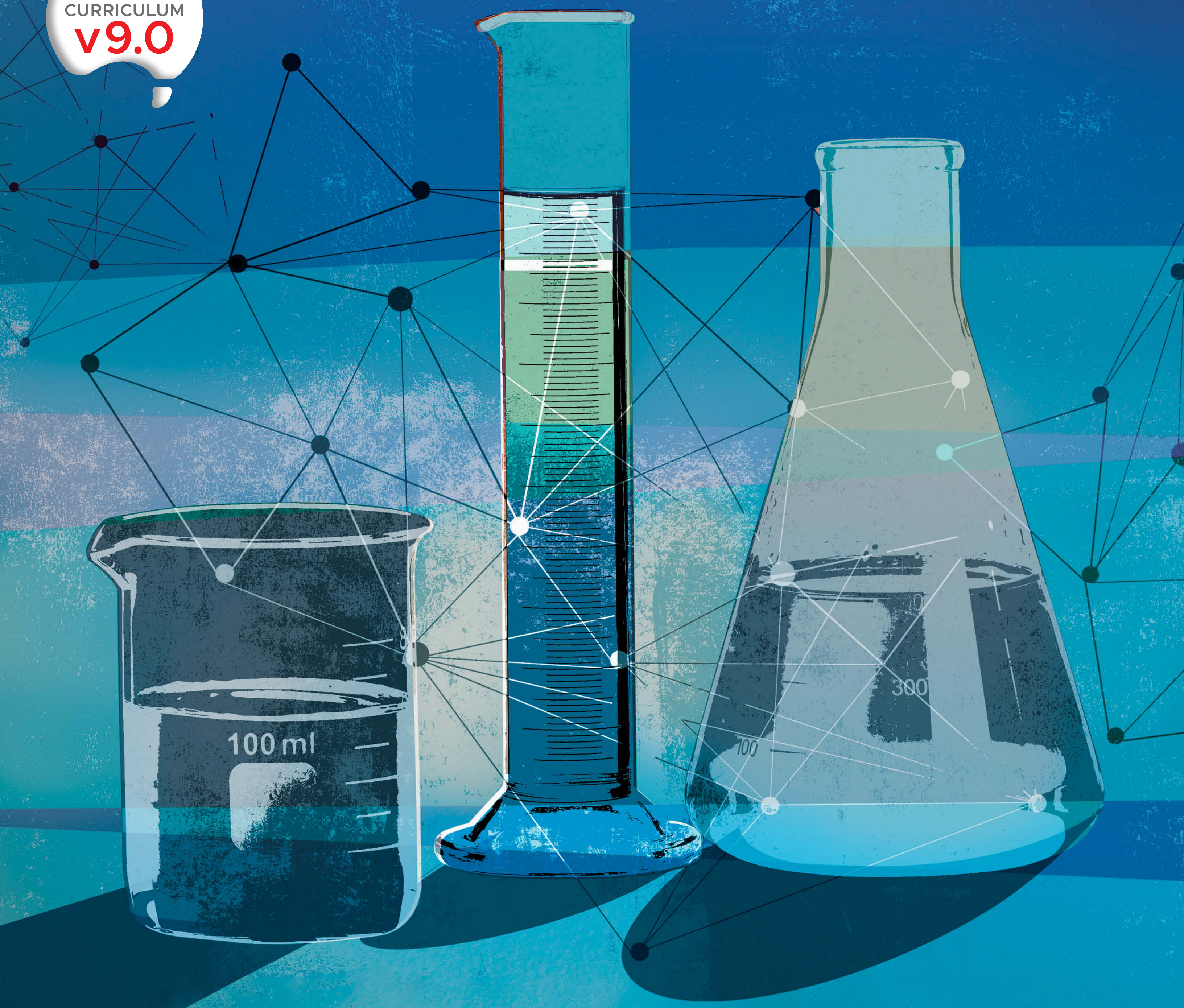
GRAEME LOFTS | MERRIN J. EVERGREEN

JACARANDA SCIENCE QUEST 7

AUSTRALIAN CURRICULUM | FOURTH EDITION

AUSTRALIAN CURRICULUM v9.0



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GRAEME LOFTS

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AUSTRALIAN CURRICULUM v9.0

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The Publishers of this series acknowledge and pay 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.

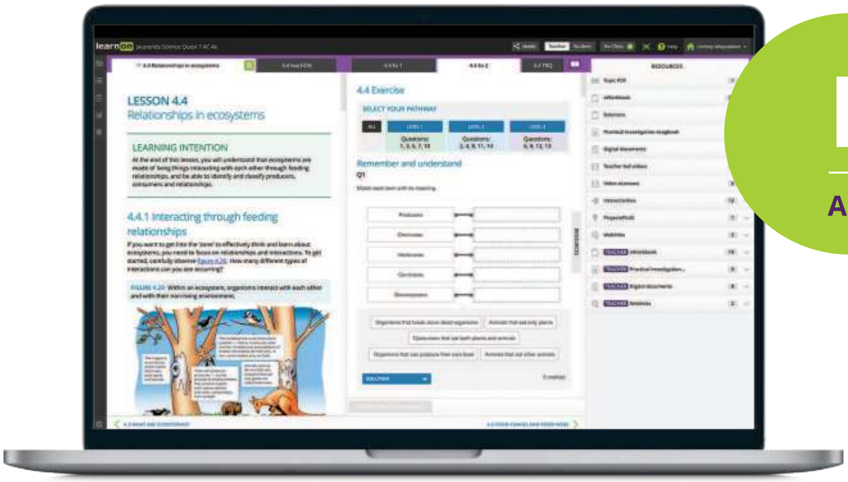
It is strongly recommended that teachers examine resources on topics related to Aboriginal and/or Torres Strait Islander Cultures and Peoples to assess their suitability for their own specific class and school context. It is also recommended that teachers know and follow the guidelines laid down by the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

About this resource



NEW FOR

AUSTRALIAN CURRICULUM V9.0

JACARANDA

SCIENCE QUEST 7 AUSTRALIAN CURRICULUM

FOURTH 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

Whether students need a challenge or a helping hand, you'll find what you need to create engaging lessons.

Whether in class or at home, students can access carefully scaffolded and sequenced lessons to support in-depth Science Inquiry Skills development and step students through scientific inquiry with engaging interactive content and practical investigations. Automatically marked, differentiated question sets are all supported by detailed solutions — so students can get unstuck and progress!

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Through real-time results data, students can track and monitor their own progress and easily identify areas of strength and weakness.

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Learn online with Australia's most

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

- Trusted, curriculum-aligned content
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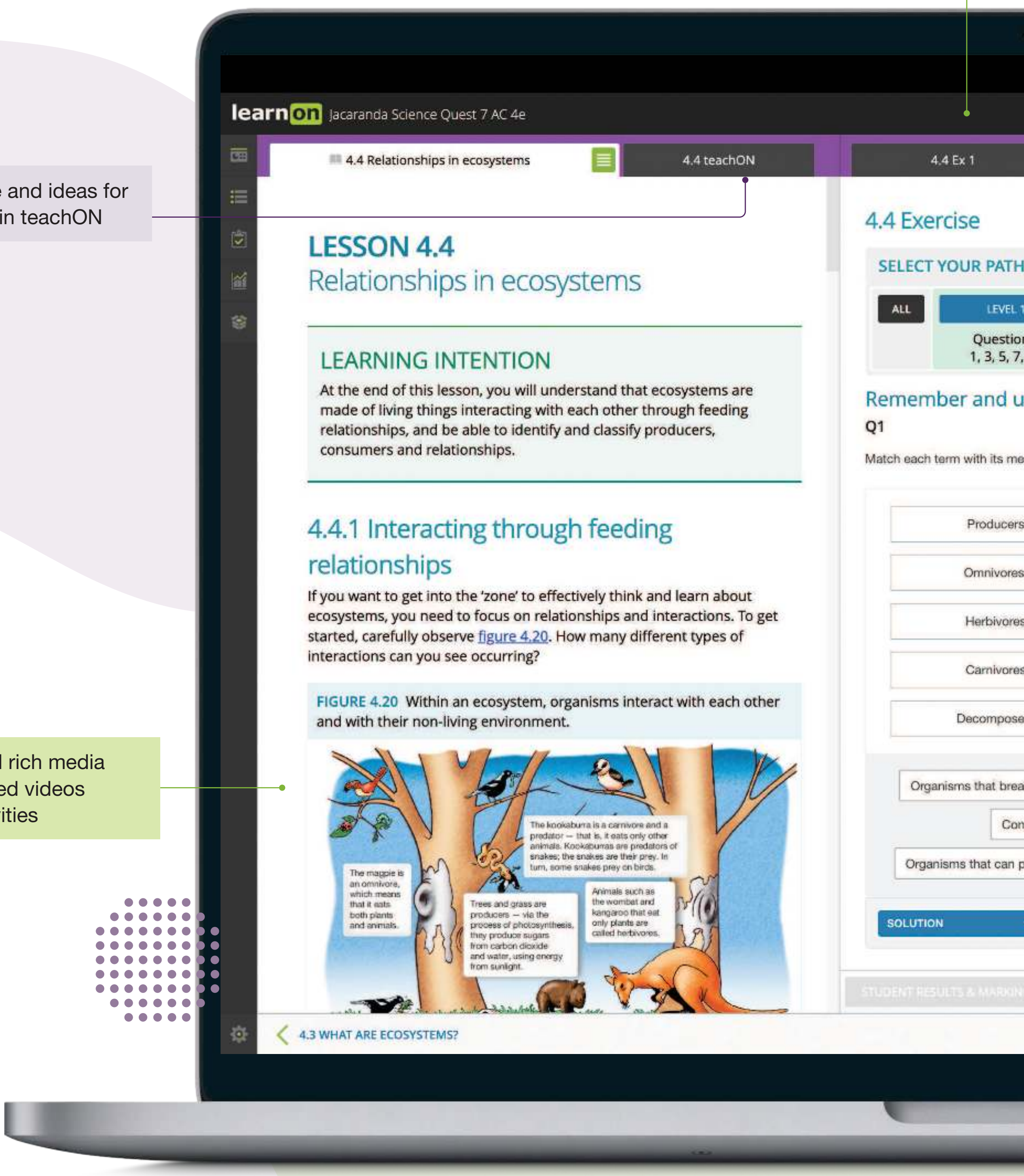
- All the teaching-support resources you need
- Deep insights into progress
- Immediate feedback for students
- Create custom assignments in just a few clicks.

Practical teaching advice and ideas for each lesson provided in teachON

Reading content and rich media including embedded videos and interactivities



powerful learning tool, learnON

New! Quick Quiz questions
for skill acquisition

Differentiated question sets

Teacher and student views

Textbook questions

Fully worked solutions

eWorkbook

Practical investigation eLogbooks

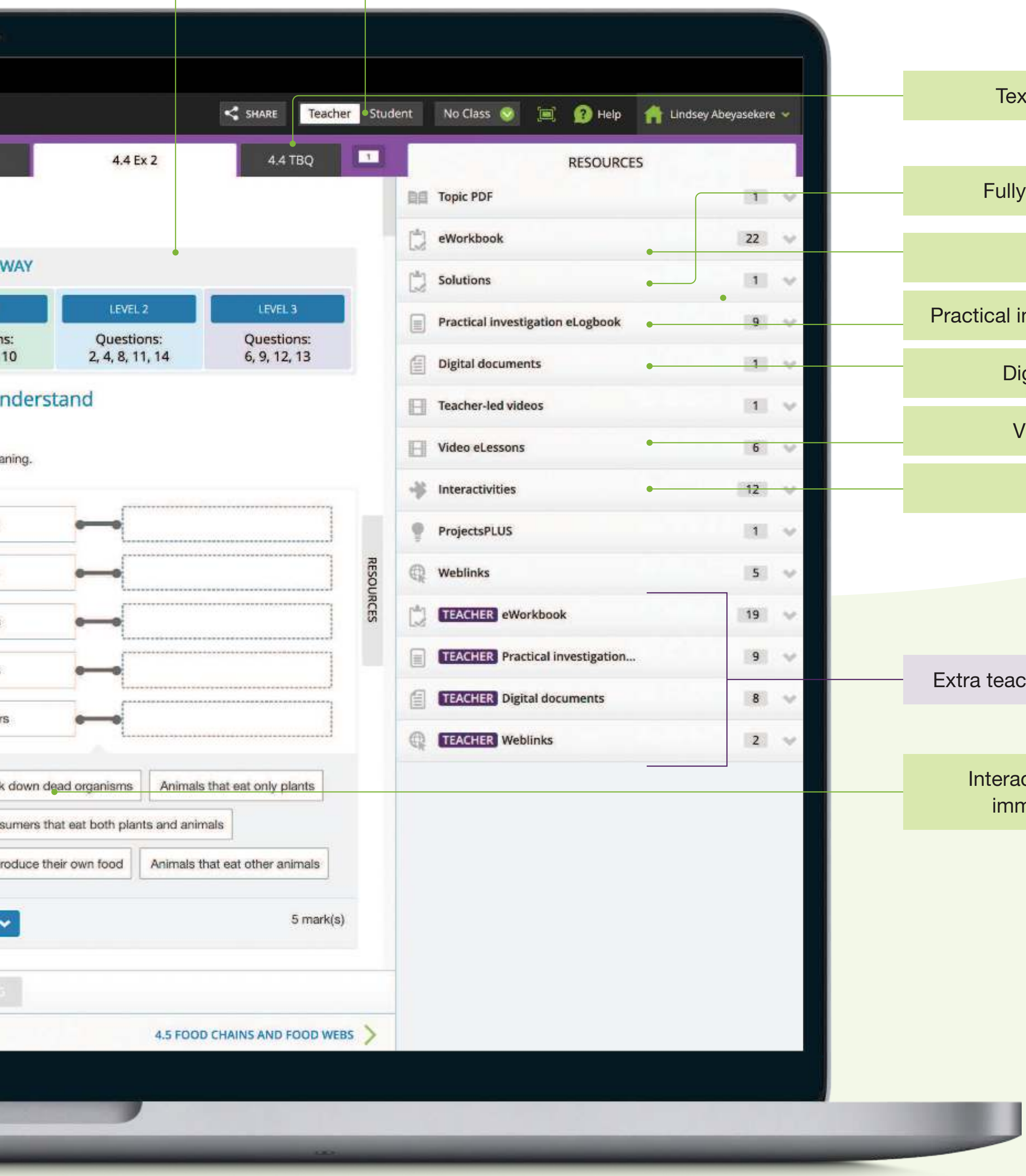
Digital documents

Video eLessons

Interactivities

Extra teaching support resources

Interactive questions with immediate feedback

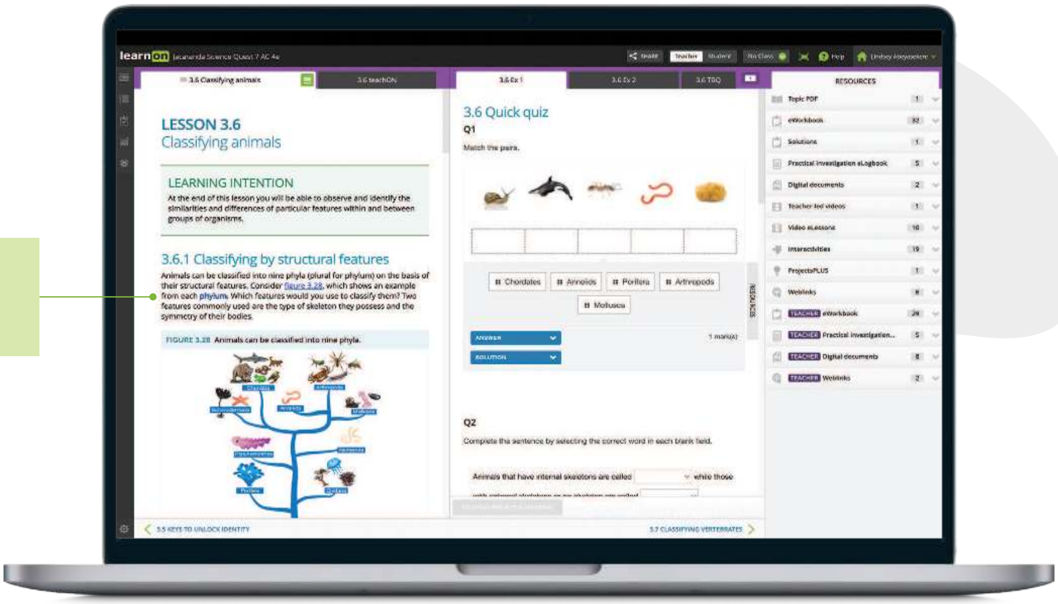


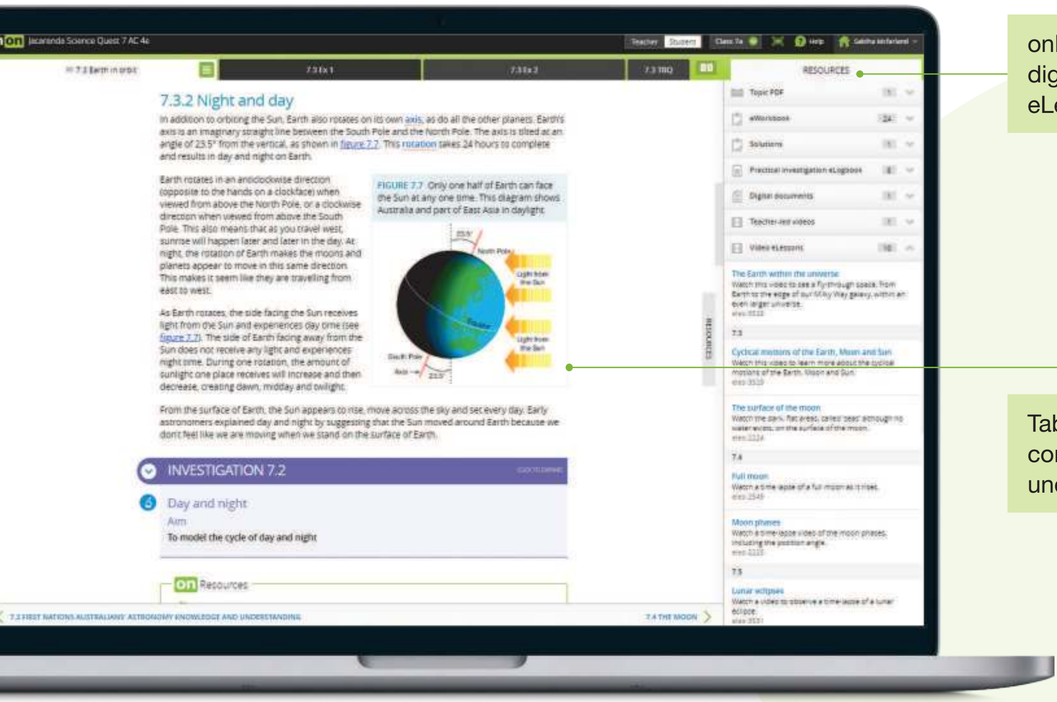
Get the most from your online resources

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.

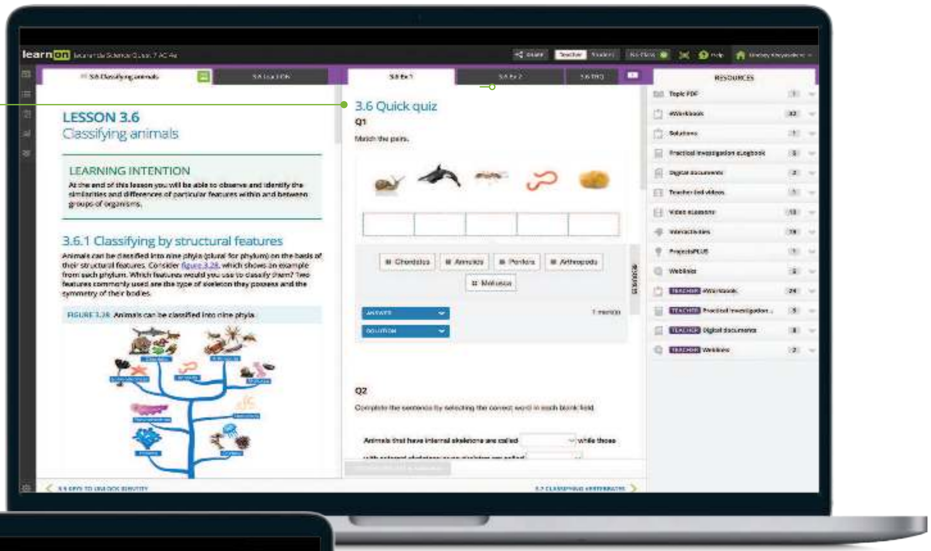


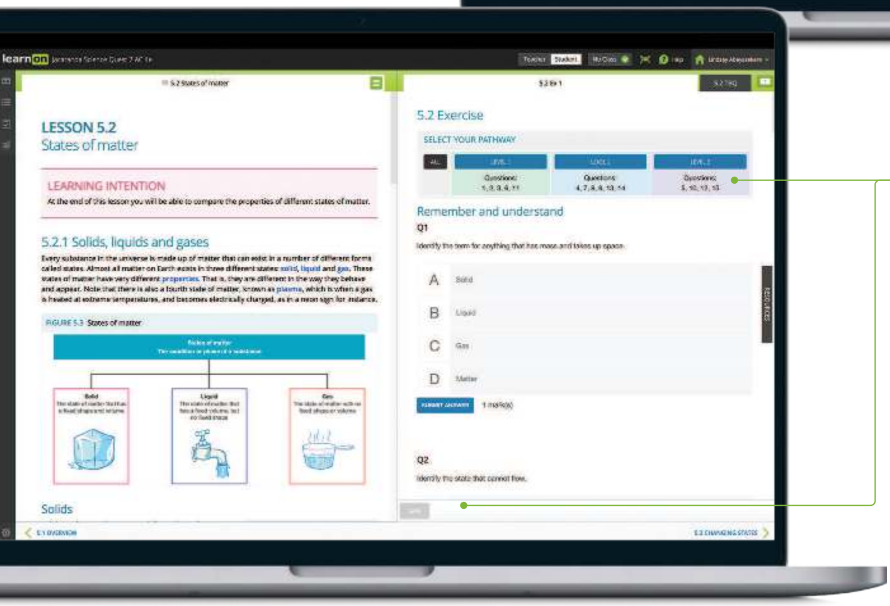


onResources link to targeted digital resources including video eLessons and weblinks.

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

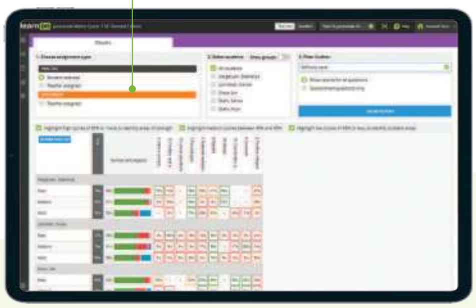
Brand new! Quick Quiz questions for skill acquisition in every lesson.

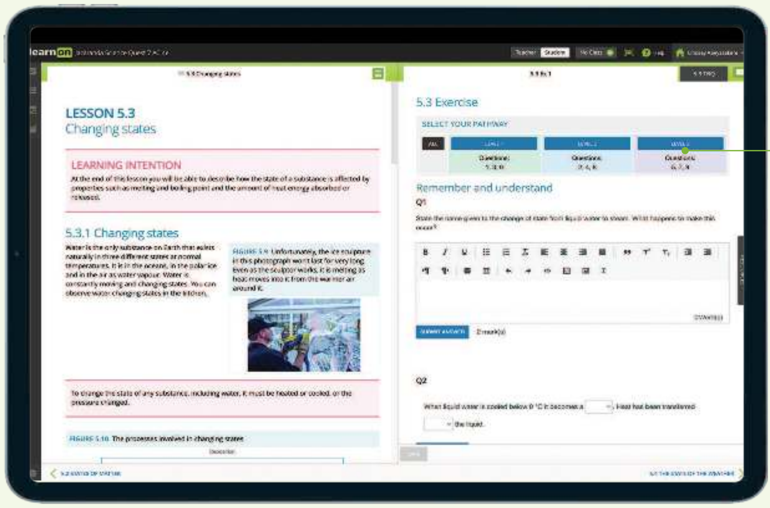




Three differentiated question sets, with immediate feedback in every lesson, enable students to challenge themselves at their own level.

Instant reports give students visibility into progress and performance.

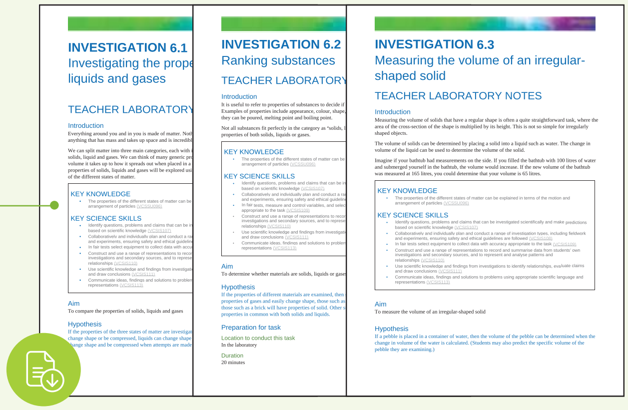




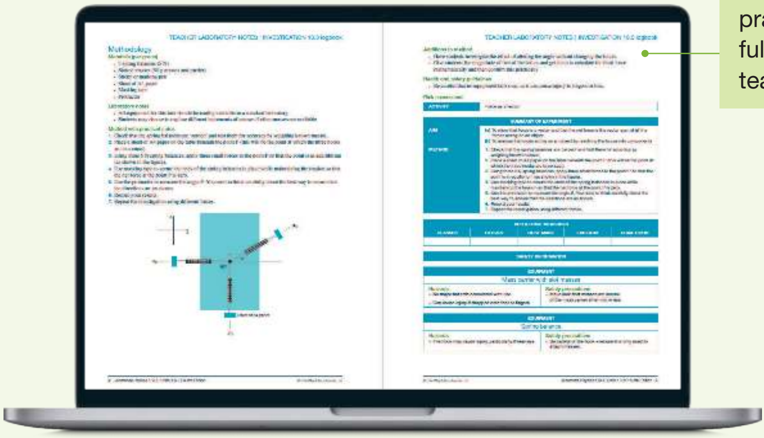
Every question has immediate, corrective feedback to help students overcome misconceptions as they occur and get unstuck as they study independently — in class and at home.

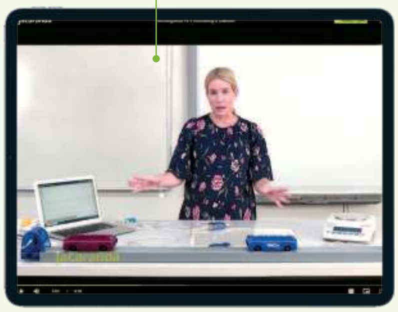
Practical Investigation eLogbook

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.

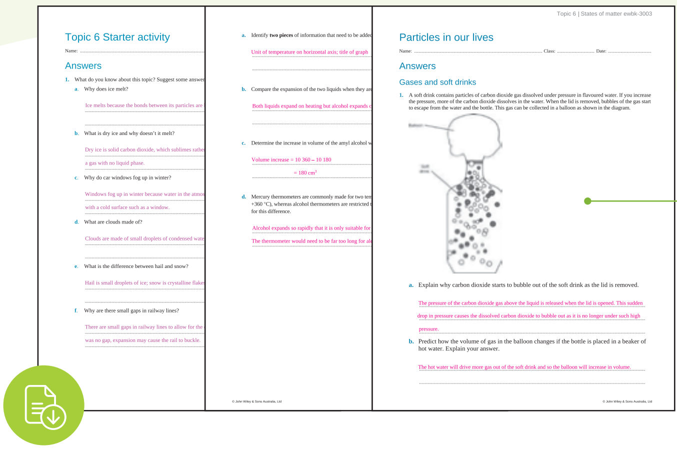


Enhanced practical investigation support includes practical investigation videos and an eLogbook with fully customisable practical investigations — including teacher advice and risk assessments.



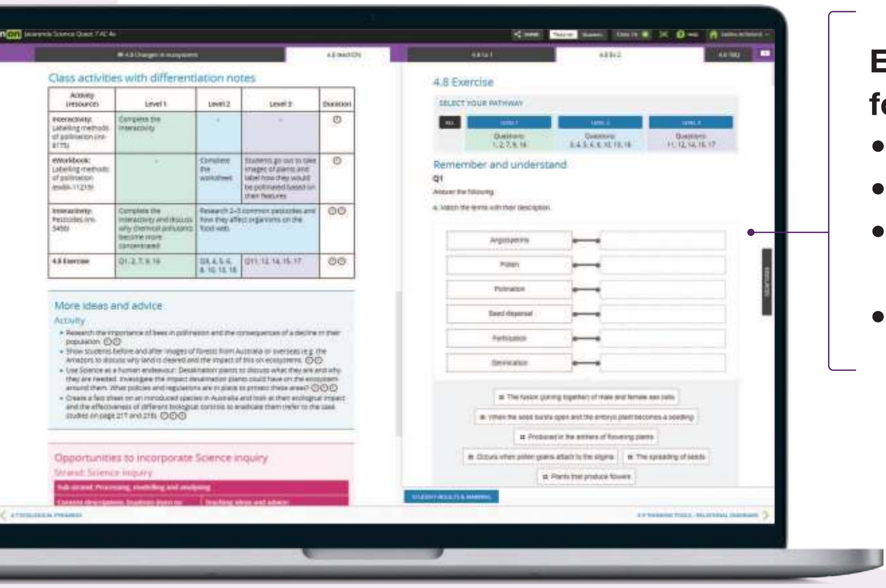


eWorkbook



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.

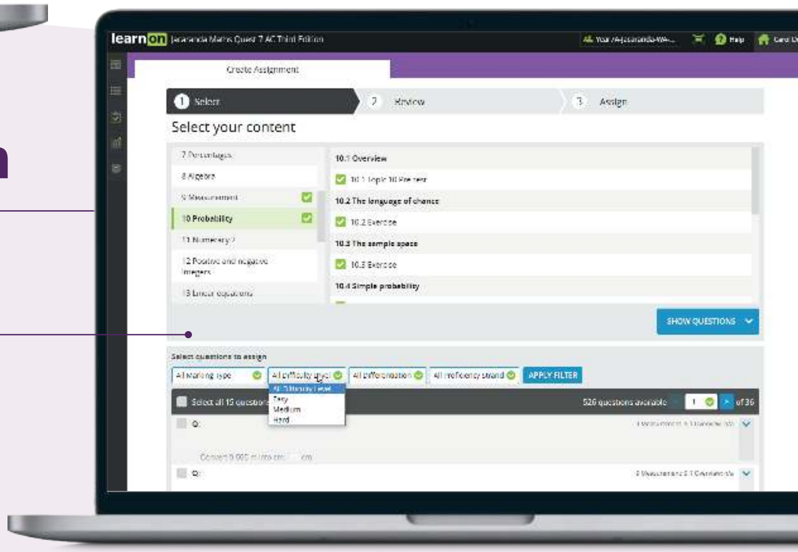
A wealth of teacher resources



Enhanced teaching-support resources for every lesson, including:

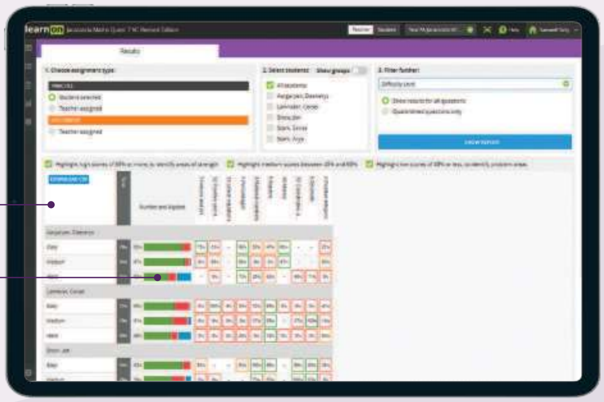
- work programs and curriculum grids
- practical teaching advice
- three levels of differentiated teaching programs
- quarantined topic tests (with solutions)

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.

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1 Discovering science

LESSON SEQUENCE

SCIENCE INQUIRY AND INVESTIGATIONS

Science inquiry is a central component of Science curriculum. Investigations, supported by a **Practical investigation eLogbook** and **teacher-led videos**, are included in this topic to provide opportunities to build Science inquiry skills through undertaking investigations and communicating findings.

LESSON
1.1 Overview

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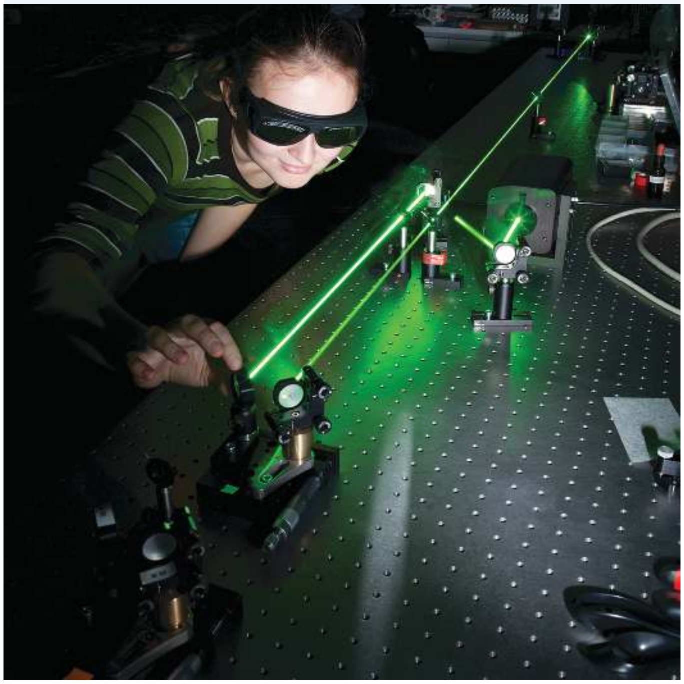
1.1.1 Introduction

Science is how humans discover new information about the physical and natural world. Imagine how exciting it would be to discover and understand something no-one has ever achieved before. The word *science* comes from the Latin word *scientia*, meaning ‘knowledge’. Everybody uses scientific knowledge — or devices made using scientific knowledge — to solve problems or interpret information every day.

FIGURE 1.1 We use the products and results of scientific knowledge every single day.



on Resources

Video eLesson Career spotlight: scientist (eles-0053)

Watch this video to learn about an exciting career in marine science. Marine biologist Jodie Haig talks about her experience and her day-to-day life working in the marine science field. She is doing her PhD at Griffith University in marine biology. Her research work includes lots of planning, thinking, reading, field work, lab testing, data analysis and results writing.

1.1.2 Think about science

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 observations do you make in your life? Do you think you are a good observer?

1.1.3 Science inquiry

Science is everywhere

Scientific knowledge is all around you. Whenever you turn on a light, eat food, watch television or flush the toilet, you are using the products of scientific knowledge.

FIGURE 1.2 How might scientists have been involved in each of these activities?

1. Work in a small team for this activity. You may like to take photographs in or outside of school for this activity, otherwise use the ones in figure 1.2. For each of the photographs, work together to write a paragraph about how scientists might be involved in the activity shown. Then, share your ideas with the class.
2. **a.** Make a mind map listing as many things as you can think of that a scientist might study.
   b. Circle the five you would be most interested in studying.
   c. Select one of the five you chose and research the following:
      i. What is a scientist who studies this called?
      ii. What do they do in their day-to-day job?
      iii. What you would need to study and do to get a job in that field?
3. **a.** Draw a picture of your own idea of what a scientist looks like.
   b. Make a list of the differences between real scientists and the scientist you have drawn. Think about the way they look as well as what they do.
   c. Get together in a group and compare your lists and drawings. Together, create a group list and draw a group image or description of a scientist.
   d. As a group, suggest one single word that describes what all scientists do.

on Resources

eWorkbooks	Topic 1 eWorkbook (ewbk-11006) Student learning matrix (ewbk-11010) Starter activity (ewbk-11008)
Practical investigation eLogbook	Topic 1 Practical investigation eLogbook (elog-1975)

LESSON
1.2 Branches of science

LEARNING INTENTION

At the end of this lesson you will be able to describe examples of the main branches of science.

1.2.1 Scientific knowledge

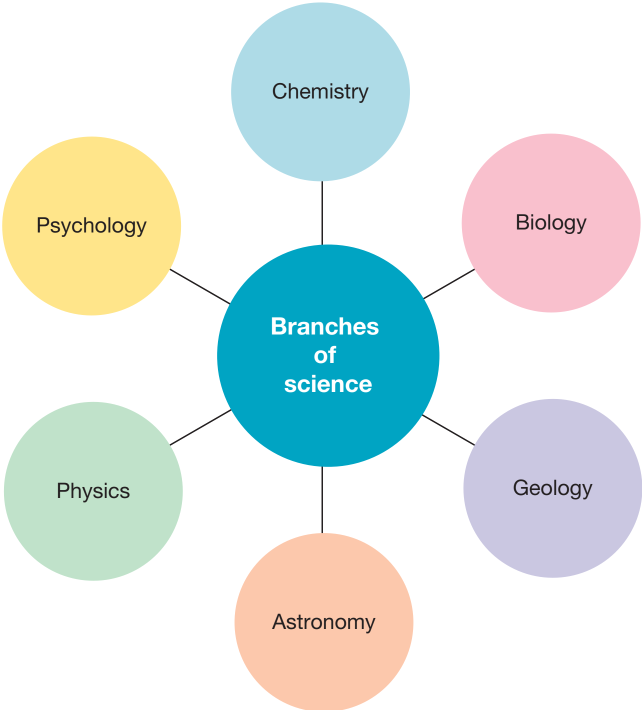
Scientific knowledge is all around you. Whenever you ride a bicycle, turn on a tap, use a phone or watch a video, you are using the products of scientific knowledge. Nurses, police, dietitians, teachers, doctors, vets, mechanics, gardeners, stage designers and artists all use scientific knowledge. In fact, you could easily add to this list yourself. For example, engineers use scientific knowledge to design bridges, computers, factories, artificial limbs, sewerage systems and buildings.

FIGURE 1.3 Scientific knowledge is used in many jobs, including those of gardeners.

1.2.2 Branches of science

There are many branches of science, and some jobs use more than one branch, with different areas of science overlapping in the one profession. Figure 1.4 shows some of the main branches of science.

FIGURE 1.4 Branches of science



Biology

Biology is the study of living things. There are many branches of biology. For example, **zoology** is the study of animals, and **botany** of plants. **Entomology** is the study of insects, while **microbiology** is the study of living things that are too small to see without the help of a microscope. There are also many branches of health sciences involving biology. Some examples of these are medicine, beauty science, nursing and dentistry.

Physics

Physics is the study of movement and different forms of energy such as light, heat, electricity and nuclear energy. Branches of physics include **acoustics**, the study of sound, and **biomechanics**, the study of the forces involved in human and other animal movement, as shown in figure 1.5.

FIGURE 1.5 Physics is the study of movement and different forms of energy.

Astronomy

Astronomy is the study of the stars, the Sun, the planets, their moons and other heavenly bodies such as comets and asteroids. Examples of some areas being studied in astronomy are: astrogeology, extra-terrestrial life, gravity, and the origins of the universe. The Australia Telescope Compact Array (seen in figure 1.6) is important in radio astronomy.

Geology

Geology is the study of the Earth and how it changes. A geologist might, for example, be concerned with how mountains are formed, or with using rocks to trace the Earth's history. Some of the branches of geology include: **vulcanology**, the study of volcanoes; **seismology**, the study of earthquakes; **palaeontology**, the study of fossils (seen in figure 1.7); and earth sciences including meteorology, climate science and pollution.

zoology the study of animals

botany the study of plants

entomology the study of insects

microbiology the study of microorganisms, living things too small to see without a microscope

acoustics the study of sound and how the design of a room or theatre affects what is heard

biomechanics the study of how animals, including humans, move

vulcanology the study of volcanoes

seismology the study of earthquakes

palaeontology the study of fossils

FIGURE 1.6 The Australia Telescope Compact Array

FIGURE 1.7 Palaeontologists study fossils.

Psychology

Psychology is the study of the mind and behaviour. 'Psych' comes from the Greek word *psyche*, meaning 'soul' or 'mind'. Most psychologists are concerned with human thought and emotion, but some work with other animals. Branches of psychology include **sports psychology**, which deals with the motivation of athletes (as seen in figure 1.8), and **forensic psychology**, which deals with psychology and the law.

Chemistry

Chemistry is the study of substances, what they are made of, how they are formed, how they change and what happens when they are combined (as shown in figure 1.9). Branches of chemistry include **radiochemistry**, the study of radioactive substances, and **pharmacology**, the study of the effect of drugs on living things.

sports psychology the study of how athletes train their minds to help improve sporting prowess

forensic psychology a branch of psychology dealing with the law

radiochemistry the study of radioactive substances

pharmacology the study of the effect of drugs on living things

FIGURE 1.8 Sports psychologists study how psychological factors can affect performance of athletes.

FIGURE 1.9 Some scientists like this chemist work in laboratories.

1.2.3 Scientists in different disciplines

Scientists can be found just about anywhere. They could be on a riverbank taking water samples, on a boat fitting dolphins with radio transmitters to track their movements, searching for fossils in outback cliffs, in a laboratory searching for the cause of a disease, beside a freeway measuring the effects of sound barriers — even in space investigating the effects of weightlessness. They work in groups with scientists from other disciplines or their own branch of science.

Some scientists work in more than one branch. For example, a **biochemist** works in biology and chemistry, studying the substances in living things. A **biophysicist** might study the small electrical signals that travel from your ear to your brain, which enable you to hear.

biochemist a scientist who studies the composition and interaction of substances in living things

biophysicist a scientist who studies the forces, energy and electrical processes in living things

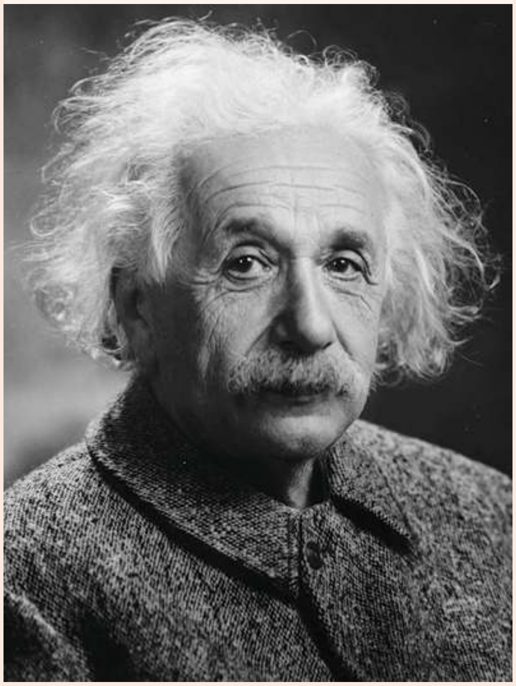
on Resources

eWorkbook	Exploring the branches of science (ewbk-11011)
Interactivities	The disciplines of science (int-5609) How science helps improve performance (int-7130)

SCIENCE AS A HUMAN ENDEAVOUR: Are all scientists high achievers at school?

Not all scientists were high achievers at school. Some very famous scientists were average or below average school students. Albert Einstein is probably the most famous example. He did not talk until he was three years old. He left school at the age of 15 and went back later. He passed his university exams by studying the notes of his classmates.

FIGURE 1.10 Albert Einstein



1.2.4 STEM

Since prehistoric times, people have been making scientific discoveries that have improved the quality of life. The use of scientific ideas to design devices that make life easier is called **technology**. The invention of the wheel is a good example of early technology. The scientific idea behind the wheel is that objects roll over surfaces more easily than they slide across them. The interaction of science, technology, engineering and mathematics (**STEM**) has been the driving force behind our modern technological world. It is also predicted that many jobs of the future will be focused in these STEM areas.

technology the application of science to the design of a device or process

STEM acronym: stands for the disciplines of science, technology, engineering and mathematics

on Resources

Weblink	100 jobs of the future

1.2 Activities

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1.2 Quick quiz on	1.2 Exercise

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

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Remember and understand

1. Match each of the following occupations with the way people in these occupations might use science in their daily work.

Occupation	Activities
a. Nurse	A. Knowing how to design a building that will not collapse under the weight of the roof
b. Mechanic	B. Adding chemicals to soil to make certain plants grow better
c. Gardener	C. Measuring blood pressure
d. Chef	D. Doing tests to find out the blood type left on a broken window during a crime
e. Architect	E. Using oil to stop parts from wearing too fast
f. Police officer	F. Using a saucepan lid to make something boil faster

2. What would each of the following types of scientist be mainly concerned with?

Type of scientist	Activities
a. Biochemist	A. The natural behaviour of the Earth
b. Geophysicist	B. The way in which living things interact with each other in the marine environment
c. Marine ecologist	C. Substances in living things

3. a. What do the initials CSIRO stand for?
   b. What does this organisation do?

Apply and analyse

4. Match each of the following scientists with the way they could improve an athlete's performance.

Type of scientist	Activities
a. Nutritionist	A. Research the effects of frictional forces on balls, racquets and playing surfaces; they may also examine the effects of different materials for use in racquets
b. Sports psychologist	B. Might develop an eating program that will provide the right combinations of nutrients at different stages of the player's training regimen and performance
c. Physicist	C. Help by training the mind for motivation and performance

5. List five devices that you have used today that would not have been invented without scientific knowledge.

Evaluate and create

6. Imagine that you are given the chance to interview any scientist from the past or present. Who would you choose? Give reasons for your choice and prepare a list of questions that you would ask.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
1.3 The science laboratory

LEARNING INTENTION

At the end of this lesson you will be able to describe the function of different laboratory equipment, and how to use this equipment safely.

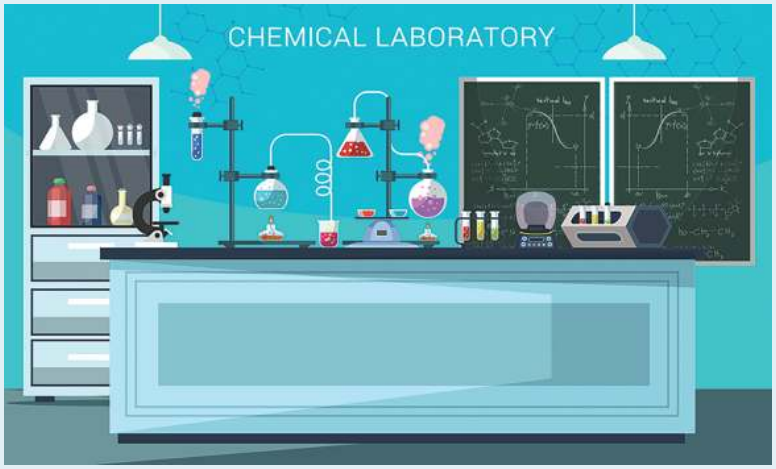
1.3.1 Getting to know the science lab

Science laboratories (often referred to as 'labs') are found in many locations such as schools, industrial sites and universities. Your school may have one lab or multiple labs. All science labs have many common features that are important for its use in science and for safety.

ACTIVITIES: A map of the science room

a. Sit quietly for a minute or two and look around the science laboratory.
b. List as many differences as you can between the science laboratory and other general classrooms at your school.
c. Draw a map of the science laboratory on a sheet of A4 paper, labelling each of the following items clearly.

- Student tables and work benches
- Teacher's desk or demonstration bench
- Gas taps
- Sinks
- Eye wash
- Fire blanket
- Doors
- Broken glass bin
- Power points
- Fume cupboard
- Fire extinguishers
- Sand bucket
- Rubbish bin



1.3.2 Laboratory equipment

Some of the equipment that you are likely to use in the science laboratory is illustrated in figure 1.11.

int-3414

FIGURE 1.11 Some equipment that you are likely to use in the science laboratory

TABLE 1.1 Scientific equipment and their uses in the science laboratory

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

ACTIVITY: Finding scientific equipment

Can you find all the equipment outlined in figure 1.11 and table 1.1 in your science classroom? Write a list of all the equipment and note down where it was located in your laboratory.

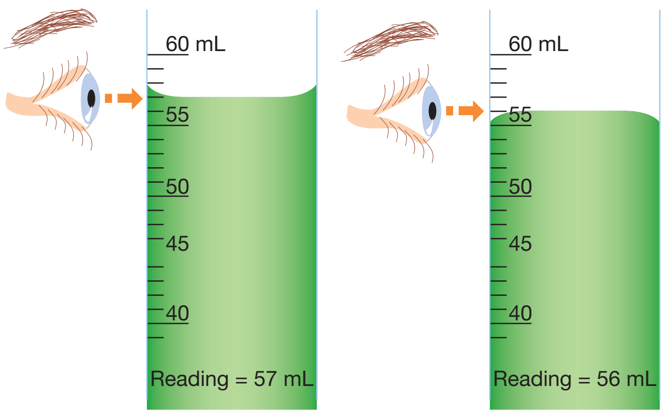
1.3.3 Measuring and reading scales

Measuring volume

Liquids inside 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 (as shown in figure 1.12).

meniscus the curve seen at the top of a liquid, when in contact with a surface, specifically within a tube

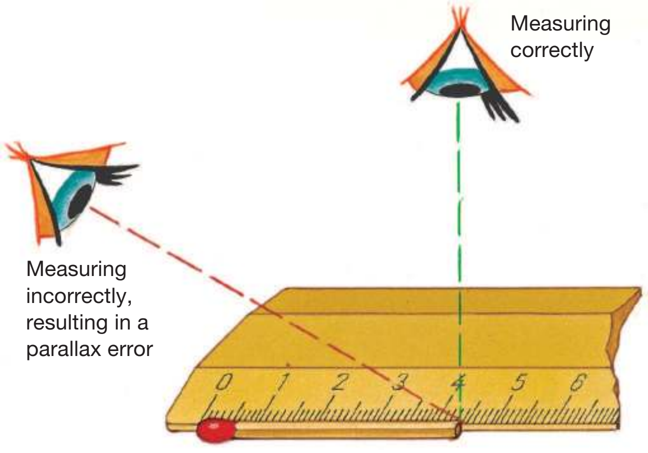
FIGURE 1.12 For an accurate reading, measure the volume of liquids from the flat section of the meniscus.



Parallax error

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**. This type of reading error is called **parallax error** (as shown in figure 1.13).

FIGURE 1.13 It is important to keep your eye in line with the measurement for the reading you are taking.



Measuring temperature

A **thermometer** is used to measure temperature. The unit of measurement commonly used is degrees Celsius (°C). The thermometers used in schools are filled with alcohol, dyed red so that they are easier to read. When using thermometers, remember the following points:

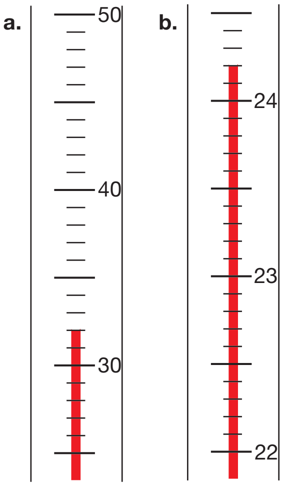
- Never rest the bulb of the thermometer on the bottom of a container being heated as the bottom may be hotter than the rest of its contents.
- Ensure that the liquid for which you are measuring the temperature fully covers the thermometer bulb.
- Read the thermometer with your eye level with the top of the alcohol column.

Reading scales

In science, a scale or set of numbered markings generally accompanies each measuring device. For example, your ruler measures length, and its scale has markings enabling you to measure with an accuracy of 0.1 cm. A laboratory thermometer has a scale that measures temperature with an accuracy of 0.5 °C.

When reading a scale, it is important to determine what each of the markings on the scale represents, as shown in the figure 1.14.

FIGURE 1.14 The temperatures measured by thermometers A and B are 32 °C and 24.2 °C, respectively.



on Resources

eWorkbook The science laboratory (ewbk-11013)

1.3.4 Safety in the laboratory

Doing experiments in science can be exciting, but accidents can happen if investigations are not carried out carefully. There are certain rules that must be followed for your own safety and the safety of others.

accurate describes a measurement that is close to the true value

parallax error a reading error in which, when scales are read from a different angle, the reading is not accurate

thermometer a device which measures temperature

Tips for investigating safely

- Use a **filter funnel** when pouring from a bottle or container without a lip.
- Never put wooden test tube holders near a flame.
- Always turn the tap on before putting a **beaker**, **test tube** or **measuring cylinder** under the stream of water.
- Remember that most objects get very hot when exposed to heat or a naked flame.
- Do not use tongs to lift or move beakers.

filter funnel used with filter paper to separate solids from liquids

beaker container for mixing or heating substances

test tube thin glass container for holding, heating or mixing small amounts of substances

measuring cylinder container used to measure volumes of liquids accurately

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 chairs in 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 1.15 It is important to 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's 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 1.16 Experiments should not be left unattended.

ACTIVITY: Safety rules

Select one of the safety rules and choose a strategy for publicising your message to the class. You might create a safety poster, video clip or play.

What is your strategy?

Why did you choose it?

1.3.5 Working with dangerous chemicals

Your teacher will tell you how to handle the chemicals in each experiment. At times, you may come across substances that are dangerous and have warning labels as shown in table 1.2.

TABLE 1.2 Different hazardous symbols and their meaning

	Always wear gloves and **safety glasses** when using chemicals with this symbol. Corrosive substances can cause severe damage to skin and eyes. Acid is an example of a **corrosive** substance.
	These substances are easily set on fire so keep them away from flames. Methylated spirits is **flammable**.
	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 toxic substance.

1.3.6 Heating substances

Many experiments that you will conduct in the laboratory require heating. In school laboratories, heating is usually done with a Bunsen burner, outlined in figure 1.17.

The barrel is the part of the burner from where the flame comes out. Never touch the barrel with your bare hand as it is very hot long after use. The base of the burner is the safest part to touch, as it is designed to not get hot.

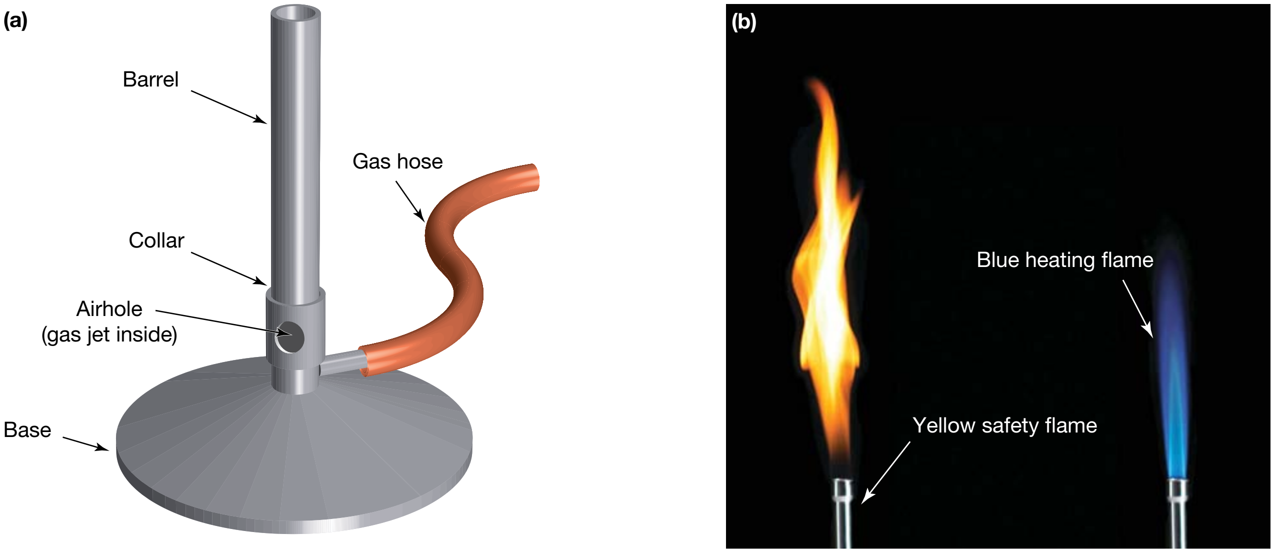
safety glasses plastic glasses used to protect the eyes during experiments

corrosive describes a chemical that wears away the surface of substances, especially metals

flammable substances such as methylated spirits that burn easily

int-8166

FIGURE 1.17 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.



ewbk-11017

The air hole controls the amount of oxygen that can mix with the gas in the burner. This air hole can be partially or completely open by turning it. The collar is a metal ring that can be adjusted to adjust the amount of oxygen that can enter the burner. Always light the Bunsen burner with the air holes completely closed. The gas inlet is where the gas enters the burner and mixes with the oxygen.

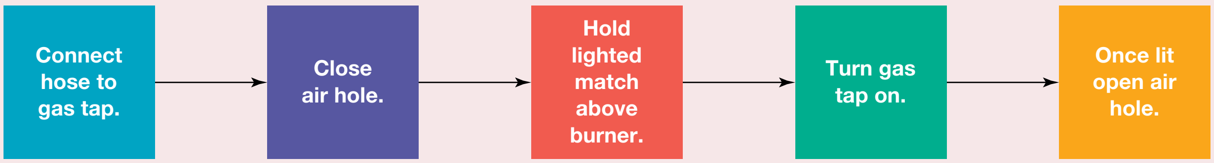
The flames of a Bunsen burner vary depending on their temperature and use, as seen in figure 1.17b. The bright yellow, visible flame is known as the safety flame. This flame will be least hot due to less oxygen in the gas. The light blue, less visible flame is known as the heating or roaring flame. This flame is used when heating something. Always tie hair back and wear safety glasses and a laboratory coat or apron when using a Bunsen burner.

eles-2360

A GUIDE TO USING THE BUNSEN BURNER

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.

