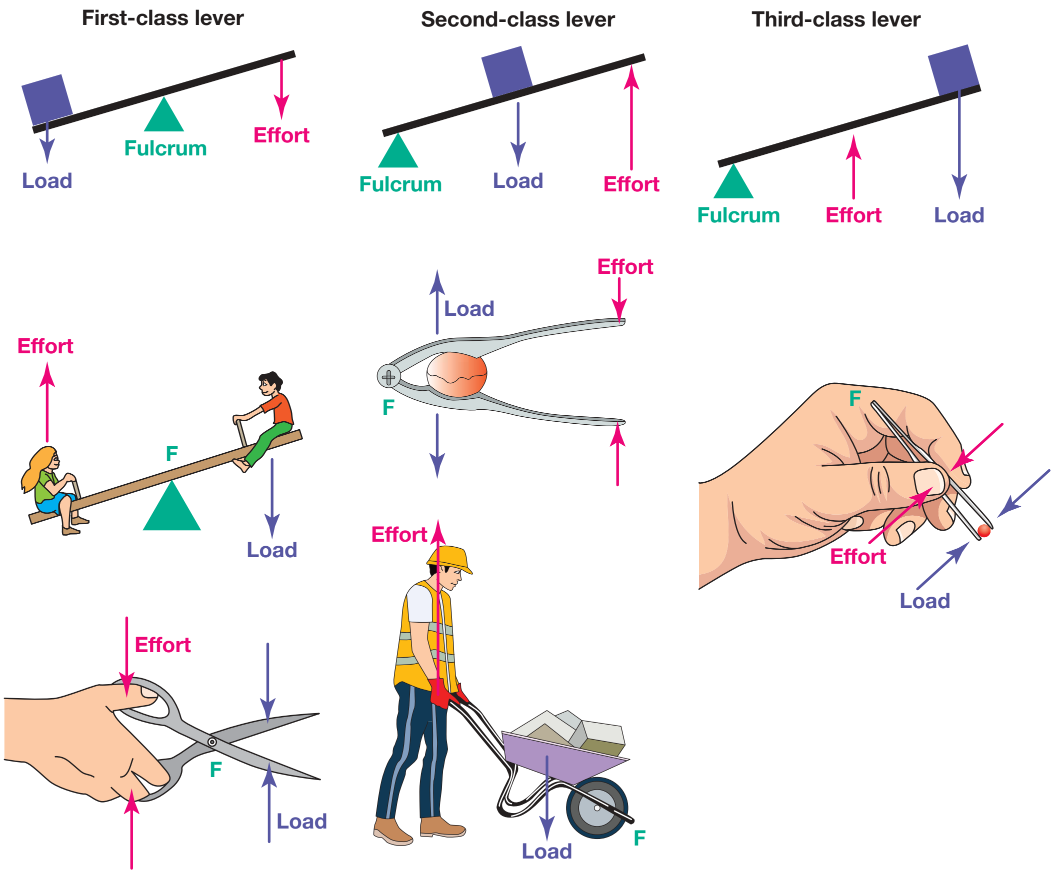
Can-openers, scissors, tongs, spanners, hammers, brooms, tennis racquets and staplers are levers . A lever is a simple machine that uses the turning effect of a force.

The turning point of a lever is called its **fulcrum**. The resistance to motion that a lever works against is called the **load**. The force used to cause movement is called the **effort**.

Levers are classified into the following three types based on the position of the fulcrum, load and effort:

- first-class lever
- second-class lever
- third-class lever.

FIGURE 9.4 The three classes of lever differ depending on the relative positions of the fulcrum, effort and load.

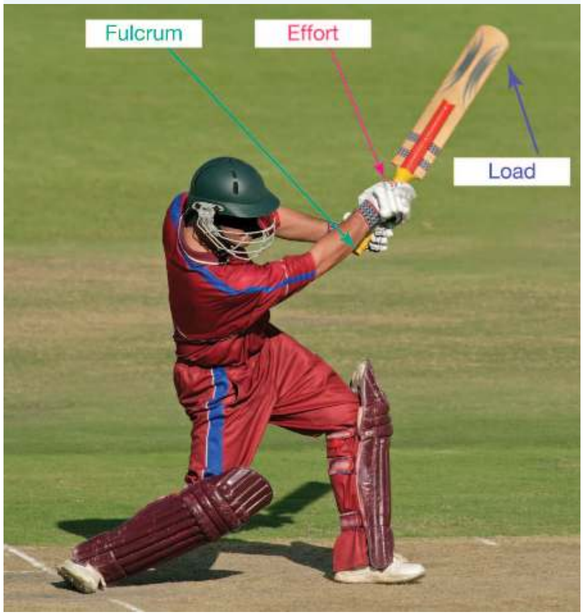


9.2.2 Types of levers

For first- and second-class levers, the effort is smaller than the load. They are said to act as **force multipliers** because they increase the effect of the force applied to an object.

Third-class levers are not force multipliers. They move a load through a larger distance than the effort moves in the same time and are therefore **speed multipliers**. The cricket bat shown in figure 9.5 is a third-class lever. Golf clubs, tennis racquets and brooms are also third-class levers designed to move a small load quickly with a large effort.

FIGURE 9.5 A cricket bat is a third-class lever designed to move a small load quickly.



KEY IDEA

First-class and second-class levers are force multipliers. Third-class levers are speed multipliers.

What is the advantage?

The advantage of force-multiplying levers is that they allow you to move a heavy load with a small effort.

KEY IDEA

The **mechanical advantage** of a force-multiplying lever is defined as:

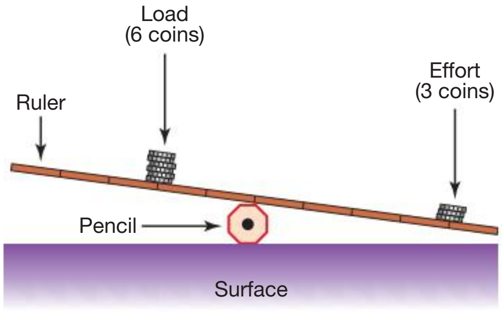
$$\text{mechanical advantage} = \frac{\text{load}}{\text{effort}}$$

For example, when you use the lever in figure 9.6 to raise a load of six coins with an effort of only three coins, the mechanical advantage is given by:

$$\text{mechanical advantage} = \frac{\text{load}}{\text{effort}}$$
$$= \frac{6}{3} = 2$$

In other words, the lever lifts a load that is two times greater than the effort.

FIGURE 9.6 The mechanical advantage of this lever is 2.



ACTIVITY: Pushing your barrow

You will need a wheelbarrow, a few bricks and a partner for this activity. Place a few bricks in the wheelbarrow and lift it by the ends of the handles. Without changing the load, lift the wheelbarrow with your hands as far down the handle as possible. While holding the wheelbarrow up, have your partner move the load so that it is closer to the handle. How does the position of the effort affect its ability to raise the load? How does the position of the load affect the amount of effort needed to raise it?

SCIENCE AS A HUMAN ENDEAVOUR: Moving the world

The concept of simple machines, such as levers, has been explored for thousands of years. Archimedes, a Greek mathematician and scientist, was one of the first to describe the principles of levers mathematically around 2300 years ago. His famous statement, 'Give me a lever long enough and a fulcrum on which to place it, and I shall move the world,' highlights the incredible power of simple machines in amplifying force.

FIGURE 9.7 A fulcrum and lever can be used to move a heavy load.

Throughout history, humans have used simple machines to make work easier. Ancient Egyptians used levers and **ramps** to build the pyramids, while early civilisations used pulleys and inclined planes to move heavy objects. Even today, simple machines are fundamental to engineering and construction, appearing in everything from car jacks to seesaws in playgrounds.

Scientific knowledge about simple machines has evolved over time as new discoveries have been made. For example, the development of mechanical advantage equations has helped engineers design machines that require less effort to perform tasks more efficiently.

Archimedes' early principles of levers and pulleys laid the foundation for modern physics, which has expanded our knowledge of forces and motion. Today, this understanding is used to create advanced machinery for construction, transportation and space exploration.

By studying simple machines, scientists and engineers continue to improve the way we build structures, transport goods and develop technology that makes life easier.

1. Who was Archimedes? What was his contribution to our understanding of simple machines?
2. What does Archimedes' famous quote about levers mean?
3. How have humans used simple machines throughout history?
4. How has our understanding of simple machines changed over time?
5. What role do simple machines play in modern technology and engineering?
6. Can you think of an example of a simple machine that is used in everyday life to reduce effort?
7. What would happen if we didn't use simple machines in construction and transportation today?

Scientific knowledge, including models and theories, can change because of new evidence (VC2S8H01)

INVESTIGATION 9.2

Get a load of this

Aim

To investigate the relationship between effort and its distance from the fulcrum

Materials

- ruler at least 30 cm long
- pencil
- 6 identical coins or 50 g weights
- plasticine (to hold pencil in place if it rolls)

Method

1. Draw up a table like the one shown in the results section.
   - Use the pencil and ruler to set up a seesaw so that it balances without any weights on it.
   - Place a load of three weights 4.0 cm to the left of the fulcrum. Place the other three weights (the effort) to the right of the fulcrum so that the effort balances the load.
2. Record the distance from the effort to the fulcrum in your table.
   - Remove two of the weights from the effort and raise the load of three weights with an effort of only one weight.
3. Record the new distance from the effort to the fulcrum in your table.
   - Experiment with your seesaw to see where various efforts need to be placed to raise loads of five, four or two weights.
4. Record your observations in your table.
   - Do some more testing, including raising small loads with a small effort.

Results

Copy and complete the table with your observations.

Load		Effort	
Number of weights	Distance from fulcrum (cm)	Number of weights	Distance from fulcrum (cm)
3	4.0	3	
3	4.0	1	
5		1	
4		2	
4		1	
2		1	

Discussion

1. Explain why this type of lever is described as a force multiplier.
2. Describe any patterns that you see in this data.
3. Predict where you would place two weights in order to balance out a load of five weights placed 2 cm from the fulcrum. Explain your reasoning.
4. Describe a real world situation in which it would be useful to raise a light load with a large effort with this type of lever.

Conclusion

Write a sentence describing the relationship between the effort and its distance from the fulcrum.

9.2.3 Levers in your body

Many of the bones in your own body are levers. The long bones in your arms and legs are the most obvious examples of levers. Joints such as your elbow and knee act as fulcrums. Your muscles pull on part of the bone to provide the effort. The load is the resistance to motion that your bone works against. The load could be the weight of a basketball, a soccer ball, a bucket of water or a heavy weight in the gym.

When you bend your arm to lift a weight, the effort is provided by your biceps muscle where it joins a bone called the radius in your forearm, just below the elbow. Your elbow is the fulcrum. It is the turning point of the lever. The load is the weight that you are trying to lift upwards. The effort is between the fulcrum and the load, so your forearm is acting as a third-class lever and a speed multiplier (see figure 9.8).

When you straighten your arm to push downwards, such as when you do push-ups or push a weight down, your forearm acts as a first-class lever and force multiplier. The fulcrum is your elbow. The effort is provided by your triceps muscle, which is joined to a bone in your forearm called the ulna. The load is the resistance to your downward push. In this case, the fulcrum is between the effort and the load (see figure 9.9).

FIGURE 9.8 When you bend your arm to lift a load, your forearm acts as a third-class lever.