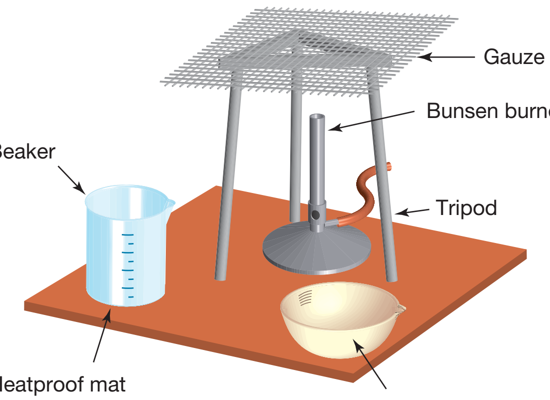
FIGURE 1.18 The process of lighting a Bunsen burner



ewbk-11019

int-8167

FIGURE 1.19 The equipment used to heat substances and containers



Heating containers

Beakers and evaporating dishes can be placed straight onto a gauze mat for heating. Use a gauze mat over a tripod to hold containers over a Bunsen burner flame. Never look directly into a container while it is being heated. Wait until the equipment has cooled before handling it.

SCIENCE AS A HUMAN ENDEAVOUR: The invention of the Bunsen burner

Have you noticed that 'Bunsen burner' is always spelt with a capital 'B'? It is named after Robert Bunsen, a German scientist who, along with his laboratory assistant Peter Desaga, improved on earlier models of laboratory burners. This improved their laboratory work. Bunsen also developed the most effective antidote for arsenic poisoning, which is still used today.

elog-0482

INVESTIGATION 1.1

Which flame is hotter?

Aim

To determine which is the hotter Bunsen burner flame: blue or yellow

Materials

- Bunsen burner
- Matches
- Pieces of porcelain
- Clock or watch
- Heatproof mat
- Tongs
- Safety glasses

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. Make a prediction about which flame is hotter.
2. Light the Bunsen burner according to the guide in section 1.3.6.
3. Open the airhole.
4. Hold a piece of porcelain over the flame with the airhole open.
5. Record roughly how long it takes for the porcelain to turn red-hot.
6. Let the porcelain cool on the heatproof mat.
7. Close the airhole.
8. Hold the porcelain in the yellow flame for a few minutes.

Results

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. What else do you notice about the porcelain after heating in the yellow flame?

Discussion

1. Give reasons for your prediction.
2. Which is the hotter flame? What observations did you make that support your answer?

Conclusion

Write a conclusion for this investigation, linking back to your aim and the prediction you made.

elog-0484

INVESTIGATION 1.2

Where is the hottest part of the flame?

Aim

To locate the hottest part of a Bunsen burner flame

Materials

- Bunsen burner
- Heatproof mat
- Matches
- Safety glasses
- Nichrome wire
- Tongs
- Pin

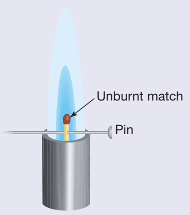
CAUTION

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

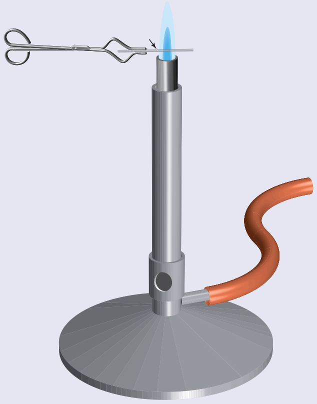
Part A

1. Predict where the hottest part of the flame will be.
2. Use a pin to hang an unburnt match over the barrel of a Bunsen burner.
3. Light the Bunsen burner according to in section 1.3.6.
4. Turn the collar to produce a blue flame.
5. Turn the Bunsen burner off and remove the match and pin with tongs.



Part B

6. Re-light the Bunsen burner and turn the collar to produce a blue flame again.
7. Use the tongs to hold the wire across the flame, close to the barrel of the Bunsen burner, and observe the wire.
8. Move the wire up a little and continue observing.



Results

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.

Discussion

1. Students often heat substances in a test tube with a Bunsen burner. Why would it be unwise to:
   a. use a yellow flame rather than a blue flame
   b. position the test tube at the base of a blue flame?
2. Why is the yellow flame often called the safety flame?
3. Give reasons for your prediction about the hottest part of the flame. Was your prediction correct?

Conclusion

Write a conclusion for this investigation, linking back to your aim and the prediction you made.

elog-0486

INVESTIGATION 1.3

Heating a substance in a test tube

Aim

To safely heat a substance in a test tube

Materials

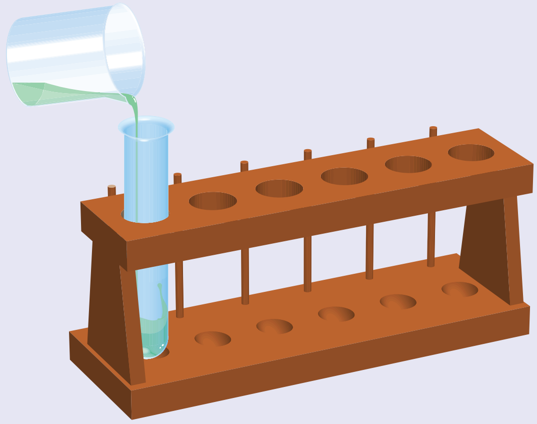
- 100 mL beaker
- Bunsen burner and heatproof mat
- Matches
- Safety glasses
- Test tube
- Test tube rack
- Test tube holder
- Food colouring

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. 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 as shown. Remember that the open end of the test tube should be pointing away from you and your fellow students. The base of the test tube should be moved gently in and out of the flame. This prevents the liquid from splashing out of the test tube.
3. Once the water 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

1. Make a list of any changes you observed inside the test tube as you heated the water.

Discussion

1. Outline five safety techniques you used when heating your test tube.
2. Why is the test tube placed in a test tube rack rather than in your hand?

Conclusion

Write a conclusion for this investigation, linking back to your aim and the prediction you made.

Resources

eWorkbook	Playing it safe (ewbk-11015)
Video eLesson	Science safety rules (eles-2245)
Interactivity	Danger in the laboratory (int-3415)

1.3 Activities

learnON

1.3 Quick quiz ON	1.3 Exercise

Select your pathway

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

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Remember and understand

1. MC Why should you always wear gloves when working with corrosive substances?
   A. In case the chemical dyes your hand
   B. To prevent severe damage to the skin should the chemical be spilled
   C. To protect against corrosive substances leaching through the glassware
   D. To make sure you have more grip so you can hold the glassware better
2. Your teacher tells you it is safe to smell a chemical. Fill in the gaps in the sentence below to show the technique you should use.
   ____________ the odour from ____________ the mouth of the test tube or beaker to your nose with your hand.
3. Which colour flame of a Bunsen burner is hottest?
4. MC What should you do if you cut or burn yourself in the laboratory?
   A. Get yourself a band-aid.
   B. Leave the laboratory.
   C. Continue with the experiment.
   D. Tell your teacher immediately.
5. Complete the following passage.
   When in the science laboratory, matches cannot be washed down the ____________.
   Always point a test tube ____________ from you when heating.
   Water spills ____________ need to be cleaned up.

Apply and analyse

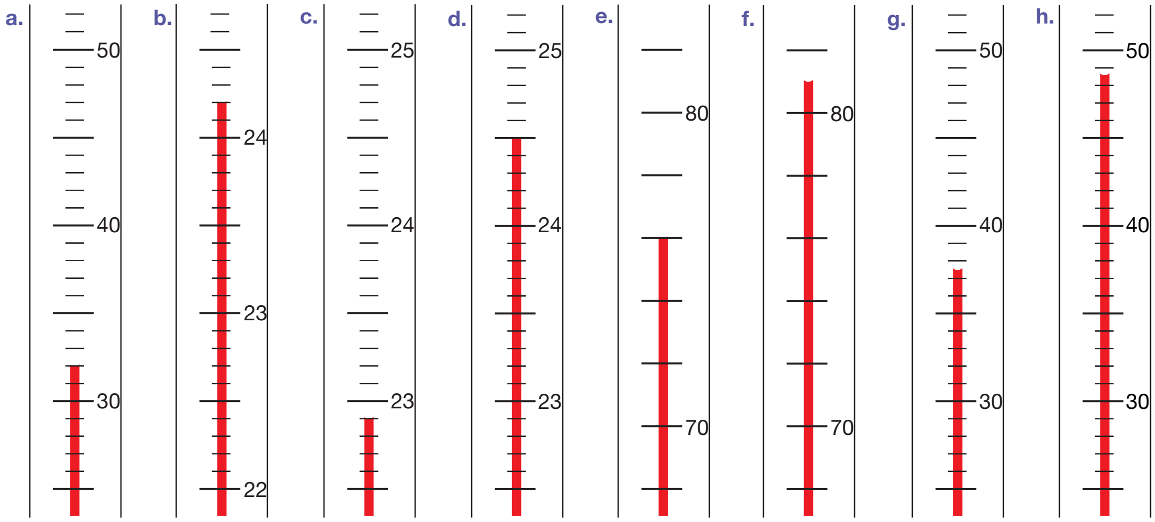
6. Match the following pieces of equipment with their purpose.

Equipment	Purpose
a. Heatproof mat	A. Used with clamps and bossheads to hold equipment at the required height
b. Evaporating dish	B. Protect benches from heat damage
c. Test tube rack	C. Porcelain container for evaporating small amounts of substances over a Bunsen burner
d. Retort stand	D. Hold test tube upright

7. Match the item of equipment you would use for each of the following activities.

Activity	Equipment
a. Hold a test tube that is to be heated	A. Spatula
b. Measure a volume of water exactly	B. Measuring cylinder
c. Transfer a small sample of a powder to a beaker	C. Stirring rod
d. Mix a sample of powder with water so it dissolves	D. Test tube holder

8. Determine the temperatures measured by each of the thermometers shown.



Evaluate and create

9. Look carefully at the picture of students in a laboratory.

a. List at least five dangerous situations you can see.
b. Explain why each situation is dangerous.

10. You are going to a primary school to teach students about lab safety. Explain your top five tips and describe how you would explain these to a group of seven-year-olds.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
1.4 SkillBuilder — Measuring and reading scales

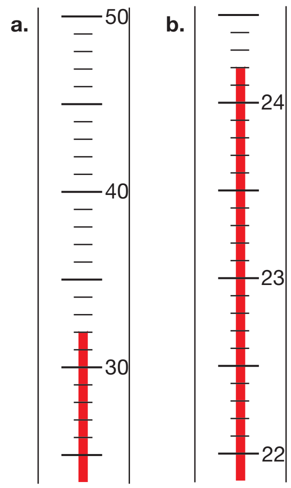
LEARNING INTENTION

At the end of this lesson you will be able to read and record measurements accurately.

online only

Why do we need to measure and read scales?

When conducting experiments, it is critical that measurements and data are recorded accurately. Whether measuring volume or temperature, or interpreting alternate scales, it is important that they are recorded accurately.



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- **Let me do it:** an interactivity, question set and SkillBuilder activity for you to practice and consolidate your understanding of the skill

on Resources

eWorkbook	SkillBuilder — Measuring and reading scales (ewbk-11021)
Video eLesson	Measuring and reading scales (eles-4153)
Interactivity	Reading scales (int-0201)

LESSON
1.5 SkillBuilder — Using a Bunsen burner

LEARNING INTENTION

At the end of this lesson you will understand how to operate a Bunsen burner safely.

online only

Why use a Bunsen burner?

Many experiments in the laboratory require heating using a Bunsen burner. A Bunsen burner provides heat when a mixture of air and gas is lit. Bunsen burners heat objects or liquids with a naked flame, and therefore there are precautions that must be taken to ensure the safe usage of a Bunsen burner.

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- **Let me do it:** an interactivity, question set and SkillBuilder activity for you to practice and consolidate your understanding of the skill

Resources

- **eWorkbook** — SkillBuilder — Using a Bunsen burner (ewbk-11023)
- **Video eLesson** — Using a Bunsen burner (eles-4154)
- **Interactivity** — Using a Bunsen burner (int-8088)

LESSON
1.6 Scientific inquiry

LEARNING INTENTION

At the end of this lesson you will be able to describe and apply the scientific method.

1.6.1 Scientific investigations

Crime scene investigators make **observations** at the scene of the crime. A footprint, the smell of perfume, an unusual sound or a warm log in a fireplace could provide clues to a crime.

The investigators also collect evidence so that they can make more observations in the laboratory. They use their observations to make an inference about what happened. An **inference** is a suggested explanation of what took place. But inferences are not always right. Further investigation is usually needed. The investigators often form a **hypothesis** about what happened. A hypothesis is a reasoned prediction about the outcome of an experiment. Your hypothesis should relate to your **aim** (the purpose of your investigation) and should be **testable** and **falsifiable** with an experiment, measurement or observation. A hypothesis is usually written in an '*If* … *then* …' format (for example, '*If* the balloon is more inflated, *then* it will fly for longer when let go').

After testing a hypothesis you can consider the evidence and you might be able to form a **conclusion** about what happened. A conclusion is a final explanation of what took place. Sometimes the investigator has to return to the scene of the crime to gather more evidence to make further observations and start the process all over again before a conclusion can be formed.

The process used by crime scene investigators, called the **scientific method**, is used in almost all scientific investigations.

observations information obtained by the use of our senses or measuring instruments

inference a suggested logical explanation for an event or occurrence

hypothesis a testable statement from an observation, usually written in *if* … *then* … format, that acts as a prediction for the investigation

aim a statement outlining the purpose of an investigation

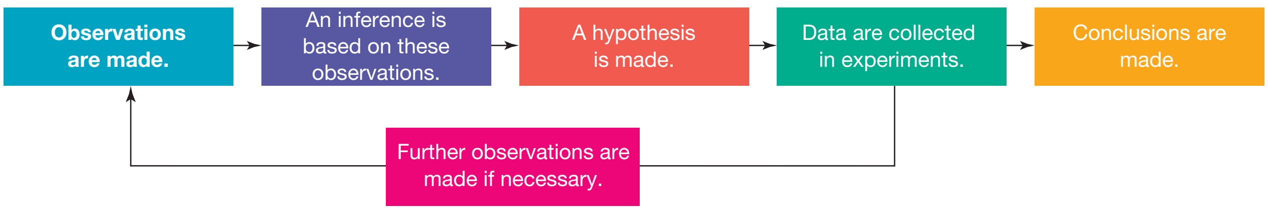
testable able to be supported or proven false through the use of observations and investigation

falsifiable able to be proven false

conclusion a general statement that sums up the observations or results of an experiment

scientific method the process of making an observation, developing a hypothesis and testing this through scientific investigation

FIGURE 1.20 This flowchart summarises the process of many scientific investigations.



1.6.2 Observing and making inferences

To solve the mystery shown in figure 1.21, careful observations have to be made. Normally you are able to use all five senses to make observations. However, in this case you can use only your sense of sight.

1. Write down as many observations as you can that might help solve the mystery.
2. Make an inference about what happened.
3. Form a hypothesis about the mystery that can be tested by closer observation, measurement or an experiment. (Try to do this in '*If* ... *then* ...' format.) Explain how your hypothesis could be tested by a real crime scene investigator.
4. Why is it not possible to form a conclusion about who or what caused the mess using the photo alone?

FIGURE 1.21 Who or what did it?

CASE STUDY: Fictional detections

One of the most famous fictional detectives of all time was Sherlock Holmes. Together with Dr Watson he used observations and clever hypotheses to solve many crimes. Every hypothesis had to be tested until he could reach a conclusion about the crime. One of Sherlock's scientific tools was a simple magnifying glass.

elog-0488

INVESTIGATION 1.4

Are you a good observer?

Aim

To form clear observations around a lit candle

Materials

- Candle and matches
- Jar lid

Method

1. Light a candle and place it on the lid of a jar. Write down as many observations as you can of the burning candle, using sound, smell and sight. DO NOT TOUCH THE FLAME OF THE CANDLE.
2. Michael Faraday (1791–1867), a scientist famous for his discoveries in electricity and chemistry, made 53 observations of a burning candle. Take note of the number of observations you made.

Results

1. Write down your observations using a table to group them according to which sense you used to make the observation.
2. Use a table like the one shown to record the number of observations made by the people in your class.

TABLE Observations made by the people in the class

'Score' (number of observations made)	Number of people
0–9	
10–19	
20–29	
30–39	
More than 39	

Discussion

1. How many observations did you record?
2. Form a hypothesis about whether you are a better observer than most people in your class.
3. Was your hypothesis supported by the data?
4. Which sense did you use to make most of your observations? Suggest why this sense is most used.

Conclusion

Write a conclusion to answer the question ‘Am I a better observer than most people in my class?’

ACTIVITY: Outdoor observations

Sit quietly in a nearby outdoor location and write down as many observations as you can within five minutes.

- Identify the sense that you used the most.
- Which other senses did you use?
- Compare your observations with those of other classmates. What interesting observations did others make?

on Resources

eWorkbook Observing and recording (ewbk-11025)

1.6 Activities

learnon

1.6 Quick quiz on | **1.6 Exercise**

Select your pathway

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

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Remember and understand

1. How is a scientist like a detective?
2. What is the difference between a hypothesis and a conclusion?

Apply and analyse

3. State the five senses that can be used to make observations and describe their functions.
4. Explain the difference between an inference and a hypothesis.
5. Read the following statements and decide whether each sentence is an observation, inference or conclusion.

Statement	Observation, inference or conclusion?
a. The dog in the house next door is barking.	
b. There are no lights on in the house.	
c. The owners must be asleep.	
d. There could be a prowler in the backyard.	
e. I heard the sound of breaking glass.	
f. The dog is distressed as it is hungry.	

Evaluate and create

6. Imagine that you have lost your senses of sight and hearing. Write a description, giving as much detail as you can, about walking through a remote forest. Don't forget that your observations can be made only with your senses of touch, taste and smell.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
1.7 SkillBuilder — Writing an aim and forming a hypothesis

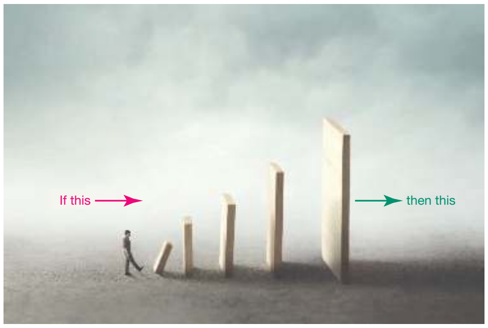
LEARNING INTENTION

At the end of this lesson you will be able to write aims and hypotheses.

online only

Why do we need to write aims and form hypotheses?

In science, we conduct investigations to gather data and results and draw conclusions. Every investigation requires an aim — a short statement of what we are trying to achieve. Alongside an aim, the ability to formulate predictions is important in science. This is done through the use of a hypothesis. Being able to write aims and hypotheses are vital skills for any scientist.



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on Resources

eWorkbook	SkillBuilder — Writing an aim and forming a hypothesis (ewbk-11027)
Video eLesson	Writing an aim and forming a hypothesis (eles-4155)
Interactivity	Writing an aim and forming a hypothesis (int-8089)

LESSON
1.8 Controlled investigations

LEARNING INTENTION

At the end of this lesson you will be able to describe how to investigate reliably using controlled variables and controls.

1.8.1 Being scientific

In order to answer a question scientifically, a controlled investigation needs to be performed. In a controlled investigation, every variable except the one being tested is held constant, which stops the **results** being affected by an uncontrolled factor. The investigation must also be reliable, which means that any conclusions made are supported by data. The simple investigation of bouncing balls made of different materials illustrates how experiments can be both controlled and reliable.

FIGURE 1.22 Bouncing a ball can become a scientific experiment.

Variables

There are many factors that affect how high a ball bounces after being dropped. They include:

- the height from which the ball is dropped
- the type of ball
- the type of surface the ball is dropped onto
- how much the ball has been used
- the method of dropping
- the technique used to measure the bounce height.

These factors are called **variables**. The variable that you are investigating is called the **independent variable**. In this investigation the independent variable is the type of material that the ball is made of. You are comparing balls of similar sizes made from different materials. The variable that you are measuring (the height of the bounce) is called the **dependent variable**. The dependent variable often relies on changes made to the independent variables.

results the details or data that are recorded from the outcome of an investigation

variables quantities or conditions in an experiment that can change

independent variable the variable that the scientist changes to observe its effect on another variable

dependent variable a variable that is observed or measured during the experiment

fair test a test that changes only *one* variable and controls all other variables when attempting to answer a scientific question

controlled a parallel experiment where everything is the same as the test set-up except the variable

Fair testing

Scientific investigations must be **fair tests**. In a fair test only one variable is changed at a time — the independent variable. In this investigation about the tennis ball bounce, that is the type of ball. All variables other than the dependent variable must be **controlled**; that is, they must be kept the same. If they were not, you couldn't tell which variable was affecting the height of the bounce. You might find it helpful when designing your own investigations to use a table like the one shown to identify all the variables.

TABLE 1.3 Variables involved when examining the bounce of balls of differing materials

Type of variable	Variable in experiment
Independent variable	• The type of material the ball is made of
Dependent variable	• The height of the bounce

(continued)

Type of variable	Variable in experiment
Controlled variables	• The type of surface the ball is dropped onto • How much the ball has been used (use brand-new balls) • The method of dropping • The technique used to measure the bounce height

elog-0490

INVESTIGATION 1.5

Which ball bounces the highest?

Aim

To plan, conduct and report on a scientific investigation in which variables are controlled

Materials

- Tennis ball
- Baseball
- Rubber ball (about the size of a tennis ball)
- Any other ball the same size as a tennis ball
- Cricket ball
- One-metre ruler

Method

1. The question you are trying to answer is 'Which ball bounces the highest?'. Prepare a table in which to record your results.
2. Make a prediction. Write down a hypothesis.
3. Take care not to introduce unwanted variables. Make sure that the balls are dropped each time — don't accidently give them an extra push down. Also, think about which part of the ball you will measure the bounce height from.
4. You will be working in a small group, so decide who will drop the ball, who will make the measurements and who will record them.
5. Drop each ball from the same height and measure how high each one bounces. Now go ahead and answer the question — scientifically!

Results

Write a report about your investigation. You should outline your aim, materials and method, record your results and observations, summarise your findings in a **discussion**. Refer to section 1.14 if you aren't sure of what to include in your discussion.

Conclusion

Write a conclusion for this investigation that links back to your aim and hypothesis. Include this in your report.

1.8.2 Uncontrolled variables

Sometimes it is not possible to control all of the variables that need to be controlled. These variables are called uncontrolled variables. These 'out of control' variables can make your **data** unreliable. In the bouncing ball investigation the temperature of the ball is uncontrolled. However, the effect of temperature is minimised by testing balls at roughly the same time and in the same environment.

discussion detailed area of a scientific report that explains the results and how they link back to the relevant concepts. It also includes suggestions for improvements to the experiment.

data observations or measurements made and recorded during an investigation

The word *data* comes from the Latin word *datum* meaning 'something given'. The English word *datum* means a single piece of information. *Data* means more than one piece of information.

1.8.3 Repetition and reliability

If you measured the bounce height of each ball only once, your result may not be reliable. Errors often occur in measurements due to carelessness, a minor change in method (for example, in the way the ball was dropped) or inaccuracies in reading a scale (see figure 1.23). To reduce the effect of these errors, measurements should be repeated a number of times and an average calculated. Table 1.4 shows an example in which the bounce height of a wet tennis ball is compared with the bounce height of a dry tennis ball.

FIGURE 1.23 A dry tennis ball is used to test whether wetting a ball affects how high it bounces.

TABLE 1.4 Comparing the bounce height of wet and dry tennis balls

Trial	Height of bounce (cm)	
	Wet tennis ball	**Dry tennis ball**
1	47	47
2	45	48
3	42	50
4	42	48
5	44	52
Average	**44**	**49**

The average of these measurements suggests that a dry tennis ball will bounce higher than a wet one. If you recorded only trial 1, you would form a different — and incorrect — conclusion.

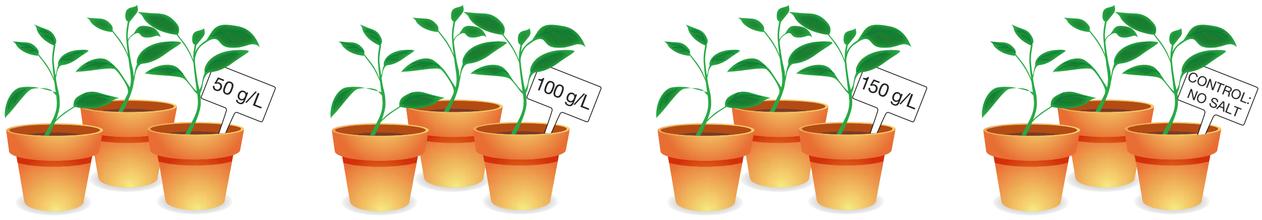
1.8.4 Including a control

Some investigations require a control or a **control group**. For example, you might be investigating the effects of watering plants with salty water. You could use three different containers of water, each with a different amount of salt in the water. The independent variable is the amount of salt dissolved in the water. The dependent variable might be the height of the plant after ten days of watering. For reliability you observe at least three plants for each amount of salt (**experimental group**). To fully investigate the effect of the salt in the water you need a control group of plants, to which you give water without any added salt. In a control group the independent variable (the salt) is not applied.

control group a group that is not affected by the independent variables and is used for comparison

experimental group test group that is exposed to the independent variable

FIGURE 1.24 Some investigations require a control group.



on Resources

eWorkbook Developing a fair test (ewbk-11029)

1.8 Activities

learnon

1.8 Quick quiz on	1.8 Exercise

Select your pathway

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

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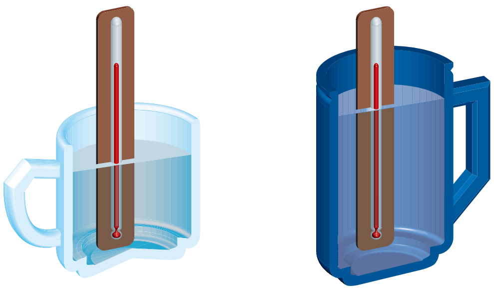
Remember and understand

1. What is a variable? Give an example of a variable.
2. State the difference between an independent variable and a dependent variable.
3. Explain why only one variable at a time should be changed in scientific investigations.
4. Identify some variables that might affect:
   a. how quickly a pot plant grows
   b. the cost of an overseas airfare
   c. the time it takes you to travel to school in the morning.

Apply and analyse

5. Advertisements for washing powders and liquids often claim that they are more effective than others. Imagine that you are conducting an experiment to test a range of washing powders and liquids.
   a. Outline a method for your experiment.
   b. List the variables you will need to control.
   c. MC What variable will you change?
      A. Mass of washing powder/liquid
      B. Duration of wash time
      C. Temperature of water
      D. Type of washing powder/liquid used
   d. How will you compare the results of your tests?
6. Amy and Nguyen are trying to find out whether stoneware or glass cups are better for keeping water hot. The diagram shows their experiment in progress.
   a. List at least two weaknesses in their experiment design.
   b. Make a list of all the variables that could affect the results of Amy and Nguyen's experiment.
   c. List any variables that Amy and Nguyen do not need to control.



7. Simon and Jessie performed an experiment to determine how effectively two plastic cups maintain the temperature of near boiling water. Their data is as follows.

TABLE The change in temperature of boiling water with respect to time in the two plastic cups

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

a. Draw a graph to display the data in the table.
b. Which cup maintained the temperature of the water more effectively?
c. Estimate the temperature of the water in Simon's cup 15 minutes after timing commenced.
d. Use your graph to estimate how long it would have taken the water in Jessie's cup to drop to a temperature of 20 °C.

Evaluate and create

8. Brainstorm and produce a list of problems that you could investigate scientifically at home or in the school laboratory without using expensive scientific equipment.
9. You are designing an investigation to find out whether distances are easier to judge with two eyes than just one. You can do this by shooting for goal with a basketball or netball from a particular spot under three conditions:
   - left eye closed
   - right eye closed
   - both eyes open.

   To produce reliable results, more than one person should take the shooting test and each goal shooter should have several attempts.
   a. Write a method for your experiment.
   b. Identify the independent and dependent variables
   c. Describe the strategies you used to ensure that this was a fair test.
10. The bounce height of a tennis ball is investigated in different conditions.
    a. Suggest how the bounce height of the tennis ball is affected (increases, decreases, varies) in the following conditions:
       i. when it is damp
       ii. when it is hot
       iii. as it gets old and worn
       iv. by different tennis court surfaces.
    b. Design an investigation to answer one or more of these questions.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
1.9 SkillBuilder — Controlled, dependent and independent variables

LEARNING INTENTION

At the end of this lesson you will be able to identify independent, dependent and controlled variables.

online only

What is the difference between controlled, dependent and independent variables?

In order to answer a question scientifically, a controlled investigation needs to be performed. In a controlled investigation every variable except the one being tested is held constant, which stops the results being affected by an uncontrolled factor. The variable that you are investigating is called the independent variable. The variable that you are measuring is called the dependent variable.

Go online to access:
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- **Show me:** a video and a step-by-step process to explain the skill
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on Resources

eWorkbook	SkillBuilder — Controlled, dependent and independent variables (ewbk-11031)
Video eLesson	Controlled, dependent and independent variables (eles-4156)
Interactivity	Controlled, dependent and independent variables (int-8090)

LESSON
1.10 Analysing data

LEARNING INTENTION

At the end of this lesson you will be able to use different types of representations and consider their strengths and limitations.

1.10.1 What is a graph?

A graph is a diagram that shows the connection between two or more things using dots, lines or bars.

Values or measurements obtained from an investigation are called data. Having collected the data, it is important to present them clearly so that another person reading them can understand them. Organising data in graph form is a widely recognised way of clearly presenting results. It makes the information easier to read and interpret, and makes it easier to show trends (patterns) and draw conclusions.

There are four different types of graph: a pie chart or sector graph, a bar chart or column graph, a histogram and a line graph.

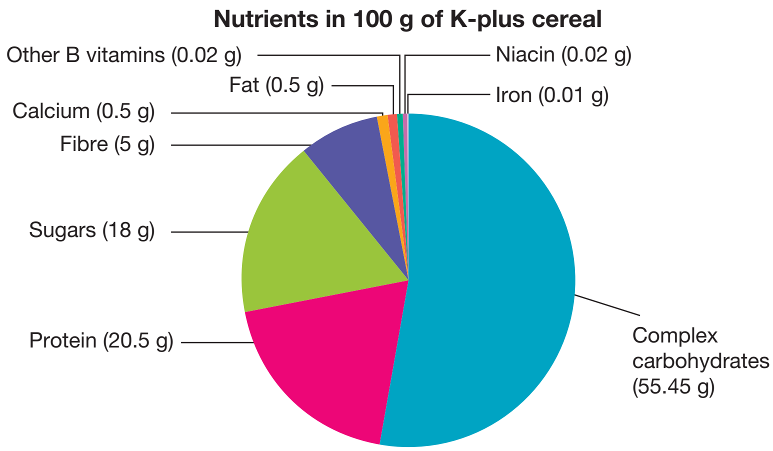
1.10.2 Pie chart (or sector graph)

A **pie chart** (also known as a **sector graph**) is a circle divided into sections that represent parts of the whole. This type of graph can be used when the data can be added as parts of a whole. The example in figure 1.25 shows the food types, vitamins and minerals that make up the nutrients in a breakfast cereal.

pie chart a diagram using sectors of a circle to compare the size of parts making up the whole; also called a sector graph

sector graph *see* pie chart

FIGURE 1.25 A pie chart



1.10.3 Column graph (or bar chart)

A **column graph** (also known as a **bar chart**) has two axes and uses rectangles (bars or columns) to represent each piece of data. The height or length of the bars represent the values in the data. The width of the bars is kept constant. This type of graph can be used when the data cannot be connected and are, therefore, not continuous.

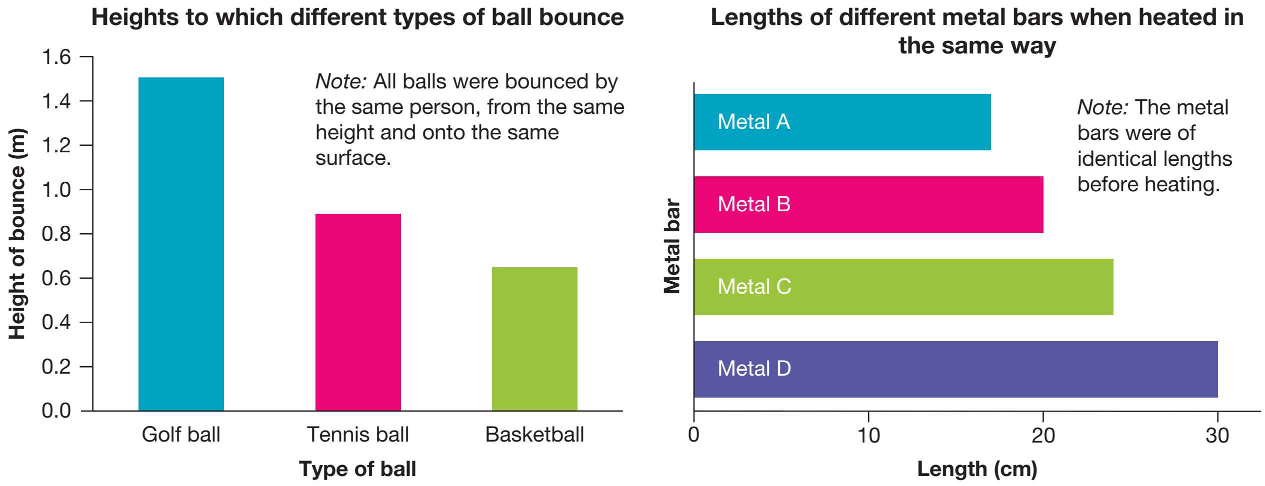
The first example on the next page shows data on the average height to which different balls bounced during an experiment. Each bar represents a different type of ball. The second example on the next page shows the lengths of different metal bars when heated. Each bar represents a different metal bar.

column graph *see* bar chart

bar chart a diagram using the lengths of rectangles (bars) to show the size of the same property for different objects or at different times

histogram a graph with equal intervals marked on the *x*-axis for the values of a quantity, and frequency of occurrence of each value shown by the height of adjoining columns

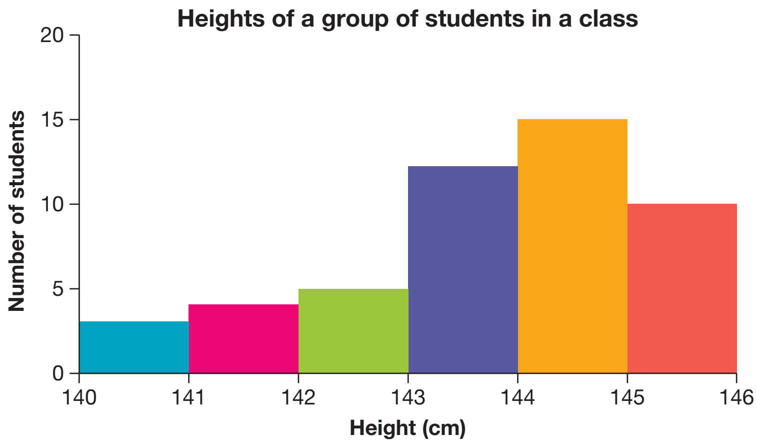
FIGURE 1.26 Two column graphs (also known as bar charts)



1.10.4 Histogram

Histograms are similar to column graphs except that the columns touch each other because the data are continuous and grouped. They are often used to present the results of surveys. In the histogram in figure 1.27, each column represents the number of students that reach a particular height.

FIGURE 1.27 A histogram



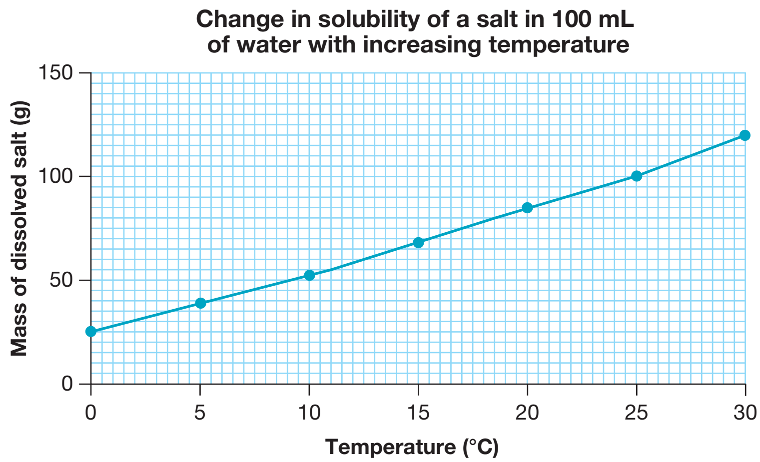
To effectively communicate data as a graph, a title must be given to state what the graph is showing, as well any necessary labels such as axis titles, a scale and/or a key, when applicable.

1.10.5 Line graph

A **line graph** has two axes — a horizontal axis and a vertical axis. The horizontal axis is known as the **_x_-axis**, and the vertical axis is known as the **_y_-axis**. The line graph is formed by joining a series of points or drawing a line of 'best fit' through the points. Each point represents a set of data for two variables, such as height and time. Two or more lines may be drawn on the same graph.

Line graphs are used to show continuous and ungrouped data — that is, data in which the values follow on from each other. For example, the line graph in figure 1.28 shows the change in the solubility of a salt in water as the temperature of the water increases. (Solubility is a measure of the mass of a substance that can be dissolved in a liquid.)

FIGURE 1.28 A line graph



1.10.6 Summary of graphs

As outlined in the earlier sections, there are many different types of graphs you can use to represent your data.

When determining the type of graph to use you should consider the type of data you have:

- Is your data all **numerical** (numbers), all **categorical** (categories such as eye colour) or both?
- If you have numerical data, can it take any value (**continuous**) or is it only set values (**discrete**)?
- Is your data in intervals?
- Does it make sense for your data to add up to 100%?

This will help you determine the type of graph you might choose to use.
For example:

- line graphs are not used for categorical data, but are used for continuous numerical data
- histograms are only used when you have intervals and frequencies
- column and bar graphs are used when you have a combination of categorical and numerical data
- pie charts are only used when you are expressing parts of a total.

line graph a graph made by plotting pairs of data as points and joining the points together

_x_-axis the horizontal axis on a graph

_y_-axis the vertical axis on a graph

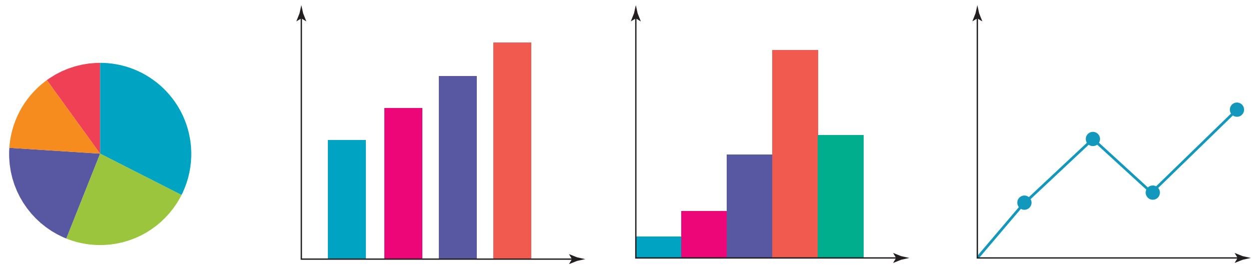
numerical data related to numbers; also known as quantitative

categorical data related to categories or non-numerical values; also known as qualitative

continuous numerical data that can be measured and be any value in a range, including decimals

discrete numerical data that can be counted and can only be certain values

FIGURE 1.29 Different types of graphs used for analysing data



Pie chart parts of a whole

Column graph, ungrouped data

Histogram continuous, grouped data

Line graph continuous, ungrouped data

on Resources

eWorkbook Selecting and constructing graphs (ewbk-11033)

1.10 Activities

learn**on**

1.10 Quick quiz **on**	1.10 Exercise

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
1, 2	3, 4	5

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Remember and understand

1. Draw a column graph using the information in the table 'Nutrients in a 30 g serving of ice-cream'.

TABLE Nutrients in a 30 g serving of ice-cream

Nutrient	Amount (g)
Protein	2.00
Fat	6.00
Carbohydrate — polysaccharide	11.00
Carbohydrate — sugar	10.00
Cholesterol	0.02
Calcium	0.10
Potassium	0.80
Sodium	0.05

2. The provided table gives the energy contained in various types of food.

TABLE Energy content of foods

Food	Energy (calories)
Apple (medium)	75
Bread (1 slice)	70
Butter (1 tbsp.)	100
Chocolate cake (medium slice)	250
Cornflakes (1 serving)	75
Milk (large glass)	150
Orange (medium)	50
Sugar (1 tbsp.)	50

a. Why are these data not suitable for graphing?
b. What would you need to do to make them suitable?

Apply and analyse

3. The provided table shows the percentage composition of salts present in sea water.

TABLE Salt composition of sea water

Salt	Percentage %
Calcium carbonate	0.34
Calcium sulfate	3.60
Magnesium bromide	0.22
Magnesium chloride	10.90
Magnesium sulfate	4.70
Potassium sulfate	2.50
Sodium chloride	77.24
All others	0.50

a. Draw a pie chart from this table.
b. MC Apart from sodium, the salts of which metal are the most abundant in sea water?
   A. Magnesium
   B. Calcium
   C. Chloride
   D. Sulfate

4. The following table shows the uses of plastics in Australia.

TABLE Uses of plastics in Australia

Use	Percentage %
Agriculture	4.0
Building	24.0
Electrical/electronic	8.0
Furniture and bedding	8.0
Housewares	4.0
Marine, toys and leisure	2.0
Packaging and materials handling	31.0
Transport	5.0
Others	14.0

a. Select a suitable graph type and prepare a graph from this table.
b. Choose two uses of plastic from your graph. For each use, state a particular item that is made of plastic.
c. There has been recent controversy about the waste products that humans create.
    i. Can you suggest any uses of plastics that would contribute to waste products? List them and explain your choices.
    ii. Can you suggest alternatives to reduce the amount of plastic waste products?

Evaluate and create

5. The table shows the amount of energy required by males and females for various activities.

TABLE Amount of energy required for various activities

Activity	Energy used per hour by average 58 kg female (kJ)	Energy used per hour by average 70 kg male (kJ)
Sleeping	240	300
Sitting, reading, desk work and studying	360	450
Light activity, such as driving, playing piano and standing with only arms moving	480	600
Walking slowly and gardening; working as a shop assistant or machinist	720	900
Physical work, such as factory or farm labouring; sports, such as cycling, tennis and cricket	960	1200
Heavy physical work, such as loading, stacking and carrying; vigorous sports, such as jogging, basketball, hockey and football (activity that leads to sweating)	1440	1800
Very heavy physical work and vigorous sports, such as football, hockey, running and swimming (activity that causes free sweating, requiring short bursts of extreme energy)	2400–4800	3000–7200
Transport	5.0	4.0

a. Draw a column graph using the information in the table.
b. Why do you think males use more energy per hour than females for the same activity?
c. The following list shows the activities for an average female for one day. Using this data, fill in the gaps to complete the sentences.

TABLE Daily activities of an average female

Activity	Number of hours
Sleeping	8
Light activity	4
Sitting, reading and desk work	10
Gardening	1
Basketball	1

    i. This female would need to consume ________________ kilojoules to provide the energy for the day's activities.
    ii. If an average male spent a similar day to the female in the previous question, he would need ________________ kilojoules.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
1.11 SkillBuilder — Constructing a pie chart

LEARNING INTENTION

At the end of this lesson you will be able to construct pie graphs.

online only

What is a pie chart?

A pie chart, or pie graph, is a graph in which slices or segments represent the size of different parts that make up the whole. The size of the segments is easily seen and can be compared. Pie graphs give us an overall impression of data.

Pie chart parts of a whole

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- **Let me do it:** an interactivity, question set and SkillBuilder activity for you to practice and consolidate your understanding of the skill

on Resources

eWorkbook	SkillBuilder — Constructing a pie graph (ewbk-11035)
Video eLesson	Constructing a pie graph (eles-1632)
Interactivity	Constructing a pie graph (int-3128)

LESSON
1.12 SkillBuilder — Creating a simple column or bar graph

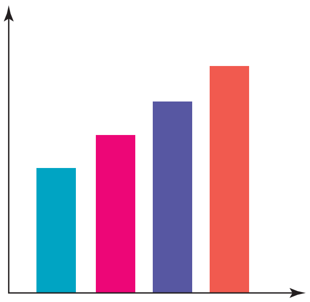
LEARNING INTENTION

At the end of this lesson you will be able to construct simple column or bar graphs.

online only

What is a column or bar graph?

Column graphs show information or data in columns. In a bar graph the bars are drawn horizontally and in column graphs they are drawn vertically. They can be hand drawn or constructed using computer spreadsheets.



Column graph, ungrouped data

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Resources

- **eWorkbook** SkillBuilder — Creating a simple column or bar graph (ewbk-11037)
- **Video eLesson** Creating a simple column or bar graph (eles-1639)
- **Interactivity** Creating a simple column graph (int-3135)

LESSON
1.13 SkillBuilder — Drawing a line graph

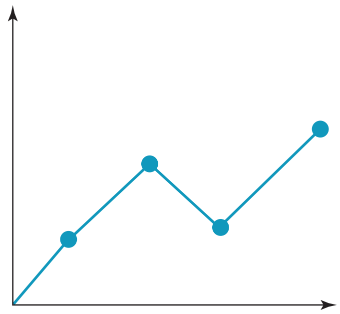
LEARNING INTENTION

At the end of this lesson you will be able to construct line graphs.

online only

What is a line graph?

A line graph displays information as a series of points on a graph that are joined to form a line. Line graphs are very useful to show change over time. They can show a single set of data, or they can show multiple sets, which enables us to compare similarities and differences between two sets of data at a glance.



Line graph continuous, ungrouped data

Go online to access:

- **Tell me:** an overview of the skill and its application in science
- **Show me:** a video and a step-by-step process to explain the skill
- **Let me do it:** an interactivity, question set and SkillBuilder activity for you to practice and consolidate your understanding of the skill

Resources

- **eWorkbook** SkillBuilder — Drawing a line graph (ewbk-11039)
- **Video eLesson** Drawing a line graph (eles-1635)
- **Interactivity** Drawing a line graph (int-3131)

LESSON
1.14 Reporting on investigations

LEARNING INTENTION

At the end of this lesson you will be able to write a scientific report.

1.14.1 Scientific reports

When scientists conduct investigations, they need to write reports to tell other people about their work. When you conduct experiments, you need to write reports that allow others to understand what you did and to read about what you found out.

Components of a scientific report

Aim

A statement outlining the purpose of the experiment

Hypothesis

A testable statement including the independent and dependent variables, usually written in '*If ... then...*' format, that acts as a prediction for the investigation.

Materials

A list of the equipment and chemicals that were used

Method

Step-by-step instructions for the experiment. This will often include a diagram showing how your equipment was set up. There should be enough details included that the reader could repeat your experiment exactly.

Results

A presentation of your data. This might include a list of observations, tables and/or graphs, with clear titles.

Discussion

An explanation of your results and how they link back to the relevant concepts. This section also includes suggestions for improvements to the experiment.

Conclusion

A brief account of what you found out and how your findings relate to your aim. It is a good idea to read your aim again before you write your conclusion.

1.14.2 Drawing science equipment

When reporting your experiments, a good, simple diagram can make it much easier for the reader to understand what was done. There are some rules to remember:

1. Diagrams in scientific reports should be drawn in pencil.
2. Straight lines should be drawn with a ruler.
3. Each item of equipment should be labelled.
4. Provide a title for the diagram.

Figure 1.30 shows how some commonly used items of equipment should be drawn.

FIGURE 1.30 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.

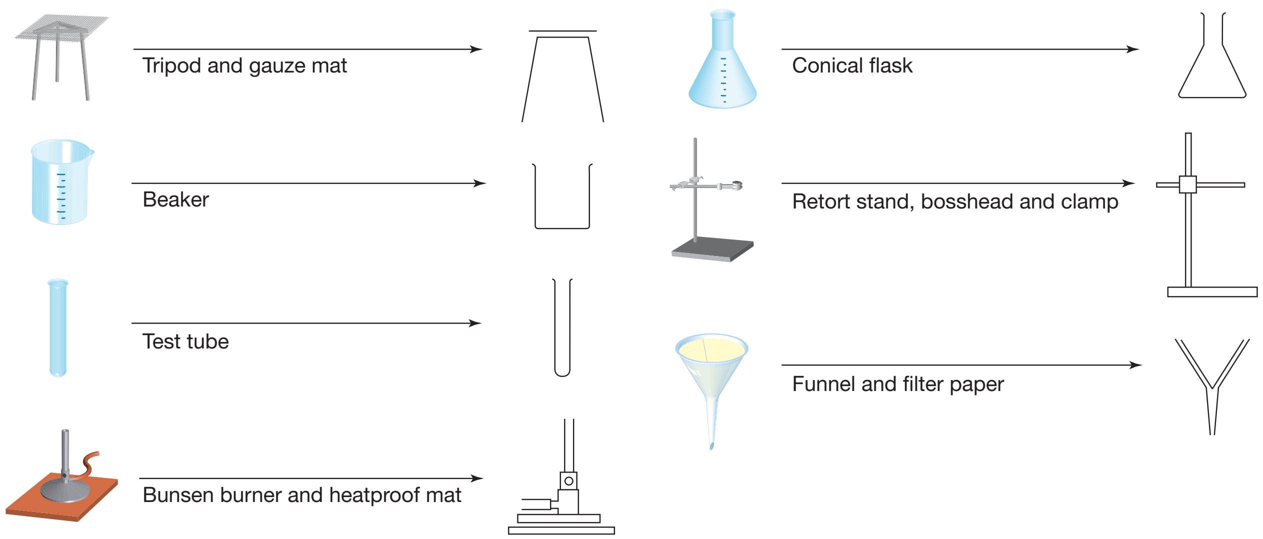


FIGURE 1.31 A good quality report of an experiment

Dissolving sugar

Aim

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

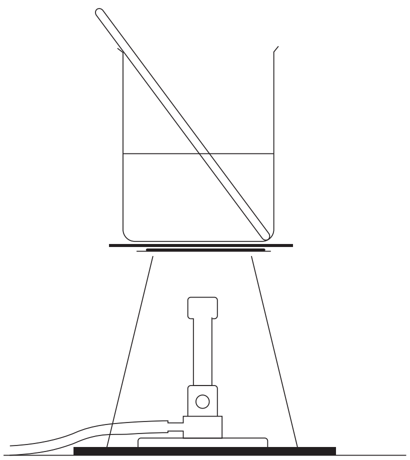
Materials

- 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.

1.14.3 Organising observations and data

When making a lot of observations, it is often helpful to organise them in a table. Observations and measurements that are organised in tables are easier to read. Tables also make it easier for you to draw graphs. Observation tables should have the title and table number if more than one table is used in a report.

elog-0492

INVESTIGATION 1.6

Recording observations in a table

Aim

To record method and observations of simple experiments in a table

Materials

- Four 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

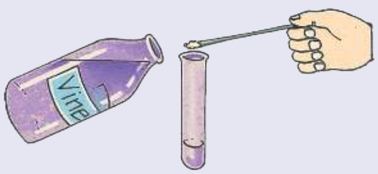
CAUTION

Safety glasses should be worn while conducting these experiments.

Method

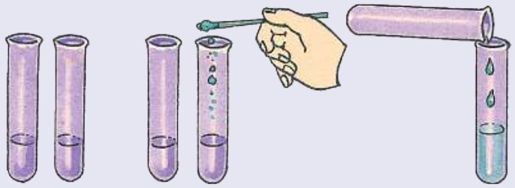
Activity 1

Pour vinegar into a clean test tube to a depth of about 1 cm. Add a spatula full of sodium bicarbonate.



Activity 2

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

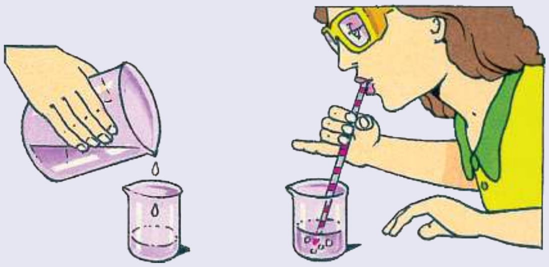


Activity 3

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

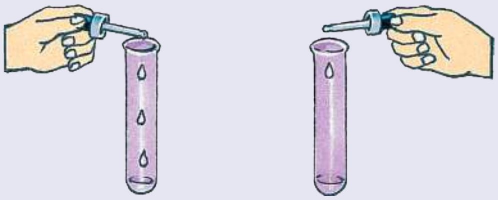
Activity 4

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



Activity 5

Put a few drops of starch suspension in a clean test tube. Add a drop of iodine solution. Take care not to get iodine solution on your skin or clothes.



Results

Draw a table like the one shown to record your observations in each of the following activities.

TABLE Observation table for the five activities

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

Discussion

1. What senses did you use in making your observations?
2. Describe 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, why it is not a good idea to return any unused limewater to the original bottle?

Conclusion

Write a conclusion for this investigation.

tlvd-10652

elog-0494

INVESTIGATION 1.7

Graphing temperature

Aim

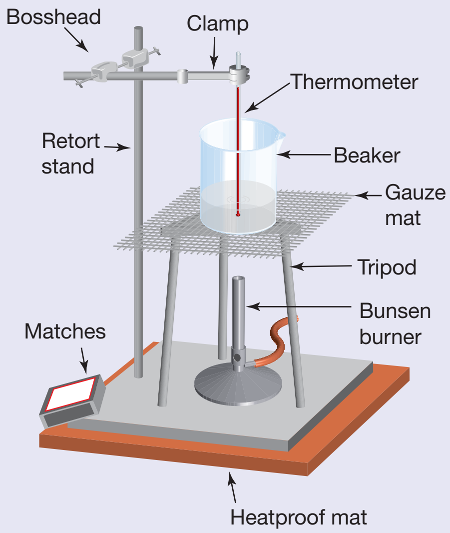
To observe how the temperature of water changes while it is heated over a Bunsen burner

Materials

- 100 mL measuring cylinder
- Bunsen burner
- Matches
- Gauze mat
- Safety glasses
- Retort stand, bosshead and clamp
- Thermometer or data logger and temperature sensor
- 250 mL beaker
- Heatproof mat
- Tripod
- Stopwatch

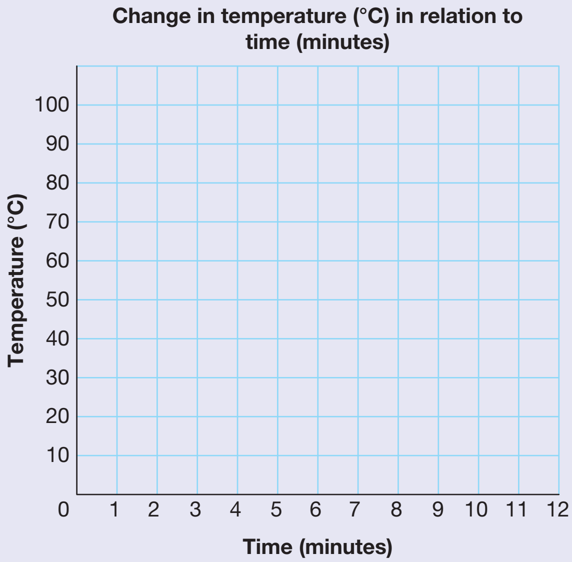
Method

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. The initial temperature is recorded when time is 0 minutes.
6. Put your safety glasses on.
7. Light the Bunsen burner.
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. Construct a table showing the change in temperature every minute. Make sure you include the initial temperature.
2. Plot a line graph of the data you have collected on a sheet of graph paper using labels like the following.



3. Draw a smooth line near as many points as possible to show the overall trend in the water temperature over time.

Discussion

1. Why didn't you record the starting temperature of the water as soon as you poured the water into the beaker?
2. Describe in words how the temperature increased.
3. How does your graph compare with those of other groups?
4. Predict what would happen to the temperature of the water if you continued heating for another two minutes.

Conclusion

Write a conclusion for this investigation.

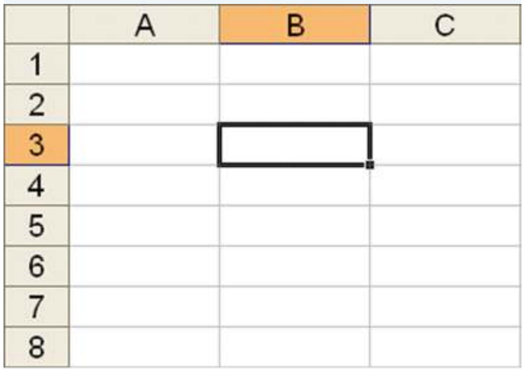
1.14.4 Using technology: spreadsheets

A spreadsheet is a document that stores data in columns and rows. Spreadsheets used to be written on paper by hand. Shopkeepers and bank tellers needed to keep neat handwritten ledgers to record all transactions. Today, computers and software such as Microsoft Excel are used to create and edit spreadsheets. Spreadsheets can also be used to create graphs and charts at the click of a button.