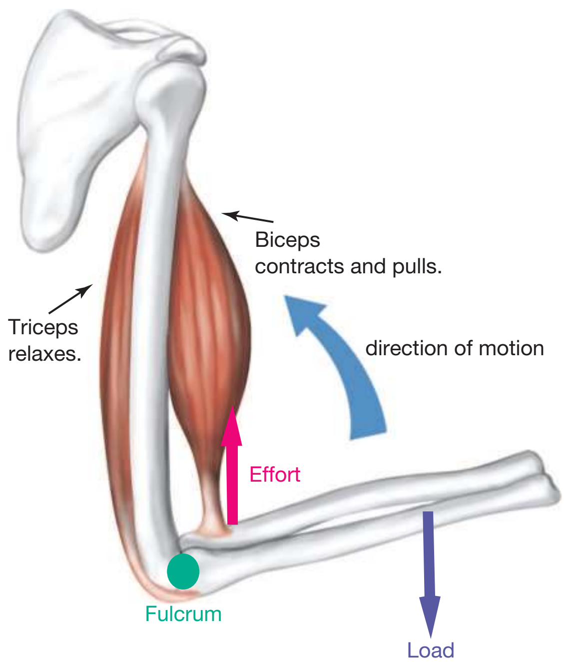
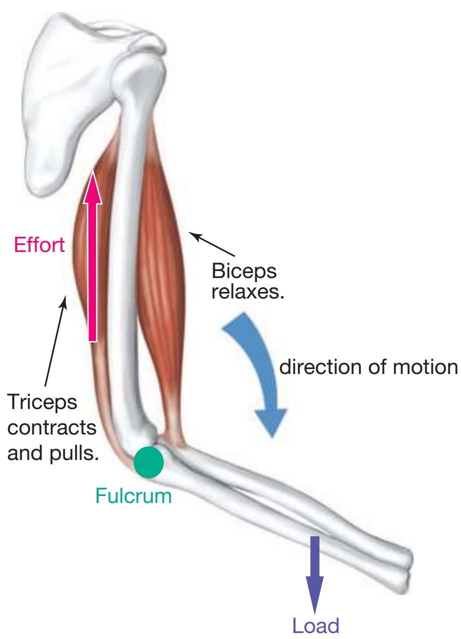


FIGURE 9.9 When you straighten your arm to push down loads, your forearm acts as a first-class lever.

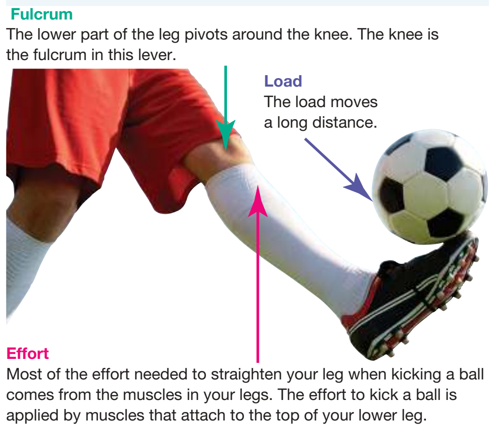


Levers in sport

When a ball is kicked, bones in the lower leg act as a third-class lever (see figure 9.10). The knee is the fulcrum. The effort needed to straighten the leg is provided by muscles attached to the top of the lower leg. The load is the resistance to motion of the football. Although there is little movement where the effort is applied, the foot (where the load is) moves a long distance.

In ball games such as tennis, badminton, cricket, baseball, golf and hockey, the racquet, bat, club or stick is used as a first-class lever. The end of the lever that strikes the load (the ball) moves much faster than the end of the lever where the effort is applied.

FIGURE 9.10 The knee acts as a fulcrum.



When a tennis ball is served, the lever consists of your whole arm and the tennis racquet (see figure 9.11). The fulcrum is your shoulder, the effort is applied by the muscles attached to the bones of your upper arm, and as the ball hits the racquet, the load is at the centre of the racquet. The larger the distance between the load and the effort, the faster the serve. Professional tennis players can serve tennis balls at speeds of up to 240 km/h. This is many times the speed of the upper arm where the effort is applied.

FIGURE 9.11 When serving, the arm and tennis racquet work together as a third-class lever and speed multiplier.

Why warm up?

The muscles that pull on your bones to make them move are made up of tough and elastic fibres. When they are cold, the muscles are less elastic. If you overload muscles without warming up, they can easily tear. Even with warming up, if muscles have not been prepared for sport by proper training, they can easily be torn when sudden movements are made.

ACTIVITY: Encouraging warming up

Create a poster or short series of PowerPoint slides that could be used to encourage people to warm up before going for their daily run around the block.

9.2.4 Aboriginal and Torres Strait Islander Peoples' application of knowledge about levers

You may be familiar with a device like the one shown in figure 9.12, which is used to launch a tennis ball for dogs. This device acts as a lever — by lengthening the distance of the load (the tennis ball) and the fulcrum (your wrist), it acts as a speed multiplier.

FIGURE 9.12 A dog ball launcher

This device is actually an adaptation of a device used as a spear thrower called a woomera. It was developed thousands of years ago by Aboriginal and Torres Strait Islander Peoples, and traditionally crafted from hardwood. It ranges in length from approximately 50 cm to 100 cm and comes in various shapes and widths.

One end of the woomera features a resin-coated notch or peg that holds the base of the spear, allowing the thrower to propel it with increased force. The opposite end serves as a handle, enabling a firm grip. Some woomeras also functioned as multipurpose tools, used for tasks such as carrying food or cutting materials.

By extending the arm and acting as a lever, the woomera magnifies the speed and distance of the spear throw. The force applied by the thrower is transmitted through the woomera, allowing spears up to three metres in length to travel much further and faster than they would if thrown by hand alone.

FIGURE 9.13 One end of the woomera has a hook or notch that holds the base of the spear, while the other end serves as a handle for the thrower.

9.2 Activities

learnon

9.2 Quick quiz on	9.2 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 3, 6, 12	4, 5, 7, 8, 9, 11	10, 13, 14, 15

Remember and understand

1. MC **Identify** which body parts provide the effort when bones act as levers.
   A. Joints
   B. Muscles
   C. Nerves
   D. Bones
2. MC **Identify** which of the following best describes a lever.
   A. A simple machine
   B. A complex machine
   C. A force of attraction
   D. A machine that relies on electricity
3. When you bend your forearm upwards to lift a bucket of water, it acts as a lever.
   a. Where is the fulcrum?
   b. Which muscle provides the effort?
   c. What is the load?
   d. Which type of lever is your forearm acting as?

4. When you straighten your arm to do push-ups, your forearm acts as a lever.
   a. Where is the fulcrum?
   b. Which muscle provides the effort?
   c. What is the load?
   d. Which type of lever is your forearm acting as?
5. **Explain** why warming up before sport is important for muscle function when using levers in movement.
6. **Outline** why first-class and second-class levers are called force multipliers.
7. **Explain** how the woomera uses the principle of a lever to act as a speed multiplier.

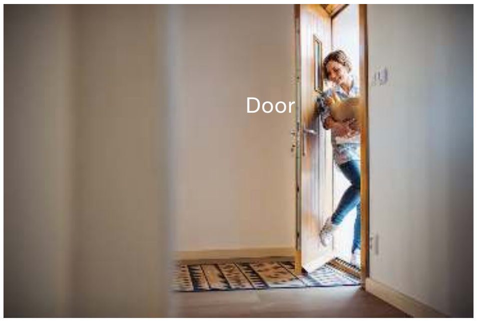
Apply and analyse

8. **Explain** why a lever cannot provide more force or motion than is applied to it.
9. In cricket, the arm acts as a lever when the ball is bowled.
   a. Which class of lever is the arm acting as?
   b. Is the arm acting as a speed multiplier or a force multiplier? **Explain** your answer.
   c. Which part of the body acts as the fulcrum?
10. In tennis and cricket, how does the length of a player's arm affect the mechanical advantage of their levers? **Justify** your answer.
11. i. Label the load, effort and fulcrum on the lever in each image below.
    ii. Which of the levers are speed multipliers? **Explain** how its design influences this function.
    iii. Which of the levers are second-class levers? **Explain** how its design influences this function.

a.


b.


c.


d.


12. a. **Explain** how third-class levers increase speed but require more effort.
    b. Provide four examples of third-class levers used in daily life.

Evaluate and create

13. **Explain** why door handles are placed as far away from the hinges as possible.
14. Many athletes do not just warm up. They also go through 'cooling down' exercises after strenuous activity. Think about why they do this and write a summary explanation.
15. SI a. If a lever allows one coin to lift a load of three coins, what is its mechanical advantage? **Explain** your reasoning.
    b. Animals have different jaw shapes that act as levers. Short, strong jaws act as force multipliers, while long, slender jaws act as speed multipliers. **Explain** how these different jaw types provide an advantage in hunting or eating.

Answers and sample responses are available in your digital formats.

LESSON 9.3 Pushing uphill using ramps, wedges and screws

LEARNING INTENTION

In this lesson you will describe how a ramp, wedge and screw reduce the force needed to lift or move objects.

9.3.1 Inclined planes — ramps

Lifting objects can be difficult. If an object is heavy, it takes a very strong person to lift it. Many objects are too heavy for people to lift, even if they work together in a group. However, by pushing or pulling objects up ramps, people can quite easily lift heavy objects.

A ramp is a machine because it makes the physical task of raising an object easier. A ramp is simply an inclined plane — a surface that is set at an angle to the horizontal (see figure 9.14). It allows objects to be raised with less effort than would be needed to lift them straight up because the object is lifted gradually, instead of all at once. Stairs and ladders are examples of ramps, while escalators are moving ramps . Imagine trying to climb straight up a wall to get to the second floor of a building.

Although a smaller effort is needed when using a ramp, the load must be moved through a larger distance. Longer ramps make it easier to lift objects, but more time and overall effort is needed due to the longer distance travelled. The winding mountain road as shown in figure 9.15 is also a ramp. Imagine how much shorter the trip would be if the road went straight up the mountain — but no vehicle would be powerful enough to use the road.

FIGURE 9.14 Lifting a heavy object is made much easier with a ramp.

FIGURE 9.15 This winding mountain road is a ramp. How does this make driving easier?

SCIENCE AS A HUMAN ENDEAVOUR: The Great Pyramid

The construction of the Great Pyramid of Giza, one of the most remarkable engineering achievements of the ancient world, remains a subject of scientific and historical inquiry. Built more than 4500 years ago, the pyramid was constructed using more than 2.3 million blocks of limestone, with each block weighing between two and 15 tonnes. Despite having no modern machinery, the ancient Egyptians developed ingenious engineering methods to transport and lift these massive stones.

FIGURE 9.16 Building the pyramids required ramps leading to the increasingly high levels.

Historians and scientists believe that the primary tool used in pyramid construction was the simple machine known as the inclined plane — in the form of long ramps made of mudbrick, sand and limestone chips. These ramps allowed workers to drag heavy stone blocks upward using sleds and ropes. Some researchers suggest that water may have been poured onto the sand to reduce friction, making it easier to pull the sleds.

Additionally, levers and rollers may have been used to position the stones precisely. Recent archaeological evidence also suggests that wooden sleds and copper tools were employed to shape, move and lift the blocks. The fact that the pyramids still stand today demonstrates the effectiveness of these early engineering techniques and highlights how humans have always sought innovative ways to solve difficult problems.

The construction of the Great Pyramid also emphasises how scientific knowledge and engineering practices evolve over time. While ancient Egyptians used basic machines such as ramps and levers, today's engineers rely on cranes, conveyor belts and hydraulics for heavy lifting. Modern scientists continue to study ancient Egyptian construction methods to gain insights into sustainable building techniques and the use of natural resources.

The mystery of how the pyramids were built continues to inspire scientists and engineers, showing how scientific theories can change as new evidence is discovered.

1. What materials were used to build the Great Pyramid?
2. How did the ancient Egyptians transport and lift such heavy blocks?
3. What simple machines were used in the construction of the Great Pyramid?
4. Why do scientists believe ramps were essential to pyramid construction?
5. What evidence supports different theories about how the pyramids were built?
6. How has our understanding of pyramid construction changed over time?
7. How do modern engineers lift and transport heavy materials today? How is it different from ancient Egyptian methods?
8. What other ancient structures used simple machines for their construction?

Scientific knowledge, including models and theories, can change because of new evidence (VC2S8H01)

INVESTIGATION 9.3

Inclined to make it easier

Aim

To investigate how an inclined plane changes the force and work required to complete a task

Materials

- 3 textbooks
- 500 g mass with hook
- spring balance

Method

1. Place three textbooks on top of each other. Measure and record the height of the textbooks.
2. Place the 500 g mass next to the pile of books and use the spring balance to slowly lift the mass so that its base is level with the top of the pile.
3. Record the force measured by the spring balance.
4. Lean a ramp against the pile of books. Measure and record the distance from the bottom of the ramp to where it meets the top edge of the pile of books.
5. Place the 500 g mass at the bottom of the ramp and use the spring balance to slowly pull it until its far end reaches the top of the pile.
6. Record the force measured by the spring balance.

Results

Copy and complete the table. You may need to add rows if you test multiple heights.

Height of books (cm)	Force to lift mass (N)	Distance of ramp (cm)	Force to move mass up ramp (N)

Discussion

1. Does it take more force to lift the mass straight up or pull along the ramp?
2. In which case does the mass have to move further — straight up or along the ramp?
3. Which method of raising the mass is better? Why?
4. The mechanical advantage of a simple machine is a measure of the number of times greater a load is than the effort (see section 9.2.2). What is the mechanical advantage of your ramp?

Conclusion

Write a short paragraph summarising your findings.

9.3.2 Inclined planes — wedges and screws

Wedges

Wedges are inclined planes. They can be used to penetrate or split objects, or to stop them from moving. Axes, knives and your front teeth are examples of wedges. They reduce the force needed to cut through objects. If you have ever tried to cut through a hard piece of food like an apple with a blunt knife, you will know the value of a wedge.

FIGURE 9.17 A participant uses a wedge to cut through a log in a wood-chopping competition.

Screws

Screws are inclined planes. A screw is a curved ramp. However, instead of an object being pushed up the ramp, the ramp is pushed down into the object. The ramp cut into a screw is called the **thread**; the distance between two turns of the thread is called the **pitch**. Because the total length of the thread is so great, its force-multiplying effect is very large. Many simple car jacks use a large screw to lift a huge load with little effort. Similarly, a corkscrew is used to penetrate the tightly fitted cork of a wine bottle with little effort. The cork is then removed by pulling the corkscrew out directly.

FIGURE 9.18 A car jack is a large screw that allows you to lift a heavy car with little effort. This is useful when you need to change a car tyre.

INVESTIGATION 9.4

Inclined planes on the move

Aim

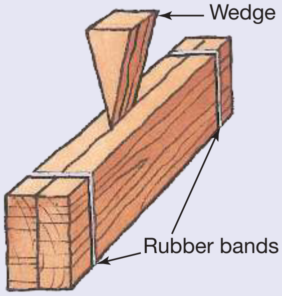
To investigate how wedges and screws are used to make tasks easier to complete

Materials

- wooden door wedge
- 2 rubber bands
- 2 blocks of wood (soft pine)
- self-tapping screw
- screwdriver

Method

1. Use two rubber bands to hold the two blocks of wood together. Try to pull the two blocks of wood apart with your fingers. Take care not to break the rubber bands.
2. Place the sharp edge of the door wedge between the two blocks and push it down. Be very careful to ensure the elastic bands do not flick off.
3. Use the screwdriver to insert the screw halfway into one of the blocks of wood. Look closely at the thread of the screw as it moves into the wood.



Results

1. Describe your observations when you used a wedge to try to separate the two blocks.
2. Describe your observations when you used the screwdriver to insert the screw into the block of wood.
3. Explain how the shape and movement of the screw allowed it to more easily go into the block.

Discussion

1. Would you have been able to get the screw halfway into the wood by pushing straight down on it?
   a. Does the wedge make it easier to separate the two blocks?
   b. Explain why this is the case.
2. Describe your observations when you used the screwdriver to insert the screw into the block of wood.

Conclusion

Summarise your findings of how wedges and screws make it easier to complete tasks.

9.3 Activities

learnon

9.3 Quick quiz on	9.3 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 5	3, 4, 7, 9	6, 8, 10

Remember and understand

1. **Explain** what a ramp is.
2. MC **Identify** the two incline planes.
   A. Playground slides
   B. Tables
   C. Ski slopes
   D. Doorways
3. **Construct** a table with three columns headed 'Ramps', 'Wedges' and 'Screws'. **List** as many examples of each type of inclined plane as you can.

Apply and analyse

4. **Describe** how an inclined plane reduces the effort needed to move an object and what trade-off is involved**.**
5. **Explain** the difference between the thread of a screw and the pitch of a screw.
6. A ramp makes it easier to push or pull objects upwards. **Discuss** the 'penalty' for making the task easier.
7. **Explain** why inclined planes are called force multipliers. Use an example to support your answer.
8. **Describe** how a ramp increases mechanical advantage. What happens when the ramp is longer?

Evaluate and create

9. **Explain** why sharpening a knife improves its ability to cut. How does this relate to inclined planes?
10. SI Observe a wheelchair ramp in your school or community.
    a. **Explain** how a wheelchair ramp makes it easier for a person to move up and down a slope.
    b. **Analyse** how the length and angle of the ramp can affect the effort needed to use it.

Answers and sample responses are available in your digital formats.

LESSON 9.4 Wheels, axles and pulleys

LEARNING INTENTION

In this lesson you will describe how a wheel-and-axle system and pulleys can change the direction and size of forces used to move objects.

9.4.1 Wheels and axles

When a lever is fixed at one end and rotated, it becomes a simple machine called a wheel and axle, because the lever is often disguised as a circular object. The lever, or circular part, is the wheel. The axle is attached to the fulcrum, or turning point, of the system (see figure 9.19).

A doorknob is a force multiplier. The handle is the wheel, which turns in a circle. The spindle inside is the axle, and it turns in a smaller circle. You apply a small effort to the wheel to move a large load with the axle. However, there is a penalty: you pay for the extra force with extra distance. The wheel (handle) moves further than the axle. But imagine how difficult it would be to turn the axle without a handle.

Bathroom taps and car steering wheels are also force-multiplying wheels and axles. Can you think of any others?

FIGURE 9.19 The components of a wheel and axle

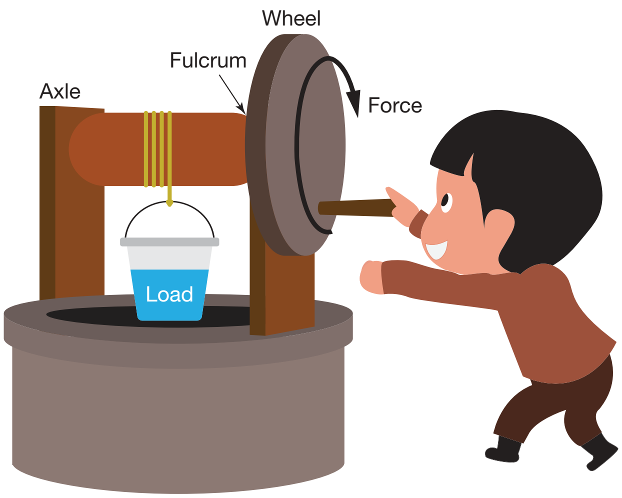
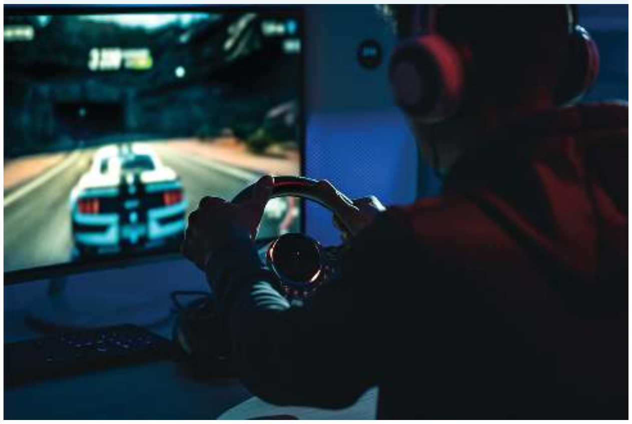


FIGURE 9.20 This doorknob is a wheel-and-axle machine.

FIGURE 9.21 Steering wheels are force-multiplying levers.



ACTIVITY: Model wheel and axle

Make a model wheel and axle. Use cotton thread and two sets of slotted weights to show how your model can be used as a force multiplier.

a. Calculate the mechanical advantage of your wheel and axle.
b. Explain how your model changes the applied force. Does it act as a force multiplier or a speed multiplier?

9.4.2 Speed it up

Wheel-and-axle systems can be used to increase speed. The ceiling fan in figure 9.22 is an example of a speed multiplier.

A large force is applied to the axle (the central rotating part). Each time the axle turns, the fan blades move a greater distance in the same amount of time, tracing out a full circle. This allows the fan to rotate faster than the axle itself.

The wheel-and-axle system helps distribute force efficiently, making it useful in machines designed for motion, such as bicycles, fans and car wheels.

A car wheel is another example of a speed multiplier. The axle turns when a large force is applied to it. The outside of the wheel moves faster, covering a much greater distance in the same time. Pairs of wheels and axles are sometimes joined together with a chain or belt (see figure 9.23). This either reduces the effort needed to make one of the wheels turn or makes one of the wheels turn faster. An example of this is the wheels of a skid steer loader. The chain connecting the wheels allows one engine to create a lot of force and easily move the vehicle.

FIGURE 9.22 This ceiling fan is a speed-multiplying wheel and axle machine.

FIGURE 9.23 These wheels and axles are joined by a belt to operate a skid steer loader.

INVESTIGATION 9.5

Investigating wheels and axles

Aim

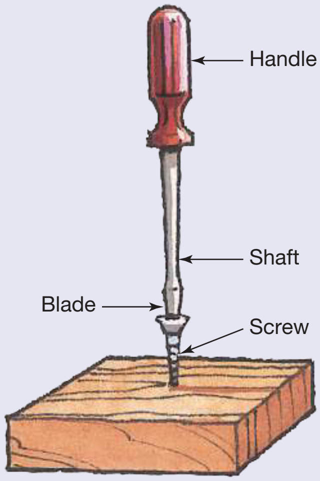
To investigate how a screwdriver can be used as a wheel and axle

Materials

- screw firmly embedded in a block of wood
- screwdriver

Method

1. Try to remove the screw from the block of wood with the screwdriver by turning the shaft instead of the handle.
2. Remove the screw by using the screwdriver as it is meant to be used — by turning the handle.
3. Use the screwdriver to replace the screw firmly into the wood.



Results

Summarise your observations in this investigation. What happened to the screw when the shaft was turned?

Discussion

1. What difference does using the handle make to the effort needed to remove the screw?
2. During one full turn of the screwdriver, which moves further — the outside edge of the handle or the outside edge of the shaft?
3. Draw a diagram of the screwdriver and show the wheel and the axle.
4. Explain why a screwdriver handle makes makes removing and inserting screws easier.

Conclusion

Summarise your findings about how wheels and axles make tasks easier.

INVESTIGATION 9.6

Wheels and axles at work

Aim

To investigate how wheels and axles can become force or speed multipliers

Materials

- selection of wheels and devices
  - doorknob
  - hand drill
  - toy cars
  - spinning toys
  - wind-up toys
  - taps
  - screwdrivers
  - wing nut
  - small wheels

Method

1. Examine the wheel and axle machines provided.
2. Draw a diagram of each, labelling the wheel and axle.

Results

For each machine examined, write down whether it is a force multiplier or a speed multiplier, noting your observations in a table similar to the one below.

Machine	Force multiplier or speed multiplier

Discussion

1. What features did all of the objects have in common?
2. Describe what evidence you used to help you determine if a machine was a force multiplier or a speed multiplier.
3. Are any machines both force and speed multipliers? Explain your answer.

Conclusion

In a short paragraph, summarise your findings from this investigation, outlining how wheels and axles work to act as force or speed multipliers.

9.4.3 Getting a lift

A pulley is a special type of wheel and axle that makes it easier for you to lift a load. The wheel has a groove around it so that a rope or cable can be passed over or under it. A pulley does not decrease the size of the force, or effort, needed to lift the load. It changes the direction of the effort.

It is easier to pull down on a rope to lift a load using a pulley than it is to pull it upwards with the rope. When you pull down on a rope, your own weight can be used to your advantage.

When more than one pulley is used, a large load can be lifted with a small effort. A system of two or more pulleys therefore acts as a force multiplier. It magnifies the size of the effort because multiple pulleys create multiple ropes or cables pulling up on the load. As with other force multipliers, there is a cost. The rope needs to be pulled through a large distance to move the load through a small distance.

The woman in figure 9.24 is using a pulley to change the direction of the force she applies, making it easier to lift the weight. Instead of lifting the load directly, she pulls downward on the rope, which allows her to use her bodyweight and arm strength more effectively to move the object.