Some spreadsheet terminology

In a spreadsheet, the data are organised in rows and columns. The columns are named using letters (such as column B) and the rows are named using numbers (such as row 3). Cells are the boxes in the spreadsheet. The cell reference tells us which column and row the cell is in. For example, cell B3 is in column B and row 3. The active cell is the cell you will type the data in. In Excel, it has a dark border around it. This is shown in the diagram in figure 1.32.

FIGURE 1.32 Cell B3 is the active cell.



Working with Excel spreadsheets

When you create a spreadsheet, you need to decide how many columns and rows you will need and enter a suitable heading for each column. This is similar to designing a table. Make sure that you include units where relevant. When using Excel, you can format cells in a variety of ways by using the Format tool. Depending on your version, Excel may look different to your classmates' versions. There is lots of help online for your particular version if you are stuck!

Drawing graphs and charts

Drawing a graph using Excel is easy. Just highlight the data you want to graph, click on the Insert tab, select the type of graph you want to draw and then follow the prompts. Remember that a scatter graph (XY chart) is used to plot one set of values against another in Excel.

on Resources

eWorkbooks Scientific reports (ewbk-11041)
Designing an experiment (ewbk-11043)

Digital document Scientific report checklist (doc-34910)

1.14 Activities

learnon

1.14 Quick quiz on	1.14 Exercise

Select your pathway

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

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Remember and understand

1. Explain why scientists write reports about their experiments.

2. Under which heading of your report of an experiment should the following information be included?

TABLE The different components of an experimental report

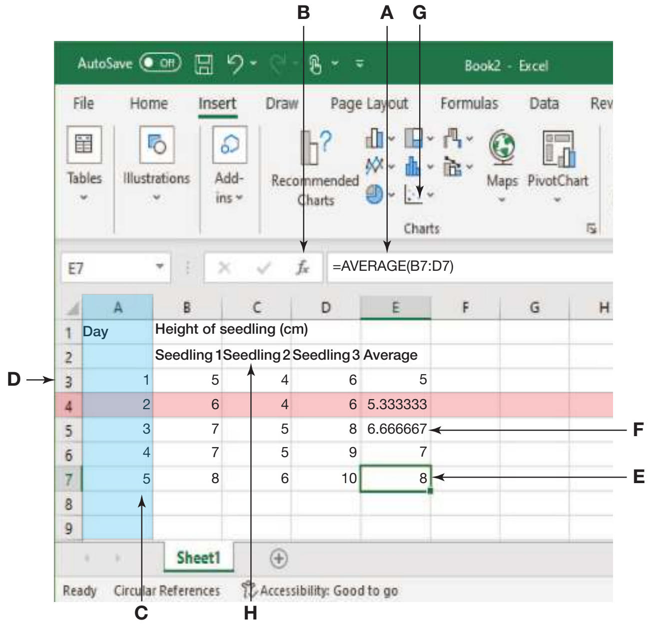
Information	Part of the experiment report
a. Suggestions for improvements to your experiment	
b. A reason for doing the experiment	
c. Graphs and tables	
d. A description of what you did	
e. A statement saying what you found out by doing the experiment	

3. Draw a neat, labelled scientific diagram of the equipment set-up for the following experiment:
- Water in a conical flask is being heated with a Bunsen burner.
- The conical flask is supported by a gauze mat on a tripod.
- The Bunsen burner is standing on a heatproof mat.

Apply and analyse

4. Using the Excel spreadsheet screenshot, identify the letter pointing to each of the following.

a. Cell C2
b. Cell E5
c. The active cell
d. A formula
e. The Insert scatter graph button
f. The Insert function button
g. A column
h. A row



5. List two advantages and two disadvantages of using a computer spreadsheet program to store data, rather than keeping handwritten records in a book.

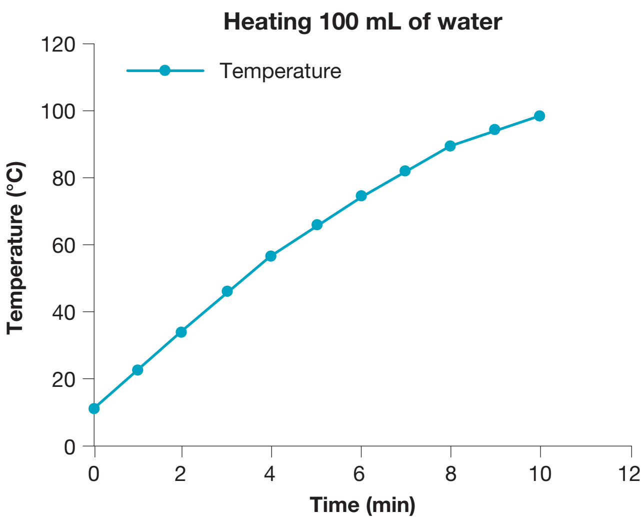
6. Draw a neat, labelled scientific diagram of the two sets of equipment that would be needed to safely perform the following activities.
   a. Muddy salt water is being poured from a beaker into a filter funnel (with filter paper). The filter funnel is resting in the opening of a conical flask.
   b. The filtered salt water, now in an evaporating dish, is being heated by a Bunsen burner. The evaporating dish is supported by a gauze mat on a tripod.
7. A hypothesis is often included in a scientific report — usually under the 'aim' heading, immediately after the reason for carrying out the experiment. What is a 'hypothesis'?

Evaluate and create

8. Design an experiment to investigate whether adding salt to water changes how the temperature rises when the water is heated. Write a scientific report outlining the design of your experiment.
9. a. Create a spreadsheet with column headings 'Time (min)' and 'Temperature (°C)'. Enter your data from Investigation 1.7 (or research expected results). You should end up with a table similar to the one shown.
   b. Use your data to create a scatter graph with the points joined by straight lines.
   c. Create a title for your graph.
   Label the *x*-axis 'Time (min)' and the *y*-axis 'Temperature (°C)'.

◇	A	B
1	Time (min)	Temperature (°C)
2	0	12
3	1	23
4	2	33
5	3	44
6	4	53
7	5	63
8	6	72
9	7	82
10	8	90
11	9	95
12	10	98
13		

10. Use the graph provided to answer the following questions.
    a. For how long did the experiment run?
    b. What was the temperature of the water when the experiment began?
    c. How long did it take for the water to boil?
    d. How many readings were taken?
    e. What would you expect the graph to look like after 10 minutes?
    f. How would you expect the graph to change if only 50 mL of water was heated?
    g. Sketch a graph of what the predicted results would be for a 200 mL beaker of water. Perform the experiment to check your predictions.



11. a. Collect the following data for each student in your class.
       i. First name
       ii. Gender
       iii. Foot length (cm)
       iv. Height (cm)
       v. Favourite subject
       vi. Country where mother was born
    b. Enter the data you collected into a spreadsheet.
    c. Click on the Insert tab, then use the Chart function button to construct a scatter graph (without joining points) showing foot length on the *x*-axis and height on the *y*-axis.
    d. Use your graph to decide whether there is a relationship between foot length and height.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
1.15 SkillBuilder — From observation to conclusion

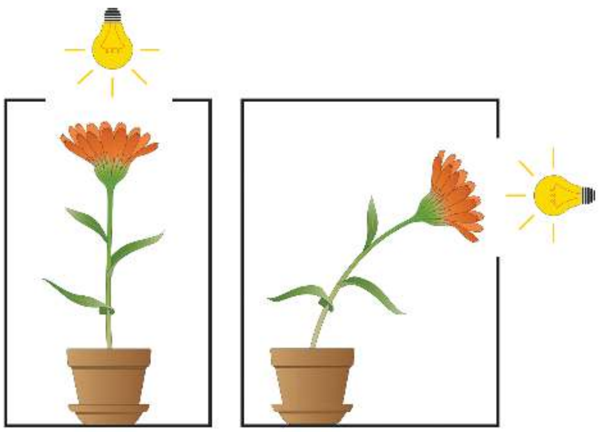
LEARNING INTENTION

At the end of this lesson you will be able to write conclusions from observations.

online only

How do I draw a conclusion from my observations?

An investigation conclusion is a brief account of what you found out and how your findings relate to your aim. It is a good idea to read your aim again before you write your conclusion.



Go online to access:
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- **Show me:** a video and a step-by-step process to explain the skill
- **Let me do it:** an interactivity, question set and SkillBuilder activity for you to practice and consolidate your understanding of the skill

on Resources

eWorkbook	SkillBuilder — From observation to conclusion (ewbk-11045)
Video eLesson	From observation to conclusion (eles-4160)
Interactivity	From observation to conclusion (int-8094)

LESSON
1.16 Extended investigation

LEARNING INTENTION

At the end of this lesson you will be able to perform an extended controlled experiment and prepare a formal report.

1.16.1 Think like a scientist

Being able to design an investigation takes time, planning and care. There are many different ways you can design and conduct an investigation.

The following sections outline how an investigation exploring the growth of bean plants is designed, conducted and analysed. This shows the process of thinking like a scientist and shows you how to apply the concepts learned in earlier lessons. You may use this to help you design your own investigations.

1.16.2 Planning your investigation

In planning your investigation, you need to ask yourself some key questions.

FIGURE 1.33 You should aim to have multiple experimental groups.

What is your research question?

What do you want to find out?

Answering these questions will help you to answer the next questions concerning which variable you will deliberately change (independent variable), which you will measure (dependent variable) and which you will keep the same or constant (controlled variables).

What is the one thing you are going to change?

In designing your investigation you should change only *one* variable at a time. The variable that you deliberately change is called the independent variable.

What thing are you going to measure?

The variable that you measure is called the dependent variable.

What other variables are there to keep the same? How can you keep them the same?

It is important to keep the variables that you are *not* investigating the same. These are called controlled variables. This increases the chance that it is the variable you are changing that is causing the effect you are measuring, rather than some other variable.

How can you make sure that the investigation is fair and not a 'fluke' or mistake?

A control enables you to see whether the independent variable has an effect on the dependent variable and provides a baseline for comparison. A large **sample size** and repeating the investigation decreases the chance that your findings were a fluke or due to a **human error**. It also helps to reduce the effects of individual variations that may occur in your data.

sample size the number of repeated observations in an experiment

human error mistakes made by the person performing the investigation

What is your prediction of the answer to your research question?

A hypothesis is an educated guess or prediction of what the results of an investigation may be. An example is 'that bean growth is faster when watered with tap water rather than salt water' or 'that bean germination decreases with increasing salt concentration'.

What materials and equipment do you need for your investigation?

Once you have decided on the variables in your investigation, you can write a list of what you will need to perform it. Include quantities and specific descriptions so that you remember to keep your controlled variables constant.

What are you going to do in your investigation? What steps are you going to follow?

By having your steps clearly outlined you could repeat the investigation in exactly the same way if you were to do it again. This is your procedure or method. Others could repeat it as well. If you make any changes to your plan when you are conducting your investigation, make sure you record them. If you are using bean seeds, remember to soak your bean seeds (10 seeds or more) in a dish of water overnight. There are some examples of set-ups for you to consider in figures 1.34 and 1.35.

FIGURE 1.34 Planting your seeds

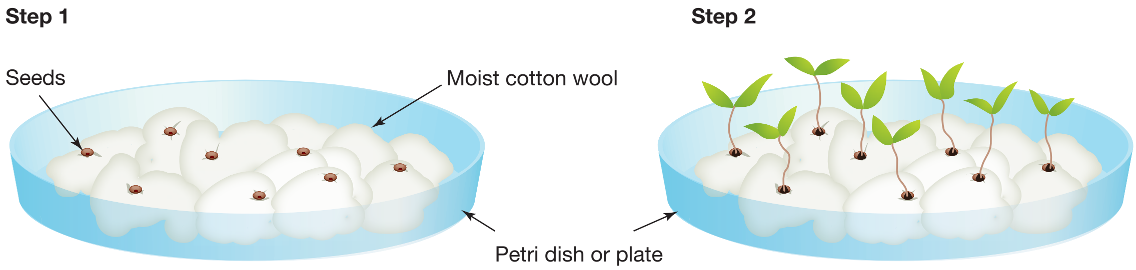
Step 1 | Step 2 | Step 3

Step 1: Press a hole about 2 cm deep into the potting mixture with a pencil, and place your seed in the hole.

Step 2: Label your container with your name, date and any information about your independent variable, for example, ‘salty water’, ‘red light’.

Step 3: Water your seeds, but take care not to overwater. Leave your seeds in a warm and sunny position.

FIGURE 1.35 Another way to set up your experiment



Step 1: Put some cotton wool in a Petri dish or plate. Add enough water to moisten the cottonwool. Place the pre-soaked seeds on top of the cottonwool.

Step 2: Water the seeds as required to keep the cotton wool moist, but do not overwater as mould will grow on the seeds.

What are you going to record and how are you going to record it?

In your procedure you should have outlined what you intended to measure and how you intended to measure and record it. The details that you record are your results or data. You may decide to record your results in a table similar to the one shown in table 1.5 or you may use a journal or diary to record observations as diagrams with descriptive labels and measurements.

TABLE 1.5 Sample table: Effect of salt water on the height of seedling

			Height of seedling (mm)												
			Tap water						Salt water						
Date	**Day**	**Action**	**A**	**B**	**C**	**D**	**E**	**Ave.**	**A**	**B**	**C**	**D**	**E**	**Ave.**	**Observations and diagrams**
5/3	10	Watered all plants at 3 pm; gave each plant 50 mL water	7.1	8.0	8.9	7.5	8.2	7.4	5.0	4.4	5.8	4.8	5.2	5.0	

Example of investigation planning

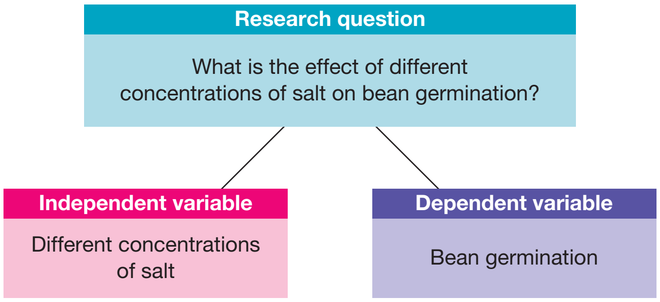
TABLE 1.6 Planning a practical investigation

Practical investigation planning	
Research question	What is the effect of different concentrations of salt on bean germination?
Variables	• **Independent variable:** different concentrations of salt • **Dependent variable:** bean germination • **Controlled variables:** types, ages and sizes of beans, type of salt, volume of solution added, temperature, intensity and colour of light.
Control and experimental groups	• **Control:** Set-up that had everything the same, but used water with no salt. This could be used as a baseline for control to see whether the addition of salt had an effect on bean germination. • **Sample size:** Using 10 bean seeds instead of one seed in each set-up and using class results to increase the number of times that the investigation was performed.

TABLE 1.7 Examples of variables that you may choose to investigate in an experiment on bean growth

Dependent variable	Independent variables (vary only one at a time)
Number of seeds germinated in a week	Salt concentration Volume of water added each day Amount of light (e.g. using different types of cloth to cover)
Time taken for seeds to germinate	Colour of light (e.g. red, green, blue or yellow cellophane covers) Different substances added to water (e.g. caffeine, sugar, salt or garlic)
Height of shoots each day	Type of growth medium (e.g. water, sand, soil, gravel or cottonwool)

FIGURE 1.36 Scientific design for investigations

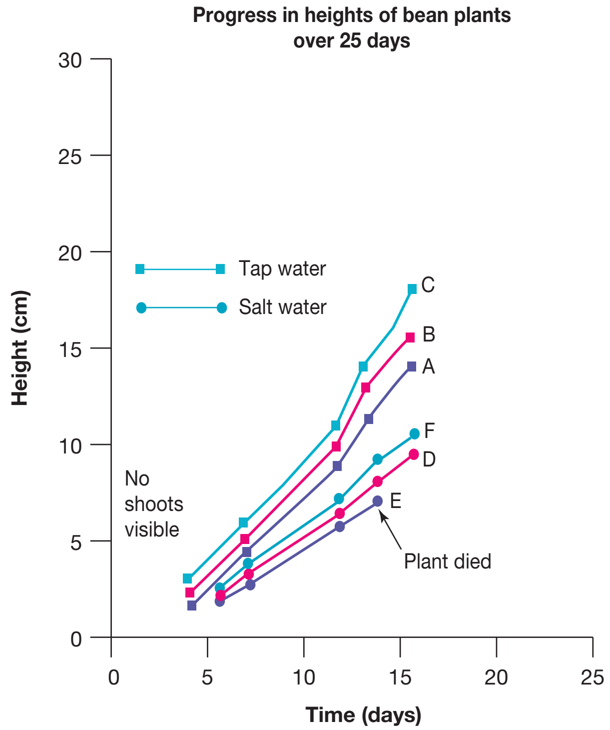


1.16.3 Reformatting your data

While your bean plants are growing, you can record their progress on a line graph such as the one in figure 1.37. This graph shows how the heights of two groups of plants change. If any of your plants die, your investigation is not a failure. You should, however, make a reasonable attempt to suggest why they died.

By changing the format of your data into graphs, it can help you see patterns. It will make it easier for you to make conclusions about your data.

FIGURE 1.37 Use a graph to record the progress of your plants. The independent variable is on the *x*-axis; the dependent variable is on the *y*-axis.



1.16.4 Writing your report

In reporting your investigation to others, you should use these headings listed below.

- **Aim:** you may include your **research question**
- **Hypothesis**: usually '*If … then* …' format
- **Materials**: the equipment and substances you use
- **Method**: the steps or procedure of your investigation
- **Results:** all of the data that you have collected including graphs, diagrams and tables
- **Discussion:** comments on patterns, relating your data to theory and what your results suggest
- **Conclusion:** relate your key findings to the purpose of your investigation

research question a question that is the focus of the investigation, which the experiment aims to answer

1.16 Activities

learnon

1.16 Quick quiz on

1.16 Exercise

Select your pathway

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

These questions are even better in jacPLUS!

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Remember and understand

1. In a graph, on which axis would you show the:
   a. independent variable
   b. dependent variable?

2. Complete the sentences in the table by matching the term to its meaning.

Term	Meaning
a. Independent variable …	A. is used to see whether the independent variable had an effect on the dependent variable. It provides a baseline for comparison.
b Dependent variable …	B is an educated guess or prediction of what the results of the investigation may be.
c Controlled variables …	C is the variable that you measure.
d Control …	D are variables that you keep the same or constant.
e Hypothesis …	E is a variable that you deliberately change.

3. In the research question 'What is the effect of different coloured light on pea germination?', identify the:
   a. independent variable
   b. dependent variable
   c. controlled variables
   d. control
   e. sample size.

Apply and analyse

4. In the table shown, five bean plants are watered with each type of water. Explain why this is better than testing just one plant with each type of water.

TABLE Progress in heights of bean plants

			Height of seedling (mm)												
			Tap water						Salt water						
Date	Day	Action	A	B	C	D	E	Ave.	A	B	C	D	E	Ave.	Observations and diagrams
5/3	10	Watered all plants with 50 mL of water at 3 pm	7.1	8.0	8.9	7.5	8.2		5.0	4.4	5.8	4.8	5.2		

5. Genevieve is investigating the effect of shadecloth on the growth of bean plants at home. She places three plants under the pergola at the back of her house, which is covered with shadecloth. She places the other three against the wall at the front of the house. All plants are in the same size pots and are given the same amount of water. Describe how Genevieve could improve her experimental design.
6. Cameron is trying to find out whether sand or garden soil is better for growing radishes. He also wants to find out if sugar added to the water that is given to plants makes a difference. Cameron plants three seeds in sand and three seeds in garden soil. The plants growing in sand are watered with tap water. The plants growing in garden soil are given the same amount of a mixture of sugar and water.
   a. What two questions is Cameron trying to answer with his experiment?
   b. Identify the major problem with Cameron's experimental design.
   c. Is it possible for Cameron to design a better experiment to answer both of his questions with only six seeds? Explain how.
7. Summarise what you know about scientific method and show this as a mind map or another visual map.

Evaluate and create

8. Propose how a plant would grow in a fully enclosed container with a hole in one side. Design an experiment that would allow you to find this out.
9. Can a plant grow without soil? Design an experiment that would allow you to find this out.
10. Research and explain hydroponic method of growing plants and how it might be useful for the future.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
1.17 Project — Bigger, better beans

Scenario

The local agricultural show will be running its annual competition to find the biggest bean plant and you are determined that this year you are going to win. In previous years, you have just planted your seeds in their pots, added some fertiliser, put them in the Sun and watered them every day but, while the plants did grow, they didn't grow big enough to have a chance at the prize. As a good science student, you know that the growth of plants depends upon the process of photosynthesis, whereby light energy from the Sun causes water and nutrients and carbon dioxide to be combined by the plant to produce oxygen and starch (which is a form of chemical potential energy). The plant then uses this starch to grow. So, if the growth of the plants depends upon how much starch is produced, maybe there's something you could do to the plants that would make them produce more starch and grow faster and bigger?

FIGURE 1.38 We can test different growth conditions of plants and measure the results.

Your task

You will design and carry out an investigation that will test a number of different growth conditions (for example, different amounts of sunlight or different substances added to the soil) to determine which will give the greatest rate of growth over a three-week period of time. Use lesson 1.16 to assist you in designing your investigation. Your findings will be presented in the form of a scientific report. At the end of this investigation analyse your method and suggest any improvements that can be made.

FIGURE 1.39 There are many ways you can conduct your investigation.

on Resources

ProjectPLUS Bigger, better beans (pro-0091)

LESSON
1.18 Review

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Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-11055	ewbk-11057	ewbk-11059

1.18.1 Summary

Branches of science

- The main branches of science are astronomy, biology, chemistry, geology, physics and psychology.

The science laboratory

- To measure the volume of liquids, look at the reading from the middle flat section of the meniscus, the curved boundary a liquid makes at its surface.
- When scales are read from an angle, not level with the eye, the reading is not accurate. This type of reading error is called parallax error.
- A Bunsen burner provides heat when a mixture of air and gas is lit. Bunsen burners heat objects or liquids with a blue flame. A yellow flame, or safety flame, is not as hot as the blue flame.
- To reduce the risk to yourself and others in the laboratory, follow your teacher's instructions, point test tubes away from eyes and wear safety equipment.
- Some dangerous chemicals could be corrosive like acid, flammable like methylated spirits or toxic like mercury.

Scientific inquiry

- An inference is a suggested logical explanation for an event or occurrence.
- A hypothesis is a testable statement from an observation — usually written in an *If ... then ...* format — that acts as a prediction for the investigation.
- A conclusion is what was found out in an investigation. It is a general statement that sums up a number of observations or the results of an experiment. The conclusion of an experiment relates to the stated aim.

Controlled investigations

- The independent variable is the variable that the scientist changes to observe its effect on another variable.
- The dependent variable is a variable that is expected to change when the independent variable is changed. The dependent variable is observed or measured during the experiment.
- Fair tests are tests that change only one variable and and control all other variables when attempting to answer a scientific question.
- In a controlled investigation, everything is the same as the test set-up except the variable.
- Measurements should be repeated a number of times and an average calculated.

Analysing data

- A pie chart is a diagram using sectors of a circle to compare the size of parts making up the whole; also called a sector graph.
- A bar chart or column graph is a diagram using the lengths of rectangles (bars) to show the size of the same property for different objects or at different times.
- Histograms are similar to column graphs except that the columns touch each other because the data are continuous and grouped.

Reporting on investigations

- A scientific report should contain an aim, usually a hypothesis, materials, method, results, discussion and a conclusion.
- A scientific drawing is a flat version of the equipment used in an investigation.

1.18.2 Key terms

accurate describes a measurement that is close to the true value
acoustics the study of sound and how the design of a room or theatre affects what is heard
aim a statement outlining the purpose of an investigation
bar chart a diagram using the lengths of rectangles (bars) to show the size of the same property for different objects or at different times
beaker container for mixing or heating substances
biochemist a scientist who studies the composition and interaction of substances in living things
biomechanics the study of how animals, including humans, move
biophysicist a scientist who studies the forces, energy and electrical processes in living things
botany the study of plants
categorical data related to categories or non-numerical values; also known as qualitative
column graph *see* bar chart
conclusion a general statement that sums up the observations or results of an experiment
continuous numerical data that can be measured and be any value in a range, including decimals
control group a group that is not affected by the independent variables and is used for comparison
controlled a parallel experiment where everything is the same as the test set-up except the variable
corrosive describes a chemical that wears away the surface of substances, especially metals
data observations or measurements made and recorded during an investigation
dependent variable a variable that is observed or measured during the experiment
discrete numerical data that can be counted and can only be certain values
discussion detailed area of a scientific report that explains the results and how they link back to the relevant concepts. It also includes suggestions for improvements to the experiment.
entomology the study of insects
experimental group test group that is exposed to the independent variable
fair test a test that changes only *one* variable and controls all other variables when attempting to answer a scientific question
falsifiable able to be proven false
filter funnel used with filter paper to separate solids from liquids
flammable substances such as methylated spirits that burn easily
forensic psychology a branch of psychology dealing with the law
histogram a graph with equal intervals marked on the x-axis for the values of a quantity, and frequency of occurrence of each value shown by the height of adjoining columns
human error mistakes made by the person performing the investigation
hypothesis a testable statement from an observation, usually written in *if … then* … format, that acts as a prediction for the investigation
independent variable the variable that the scientist changes to observe its effect on another variable
inference a suggested logical explanation for an event or occurrence
line graph a graph made by plotting pairs of data as points and joining the points together
measuring cylinder container used to measure volumes of liquids accurately
meniscus the curve seen at the top of a liquid, when in contact with a surface, specifically within a tube

microbiology the study of microorganisms, living things too small to see without a microscope
numerical data related to numbers; also known as quantitative
observations information obtained by the use of our senses or measuring instruments
palaeontology the study of fossils
parallax error a reading error in which, when scales are read from a different angle, the reading is not accurate
pharmacology the study of the effect of drugs on living things
pie chart a diagram using sectors of a circle to compare the size of parts making up the whole; also called a sector graph
radiochemistry the study of radioactive substances
research question a question that is the focus of the investigation, which the experiment aims to answer
results the details or data that are recorded from the outcome of an investigation
safety glasses plastic glasses used to protect the eyes during experiments
sample size the number of repeated observations in an experiment
scientific method the process of making an observation, developing a hypothesis and testing this through scientific investigation
sector graph *see* pie chart
seismology the study of earthquakes
sports psychology the study of how athletes train their minds to help improve sporting prowess
STEM acronym: stands for the disciplines of science, technology, engineering and mathematics
technology the application of science to the design of a device or process
test tube thin glass container for holding, heating or mixing small amounts of substances
testable able to be supported or proven false through the use of observations and investigation
thermometer a device which measures temperature
variables quantities or conditions in an experiment that can change
vulcanology the study of volcanoes
***x*-axis** the horizontal axis on a graph
***y*-axis** the vertical axis on a graph
zoology the study of animals

on Resources

eWorkbooks	Study checklist (ewbk-11048) Reflection (ewbk-11047) Literacy builder (ewbk-11049) Crossword (ewbk-11051) Word search (ewbk-11053)
Digital document	Key terms glossary (doc-39619)
Practical investigation eLogbook	Topic 1 Practical investigation eLogbook (elog-1975)

1.18 Activities

learnon

1.18 Review questions

Select your pathway

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

Remember and understand

1. Match the following scientists with their work.

Scientist	Work
a. Physicist	**A.** Investigates how rocks and mountains form
b. Chemist	**B.** Studies living things
c. Biologist	**C.** Explains things like movement, heat and light
d. Astronomer	**D.** Studies how substances react with others
e. Earth scientist	**E.** Studies the sky

2. Complete the table, by stating what each of the following scientists study.

Scientist	Studies
a. Seismologist	
b. Biochemist	
c. Entomologist	
d. Botanist	
e. Zoologist	
f. Vulcanologist	

3. Explain which of the scientists listed in question 2 could be correctly described as geologists.

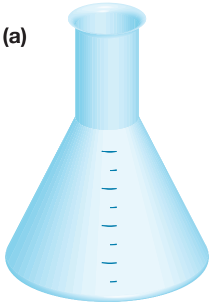
4. Indicate whether each of the following actions is a 'do' or a 'don't' in the science laboratory.

Action	'Do' or a 'don't'
a. Wear safety glasses while mixing chemicals.	
b. Pour all substances down the sink when finished with them.	
c. Run in the science laboratory.	
d. Drink water from the taps in the science laboratory.	
e. Tie long hair back before using a Bunsen burner.	
f. Wait until the end of the lesson to tell your teacher that you have burnt yourself.	

5. Write a list of all of the equipment that you would need to boil water in a beaker in your science laboratory. Draw a labelled scientific diagram to show the equipment in use.

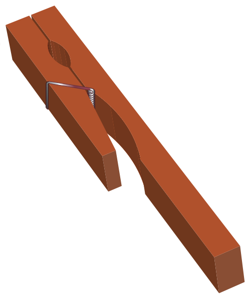
6. Rewrite the following sentences correctly by selecting the appropriate words in *italics*.
   a. When lighting a Bunsen burner, light the match *before/immediately after* turning on the gas.
   b. When using a thermometer to measure the temperature of a liquid as it is heated, place the bulb of the thermometer on the *bottom/near the centre* of the beaker.
   c. When heating a test tube, hold the test tube using *tongs/a test tube holder* at the *top/middle* of the test tube and *keep it steady/move it back and forth* over the flame.
7. Name each item of equipment.

(a)

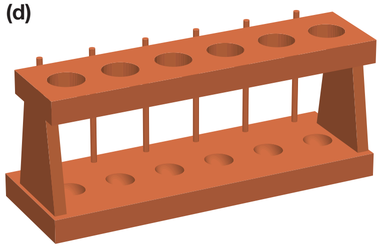


(b)

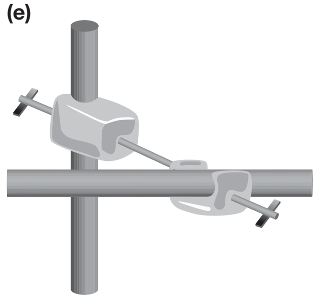
(c)



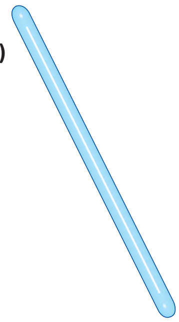
(d)



(e)



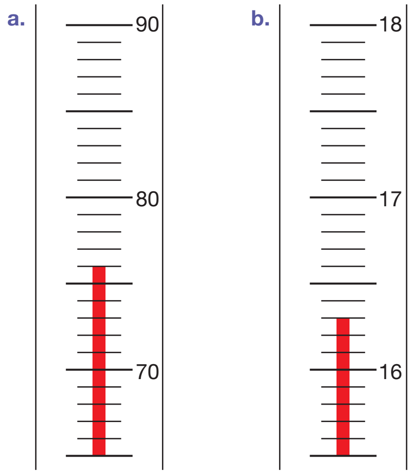
(f)



Apply and analyse

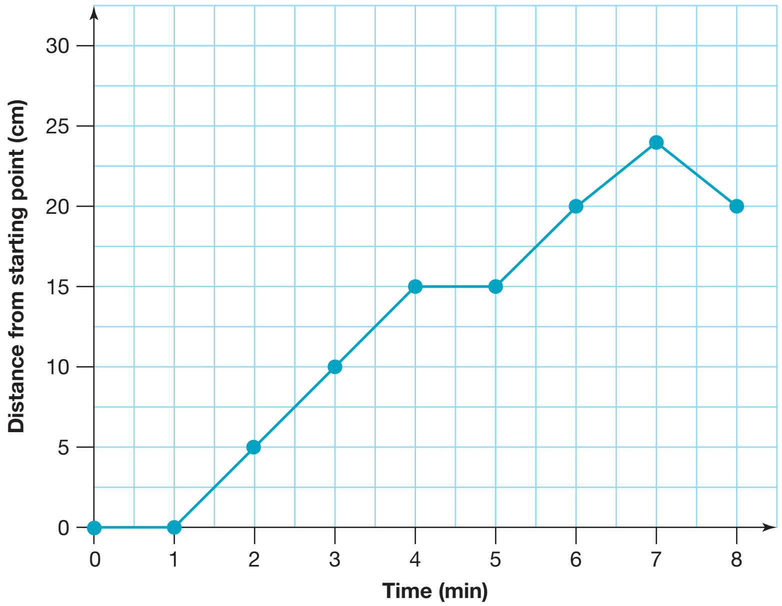
8. **MC** Identify which of the following is an important safety rule in science.
   A. When smelling chemicals, place your nose carefully over the container.
   B. Dispose of all materials in the rubbish bin.
   C. When reading the volume of a liquid, always read the bottom of the meniscus.
   D. Point test tubes away from your eyes and away from your fellow students.
9. **MC** Which equipment is used for measuring the volume of liquids?
   A. Conical flask, beaker, measuring cylinder
   B. Measuring cylinder, crucible, beaker
   C. Watchglass, filter funnel, conical flask
   D. Evaporating basin, test tube, beaker
10. Kimberley and Glenn were walking past their neighbour's house when they noticed that a front window was broken. Glenn told Kimberley that somebody had probably thrown a ball through the window. They had a closer look and noticed clothes scattered all over the floor and drawers open. Kimberley noticed some blood on the broken glass. She told Glenn that the house had been burgled. Glenn agreed and they called the police.
    a. What were the observations that were made?
    b. Who made an inference? What was the inference and why was it suggested?
    c. What conclusion was reached by Kimberley and Glenn?
    d. Suggest a different conclusion based on the observations that were made.
11. What item of equipment would you use to measure:
    a. the temperature of hot water
    b. the mass of a small beaker of water
    c. the volume of a small quantity of water?

12. Study the thermometers and identify the temperatures shown.



Evaluate and create

13. The graph shows how far from the starting point a snail moves in an experiment.



a. Calculate how far from the starting point the snail was 7 minutes after timing began.
b. During what times did the snail not move at all?
c. What does the graph tell us about the snail's movement between 7 and 8 minutes after timing began?
d. Propose why a smooth line was not drawn in this graph.

14. Huang and Tina conducted an investigation to find out whether radish plants grow better in the shade. They placed three seedlings under a verandah at the back of the house and another three in a sunny place in the front yard. All plants were planted in the same soil and were watered equally each day. Huang and Tina measured the height of each plant and the number of healthy leaves at the same time every second day.

a. What was the independent variable in the investigation?
b. What were the dependent variables?
c. List the variables that should have been controlled.
d. How could Huang and Tina improve the design of their experiment? List as many improvements as possible.
e. In your opinion, did Huang and Tina conduct a fair test? Give reasons for your opinion.

Fully worked solutions and sample responses are available in your digital formats.

Online Resources

on Resources

Below is a full list of **rich resources** available online for this this topic. These resources are designed to bring ideas to life, to promote deep and lasting learning and to support the different learning needs of each individual.

1.1 Overview

eWorkbooks
- Topic 1 eWorkbook (ewbk-11006)
- Student learning matrix (ewbk-11010)
- Starter activity (ewbk-11008)

Practical investigation eLogbook
- Topic 1 Practical investigation eLogbook (elog-1975)

Video eLesson
- Career spotlight: scientist (eles-0053)

1.2 Branches of science

eWorkbook
- Exploring the branches of science (ewbk-11011)

Interactivities
- How science helps improve performance (int-7130)
- The disciples of science (int-5609)

1.3 The science laboratory

eWorkbooks
- The science laboratory (ewbk-11013)
- Labelling a Bunsen burner (ewbk-11017)
- Labelling the equipment used to heat substances (ewbk-11019)
- Playing it safe (ewbk-11015)

Practical investigation eLogbook
- Investigation 1.1 Which flame is hotter? (elog-0482)
- Investigation 1.2 Where is the hottest part of the flame? (elog-0484)
- Investigation 1.3 Heating a substance in a test tube (elog-0486)

Video eLessons
- Science safety rules (eles-2245)
- How to light a Bunsen burner (eles-2360)

Interactivities
- Measuring and reading scales (int-0201)
- What's my use? (int-3414)
- Labelling a Bunsen burner (int-8166)
- Labelling the equipment used to heat substances (int-8167)
- Danger in the laboratory (int-3415)

1.4 SkillBuilder — Measuring and reading scales

eWorkbook
- SkillBuilder — Measuring and reading scales (ewbk-11021)

Video eLesson
- Measuring and reading scales (eles-4153)

Interactivity
- Measuring and reading scales (int-0201)

1.5 SkillBuilder — Using a Bunsen burner

eWorkbook
- SkillBuilder — Using a Bunsen burner (ewbk-11023)

Video eLesson
- Using a Bunsen burner (eles-4154)

Interactivity
- Using a Bunsen burner (int-8088)

1.6 Scientific inquiry

eWorkbook
- Observing and recording (ewbk-11025)

Practical investigation eLogbook
- Investigation 1.4 Are you a good observer? (elog-0488)

1.7 SkillBuilder — Writing an aim and forming a hypothesis

eWorkbook
- SkillBuilder — Writing an aim and forming a hypothesis (ewbk-11027)

Video eLesson
- Writing an aim and forming a hypothesis (eles-4155)

Interactivity
- Writing an aim and forming a hypothesis (int-8089)

1.8 Controlled investigations

eWorkbook
- Developing a fair test (ewbk-11029)

Practical investigation eLogbook
- Investigation 1.5 Which ball bounces the highest? (elog-0490)

1.9 SkillBuilder — Controlled, dependent and independent variables

eWorkbook
- SkillBuilder — Controlled, dependent and independent variables (ewbk-11031)

Video eLesson
- Controlled, dependent and independent variables (eles-4156)

Interactivity
- Controlled, dependent and independent variables (int-8090)

1.10 Analysing data

eWorkbook
- Selecting and constructing graphs (ewbk-11033)

1.11 SkillBuilder — Constructing a pie chart

eWorkbook
- SkillBuilder — Constructing a pie graph (ewbk-11035)

Video eLesson
- Constructing a pie graph (eles-1632)

Interactivity
- Constructing a pie graph (int-3128)

1.12 SkillBuilder — Creating a simple column or bar graph

eWorkbook
- SkillBuilder — Creating a simple column or bar graph (ewbk-11037)

Video eLesson
- Creating a simple column or bar graph (eles-1639)

Interactivity
- Creating a simple column graph (int-3135)

1.13 SkillBuilder — Drawing a line graph

eWorkbook
- SkillBuilder — Drawing a line graph (ewbk-11039)

Video eLesson
- Drawing a line graph (eles-1635)

Interactivity
- Drawing a line graph (int-3131)

1.14 Reporting on investigations

eWorkbooks
- Scientific reports (ewbk-11041)
- Designing an experiment (ewbk-11043)

Teacher-led video
- Investigation 1.7: Graphing temperature (tlvd-10652)

Practical investigation eLogbook
- Investigation 1.6 Recording observations in a table (elog-0492)
- Investigation 1.7 Graphing temperature (elog-0494)

Digital document
- Scientific report checklist (doc-34910)

1.15 SkillBuilder — From observation to conclusion

eWorkbooks
- SkillBuilder — From observation to conclusion (ewbk-11045)

Video eLesson
- From observation to conclusion (eles-4160)

Interactivity
- From observation to conclusion (int-8094)

1.17 Project — Bigger, better beans

ProjectPLUS
- Bigger, better beans (pro-0091)

1.18 Review

eWorkbooks
- Topic review Level 1 (ewbk-11055)
- Topic review Level 2 (ewbk-11057)
- Topic review Level 3 (ewbk-11059)
- Study checklist (ewbk-11048)
- Word search (ewbk-11053)
- Literacy builder (ewbk-11049)
- Crossword (ewbk-4649)
- Reflection (ewbk-11047)

Digital document
- Key terms glossary (doc-39619)

To access these online resources, log on to **www.jacplus.com.au**

SkillBuilder — Measuring and reading scales

1.4.1 Tell me

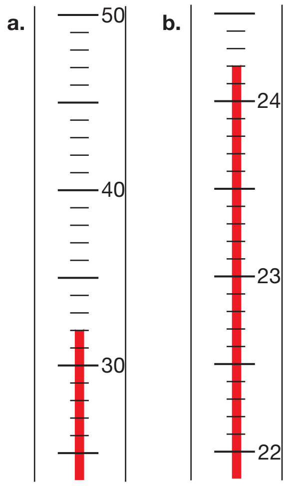
Why do we need to measure and read scales?

When conducting experiments, it is critical that measurements and data are recorded accurately. Whether measuring volume or temperature, or interpreting alternate scales, it is important that they are recorded accurately.

What is the application of measuring and reading scales in science?

In science applications, measuring and reading scales are used to observe and record many variables including volumes of liquids or gas, mass, length and temperature. It is important that scales are used correctly to reduce random errors and ensure that the data obtained is accurate, in order to obtain valid conclusions.

FIGURE 1 The temperatures measured by thermometers A and B are 32 °C and 24.2 °C, respectively.



1.4.2 Show me

How do we measure and read scales?

Materials

- thermometer with a liquid column (alcohol or mercury)
- 250 mL measuring cylinder or burette

Method

Step 1

A thermometer with a liquid column should have markings on its scale. Find the top of the measuring column and position your eye so that it is level with the top of the column. This will avoid any parallax errors in reading the temperature. Read the number on the largest scale division below the top of the column.

Step 2

Read the number on the largest scale division above the top of the column and count how many scale divisions there are between the lower and higher scale divisions. Divide the number of divisions into the temperature difference between the upper and lower scale divisions. This will give you the amount each scale division is worth. Count up from the lower scale division and read the correct temperature. If the column is in the middle of two divisions, the reading will be half a scale division above the lower reading.

Step 3
Liquids in containers such as measuring cylinders often have a curved surface at the top edge. The curve is called a meniscus. The edges of the meniscus may curve up or down. Locate the middle flat section of the meniscus and position your eye so it is level with it.

Step 4
Using the procedure in Step 2, read the volume of the middle flat section of the meniscus.

on Resources

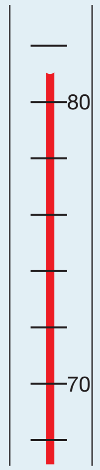
eWorkbook	SkillBuilder — Measuring and reading scales (ewbk-11021)
Video eLesson	Measuring and reading scales (eles-4153)
Interactivity	Reading scales (int-0201)

1.4.3 Let me do it

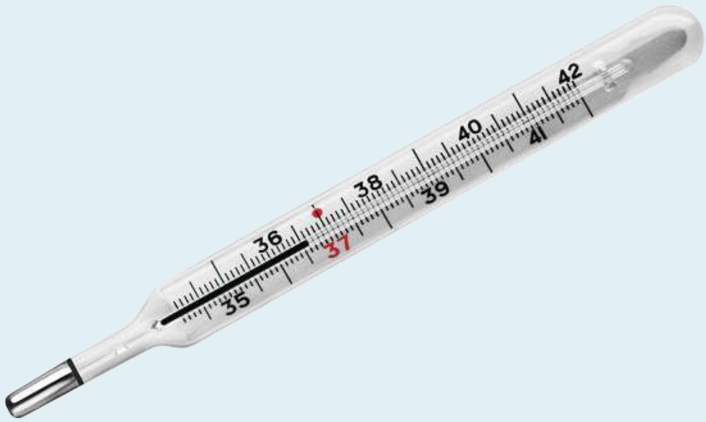
Complete the following activities to practise this skill.

1.4 ACTIVITIES

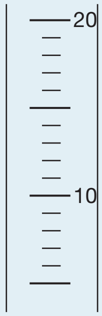
1. The diagram shows a portion of a thermometer measuring a temperature in degrees Celsius. Answer the questions that follow.



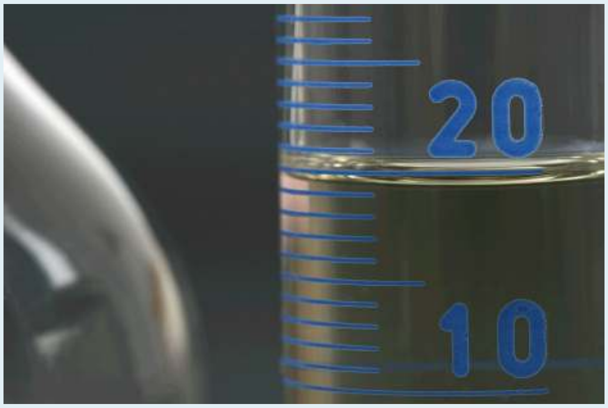
   a. i. Write the value of the lower scale marker.
      ii. Write the value of the higher scale marker.
      iii. Calculate the value of each scale division.
      iv. What is the reading of the red column of the thermometer?
2. Human body temperature is normally 37 ˚C. If a person is said to be running a temperature, they may be suffering an illness. The thermometer below shows the temperature of a patient. Write the temperature that is shown.



3. The diagram that follows represents a section of an alcohol thermometer. Colour in the centre strip to show a temperature of 14 °C.



4. a. MC The photo below shows a measuring cylinder containing some water. Read the scale to determine the volume of water in the measuring cylinder. Select which of the available options is the correct reading.



A. 19.5 mL B. 20.5 mL C. 21.0 mL D. 22.0 mL

b. Give an explanation of how you reached your answer.

Checklist

I have:

- p ositioned my eye parallel with the top of the column or the meniscus of the liquid that is to be measured
- noted the lower scale reading below the column or meniscus
- noted the upper scale reading above the column or meniscus
- calculated the scale divisions between the upper and lower scale divisions and used this to count up from the lower division to take the column reading.

SkillBuilder — Using a Bunsen burner

1.5.1 Tell me

Why use a Bunsen burner?

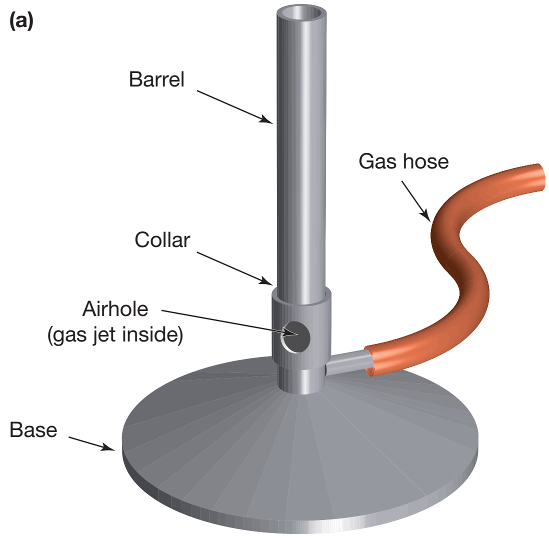
Many experiments in the laboratory require heating using a Bunsen burner. A Bunsen burner provides heat when a mixture of air and gas is lit. Although the same amount of gas comes out of the gas jet located inside the barrel, attached to the base of the burner, the amount of air and hence oxygen is able to be varied by changing the size of the airhole by rotating the collar. Bunsen burners heat objects or liquids with a naked flame, and therefore there are precautions that must be taken to ensure the safe usage of a Bunsen burner.

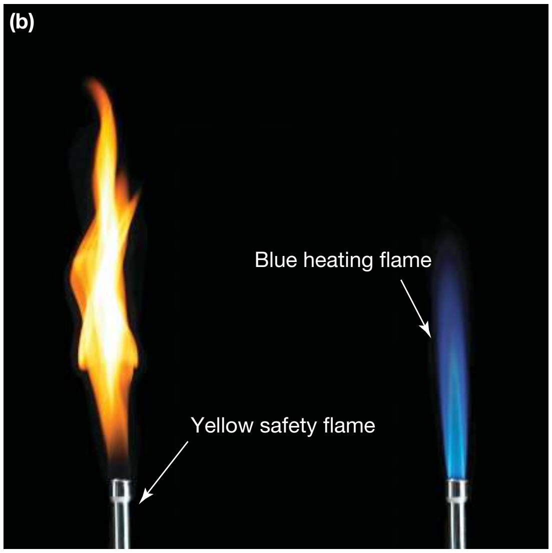
The Bunsen burner must be ignited using the yellow or safety flame, with the airhole closed, so that the flame can be seen. The blue flame of the Bunsen burner, seen when the airhole is open, is used for heating but it is difficult to see. Because the flame appears at the top of the Bunsen burner, the barrel can become hot and may cause burns to skin if touched. Do not handle the barrel; allow it to cool at the end of an experiment. Use the base of the Bunsen burner if the burner needs to be moved or handled; it is designed not be become hot.

What is the application of Bunsen burners in science?

Bunsen burners provide heat, the amount of which can be changed by adjusting the airhole on the collar. It is the ease of adjusting the path and intensity of the flame that makes the Bunsen burner so versatile and useful in the science laboratory. This allows liquids in test tubes to be heated evenly and without boiling over.

FIGURE 1 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.





1.5.2 Show me

How do we use a Bunsen burner?

Materials

- Bunsen burner
- matches or Bunsen burner lighter
- heatproof mat
- safety glasses
- lab coat

CAUTION

Ensure long hair is tied back and wear a lab coat and safety glasses.

Method

Step 1

Place the Bunsen burner on a heatproof mat.

Check that the gas tap is in the 'off' position.

Step 2

Connect the rubber hose to the gas tap.

Step 3

Close the airhole of the Bunsen burner collar.

Step 4

Light a match and hold it a few centimetres above the barrel.

Step 5

Turn on the gas tap and a yellow flame will appear.

Step 6

Adjust the flame by moving the collar until the airhole is open and a blue flame appears.

on Resources

eWorkbook SkillBuilder — Using a Bunsen burner (ewbk-11023)

Video eLesson Using a Bunsen burner (eles-4154)

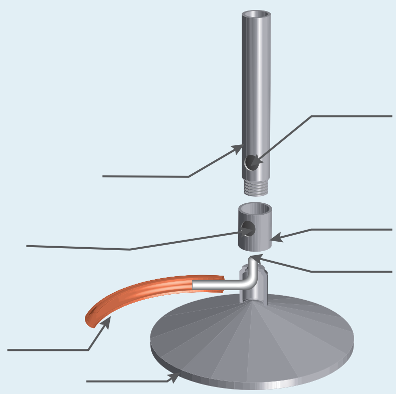
Interactivity Using a Bunsen burner (int-8088)

1.5.3 Let me do it

Complete the following activities to practise this skill.

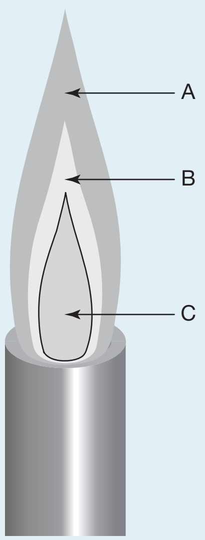
1.5 ACTIVITIES

1. The diagram of the Bunsen burner provided has the parts separated so you can see them clearly.



a. Name each of the parts of the Bunsen burner.
b. Describe the function of the third and fourth labels from the top and the effect on the flame.

2. a. Give two reasons why the blue flame can be hazardous.
   b. Why is the yellow flame also referred to as the 'safety flame'?
   c. Which is the hottest part of the flame in the diagram that follows, at label A, B, or C?



3. Identify if each of the following statements is true or false.
   a. Always wear safety glasses and a lab coat when using a Bunsen burner.
   b. If you have long hair, always tie it back when using a Bunsen burner.
   c. Always light the Bunsen burner with the airhole fully opened.
   d. Always light a match and hold it above the Bunsen burner barrel before turning on the gas tap.
   e. Always leave the Bunsen burner on the blue flame when you are not heating anything.
   f. Always leave the Bunsen burner on the blue heating flame when you are heating something.
   g. Always extinguish a Bunsen burner flame by turning off the gas tap.
   h. If the Bunsen burner goes out accidentally, turn the gas tap off immediately.

Checklist

I have:

- identified the main parts of the Bunsen burner
- tied long hair back, worn a lab coat and safety glasses
- identified that the yellow flame is used for lighting the Bunsen burner and the blue flame is used for heating
- allowed the Bunsen burner to cool before touching it after an experiment.

SkillBuilder — Writing an aim and forming a hypothesis

1.7.1 Tell me

Why do we need to write aims and form hypotheses?

In science, we conduct investigations to gather data and results and draw conclusions. Every investigation requires an aim — a short statement of what we are trying to achieve. Alongside an aim, the ability to formulate predictions is important in science. This is done through the use of a hypothesis. Being able to write aims and hypotheses are vital skills for any scientist.

What is the application of aims and hypotheses in science?

A hypothesis is an idea that is based on observation, which can be tested in an investigation by experiment or data. Investigations can involve testing, field work, using models or simulations, finding and using information for various sources and conducting surveys.

The aim is a question or a statement about the direction of the scientific investigation. It provides a purpose of the investigation.

A hypothesis is an educated prediction of the outcome of an investigation, which can be supported or unsupported through the results of an investigation.

1.7.2 Show me

How do we write aims and form hypotheses?

Materials

- an idea for an investigation that interests you such as finding out if the bushfood, warrigal greens (scientific name: *Tetragonia tetragonioides*) grows best from seeds or from cuttings. Warrigal greens are an indigenous crop to Australia and New Zealand; the leaves are a tasty alternative to spinach.

Method

Step 1

To write an aim, you need to first identify your independent and dependent variables. The independent variable is what you are changing: Using seeds or cuttings from warrigal greens.

The dependent variable is what you are examining: The growth of warrigal greens.

Step 2

It often helps to write your idea as a scientific question; for example, how are warrigal greens best grown?

Step 3

Use this to develop your aim. An aim usually is in one of two formats:

a. to ______________ **the independent variable** on **the dependent variable**
b. to ______________ if **the dependent variable** is affected by the **independent variable**.

For this investigation, some example aims may be:

- to compare the difference between the use of seeds and cuttings on the growth of warrigal greens
- to observe if the growth of warrigal greens is affected by the use of seeds or cuttings during planting
- to determine whether warrigal green seeds or warrigal green cuttings result in the greatest amount of plant growth.

Step 4

Refine your aim into a hypothesis, in this case written as an íf' and 'then' statement. This should again link your variables. For example, if the same number of warrigal seeds and cuttings are planted and the two crops compared after one month, then the cuttings will produce a greater weight of picked leaves.

Step 5

Check that your hypothesis is able to be tested or backed up by data. In this case the two crops of leaves can be weighed and compared.

on Resources

- **eWorkbook** SkillBuilder — Writing an aim and forming a hypothesis (ewbk-11027)
- **Video eLesson** Writing an aim and forming a hypothesis (eles-4155)
- **Interactivity** Writing an aim and forming a hypothesis (int-8089)

1.7.3 Let me do it

Complete the following activities to practise this skill.

1.7 ACTIVITIES

1. Decide if the statements below are true or false.
   a. The aim of an investigation starts with an idea or problem.
   b. The aim is written as an if–then statement.
   c. The hypothesis is written as a question.
   d. The hypothesis must be able to be tested by experiment results or data.
2. A student was interested in investigating how to grow the bushfood warrigal greens, using seeds, to produce a plentiful crop in the shortest amount of time. The student observed that some plant seeds germinate only when soaked in water or exposed to smoke.
   a. Write an aim for the student's investigation.
   b. From your aim, write a hypothesis for an investigation.
   c. Describe how your hypothesis could be tested.
3. a. Decide if each of the options below is written as an aim, a hypothesis or neither and then circle your choice.
      i. To determine how much rubbish is collected from my school in one day.
      ii. If the different colours of new cars purchased this year were calculated, then the most popular colour would be black.
      iii. Chocolate is the most popular snack food at my school.
      iv. If the temperature drops below five degrees Celsius for three days in a row then it will rain on the fourth day.
      v. To investigate how tall a wall mirror should be in order for me to see my full height (185 cm) from one metre away.
   b. For any of the options in part a, that is neither an aim nor a hypothesis, rewrite it as a possible hypothesis.

Checklist

I have:
- chosen an idea or problem that is not too general
- rewritten the idea as a question to form the aim
- developed my aim into a hypothesis in the form of an if–then statement
- checked to see if my hypothesis is able to be tested or backed up by data.

SkillBuilder — Controlled, dependent and independent variables

1.9.1 Tell me

What is the difference between controlled, dependent and independent variables?

In order to answer a question scientifically, a controlled investigation needs to be performed. In a controlled investigation every variable except the one being tested is held constant, which stops the results being affected by an uncontrolled factor. The variable that you are investigating is called the independent variable. The variable that you are measuring is called the dependent variable.

What is the application of variables in science?

In many branches of science research, questions are being asked such as what is the best way of doing this, how can this be done faster or more efficiently, how can we cure this disease? In order to answer complicated questions, investigations must be carried out that are well thought out and planned so that the results can be trusted and repeated.

When creating scientific questions, developing aims and formulating hypotheses, it is vital to know which variables are which. Understanding variables ensures that a fair test is created and your questions, aims and hypotheses are specific and targeted.

1.9.2 Show me

How do you identify and use controlled, dependent and independent variables?

Materials

- 2 thermometers or temperature probes
- 2 identical glasses or beakers
- ice-cube trays that make cube-shaped iceblocks
- ice-cube trays that make spherical-shaped iceblocks
- 1 L of water
- measuring cylinder

Method

Step 1

Determine which variable you are changing and testing in your investigation; this is the independent variable. In this investigation, the aim is to investigate which iceblock's shape is most successful at reducing the temperature of the water.

Therefore, the independent variable is the shape of the iceblocks.

Step 2

Determine which variable you are measuring in your investigation. In this case it is the temperature of the water.

Step 3

Ensure a fair test is created by making sure all other variables are controlled. Consider all the factors that need to be controlled: the amount of water, the volume of the iceblock, the initial temperature of the water, the number of iceblocks and the time.

Step 4

Conduct the investigation.

Determine the volume of water needed to fill the spherical ice-cube tray by filling it using the measuring cylinder and recording the volume.