FIGURE 9.24 A pulley changes the direction the effort is needed to lift a load, making it easier.

EXTENSION: Multiple-pulley systems

A multiple-pulley system is usually called a **block and tackle**. An example of this is shown in figure 9.25. The block is the frame around the pulleys. The tackle is the string or cable joining the load to the effort. With a block and tackle it is possible to lift many times your own weight. Of course, you have to pay for it by pulling over a long distance.

A block and tackle system is used in garages to lift engines out of cars. It is also used on cranes, wharves and ships.

FIGURE 9.25 A block and tackle

INVESTIGATION 9.7

Lifting that load

Aim

To compare the mechanical advantage of three pulley arrangements

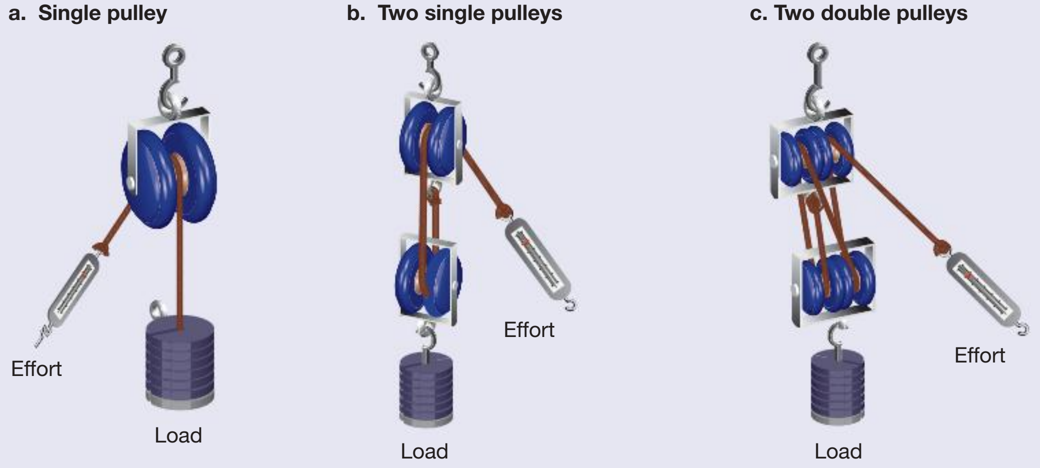
Materials

- 2 single pulleys
- 2 double pulleys
- 1 m length of string
- set of slotted 50-gram masses
- 5.0 newton spring balance
- metre ruler
- hook from which to suspend pulleys

Method

1. Load the slotted masses to a mass of 400 g and attach them to one end of the string.
2. Use the spring balance to measure the weight, in newtons (N), of the slotted masses. This weight is the load that must be lifted.
3. Record the load in a table of your results.
4. Thread the other end of the length of string over the wheel of a single pulley and attach it to the spring balance as shown in diagram a. Make sure the pulley is securely attached to a retort stand to hold it in position.
5. Pull slowly on the spring balance so that the load is lifted slowly and steadily upwards through a distance of 5 cm.
6. Record the force in newtons (N) measured by the spring balance. This force is the effort. Also record the distance through which you had to pull the spring balance to lift the load 5 cm.
   - The distance moved by the effort (your pull on the spring balance) is called the effort distance.
7. Arrange the system with two single pulleys as shown in diagram b. The pulleys should be about 10 cm apart.

8. Pull slowly on the spring balance to lift the load steadily.
9. In your table, record the force and effort distance needed to lift the load through a distance of 5 cm.
10. Repeat the previous two steps using the system with the two double pulleys shown in diagram c.



Results

Create a table for your results like the one below.

Pulley arrangement	Load (N)	Load distance (cm)	Effort (N)	Effort distance (cm)	Mechanical advantage (load/effort)
Single pulley		5			
Two single pulleys		5			
Two double pulleys		5			

Discussion

1. How does the effort needed to lift the load using two single pulleys compare with that needed to lift it with one single pulley?
2. How does the effort needed to lift the load with two double pulleys compare with that needed to lift it with one single pulley?
3. Would it be true to say that the system with two double pulleys has the same advantage as one with four single pulleys? Why?
4. How many ropes were pulling up on the load in each situation? How is this connected to the effort needed to lift the load?
5. Looking at your tabulated results, how would you say the effort needed changes as the number of pulleys increases?
6. How does the effort distance change as the effort itself decreases?
7. Predict how much effort would be needed to lift the same load by 5 cm if you used two triple pulleys instead of two double pulleys. How far would you need to pull on a string to lift the load 5 cm?

Conclusion

Summarise your findings about the three pulley systems and the differences in their mechanical advantage.

9.4 Activities

learnon

9.4 Quick quiz on	9.4 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 5, 7	3, 4, 6, 10, 12	8, 9, 11, 13

Remember and understand

1. **Name** which part of a circular doorknob the wheel is and which part the axle is.
2. Is a circular doorknob a force multiplier or a speed multiplier? **Explain** your answer.
3. **Explain** how a single fixed pulley is useful even though it does not decrease the size of the force needed to lift a load.
4. **Explain** what a block and tackle is and what it is used for.
5. **Construct** a two-column table with the headings 'Force multipliers' and 'Speed multipliers'. **List** as many wheel and axle machines as you can think of in the appropriate column.
6. **Identify** what the following equation tell us about simple machines.
   load × load distance = effort × effort distance

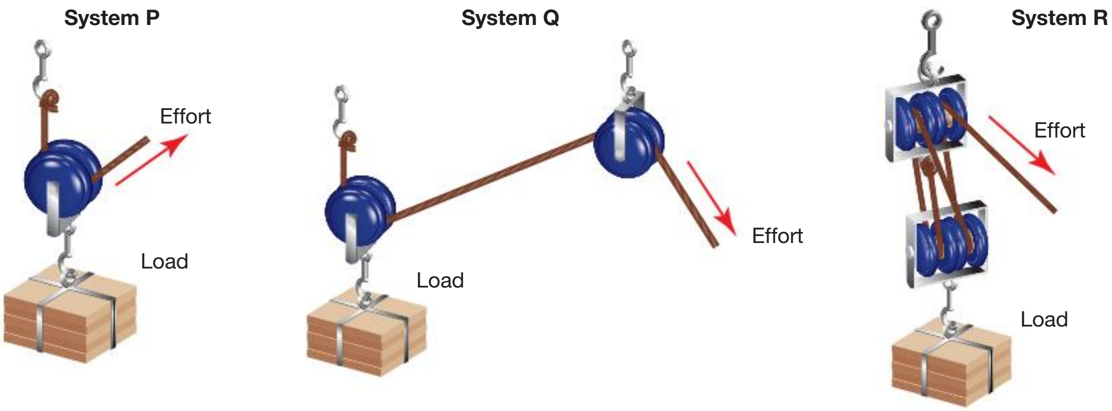
Apply and analyse

7. **Describe** why a ceiling fan is a speed multiplier. How does the rotation of the axle affect the movement of the fan blades?
8. Look at the image of a car steering wheel.
   a. Draw an arrow to show where the effort is applied when turning right.
   b. Label the wheel and the location of the axle.
   c. Determine the load being moved by the steering wheel.
   d. Classify the steering wheel as a force multiplier or a speed multiplier.
   e. If you wanted to change your steering wheel to one that was easier to turn, should you get a larger one or a smaller one?

9. **Explain** why using two single pulleys together is better than using only one single pulley when lifting heavy loads. What trade-offs come with this setup?
10. A system of multiple pulleys can make lifting a load easier. However, there is always a trade-off. **Explain** what is gained and what is lost when using a multiple-pulley system.

Evaluate and create

11. Study systems P, Q and R.



Identify and **explain** in which of the systems you would need to:
a. apply the least effort
b. apply the most effort
c. pull the string through the greatest distance
d. apply an effort equal to the load
e. apply an effort equal to half of the load.

12. SI Think about the wheels and axles on a bicycle.
a. **Identify** how many there are.
b. **Describe** the purpose of each wheel and axle.
c. **Explain** the function of the chain.

13. SI Pulleys are important in the functioning of rollercoasters.
a. **Outline** the role of pulleys in rollercoasters.
b. Determine where pulleys are most important during the ride.
c. **Analyse** how pulleys reduce the effort needed to lift the rollercoaster cars.

Answers and sample responses are available in your digital formats.

LESSON 9.5 Getting into gear

LEARNING INTENTION

In this lesson you will explain how gears are used to change the speed and direction of rotation of objects.

9.5.1 Driven by gears

Gears are a combination of a wheel and axle and a wedge. A gear is a wheel and axle with teeth. The teeth of one gear fit between the teeth of another gear. When one gear turns, the other can be made to turn faster, slower or in a different direction. Multiple gears connected together are called a **gear train**.

Gears in cars and bikes can be changed to provide more force or to allow for more speed. Gears are also found in many kitchen appliances. The different speeds of a blender are controlled by gears. Gears are used in many clocks and watches to make the hour and minute hands move at different speeds. Gears are also used in wind turbines (see figure 9.26), changing the slow rotation of the blades into a faster rotation, leading to the generation of more electricity.

FIGURE 9.26 A combination of gears in a wind turbine allow it to spin quickly.

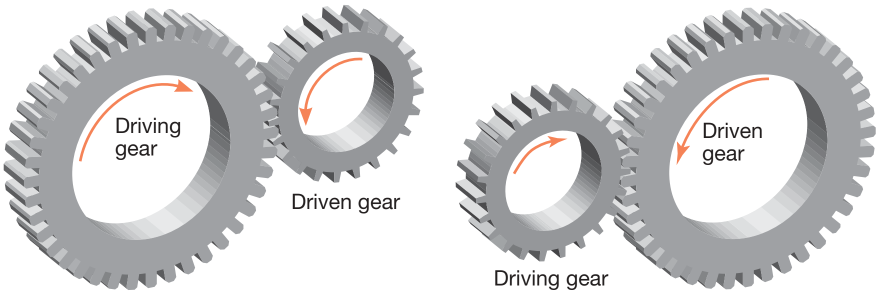
In a gear train, the wheel that is moved first is called the **driving gear**. Usually the driving gear is moved by a person or a motor. On a bicycle, it is moved by pedalling, while in a wind turbine it is moved by the blades.

In a gear train, any gears that are moved by the driving gear are called the driven gear. On a bicycle, these are the gears that are connected to the wheels. Gear trains are also found in clocks.

FIGURE 9.27 On a bicycle, the driving gear is moved by pedalling.

FIGURE 9.28 The gears in this clock form a gear train and allow its three hands to move around its face at different speeds.

FIGURE 9.29 Two different gear trains consisting of a driving gear and a driven gear — the first gear train is a speed multiplier and the second is a force multiplier



INVESTIGATION 9.8

Looking at gears

Aim

To investigate the differences between driving and driven gears and how these interact with each other

Materials

- hand-operated eggbeater or hand drill

Method

1. Identify the driving gear and the driven gear or gears.
2. Rotate the driving gear and observe the motion of each driven gear. Record your findings in your results (including a diagram).
3. Count and record the number of teeth on the driving gear and the number of teeth on each driven gear. Record your results.
4. Use the handle to rotate the driving gear slowly through one complete turn while your partner counts and records the number of turns completed by each driven gear.

Results

1. Draw a diagram of the eggbeater or hand drill. Label the driving and driven gears and draw arrows to indicate the direction of motion of each gear.

2. Summarise your findings for each gear (driving and driven gears) in a table like the one below.

Gear	Number of teeth	Number of turns in one turn of driving gear
Driving gear		
Driven gear 1		
Driven gear 2		

Discussion

1. Which is larger, the driving gear or each driven gear?
2. Which moves faster, the driving gear or the driven gears?
3. Is this system of gears working as a force multiplier or as a speed multiplier?
4. How many times does each driven gear turn for each rotation of the driving gear?
5. Does the number of teeth on each gear seem to affect the way the gear system works? In what way?

Conclusion

Write a short paragraph summarising your findings on driving and driven gears and how these work together.

9.5.2 Big wheels, small wheels

Different sizes and arrangements of gears are used to make wheels turn faster, slower or in different directions, as shown in figure 9.30 and figure 9.31.

A large driving gear makes a small driven gear move faster, but in the opposite direction. Hand-operated drills and wind turbines use this combination of gears to make things spin quickly. This arrangement is a speed multiplier.

A small driving gear makes a large driven gear move slower but in the opposite direction. This arrangement acts as a force multiplier. It is used to move large loads with a small effort. This arrangement is used in cars to allow them to climb hills or gather speed quickly. It is also used in rotating shop-window displays to make them turn slowly.

Pairs of gears the same size change the direction of turning without changing the speed.

Gear wheels at right angles to each other can change vertical motion into horizontal motion. Hand-operated eggbeaters and drills use this arrangement.

An idler gear can be used between the driving and driven gears to make them turn in the same direction.

Rack and pinion gears consist of a flat row of teeth, called a rack, and a circular gear wheel. A corkscrew uses rack and pinion gears to change the circular movement of the driving gears into the upward, straight-line movement that pulls the cork out.

FIGURE 9.30 Gears in a car transmission

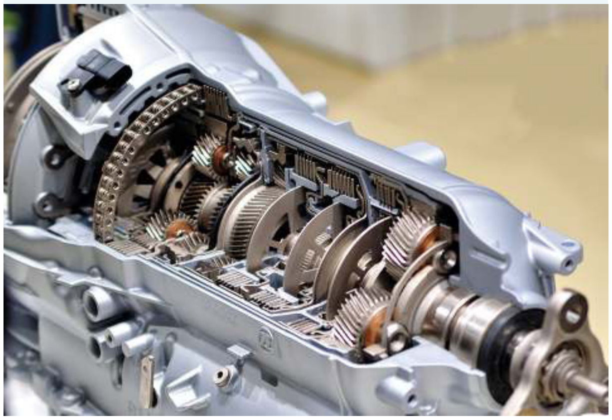
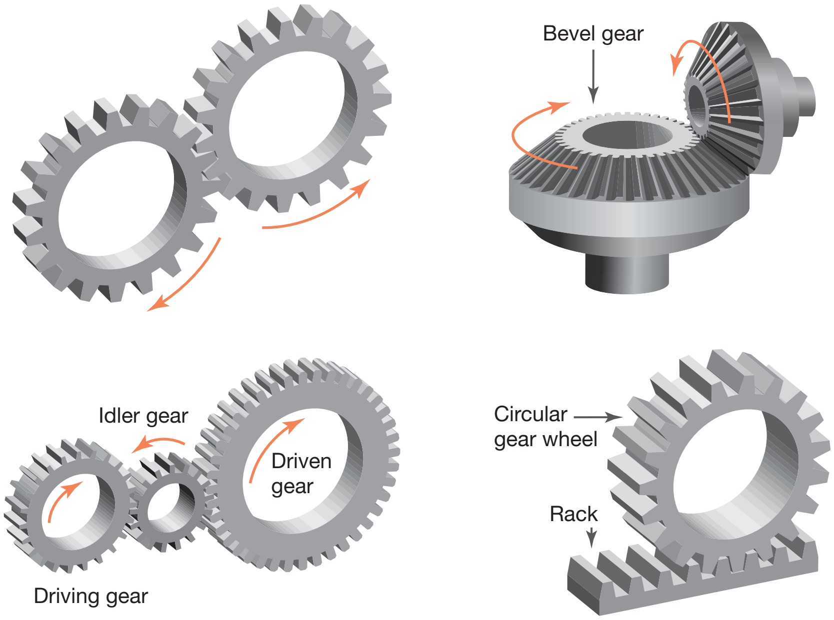


FIGURE 9.31 Different sizes and arrangements of gears make wheels turn at different speeds or directions.



SCIENCE INQUIRY: Investigating the role of gears in everyday machines

Gears are an essential part of many machines, allowing them to function efficiently by controlling motion, speed and force. They are used in transport, tools and even household appliances. But how do gears actually work, and why are different types used for different tasks?

Imagine riding a bicycle. When you pedal, the chain moves over gears of different sizes. If you start on a flat road, you might use a gear that lets you move faster with less force. But when you ride uphill, you switch to a different gear that moves more slowly but requires less effort. This simple change allows you to control how much work your legs need to do.

Gears are also used in clocks, cars, power tools and even amusement park rides. Wind turbines use gears to increase the speed of rotation, while construction cranes use them to lift heavy objects with minimal effort.

One interesting application of gears is in robotics. Engineers design robots with carefully arranged gears to ensure smooth movement and precise control. Without the right gears, robots might move too fast or too slowly, or not have enough force to complete tasks.

By studying gears and how they work, we can design more efficient machines that make tasks easier. Engineers and scientists continue to develop improved gear systems to enhance transportation, renewable energy and mechanical devices used in medicine and industry.

1. Why do bicycles have different gears? How do they affect movement?
2. How do gears help machines perform tasks more efficiently?
3. What would happen if gears were removed from everyday machines like cars or clocks?
4. How do engineers decide what type of gears to use in different machines?
5. What patterns or trends can we observe in how different-sized gears affect speed and force?
6. Can you design a simple experiment to test how different gear arrangements impact movement?
7. Why do wind turbines need high-speed gears while cranes use low-speed force multipliers?
8. How might future technology change the way gears are designed and used?

Information and processed data can be analysed to show patterns, trends and relationships, and to identify anomalies (VC2S8I05)

DISCUSSION

What do you think ‘worm’ gears look like? What about ‘spiral’ gears and ‘helical’ gears? What do you think their purpose is?

9.5 Activities

learnon

9.5 Quick quiz on	9.5 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 4	3, 5, 7, 9	6, 8, 10

Remember and understand

1. **Explain** what gears are.
2. **Explain** the difference between a driving gear and a driven gear.
3. Which gear turns faster if the driving gear is:
   a. larger than the driven gear
   b. smaller than the driven gear
   c. the same size as the driven gear?
4. Other than changing speed, **describe** two other functions of gears. Provide examples.
5. **List** as many devices that use gears as you can.

Apply and analyse

6. **Explain** the importance of an idler gear in a gear train.
7. **Describe** the differences between gears that are speed multipliers and force multipliers, providing examples of each.
8. The driving gear on a hand-operated eggbeater has 40 teeth, and each driven gear has 10 teeth.
   a. **Calculate** how many times the blades will turn for each full turn of the handle.
   b. **Suggest** a design change to make the blades spin faster without increasing the handle’s turning speed.
   c. **Propose** a modification to make the eggbeater easier to turn. What trade-off would this create?

Evaluate and create

9. Mountain bikes have different gears for different riding conditions. **Summarise** how gears help when riding:
   a. uphill
   b. on flat ground
   c. downhill.
10. **Construct** a design for a machine with at least two gears that could be used to:
   a. lift a heavy load
   b. make a wheel turn in the same direction as the handle
   c. make a wheel turn in the opposite direction from the handle.
   Describe how the machine would work.

Answers and sample responses are available in your digital formats.

LESSON 9.6 Compound machines

LEARNING INTENTION

In this lesson you will:
- describe a compound machine
- identify the simple machines used in many common compound machines.

9.6.1 On your bike

All compound machines are made up of two or more simple machines, including levers, wheels and axles, pulleys and gears. A bicycle is a compound machine made up of many simple machines. The obvious ones are the front and rear wheels, handbrake and pedals, but if you look carefully you can find many others.

FIGURE 9.32 The rear wheel of a bicycle is made to turn by the pedals.

Front and rear wheels

Each of the front and rear wheels is an example of a wheel and axle. The rear wheel is made to turn by another wheel and axle — the pedals. The axle of the pedals is joined to the axle of the rear wheel by a chain. The rear wheel and axle is a speed multiplier. The rear wheel axle is much smaller than the back wheel. When it turns, the back wheel turns very quickly. The front wheel is pushed along the road by the rest of the bicycle.

Gears

The gears on a bicycle usually act as speed multipliers, as shown in figure 9.33. The front and rear gears are connected by a chain, but they work just like gears with teeth that fit together. The front gears are larger and have more teeth than the rear gears.

FIGURE 9.33 Gears on a bicycle usually act as speed multipliers.

The highest wheel speed can be reached with the least effort when the larger front gear is used with the smallest rear gear. This combination is most suitable when riding quickly on a level road. When riding up a steep slope, speed is less important. If the smaller front gear is used with the largest rear gear, you can climb the slope with less effort. You do, however, need to make more turns of the pedals.

Handbrake

A bicycle handbrake is an example of a first-class lever. The fulcrum is between the effort and the load. When the rider squeezes the handle of the handbrake, the effort is transferred along a cable to the brake pads that push against the wheel.

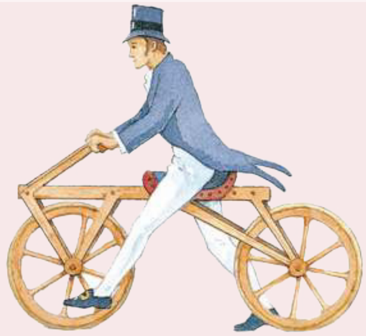
ACTIVITY: Examining a bicycle

In small groups, have a look at a bicycle. Carefully examine the wheel and axle, the gears and the handbrake, observing the different simple machines outlined. Draw a clear diagram of each part showing how each of these simple machines work.

SCIENCE AS A HUMAN ENDEAVOUR: The swiftwalker

One of the earliest bicycles, known as the swiftwalker, was invented in 1817 by Karl Drais, a German baron and inventor. Officially called the Laufmaschine (German for 'running machine') or Draisine, this early bicycle had no pedals, gears or chains. Instead, riders propelled themselves forward by pushing off the ground with their feet, much like how children use balance bikes today.

FIGURE 9.34 The swiftwalker



Drais invented the swiftwalker as a response to a transportation crisis. In 1815, Mount Tambora, a volcano in Indonesia, erupted, causing a global climate disaster in 1816 known as the 'Year Without a Summer'. The extreme weather led to widespread crop failures, and as a result, horses (an essential mode of transport at the time) became scarce and expensive to feed. This inspired Drais to design a human-powered alternative, leading to the invention of the first bicycle-like machine.

While the swiftwalker was an exciting innovation, it had its drawbacks. The wooden wheels with iron rims made the ride bumpy, especially on cobblestone streets. Additionally, because it had no pedals or chains, riders had difficulty traveling uphill, needing smooth, flat roads to travel efficiently. Despite these challenges, the swiftwalker laid the foundation for modern bicycles. Over time, inventors improved the design by adding pedals, chains, rubber tyres and gears, making cycling a more practical and efficient mode of transportation.

The swiftwalker represents an important step in the evolution of transport technology, showing how scientific innovation responds to societal challenges. It also highlights how scientific knowledge and engineering designs change over time, improving based on new discoveries, materials and needs.

1. Why do you think this invention was called 'the swiftwalker'? In many ways, it resembles a scooter or young child's balance bike, which are used today. Why might they be more successful than the swiftwalker was?
2. Who invented the swiftwalker? Why was it created?
3. How did the swiftwalker work? What made it different from modern bicycles?
4. Why do you think the swiftwalker was called a 'running machine' or 'swiftwalker'?
5. What challenges did people face when using the swiftwalker?
6. How did later inventors improve the swiftwalker to make it easier to use?
7. What scientific and technological advancements helped improve bicycle designs over time?
8. Can you think of other inventions that were created due to changes in society or the environment?

Scientific knowledge, including models and theories, can change because of new evidence (VC2S8H01)

9.6.2 On four wheels

The car is also a compound machine, but it is made up of many more simple machines than the bicycle. Most of the simple machines in a car are under the bonnet, but the most obvious ones are the wheels and axles that roll along the road, and the steering wheel.

FIGURE 9.35 Steering wheels are force-multiplying levers. This contains a wheel connected to an axle and gears (rack and pinion gear).