Using the measuring cylinder, fill the cube-shaped ice-cube tray with the same volume of water as used to fill the spherical ice-cube tray. Freeze both trays overnight for the same amount of time.

Step 5
Fill each glass to half its volume with water using the measuring cylinder to ensure each glass has the same volume in it. Add the thermometer or temperature probe to each glass. At the same time, add two spherical iceblocks to one glass but ensure it does not overflow and add the same number of cube iceblocks to the other glass ensuring that the water does not overflow.

Step 6
Measure and record the temperature in each glass until it stops falling and starts to rise. Repeat the experiment using the remaining iceblocks.

on Resources

eWorkbook	SkillBuilder — Controlled, dependent and independent variables (ewbk-11031)
Video eLesson	Controlled, dependent and independent variables (eles-4156)
Interactivity	Controlled, dependent and independent variables (int-8090)

1.9.3 Let me do it

Complete the following activities to practise this skill.

1.9 ACTIVITIES

1. For the previous investigation:
   a. identify the independent variable
   b. identify the dependent variable
   c. identify three controlled variables.
2. The investigation can be used to determine which iceblock cools a drink to the lowest temperature.
   a. Describe how this could be done.
   b. What is the dependent variable in this case?
3. To investigate various ways of keeping cut flowers alive, several different substances were added to the water in three identical vases. The substances were 5 g of sugar, 5 g of salt and 5 g of vinegar. A fourth vase was set up using only water with nothing added. A bunch of flowers was divided up so that there were the same number of individual flowers in each of the four vases.
   a. Identify the independent variable.
   b. Identify the dependent variable.
   c. Which two variables are controlled?
   d. Why was one vase set up with only water in it?

Checklist
I have:
- identified the dependant variable
- identified the independent variable
- identified the controlled variables.

SkillBuilder — Constructing a pie chart

1.11.1 Tell me

What is a pie graph?

A pie chart, or pie graph, is a graph in which slices or segments represent the size of different parts that make up the whole. The size of the segments is easily seen and can be compared. Pie graphs give us an overall impression of data.

How are pie graphs useful?

Pie graphs give us an overall impression of data. They are useful for comparing proportions of categories. However, if there are more than eight segments, the graph becomes difficult to read and it is better to use a bar graph. Unlike line graphs, pie graphs are not useful for showing a trend over time.

A good pie graph:

- has a clear and accurate title that explains the purpose of the graph
- has segments that are either labelled directly or indicated by means of a colour key
- includes percentages or raw figures
- has segments drawn clockwise from largest to smallest, starting at 12 o'clock with the largest and finishing at 12 o'clock with the smallest, unless there is 'other', which is always last
- includes the source of the data.

What is the application of pie graphs in science?

Pie graphs are used in scientific applications when a quick and easily understood representation of data is required. Pie graphs are usually easily understood even if an understanding of the science behind the data is not understood, and so are effective in communicating results of discreet data that are part of a whole.

1.11.2 Show me

How to complete a pie graph

Materials

- paper
- a pencil
- a protractor
- a ruler
- coloured pencils
- a data set — in this case, energy generated from renewables in New Zealand (table 1)

Model

TABLE 1 Percentage of electricity generated from renewables in New Zealand by energy source (2010)

Renewable energy	Percentage (%)
Hydro	28
Bioenergy and solar	20
Wind	2
Geothermal	50

Note: In 2011, 77% of all electricity generated in New Zealand came from renewable resources.

Source: New Zealand Energy Data File 2012

Method

Step 1

Order the statistics from largest to smallest. If there is an 'other' category, put it last.

The largest amount of renewable energy is generated by geothermal so it is at the top of the table, as per the example that follows.

Renewable energy	Percentage (%)
Geothermal	50
Hydro	28
Bioenergy and solar	20
Wind	2

Step 2

If there are raw figures, convert them to percentages. You divide each category by the total figure and multiply by 100.

The categories are already percentages and add to 100%.

Step 3

Convert the percentage to degrees of a circle by multiplying by 3.6. (100 per cent of the circle = 360 degrees, so 1 per cent of the circle = 3.6 degrees.)

TABLE 2 Converting percentages to degrees in circle

Renewable energy	Percentage (%)	Degrees in circle (percentage × 3.6)
Geothermal	50	180
Hydro	28	100.8
Bioenergy and solar	20	72
Wind	2	7.2

Step 4

Using a protractor or digitally, construct a circle to fit your page. Draw a straight line from the centre of the circle to 12 o'clock.

Step 5

Use the protractor to mark the first and largest segment, working clockwise. To do this, place the 0 degrees line on the protractor along the line you have just drawn. Now mark in the second largest group. Use the protractor to mark each of the other segments in descending size, marking the 'other' category last.

Step 6

Label and colour each segment, making sure you include the percentage.

Step 7

Provide a clear title and source.

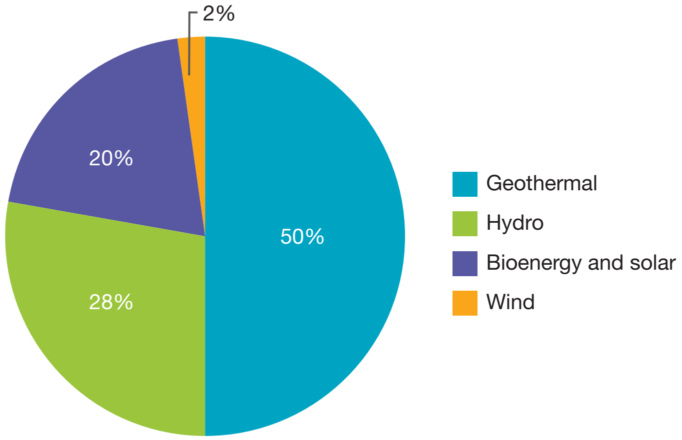
on Resources

eWorkbook SkillBuilder — Constructing a pie graph (ewbk-11035)

Video eLesson Constructing a pie graph (eles-1632)

Interactivity Constructing a pie graph (int-3128)

FIGURE 1 Percentage of electricity generated from renewables in New Zealand by energy source (2010)



Source: New Zealand Energy Data File 2012

1.11.3 Let me do it

Complete the following activities to practise this skill.

1.11 ACTIVITIES

1. Use the data in table 3 to create a pie graph. Use the checklist to ensure you cover all aspects of the task.

TABLE 3 Source of electricity worldwide, 2010

Source of electricity	Percentage (%)
Coal	42
Oil	5
Natural gas	21
Nuclear	13
Hydro	16
Other	3

2. Once you have created your pie graph, apply the skills you have developed in this SkillBuilder to answer the following questions.
   a. What is the most common source to produce electricity?
   b. Are renewables or non-renewables the main source of electricity?
   c. Name a renewable that is part of the 'other' category.
   d. In Iceland 70 per cent of all electricity is produced from hydropower and 30 per cent is produced from geothermal power. Is this similar to or different from the world trend?
   e. Research the sources of energy production for another country. Compare your results to Australia and Iceland.

Checklist

I have:
- provided a clear title and source
- plotted the data accurately and labelled each segment
- included the percentages
- shown largest to smallest clockwise from 12 o'clock with 'other' last.

SkillBuilder — Creating a simple column or bar graph

1.12.1 Tell me

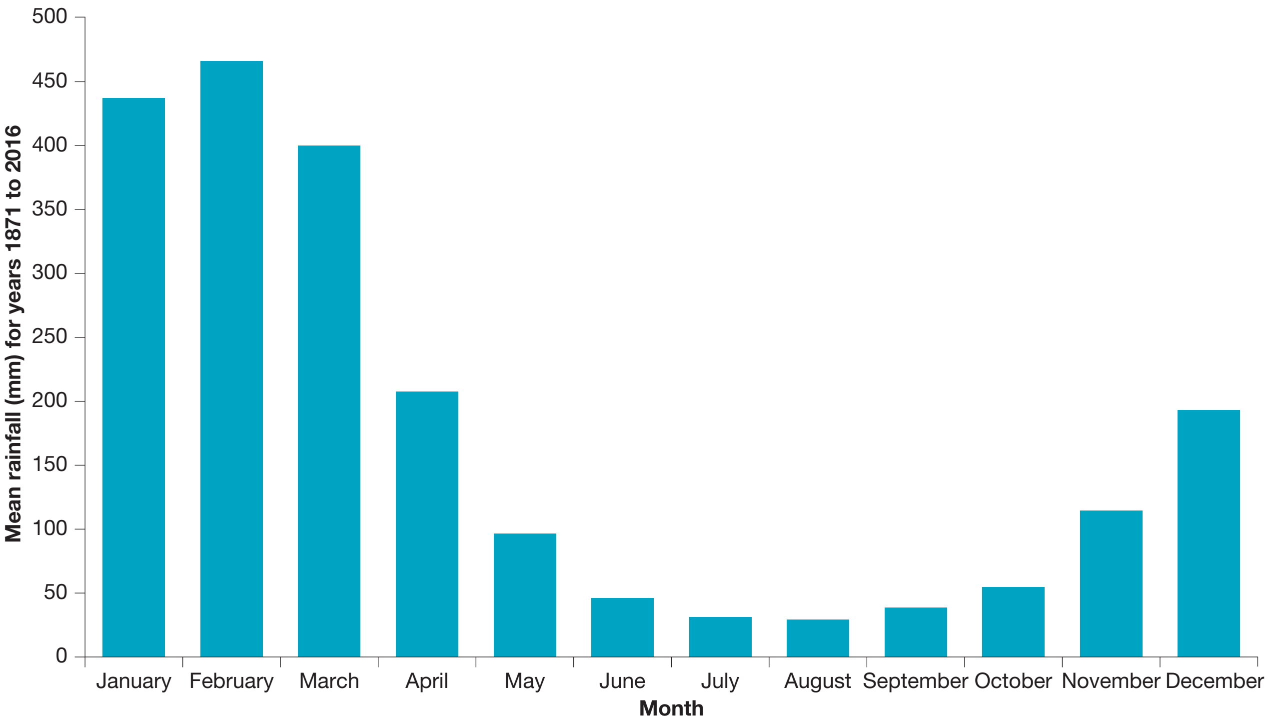
What are column or bar graphs?

Column graphs show information or data in columns. In a bar graph the bars are drawn horizontally and in column graphs they are drawn vertically. They can be hand drawn or constructed using computer spreadsheets.

How are column graphs useful?

Column graphs are useful for comparing quantities. They can help us understand and visualise data, see patterns and gain information. For example, we can use them to help understand rainfall patterns in different months (see figure 1).

FIGURE 1 Rainfall at Darwin Airport



Source: © Bureau of Meteorology

A good column graph has:

- ruled axes
- labelled axes
- a space between each column
- a title
- the source of information.

What is the application of column or bar graphs in science?

Column or bar graphs are useful to compare or investigate one or more numerical variables across different categories. There are different types of column or bar graphs including individual, clustered and stacked.

1.12.2 Show me

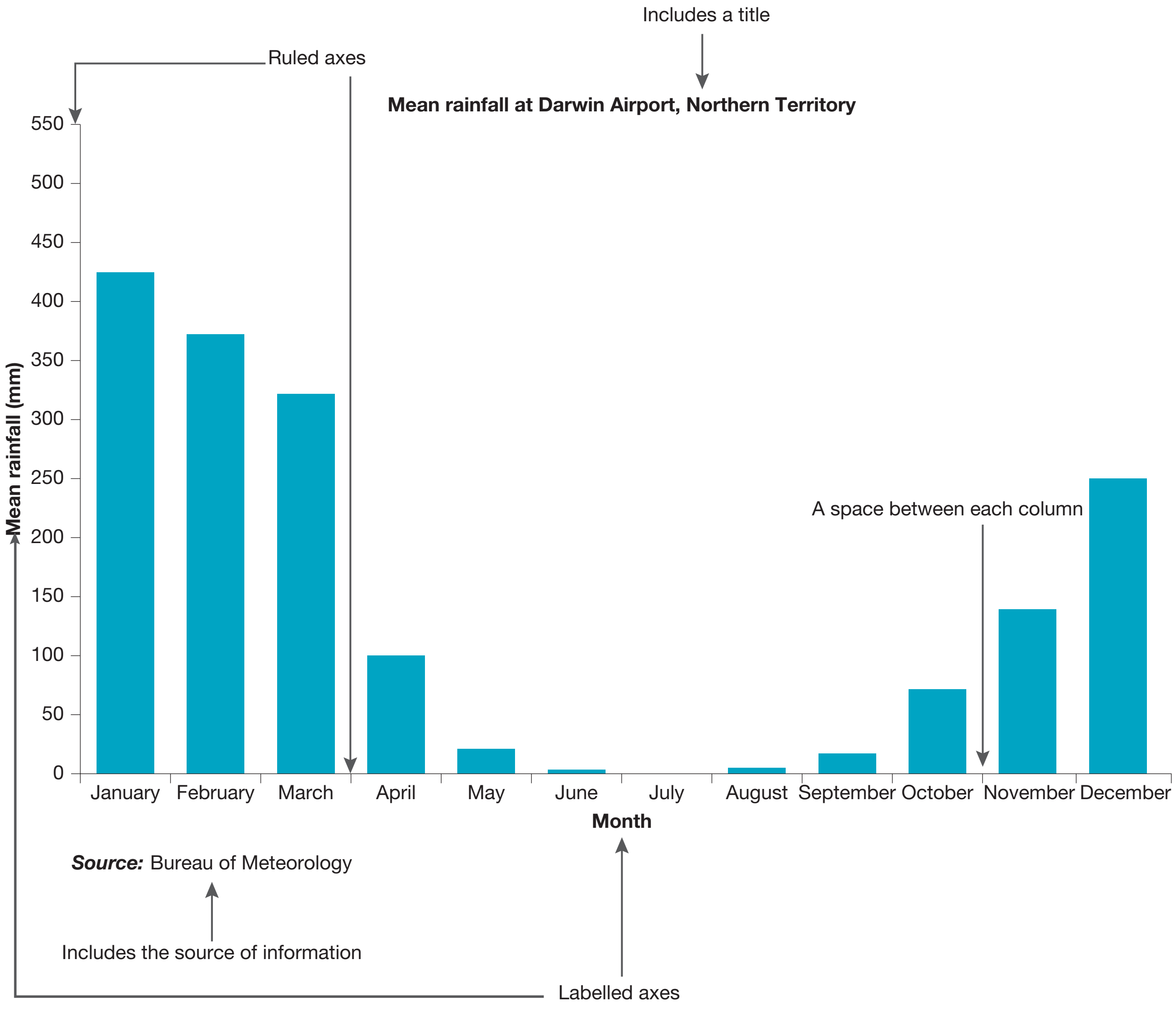
How to complete a column graph

Materials

- a table of data (table 1)
- graph paper
- a pencil
- a ruler.

Model

FIGURE 2 A labelled column graph



Method

Step 1

Examine the data. Decide on the scale to use for your vertical axis. For this example the vertical axis should start at zero and increase at intervals to suit the data. As the highest rainfall for any month for Cardwell is 465.9 mm, intervals of 50 would be suitable. For this exercise you could use 1 cm to represent 50 mm of rainfall. Draw your vertical axis according to the scale you have devised.

TABLE 1 Mean monthly rainfall for the years 1871 to 2016, Cardwell, Queensland

Statistics	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean rainfall (mm) for years 1871 to 2016	438.5	465.9	400	208.6	94.7	47	32.4	29.2	38.5	54.4	115.2	193.5

Source: © Bureau of Meteorology

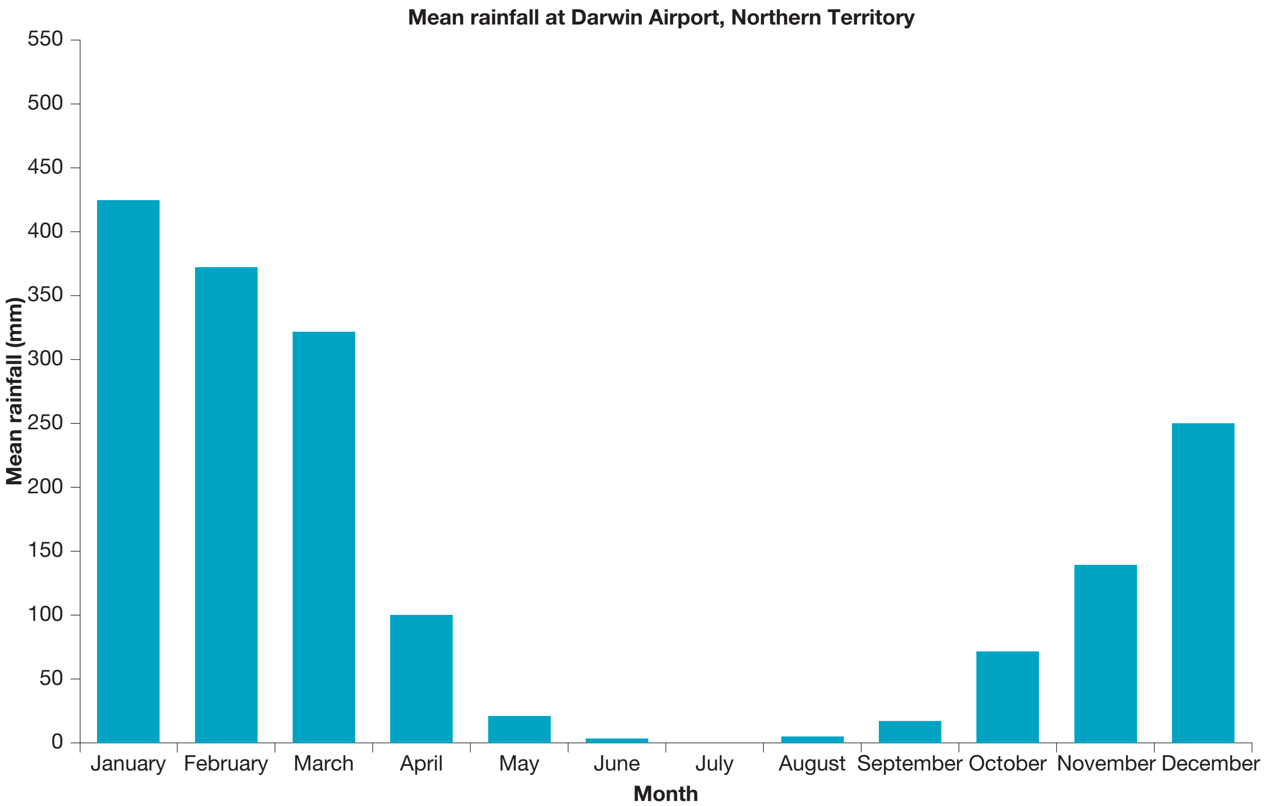
Step 2
Decide on the width and spacing of the columns and draw your horizontal axis to fit. Ensure that each column is the same width.

Step 3
For each column, mark the meeting point of the two pieces of information with a dot, then use your ruler to neatly complete the column. Shade it in using colour.

Step 4
Label the vertical and horizontal axes and give the graph a title. Include a key if necessary.

Step 5
Provide the source beneath your graph, to enable the reader to locate the source data if they wish.

FIGURE 3 Mean monthly rainfall for the years 1871 to 2016, Cardwell, Queensland



Source: © Bureau of Meteorology

on Resources

- **eWorkbook** SkillBuilder — Creating a simple column or bar graph (ewbk-11037)
- **Video eLesson** Creating a simple column or bar graph (eles-1639)
- **Interactivity** Creating a simple column graph (int-3135)

1.12.3 Let me do it

Complete the following activities to practise this skill.

1.12 ACTIVITIES

1. Using the data in table 2, construct your own graph of average monthly rainfall for Innisfail, Queensland.

TABLE 2 Mean rainfall (mm) for the years 1881 to 2016, Innisfail, Queensland

Statistics	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean rainfall (mm) for years 1881 to 2016	507.3	590.1	662.2	456.3	302.2	189	137.6	116.9	86.1	87.7	157.9	262.6

2. Once you have constructed your graph, apply the skills you have learned in this SkillBuilder to answer the following questions.
   a. Which month has the most rainfall?
   b. Which month is the driest?
   c. Imagine you are a filmmaker, planning to film on location in Innisfail for three months. As rain would cause problems for your filming schedule, which months would be best for your requirements?

Checklist

I have:

- ruled axes
- labelled axes
- a space between each column
- included a title
- included the source of information.

SkillBuilder — Drawing a line graph

1.13 Tell me

What is a line graph?

A line graph displays information as a series of points on a graph that are joined to form a line. Line graphs are very useful to show change over time. They can show a single set of data, or they can show multiple sets, which enables us to compare similarities and differences between two sets of data at a glance.

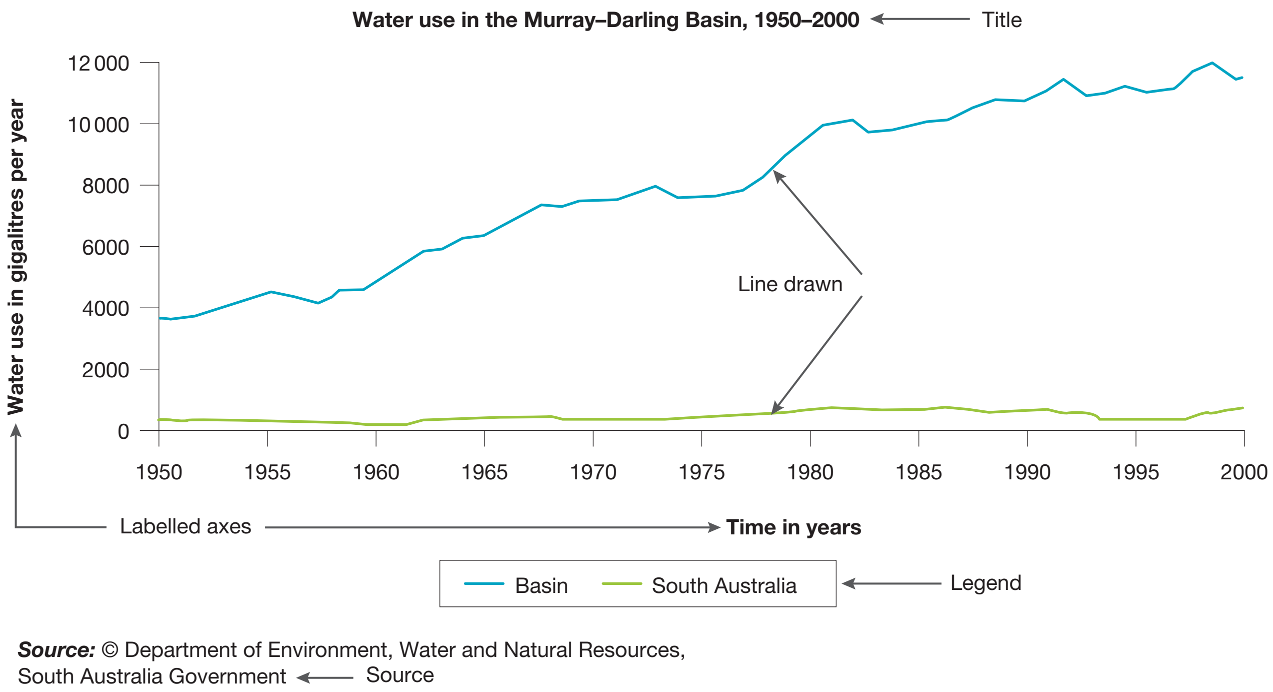
How are line graphs useful?

Line graphs are very useful to show change over time. They can show a single set of data, or they can show multiple sets based on a common theme such as water use in the Murray–Darling Basin compared to water use in South Australia (see figure 1). This enables us to compare similarities and differences between two sets of data at a glance.

A good line graph has:

- been drawn in pencil
- an appropriate scale to show the data clearly
- labelled axes
- small dots joined by a line to make a smooth curve
- a legend, if necessary
- a clear and accurate title that explains the purpose of the graph
- the source of the data.

FIGURE 1 Water use in the Murray–Darling Basin



What is the application of line graphs in science?

Line graphs are very useful in science to show change over time for continuous data such as the increase in temperature when heating water with a Bunsen burner. Line graphs can show a single or multiple sets of data, which allows comparison and trends in data to be observed.

1.13.2 Show me

How to complete a line graph

Materials

- data
- graph paper
- a pencil
- a ruler

Model

TABLE 1 Use of rainwater tanks by household, 2001–2010

Year	Use of rainwater tanks by household (%)
2001	16
2004	17
2007	19
2010	26

Method

Step 1

Select the data you wish to compare or interpret (table 1).

Draw a horizontal and vertical axis using a ruler.

Evenly space and then label the years along the horizontal axis. Look carefully at your range of data and work out appropriate increments for the vertical axis, then evenly space and label this information on the axis. Start at zero where the axes join. For the table 1 data, an increment of 5 percentage points would be appropriate.

Step 2

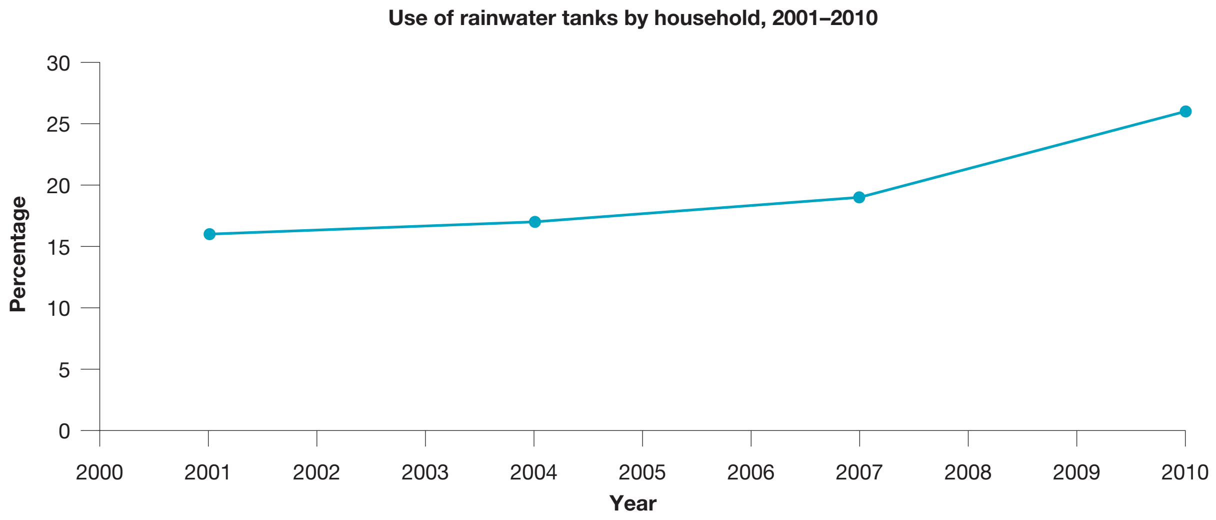
Label the X and Y axes. In this case, the X axis would be labelled 'Year', and the Y axis would be labelled 'Percentage'.

Plot the statistics. Draw a dot at the point where the year on the horizontal axis meets the relevant position on the vertical axis. Once you have plotted all the statistics, join the dots. This can be done freehand or using a ruler.

Step 3

Add a title and a source to the graph.

FIGURE 2 Use of rainwater tanks by household, 2001–2010



Source: © Australian Bureau of Statistics

on Resources

eWorkbook SkillBuilder — Drawing a line graph (ewbk-11039)

Video eLesson Drawing a line graph (eles-1635)

Interactivity Drawing a line graph (int-3131)

1.13.3 Let me do it

Complete the following activities to practise this skill.

1.13 ACTIVITIES

1. Use the data in table 2 to create a line graph. Use the checklist to ensure you cover all aspects of the task.

TABLE 2 Daily residential water consumption for South Australia

Year	Daily residential water consumption (litres)
2001	539
2002	502
2003	532
2004	460
2005	465
2006	440
2007	413
2008	410
2009	395

2. Based on what you have learned in this SkillBuilder and referring to your graph, apply your skills to answer the following questions.
   a. In which year is water consumption lowest?
   b. Describe the pattern shown by the graph.
   c. What reasons might explain the changes from 2001 to 2009?
   d. When water restrictions were lifted in 2011, predict what happened to water consumption.

e. If the government made every household adopt water saving measures in 2022, what might happen to water consumption?

f. Find statistics for water consumption for your area and compare these to another area.

g. Explain how useful the graph was in helping you understand the changes that occurred to water consumption in South Australia compared to reading a table of figures.

Checklist

I have:

- labelled the axes
- provided a clear title and source
- plotted the data accurately
- joined the points with a smooth line.

SkillBuilder — From observation to conclusion

1.15.1 Tell me

How do I draw a conclusion from my observations?

An investigation conclusion is a brief account of what you found out and how your findings relate to your aim. It is a good idea to read your aim again before you write your conclusion. Then look at your observations or results and write in your conclusion what you found, if there was a better way to perform the investigation and possibilities for further investigation.

Why is it important to draw conclusions in science?

A well-written conclusion will allow others to learn from your investigation and further develop the knowledge and research in the area.

What is the application of observations and drawing conclusions in science?

Making and reporting observations and drawing conclusions are an important part of a scientific report. The observations allow other scientists to see if their findings are consistent with yours and where differences may be found. The conclusion points the way for new or improved ways of doing the investigation and also to new areas of scientific research.

1.15.2 Show me

How do we draw conclusions from observations?

Materials

- Investigation results; for example, growth of bean plants watered with salt water for six days.

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
Plant 1 (salt water) Height (cm)	30.0	30.0	29.0	29.0	28.0	27.0
Plant 2 (salt water) Height (cm)	29.0	29.0	28.0	27.0	27.0	26.0
Plant 3 (salt water) Height (cm)	27.0	27.0	26.0	26.0	26.0	26.0
Plant 4 (tap water) Height (cm)	27.0	27.0	28.0	30.0	32.0	33.0

- An aim; for example, how does salt water affect the growth of bean plants?
- A hypothesis; for example, if bean plants are watered with salt water, then they will grow faster than when watered with tap water.

Method

Step 1
Carefully look at your results and observe any trends and patterns.

Step 2
To start your conclusion, summarise your findings with a link back to the aim of the investigation. For example, in this investigation, the effect of salt water on the growth of bean plants was examined. It was found that the bean plants did not grow, instead decreasing in size.

Step 3
Look at the results and make some observations with a clear link to the data. For example, on average the bean plants did not grow but decreased in height over 6 days, by an average of 2.3 cm. The plant watered with tap water, by comparison, grew 5 cm.

Step 4

State whether your hypothesis is supported. For example, the hypothesis is not supported, as salt water does not make bean plants grow.

Step 5

Evaluate your investigation and bring your findings together. In this investigation, the effect of salt water on the growth of bean plants was examined. It was found that the bean plants did not grow, instead decreasing in size. On average the bean plants did not grow but decreased in height over 6 days, by an average of 2.3 cm. The plant watered with tap water, by comparison, grew 5 cm. The hypothesis is not supported, as salt water does not make bean plants grow better than plants watered with tap water. *Note:* In some cases, you may also be required to outline any errors and suggest improvements to your investigation. This is usually covered in your discussion, but may also be touched on in your conclusion.

on Resources

eWorkbook	SkillBuilder — From observation to conclusion (ewbk-11045)
Video eLesson	From observation to conclusion (eles-4160)
Interactivity	From observation to conclusion (int-8094)

1.15.3 Let me do it

Complete the following activities to practise this skill.

1.16 1.15 ACTIVITIES

1. Decide if each of the following is true or false.
   a. A conclusion should list the outcomes you wanted to happen.
   b. A conclusion should make predictions about what might happen during subsequent investigations.
   c. Whether your hypothesis is supported or not is included in your conclusion.
   d. The full equipment list and method is repeated in your conclusion.
2. The following results were found when some marsh plants were watered with salt water.

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
Plant 1 height (cm)	30.0	31.0	31.0	32.0	33.0	33.0
Plant 2 height (cm)	29.0	29.0	30.0	30.0	31.0	31.0
Plant 3 height (cm)	27.0	27.0	28.0	28.0	28.0	29.0

   a. Summarise these results and make an observation.
   b. Write a hypothesis that would suit the results of this investigation.
   c. Write a conclusion that might match the results in the table. B e sure to include all the steps mentioned in section 1.7 .2.
3. Give two reasons why a well- written conclusion is important in an investigation.

Checklist

I have:

- summarised the results of the investigation
- linked my findings back to the aim
- stated whether the results support my aim and hypothesis.

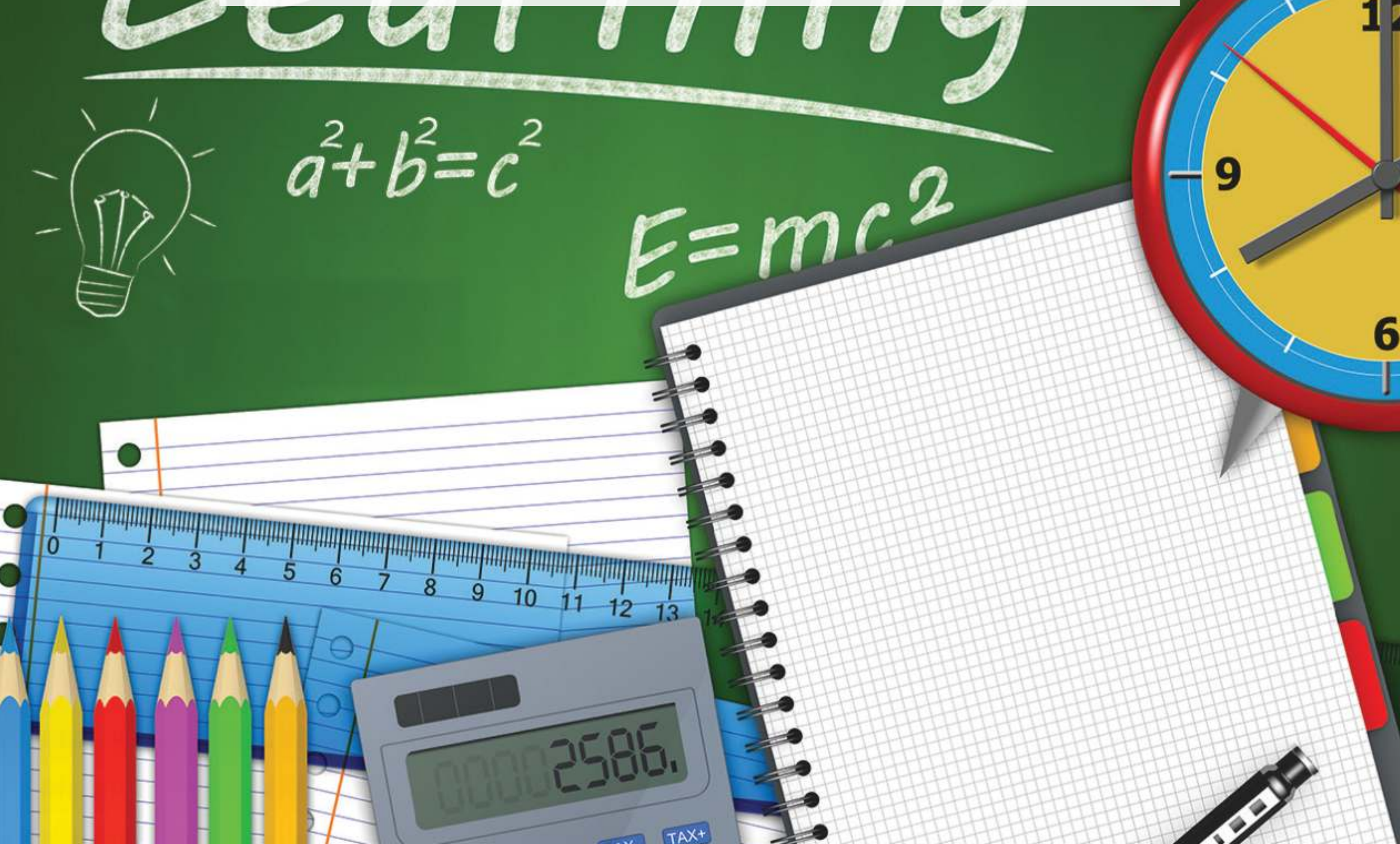
2 Learning keys

online only

LESSON SEQUENCE

SCIENCE INQUIRY AND INVESTIGATIONS

Science inquiry is a central component of Science curriculum. Investigations, supported by a **Practical investigation eLogbook** and **teacher-led videos**, are included in this topic to provide opportunities to build Science inquiry skills through undertaking investigations and communicating findings.



LESSON
2.1 Overview

Hey students! Bring these pages to life online

Watch videos

Engage with interactivities

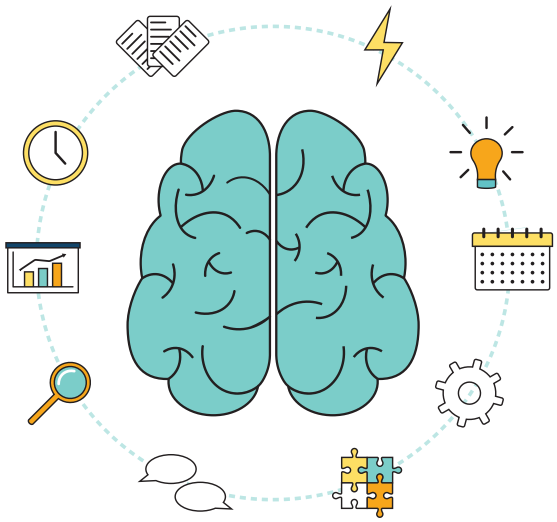
Answer questions and check results

Find all this and MORE in jacPLUS

2.1.1 Introduction

Do you have keys to unlock your own learning? What happens when you learn? In this topic, we will explore different ways of learning and thinking. We will also introduce you to some 'thinking tools' and 'learning keys' to help you become a better learner.

FIGURE 2.1 You learn in many different ways for many different reasons.



on Resources

Video eLesson Unlocking learning: flowcharts, cluster maps and concept maps (eles-0856)

This video explains some strategies to make learning easy and fun. There are three types of learning tools discussed in this video: flowcharts, cluster maps and concept maps. Each of these allows you to represent information in different ways, which can strengthen learning.

2.1.2 Think about learning

1. What are three different types of intelligence?
2. How can you use an 'alphabet' key to help unlock your thinking?
3. What are two ways of practising collaborative skills with your partner?
4. What are potential benefits of being an active learner?

2.1.3 Science inquiry

Thinking with different hats

There are a number of very useful tools that can help develop your thinking. One of these was created by a great thinker by the name of Edward de Bono. He created the idea of using different coloured **thinking hats** for different types of thinking. These hats don't even have to be on your head. The idea behind each hat just needs to be *in* your head.

thinking hats a thinking tool developed by Edward de Bono using different coloured hats for different types of thinking

Six thinking hats

Figure 2.2 and table 2.1 show different types of questions that can be asked when 'wearing' the different coloured hats. These hats can be used to help direct your thinking about a particular problem in different ways.

FIGURE 2.2 The six coloured thinking hats

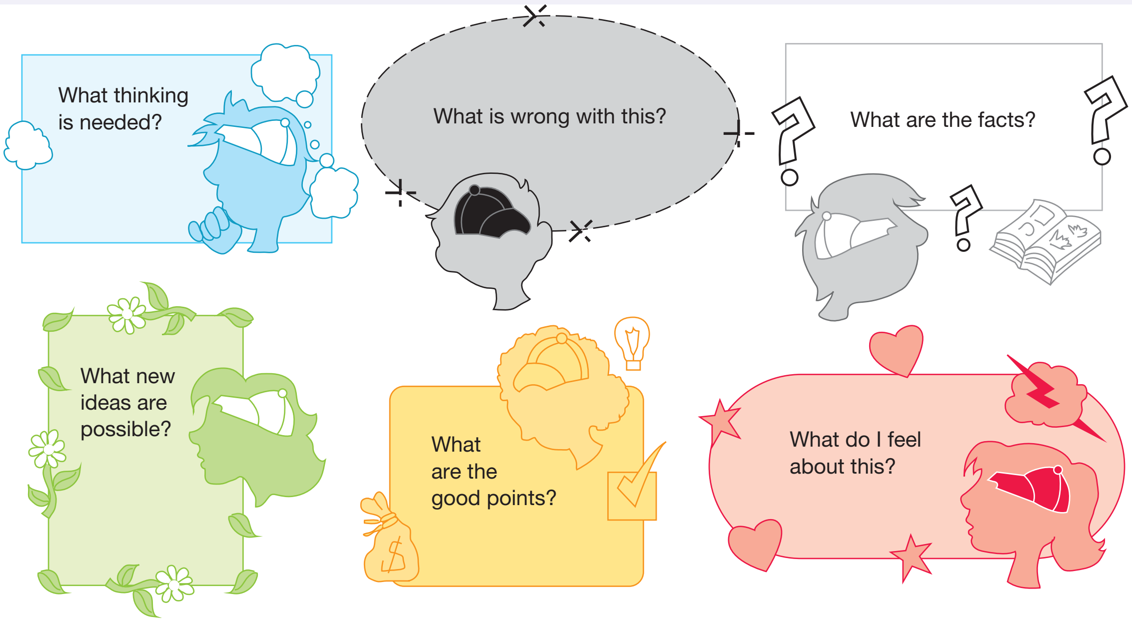


TABLE 2.1 Coloured hat questions

Problem	Students are to wear only black coloured clothes to school
Red hat	How do you feel about wearing only black clothes to school?
Yellow hat	What's good about the idea?
Black hat	What's wrong with this idea?
White hat	What information do you have (or need to have) on this idea?
Green hat	What are some ways to help this to happen?
Blue hat	What do you need to do next, or have done so far?

1. With your partner, select one of the following problems.
   - Unhealthy food in the school canteen
   - Too much homework
   - Too much school litter
   - Sleepy students

   a. Using each coloured hat, write down an answer using that type of thinking. Taking turns, share your answers with your partner.

   b. How were your answers and those of your partner similar, and how were they different? Suggest some reasons for these findings.

   c. If you were to think about this particular problem again, how would your thinking be different?
2. Suggest two other problem-type questions that could be used with the thinking hats. Add these to a class collective thinking jar, for some more 'hat thinking' at another time.

Resources

eWorkbooks Topic 2 eWorkbook (ewbk-11061)
Student learning matrix (ewbk-11066)
Starter activity (ewbk-11063)
Your quest (ewbk-11065)

LESSON
2.2 Understanding learning and thinking

LEARNING INTENTION

At the end of this lesson you will be able to describe the factors that may influence how you learn and think.

2.2.1 Tinkering with your toolbox

Can you describe when, where and how you learn the best? Do you know why?

There are many factors that may influence how you learn and think, such as:

- visual — colour, lighting, shape
- auditory — sound, music
- kinaesthetic — movement, dance
- interactive — social, teams.

These factors can link with the types of tools in your multiple intelligence toolbox. Although you may have a preference for some of these over others, it is important to try them all whenever you can.

FIGURE 2.3 What type of learner are you?

2.2.2 Hearing: auditory learning

Auditory learning can include musical or rhythmic and verbal or linguistic activities. Many melodies that you may know well (such as *Row Row Row Your Boat* and *Twinkle Twinkle Little Star*) can be linked to new learning by rewriting the lyrics with key words from your lesson or topic. Different types of music can also help you focus on the task that you are involved in.

auditory learning learning through listening

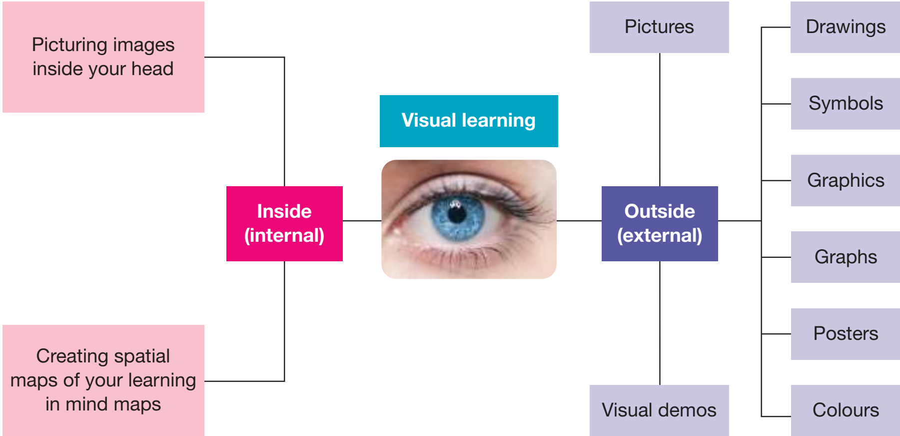
FIGURE 2.4 The various types of auditory learning

2.2.3 Looking: visual learning

Visual learning can involve seeing an image with your eyes or visualising it in your mind.

Looking at advertisements for various products, you will be able to see how they have used various visual cues to help you remember their product. The Nike sports clothing company, for example, has a tick symbol. How many symbols from other advertisements can you remember?

FIGURE 2.5 The various types of visual learning



2.2.4 Smelling: olfactory learning

Smell and an awareness of aromas can help you become a very effective learner and is known as **olfactory learning**. Research suggests that peppermint, basil, lemon, cinnamon and rosemary enhance mental alertness. Lavender, chamomile, orange and rose calm nerves and encourage relaxation.

Your olfactory regions in your nose are rich in receptors for endorphins, chemicals that generate feelings of pleasure and wellbeing. You can distinguish odours with only tiny variations in their chemical structures. Can you think of examples of odours that make you remember a happy moment?

visual learning using text or images to learn

olfactory learning using the sense of smell to learn

kinaesthetic learning using touch or manipulating materials to learn

social learning collaborating and sharing with peers to learn

2.2.5 Doing: kinaesthetic learning

Kinaesthetic learning can involve learning through movement, touch and feeling, role-plays, pantomime stories, puppet shows, stretching, building models, exercise, sign language, hands-on experiments and dance. Movement and activity are also important to get more oxygen to your brain so that you can think better.

2.2.6 Social: interactive learning

It can be fun to learn with others. Interactive or **social learning** can involve learning through sharing, peer teaching, collaboration, discussion, and learning in pairs, groups and teams, and can help in your own development of self-awareness and an awareness and empathy for others. Learning these sorts of interpersonal skills is very important for both your learning and sense of wellbeing.

FIGURE 2.6 Collaboration is a technique of interactive or social learning.

Self

Not all learning needs to be with others. It is also important to be able to learn on your own, by yourself. Solo thinking activities, such as imagery, journal writing, focusing and concentration exercises, self-assessment and reflection, are very useful.

ACTIVITY: Games to help with revision

Play these games to help you revise a topic.

Add-ons

- To start, one student comes to the front of the room and acts out or postures something that they have learned from the topic.
- Another student joins the first student to act out something they have learned, then other students do the same, creating a 'living sculpture'.

Brain ball toss

- Six to eight students stand in a circle facing each other about three metres apart.
- To start, one person tosses a ball or beanbag to anyone in the circle.
- The student who catches it asks a question about the topic, then throws the ball or beanbag to another student who must answer the question. They, in turn, throw the ball or beanbag to another student, and ask a new question etc.

2.2 Activities

learnon

2.2 Exercise

Select your pathway

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

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

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Remember and understand

1. Describe a technique that a visual learner might use.
2. Describe a technique that a kinaesthetic learner might use.

Apply and analyse

3. Explain how a teacher might plan a lesson based on interactive learning.

Evaluate and create

4. Create a concept (or mind) map to describe your ideal learning environment.
5. Design a game that helps others find out the type of learner they are and what their ideal learning environment is like.
6. SIS
   a. Record images that you have when you think of the aromas of the following.
      i. Freshly baked bread
      ii. Garlic
      iii. Strawberries
      iv. Orange juice
      v. Manure
      vi. Freshly baked chocolate cake
   b. Compare your images with a partner. How are they similar and how are they different?
   c. Design an experiment to find out which aromas relax you and which ones make you mentally alert.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
2.3 Types of intelligence

LEARNING INTENTION

At the end of this lesson you will be able to describe the theory about the eight different types of intelligence and how to develop mindful habits.

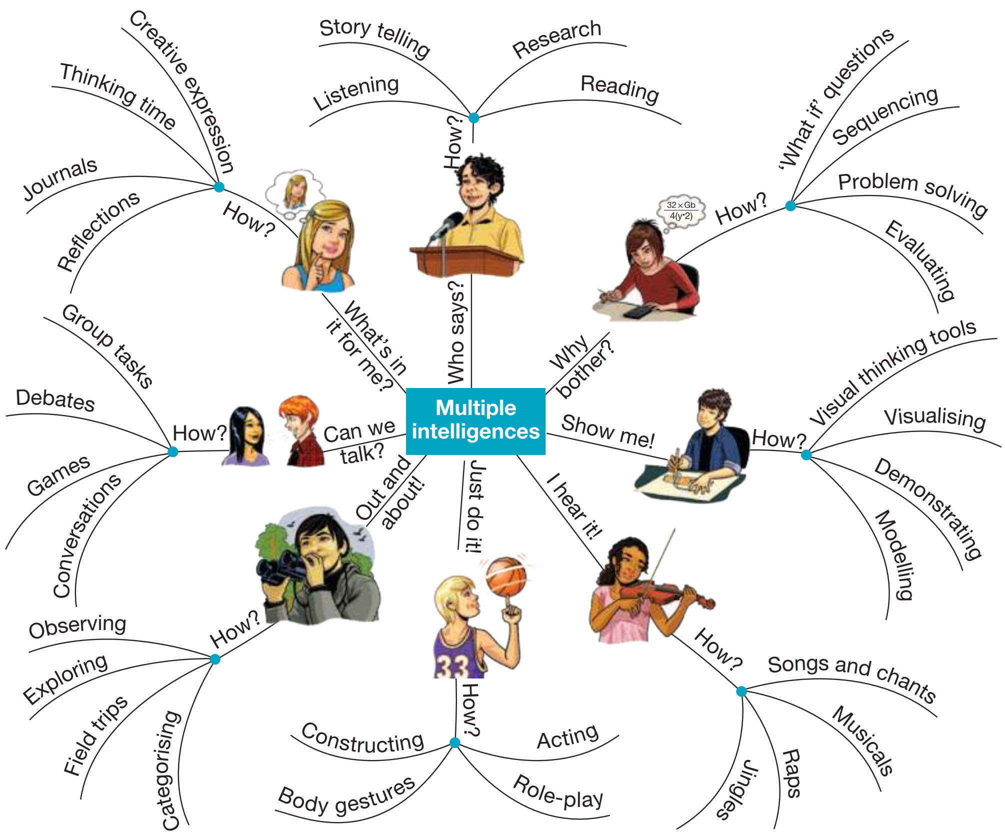
2.3.1 Intelligence multiplied

Did you know that it's not how smart you are that's important, but how you are smart? A great thinker by the name of Howard Gardner introduced a theory about eight different types of intelligence. He referred to these as:

- bodily/kinaesthetic intelligence
- verbal/linguistic intelligence
- logical/mathematical intelligence
- visual/spatial intelligence
- musical/rhythmic intelligence
- interpersonal intelligence
- intrapersonal intelligence
- naturalist intelligence.

By using a variety of strategies that use all types of intelligence, you can increase the effectiveness of your learning. Some examples of how multiple intelligences are used can be seen in figure 2.7.

FIGURE 2.7 There are many different types of intelligences.



Y charts and multiple intelligences

You can use your **multiple intelligences** to help you understand how to develop some very useful mindful habits. For example, using your verbal/linguistic, visual/spatial and intrapersonal intelligences, you can construct **Y charts** for what the mindful habits may sound like, look like and feel like. The Y charts in figures 2.8 and 2.9 show examples of this for ‘persevering’ and ‘stopping and thinking before you leap’.

multiple intelligences eight types of intelligences suggested by Howard Gardner

Y chart a visual thinking tool that helps you visualise and reflect

FIGURE 2.8 Persevering — persisting even when things get tough. Can you suggest other comments for this Y chart?

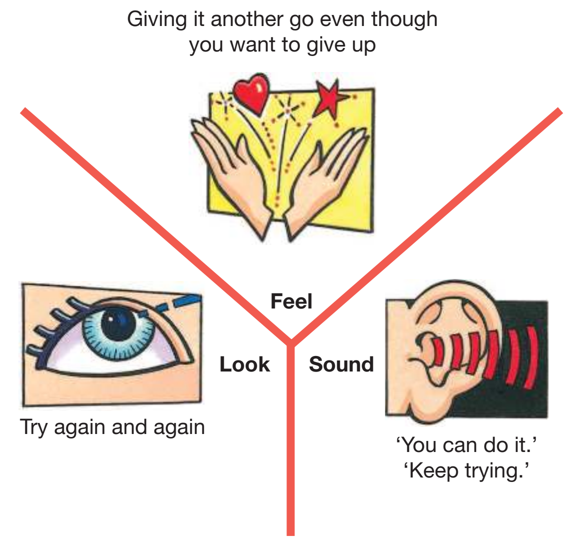
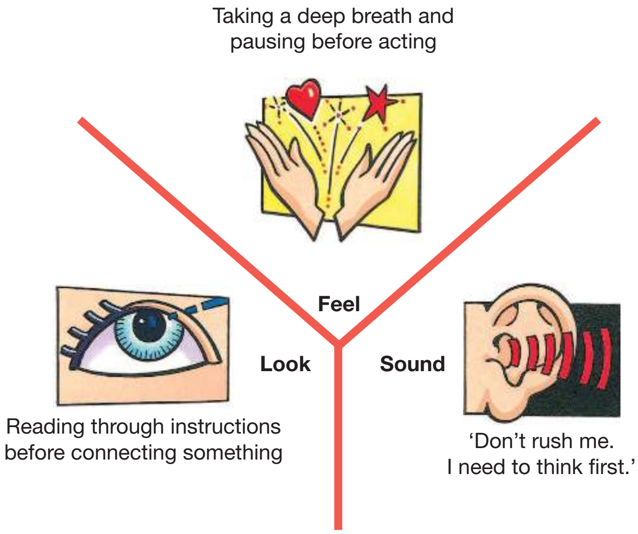


FIGURE 2.9 Stopping and thinking before you leap — considering the consequences first. Can you suggest other comments for this Y chart?



2.3.2 Mindful habits

In life, it is a very good idea to be thoughtful about what you are doing. Sometimes it is less important to know something than to know how to act when you have that knowledge. Two ‘mindful’ thinkers, Bena Kallick and Arthur Costa, thought a lot about how some types of thinking and behaviour are more useful than others on our life’s journey. They called these 16 types of thinking behaviours ‘**habits of mind**’ and they are shown in figure 2.10.

habits of mind types of thinking behaviours promoted by Bena Kallick and Arthur Costa

FIGURE 2.10 Sixteen mindful habits

on Resources

eWorkbook Intelligence toolbox (ewbk-11068)

2.3 Activities

learnon

2.3 Exercise

Select your pathway

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

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- Receive immediate feedback
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Remember and understand

1. List three different mindful habits that you would like to focus on developing this month.
2. Which three multiple intelligences are used in a Y chart?

Apply and analyse

3. Which mindful habit matches each of the following descriptions?
   a. Working through frustration
   b. Self-evaluating
   c. Controlling quality
   d. Wide-eyed
4. Which mindful habit matches each of the following descriptions?
   a. Cooperative
   b. Trying hard to understand others
   c. Curious
   d. Diligent
5. Which mindful habit matches each of the following descriptions?
   a. Looking at situations in alternative ways
   b. Checking over your results several times
   c. Compassionate
   d. 'Hanging in there'
6. Which mindful habits would be useful to develop your:
   a. logical/mathematical intelligence
   b. musical/rhythmic intelligence
   c. interpersonal intelligence
   d. bodily/kinaesthetic intelligence?
7. Find out the exact terms used by Kallick and Costa for the 16 habits of mind.
8. Find out more about metacognition and ways that you could do more of it yourself.

Evaluate and create

9. Create examples of how you could teach a classmate something about 'mindful habits' using each of the different types of multiple intelligences.
10. a. Select three mindful habits.
    b. Discuss how you could describe each of these mindful habits.
    c. For each mindful habit, brainstorm what it would 'look like', 'feel like' and 'sound like'. Record your brainstorm in a Y chart, cluster map or mind map.
    d. Compare your records with others or with online research.
    e. Make any modifications or additions you wish to your charts or maps.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
2.4 Thinking keys

LEARNING INTENTION

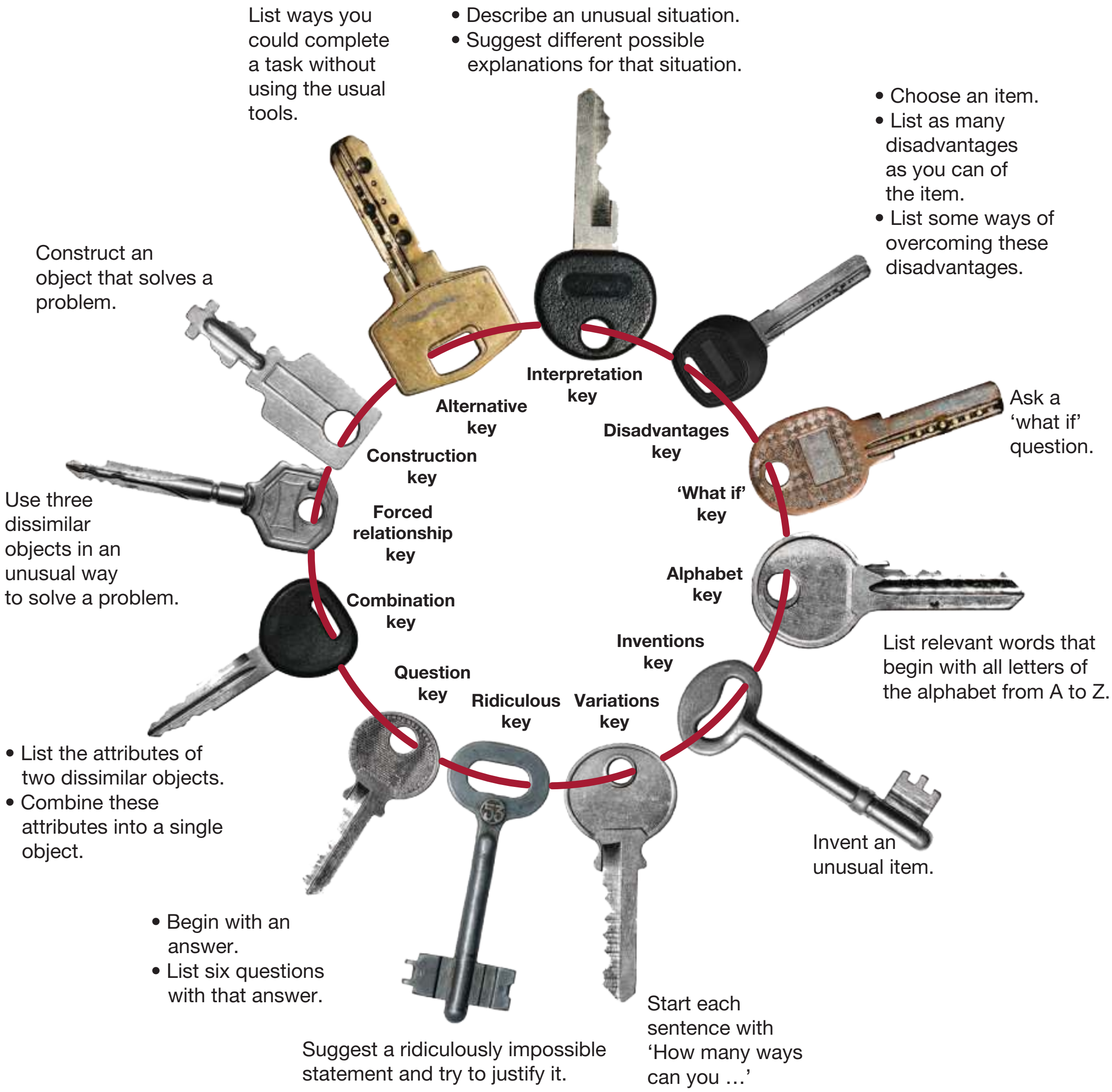
At the end of this lesson you will be able to describe the 'thinking keys' and use them to help you think creatively to solve problems.

2.4.1 Thinking keys

A creative thinker by the name of Tony Ryan developed the idea of '**thinking keys**' to unlock your thinking. The 12 thinking keys, and how they can be used, are shown in figure 2.11. Different keys unlock different types of thinking. These keys can 'tune' or focus your brain into thinking about tasks, situations or problems in creative, logical or challenging ways.

thinking keys a tool developed by Tony Ryan to help unlock thinking

FIGURE 2.11 The 12 thinking tools developed by Tony Ryan



DISCUSSION

Give an example of the use of one of these thinking key questions to think about an issue of your choice.

These thinking keys can be used to:

- 'switch you on' — they can motivate you, get you excited or interested, or 'hook' you into thinking about something
- 'open different doors' of your thinking — they can help you look at situations in different ways
- 'unlock your thinking' — they can help you become more effective at thinking critically and creatively
- 'unlock your feelings' — they can increase your interpersonal and intrapersonal experiences and help you to reflect.

DISCUSSION

How do preconceptions limit ideas and alternatives? Give an example.

on Resources

eWorkbook Thinking keys (ewbk-11070)

2.4 Activities

learnon

2.4 Exercise

Select your pathway

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

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- Access sample responses
- Track results and progress

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Remember and understand

1. What is the purpose of the 12 thinking keys?

Apply and analyse

2. Use your 'what if' key in figure 2.11 to write a story about one of the following.
   - What if mosquitoes were the size of humans?
   - What if all plants were purple?
   - What if there were only female humans on Earth?
   - What if we could have holidays on Mars?
3. Use your 'disadvantages' key in figure 2.11 to unlock your thinking about an item in your classroom.
4. Use your 'alphabet' key in figure 2.11 for one of the following.
   - Biological classification
   - An ecosystem
   - Chemicals in your home
   - Food webs
   - Weather and climate

5. Use your ‘variations’ key in figure 2.11 to list as many ways as possible to do one of the following.
   - Hang out the washing
   - Get to school
   - Tell someone not to be a bully
   - Encourage a timid teammate to contribute to a discussion
6. Use your ‘ridiculous’ key in figure 2.11 to justify one of the following statements.
   - Children should be paid to go to school.
   - School should be 9 pm – 3 am instead of 9 am – 3 pm.
   - Students should only be taught maths, English and science at school.
7. Use your ‘question’ key in figure 2.11 for one of the following terms.
   - Gravity
   - Heart
   - *Diprotodon*
   - *Bufus marinus*
8. Use your ‘interpretation’ key in figure 2.11 for one of the following.
   - A fellow student with bright purple spots on their face
   - One of your teachers shrinking to the size of a coffee mug
   - A giant hole in the middle of your schoolyard
9. Use your ‘combination’ key in figure 2.11 to create items from one of the following pairs of items.
   - Pen and sunglasses
   - Phone and a microwave oven
   - Paperclip and a feather
10. Use your ‘inventions’ key in figure 2.11 for one of the following.
    - Banana peeler
    - Hat with four functions
    - Attachment that can be worn on your finger to assist in your learning
    - Earring with three functions
11. Use your ‘construction’ key in figure 2.11 to make a model from household materials that demonstrates one the following.
    - How mixtures can be separated
    - How gravity affects objects on Earth
    - The water cycle
    - Why we have seasons
12. Use your ‘forced relationship’ key in figure 2.11 to work out how to catch a cockroach with a match, a toothpaste tube and a mug.
13. Use your ‘alternative’ key in figure 2.11 to work out a way of tying your shoelaces without using your hands.

Evaluate and create

14. a. Draw a table with the column headings: ‘Type of thinking key’, ‘Switch you on’, ‘Open different doors’, ‘Unlock your thinking’ and ‘Unlock your feelings’.
    b. List all the thinking keys from figure 2.11 in the first column.
    c. Use a tick or cross in the other four columns to show which types of thinking each key may be used for.
    d. Compare your results with those of others in your class.
    e. Discuss reasons for any similarities or differences.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
2.5 Learning together

LEARNING INTENTION

At the end of this lesson you will be able to describe different ways to communicate with and work successfully with a partner or group.

2.5.1 Learning together

Who will your partner be today? How will they be selected? Once you have a partner, there are lots of different ways in which you can interact.

There are also many different ways to 'pair up' to discuss your thoughts before they are shared with a larger group. It could be the 'shoulder partner' who sits next to you, or even a 'face partner' who sits behind or in front of you in class. You can even be paired with someone who is the same star sign or who has the same favourite colour or music.

FIGURE 2.12 Choose as many different learning partners throughout the year to gain a broad perspective of the world.

It's a good idea to work with as many different partners as you can to share your thoughts with throughout the year. You will learn a lot more and become a better thinker because you will have the opportunity to see things through different eyes and broaden the way that you see the world. Developing ways to communicate with your partners involves knowing what to say and when to say it.

2.5.2 Are you a good listener?

To communicate effectively with others also means being able to listen to others with respect, empathy and understanding. Do you really listen to what others are saying or are you rehearsing what you are going to say when it's your turn to speak? Are there other things going on that distract you from really listening to what is being said? What sorts of things do you find distracting? How could you be a better listener?

Are you easy to understand?

Are you a vague or specific communicator? Do you use specific terminology or do you over-generalise? Do your thoughts spill out of your mouth in a jumble or are they organised and concise? What are some strategies that you could use to help you organise your thoughts? By organising your thoughts before you let them out, you can learn to express yourself with clarity and precision.

ACTIVITY: Are you a good listener?

Complete the following activity in a pair.

- **a.** Partner A listens to partner B speak for three minutes about their favourite topic or hobby. Partner A must not interrupt, make any comments or ask any questions during this time.
- **b.** After the three minutes, partner A paraphrases what the speaker, partner B, said.
- **c.** Partner A may then make appropriate comments or queries.
- **d.** Repeat steps (a) to (c) with the roles reversed.
- **e.** Comment on the usefulness of paraphrasing in listening.

2.5.3 None of us are as clever as *all* of us!

You can learn a lot more when you learn with others. You learn not only the content of the topic you are studying, but also how to get along and work with other people. Developing helpful habits, such as well-developed social and collaborative skills, can be very useful throughout your life.

Getting along

There are many social skills that you can focus on developing during your teamwork. These include:

- resolving conflicts or disagreements respectfully
- controlling impulsive actions and comments that may hurt others
- looking at each other while you talk and using people's names
- using both non-verbal and verbal praise and encouragement
- actively encouraging others to be involved and feel valued.

ACTIVITY: Matching game

Find someone in the class who matches one of the criteria in the list. Get them to sign their name next to the criterion. No person can sign more than one criterion. As you are seeking out criterion–classmate matches, think carefully about how you are communicating with them. Think about both your verbal and non-verbal messages during your communication.

a. Likes to get up early
b. Loves hip hop music
c. Watches old movies
d. Sends text messages more than ten times a day
e. Keeps a diary or journal
f. Has a younger brother
g. Has a pet cat

Face to face

Some of the collaborative skills that you can develop while working as a team involve how you interact with your teammates. You can practise these by:

- actively listening with understanding and empathy
- being patient and understanding
- choosing fair ways to make decisions
- taking turns equally and not leaving anybody out
- criticising ideas rather than people
- sharing materials and equipment
- keeping each other focused and on-task
- being organised and well prepared, and managing time effectively
- helping others out when they have difficulties.

Often, establishing some learning team guidelines, such as 'only one person speaks at a time' or 'always be respectful of the feelings, opinions and space of others', can help you to interact effectively as a team.

FIGURE 2.13 Being a good listener and communicator is an important skill for everyday life. But remember, not everyone listens and communicates in the same way.

DISCUSSION

In a pair, take turns telling each other what you think about:

a. the benefits of eating breakfast
b. the reasons people decide to become scientists
c. life as an astronaut.

Hogs and logs

One way to make teams work more effectively is to allocate roles. Figures 2.14 and 2.15 describes the various roles that can be allocated, including examples of the way a person in each role might talk or act. These roles help you to work effectively together, particularly if you are given a project or a discussion topic but not told exactly how to perform the project or discussion.

FIGURE 2.14 Allocating roles can help the team work together more effectively.

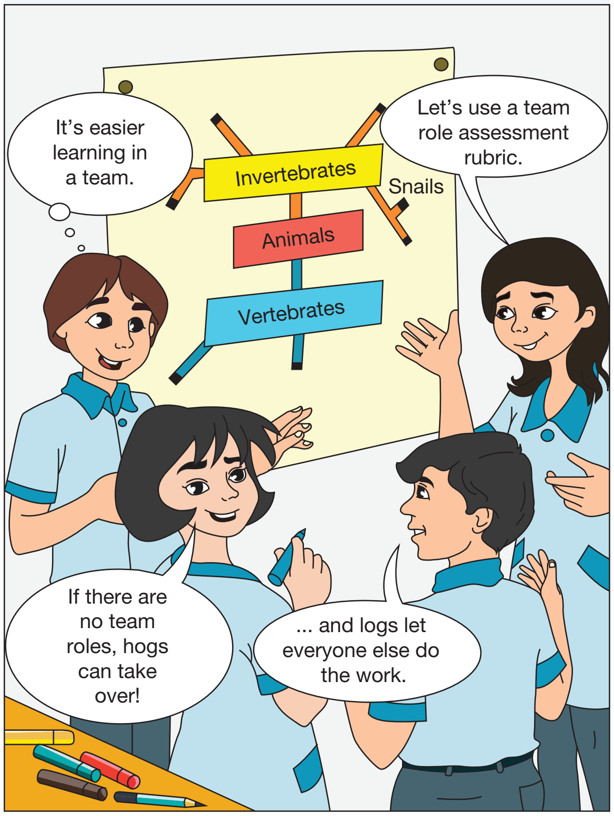
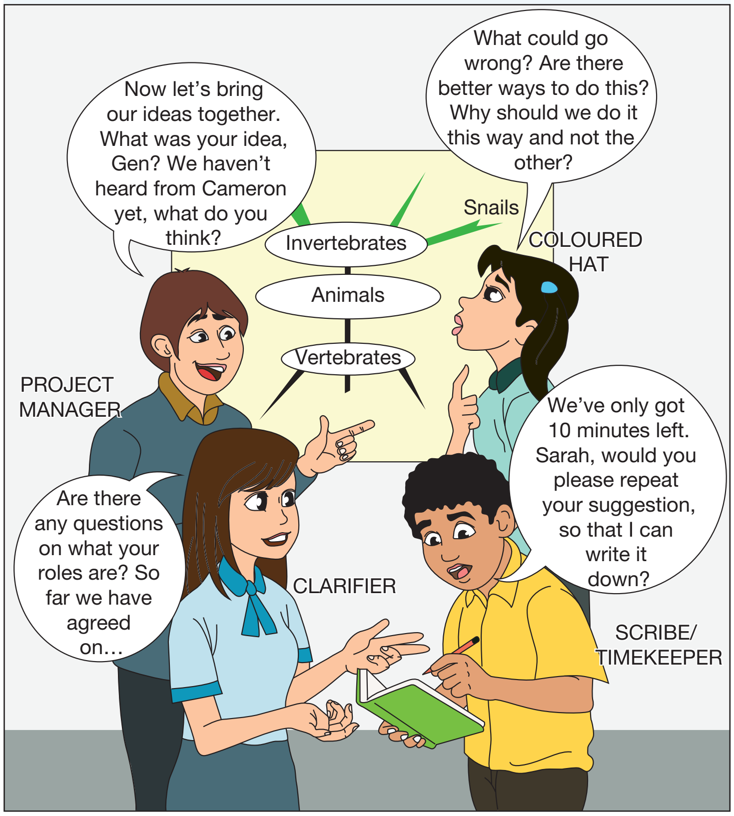


FIGURE 2.15 Cooperative roles — you can allocate different roles on a project.



ACTIVITY: Helpful habits

In this activity you will learn some strategies for working in a team.

1. In your team, discuss the following helpful habits and suggest (i) how they can be useful to both the individual and the team, (ii) some strategies that could be used to develop them and (iii) some obstacles that make them difficult to achieve.
   a. Persistence (optimism, sticking to the job, effort and hard work)
   b. Confidence (failing wisely, taking responsible risks and speaking up)
   c. Resilience (keeping perspective, maintaining your cool and bouncing back)
   d. Organisation (goal setting and time management)
   e. Social skills (tolerance, following instructions, resolving conflicts, managing impulsive behaviour)
2. Share and record the findings of your discussion with other teams and then collate them all into a class instruction and information booklet on helpful habits for your team activities.

on Resources

eWorkbook Mapping your future (ewbk-11072)

2.5 Activities

learnon

2.5 Exercise

Select your pathway

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

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Remember and understand

1. a. What is empathy?
   b. What do you think it means to listen with empathy?
   c. What does empathy look like, feel like and sound like?
2. Brainstorm as many ideas as you can that:
   a. would help you to listen to what others are saying
   b. hinder or get in the way of listening to others.

Apply and analyse

3. Suggest four reasons why a team of four enables more effective communication than a team of three members. Discuss your suggestions in a group of four.
4. Consider any team project you have done and how you think team members should be assessed on their effectiveness. Design a rubric similar to the one shown to evaluate how well each member of the team did their job and how well the team worked together. Compare your rubric to others.

TABLE Example of an assessment rubric

	Score			
Role/task	0	1	2	3
A				Job always done really well
B	Not done			
C			Usually OK	
D		Sometimes job done well		

Evaluate and create

5. Suggest how you can create a good relationship with other members of the team. Make a list of 'getting to know you' questions that you all can answer.
6. Think about how you would form a team and explain how you would decide on a name, logo or a group cheer or handshake.
7. Brainstorm phrases and actions that would help you perform effectively in each of the cooperative roles shown in figure 2.15.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
2.6 Unlocking learning

LEARNING INTENTION

At the end of this lesson you will be able to explain the difference between active and passive learning and ways to make your learning more effective.

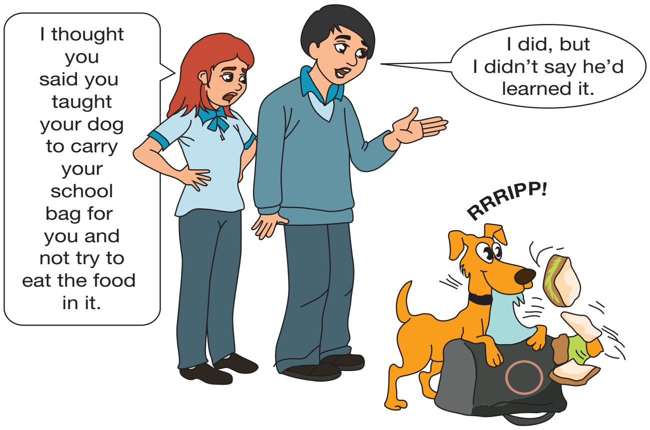
2.6.1 Learning can be scary!

Learning can be scary! It can be full of lots of words and experiences that are new to you. It can also be messy, frustrating, difficult and time consuming. So … why learn? Why bother?

2.6.2 Listening isn't learning

Teaching is more than telling, and learning is more than listening. Although you may learn many things by listening, just 'being told' is not the most effective way to learn. You may be able to remember some of what you heard, but you may not understand it. Think about the last lesson that you were in. What do you remember from it? What did you learn? What did you understand? What does it mean 'to understand'?

FIGURE 2.16 If you are told something, does that mean that you have learned it?



Are you an active or a passive learner?

Do you lift the lid on your brain and wait for information to be poured in? Are you a passive learner? If so, you may not be learning very much. You need to be actively involved in your learning to get the most out of it.

If you are an active learner then you have more chance of developing an understanding of what you are learning. You are more likely to be able to remember it and explain it to others. Very importantly, you will be better equipped to be able to transfer this learning into new situations. This is a very valuable life skill to develop. It is an especially important skill for a scientist.

If it gets too hard, do you just give up?

What do you do when you are introduced to something new? What do you think? Do you try to connect this new information to what you already know? If so, how do you go about it? Do you ever give up because it looks or sounds 'too hard'? If you do get stuck in your learning, what can you do to move on? What sorts of questions and strategies could you use to help get through the difficult and frustrating times in your learning?

2.6.3 Linking your learning

When possible, it is a good idea to try to link your new learning to your previous knowledge. At times, you may even find that your new learning may change how you think about things! As well as learning new things, it is worthwhile thinking about strategies that you used to 'move' from what you used to know to what you now know. This type of thinking about your thinking (metacognition) will help you to become a more active and effective learner.

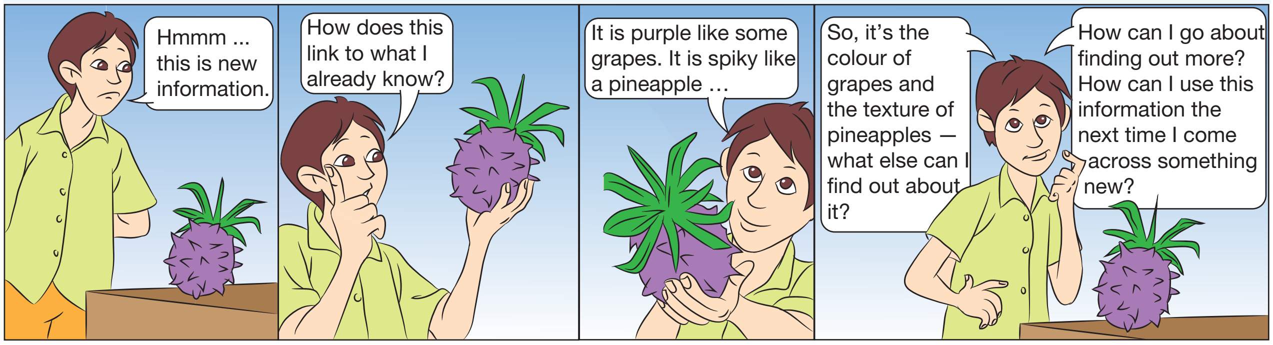
Recognising what is new is a great way to start learning

What do you do when you come across a word that you haven't seen before? Does it contain parts that you have seen before in other words? Do these parts of the word give you a hint about its meaning? Sometimes this may be helpful — at other times, you need to find other ways to help you learn the new terms and link them to what you already know.

The first step is to recognise the new term. The next step is to remember what it means and what other terms or ideas it could be linked to. It may be helpful to talk to others and to tell them how you remember the term and hear how they go about it. This type of shared learning can be quite powerful in helping you to develop your scientific literacy. It can help you to learn new ways to be able to communicate what you know. Talking and sharing your learning can help you get closer to understanding what you are learning.

int-6596

FIGURE 2.17 What do you think when you are introduced to something new?



ACTIVITY: Recognition cards

a. Make up your own set of term recognition cards. On one side write the following statements and on the other side add a coloured circle, as indicated in the table.

TABLE Setting out your recognition cards

On front of card	On back of card
Never seen the term before	Red circle
Recognise the term	Orange circle
Recognise the term and can give definition or description	Yellow circle
Recognise the term and could help others to understand it	Green circle

b. These cards can be used at the beginning and end of each topic you study. You can create your own list of the key terms in the chapter or use a list supplied by your teacher. Score each term between 0 (never seen the term before) and 3 (recognise and could help others to understand the term). Use this to inform yourself and your teacher about where you are in your learning of these terms.

c. Score each of the terms in a table like the one provided. Either as a class or in a team, hold up the card for each term. Share what you know about the terms with others in your team or class.

TABLE How well do you recognise these terms?

Term	Term comfort zone (circle the appropriate score)			
Mollusc	0	1	2	3
Cnidarian	0	1	2	3
Arthropod	0	1	2	3
Amphibian	0	1	2	3
Annelid	0	1	2	3

Reptile	0	1	2	3
Vertebrate	0	1	2	3
Echinoderm	0	1	2	3
Marsupial	0	1	2	3
Nematode	0	1	2	3
Invertebrate	0	1	2	3
Monotreme	0	1	2	3

d. Use a variety of sources to collect information on each of the terms and then construct a mind map or concept map to link them. (You may add other terms that are not on the list.)

2.6 Activities

learnon

2.6 Exercise

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
1, 3	2, 4	5

Remember and understand

1. Why is active learning more effective than passive learning?

Apply and analyse

2. Explain how the 'habits of mind' (see section 2.3.2) may help you to be a more effective and active learner.
3. Identify each of the following as active or passive.
   a. Listening to a lecture
   b. Creating your own podcast on a topic
   c. Reading a textbook
   d. Teaching others a concept you learned

Evaluate and create

4. a. Construct a table with two columns. Label the first column 'Learning question' and the second column 'My response'.
   b. In the first column, write the questions from the *If it gets too hard, do you just give up?* (See section 2.6.2).
   c. Add your responses to the questions in the second column. (You may wish to discuss ideas with those around you.)
5. Create a cartoon or image to show what two of the following might look like in your classroom.
   a. Passive learning versus active learning
   b. Metacognition or 'being aware of your thinking'
   c. Persevering when 'stuck' in your learning
   d. Making links between 'old' knowledge and 'new' knowledge

Fully worked solutions and sample responses are available in your digital formats.

LESSON
2.7 Question keys

LEARNING INTENTION

At the end of this lesson you will be able to describe the different levels of questioning and learning.

2.7.1 Levels of thinking

- How do you find out what a question is asking?
- How can you unlock it?
- Are there any clues?
- What are the words in questions that tell you what to do?

Some question words, such as 'identify', do not require much thinking and may just require you to recognise and recall a name or list of names. Others may require you to think quite deeply and make comparisons or predictions. Other question words may expect you to explain your reasoning and understanding. Yet others, such as 'construct' or 'design', may require you to build, create or investigate a particular object or problem.

2.7.2 Science Quest question patterns

When you browse through the exercise question sets for each lesson in this text, you may see a pattern in the question terms that are used. In the 'Remember and understand' sections, the information that you need to answer the question will be located somewhere in that section. You won't need other resources to find the answer. The question words that you will find in this section include: *define, identify, outline, which, list, what is, recall and describe,* and *explain why*.

In the 'Apply and analyse' sections, you need to consider the information in the pages of the lesson, but you may also need to think or discuss to be able to respond to the question. You may need to do something more with the information other than simply recall it. Examples of question words in these sections include: *identify, describe, explain, state how, what would, calculate, classify, differentiate, justify, outline, summarise, construct, compare and contrast, propose* and *interpret*.

FIGURE 2.18 Some question words require you to think quite deeply.

The 'Evaluate and create' sections often require you to think even more deeply about the question and your response. You may need to *design* an investigation, *conduct* it and *explain* the results that you get. Such questions may require a different type of thinking. You may need to use your imagination and creativity to apply what you have learned to *evaluate* or *create* something. You may need to conduct thorough research on a topic and present your findings in a variety of ways.

int-6597

FIGURE 2.19 Question keys can unlock what the question is asking.

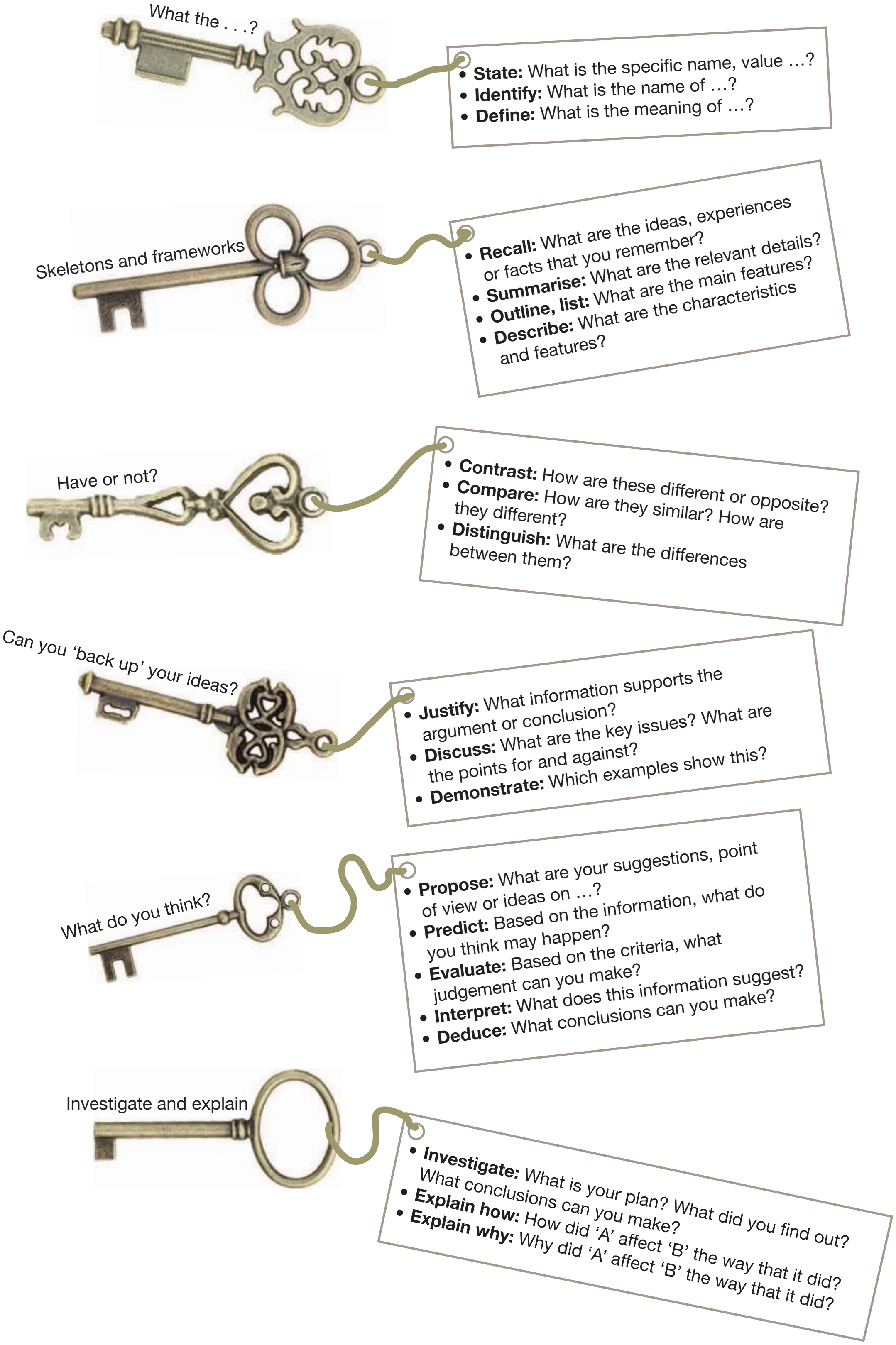
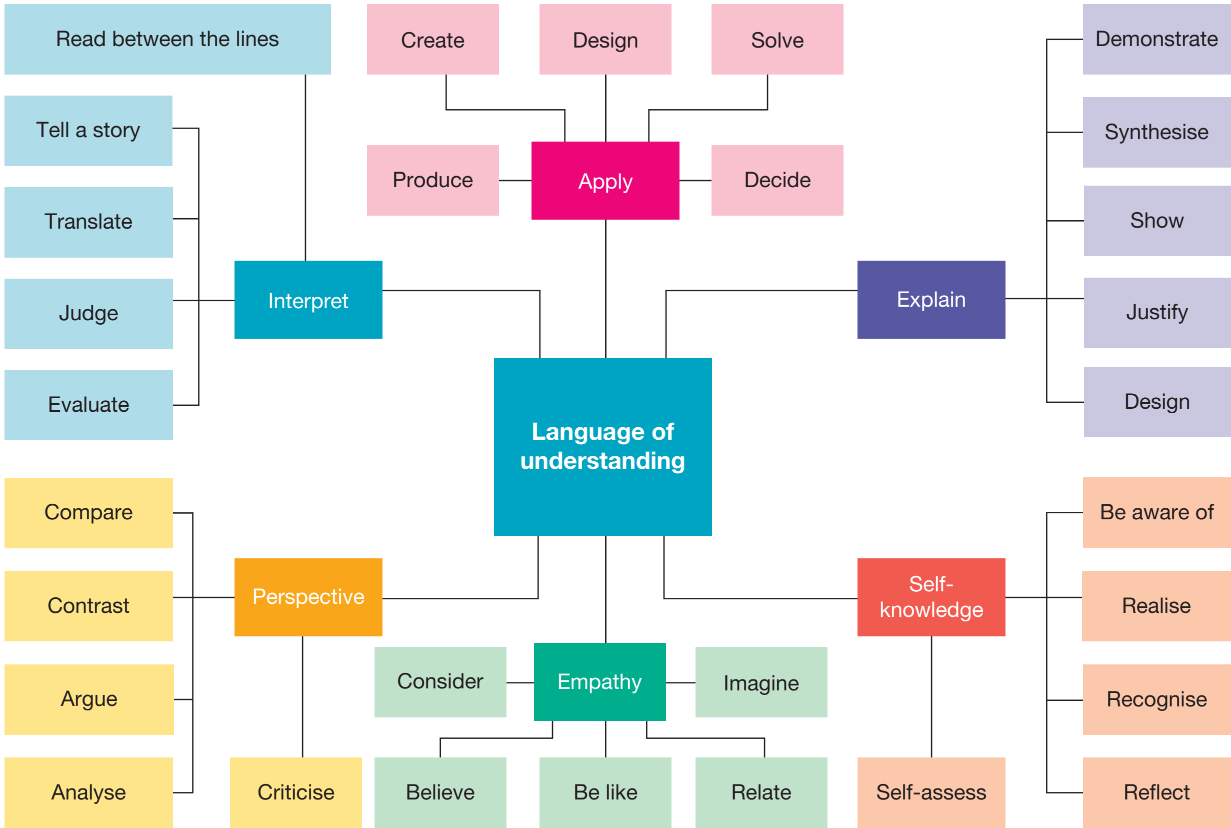


FIGURE 2.20 When you are trying to make sense of words associated with understanding, it is helpful to divide them into categories. There are many different ways of doing this. You just need to find the way that suits you.



on Resources

eWorkbook Language of learning (ewbk-11074)

2.7 Activities

learnon

2.7 Exercise

Select your pathway

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

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- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. State two question words that could require you to respond with the name of something.
2. Identify the term used to ask you what the meaning of something is.
3. Distinguish between the terms ‘contrast’ and ‘compare’.
4. Compare the terms ‘predict’ and ‘evaluate’.

Apply and analyse

5. a. Predict what you are going to have for dinner tonight.
   b. Justify your suggestion in part (a).
6. Demonstrate that you understand the meaning of the term 'deduce'.
7. Explain how you travel to school.
8. Explain why you go to school.
9. a. Formulate five questions of your own about scientific topics.
   b. Suggest how you could find out the answers to them.

Evaluate and create

10. Etymology is the study of the origin of words. Find out about the etymology of one of the question words from figure 2.20 and report on it.
11. Create a rhyme, story, poem or song to help you remember the meaning or use of four question words from figure 2.20, and clearly explain its meaning.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
2.8 Feeding your brain

LEARNING INTENTION

At the end of this lesson you will be able to describe which foods the brain and body need to maximise your alertness and energy levels.

2.8.1 Brain 'food'

Your brain needs two key things to function properly: oxygen and glucose. When you breathe, you provide the necessary oxygen and when you eat, the food breaks down into glucose.

Thinking about how and when you eat

It is better for your brain if you nibble during the day, rather than having one or two big meals. Too much time between meals can cause loss of concentration and decreased alertness. Do you eat to get rid of hunger or boredom, rather than for optimal learning? Before you put that next piece of food into your body, think what else it can do for you!

2.8.2 Feeling thirsty?

Dehydration is a very common problem that is linked to poor learning. As the brain is made up of 80 per cent water, it is important to stay hydrated. Dehydration can result in a loss of attentiveness, and then tiredness, laziness and sluggishness can set in.

When you feel thirsty it means that the amount of water in your body has dropped, and that the salt concentration in your blood is increasing. An increase in salt levels in your blood can lead to the release of fluids from your cells into your bloodstream. This can result in an increase in your blood pressure and increase in stress. Drinking water can decrease these effects within five minutes.

FIGURE 2.21 Water is crucial for brain function

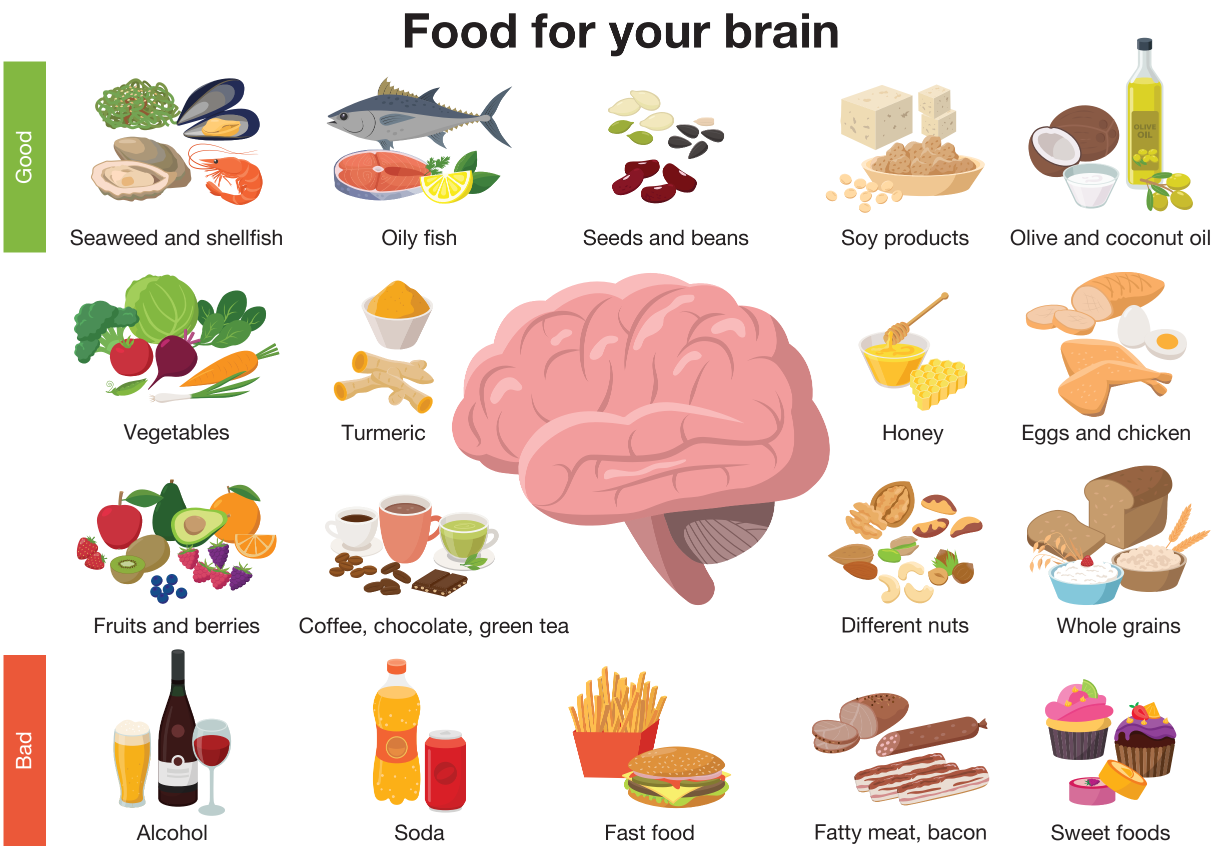
2.8.3 'Brekkie' for the brain

Some of the foods that you eat contain proteins. Protein is good for boosting your alertness and mental performance and includes foods such as eggs, fish, turkey, tofu, pork, chicken and yoghurt. This is because proteins are made up of amino acids, which can have different effects on the brain. For example, the amino acid tyrosine enhances thinking, while tryptophan has a calming effect.

Your brain also uses tyrosine to make chemical messengers such as dopamine and norepinephrine, which are very important for alertness, quick thinking and fast reactions. Norepinephrine enables your body to 'get up and go' when action is required. This might be when you are riding a roller-coaster, are involved in an accident, or when there is a conflict of which you need to 'fight' your way out. At school, norepinephrine may be useful in doing maths calculations, maintaining your attention span and increasing your conscious awareness.

In these types of situations, norepinephrine is released all over your body and it increases the blood flow to your brain, which increases your alertness. Too much norepinephrine can make you feel 'hyper' and stressed; too little can cause drowsiness and make you feel 'out of it'. If you want to get your day going, a 'thinking breakfast' including any of the foods listed in figure 2.22 would be a great start!

Figure 2.22 Your brain needs a variety of foods to provide the necessary nutrients, vitamins and minerals for it to function at its best.



2.8.4 Minerals and your A, B, Cs

Vitamins that are very important to learning include vitamins A, C, E and most of the Bs. These vitamins assist our alertness, memory, visual–spatial ability, attention span and planning or organisational skills.

Minerals that are important to learning include magnesium, sodium, potassium, zinc, iron, boron and selenium.

on Resources

eWorkbook You are what you eat (ewbk-11076)

2.8 Activities

learn**on**

2.8 Exercise

Select your pathway

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

Remember and understand

1. State the two ‘foods’ that your brain is most hungry for.
2. What is the name of the chemical that is the sole source of fuel for your brain cells?
3. Why is dehydration linked to poor learning?
4. List five examples of protein-rich foods that are best for boosting your alertness and mental performance.
5. Name the chemical in milk and yoghurt that acts as a ‘cleaner’ for the spaces between your neurons.

Apply and analyse

6. **a.** Megadoses of vitamins can be toxic. Find out the recommended amounts of vitamins A, B, C and E for your age group.
   b. Many vitamin supplements are absorbed better if taken with some foods. Find out which foods increase absorption and which decrease absorption.
7. **a.** List four foods that are sources of tyrosine.
   b. What is the link between tyrosine and norepinephrine?
   c. Suggest how norepinephrine is useful for your learning.
8. Brainstorm a list of examples of thinking foods. Survey your school canteen or cafeteria to find out how many of these thinking foods they have.

Evaluate and create

9. Design an experiment to find out what type of breakfast food keeps you alert for the longest time during the day.
10. **a.** Keep a diary for a week to determine which times of day you find learning and thinking the easiest and the hardest. Include what and when you have eaten in your diary.
    b. Do you have learning highs and lows?
    c. Does the type of food eaten or time it was eaten have any effect?

Fully worked solutions and sample responses are available in your digital formats.

LESSON
2.9 Discovering your brain

LEARNING INTENTION

At the end of this lesson you will be able to describe the structure of the brain and explain the mechanism by which the brain connects thoughts and ideas.

2.9.1 How often have you thought about your brain?

Throughout the day your brain is constantly registering your environment and monitoring vital signals such as your heart, hormone levels, breathing and digestion. It is also continually matching new learning with that from your past, and attaching emotions to each event and thought, to make patterns of meaning that make up the 'total picture'.

2.9.2 Celebrating your cerebrum

The largest part of the brain is called the **cerebrum**. It makes up about 80 per cent of your brain and is responsible for higher order thinking and decision making. Your cerebrum is made up of billions of nerve cells (called **neurons**), with four primary areas called **lobes**. The functions of the four lobes are described in the diagram in figure 2.23.

cerebrum the largest part of the brain, responsible for higher order thinking and decision making

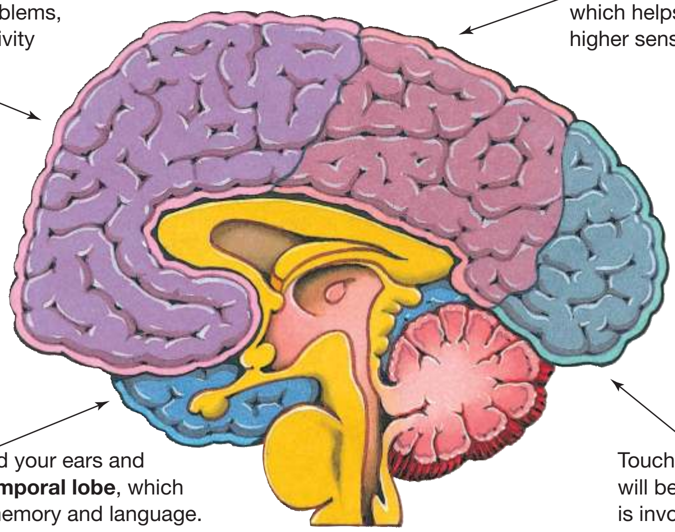
neuron cell designed to carry electrical impulses by which the nervous system functions nerve cells

lobe one of the four primary areas of the cerebrum

int-8164

ewbk-11078

FIGURE 2.23 The four primary areas of your cerebrum are called lobes.



2.9.3 Left and right — two brains in one?

Your cerebrum is also divided into left and right sides or hemispheres. Although each hemisphere processes information differently, they are both involved in putting together the total picture of what you sense around you. For example, when you listen to someone speak, your left side processes words, definition and language. Research suggests that the right side processes the inflection, tones, tempo and volume of the speaker, which assists in getting meaning of the conversation rather than just the words.

2.9.4 Windows of your brain

Next time you enter your classroom, notice what you see around you. Are there any posters, plants, colours, objects or shapes? Because 80 - 90 per cent of all information absorbed by your brain is usually visual, changes in colour, size, contrast, shape and movement around your environment are very important. Your eyes can register 36 000 visual messages in an hour, and about 40 per cent of all the nerve fibres in your brain are connected to the retinas in your eyes.

2.9.5 Your brain is unique

Like your thumbprint, your brain is unique. Not only may it be a different size and weight from your friends, but the learning connections between cells in your brain are different. These connections are made as a result of your experiences and this forms your own personal 'cognitive map', which can change over time as you build up more experiences. This difference in our brain's 'internal wiring' can explain why people at the scene of the same accident can have such different eyewitness reports.

ACTIVITY: Juggling jigsaws

In Juggling jigsaws, each member (or pair) of the team specialises in one specific part of the learning task. Once their part in the learning task is mastered, they become experts on it. The team then reunites and each expert (or expert pair) teaches the others in the team what they have learned.

Expert Team 1 challenge

Each member is to research a part of the brain that is mentioned in lesson 2.9. Find out the facts and any interesting research on this part of the brain and how it may be involved in learning. Share your findings with the rest of your Expert Team.

Expert Team 2 challenge

Each member is to find as many songs or poems about the brain as they can. Share your findings with the rest of your Expert Team.

Expert Team 3 challenge

Collectively this team needs to summarise information from lesson 2.8 and create a song with actions that they can teach to each other and then to the rest of the class.

Expert Team 4 challenge

This team needs to design a classroom that they consider will be an effective learning environment. They then need to build a model of this wonderful learning classroom.

ACTIVITY: Setting goals, being persistent and failing wisely

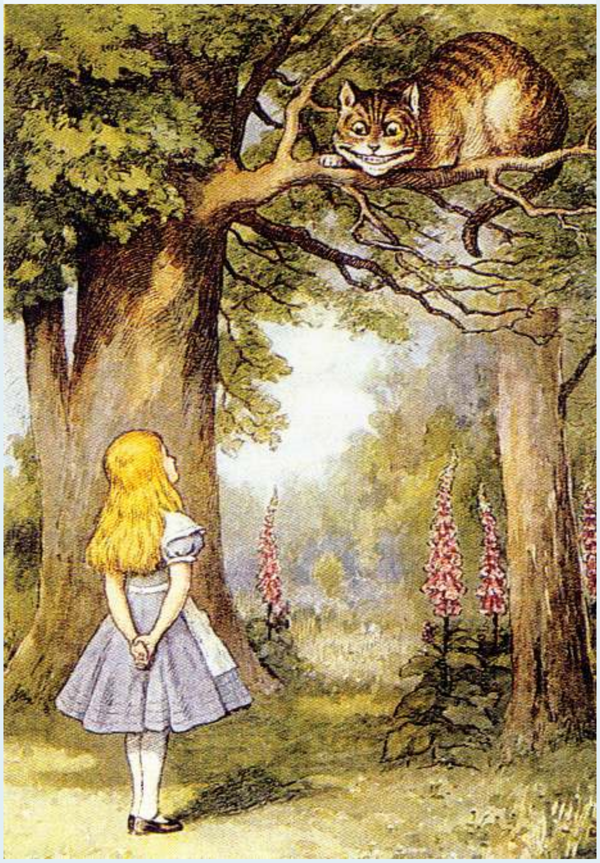
Have you thought about your thinking and learning throughout this topic? Have you reflected on the 'mountains and valleys' of your learning?

1. Construct a learning and thinking journal that includes answers to the following questions.
   a. How, what, where and when have you learned most effectively?
   b. Which of your social and collaborative skills were the most developed? Which of these skills would you like to focus on developing in your next unit of study?

c. How well did you set goals and how well did you meet them?
d. Were you persistent or did you give up when things got a bit too tough, hard or uncomfortable for you?
e. Everybody fails at some time. It is okay to fail. The important thing is what happens after you fail. Have you failed wisely? What did you learn from failing? How could you use what you have learned to your advantage?

2. Select a classmate(s) you respect and have learned to trust during your recent learning. Listen to each other talk about some key points of this learning journey. Share and discuss each other's learning and thinking journals. Make constructive suggestions that may help each other's learning.
3. In a pair or team of four, suggest at least six slogans, pictures, visuals, cartoons, stories/fables, quotes or sayings that could be used as prompts to help you to become effective learners.
4. What do you think the Cheshire Cat in *Alice in Wonderland* meant when he said, 'If you don't know where you are going, any road will take you there'? Construct a bubble map to record your suggestions.

FIGURE 2.24 If you don't know where you are going, any road will take you there.



2.9 Activities

learnon

2.9 Exercise

Select your pathway

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

Remember and understand

1. State the name of the most complex organ in your body.
2. List five functions of your brain.
3. How is your brain different from that of others in your class?
4. Name the part of your brain that is responsible for higher order thinking and decision making.
5. What is another name for nerve cells?
6. Approximately what percentage of information received by your brain is visual?

Apply and analyse

7. Select one of the environmental influences on learning listed and find out what effects it may have on your body and, consequently, your learning.
   - Colours
   - Type of lighting
   - Plants
   - Room arrangements
   - Seating options
   - Objects
8. Emotions can change the parts of your brain that are most active. Research and report on your findings.
9. Albert Einstein had an average-sized brain. Find out what other sorts of information has been found out about his brain. Which thinking hat are you using?

Evaluate and create

10. Draw an outline of your brain and label the four lobes of your cerebrum. Add to each label why the lobe is important.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
2.10 Thinking tools — Making thinking visible

2.10.1 Tell me

There are so many different ways to see and share what is happening inside your brain. Here are some tools that can be used to make your thinking visible so that you can share and discuss it with others.

Like a builder, it is important for you to use the right tool to get the job done:

- **storyboards**, **flowcharts**, **timelines** and **cycles** are useful tools to sequence your thoughts (figure 2.25)
- **matrixes** and **SWOT analysis charts** are useful when you want to classify or organise your thoughts (figure 2.26)
- **Venn diagrams** and **fishbone diagrams** are useful tools to focus your thoughts, such as when you need to analyse and compare things in order to make a decision (figure 2.26)
- **concept maps**, **PMI charts** and **Y charts** help you to visualise or reflect on an idea (figure 2.27)
- **priority grids**, **target maps**, **continuums** or **pie charts** can be used to quantify or rank ideas (figure 2.28)

There are also times when combinations of these tools can help you to use your brain and time more effectively. You will find these thinking tools explored further throughout lessons before the review in Science Quest 7–10.

storyboard a visual thinking tool that shows order and sequence

flowchart a visual thinking tool that shows order and sequence

timeline a visual thinking tool that helps sequence thoughts

cycle a visual thinking tool that shows order and sequence

matrixes thinking tools that can be used to compare properties of multiple topics

SWOT analysis chart a visual thinking tool that helps classify or organise thoughts

Venn diagram a visual thinking tool that analyses and compares

fishbone diagram a visual thinking tool that identifies causes of an event

concept map a visual thinking tool that shows the connection between ideas

PMI chart a thinking tool that helps you visualise and reflect on an idea, consisting of three columns headed 'plus', 'minus' and 'interesting'

priority grid a thinking tool that helps quantify or rank ideas

target map a visual thinking tool that analyses and compares

continuum a visual thinking tool that shows extremes of an idea or where people 'stand' on a particular idea or issue

pie chart a diagram using sectors of a circle to compare the size of parts making up the whole; also called a sector graph

2.10.2 Show me

FIGURE 2.25 Thinking tools that help you order or sequence your thoughts

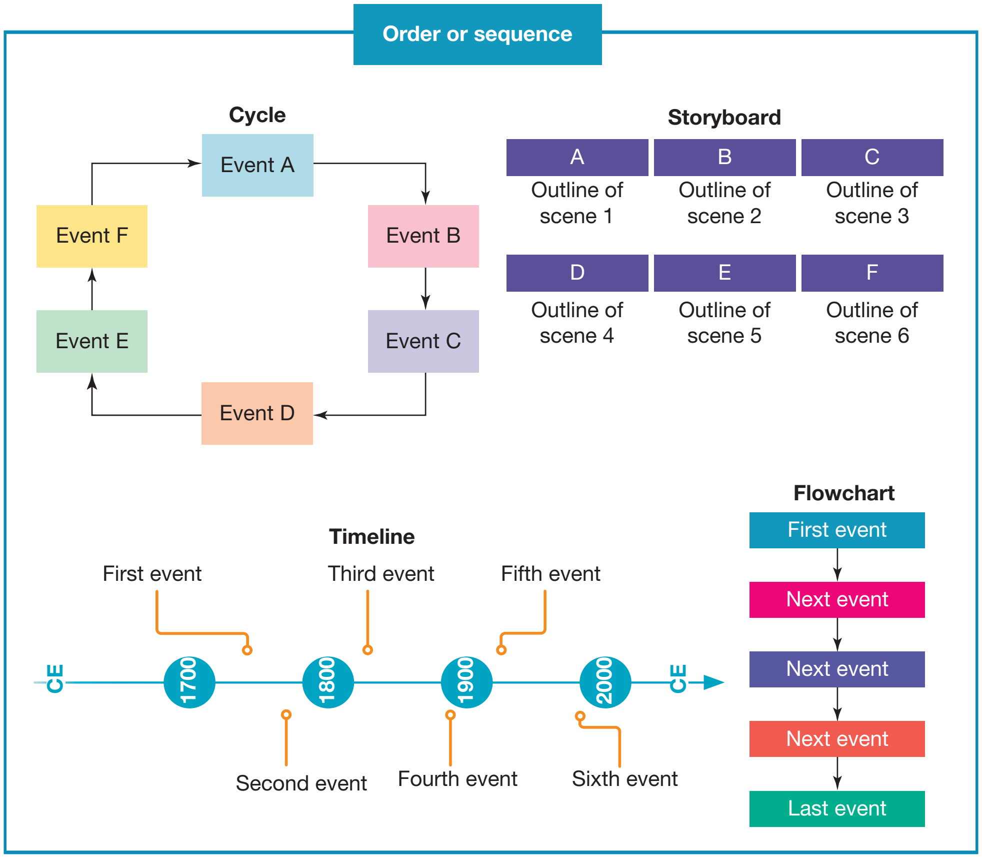


FIGURE 2.26 Thinking tools that help you analyse or compare your thoughts

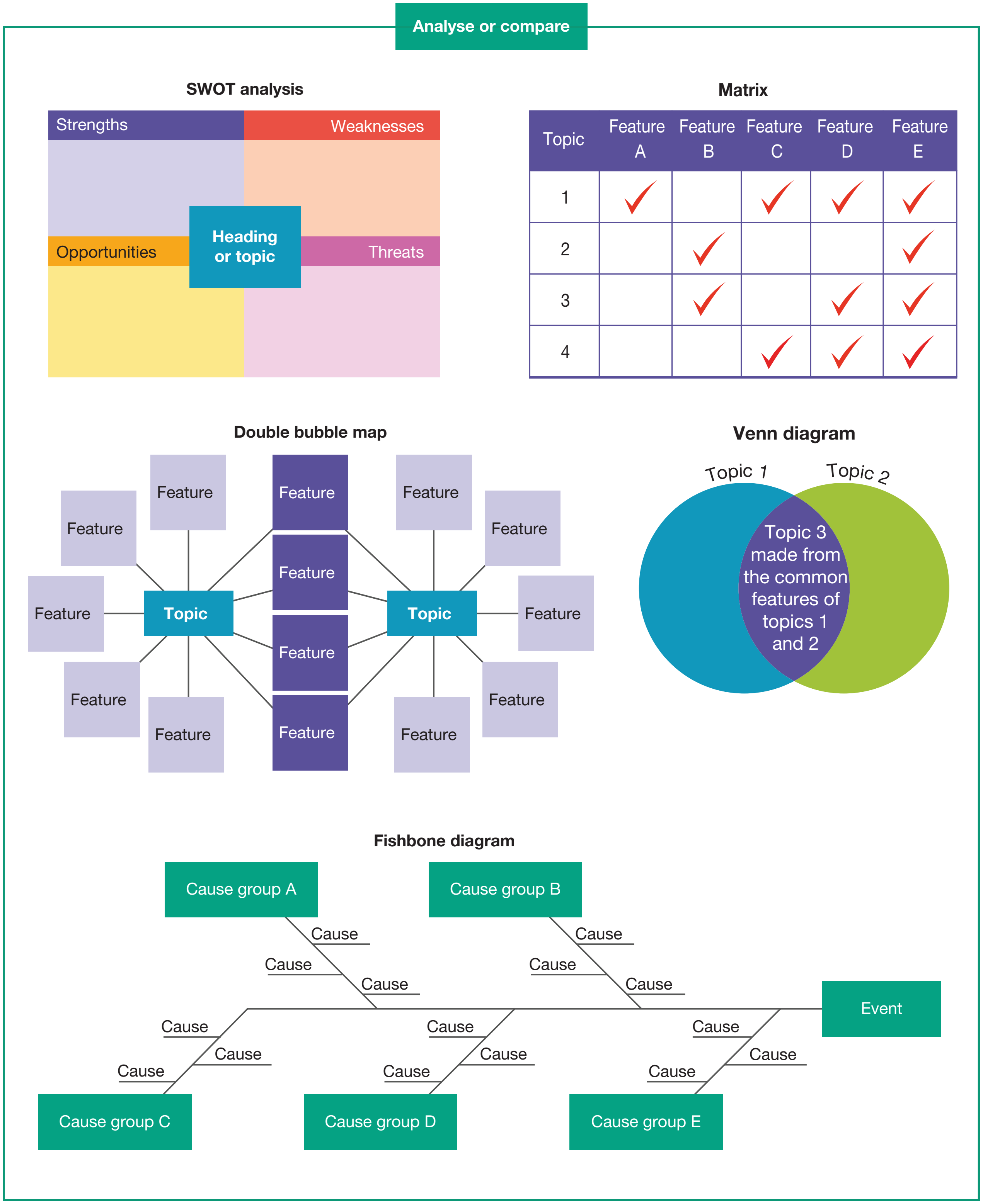


FIGURE 2.27 Thinking tools that help you visualise or reflect on your thoughts

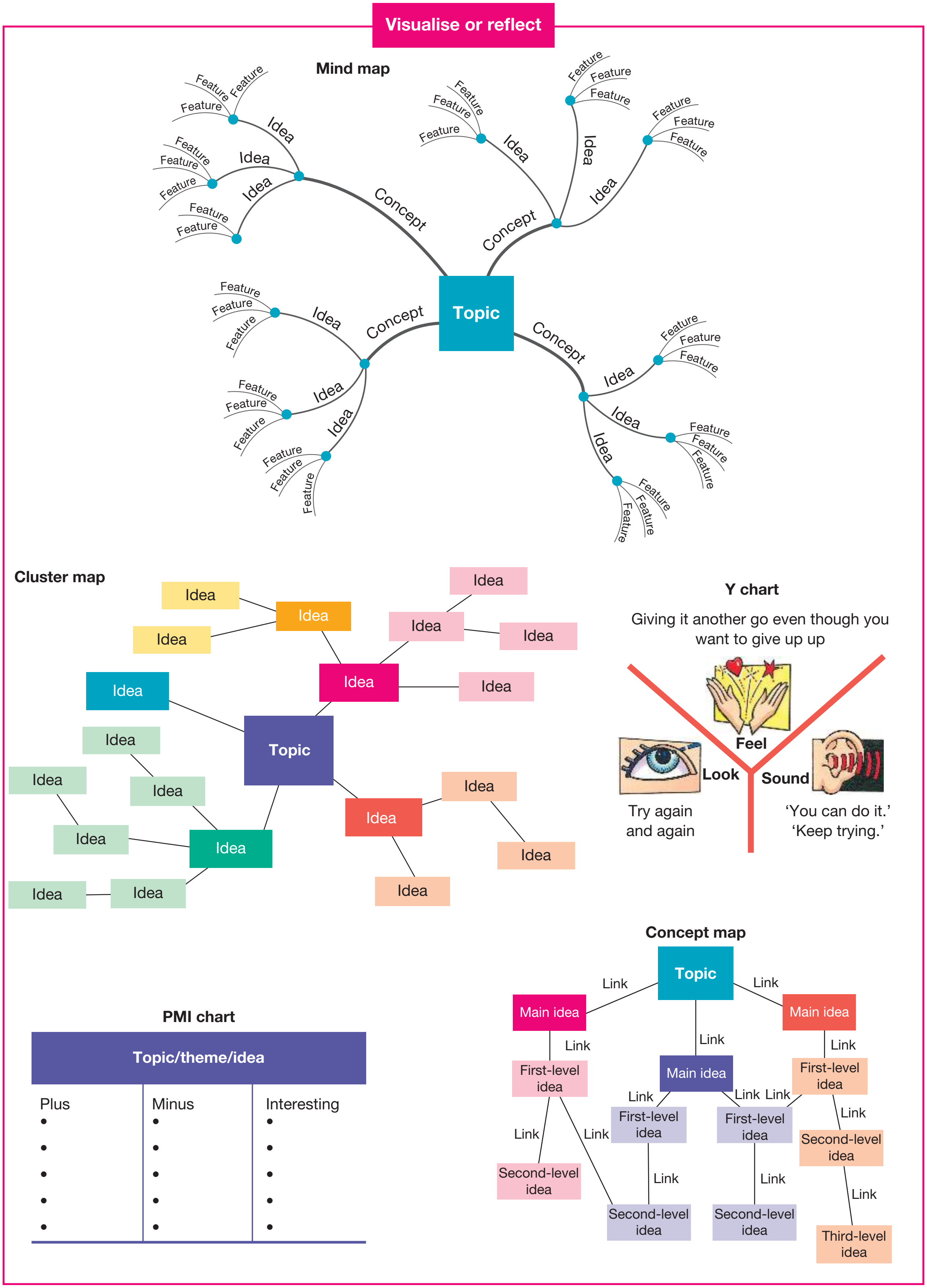
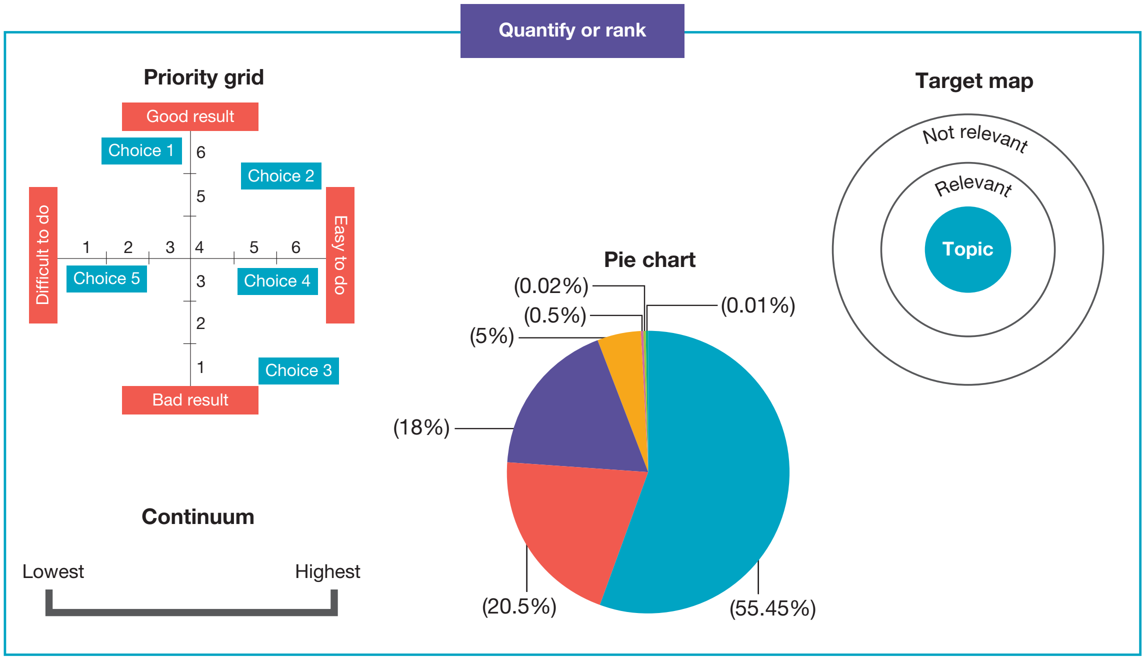


FIGURE 2.28 Thinking tools that help you quantify or rank your thoughts



2.10.3 Let me do it

2.10 Activities

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

1. MC Which visual thinking tools are useful tools to sequence your thoughts?
   A. Storyboards and SWOT analysis
   B. Storyboards and flowcharts
   C. Flowcharts and Venn diagrams
   D. Timelines and Venn diagrams
2. MC Which visual thinking tool would be most appropriate to compare the similarities and differences between plant and animal cells?
   A. SWOT analysis
   B. Timeline
   C. Flowchart
   D. Venn diagram
3. State the visual thinking tools that are best for helping you to:
   a. sequence your thoughts
   b. classify information
   c. quantify or rank ideas
   d. analyse and compare.
4. Select and construct a different visual thinking tool to respond to each of the following.
   a. To instruct someone how to tie a shoelace or a necktie
   b. The similarities and differences between the stories of *Goldilocks and the Three Bears* and *Jack and the Beanstalk*
   c. The amount of chocolate eaten in a week for each member of your class

Fully worked solutions and sample responses are available in your digital formats.