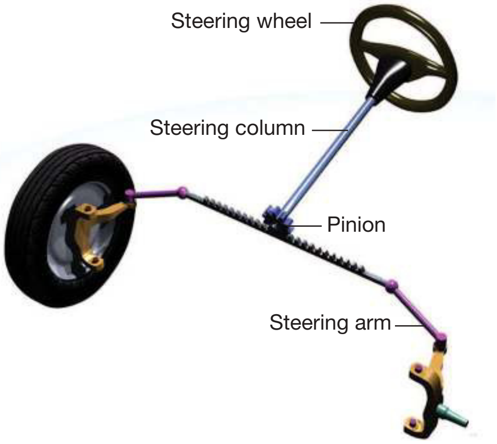


FIGURE 9.36 The front wheel and axle of this vehicle act as a speed multiplier. The outside edge of the wheel turns in a large circle, and much faster than the axle.

EXTENSION: Rube Goldberg machines

A Rube Goldberg machine is a complex machine using many simple machines to complete a very simple task. Research examples of Rube Goldberg machines, identifying the simple machines in it, and then design your own.

9.6.3 Untouched by human hands

Robots are compound machines that perform physical tasks without direct human assistance. They can be used to do jobs that are unpleasant, dangerous or boring. Robots can work in hot weather, cold weather, underwater, under the ground, in outer space and in noisy places. They do not spread germs and they do not get tired.

FIGURE 9.37 These robots are used to put the parts of a car body together.

DISCUSSION

What everyday tasks do you wish robots were able to do to make your everyday life easier? Discuss with your classmates and come up with a combined 'Top five jobs for robots' list.

Robot vacuum cleaners

Robotic vacuums are compound machines that also contain a variety of sensors, motors and computer circuits. Most robot vacuums have five motors in total. They are moved by two wheels controlled by individual motors so the robot can turn depending on how fast each wheel turns. A third wheel can freely rotate and balances the robot. The other three motors control the vacuum suction, the side sweeping brush and an agitating brush.

The buttons on robotic vacuums hide levers. The wheels are connected to the motors using a wheel and axle arrangement. Gear systems are used to change the speed of the wheels, allowing it change directions and move in both straight lines and in circles. An inclined plane is used to help the vacuum collect heavy pieces of dirt or dust that are too heavy to be sucked directly upwards. The speed and direction of the brushes is controlled by another set of gears.

FIGURE 9.38 Most robot vacuums have five motors.

9.6 Activities

learnon

9.6 Quick quiz on	9.6 Exercise

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 6, 9, 11	3, 4, 7, 10, 13	5, 8, 12, 14

Remember and understand

1. **Explain** the difference between a simple machine and a compound machine.
2. **List** as many situations as you can in which robots could be used to rescue people where humans could not.
3. **Identify** which type of simple machine bicycle pedals act as.
4. **Identify** which class of lever a bicycle handbrake is.
5. **Identify** the source of input force for each of the following machines and **describe** how it is applied.
   a. Bicycle
   b. Car
6. **Explain** how robots differ from other machines in the way they function and respond to their environment.
7. **State** where the load that a bicycle handbrake pushes against is.

Apply and analyse

8. **Discuss** why using a machine does not reduce the total amount of work required, even though it reduces the effort force needed.
9. Is a bicycle handbrake a speed multiplier or a force multiplier? **Explain** your answer.
10. **Outline** how robots are used in food packaging. What advantages do they offer over human workers?
11. Should robots replace humans in unpleasant or boring jobs? **Discuss** some advantages and disadvantages before giving your opinion.

Evaluate and create

12. Machines are used to replace various parts of the human body. Artificial arms, hands and legs are all machines. More recently, artificial hearts have been implanted. What are the arguments for and against the use of a machine to replace a failing human heart? What do you think? **Justify** your answer.
13. **SI** Think about a compound machine of your choice. **Describe** its components, how it works and how it makes life easier. What simple machines does it include?
14. **SI** Cars are compound machines that people rely on to get around. Think of the advantages of having one, but think also of all of the problems that cars cause — air pollution is just one of them.
    a. **List** the advantages and disadvantages of cars, using a table like the one below.

Comparing advantages and disadvantages of cars

Advantages of cars	Disadvantages of cars

    b. Refer to your table to answer the following.
        i. **Evaluate** whether cars are essential for modern life. Could society function without them?
        ii. **Analyse** whether cars influence our daily lives too much. How do they affect where we live, work and travel?
    c. Write one or two paragraphs to **state** your own opinion on whether the car is our servant or our master. **Justify** your opinion.

Answers and sample responses are available in your digital formats.

LESSON 9.7 Review

9.7 Success criteria

Tick the column to indicate that you have completed the lesson and how well you think you have understood it using the traffic light system.

(**Green:** I understand; **Yellow:** I can do it with help; **Red:** I do not understand)

Lesson	Success criteria	Green	Yellow	Red
9.2	I can explain that levers of different types allow you to change the direction, speed or size of a force exerted on an object.			
9.3	I can describe how a ramp, wedge and screw reduce the force needed to lift or move objects.			
9.4	I can describe how a wheel-and-axle system and pulleys can change the direction and size of forces used to move objects.			
9.5	I can explain how gears are used to change the speed and direction of rotation of objects.			
9.6	I can describe a compound machine.			
	I can identify the simple machines used in many common compound machines.			

learnon

Post-test	Topic 9 Post-test
eWorkbook	Topic 9 eWorkbook
Digital document	Key terms glossary

9.7 Activities

learnon

9.7 Review questions

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 5, 8	3, 4, 6, 7	9, 10

Remember and understand

1. Label the fulcrum, load and effort on each of the levers shown. For each, **identify** what class it is.

a.

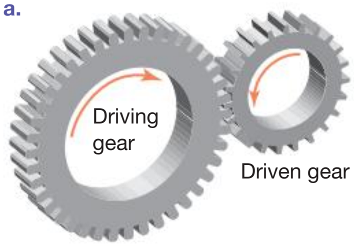
b.

c.

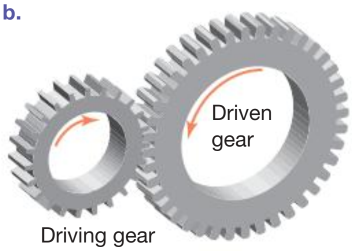
d.

2. **Identify** which of the following is a speed multiplier and which is a force multiplier.

a.



b.



3. Bicycles are made up of many simple machines. **Name** as many as you can. Classify the simple machines that you identify as levers, inclined planes, wheels and axles, pulleys and gears.

Apply and analyse

4. A flight of stairs is an example of a simple machine.
   a. **Name** which simple machine a flight of stairs is most similar to.
   b. Are stairs force multipliers or speed multipliers? **Explain** your answer.
   c. Would a longer, shallower staircase be easier or harder to climb? **Justify** your answer.
5. Imagine that you wanted to drive a screw into a length of wood. If you had a choice of using one of the screwdrivers shown, which one would you use? **State** a reason for your choice.

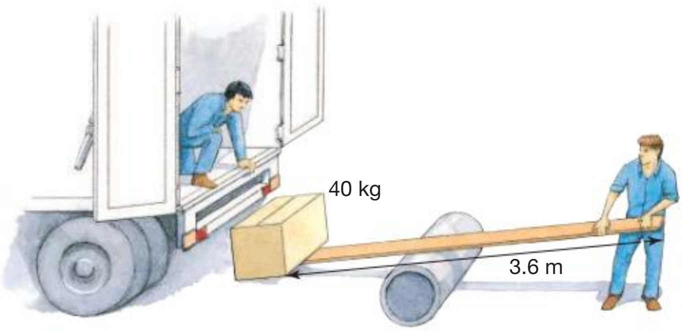
a.

b.

6. A cricket bat is an example of a speed-multiplying lever.
   a. **Explain** why the cricket bat is not a force-multiplying lever.
   b. **Identify** the fulcrum of the cricket bat.
   c. Which class of lever (first, second or third) is the cricket bat?
   d. Which other lever is used to help the cricket ball on its way at high speed?
7. **Describe** the type of simple machine in each of the following and **state** whether it is a speed multiplier or a force multiplier.
   a. Water tap
   b. Eggbeater
   c. Corkscrew
   d. Bicycle gears

Evaluate and create

8. Robots are used in many industries. **List** the advantages and disadvantages of using robots in:
   a. manufacturing (e.g. car assembly)
   b. medicine (e.g. robotic surgery)
   c. space exploration (e.g. Mars rovers).
9. A student uses a pencil, a ruler and some coins to model a first-class lever. It is tested by lifting coins placed at one end of the ruler.
   a. Draw a diagram to show how a pencil, ruler and coins can be set up to model a first-class lever. Label the fulcrum, effort and load.
   b. **Calculate** the mechanical advantage of the lever when it uses 4 coins to lift 12 coins.
   c. **Calculate** the correct placement of the 4 coins if the 12 coins are placed 6 cm from the fulcrum.
10. The plank shown is 3.6 m long. It is being used as a lever to lift a 40 kg box. This represents a load of 400 newtons.
   a. If the fulcrum were placed in the centre of the plank, **identify** the downward effort the man on the right of the diagram would need to apply to raise the box.
   b. If the man wants to push down on the end of the plank with an effort of only 200 newtons:
      i. **determine** how far along the plank the fulcrum should be placed.
      ii. **evaluate** the mechanical advantage of the lever in this setup.
   c. **Suggest** ways to increase the mechanical advantage of the lever.



   d. Is the plank being used as a speed multiplier or a force multiplier? **Explain** your answer.
   e. **Propose** another way to use the plank as a simple machine to move the box into the truck. Would this method be more efficient? Why?

Answers and sample responses are available in your digital formats.

on To test your understanding and knowledge of this topic, go to your learnON title at jacplus.com.au and complete the **post-test**.

GLOSSARY

abiotic factors the non-living things in an ecosystem
acid rain rainwater, snow or fog that contains dissolved chemicals, such as carbon dioxide, that make it acidic. Acid rain can cause rock to weather faster than pure rain can.
aerodynamics scientists scientists who study the forces and motion of objects through air
agriculture the use of land to grow crops or raise farm animals
air resistance the force of air pushing on an object as it moves through the air
algae aquatic photosynthetic organisms that are often unicellular
analog descibes a device that represents information by a continuously variable physical quantity (e.g. a clock, where the hands move to represent time)
analog measuring devices instruments that use analog means to take measurements, usually via a scale (e.g. a ruler)
angiosperms vascular plants that produce seeds and flowers
annular solar eclipses occurs when the Moon moves between the Sun and Earth
antibiotic a substance derived from a microorganism and used to kill bacteria in the body
aqueous solutions solutions in which water is the solvent
arthropods are animals with jointed legs, a hard outer skeleton (exoskeleton), and segmented bodies. This group includes insects, spiders, crabs, and centipedes.
asphyxiation a condition caused by not having enough oxygen
astronomers scientists who study space, including stars, planets, comets and galaxies
asymmetry lack of symmetry
autotrophs organisms that can produce their own nutrients
axis an imaginary line from the North Pole to the South Pole that Earth spins on
bilateral symmetry symmetrical or looking the same along one plane
binomial nomenclature a system developed by Linnaeus for naming species using two words — the genus name and a descriptive name
biodegradable able to break down or decompose easily in the environment
biodegradation is the natural process where microorganisms, like bacteria and fungi, break down substances into simpler, harmless materials such as water, carbon dioxide, and nutrients.
biodiversity is the variety of all living things on Earth, including different plants, animals, fungi, and microorganisms, as well as the ecosystems they form and the genetic differences within each species.
biologists scientists who study living things
biomass material produced by living organisms; the total amount of mass of living organisms
biomechanics is the study of how living things move, focusing on the forces and mechanics involved in movement. It combines biology and physics to understand how muscles, bones, and joints work together.
biostimulants substances that stimulate processes of living organisms to enhance their growth
biotic factors the living things in an ecosystem
black coal a harder, drier from of coal than brown coal, formed from peat compressed over millions of years
block and tackle system of pulleys in which there are both fixed and moving pulleys
boiling point the temperature at which a liquid changes to a gas
booms devices that float on the surface of the ocean and assist in containing oil spills by extending below the oil spill
botanists scientists who study plants
brown coal a form of coal formed from peat compressed over millions of years, also known as lignite
buoyancy an upward force acting on a floating object provided by a fluid
calcination in chemistry, the process of heating a mineral to remove the water
carnivores animals that eat other animals
cellular respiration the chemical reaction involving oxygen that moves the energy in glucose into the compound ATP