LESSON
2.11 Review

Hey students! Now that it's time to revise this topic, go online to:

Review your results | **Watch teacher-led videos** | **Practise questions with immediate feedback**

Find all this and MORE in jacPLUS

Access your topic review eWorkbooks

on Resources

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-11088	ewbk-11090	ewbk-11092

2.11.1 Summary

Understanding learning and thinking

- There are many different types of learning.
- Auditory learning involves musical, rhythmic, verbal or linguistic activities. Auditory learners may learn by singing a melody and changing lyrics to content they are trying to remember.
- Visual learning involves seeing or visualising concepts. Visual learners may best remember things when they see them, rather than when they hear about them.
- Kinaesthetic learning involves movement, touch and feel. Kinaesthetic learners may remember things better if they actively do something such as a build a model, act out a scenario or do a hands-on experiment.
- Interactive learning involves collaboration with other people. Interactive learners may learn best when they discuss a topic in a group or team.

Types of intelligence

- Howard Gardner introduced the theory of the eight different types of intelligence. They are:
  - bodily/kinaesthetic intelligence
  - verbal/linguistic intelligence
  - logical/mathematical intelligence
  - visual/spatial intelligence
  - musical/rhythmic intelligence
  - interpersonal intelligence
  - intrapersonal intelligence
  - naturalist intelligence.
- Bena Kallick and Arthur Costa developed the theory of 16 thinking behaviours called the 'habits of mind'.
- Y charts can be used to document what the mindful habits may look, feel and sound like.

Thinking keys

- Tony Ryan developed the idea of 12 'thinking keys' that can be used to focus your brain in certain ways.
- The thinking keys can be used to switch you on, open different doors of your thinking, unlock your thinking or unlock your feelings.

Unlocking learning

- Simply listening is not the most effective way of learning new information.
- In order to learn most effectively you must become an active listener, asking questions and probing for more information to consolidate your knowledge.
- If you are able to link new information to things you already know you will have a much greater chance of understanding it.

Question keys

- Questions will often use very specific language that informs what you need to do to answer them satisfactorily.
- For example, a question that asks you to *justify* will require a more detailed response than a question that asks you to *identify*.

Feeding your brain

- Your brain requires food to act as fuel and keep it powering on throughout the day.
- The source of energy for the brain is glucose, which is a sugar found in many foods.
- Dehydration can lead to tiredness, laziness, sluggishness and a loss of attentiveness.
- Protein is important to your brain as it boosts alertness and mental performance.
- Vitamins and minerals assist alertness, memory, attention span and planning or organisational skills.

Discovering your brain

- Information is retrieved from the brain by nerve cells (neurons) firing along different paths within the brain.
- The largest part of your brain is called the cerebrum. It makes up about 80 per cent of your brain and contains four primary areas; the frontal lobe, the parietal lobe, the temporal lobe and the occipital lobe.
- The cerebrum is also split into the left and right hemispheres.
- Approximately 40 per cent of the nerve fibres in your brain are connected to the retinas in your eyes.

2.11.2 Key terms

auditory learning learning through listening
cerebrum the largest part of the brain, responsible for higher order thinking and decision making
concept map a visual thinking tool that shows the connection between ideas
continuum a visual thinking tool that shows extremes of an idea or where people 'stand' on a particular idea or issue
cycle a visual thinking tool that shows order and sequence
fishbone diagram a visual thinking tool that identifies causes of an event
flowchart a visual thinking tool that shows order and sequence
habits of mind types of thinking behaviours promoted by Bena Kallick and Arthur Costa
kinaesthetic learning using touch or manipulating materials to learn
lobe one of the four primary areas of the cerebrum
matrixes thinking tools that can be used to compare properties of multiple topics
multiple intelligences eight types of intelligences suggested by Howard Gardner
neuron cell designed to carry electrical impulses by which the nervous system functions nerve cells
olfactory learning using the sense of smell to learn
pie chart a diagram using sectors of a circle to compare the size of parts making up the whole; also called a sector graph
PMI chart a thinking tool that helps you visualise and reflect on an idea, consisting of three columns headed 'plus', 'minus' and 'interesting'
priority grid a thinking tool that helps quantify or rank ideas
social learning collaborating and sharing with peers to learn
storyboard a visual thinking tool that shows order and sequence
SWOT analysis chart a visual thinking tool that helps classify or organise thoughts
target map a visual thinking tool that analyses and compares

thinking hats a thinking tool developed by Edward de Bono using different coloured hats for different types of thinking
thinking keys a tool developed by Tony Ryan to help unlock thinking
timeline a visual thinking tool that helps sequence thoughts
Venn diagram a visual thinking tool that analyses and compares
visual learning using text or images to learn
Y chart a visual thinking tool that helps you visualise and reflect

on Resources

Digital document	Key terms glossary (doc-39620)
eWorkbooks	Study checklist (ewbk-11081) Reflection (ewbk-11080) Literacy builder (ewbk-11082) Crossword (ewbk-11084) Word search (ewbk-11086)

2.11 Activities

learnon

2.11 Review questions

Select your pathway

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

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

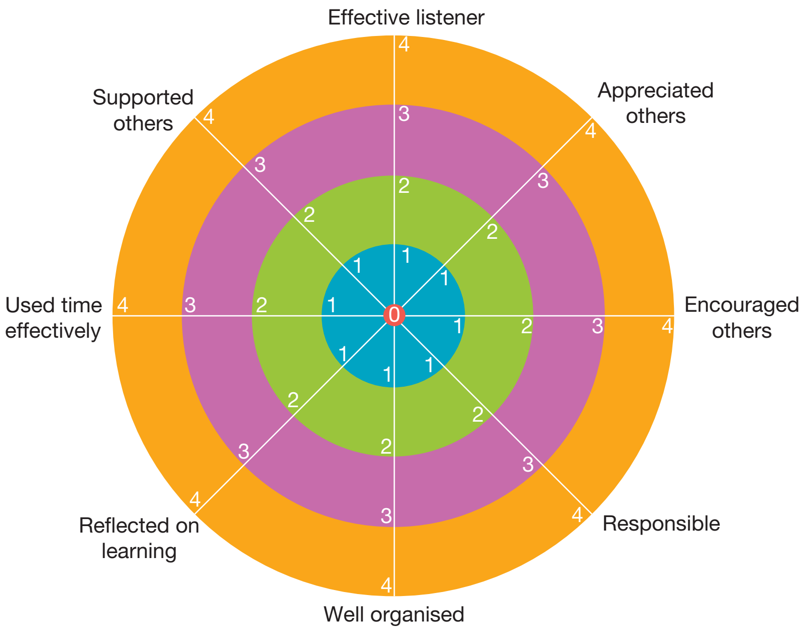
Find all this and MORE in jacPLUS

Remember and understand

1. Create a mind map to show what you have learned in this topic.
2. State examples of at least five:
   a. thinking keys
   b. mindful habits.
3. Select the appropriate language of learning category (interpret, apply, explain, perspective or self-knowledge) of the following.
   a. Produce
   b. Reflect
   c. Contrast
   d. Criticise
   e. Translate
   f. Relate
   g. Self-assess
   h. Decide

Apply and analyse

4. What type of learner would you describe yourself as?
5. a. Use the learning wheel given to score how effective you think you have been as a team member during your learning about the brain. Give yourself a mark or dot out of 4 for each of the traits in the learning wheel. You should use the following scale: 0 = needs a lot of improvement; 1= needs improvement; 2 = okay; 3 = very good; 4 = excellent.
   b. Join the dots together to show your team profile.
   c. Comment on your strengths as a team member and suggest ways that you could improve in areas in which you did not score highly.



6. a. Reflect on your learning style and find out your profile in the learning wheel given. You should use the following scale: 0 = needs a lot of improvement; 1= needs improvement; 2 = okay; 3 = very good; 4 = excellent.
   b. What other sorts of learning factors are there? Make a list of them and construct another 'wheel of learning'. First find out your own learning profile and then get other team members to try it out.
   c. Compare your learning wheel with those of your teammates. Use a Venn diagram to show how they are similar and different.
   d. Survey the class to find out the overall pattern of the learning wheel. Is this the pattern that you would have expected? Discuss your view with others in the class. Suggest ways in which you could use this information.

7. Use the 'alphabet' key to summarise points that you have learned in this topic.

Evaluate and create

8. Construct a cluster map or concept map to outline the following.
   a. Ways to work as a team
   b. Learning how to learn
9. Create a cartoon or picture book to explain why protein foods are best for boosting your alertness and mental performance. Include examples of foods that are good sources of protein.

Fully worked solutions and sample responses are available in your digital formats.

Online Resource

on Resources

Below is a full list of **rich resources** available online for this topic. These resources are designed to bring ideas to life, to promote deep and lasting learning and to support the different learning needs of each individual.

2.1 Overview

eWorkbooks
- Topic 2 eWorkbook (ewbk-11061)
- Student learning matrix (ewbk-11066)
- Starter activity (ewbk-11063)
- Your quest (ewbk-11065)

Video eLesson
- Unlocking learning: flowcharts, cluster maps and concept maps (eles-0856)

2.3 Types of intelligence

eWorkbook
- Intelligence toolbox (ewbk-11068)

2.4 Thinking keys

eWorkbook
- Thinking keys (ebwk-11070)

2.5 Learning together

eWorkbook
- Mapping your future (ewbk-11072)

2.6 Unlocking learning

Interactivity
- What do you think when you are introduced to something new? (int-6596)

2.7 Question keys

eWorkbook
- Language of learning (ewbk-11074)

Interactivity
- Question keys can unlock what the question is asking (int-6597)

2.8 Feeding your brain

eWorkbook
- You are what you eat (ewbk-3891)

2.9 Discovering your brain

eWorkbook
- Labelling the lobes in the brain (ewbk-3893)

Interactivity
- Labelling the lobes in the brain (int-8164)

2.11 Review

eWorkbooks
- Topic review Level 1 (ewbk-11088)
- Topic review Level 2 (ewbk-11090)
- Topic review Level 3 (ewbk-11092)
- Study checklist (ewbk-11081)
- Word search (ewbk-11086)
- Literacy builder (ewbk-11082)
- Crossword (ewbk-11084)
- Reflection (ewbk-11080)

Digital document
- Key terms glossary (doc-39620)

To access these online resources, log on to **www.jacplus.com.au**

3 Classification

CONTENT DESCRIPTION

Investigate the role of classification in ordering and organising the diversity of life on Earth and use and develop classification tools including dichotomous keys (AC9S7U01)

LESSON SEQUENCE

SCIENCE INQUIRY AND INVESTIGATIONS

Science inquiry is a central component of Science curriculum. Investigations, supported by a **Practical investigation eLogbook** and **teacher-led videos**, are included in this topic to provide opportunities to build Science inquiry skills through undertaking investigations and communicating findings.

LESSON
3.1 Overview

Hey students! Bring these pages to life online

Watch videos | **Engage with interactivities** | **Answer questions and check results**

Find all this and MORE in jacPLUS

3.1.1 Introduction

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

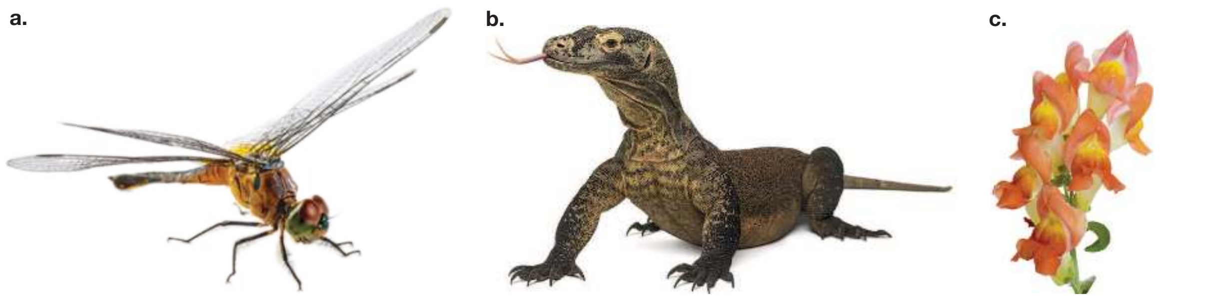
Using names to label things can help us to sort out what we know (what is familiar) from what we do not (what is unfamiliar). We can also look for clues in names to help us to make the unfamiliar, more familiar. Although this linking can often be useful, sometimes it may result in confusion.

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?

FIGURE 3.1 Sea dragon

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 3.1 and compare it to images of other examples of 'dragons' in figure 3.2. Although the sea dragon, Komodo dragon, dragonfly 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 3.2 a. Dragonfly **b.** Komodo dragon **c.** Snapdragon flower



on Resources

Video eLesson Komodo dragons (eles-3274)

Do Komodo dragons share any features with mythical dragons? Is the name dragon appropriate? Watch this video to observe a Komodo dragon in its natural environment and see the features it possesses.

3.1.2 Think about classification

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

3.1.3 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 Komodo dragon, dragonfly, and the snapdragon in figure 3.2.
   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, which 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.

on Resources

eWorkbooks	Topic 3 eWorkbook (ewbk-11108) Student learning matrix (ewbk-11112) Starter activity (ewbk-11110)
Practical investigation eLogbook	Topic 3 Practical investigation eLogbook (elog-1984)
Video eLesson	The weedy seadragon (eles-2067)
Weblink	The ruby seadragon

LESSON
3.2 Classification systems

LEARNING INTENTION

At the end of this lesson you will be able to consider the reasons for classifying living things, identify similarities and differences within and between groups of organisms and be aware that biological classification has changed over time, including systems used by First Nations Australians.

3.2.1 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 a spider.
- 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?

3.2.2 Living, dead or non-living

Prior to classifying organisms, we need a shared understanding of their features. All living things **respond** to changes in their environment, need energy to survive, **assimilate** substances, produce and **excrete** wastes, **grow** and **reproduce**. Features that are common to all living things are outlined in figure 3.3.

One method we can use to sort all things is shown in figure 3.4, in which things can be distinguished as non-living or living. If a living thing stops living, then it is **dead**. If something is **non-living**, then it has never had all of the characteristics of living things. For example, a squashed snail and roast chicken are dead, whereas a rock, a car and a computer are non-living.

classification grouping animals and plants according to their similarities
organisms living things made up of one or more cells
respond react to a stimulus
assimilate take in and process
excrete get rid of waste
grow undergo development
reproduce create offspring
dead once alive but now not alive
non-living not ever alive, as distinct from dead

FIGURE 3.3 Features common to all living things

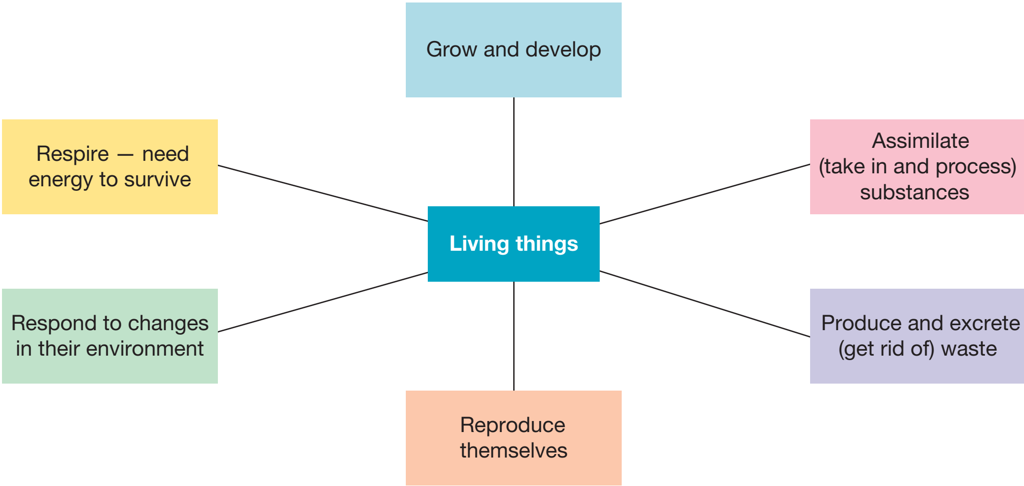
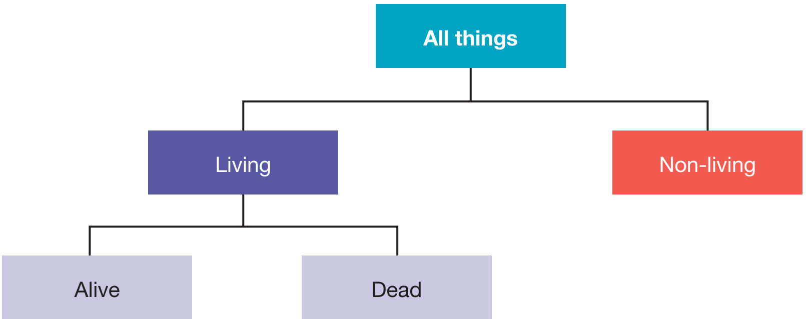


FIGURE 3.4 Living, non-living or dead?



on Resources

eWorkbook Is it alive? (ewbk-11113)

Interactivity Alive, not alive or dead? (int-3422)

3.2.3 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 naturalist, botanist, zoologist and physician Carl Linnaeus (1707–1778) is considered by many to be the 'father of taxonomy' because his classification system formed the basis of our current system.

taxonomy the study of the classification of organisms

kingdom a scientific classification referring to a group of related phyla with similar features and distinctive characteristics

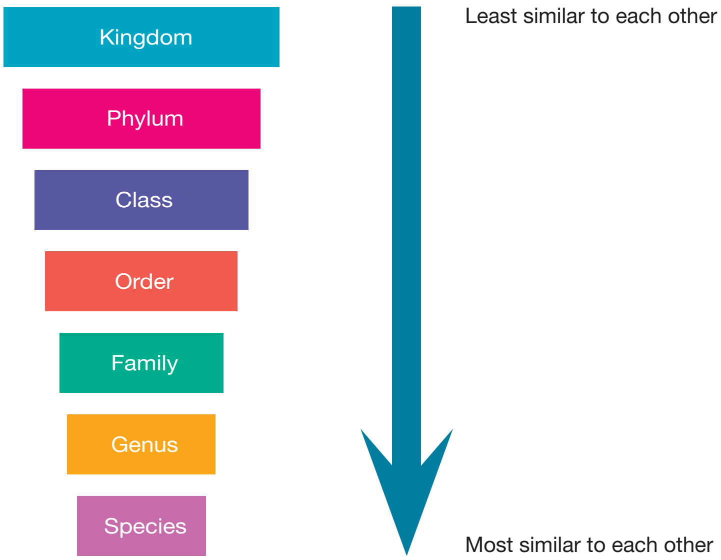
species a group of organisms with many features in common, that can mate with each other to produce fertile young under natural conditions

The Linnaeus classification system

Linnaeus (see figure 3.5) sorted organisms into groups based on their physical similarities. He called the largest grouping **kingdoms** 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 3.6), the more alike its members are.

FIGURE 3.5 A portrait of Carl Linnaeus as a young man

FIGURE 3.6 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.

3.2.4 Classification systems of First Nations Australians

First Nations Australians have developed a complex and diverse classification system that differs significantly from the Linnaeus classification system. This system includes reference to an organism's age, use, stage in life cycle, sex and place within the kinship system. This includes any special significance of the organism to First Nations Australians. Organisms are classified as being edible or inedible, useful or not useful, living or dead. One way First Nations Australians 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 by their use in the community. Turtles, barramundi and dugongs are grouped together as they are all aquatic organisms with fins or flippers.

FIGURE 3.7 First Nations Australians spearfishing from a canoe on Melville Island, Australia

First Nations Australians classification of organisms focusses on their importance to the community and is 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: Discovering 'new' species?

At the time of European colonisation of Australia, First Nations Australians had been living on the continent for thousands of years and had a deep knowledge of their environment.

Early European naturalists such as Joseph Banks, who travelled to Australia with Captain Cook on HMS *Endeavour* and made the first western major collection of Australia fauna, or John Gould, who described hundreds of species of birds and nearly 50 species of mammals, are credited with discovering an abundance of new species in Australia.

However, to the first peoples of the land, these species were not new at all. Early European naturalists used First Nations Australians' vast knowledge of their lands to help in the 'discovery' of native plants and animals.

For instance, the Lumholtz's tree-kangaroo that lives in the rainforests of Far North Queensland is named after Norwegian explorer Carl Sofus Lumholtz, who described it after learning about this animal from the Warrgamay people.

Similarly, by the time the tea tree was first 'discovered' in 1732, First Nations Australians were already using it as traditional bush medicine.

FIGURE 3.8 Lumholtz's tree-kangaroo with joey in pouch, Queensland

A huge chunk of traditional knowledge of Australia's ecosystems has been lost as a result of colonisation and poor treatment of First Nations Australians; however, as a society, we are now more aware of the importance of protecting, embracing and conserving traditional knowledge, skills, culture and customs.

Do you know the name of any of the local plants or animals in the languages of the First Nations Australians in your region? Do you know any bush plants that are edible?

3.2.5 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 very simple structures with all of their contents mixed together. Eukaryotic cells contain small structures called organelles. Organelles have specific jobs to do within the cell.

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.

unicellular made up of a single cell

multicellular made up of many cells

prokaryotic any cells or organisms without a membrane-bound nucleus (e.g. bacteria)

eukaryotic any cells or organisms with a membrane-bound nucleus (e.g. plants, animals, fungi and protists)

virus a non-cellular pathogen that uses the host cells in order to reproduce

viroid the smallest infectious known pathogen, comprised solely of a short single-stranded piece of RNA

prions infectious proteins that can cause disease

microscopy the use of microscopes to view structures that can't be seen with the naked eye

3.2.6 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 to group organisms rather than physical characteristics. Carl Woese 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 3.9 and table 3.1.

FIGURE 3.9 The kingdom system suggested by Woese

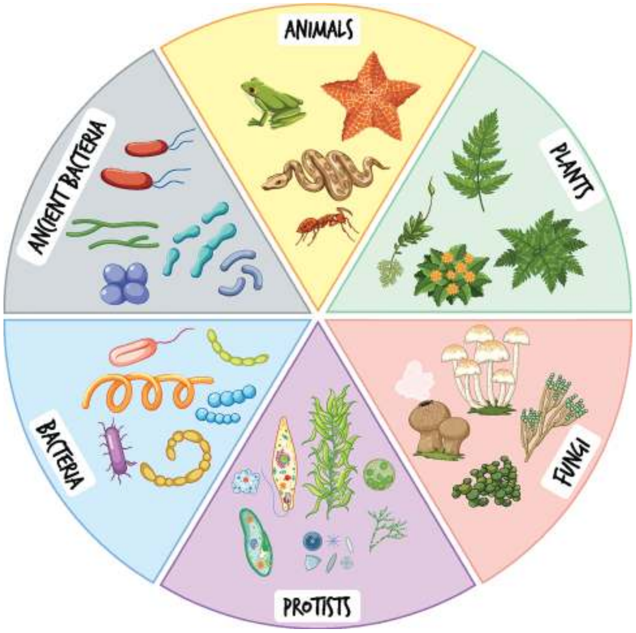


TABLE 3.1 Features used to divide organisms into five kingdoms proposed by Whittaker

Kingdom	Animalia	Plantae	Fungi	Protista	Bacteria	Archaea
Unicellular or multicellular?	Multicellular	Multicellular	Most multicellular; some unicellular	Unicellular	Unicellular	Unicellular
Cell wall	No cell wall	Cellulose cell wall	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 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
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. *E. coli, Staphylococcus aureus)*	Ancient micro-organisms with a similar structure to bacteria

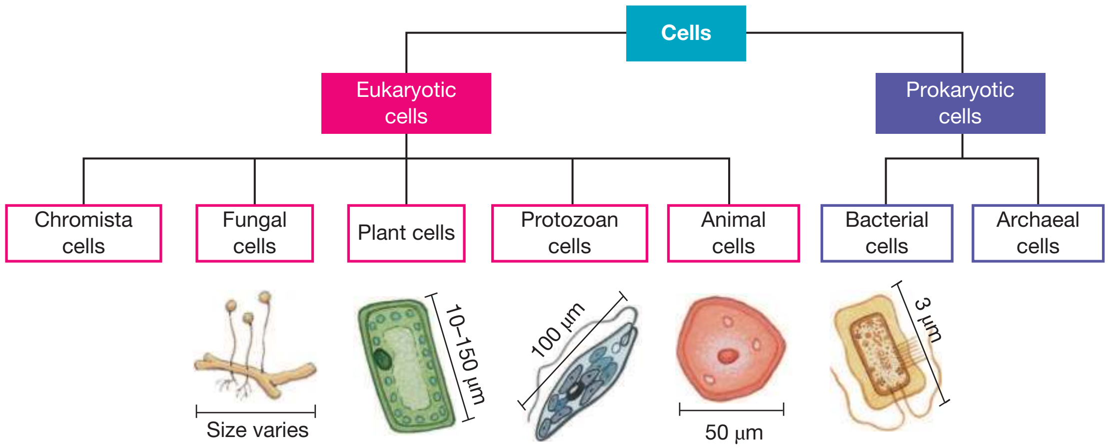
3.2.7 Classification systems are still changing

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 3.10.

int-8232

ewbk-11115

FIGURE 3.10 Current 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.



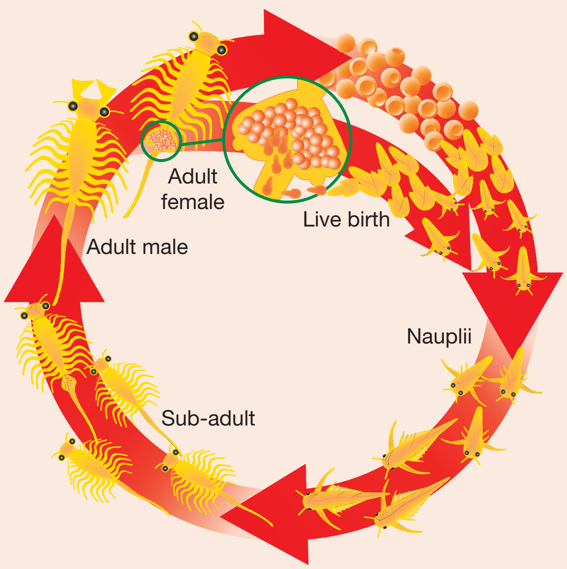
CASE STUDY: Instant life?

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

FIGURE 3.11 The life cycle of the sea monkey (*Artemia salina*)



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. Investigate what it means 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 3.12 Sea monkeys require nutrients and produce waste.

on Resources

eWorkbooks	Five-kingdom classification (ewbk-11117) Creatures from a parallel universe (ewbk-11119)
Video eLesson	Sunflower seedlings (eles-2205)
Interactivity	Kingdoms (int-0204)
Weblinks	What are sea monkeys?

3.2 Activities

learnon

3.2 Quick quiz on | **3.2 Exercise**

Select your pathway

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

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Remember and understand

1. a. Identify whether the statements are TRUE or FALSE.

Statements	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.	

(continued)

(continued)

Statements	True or false?
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 true.

2. Complete these sentences by matching the term on the left with its definition.

Term	Definition
a. Cells …	**A.** describes something that has never been alive (e.g. a clock).
b. Kingdom …	**B.** is the smallest grouping of living things used by Linnaeus.
c. Non-living …	**C.** are the building blocks that make up all living things.
d. Plant …	**D.** describes an organism made up of only one cell.
e. Species …	**E.** is the largest grouping of living things used by Linnaeus.
f. Taxonomy …	**F.** is the use of a formal system for classifying living things.
g. Unicellular …	**G.** is a multicellular organism containing chloroplasts and a cellulose cell wall.

3. Identify two examples of each of the following.

a. A non-living thing **b.** A living organism **c.** A dead thing

Apply and analyse

4. SIS State why scientific definitions of classifications systems sometimes change over time.

5. a. In the table, list two examples for each of the kingdoms shown.

TABLE Examples in the five-kingdom classification system

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

b. Who proposed this classification system of five kingdoms?

c. How does it differ from classification systems used today?

6. Distinguish between the following.

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. **SIS** Justify the practice of scientists classifying living things into groups.
10. a. In the table provided, identify the correct features for each kingdom.

TABLE Features of different kingdoms

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

b. Research and summarise at least three other features within each kingdom.
c. Research the kingdom Chromista. Identify whether these organisms are unicellular or multicellular and if they have a cell wall.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
3.3 Patterns in scientific language

LEARNING INTENTION

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

3.3.1 Historic keys

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.

etymology the study of words, their origin and their grammar

3.3.2 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.

Name me a dino …

Tyrannosaurus, Megalosaurus, Stegosaurus … Did you ever wonder why the dinosaurs had such big names? Do you know what they mean? The term 'dinosaur' was actually decided on by the British anatomist and palaeontologist Sir Richard Owen in 1842. *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 3.13 Based on their structural features, suggest criteria to separate these dinosaurs into groups.

Plants and pigments

The terms 'chlorophyll' and 'chloroplast', for example, 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 (*photo* = 'light' and *synthes*is = 'to make'). The presence of chlorophyll in the chloroplasts is the reason that they (and plants) appear to be green.

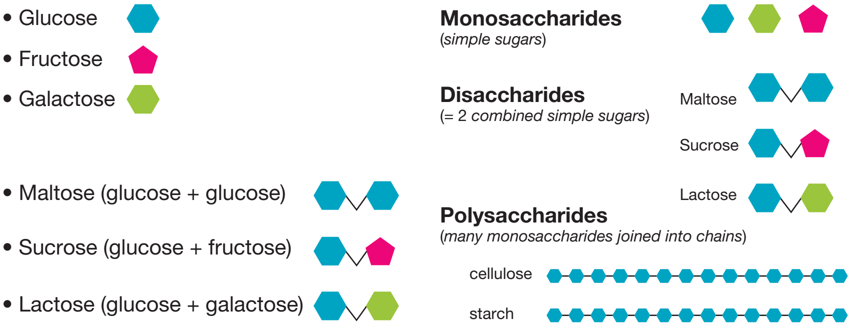
FIGURE 3.14 Chlorophyll, the green pigment located in plant chloroplasts, captures light energy so plants can make their own food.

Leucoplasts (*leuco* = 'white') and chromoplasts (*chromo* = 'colour'), like chloroplasts, are plastids found in plant cells. Leucoplasts are not coloured as 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 made up of two monosaccharides. Starch is a *poly*saccharide and is made up of many monosaccharides.

FIGURE 3.15 Monosaccharides contain only one saccharide; disaccharides are made up of two monosaccharides, and polysaccharides are made up of many monosaccharides.



Cell speak

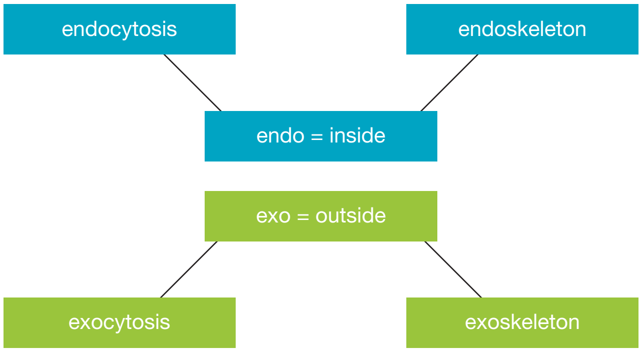
When you study different types of blood cells, you will come across terms containing the suffix or prefix *cyte*. This is a variation of *cyto*, which means 'cell'. Examples of terms that you may come across include:

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

Inside or within

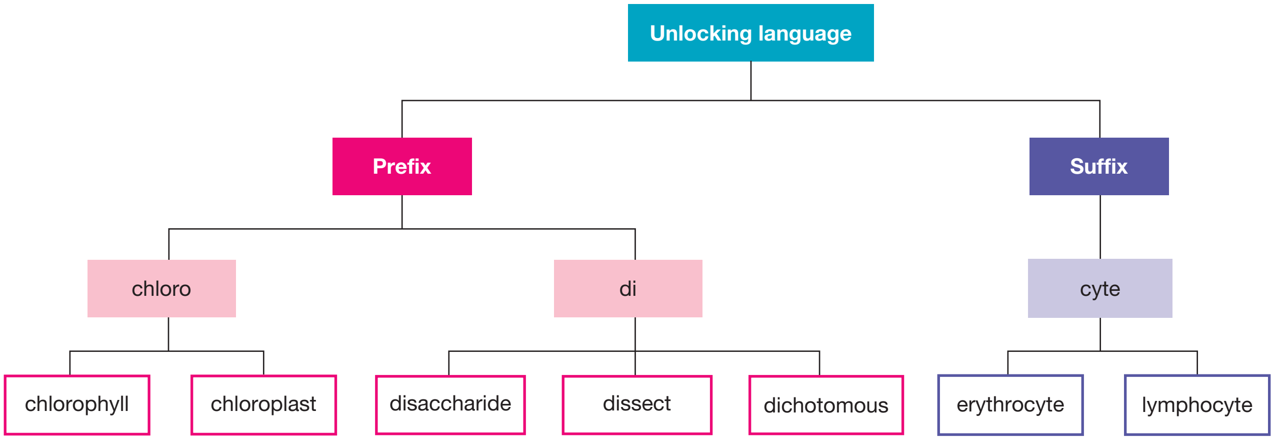
In science, you will learn about endoskeletons, endocytosis, endoplasmic reticulum, the endocrine system and endoparasites. The prefix *endo* in these words tells you that they all have something to do with 'inside' or 'within'. The prefix *exo* (as well as the prefix *ecto*) refers to outside (exoskeleton, 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 3.16 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 3.17 The prefixes and suffixes of scientific terms often give you hints about what they mean.



ACTIVITIES: Terminology cards

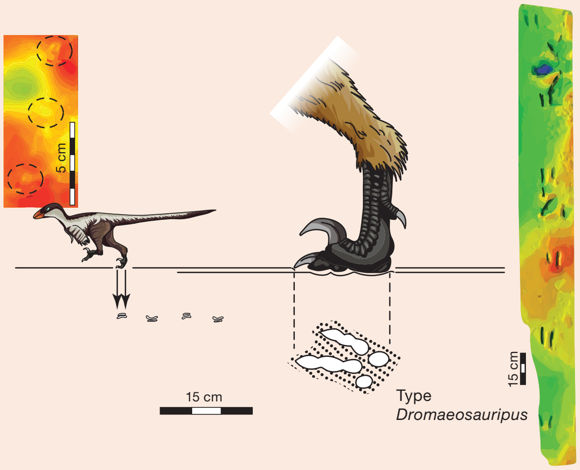
1. Start with a prefix hunt! Find as many different prefixes used in science as you can — for example, chloro-, thermo-.
2. Create your own set of scientific terminology cards, using a particular colour for each prefix and adding a diagram or image for each that provides a hint about its meaning.
3. Design a game that uses the cards to teach students about scientific terminology. Include an instruction brochure or rule book with your game.

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

Dr Anthony Romilo of the University of Queensland knows from experience that dinosaur footprints can be big — and they can be very, very small. He was part of a team in 2017 that recorded enormous 1.7 m fossilised dinosaur footprints in Western Australia.

More recently, in South Korea with another team, he recorded the smallest ever fossilised dinosaur footprints. These 1 cm-long tracks suggested that the dinosaur that made them could fit into your hand! Although tiny, this dinosaur, who is related to the *Velociraptor* predatory dinosaurs in the 1993 movie *Jurassic Park*, was given a very big name: *Dromaeosauriformipes rarus.*

FIGURE 3.18 *Dromaeosauriformipes rarus* compared to the foot and track of the *Dromaeosauripus jinjuensis*



Resources

Weblink Tiny raptor tracks big discovery

ACTIVITIES: 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 (refer to the lesson 2.10 Thinking tools if you need assistance on creating Venn diagrams).
   a. *Microceratops* and *Triceratops*
   b. *Triceratops* and *Pentaceratops*
   c. *Microdontosaurus* and *Heterodontosaurus*
   d. *Microdontosaurus* and *Microceratops*
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.
5. Create a specific question that could be researched for each type of dinosaur.
6. Write a paragraph to discuss what you have learnt about the prefixes used in scientific terms.

Microceratops
- Name means ‘small-horned face’
- Only 76 cm long
- Lived about 83–65 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

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

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

elog-0382

INVESTIGATION 3.1

Cryptonym game

Aim

To increase familiarity with scientific prefixes and suffixes

Materials

- Blank cards
- Pen or marker

Method

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

TABLE The origin of some scientific terms

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

Results

The first team member to identify the term gets to shuffle the cards and act out the next term. Record the terms you guessed correctly, the terms you provided clues for and the terms you missed.

Discussion

1. A *crypto*graph refers to secret writing and a *crypto*nym 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. What were some of the biggest challenges that you faced in this task?
4. Suggest how you could transfer what you have learned in this activity to predicting the meanings of scientific terms.

Conclusion

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

on Resources

eWorkbook Unlocking scientific language (ewbk-11121)

Interactivity The language of science (int-0935)

3.3 Activities

learn**on**

3.3 Quick quiz **on**	3.3 Exercise

Select your pathway

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

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Remember and understand

1. a. Identify whether the statements are TRUE or FALSE.

Statements	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 true.
2. State the difference between the terms 'prefix' and 'suffix'.
3. MC Which of the following is a suffix that sugars may share in their names?
   A. Saccharide B. Cyte C. Plast D. Synthesis
4. Identify the shared feature between each group of terms.
   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.

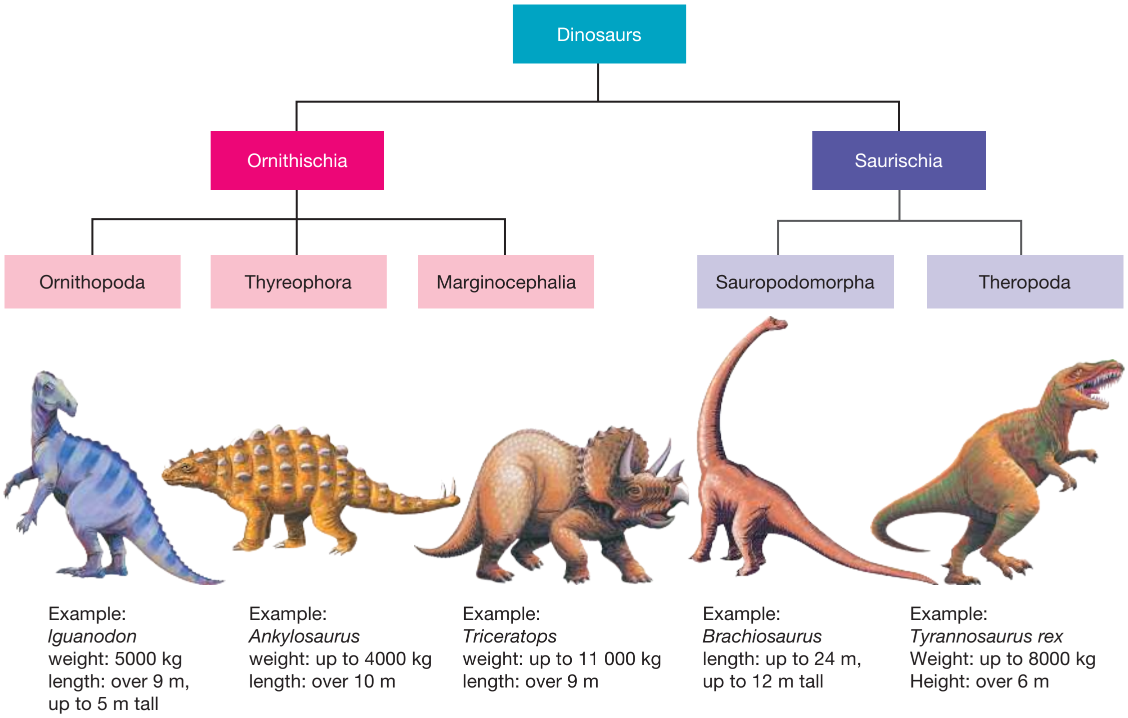
Apply and analyse

7. SIS Chlorine is an element. Based on its name, predict the colour of chlorine.
8. Find out the definition and two key points for the following terms
   a. endocytosis b. endoskeleton c. exocytosis d. exoskeleton
9. Find at least five examples of scientific terms that begin with the following prefixes: *endo, bio, anti, chloro, thermo, bi, hetero*.

10. Determine the role of palaeontologists.
11. a. Predict the prefixes for *one, two, three, four, ten* and *hundred* that have originated from Latin or Greek words.
    b. Find out whether your predictions for part a were correct.
    c. State an example of a scientific term that uses each prefix.
12. Answer the following questions.
    a. Predict the meaning of each of the terms.
        i. Microscope, telescope, periscope
        ii. Millimetre, centimetre, nanometre, kilometre
        iii. Binary fission, dichotomous key, binocular
        iv. *Tyrannosaurus, Pterosaurus, Stegosaurus*
        v. Anatomist, scientist, palaeontologist
        vi. Cardiac, renal, pulmonary
        vii. Dehydrated, deoxygenated, denatured
    b. Find out whether your predictions were correct.
    c. SIS Based on the structure of each of the words, explain what is similar and what is different about each of the terms in the groups list in part a.

Evaluate and create

13. Throughout history, coloured pigments from plants and animals have been used by humans. Find out about two plant and two animal examples. Identify the scientific names of the pigments and what they mean.
14. SIS Research the life and scientific contributions of Sir Richard Owen in 1842. Construct a timeline to summarise your findings.
15. Provide an example of a contribution an Australian palaeontologist has made to our understanding of ancient life in Australia.
16. Use the information in the diagram provided to construct the following Venn diagrams.
    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



17. SIS Research examples of Australian megafauna. Formulate clues within their names that help describe what they may have looked like.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
3.4 Understanding scientific names

LEARNING INTENTION

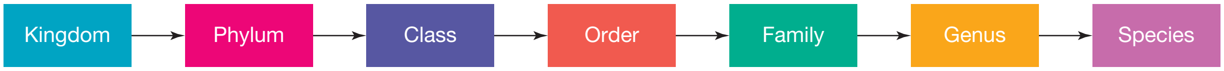
At the end of this lesson you will be able to name and classify species using scientific conventions from the Linnaean hierarchical classification system, such as kingdom, phylum, class, order, family, genus and species.

3.4.1 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 five kingdoms and that these kingdoms contain a number of sub-groups. As you move from kingdoms to species, the members of the group have more characteristics in common. Organisms of the same species resemble each other and can interbreed to produce fertile offspring.

FIGURE 3.19 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.



3.4.2 Binomial nomenclature

As well as developing a system of kingdoms (see section 3.2.3), 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 were often Latinised.

binomial nomenclature a system developed by Linnaeus for naming species using two words — the genus name and a descriptive name

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

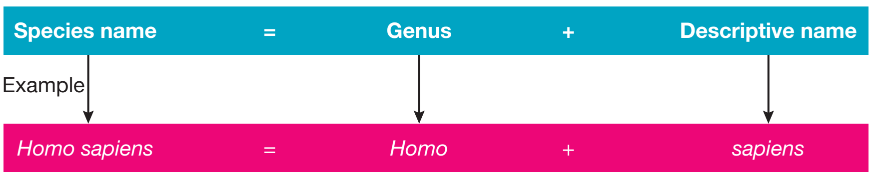
The genus name begins with a capital letter and lower case is used for the descriptive name. If handwritten, the species name should be underlined; if typed, it should be in *italics*.

Build your understanding of scientific names

The word 'binomial' comes from the Latin terms *bi-*, meaning 'two', and *nomen*, meaning 'name'. The word 'nomenclature' is used to describing naming systems.

The word 'taxonomy' comes from two Greek words: *taxis* meaning 'order' or 'arrangement' and *nomos* meaning 'law' or 'science'.

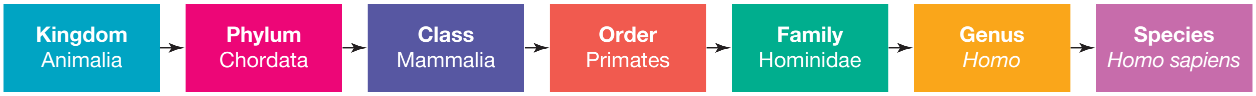
FIGURE 3.20 The species name is made up of the genus name (first word, with a capital letter) and the descriptive name (second word, with a lower case first letter).



3.4.3 Classifying and comparing

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

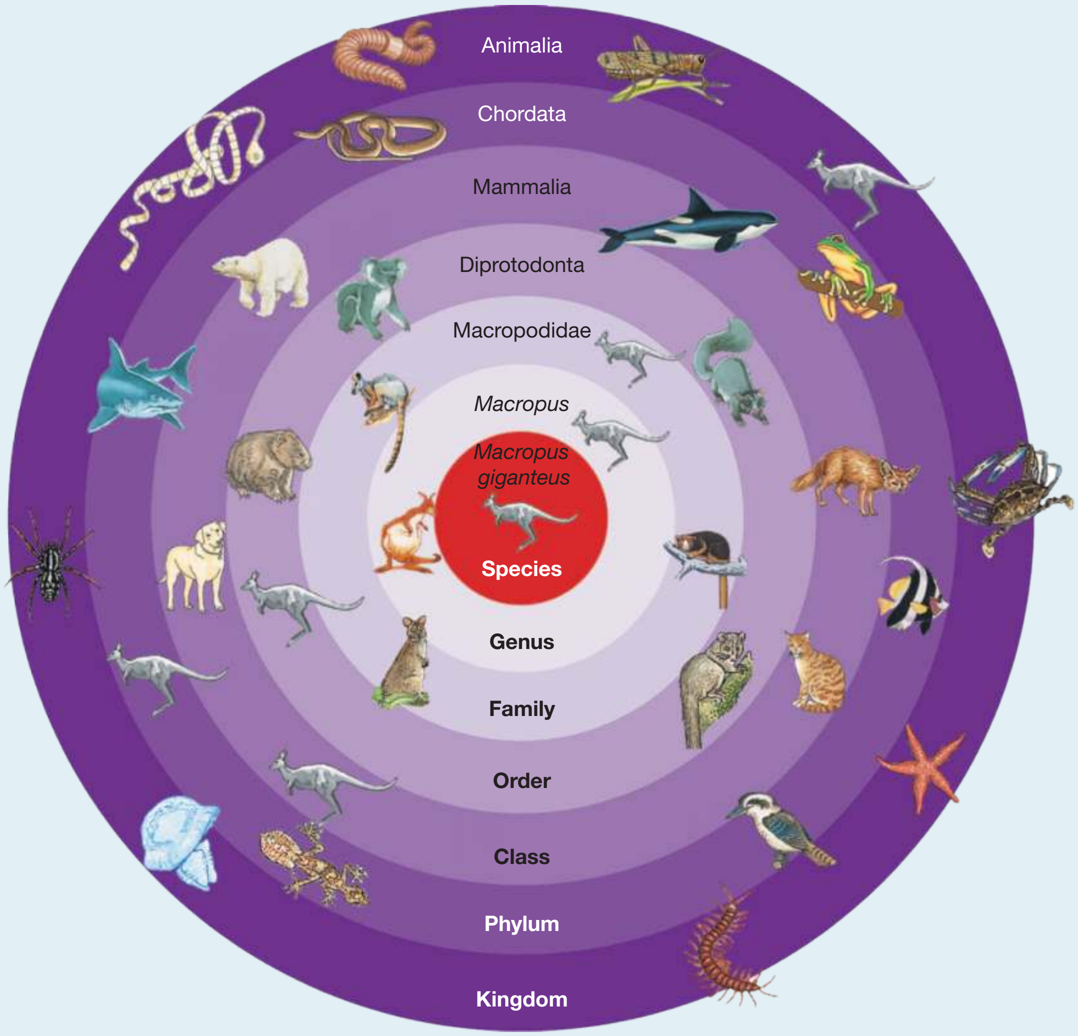
FIGURE 3.21 This flowchart shows the various groups that humans belong to.



DISCUSSION

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

FIGURE 3.22 This target map shows the classification groupings of *Macropus giganteus* (the Eastern grey kangaroo). *Macropus* is the genus name and *giganteus* is the descriptive name.



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

3.4.4 Unlocking names

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

TABLE 3.2 Some Australian animals and their species names

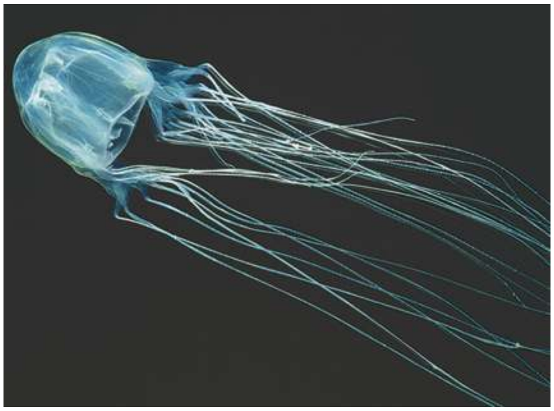
Common name: Major Mitchell's cockatoo **Species name:** *Cacatua leadbeateri*  **What's the story?** • *Cacatua* — derived from the Greek terms meaning 'dawn' and 'crest', referring to a crest like the rising dawn • *leadbeateri* — named after British naturalist Benjamin Leadbeater • cockatoo — originating 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 3.3 Some drought-tolerant Australian plants and their species names

<table>
<tr>
<td>
Common name: Native wisteria, ‘Happy Wanderer’
Species name: Hardenbergia violacea

What’s the story?

The genus was named after Countess von Hardenberg.
Wisterias are named after the American anatomist Caspar Wistar by the English botanist Thomas Nuttall.

</td>
<td>
Common name: Snow gum
Species name: Eucalyptus pauciflora

What’s the story?

The genus name comes from the Greek terms eu, meaning ‘good’ or ‘well’, and calyptos or kalyptos, meaning ‘veiled’ or ‘covered’.
The species name comes from the Latin terms pauci, meaning ‘few’, and florus, meaning ‘flowered’.

</td>
</tr>
<tr>
<td>
Common name: Kangaroo paw
Species name: Anigozanthos flavidus

What’s the story?

The species name comes from the Greek terms anis, meaning ‘unequal’, anthos, meaning ‘flower’, and flavidus, meaning ‘yellow’.
The common name is due to its similar appearance to a kangaroo’s paw.

</td>
<td>
Common name: Golden wattle
Species name: Acacia pycnantha

What’s the story?

The genus name comes from the Greek term akakia, meaning ‘thorny Egyptian tree’ (after the first thorny species discovered).
The species name comes from the Greek terms pyknos, meaning ‘dense’, and anthos, meaning ‘flower’.
In 1988 the golden wattle was proclaimed Australia’s national floral emblem.