centrifuging separating a mixture by rotating the container quickly so the heavier parts of the mixture move to the outside of the spinning container
chemical engineers are professionals who use chemistry, physics, and math to design and improve processes that turn raw materials into useful products, such as fuels, medicines, plastics, and food. They work in industries like energy, pharmaceuticals, and manufacturing.
chemical reaction a chemical change in which one or more new chemical substances is produced
chemists scientists who studies the composition of substances and how they react with each other
chlorophyll the green-coloured chemical in plants that absorbs the light energy used in photosynthesis to make food from carbon dioxide and water
chromosome a tiny, thread-like structure that contains the DNA that carries genetic information
circular muscles are ring-shaped muscles that contract to make a structure smaller or close an opening. They are commonly found in places like the iris of the eye and around the stomach or intestines, helping control movement and flow.
classification grouping animals and plants according to their similarities
commensalism a relationship where one organism benefits without affecting the other
community populations of various species living in a given area at the same time
complex machine A complex machine is an advanced system that may include compound machines, electronics or motors.
compound machine a device that combines two or more simple machines to work together and make a task easier.
compressibility the capacity of something to be reduced in size due to pressure. Solids cannot be compressed; gases can be.
concentrated a solution containing a large amount of solute
concentration the process of making a substance purer by removing the inessential portion
conclusions in science experiments are statements that explain what the results mean. They are based on the data collected and show whether the experiment supports the original hypothesis or not. A good conclusion also considers any errors or limitations in the experiment.
condenses the change in state when a gas changes into a liquid
consumers organisms that rely on other organisms for food
contact force force between objects that are touching
contaminated when a useful substance contains one or more other substances that affect its use
contracts shorten or become smaller in size
control a parallel experiment where everything is the same as the test set-up except the variable. It is used to ensure that the result is due to the variable and nothing else.
controlled burning is the planned use of fire to manage land. It helps reduce the risk of dangerous bushfires, clears dead plants, and encourages new growth in forests and grasslands.
controlled variable the variable/variables that must be kept constant to ensure that the experiment is fair
coolamon Aboriginal Peoples' vessel for carrying objects
corrosive describes a chemical that wears away the surface of substances, especially metals
crust the outer layer of Earth, including all landforms, rocks and soil
crystallisation a separation technique that uses evaporation to separate the parts of a solution, leaving the solute as crystals
cyclical a movement that keeps repeating itself, always travelling the same path in the same amount of time
data observations or measurements made and recorded during an investigation
data logger a digital device that can measure and record a variety of different quantities depending which sensors are attached
dead once alive but now not alive
decanting pouring liquid off the top when sediment has settled to the bottom of the container
decomposers small organisms that break down dead and decaying matter
degrees Celsius metric unit of temperature
density mass per unit volume

dependent variable a variable that is expected to change when the independent variable is changed. The dependent variable is observed or measured during the experiment.
deposition the change in state from a gas into a solid without first becoming a liquid
detritivores organisms that consume detritus; that is, decomposing plant and/or animal parts or faeces
dichotomous keys diagrams used to classify things by grouping them into smaller and smaller groups based on choosing one of two features
diffusion movement of one substance through another due to a movement of particles, for example from a region of higher concentration to lower concentration
digital describes a device that represents information as a series of digits
digital measuring devices instruments that use digital means to take measurements, which appear directly on the screen without having to read from a scale (e.g. a digital thermometer)
dilution the process of adding more solvent to a solution to make it less concentrated
dispersants are chemicals used to break up oil spills into smaller droplets, making it easier for natural processes and microorganisms to clean up the oil in water. They help reduce the impact of oil on coastlines and marine life.
dissolved a substance that has mixed completely with a liquid so that it is no longer visible
distillate the liquid collected during distillation when the evaporated substance condenses
distillation a separation technique that uses evaporation to separate substances
distilled water pure water collected by condensing steam
driving gear gear that causes another to move
ecological niche the role or position of a species or population in its ecosystem in relation to others
ecology the study of the way in which living things interact with other organisms and with their environment
ecosystem a geographic area that consists of all the living organisms and the physical environment in which they interact
ectoparasite a parasite that lives on the outside of its host
ectotherm an animal whose body temperature changes depending on the external environment
effort force used to cause movement
electricity a form of energy resulting from the existence of charged particles (such as electrons or protons)
electrolysis the process by which an electric current is passed through a substance to effect a chemical change
electronic scales device for measuring mass, in grams (g) and kilograms (kg)
electrostatic forces attractive or repulsive non-contact force of electric charges at rest
elliptical an oval or egg shape; the shape of Earth's orbit around the Sun
endoparasite a parasite that lives inside its host
endoskeleton a skeleton or shell inside the body
endotherms animals that can maintain their internal body temperature in a constant range
engineers are professionals who apply scientific knowledge to design, build, and improve systems, structures, machines, and technologies. They use principles from physics, chemistry, and biology to solve real-world problems and create practical solutions.
environmental chemists scientists who study the effect of chemicals on the environment
environmental impact statement (EIS) study of the possible effects of a planned project on the environment
equilibrium balanced or equal
equinox days with the same number of daylight hours as night hours
erosion the process of moving weathered rock or soil from one place to another
etymology the study of words, their origin and their grammar
eukaryotic any cells or organisms with a membrane-bound nucleus (e.g. plants, animals, fungi and protists)
eutrophication a form of water pollution involving an excess of nutrients leaching from soils
evaporates the change in state when a liquid changes into a gas. Evaporation occurs only from the surface of a liquid.
exoskeleton a skeleton or shell that lies outside the body
expands increase in size due to particles moving apart
fertilisers chemicals added to soil to provide the nutrients needed for plant growth

filter a device that allows some materials to pass through; blocks particles too large to fit through the holes or pores
filtrate liquid that has passed through a filter
filtration the process of separating suspended particles from fluid through a filter
flammable describes substances such as methylated spirits that burn easily
floatables substances that are less dense than water so can float on water
floc a clump of particles heavy enough to sink to the bottom rather than remain floating in a liquid
flocculation the process of adding a chemical to a suspension to create flocs, which settle to the bottom
fluid a substance that flows and has no fixed shape. Gases and liquids are fluids.
food chain a diagram showing feeding relationships in an ecosystem
food web a number of food chains joined together
force multiplier simple machine that supplies a greater force than the effort used
forces a push, pull or twist
forces of attraction the forces between particles in all substances. It is greatest in solids.
forensic scientists scientists who use methodical gathering and analysis of scientific evidence to establish facts that can be presented in a legal proceeding
fossil fuels substances that are formed from the remains of ancient organisms and are often burnt as fuels to produce heat
freezes the change in state when a liquid changes into a solid
friction the force applied to the surface of an object when it is pushed or pulled against the surface of another object
froth flotation process used to separate a mixture of mineral particles by adding a substance that floats to the top with one of the minerals attached
fulcrum point around which a lever turns
full moon the view of the Moon seen from Earth when the whole of its near side is in sunlight
fume cupboard a ventilated enclosure in a science laboratory, in which potentially harmful chemicals can be used or kept
fungi eukaryotic organisms that generally use spores to reproduce and contain cell walls made of chitin
gangue leftover waste rock and mineral material
gas state of matter with no fixed shape or volume
gear train multiple gears connected together
geologists scientists who study the structure of the Earth, especially its rocks
germination the first sign of growth from the seed of a plant
gravitational field is the invisible area around a mass where another object feels a force of gravity. The strength of the field depends on the mass of the object creating it—larger masses create stronger fields.
gravitational force an attractive force between two objects that have mass
gravity the force of attraction that exists between any two bodies in the Universe that have mass
gravity separation separation of heavier particles in a mixture, by shaking or spinning them
gymnosperms vascular plants that produce seeds in woody cones, but do not produce flowers
habitat the place in which a particular organism lives
helitorch a device used to drop flaming fuel onto another substance in order to ignite it
herbivores animals that eat only plants
heterogeneous mixtures a mixture in which particles are spread unevenly
heterotrophs organisms that depend on another organism to supply their complex molecules and energy
homogeneous mixtures a mixture in which particles are spread evenly
honing a technique in which a stone is repeatedly ground through grooves in a coarse rock such as sandstone to sharpen the edge of a tool
horticulturists scientists who study fruit, vegetables, flowers or ornamental plants
host the organism on which a parasite feeds
hydro-electric power produced by the energy of falling water
hydrocarbon an organic compound consisting entirely of hydrogen and carbon

hydrogen energy a clean-burning fuel that produces only water as a by-product, making it an environmentally friendly alternative to fossil fuels
hydrogen fuel cell a fuel cell that uses the chemical energy of hydrogen to cleanly and efficiently produce electricity
hypothesis a statement or question that can be tested experimentally to produce data
inclined plane simple machine that uses a sloping surface to reduce the effort required for a task
independent variable the variable that the scientist changes to observe its effect on another variable
industrial chemists are scientists who develop and improve chemical processes used in manufacturing. They work in industries like food, plastics, energy, and pharmaceuticals to create products efficiently, safely, and cost-effectively by applying chemistry knowledge.
inference a logical explanation for a set of observations
inferred concluded or judged based on evidence and reasoning
inorganic material that is not carbon-based
insoluble a substance that will not dissolve in a liquid
interdisciplinary involving two or more different subjects or areas of knowledge
interspecific between members of different species
intraspecific between members of the same species
introduced species species that are not native to an ecosystem
invasive species an organism that is not native to an area and has a negative impact on an ecosystem
invertebrates animals without backbones
kerogen the solid organic material found in some rocks that produces hydrocarbons when heated
kinetic relates to motion
kingdom a scientific classification referring to a group of related phyla with similar features and distinctive characteristics
knapping a process in which a 'core' stone is struck with a smaller, harder 'hammerstone' rock, removing flakes of the core stone to use as tools, or to sharpen the edge of the core stone
leaching removing soluble substances when they dissolve in water that penetrates the ground
lever simple machine usually consisting of a long, rigid object that moves around a turning point when a force is applied
Leyden jar an early device for storing a high-voltage electrical charge (from an external source) between electrical conductors on the inside and outside of a glass jar
lichen a mutualistic symbiotic relationship of a fungus with an alga and/or a cyanobacterium
liquid state of matter that has a fixed volume, but no fixed shape
load force, such as the weight of an object, resisting motion against which a lever works
longitudinal muscles are muscles that run lengthwise along a body or body part. When they contract, they shorten the structure, helping with movement. They are found in animals like worms and also in parts of the human digestive system to help push food along.
lubricants substances with large particles that can slide easily over each other
lunar eclipse occurs when Earth moves between the Sun and the Moon so that some or all of the Moon's surface does not receive light from the Sun and cannot be seen
lunar month the time period between the appearance of one new moon to the next, which equates to 29.5 days
machine device that makes a physical task easier by converting energy
magnetic force force acting between magnets and magnetic objects
marsupials the order of non-placental mammals that are born at a very early stage of development and then grow inside their mother's pouch
mass the quantity of matter in an object (usually measured in grams or kilograms)
matter everything that takes up space and has mass is matter
mechanical advantage the advantage of force-multiplying levers or other machines as defined by the load divided by the effort
mechanical engineers scientists who study the design and construction of engines and machines
melt the change in state when a solid changes into a liquid