</td>
</tr>
</table>

ACTIVITY: Remembering classification

Write a song or ad jingle to help you remember the following.

a. The order of the groupings kingdom, phylum, class, order, family, genus and species
b. Rules for writing scientific names
c. 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.

on Resources

eWorkbook A catalogue of cats (ewbk-11123)

Interactivity How species are named (int-3421)

3.4 Activities

learnon

3.4 Quick quiz on | **3.4 Exercise**

Select your pathway

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

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- Access sample responses
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Remember and understand

1. a. Identify whether the statements are TRUE or FALSE.

Statements	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 true.
2. Use a flowchart to show the names of the groupings in the hierarchical classification system, from largest to smallest.

3. Based on what you have learned in this topic, 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, which group contains members that have more in common?
   a. Kingdom or species b. Genus or family c. Order or phylum d. Class or order

Apply and analyse

6. SIS Research and report on how the box jellyfish *Chironex fleckeri* got its scientific name. Research the various types of jellyfish that can be found in Australian waters.
   Suggest why it is important to know the name of the type of jellyfish. Which features are 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 provided table to answer the following questions.

TABLE 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. **TABLE** Shared features for different groupings within the Animalia kingdom

Category	Group	What all the living things in the group have in common
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

a. Using the information in the provided table, 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. Which of the groups listed in the table do chimps belong to?

Evaluate and create

10. Construct a Venn diagram to show the similarities and differences between the classifications of saltwater and freshwater crocodiles.

11. **SIS** Research and report on one of the following.
- British naturalist Benjamin Leadbeater and the various species named after him
- The naming of *Crocodylus johnstoni* and other crocodiles
- The scientist Max Planck, the Max Planck Institute and *Acanthaster planci*
- The significance of the naming of *Cherax destructor*
- Radiologists in Australia — what do they do?
- Careers associated with identifying, classifying and naming organisms

12. **SIS**
a. Research features, classification and the life cycle of a crown-of-thorns starfish. How is it different from other types of starfish found in Australian waters? Outline research on 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.

13. **SIS** Research Carl Linnaeus and the binomial system of nomenclature. Document his contributions to the taxonomy of plants and animals.

14. 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.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
3.5 Keys to unlock identity

LEARNING INTENTION

At the end of this lesson you will be able to create, modify and use a dichotomous keys to classify organisms into groups and groups within groups.

3.5.1 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, 1 species of gecko, 3 species of fish and at least 20 species of insects and spiders.

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.

FIGURE 3.23 That's one big rat! A gigantic silver rat found in Papua New Guinea in an extinct volcano.

FIGURE 3.24 Giant 'rat-eating' pitcher plant *Nepenthes attenboroughii*, named after Sir David Attenborough

3.5.2 Keys for identification

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

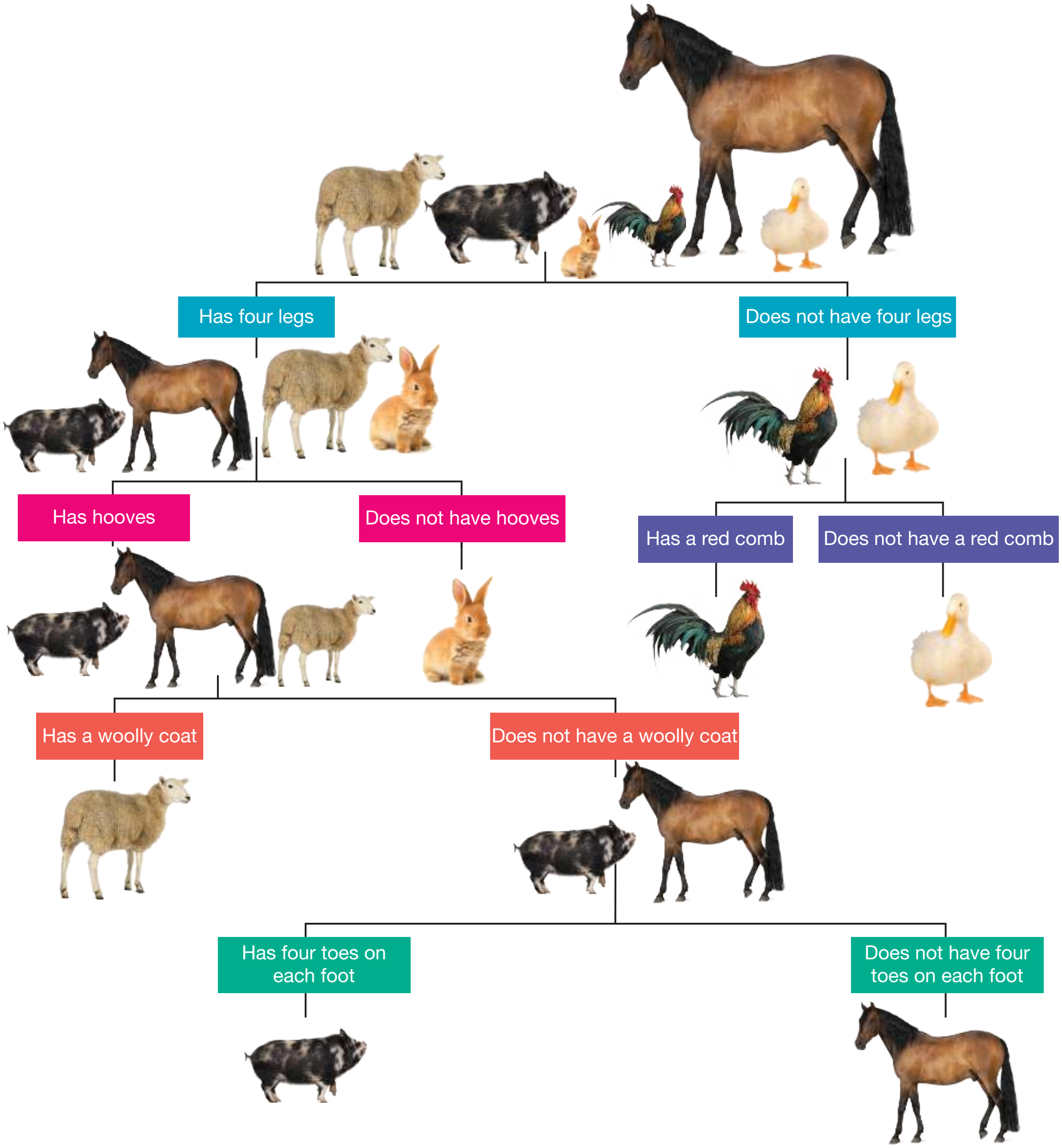
Dichotomous keys

Dichotomous keys provide choices at each branch (*dichotomous* = 'cutting in two'). Features such as size, colour, behaviour and habitat are not good for classification because they can change throughout the life of the organism. It is better to use the presence or absence of structural features, or differences in these features.

dichotomous key a diagram used to classify things, by grouping them into smaller and smaller groups based on choosing one of two features

int-3423

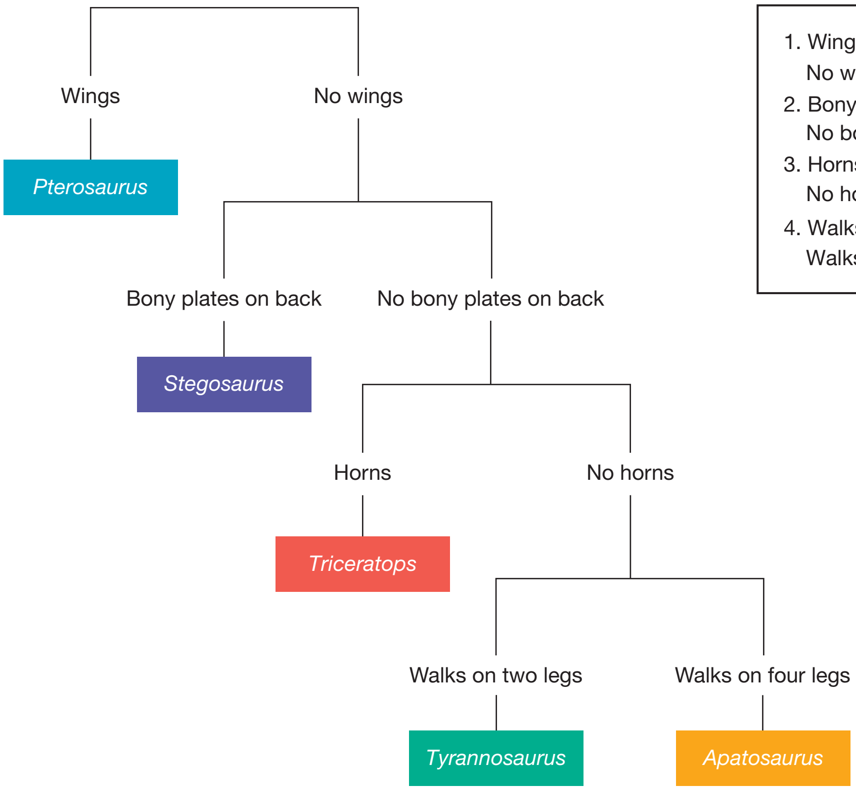
FIGURE 3.25 In a dichotomous key, you always select from two choices. In this key, you decide whether an organism has a particular feature.



int-3424

FIGURE 3.26 Dinosaurs can be classified using different dichotomous keys, such as a branching or tabular key. Can you determine which is which?

Branching key



Tabular key

1.	Wings	*Pterosaurus*
	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 a–e shown in figure 3.26 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.

int-3425

FIGURE 3.27 A circular key to unlock farm animal identity

ACTIVITIES: Classification in your everyday life

1. Explain how supermarkets provide an excellent example of the effectiveness of a classification system. Include the types of criteria that are used. Construct a dichotomous key that would enable ten different supermarket items to be identified.
2. Collect a leaf from each of 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 a tabular key.

elog-1986

INVESTIGATION 3.2

Making a class key

Aim

To use appropriate classification criteria in the construction of a class key

Materials

- Tape measures or string and rulers

Method

1. Measure, observe and record at least 10 different characteristics for each member of the class. You may like to include some of the following.
   a. Wrist size (cm)
   b. Distance from elbow to shoulder (cm)
   c. Foot length (cm)
   d. Height (cm)
   e. Eye colour
   f. Hair colour
   g. Wears watch
   h. Pierced ears
2. Have each member of the class select an appropriate secret code name.
3. Use some of these recorded class characteristics to construct a key (tree map or dichotomous key) that will separate as many individuals (using their code names) as possible. (*Hint:* You may find it best to describe measurements as 'greater than' or 'less than' a specific measurement.)
4. Have someone from outside the class use the key to find the identity of one of the class members.

Results

Draw and label the key you created.

Discussion

1. How successful was your key? Make a list of what worked well.
2. If you were to do the activity again, what would you do differently to improve its success?
3. Were some characteristics of more use than others? Explain.

Conclusion

Summarise your findings for this investigation in three to four sentences, and how a key was used to classify students in your class.

3.5.3 Field guides

Field guides are a commonly used type of reference book to help people identify organisms. These guides are specially designed to assist you in 'on-the-spot' identification. They often contain brief written descriptions and pictures, and are small enough to take outside when you are observing wildlife. There are also a number of electronic 'field guide' databases available.

on Resources

Weblink National field guide apps

ACTIVITIES: Identifying poisonous plants

Table 3.4 provides information about some poisonous plants.

a. Research what other plants look similar to those shown.

b. Create a warning poster on two of these plants.

TABLE 3.4 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 are eaten.

** Causes discomfort and irritation but is not lethal.

*** Can cause serious illness or death.

elog-1988

INVESTIGATION 3.3

Making a class field guide

Aim

To use appropriate classification criteria in the construction of a class field guide

Materials

- Paper, pencils
- Photocopies of photographs of each student (or students can sketch each class member themselves)

Method

1. Work in pairs. If there is an odd number of students in your class, your teacher might agree to participate.
2. Observe your partner and record data such as height, hair colour, eye colour, etc.
3. Interview your partner to find out some other details such as favourite music, movie, sport, colour and food.
4. Allowing about half an A4 page for each class member, present the information and the photograph/sketch.
5. Make the pages into a book or poster.

Results

Use the class field guide to see how easy it is to identify each student.

Discussion

1. What are the benefits of a field guide?
2. Which features do you think would be most useful to include in a field guide to assist in identifying a class member? Why?
3. Describe any problems that you encountered when you were constructing the field guide.
4. Which features 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, and relate them back to the aim.

on Resources

eWorkbooks My own zoo (ewbk-11125)
Branching keys (ewbk-11127)
Tabular and circular keys (ewbk-11129)

3.5 Activities

learnon

3.5 Quick quiz on	3.5 Exercise

Select your pathway

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

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Remember and understand

1. a. Identify whether the statements are TRUE or FALSE.

Statements	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.	

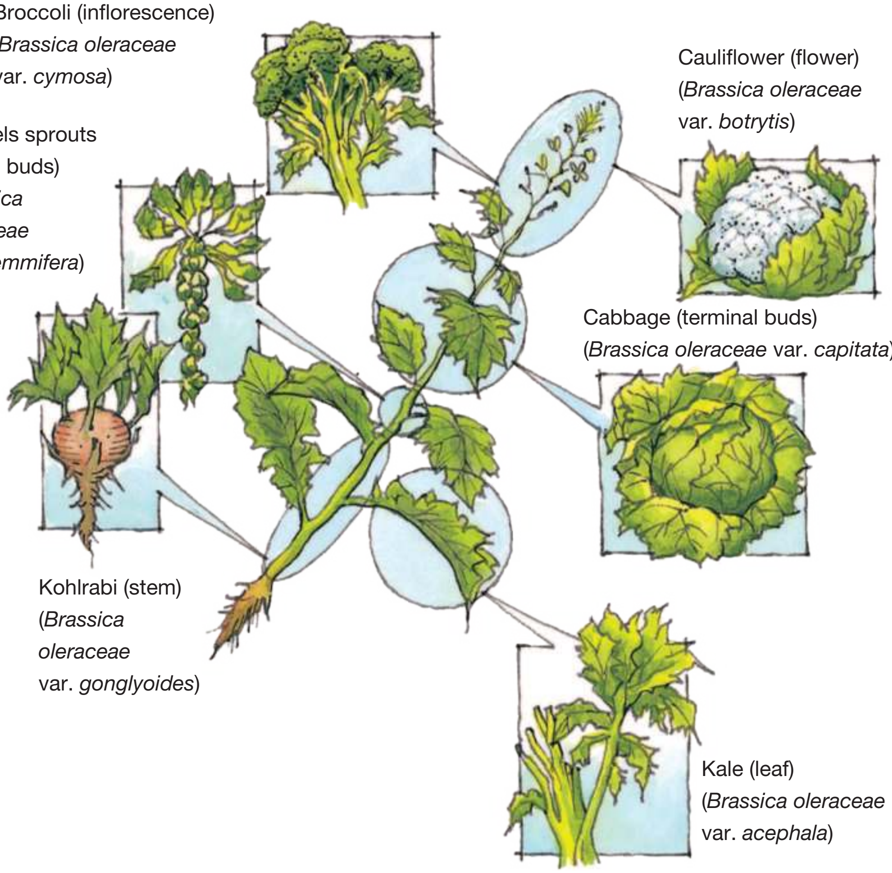
   b. Rewrite any false statements to make them true.
2. State the genus of the giant rat discovered in the extinct volcano in Papua New Guinea in 2009.
3. The giant 'rat-eating' carnivorous pitcher plant was discovered in the Philippines in 2007. State:
   a. its species name
   b. who it was named after.
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. What is a dichotomous key? Give an example of such a key.

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. **SIS** Research and report on the various types of pitcher plants and how they are classified.
13. Find and use two different online classification databases for either plants or animals. Comment on features that you find most useful in the database.
14. Refer back to table 3.4, 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.
15. **SIS** 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

16. **SIS** Examine the plants in question 15.
    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. Find out what artificial selection is and then research and report on the history of these vegetables.

17. Cave people were often interested in only two groups of living things — those that were useful to them and those that were dangerous. Research and report on examples of bush and native foods, and their parts that can be eaten and those that are poisonous. Display your findings in a format that includes dividing them into groups using relevant criteria.
18. **SIS** Research and report on one of the discoveries listed and report your findings as a newspaper article, poster, PowerPoint presentation or journal entry. Include the types of information that were used to classify and identify it in your presentation.
    - *Homo floresiensis* (possible human ancestor)
    - *Fruitadens haagarorum* (tiny dinosaur)
    - *Mycena luxaeterna* (glowing fungus)
19. **SIS** Observe the types of grass or insects in your local environment and construct a simple key to classify them.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
3.6 Classifying animals

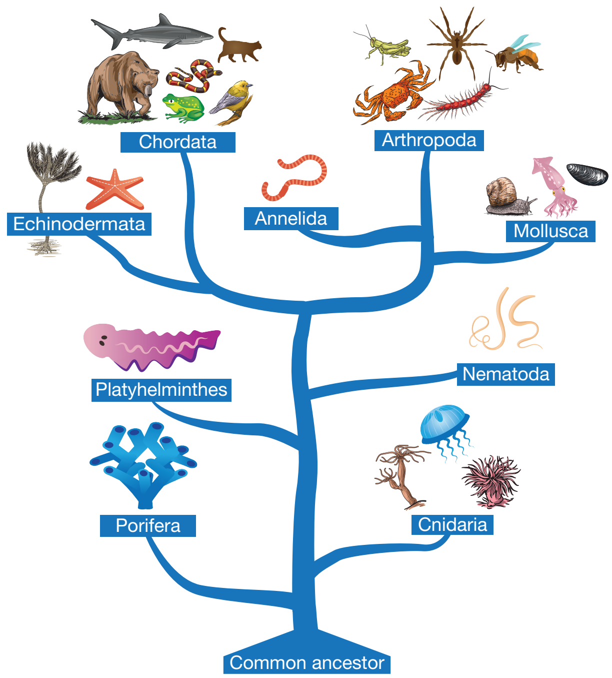
LEARNING INTENTION

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

3.6.1 Classifying by structural features

Animals can be classified into nine phyla (plural for phylum) on the basis of their structural features. Consider figure 3.28, 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.

FIGURE 3.28 Animals can be classified into nine phyla.



3.6.2 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 such as spiders, flies, snails and grasshoppers, have an external skeleton called an **exoskeleton**. Different vertebrates and invertebrates are shown in figure 3.29.

vertebrates animals with backbones

invertebrates animals without backbones

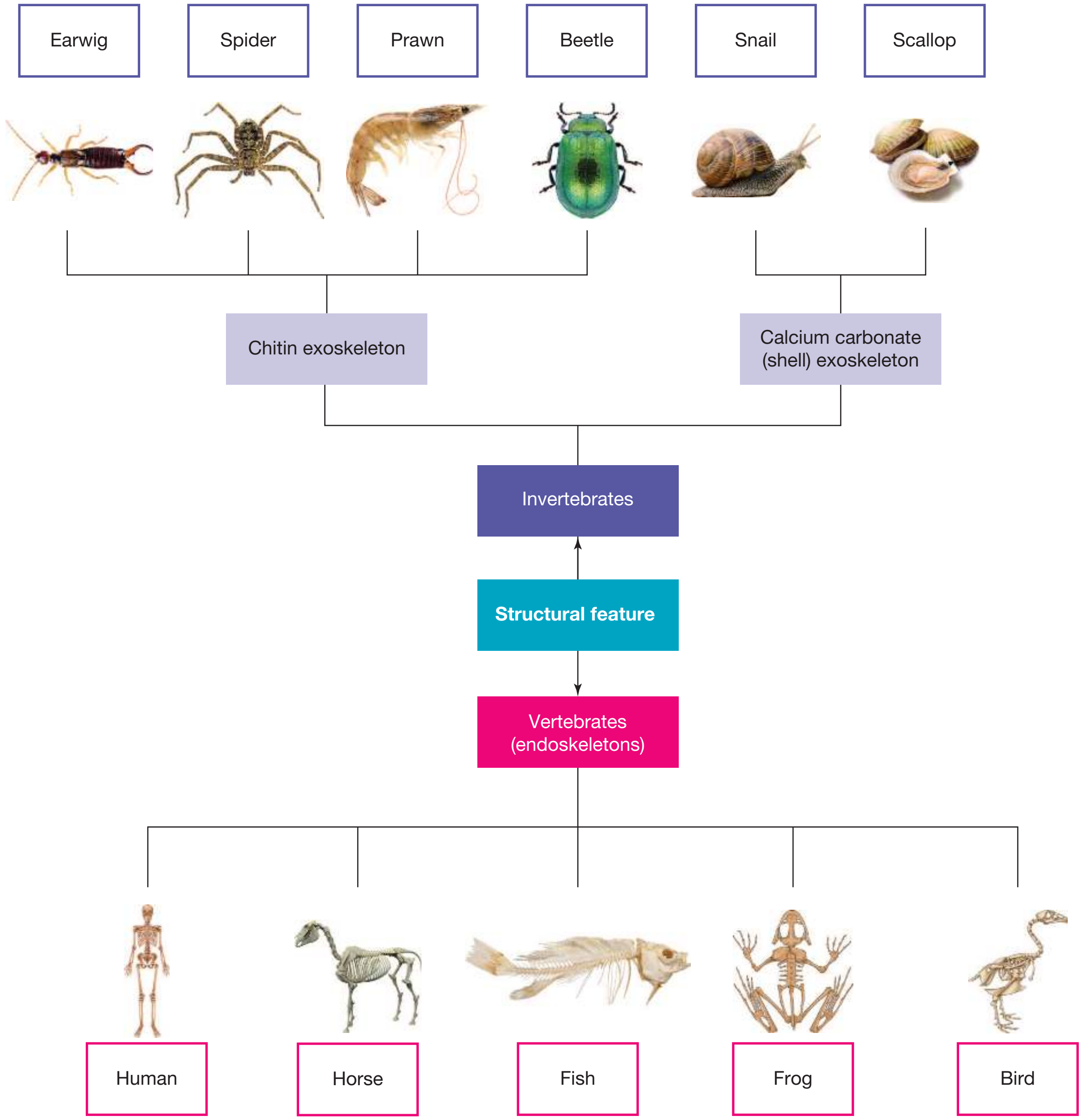
endoskeleton a skeleton or shell inside the body

exoskeleton a skeleton or shell that lies outside the body

int-8169

ewbk-11133

FIGURE 3.29 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).

In contrast, endoskeletons can support a larger body size compared to that of an exoskeleton. Table 3.5 shows some other differences between exoskeletons and endoskeletons.

TABLE 3.5 Differences between exoskeletons and endoskeletons

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, which consists of segmented worms. Each of their segments have **setae** which they use to help them grip the soil.

DISCUSSION

- What do you know about earthworms?
- What do you think would happen if they lost a lot of fluid?
- What holds them together?
- Without a skeleton, how can theseanimals move?
- What might the advantages or disadvantages of not having a skeleton be?

FIGURE 3.30 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.

setae bristle-like structures often found on invertebrates

3.6.3 Symmetry and asymmetry

The type of **symmetry** that describes an animal's body design can also be used as a structural feature to help classify it. These include **radial symmetry, bilateral symmetry** and **asymmetry**. The type of symmetry an animal possesses well suits it to its particular lifestyle.

symmetry the quality of being a mirror image across an axis

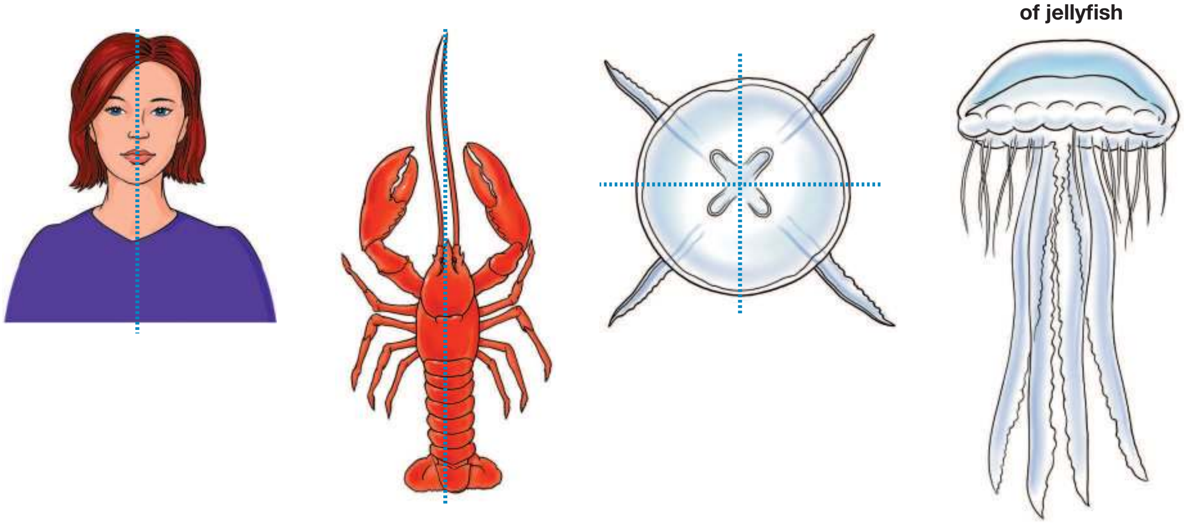
radial symmetry symmetrical about the centre axis

bilateral symmetry symmetrical or looking the same along one plane

asymmetry lack of symmetry

The bodies of jellyfish and adult sea anemones, like others in the Cnidaria phyla, possess radial symmetry and their body parts are arranged around a central axis or point. Such symmetry enables animals that possess it to be aware of their environments from all directions — which is very useful if you are attached to something stationary, floating or slow-moving.

FIGURE 3.31 Humans are vertebrates, whereas lobsters and jellyfish are invertebrates. Humans and lobsters, however, both share bilateral symmetry, whereas jellyfish possess radial symmetry.



Most animals possess bilateral symmetry. This is a bit like having two half mirror images. Animals in the Annelida, Platyhelminthes, Mollusca, Arthropoda and Chordata phyla (including humans) all possess bilateral symmetry. These animals have a head and tail, front and back, and left and right sides. This form of symmetry is thought to promote streamlined and directional motion.

TABLE 3.6 The types of symmetry observed in members of different phyla

Symmetry	Porifera	Platyhelminthes	Mollusca	Annelida	Arthropoda	Chordata	Cnidaria
Radial symmetry							✓
Bilateral symmetry		✓	✓	✓	✓	✓	
No symmetry	✓						

DISCUSSION

Members of the Porifera phyla, such as sea sponges, are made up of bodies that are asymmetrical. They also lack true tissues and organs. Considered by some to be the oldest living animals, sponges have a very interesting origin. Can you suggest an advantage of being asymmetrical that might have helped them survive so long?

FIGURE 3.32 Sea sponges are made up bodies that are not symmetrical.

SCIENCE AS A HUMAN ENDEAVOUR: Safeguarding diversity

The Great Barrier Reef is home to a diversity of living things. There are links between many of them, without which not only they, but also other organisms, may not survive. Find out more about the animals living on the Great Barrier Reef. Research and report on:

a. one invertebrate and one vertebrate
b. links between four different organisms
c. the issue of the crown-of-thorns starfish
d. the issue of tourism and the sustainability of the Great Barrier Reef
e. current research questions being investigated
f. ways to protect the diversity of the reef.

elog-1990

tlvd-10653

INVESTIGATION 3.4

Classifying animals into phyla

Aim

To investigate characteristics used to classify animals

Materials

- Preserved specimens or photos of animals from a range of phyla
- Hand lens

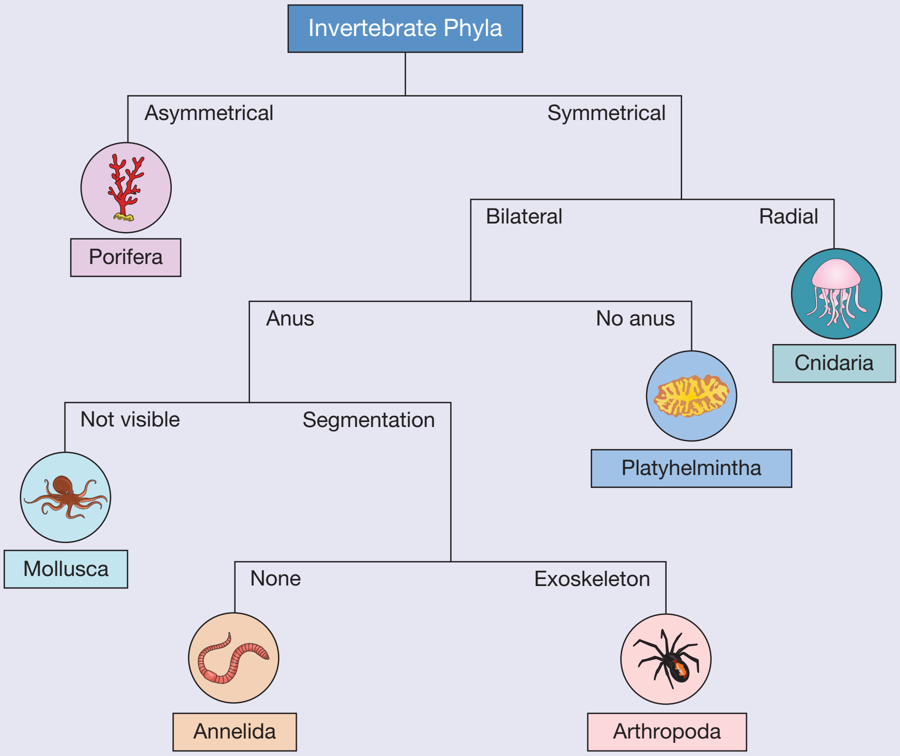
Method

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

Draw up a results table using the dichotomous key.

TABLE 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. Were there any characteristics in the key that were difficult to identify in the specimens?
2. Which phyla were most difficult to distinguish? Why?
3. Design a tabular key to classify the invertebrate phyla in this investigation.

Conclusion

Write three to four sentences to summarise your findings about the specimens you examined.

on Resources

eWorkbook Animal features (ewbk-11131)

Interactivity Features of animals (int-3428)

3.6 Activities

learnon

3.6 Quick quiz on	3.6 Exercise

Select your pathway

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

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. a. Identify whether the statements are TRUE or FALSE.

Statements	True or false?
i. The type of skeleton and their body symmetry are two structural features that can be used toclassify 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 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 anemone 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 adding the type of skeleton and type of body symmetry for each phylum.

TABLE The type of skeleton and body symmetry for different 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.

v.

a. Consider the features for each animal shown and then 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. Design 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. endoskeleton and exoskeletons.
14. Carefully observe the features of the animals in the animal kingdom tree back in figure 3.28.
   a. Construct a mind map to record as many features for 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.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
3.7 Classifying vertebrates

LEARNING INTENTION

At the end of 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.

3.7.1 Common features of vertebrates

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

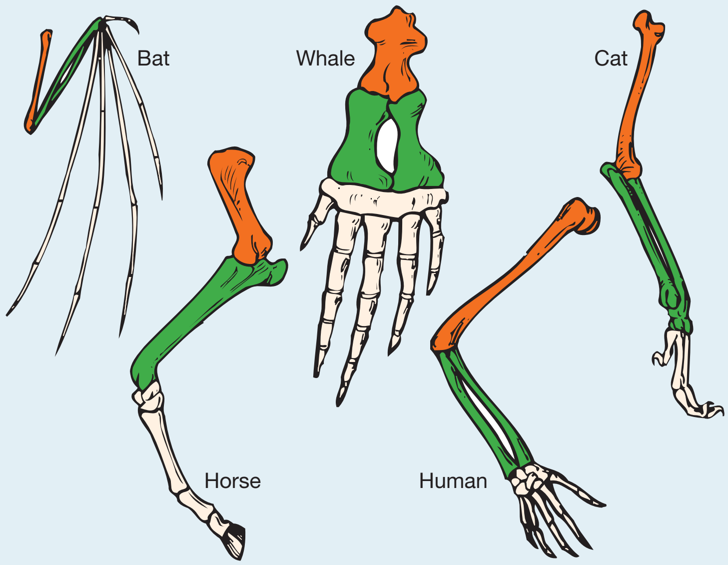
Although there are many different groups of vertebrates, they all share some common features. This similarity is because they have shared common ancestors at some point in their evolution. Some scientists study structural similarities to determine how recently groups of vertebrates may have shared common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

FIGURE 3.33 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 3.34. These vertebrates possess forelimbs that share the same basic arrangement (pentadactyl limb) because they are derived from a common ancestor.

FIGURE 3.34 The forelimbs of vertebrates share the same basic arrangement.



In groups, write a summary poster outlining:
- how the vertebrate forelimbs are similar
- how the vertebrate forelimbs are different
- how the differences in each vertebrate forelimb well suit it to its function.

3.7.2 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 and mammals. One distinguishing feature is the ability to regulate body temperature. Bird 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**.

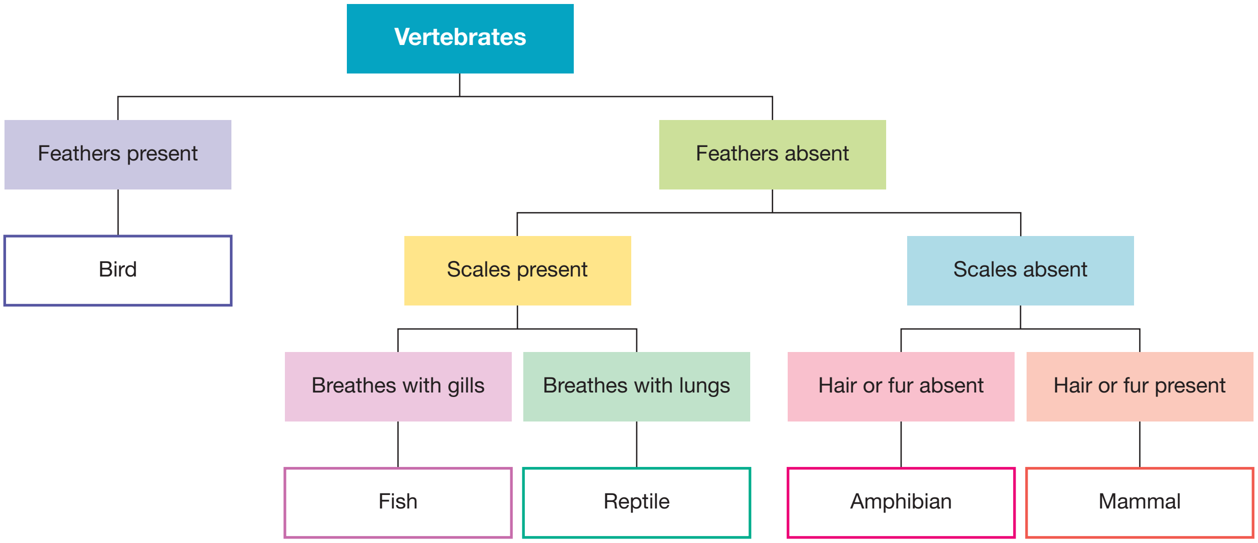
endotherm an animal that can maintain its internal body temperature in a constant range

ectotherm an animal whose body temperature changes depending on the external environment

int-0937

ewbk-11135

FIGURE 3.35 A dichotomous key can be used to help classify different types of vertebrates.



EXTENSION: Vertebrae and vertebrates

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.

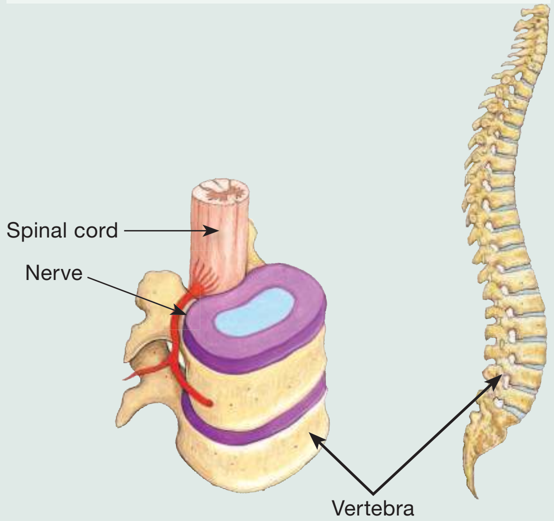
Did you know that the term 'vertebrate' is derived from the Latin word *vertebra*, which means 'joint'?

Humans have 33 vertebrae. We divide our vertebral column into five sections.

- Cervical: the top 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 3.36 Your backbone is made up of many bones called vertebrae (singular vertebra).



int-3429

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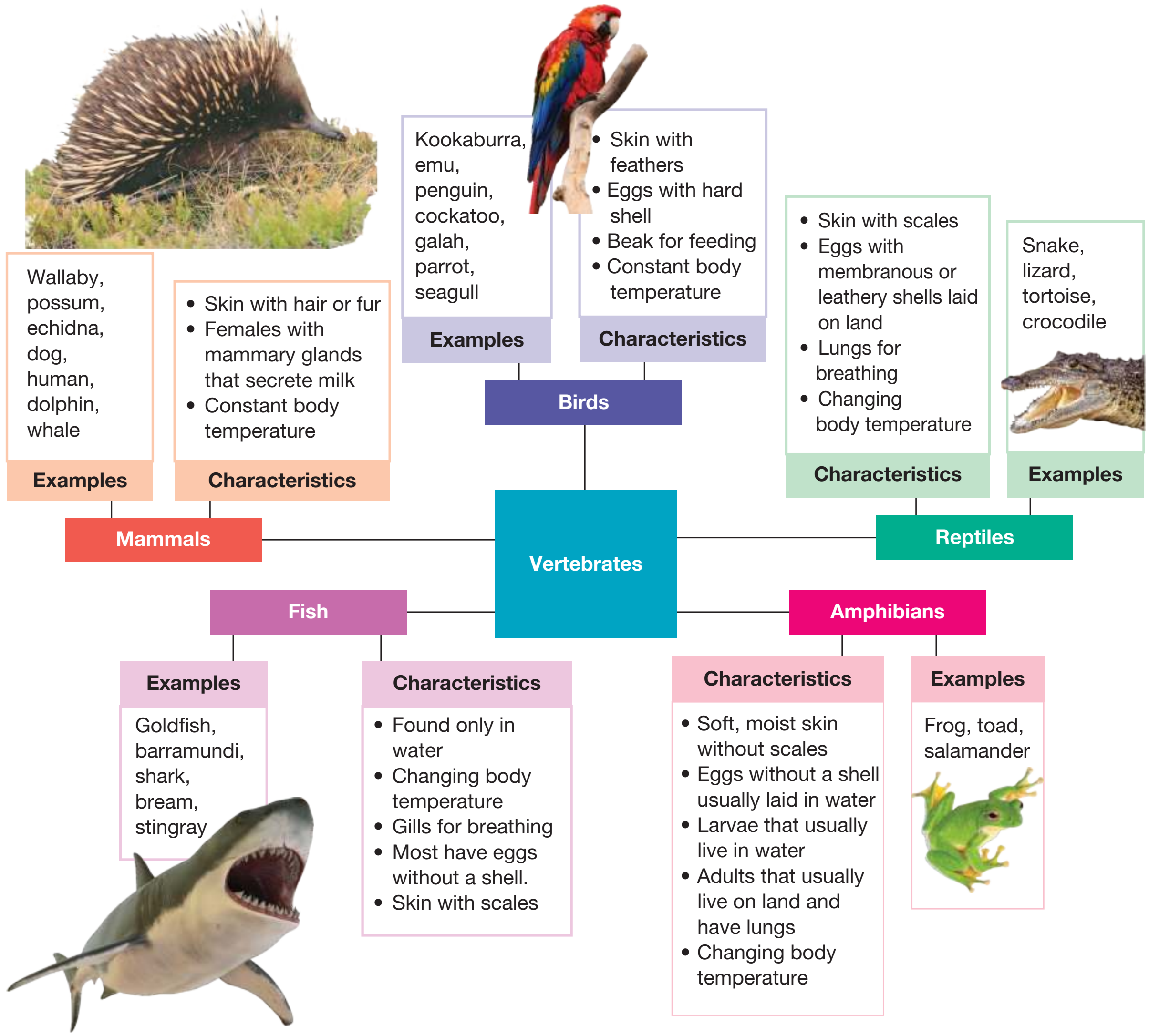
FIGURE 3.37 The five main groups of vertebrates are fish, amphibians, reptiles, birds and mammals.



ACTIVITY: *Flash 'n' mind*

Make a set of *Flash 'n' mind* cards for yourself or for your team to help you learn the characterstics 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. Type or 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 the five main groups of vertebrates diagram in figure 3.37.
3. Using the internet, magazines or other sources, find as many photographs or pictures as you can of the animals listed in the diagram. Paste these images onto separate flash 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 the diagram to see how you did.
5. As a team, use your *Flash 'n' mind* 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?

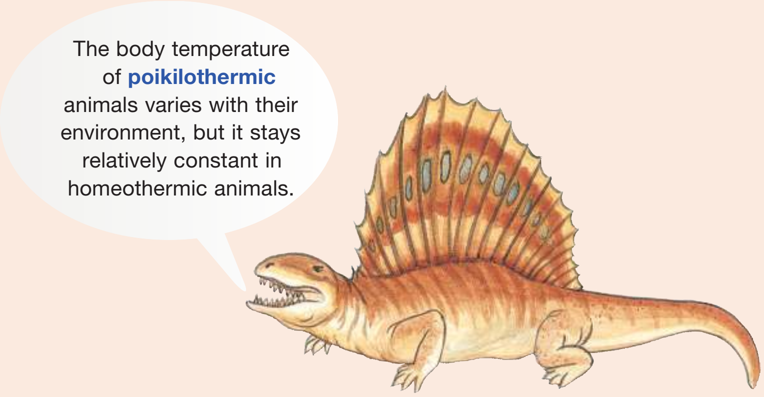
FIGURE 3.38 FrogID is a national citizen science project to discover new species of frogs, which you can take part in.

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. The pelycosaurs used this 'sail' to regulate their body temperature. They could stand in the early morning sunlight with the sail arranged towards the Sun to warm them up. They could turn it into the wind to cool off. It is thought that this fin arrangement was an early stage in the development of temperature regulation of mammals.

poikilothermic having a body temperature that fluctuates and is similar to the temperature of its environment (as in cold-blooded organisms)

FIGURE 3.39 *Dimetrodon* — a mammal-like reptile



Resources

eLesson Spinal cord (eles-2209)

Weblink FrogID

3.7 Activities

learnon

3.7 Quick quiz on	3.7 Exercise

Select your pathway

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, 21

Remember and understand

1. a. Identify whether the statements are TRUE or FALSE.

Statements	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 true.

2. MC Identify which pair of animal groups do not possess a skeleton.
   A. Humans and seastars
   B. Humans and earthworms
   C. Earthworms and jellyfish
   D. Seastars 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 the vertebrate group with its skin features.

Vertebrate group	Skin feature
a. Amphibians	A. Feathers
b. Birds	B. Skin with hair or fur
c. Fish	C. Slimy scales
d. Mammals	D. Dry scales
e. Reptiles	E. Soft, moist skin

6. Match the vertebrate group with its reproductive features.

Vertebrate group	Reproductive feature
a. Amphibians	A. Eggs with hard shell
b. Birds	B. Eggs with membranous or leathery shells laid on land
c. Fish	C. Eggs without shell usually laid in water
d. Mammals	D. Females with mammary glands that secrete milk
e. Reptiles	E. Most have eggs without a shell

7. Match the vertebrate group with its example.

Vertebrate group	Example
a. Amphibians	A. Frog
b. Birds	B. Dolphin
c. Fish	C. Penguin
d. Mammals	D. Shark
e. Reptiles	E. Snake

8. Consider what you have learned about vertebrates.
   a. List the five main groups of vertebrates.
   b. Identify which groups have changing body temperature and which have constant body temperature.
   c. State an example for each vertebrate group.
9. Identify the vertebrate group to which each of the following animals belongs.
   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 were a link between reptiles and mammals.
14. Identify the vertebrate group to which each of the following animals belongs.
    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, have 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 scientific classification each of the vertebrates shown in images a–f belong to.

TABLE The origin of some vertebrate scientific classification names

Latin or Greek word	English translation	Scientific classification
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 **a–h**. (You may wish to find photos of each animal to help you out.)

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 will 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

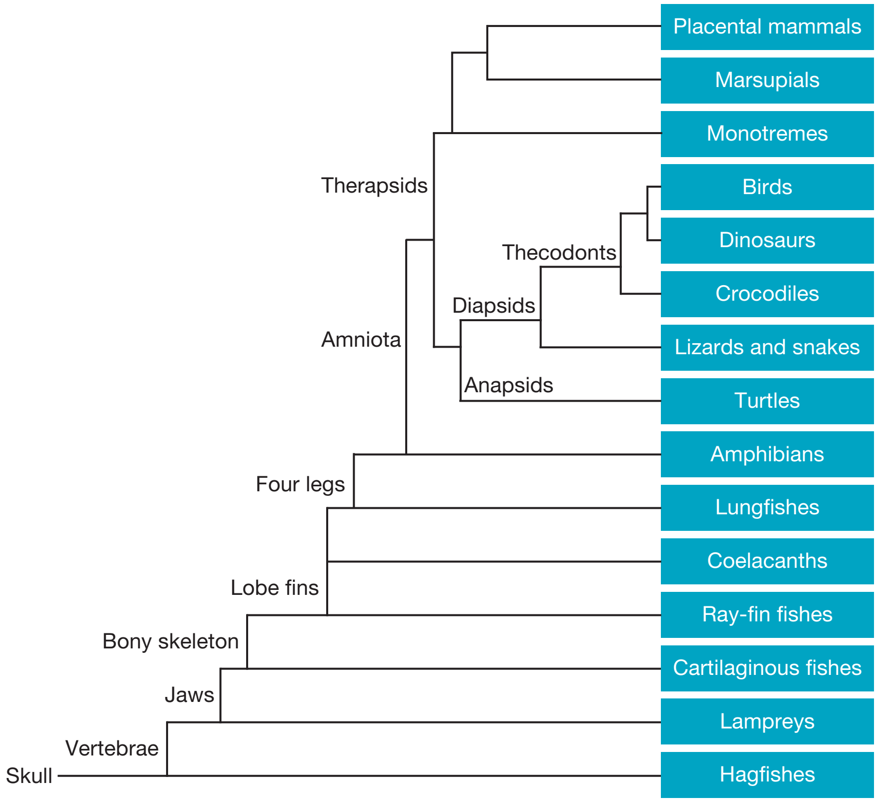
Evaluate and create

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

TABLE Features of the five main vertebrate groups

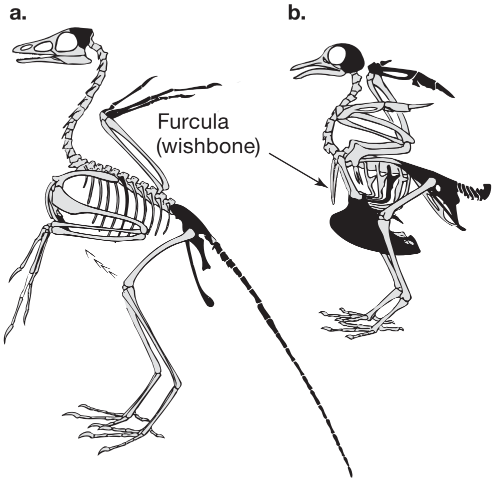
Feature	Mammals	Birds	Reptiles	Amphibians	Fish
a. Is body temperature constant or does it change?					
b. What type of body covering does it have?					
c. Does it lay eggs? If so, what type of shell do they have?					
d. Does it have lungs or gills?					
e. Does it feed its young milk?					
f. Give two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



21. Research and report on the issues and implications of tourism and overhunting on populations of the Australian freshwater crocodile, *Crocodylus johnstoni*.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
3.8 Classifying mammals

LEARNING INTENTION

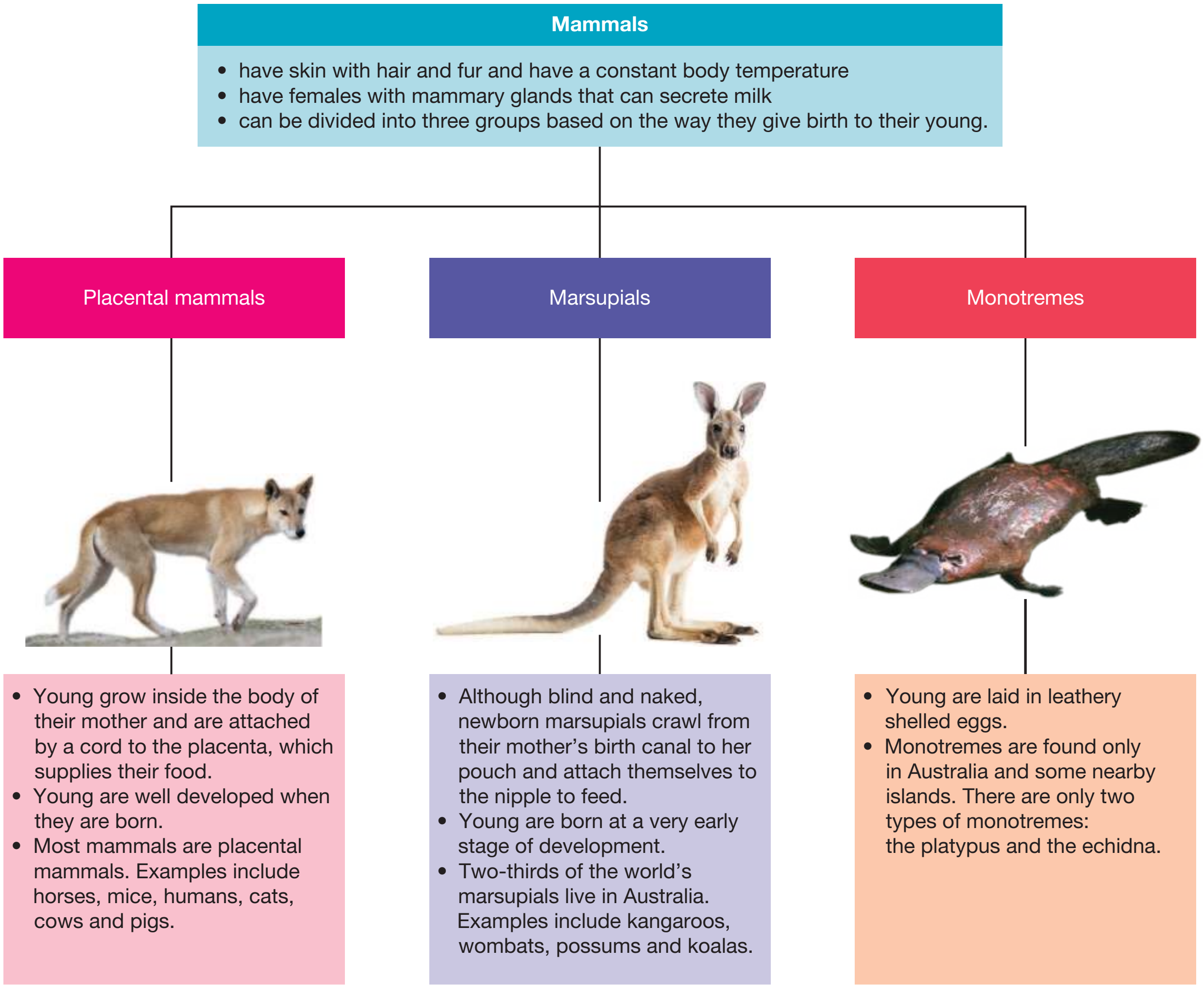
At the end of this lesson you will be able to describe both the features shared by all mammals and the features used to distinguish them as being placental mammals, marsupials or monotremes.

3.8.1 Types of mammals

Do you possess 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 divide mammals is the way in which they give birth to their young.

int-3430

FIGURE 3.40 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**, however, are born at a very early stage of development and then grow inside their mother's pouch. **Monotremes** are laid in leathery shelled eggs.

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

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

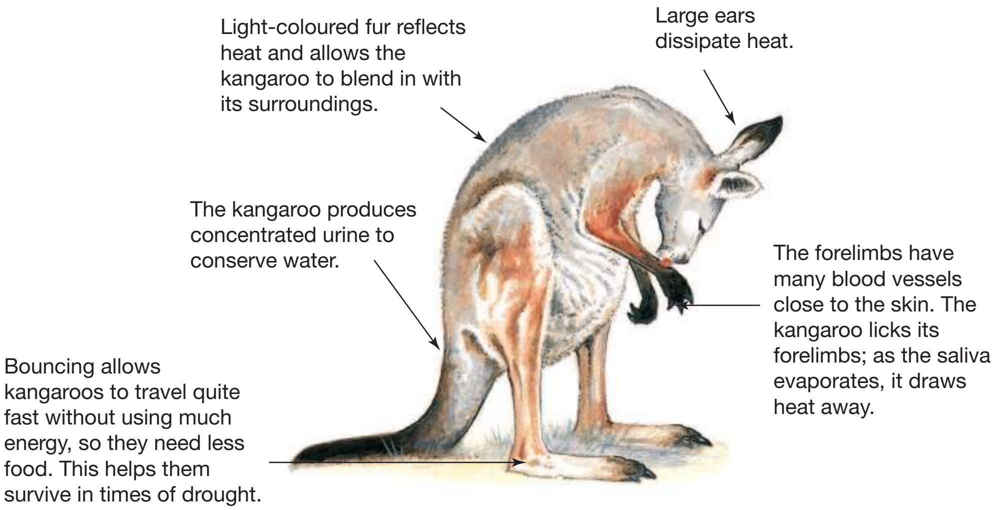
monotremes the order of non-placental mammals that lay leathery shelled eggs and secrete milk through pores in the skin

3.8.2 Australian mammals

Australia is unique in terms of 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 nearby islands. Australia's isolation from the other continents, after they separated millions of years ago, is considered the reason for the existence of Australia's unique animals, such as the kangaroo and platypus. In isolation, Australia's native mammals evolved over time to be particularly well adapted to their harsh Australian environments.

int-3431

FIGURE 3.41 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.

FIGURE 3.42 In London in 1799, an Australian sailor presented a platypus specimen to 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 British Museum (Natural History) in London.

3.8.3 Ancient megafauna of Australia

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

FIGURE 3.43 This illustration shows some of the animals that inhabited Australia in the Tertiary period. Others included marsupial lions, koalas, possums, wallabies, kangaroos, goannas and long-beaked echidnas (*Zaglossus*).

Giant kangaroo

The extinct giant kangaroo, *Procoptodon*, was heavily built and stood about 2.5 metres 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.

Diprotodons

The members of this group are all extinct. They were the largest of all the marsupials. *Diprotodon optatum*, often referred to as the diprotodon, was the largest known marsupial to have ever lived. The skeleton of the diprotodon suggests that the animal was about the size of a rhinoceros, being about 3 metres long and possibly weighing about 2 tonnes.

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

FIGURE 3.44 A timeline of some marsupial fossil finds and major mammal events

Some marsupial fossil finds and events	Era	Period	Epoch (millions of years ago)	Major mammal events
Present	Cenozoic era	Quaternary period	HOLOCENE 0.01–present	Humans investigate Earth's history.
Most of the large Pleistocene marsupials became extinct about 15 000–30 000 years ago.	Cenozoic era	Quaternary period	PLEISTOCENE 1.64–0.01 mya	Evidence of First Nations Australians at least 65 000 years ago.
Many giant browsing marsupials became extinct; there were grazing kangaroos and lots of diprotodons.	Cenozoic era	Tertiary period	PLIOCENE 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.	Cenozoic era	Tertiary period	MIOCENE 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. Diprotodons and a relative of pygmy possum fossils were found in Tasmania.	Cenozoic era	Tertiary period	OLIGOCENE 35.5–23.5 mya	First marsupials appeared in Australia. First primates appeared.
Lots of marsupial fossils of this age were found in South and North America.	Cenozoic era	Tertiary period	EOCENE 56.5–35.5 mya	Swimming and flying mammals appeared.
Dinosaurs became extinct about 65 million years ago.	Cenozoic era	Tertiary period	PALAEOCENE 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.
- First Nations Australians may have hunted them as a food source.
- First Nations Australians may have brought diseases with them that infected and killed the 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 First Nations Australians 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.

Discuss the theories suggested for the extinction of megafauna.

Put forward your own theory (which may include some of the suggestions provided) for the extinction of Australia's megafauna, and justify your thoughts.

EXTENSION: The unique platypus

New evidence-changing ideas

The platypus is a strange animal, with unique features, and 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!

chromosome a tiny, thread-like structure that contains the DNA that carries genetic information

FIGURE 3.45 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.

on Resources

eWorkbook	Looks can be deceiving (ewbk-11139)
Video eLessons	Australian animals (eles-2211)
	The platypus (eles-2212)
Weblink	Extinction of Australia's Megafauna (web-8365)

3.8 Activities

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3.8 Quick quiz on	3.8 Exercise

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Select your pathway

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

Remember and understand

1. a. Identify whether the statements are TRUE or FALSE.

Statements	True or false?
i. Kangaroos and koalas are examples of placental mammals.	
ii. Monotremes are only found in Australia and 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 true.

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

Type of mammal	Features of their young
a. Marsupials	A. Young are well developed when they are born.
b. Monotremes	B. Young are born at a very early stage of development.
c. Placental mammals	C. 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 three-column table and use it 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.