melting point the temperature at which a solid substance turns into a liquid (melts) or a liquid turns into a solid (freezes)
meniscus the curved upper surface of a column of liquid
metabolism the chemical reactions occurring within an organism that enable the organism to use energy and grow and repair cells
metallurgists scientists who study the structures and properties of metals
meteorologists scientists who use observations of the atmosphere to predict or explain the weather
metric system decimal measuring system based on the metre, litre and kilogram; the ratios between units of measurement are multiples of ten
microbiologists scientists who study extremely small (microscopic) organisms and processes
microorganisms microscopic (very small) life forms
microscopy the use of microscopes to view structures that cannot be seen with the naked eye
mine subsidence the dropping or sinking of ground into old, hollow mine workings after coal has been extracted during underground coal mining; it can cause damage to buildings or other structures
minerals natural solid substances that make up rocks
mining the process of removing mineral ore from the ground
mixture a substance that is made by a combination of two or more components, which are easy to separate
monocultures crops grown on land used for one kind of crop only
monotremes the order of non-placental mammals that lay leathery shelled eggs and secrete milk through pores in the skin
multicellular made up of many cells
mutualism a relationship between two organisms in which both benefit
natural gas a fossil fuel consisting of mainly methane
natural resources useful raw materials that we get from Earth that humans are unable to produce
neap tides a weaker high and low tide that occurs when the Sun and the Moon are not in the same line as Earth
net force the sum of forces acting on an object
new moon phase in which the side of the Moon that faces Earth is facing away from the Sun, and the Moon is not visible in the sky
newton the unit for measuring force
non-biodegradable not able to break down or decompose in the environment
non-contact force force between objects that are not touching
non-living not ever alive, as distinct from dead
non-renewable resources resources that are depleted or are not naturally replaced within a human lifetime
nuclear energy the energy stored at the centre of atoms, the tiny particles that make up all substances
nucleus central part of the atom, made up of protons and neutrons; contains genetic information and controls the growth and reproduction of a cell
observations pieces of information we collect by using our senses
ocean wave energy renewable energy created by converting the mechanical energy of ocean waves into electrical energy
ochre pigments made from naturally occurring iron ore
omnivores animals that eat plants and other animals
one-off errors an error that affects the precision of results
open-cut mining a method of mining mineral ores that are close to the surface — a large hole is made to expose the rocks, which are broken up using explosives
optimum range the range of environmental conditions in which a species can thrive
orbit the curved path of a celestial object or spacecraft about a star or planet; for example, the path of Earth around the Sun or the Moon around Earth
ore mineral a mineral from which a valuable metal can be removed for profit
organic carbon-based material derived from living things, such as plant mass
organisms living things made up of one or more cells
osmosis the process of separating using a membrane through which one constituent cannot pass
palaeontologists scientists who study fossil animals and plants

paper chromatography method of separating a mixture of different colours positioned on filter paper using a solvent
parallax error the error that occurs when scales are read inaccurately from an angle
parasites organisms that live on or within another organism, to get all or some of its nourishment
parasitism a relationship between two organisms in which one benefits by using the host's nourishment
partial solar eclipses occurs when the Moon moves between Earth and the Sun and prevents some of the Sun's light reaching a place on Earth
particle model a description of the moving particles that make up all matter and how they behave; explains the properties of solids, liquids and gases
peat partially decomposed plant matter, lightly buried and compressed over a thousand years
penicillin a substance, first extracted from moulds, that kills many types of bacteria. It was the first antibiotic drug.
pentadactyl limb a five-fingered limb
penumbra the region where only a portion of light is blocked by an object
pharmacists scientists who study the effects of drugs on living things
phases shapes observed in a repeated pattern of changes
phloem vascular tissue that transports organic substances (such as sugars) within plants
photosynthesis a process in which carbon dioxide, water and energy from the Sun produce food in the form of sugar
physicists scientists who study the laws of nature
physiology is the branch of science that studies how living things work. It focuses on the functions of organs, tissues, and cells in plants, animals, and humans, and how they all work together to keep the body alive and healthy.
physiotherapist is a healthcare professional who helps people recover from injuries, manage pain, and improve movement through exercises, massage, and other physical treatments. They work with patients of all ages to restore strength, flexibility, and function.
pitch the distance between two turns of the thread of a screw
placental mammals the order of mammals in which the young grow inside the mother, receiving nutrition via a cord attached to the placenta, and are born at a well-developed stage
plasma superheated, charged gas that is the fourth state of matter
poikilothermic animals, also known as cold-blooded animals, are those whose body temperature changes with the temperature of their environment. Examples include reptiles, amphibians, and fish.
poisonous causing or capable of causing illness or death if taken into the body
pollen fine powder containing the pollen grains (the male sex cells of a plant)
pollination the transfer of pollen from the male part of a flower to the female part of a flower
pollinators organisms such as bees, flies and other organisms that carry pollen between flowering plants
pollution the introduction of harmful substances or products into the environment
population organisms of one particular species in a given area at one time
porous having many pores or other small spaces that can hold a gas or liquid or allow it to pass through
precipitation falling water in solid or liquid form. The type of precipitation depends mostly on the temperature in the clouds and the air around them.
predictions statements about what is likely to happen in the future based on current evidence or past experience.
pressure the force exerted per unit area
primary consumers an organism that eats plants
prions infectious proteins that can cause disease
proboscis a long feeding tube attached to the head of some insects; it sometimes rolls up when not in use
producers organisms that use photosynthesis to make their own food from the Sun's energy
prokaryotic any cells or organisms without a membrane-bound nucleus (e.g. bacteria)
properties the qualities and characteristics of materials and the substances that they are composed of
pteridophytes vascular plants that produce spores usually located on the underside of their leaves

pulley a simple machine consisting of a wheel with a grooved rim and a rope or cable that is used to lift or move loads by changing the direction of force.
pure substance a form of matter that cannot easily be separated into its components
purification the removal of impurities from metals to produce a pure metal
qualitative type of observation that describes what is seen
quantitative type of observation where a measurement with a specific value is used
radial symmetry symmetrical about the centre axis
ramp simple machine, called an inclined plane, that reduces the effort required to raise objects to a higher level
random error an error that affects the precision of results
recycling treating items such as glass, paper, plastic, aluminium and steel so that new products can be made from them
reduction bringing an ore mineral into a metallic state by separating the non-metallic constituents
rehabilitated restored to its previous condition
rejected describes what happens to a hypothesis when data provide strong enough evidence to conclude that it is probably incorrect
relationships interactions with other species within an ecosystem
reliable describes consistent results obtained from repeated experiments
renewable resources resources that are not depleted (used up) or are naturally replaced within a human lifetime
residue the material remaining as a solid on a filter paper after a liquid passes through in the filtration procedure
respond react to a stimulus
reverse osmosis a technique by which a fluid moves under pressure through a membrane from a high solute concentration to a lesser concentration; used to purify water
revolution movement around an orbit
robot complex combination of machines designed to perform tasks without human assistance
rotation the turning of an object about its own axis (between the North Pole and South Pole)
safety masks masks used over the nose and mouth to protect the airway during experiments
saprophytes organisms such as fungi that obtain nutrients from dead organic matter
satellite a body such as a moon that orbits another celestial body of a larger size and mass
saturated unable to dissolve any more solute
scale a series of marks laid down at regular distances for the purpose of measurement
scientific laws statements that describe or predict natural phenomena based on data and evidence from repeated experiments or observations
scientific method a systematic and logical process of investigation to test hypotheses and answer questions based on data or experimental observations
scientific report a structured way for scientists to communicate to others the findings of an investigation: what they did, their qualitative and quantitative observations and their conclusions
scientific theories well-supported explanations of an aspect of the natural world based on consistent observations and experiment
screw curved inclined plane
secondary consumers an organism that eats primary consumers
sediment the insoluble material that collects at the bottom of a container when suspensions are left to stand
sediments tiny pieces of rocks, minerals or natural materials that are carried by water, wind or ice and eventually settle at the bottom of rivers, lakes and oceans. Over time, these tiny pieces can pile up and form layers.
seed the product of a fertilised ovule
seismologists scientists who study earthquakes
separating funnel a pear-shaped glass container, with a tap at its base, used to separate two liquids that do not mix
separation is the process of dividing a mixture into its individual parts or substances. This can involve methods like filtering, evaporating, or using magnets, depending on the properties of the materials being separated.
septic tank a sewage treatment system placed underground in backyards of houses not connected to town sewage treatment plants

setae bristle-like structures often found on invertebrates
sewage a mixture of water and substances that flow from laundries, bathrooms, kitchens and toilets
sewerage the system of drains and pipes that takes sewage away from a property
sieving separating particles of different sizes by allowing the smaller particles to fall through holes in a container
simple machine device with minimal components such as levels and wedges designed to make work easier
skimmers devices dragged by boats that scrape the oil off the surface
smelting melting ore minerals as a process of reduction
solar eclipse occurs when the Moon moves between Earth and the Sun and prevents some or all of the Sun's light reaching a place on Earth
solar energy the solar radiation emitted from the Sun as sunlight, which can be captured and converted into electricity by photovoltaic cells
solar system a group of bodies that revolve around a star
solid state of matter that has a fixed shape and volume
soluble a substance that will dissolve in a liquid
solute a substance that is dissolved in a solvent to form a solution
solution a mixture of a solute dissolved in a solvent
solvent a substance in which a solute dissolves to form a solution
species a group of organisms with many features in common that can mate with each other to produce fertile young under natural conditions
speed multiplier simple machine that increases the speed of an object
sports psychologists scientists who advise athletes on self-image and maintaining the motivation to persist and succeed in their chosen sport
sports psychology is the study of how mental and emotional factors affect performance in sports and exercise. It helps athletes improve focus, manage stress, build confidence, and stay motivated during training and competition.
spring tides a very high tide that occurs when there is a new or full moon
state of matter condition or phase of a substance. The three main states of matter are solid, liquid and gas.
stigma the female part of a flower, that catches the pollen during pollination
streamlined being shaped so that drag through a fluid is minimised
sublimation the change in state from a solid into a gas without first becoming a liquid
summer solstice the day of the year with the most daylight hours
supersaturated refers to a solution that contains more dissolved substance than it normally can at a given temperature. It's an unstable state, and the extra solute can quickly come out as crystals if disturbed.
support describes what happens to a hypothesis when data provide strong enough evidence to conclude that it is probably correct
surface tension the 'firmness' of the surface of a liquid created by the attraction between particles at the surface
surfactants substances that can break up substances such as oil into smaller particles
suspended hanging, not falling or sinking
sustainable using Earth's resources so that the needs of the world's present population can be met, without damaging the ability of future populations to meet their needs
sustainable resources are classified as natural resources that are renewable and can be replenished at the same rate, or faster, than they are being consumed.
symbiosis an ongoing relationship between members of different species
symmetry the quality of being a mirror image across an axis
tailings waste products from metal extraction
taxonomy the study of the classification of organisms
temperature a measure of how hot or cold something is
terminal speed the maximum constant speed reached by a falling body when the force of gravity pulling it down is balanced by the air resistance pushing against it
tertiary consumers an organism that eats secondary consumers
thread curved ridge of a screw formed by a winding inclined plane

tides the regular rise and fall of water level of the ocean, in a cycle close to 12.5 hours
tolerance range the range of environmental conditions in which a species can survive
total solar eclipse occurs when the Moon moves between Earth and the Sun so that all of the Sun's light to a place on Earth is blocked by the Moon
tracheophyta plants with a vascular system
traction a type of friction used to assist movement
transparent see-through; allowing light to pass through so objects behind can be seen distinctly
trophic level a feeding level within a food chain
turbine wheels that, when turned, drive electrical generators
umbra the shadow created when light is completely blocked by an object
unicellular made up of a single cell
universe all of space and the matter and energy contained in it
vascular tissue plant tissue involved in the transport of substances within the plant (and in-plant support)
vector an organism that does not cause disease, but transports another disease-causing organism
vertebrates animals with backbones
veterinarian scientists who study the prevention and treatment of animal diseases
viroids the smallest infectious known pathogen, comprised solely of a short single-stranded piece of RNA
viruses a non-cellular pathogen that uses the host cells in order to reproduce
viscous having a thick or sticky consistency
volatility how readily a substance evaporates or becomes a vapour
volume the amount of space taken up by an object or substance
vulcanologists scientists who study volcanoes
waning the change in the Moon's appearance between a full moon and the following new moon
water vapour water in the gaseous state
waxing the change in the Moon's appearance between a new moon and the following full moon
wedge simple machine that reduces the force required to cut through objects or stop them from moving
Weeds of National Significance (WONS) weeds that have been identified based on their invasiveness, potential for spread, and environmental, social and economic impacts
wheel and axle a type of lever that can rotate when an effort applied at the wheel produces a greater force on the axle
wind energy a renewable energy derived from the wind (caused by uneven heating of Earth and its oceans by the Sun)
winter solstice the day of the year with the fewest daylight hours
xylem vascular tissue that carries water and minerals from the roots up to the leaves
zoologists scientists who study the physiology, behaviour, classification and distribution of animals

INDEX

K

L

M

N

O

X

Y

Z