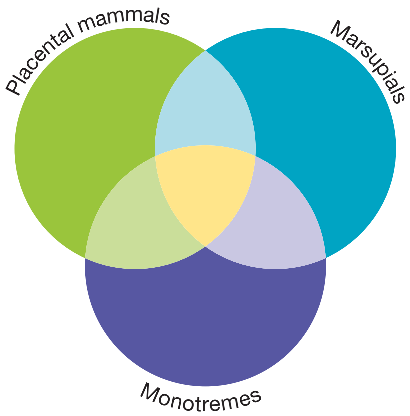
Apply and analyse

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. What do taxonomists in museums do? Why is their work important?
10. Suggest how placental mammals got their name.
11. Use the timeline in figure 3.44 to answer the following questions.
    a. About how many years ago did dinosaurs become extinct?
    b. In which epoch did fossils of swimming and flying mammals appear?
    c. In which epoch did fossils of the first marsupials appear?
    d. Evidence suggests that First Nations Australians were here how many years ago?

12. Find out more about one placental mammal, marsupial or monotreme and report on your research.
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 3.43.
    Which animals alive today are they most similar to? Give reasons for your answers.

Evaluate and create

15. Construct a triple Venn diagram to show the similarities, differences and examples of the three mammal groups.



16. SIS Did you know that 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. Find out whether hedgehogs are placental mammals or marsupials.
    b. How do hedgehogs differ from echidnas?
    c. A porcupine also has spines. What type of mammal is a porcupine?
    d. How are porcupines different from hedgehogs and echidnas?
17. SIS
    a. List theories proposed as to why Australia's megafauna became extinct.
    b. Find out which theory is most recently supported.
    c. Which theory do you support? Justify your response.
18. Refer back to the timeline in figure 3.44.
    a. List the seven epochs in order of most recent to least recent.
    b. In which epoch did marsupials appear in Australia? How do we know this?
    c. Earth's greatest ice age was in the Pliocene epoch. When was this? What other events occurred then?
    d. Look up other sources to find out what other important events occurred, and add these to your timeline.
19. Find out more about Australia's prehistoric marsupials, and summarise your findings (or present them as a poster, poem or story).
20. Besides the Cenozoic, what are the other nine eras used to describe the history of Earth? Draw a timeline showing all 10 eras, including their periods, times in millions of years and any other information you can locate.
21. Research and report on one of the following topics of research in Australia.
    - Platypus genome
    - Platypus milk and lactation
    - Platypus venom
    - Platypus sex chromosomes and mating
    - Koala diet
    - Koala diseases
    - Koala reproduction
    - Tamar wallabies
    - Bilbies
22. a. How many chromosomes decide the sex of a platypus?
    b. Compare this number of sex-determining chromosomes in other mammals.
    c. Propose a reason for this difference.
    d. Investigate recent related research to evaluate your proposal.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
3.9 Classifying invertebrates

LEARNING INTENTION

At the end of this lesson you will be able to recall the features used to distinguish invertebrates into eight major phyla, recall examples from each phylum and understand how various features have developed to be well suited to their specific function.

3.9.1 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 3.46 — how many groups and examples can you recognise?

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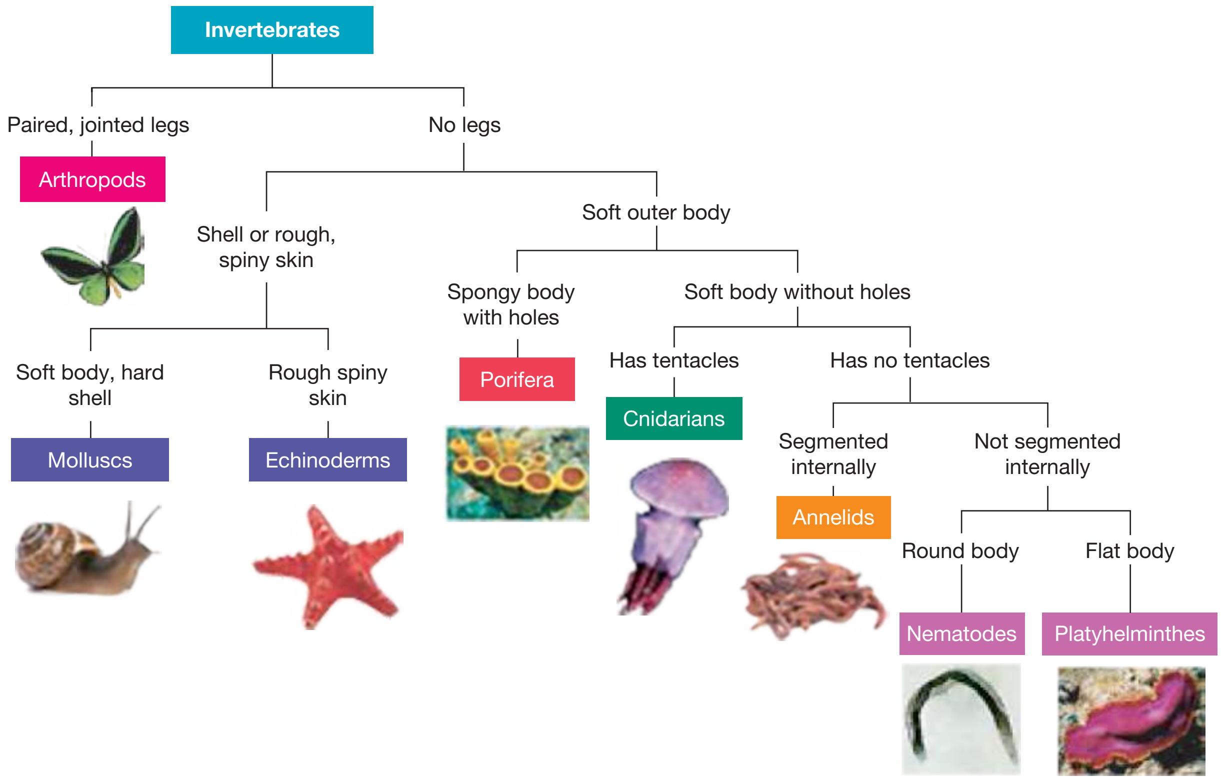
ewbk-11141

FIGURE 3.46 The eight major phyla of invertebrates — Arthropoda, Mollusca, Echinodermata, Porifera, Cnidaria, Annelida, Nematoda and Platyhelminthes — shown in a dichotomous key



EXTENSION: Extend your understanding of 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 number of the invertebrate groups contain organisms that may find you quite tasty. There are some well-known human parasites in the following groups of invertebrates:

- 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 called **parasites**. **Endoparasites**, such as tapeworms, live inside their hosts, whereas **ectoparasites**, such as head lice, live on the outside. Some of these organisms also act as carriers or **vectors**, transporting disease-causing organisms from one animal to another.

parasite an organism that lives on or within another organism, to get all or some of its nourishment

endoparasite a parasite that lives inside its host

ectoparasite a parasite that lives on the outside of its host

vector an organism that does not cause disease, but transports another disease-causing organism

arthropod an animal that has an exoskeleton, a segmented body and jointed legs (e.g. insects, crabs)

3.9.2 Arthropods

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

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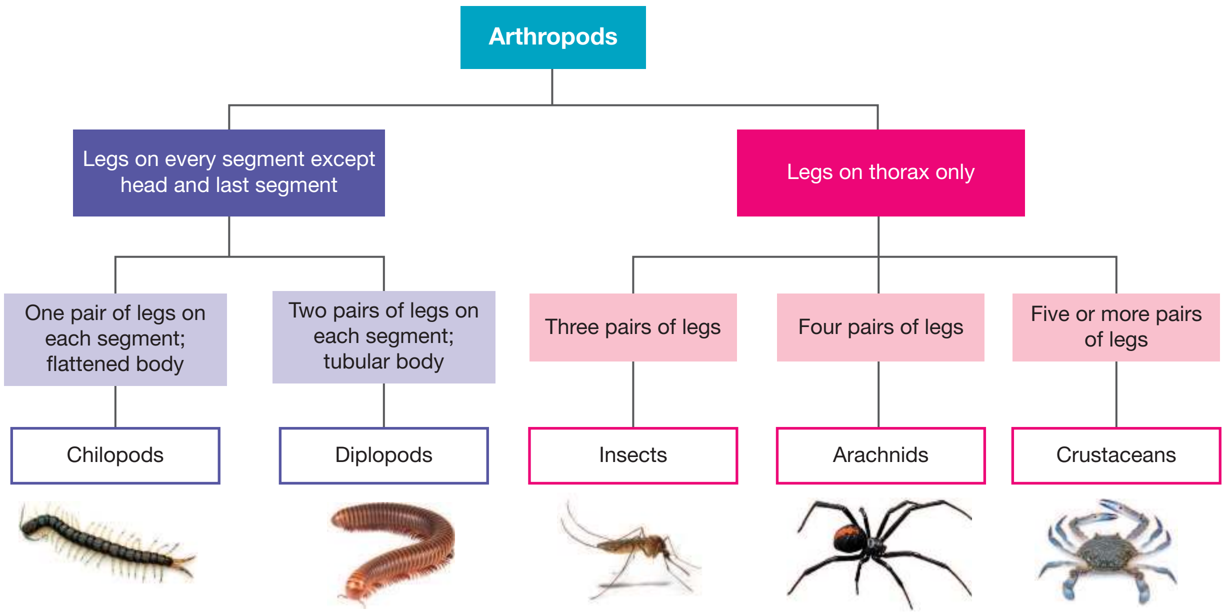
FIGURE 3.47 The classification of arthropods



ACTIVITY: Create a local arthropod field guide

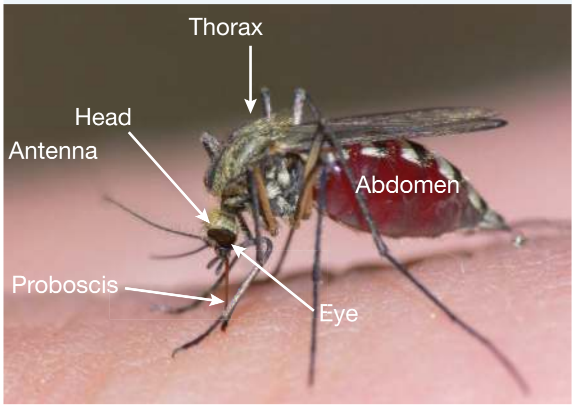
a. Record observations and take photographs of at least ten arthropods in your local area.
b. Use keys to identify the arthropods in your photo collection.
c. Using your photographs and observations, create a field guide that can be used by others.

3.9.3 Insects

The bodies of insects are divided into three parts: the head, thorax (chest) and 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 3.48). As 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 of the female mosquito is the part that is injected into the victim, to suck out the blood. Male mosquitoes do not do this. They feed on the nectar of plants.

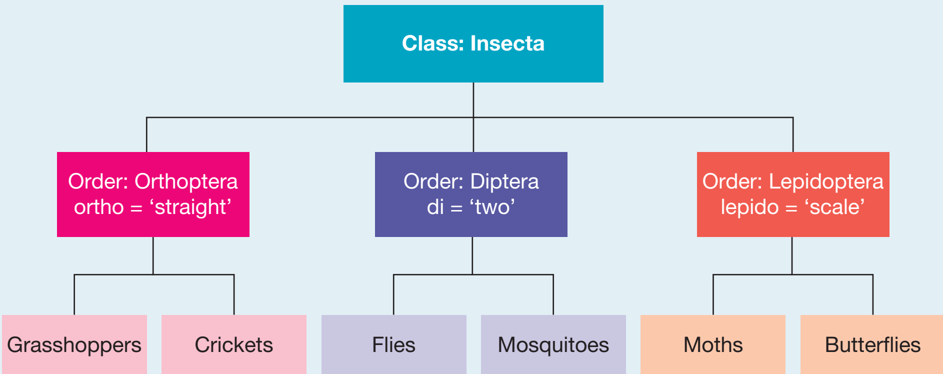
FIGURE 3.48 The proboscis of a female mosquito has a sharp needle that pierces the skin of its victim in order to suck out a blood meal.



DISCUSSION

Using the knowledge that *pteron* is Greek for 'wing', and the prefix translations in figure 3.49, can you suggest a feature that these insects all share, and one that can be used to separate them? Compare the chosen feature with those around you. Were there features suggested by others that were better choices?

FIGURE 3.49 Examples of different insects



3.9.4 Functional features of insects

All insects have the same basic mouthparts, 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.

proboscis a long feeding tube attached to the head of some insects; it sometimes rolls up when not in use

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

a.

b.

c.

d.

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 3.51 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.

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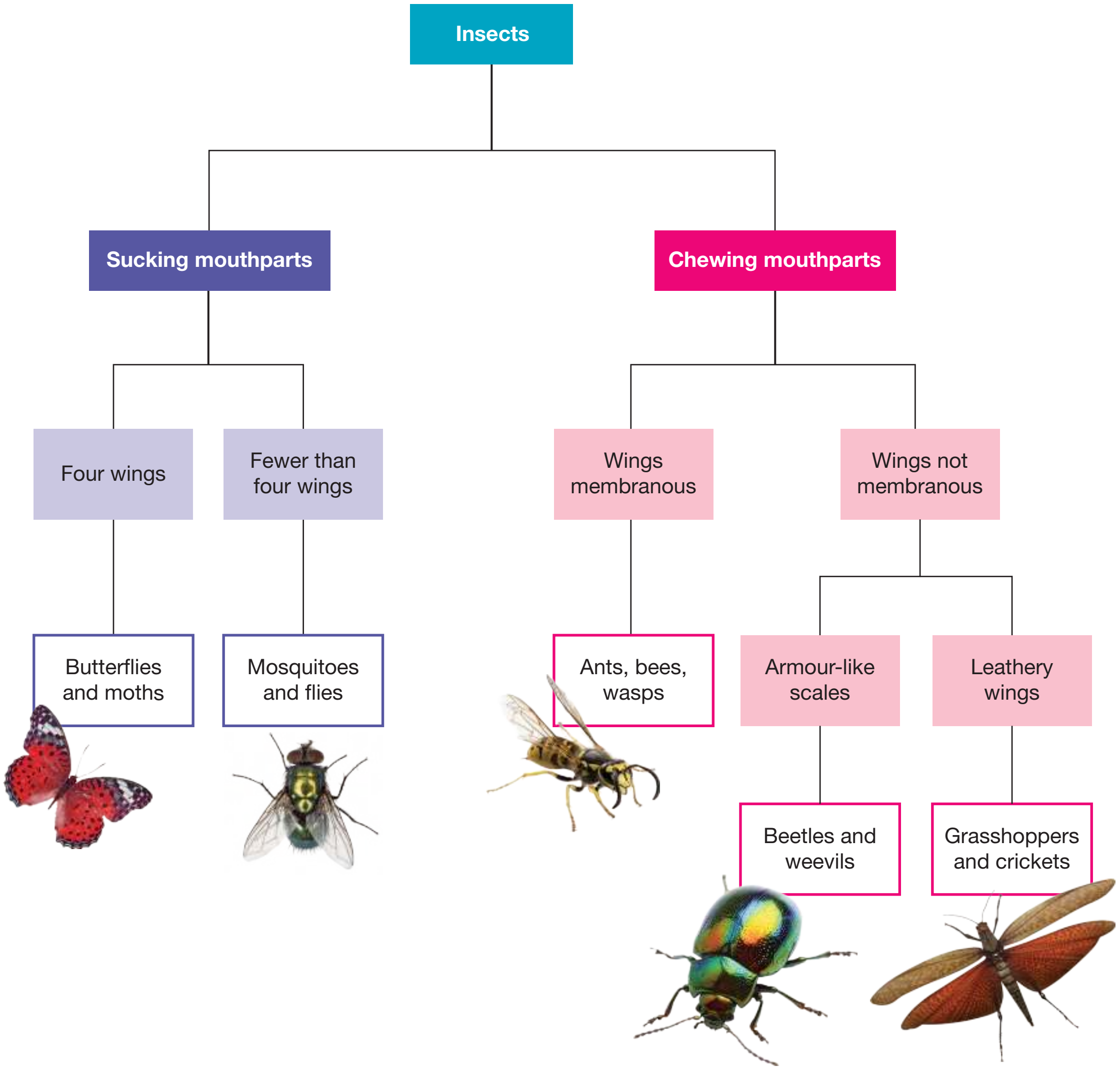
FIGURE 3.52 Categorising insects that suck and insects that chew



on Resources

eWorkbook	Classifying invertebrates (ewbk-11145)
Digital document	Human endeavours in classification (doc-26461)
Video eLessons	Praying mantis (eles-2208)
	The movement of invertebrates (eles-4235)
Weblink	Magnified portrait of insect

3.9 Activities

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3.9 Quick quiz on	3.9 Exercise

Select your pathway

■ LEVEL 1	■ LEVEL 2	■ LEVEL 3
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Remember and understand

1. a. Identify whether the following statements are TRUE or FALSE.

Statements	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 true.

2. Match the invertebrate phylum to its example from the options in the right-hand column.

Phylum	Example
a. Annelids	A. Threadworms
b. Arthropods	B. Slugs
c. Cnidarians	C. Tube sponges
d. Echinoderms	D. Sea urchins
e. Molluscs	E. Grasshoppers
f. Nematodes	F. Tapeworms
g. Platyhelminthes	G. Earthworms
h. Porifera	H. 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. Consider what you have learnt about the structural features of insects to answer the questions that follow.
   a. State the three parts in 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 with its number of legs and give an example.

TABLE A comparison of different arthropod groups

Arthropod group	Number of legs	Example
a. Arachnids		
b. Chilopods		
c. Crustaceans		

d. Diplopods		
e. Insects		

6. Outline how the types of heads and mouthparts of insects can tell you about the way that they live and feed.

Apply and analyse

7. Read the following information about bedbugs carefully, and answer the question that follows.

Understanding bedbugs

Bedbugs (*Cimex lectularius*) come out at night and feed on the blood of mammals and birds. Their mouthparts 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 five minutes or more to extract their meal before scurrying off to digest it and rest.

Explain how bedbugs are able to effectively feed on humans, using the relevant bedbug information from the passage in your own words.

8. Distinguish between endoparasites and ectoparasites and provide an example of each.
9. Use the invertebrate key in figure 3.46 to identify the invertebrate group 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 the invertebrate key in figure 3.46 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 the invertebrate key in figure 3.46 to identify which of the following pairs have the most in common.
    A. Arthropods and annelids
    B. Echinoderms and molluscs
    C. Poriferans and platyhelminthes
    D. Cnidarians and echinoderms
12. **SIS**
    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 the invertebrate key in figure 3.46 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 the arthropod key (figure 3.47) 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 the insect key (figure 3.52) to identify the group that possesses:
    a. chewing mouthparts and membranous wings
    b. sucking mouthparts and four wings
    c. chewing mouthparts and leathery wings.

16. Use the insect key (figure 3.52) to identify features that differentiate:
   a. mosquitoes from butterflies
   b. mosquitoes from bees
   c. beetles from grasshoppers.

Evaluate and create

17. a. Use the insect key (figure 3.52) to classify a variety of insects into their groups.
   b. Did you have any difficulties using the key? Suggest any changes that you could make to improve it.
18. SIS Use a magnifying glass or stereo microscope 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. SIS Find out why cnidarians are no longer classified as coelenterates.
20. 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. Make 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.
21. SIS Describe how you would design a mask to model the feeding parts of several different insects.
22. SIS
   a. Find out the similarities and differences between locusts and grasshoppers and present your results in a Venn diagram.
   b. Research the functions of the Australian Plague Locust Commission (APLC).
   c. Identify, research and report on a question or problem related to locust plagues.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
3.10 Classifying plants

LEARNING INTENTION

At the end of 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, and how their specific adaptations can enhance their chances of survival.

3.10.1 Using patterns to classify plants

More than 23 centuries ago a Greek philosopher named Aristotle developed one of the first widely used classification schemes (shown in figure 3.53). 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.

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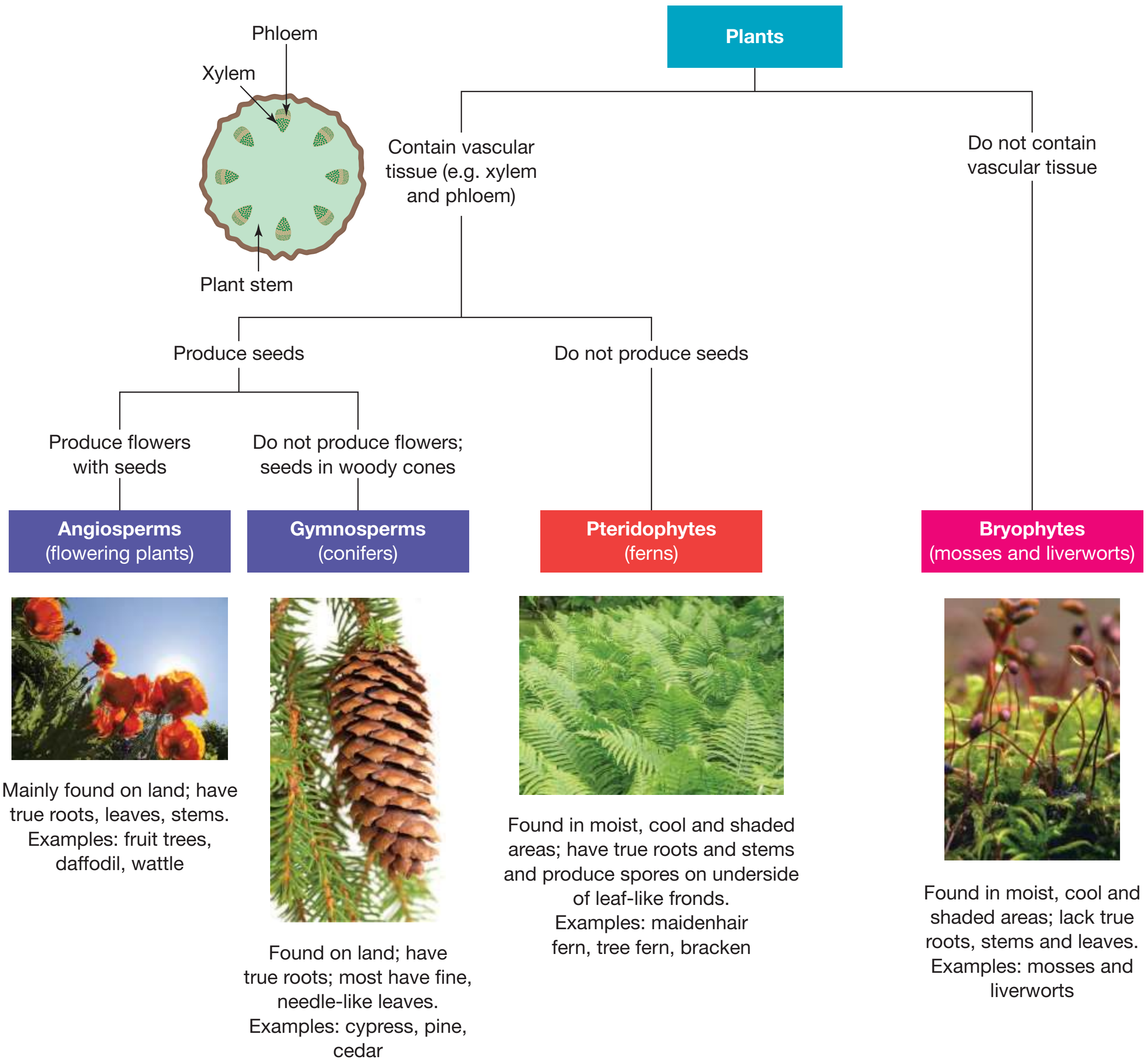
FIGURE 3.53 Classification of plants



Biologists often use the presence, absence or patterns in structural features or reproductive structures to group, classify and identify different types of plants. Plants that contain vascular tissue belong to a group called **tracheophyta** (= 'windpipe' + 'plant'), also referred to as plants with stems. 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.

tracheophyta plants with a vascular system

pteridophytes vascular plants that produce spores usually located on the underside of their leaves

gymnosperms vascular plants that produce seeds in woody cones, but do not produce flowers

angiosperms vascular plants that produce seeds and flowers

vascular tissue plant tissue involved in the transport of substances within the plant (and in plant support)

xylem vascular tissue that carries water and minerals from the roots up to the leaves

phloem vascular tissue that transports organic substances (such as sugars) within plants

3.10.2 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 as *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 words like 'tree', 'shrub', 'herb' and 'grass' to describe groups of plants. To a scientist, a tree could belong to the angiosperm or gymnosperm group. A scientist would carefully examine the characteristics of the plant to find out whether it had flowers, seeds and fruit, or cones containing seeds. The scientific names for individual plants and groups of plants are more specific than the common names.

FIGURE 3.54 The scientific name for this bottlebrush tree is *Callistemon citrinus.*

Build your knowledge of scientific language

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'.

3.10.3 Evergreen quest

Have you ever grown a herb garden — your own 'evergreen quest'? 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: Grow your own herbs

Try growing these common herbs in your own garden or planter box.

FIGURE 3.55 Common garden herbs you might try growing at home.

- Thyme is 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 stems 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.

ACTIVITY: Your school's gardens — a field guide

a. In pairs, walk around your school grounds and select ten plants.
b. Draw a sketch of each and add as many details as you can next to your diagram.
c. Construct a key to organise these plants into groups.
d. Use field guides and the internet to find out the identity of these plants.
e. 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.

DISCUSSION

Even though they might be delicious or provide essential nutrients, many of the plants we grow to eat in Australia are not native to our environment. This can have significant impacts on native plants and animals. Blackberries are one such introduced species that has become a significant problem in some parts of Australia.

Discuss whether all blackberry plants should be destroyed in Australia — including those used for growing commercial berries on farms. To help you evaluate the issue, create a PMI chart.

3.10.4 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 'unplant-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 to be 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 3.56 A four-leaf clover

Poisons and stinging hairs

Inhabitants of tropical forests used some plants to make arrow poison. In Asia and South America, some species of the genus *Strychnos* were used to obtain arrow poison from their roots and bark. The poison used on the arrows was curare. Although a person hit with a poisoned arrow could still think and sense things for quite some time, organs involved in movement would gradually fail to function. In the end, the person's ability to speak would disappear, followed by the lack of movement in other areas (such as the face) and, finally, death.

Another 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 3.57 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 two 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 3.58 A Venus flytrap

FIGURE 3.59 Sundews covered in a sticky substance

DISCUSSION

Dangerous plants

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!

What are some other examples of plants that you need to be wary of?

Do some people have bad reactions to plants that others don't?

Have you every had a negative reaction to a plant — either by coming into contact with it, or eating it?

FIGURE 3.60 Fool's parsley

on Resources

eWorkbook Getting to know plants (ewbk-11151)

Video eLesson Growing plants in Australia (eles-0055)

3.10 Activities

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3.10 Quick quiz on	3.10 Exercise

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Select your pathway

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

Remember and understand

1. a. Identify whether the statements are TRUE or FALSE.

Statements	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 true.

2. Match the scientific term in the table with its common name and provide an example.
   Common names: Conifers; Ferns; Flowering plants; Mosses and liverworts
   Examples: Cypress trees; Fruit trees; Maidenhair ferns; Mosses

TABLE The scientific and common names of different plants

Scientific term	Common name	Example
a. Angiosperms		
b. Bryophytes		
c. Gymnosperms		
d. Pteridophytes		

3. Consider what you have learnt about plants in this topic.
   a. List two features shared by angiosperms and gymnosperms.
   b. Identify a feature that distinguishes angiosperms from gymnosperms.
4. Complete the table by identifying whether the features (vascular tissue, flowers or seeds) are present or not present. Use 'Yes' for present and 'No' for not present.

TABLE Features of different plant groups

Plant group	Vascular tissue	Flowers	Seeds
a. Angiosperms			
b. Bryophytes			
c. Gymnosperms			
d. Pteridophytes			

5. Match the scientific name of each listed plant to its common name.

Scientific name	Common name
a. *Allium sativum*	A. Four-leaf clover
b. *Dendrocnide excelsa*	B. Garlic
c. *Dionaea muscipula*	C. Giant stinging tree
d. *Trifolium repens*	D. Venus flytrap

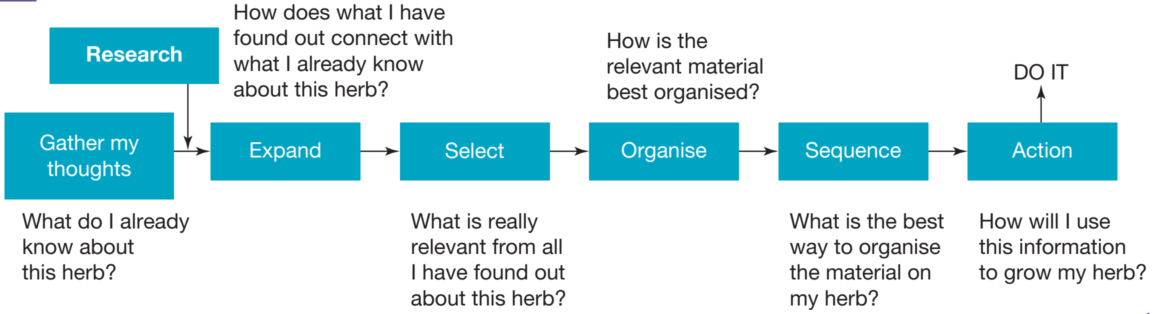
6. Describe the advantages to plants of being able to catch and digest animals as well as to photosynthesise.
7. Recall which of the following herbs, (i) rosemary (ii) sweet basil, (iii) parsley or (iv) lemon balm, can be used:
   a. as a compress for insect bites
   b. to soothe headaches and help relieve 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 the classification of plants key (figure 3.53) 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, do not produce flowers, but have seeds in woody cones
   d. contain vascular tissue, but do not produce seeds.
10. What does a taxonomist in a herbarium do? Why is this job important?
11. Find out the meaning of 'toxicology' and then find examples of Australian plant toxicology research.
12. a. Find three examples each of a tree, shrub, herb and grass. Observe and record five characteristics for 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. Growing up you may have picked dandelions, carefully blowing off the florets and watching them scatter and be taken off by the wind.
    Dandelions are actually considered weeds. Research and explain why they are classed 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. **SIS** Design a key to help a gardener tell the difference between trees, shrubs, herbs and grasses.
16. **SIS** Australia has about a thousand species of plants that are considered to be toxic to humans and our livestock. Of these, 60 per cent are natives. Investigate and report on an example of a toxic plant within each of the following Australian plant families:
    a. Legumes (Fabaceae, Mimosaceae)
    b. Nightshades and tobaccos (Solanaceae)
    c. Buttercups (Ranunuclaceae)
    d. Cycads (Cycadaceae, Zamiaceae).
17. **SIS** A flowchart has been provided to guide you in order to help you design an investigation.



a. Use the flowchart provided to organise and record your research on a herb of your choice.
b. In the 'action' phase, use your information to set up an experiment to grow your herb.
c. Take photographs throughout your experiment and keep a journal to record all of your observations.
d. Summarise your observations.
e. Explain how you might improve the design of your investigation.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
3.11 The unique flora of Australia

LEARNING INTENTION

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

3.11.1 Snugglepot and Cuddlepie

When you were young, did you 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. Did you know they are based on real Australian plants?

DISCUSSION

Cecelia 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 were 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 1918.

What other artists and writers were inspired by Australia's natural environment?

Can you think of any other characters in books, film or television that are based on Australian animals or plants?

Discuss in groups what Australian animals or plants you would include if you wrote a story and explain why you would include them.

FIGURE 3.61 May Gibbs was inspired by our Australian bush.

3.11.2 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 3.62.

FIGURE 3.62 The Gumnut Babies Snugglepot and Cuddlepie were based on the flowers of a eucalypt.

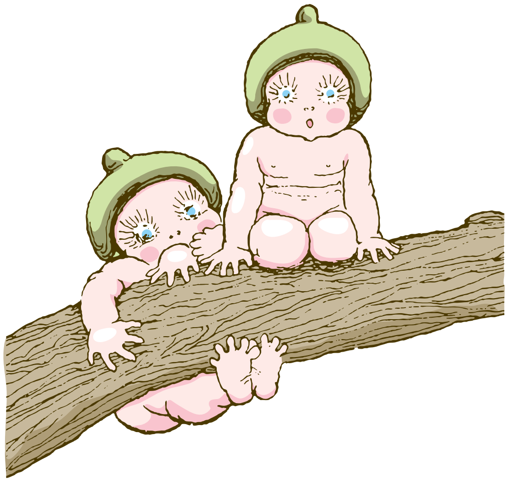


FIGURE 3.63 The flowers of a eucalypt

on Resources

Interactivity Adaptations in *Eucalyptus* trees (int-3432)

3.11.3 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 3.64 A *Grevillea*. There are more than 360 species of *Grevillea*.

FIGURE 3.65 A *Hakea*

FIGURE 3.66 Macadamia flowers and nuts

FIGURE 3.67 *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 3.68 The Banksia Man is based on the *Banksia* follicle, which is a woody, cone-like structure that develops after a *Banksia* flowers.

FIGURE 3.69 A *Banksia* flower

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

Around 1782, the genus *Banksia* was named after English naturalist Sir Joseph Banks (1743–1820). As a young man, Banks travelled to Australia on Captain Cook's first Pacific voyage (1768–1771). Many of the specimens that he recorded and collected (including both *Banksia* and *Eucalyptus*) had never been seen before in his homeland.

Swedish naturalist Carl Linnaeus was so impressed with Bank's collections that he proposed that our country should have been named Banksia rather than Australia.

Joseph Banks' passion for botany and flora, and the collection of these specimens from far and wide, meant that Kew Gardens in London became one of the most diverse botanical gardens worldwide.

The work of Sir Joseph Banks greatly influenced worldwide appreciation for the beautiful flora we have in Australia.

FIGURE 3.70 Sir Joseph Banks

ACTIVITY: Floral emblems of Australia

Did you know that each state and territory of Australia has its own floral emblem? Table 3.7 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 3.7 Floral emblems of Australia

State	Australian Capital Territory
Common name	Royal bluebell
Scientific name	*Wahlenbergia gloriosa*

State	New South Wales
Common name	Waratah
Scientific name	*Telopea speciosissima*

TABLE 3.7 Floral emblems of Australia *(continued)*

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

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

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

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

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

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

3.11 Activities

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3.11 Quick quiz on	3.11 Exercise

Select your pathway

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

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Remember and understand

1. a. Identify whether the statements are TRUE or FALSE.

Statements	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 true.
2. Consider what you have learned about Australian plants.
   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 listed.

Australian state or territory	Common name of floral emblem
a. Australian Capital Territory	A. Common heath
b. New South Wales	B. Cooktown orchid
c. Northern Territory	C. Red and green kangaroo paw
d. Queensland	D. Royal bluebell
e. South Australia	E. Sturt's desert rose
f. Tasmania	F. Tasmanian blue gum
g. Victoria	G. Waratah
h. Western Australia	H. Sturt's desert pea

Apply and analyse

6. Who was May Gibbs? Why did she include Australian plants in her stories?
7. Find out who each of the following Australian plants were named after and why they received these names.
   a. Waratah b. Proteus c. Grevillea d. Hakea e. Banksia
8. SIS Investigate and report on Australian research into Australian plants.
9. SIS Select two examples of Australian plants. Research and report on the history and importance of these plants.
10. Write a report on the importance of native flora in your life.

11. 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.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
3.12 Algae, fungi and lichens

LEARNING INTENTION

At the end of this lesson you will be able to explain the reasons why algae, fungi and lichens are no longer classified as members of the plant kingdom.

3.12.1 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 3.71.

algae aquatic photosynthetic organisms that are often unicellular

fungi eukaryotic organisms that generally use spores to reproduce, and contain cell walls made of chitin

lichen a mutualistic symbiotic relationship of a fungus with an alga and/or a cyanobacterium

FIGURE 3.71 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:

- 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: diatom, Neptune's necklace, seaweed (figure 3.72)

FIGURE 3.72 Giant kelp (seaweed) is an alga.

Fungi

Characteristics:

- 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: yeast, mould, mushrooms (figure 3.73), toadstools

FIGURE 3.73 Not all mushrooms are safe to eat! Some can be poisonous.

Lichens

Characteristics:

- Found on bare rocks (figure 3.74), 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 3.74 Several types of lichen may grow together.

FIGURE 3.75 Better dry between your toes or you may get the fungal infection athlete's foot (*Tinea pedis*).

FIGURE 3.76 Mushrooms are fungi we eat, and yeasts are very important in making bread and wine.

ACTIVITY: Lichens, fungi and algae in biology books

Look up lichens, algae and fungi in at least three different biology books 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 the table.

TABLE 3.8 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

on Resources

eWorkbook Lichen, fungi and algae (ewbk-11153)

3.12 Activities

learn**on**

3.12 Quick quiz on | **3.12 Exercise**

Select your pathway

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

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Remember and understand

1. a. Identify whether the statements are TRUE or FALSE.

Statements	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 true.
2. Recall the group (algae, gungi, 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. SIS Find out about and report on the features used to classify fungi into groups. Include labelled diagrams or sketches in your report.
6. What are the symptoms of tinea? How do you get it and how can it be prevented and treated?
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. Which, if any of these groups, do you think are most like plants? Why?
   c. If you were a biologist, would you classify any of these groups as plants? Explain.
8. a. What are 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. SIS Design an investigation, using slices of bread, to find out which conditions are best suited to growing moulds.
12. SIS Find out more about the discovery of penicllin and the influence it has had on medicine and disease.
    - 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.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
3.13 Thinking tools — Tree maps

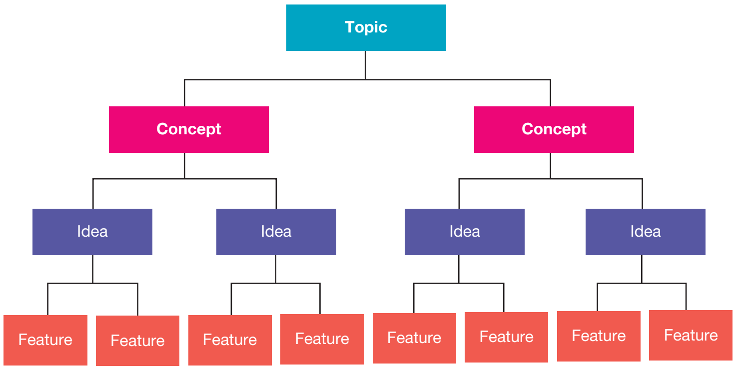
3.13.1 Tell me

What is a tree map?

A tree map or tree diagram is used when you need to show the hierarchy or order of ideas within a topic. They are also used to show the way that things can be divided into strata or levels. The dichotomous keys you have been creating and examining in this topic are a kind of tree map.

Think of this kind of diagram as a map that shows how one bigger concept or original thing can be broken down into smaller categories or parts. They are also known as branching diagrams.

FIGURE 3.77 A tree map



What is a tree map for?

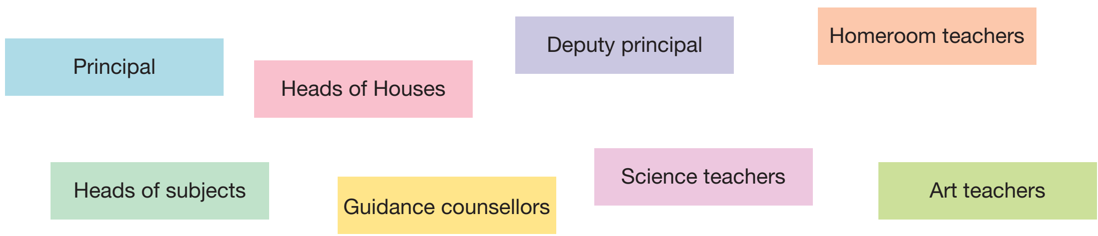
A tree map shows a hierarchy, so you use a tree diagram when you need to show an order or grading of things — from the biggest or earliest, to the smallest or latest. A great way to remember what you use a tree diagram for is to remember that your family tree is a tree diagram. A family tree organises family members from oldest to youngest by showing each generation of parents and children in order.

3.13.2 Show me

Creating a tree diagram

1. On small pieces of paper, write down all the important ideas related to your topic. This might include specific examples, ideas and bigger concepts. For example, if you were creating a tree diagram to show the jobs people have in your school, you might come up with some of those in figure 3.78.

FIGURE 3.78 Write down all your terms.



2. Arrange your pieces of paper in groups related to the main ideas within the topic. The main idea in this example is 'jobs held by people in your school'. Because tree diagrams are used to show a hierarchy or order, we can put the jobs in order of seniority or rank.

FIGURE 3.79 Group your ideas in categories.

Highest levels (in charge of school)	Next level (in charge of groups)	Homeroom/Pastoral care	Classroom teachers
Principal	Heads of Houses	Homeroom teachers	Science teachers
Deputy principal	Heads of subjects	Guidance counsellors	Art teachers

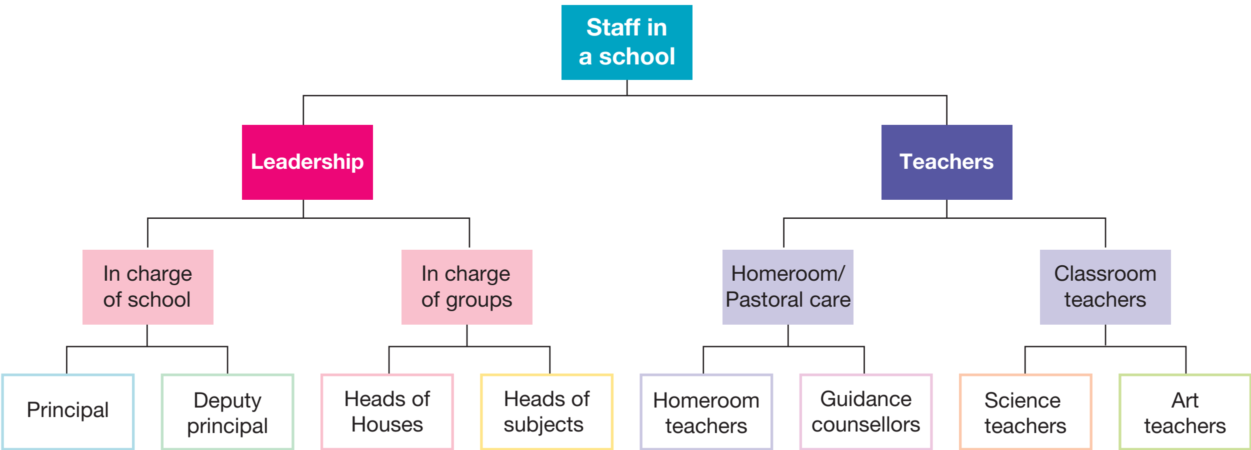
3. Within each group, arrange the ideas into their order. In this case, we have used leadership and teachers to define our groups.

FIGURE 3.80 Arrange ideas in your groups.

Leadership		Teachers	
Principal	Heads of Houses	Homeroom teachers	Science teachers
Deputy principal	Heads of subjects	Guidance counsellors	Art teachers

4. Now draw your tree diagram with the main ideas at the top and others below it. The example here is for a hierarchy of people, but the same process applies to ordering ideas.

FIGURE 3.81 A tree map showing staff in a school



3.13.3 Let me do it

3.13 Activities

1. Create a tree map showing your family or the people you live with. You may wish to include any pets as well.
2. Pick any eight items in your pencil case or around your desk. Create a tree map to sort these into groups.
3. Write down your eight favourite animals and create a tree map to classify them into groups.
4. Select one of the following groups: spiders, mushrooms, flowers or fish. Research at least eight different organisms and place them in a tree map.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
3.14 Project — Snakes alive

Scenario

Every year in Australia, an average of around 4000 people are bitten by snakes. Some of these snakes are non-venomous and their bite results in little more than a nasty wound, but many are venomous with a bite that is deadly unless medical intervention can be reached in time — in fact, Australia has more venomous snake species than any other country in the world! You can encounter a snake just about anywhere — on bushwalking trails, in your back garden, in a shed, even swimming in the ocean — so it is really important that you know what kind of snake you are looking at.

FIGURE 3.82 Some snakes found in Australia are non-venomous, but some are venomous.

Your task

Your group has been approached by State Parks and Wildlife to create a Snake Safety brochure, copies of which will be sent out to all bushwalking clubs and National Park centres in your state for distribution to bushwalkers, campers and nature lovers. The main part of the brochure will be an easy-to-follow identification key that allows the reader to quickly and easily determine the species of snake they have encountered and so learn whether it is venomous or non-venomous. The brochure will also contain a diagram indicating on a state map where different venomous species are usually found, as well as advice on what to do if you encounter a snake and what first aid you should render if someone is bitten by a venomous or non-venomous snake. You may also like to include some interesting snake statistics, or a Snake Fact or Fiction section.

FIGURE 3.83 If you encounter a snake, it is important to be able to identify what kind of snake you are looking at.

on Resources

ProjectsPLUS Snakes alive! (pro-0088)

LESSON
3.15 Review

Hey students! Now that it's time to revise this topic, go online to:

Review your results

Watch teacher-led videos

Practise questions with immediate feedback

Find all this and MORE in jacPLUS

Access your topic review eWorkbooks

on Resources

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-11163	ewbk-11165	ewbk-11167

3.15.1 Summary

Classification systems

- All living things (organisms) respond to changes in their environment, need energy to survive, assimilate (take in and process) substances, produce and excrete wastes, grow and reproduce.
- Cells are the building blocks that make up all living things.
- Organisms are made up of one (unicellular) or many cells (multicellular).
- Classifying things into groups can make them easier to remember, describe and identify.

Patterns in scientific language

- The prefixes and suffixes of many scientific terms can provide hints about their meaning.

Understanding scientific names

- In the five-kingdom system of classification, all living things are divided up into the Animalia, Plantae, Fungi, Protista (or Protoctista) and Monera (or Prokaryotae) kingdoms.
- A key characteristic used to classify organisms into the five different kingdoms was the structure of their cells.
- There are different levels in the classification hierarchy: kingdom, phylum, flass, order, family, genus and species.
- As you move from kingdoms to species, the members of the group have increasingly more in common.
- Organisms of the same species resemble each other and can interbreed to produce fertile offspring.
- Binomial nomenclature is a naming system in which each species has a name made up of two words. The genus name is the first word with a capital letter, and lower case is used for the second word (which is the descriptive name). Together they make up the scientific name for the species, which should be typed in italics or underlined if handwritten (e.g. *Homo sapiens*).

Keys to unlock identity

- Keys and field guides can be used to identify organisms. A variety of criteria are used to classify the unknown organism into small groups based on whether it has a particular feature.
- Dichotomous keys provide choices at each branch and can be presented as branching keys or tabular keys.
- Circular keys and field guides are also useful classification tools.
- The presence or absence of structural features (or differences are) better to use when classifying than size, colour and habitat, because these features can change throughout the lie of an organism.

Classifying animals

- The presence or absence of a backbone (vertebrates or invertebrates), the type of skeleton (endoskeleton, exoskeleton or no skeleton) and type of body pattern (radial symmetry, bilateral symmetry or asymmetry) are useful features to use when classifying animals.
- Animals can be classified into nine main phyla: Porifera, Platyhelminthes, Nematoda, Mollusca, Annelida, Arthropoda, Chordata, Echinodermata and Cnidaria.

Classifying vertebrates

- Vertebrates can be classified into five main groups: mammals, fish, birds, amphibians and reptiles.
- Similarities in structure (such as the pentadactyl forelimb in vertebrates) can suggest that they shared a common ancestor at some point in their evolution.

Classifying mammals

- Mammals can be classified on how they give birth to their young: placental mammals, marsupials and monotremes.

Classifying invertebrates

- Invertebrates can be classified into eight main groups: arthropods, molluscs, echinoderms, porifera, cnidarians, annelids, nematodes and platyhelminthes.
- Arthropods can be classified based on the organisation and number of their legs into chilopods, diplopods, insects, arachnids and crustaceans.
- Insects can be classified by their mouthparts and wings.

Classifying plants

- The presence or absence of vascular tissue, flowers and seeds can be used to classify plants into Angiosperms, Gymnosperms, Pteridophytes and Bryophytes.
- New technologies and discoveries have led to the proposal of alternative classification systems.

Algae, fungus and lichens

- Although once considered plants, algae, fungi and lichens are no longer classified as such.

3.15.2 Key terms

algae aquatic photosynthetic organisms that are often unicellular
angiosperms vascular plants that produce seeds and flowers
arthropod an animal that has an exoskeleton, a segmented body and jointed legs (e.g. insects, crabs)
assimilate take in and process
asymmetry lack of symmetry
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
chromosome a tiny, thread-like structure that contains the DNA that carries genetic information
classification grouping animals and plants according to their similarities
dead once alive but now not alive
dichotomous key a diagram used to classify things, by grouping them into smaller and smaller groups based on choosing one of two features
ectoparasite a parasite that lives on the outside of its host
ectotherm an animal whose body temperature changes depending on the external environment
endoparasite a parasite that lives inside its host
endoskeleton a skeleton or shell inside the body
endotherm an animal that can maintain its internal body temperature in a constant range
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)

excrete get rid of waste
exoskeleton a skeleton or shell that lies outside the body
fungi eukaryotic organisms that generally use spores to reproduce, and contain cell walls made of chitin
grow undergo development
gymnosperms vascular plants that produce seeds in woody cones, but do not produce flowers
invertebrates animals without backbones
kingdom a scientific classification referring to a group of related phyla with similar features and distinctive characteristics
lichen a mutualistic symbiotic relationship of a fungus with an alga and/or a cyanobacterium
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
microscopy the use of microscopes to view structures that can't be seen with the naked eye
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
non-living not ever alive, as distinct from dead
organisms living things made up of one or more cells
parasite an organism that lives on or within another organism, to get all or some of its nourishment
phloem vascular tissue that transports organic substances (such as sugars) within plants
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
poikilothermic having a body temperature that fluctuates and is similar to the temperature of its environment (as in cold-blooded organisms)
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
prokaryotic any cells or organisms without a membrane-bound nucleus (e.g. bacteria)
pteridophytes vascular plants that produce spores usually located on the underside of their leaves
radial symmetry symmetrical about the centre axis
reproduce create offspring
respond react to a stimulus
setae bristle-like structures often found on invertebrates
species a group of organisms with many features in common, that can mate with each other to produce fertile young under natural conditions
symmetry the quality of being a mirror image across an axis
taxonomy the study of the classification of organisms
tracheophyta plants with a vascular system
unicellular made up of a single cell
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
viroid the smallest infectious known pathogen, comprised solely of a short single-stranded piece of RNA
virus a non-cellular pathogen that uses the host cells in order to reproduce
xylem vascular tissue that carries water and minerals from the roots up to the leaves

on Resources

Digital document	Key terms glossary (doc-39610)
eWorkbooks	Study checklist (ewbk-11156) Reflection (ewbk-11155) Literacy builder (ewbk-11157) Crossword (ewbk-11159) Word search (ewbk-11161)
Practical investigation eLogbook	Topic 3 Practical investigation eLogbook (elog-1984)

3.15 Activities

learnon

3.15 Review questions

Select your pathway

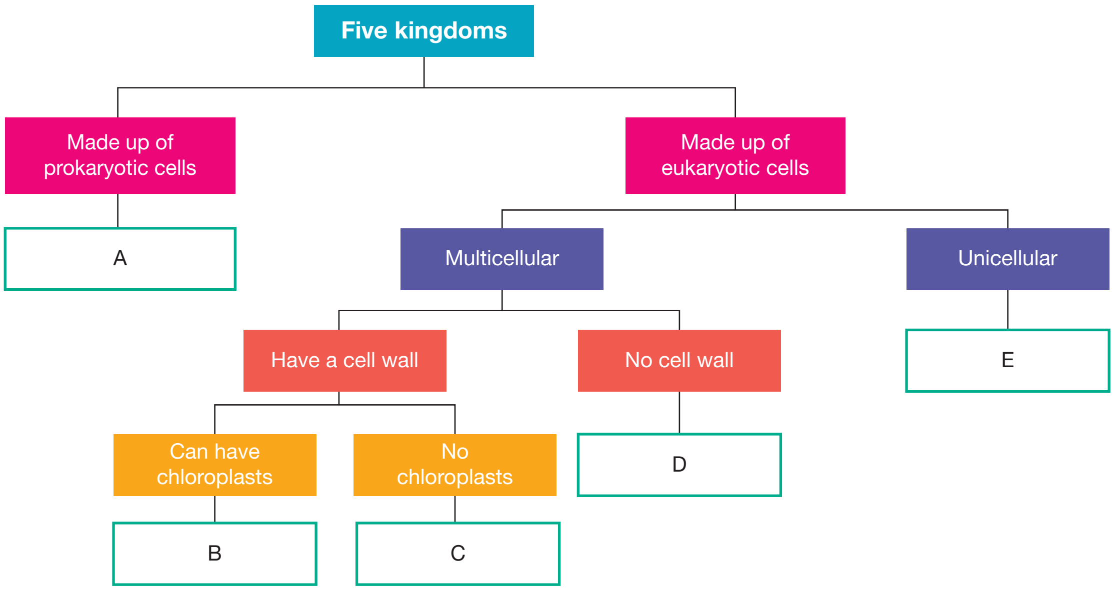
LEVEL 1	LEVEL 2	LEVEL 3
1, 3, 4, 7, 10, 13, 15	2, 5, 6, 8, 9, 11, 12, 16, 19	14, 17, 18, 20, 21

Remember and understand

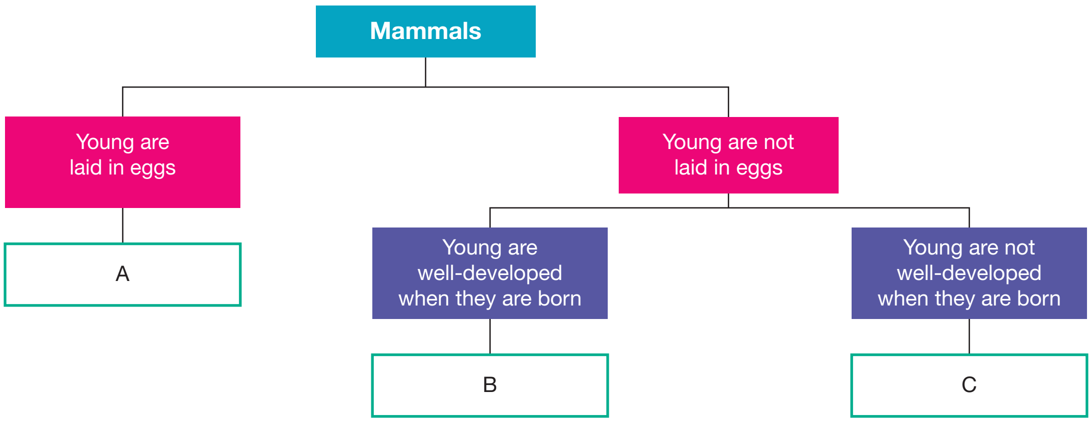
1. a. Identify whether the statements are TRUE or FALSE.

Statements	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.	

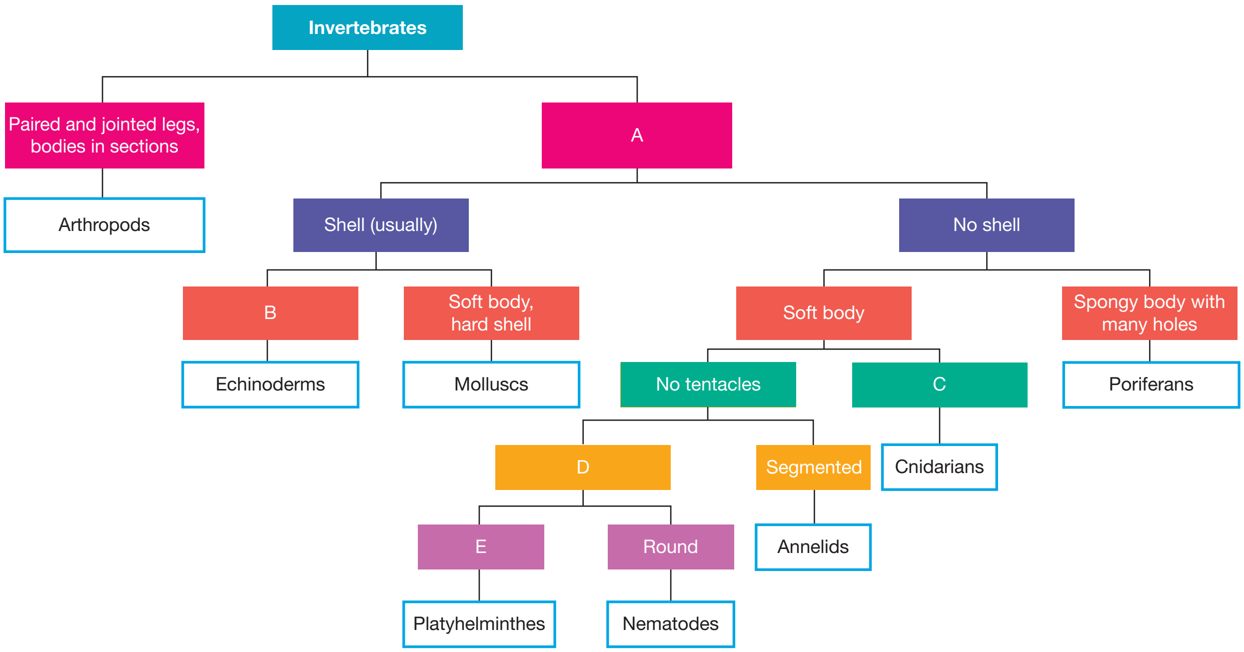
   b. Rewrite any false statements to make them true.
2. Complete the following, based on your understanding of this topic.
   a. Describe the system of binomial nomenclature.
   b. State the species name for humans.
   c. List the seven levels of classification hierarchy in order from kingdom to species.
   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 the kingdoms (A–E) in the five kingdoms key shown.



4. Suggest the identity of the type of mammals (A–C) in the diagram shown.

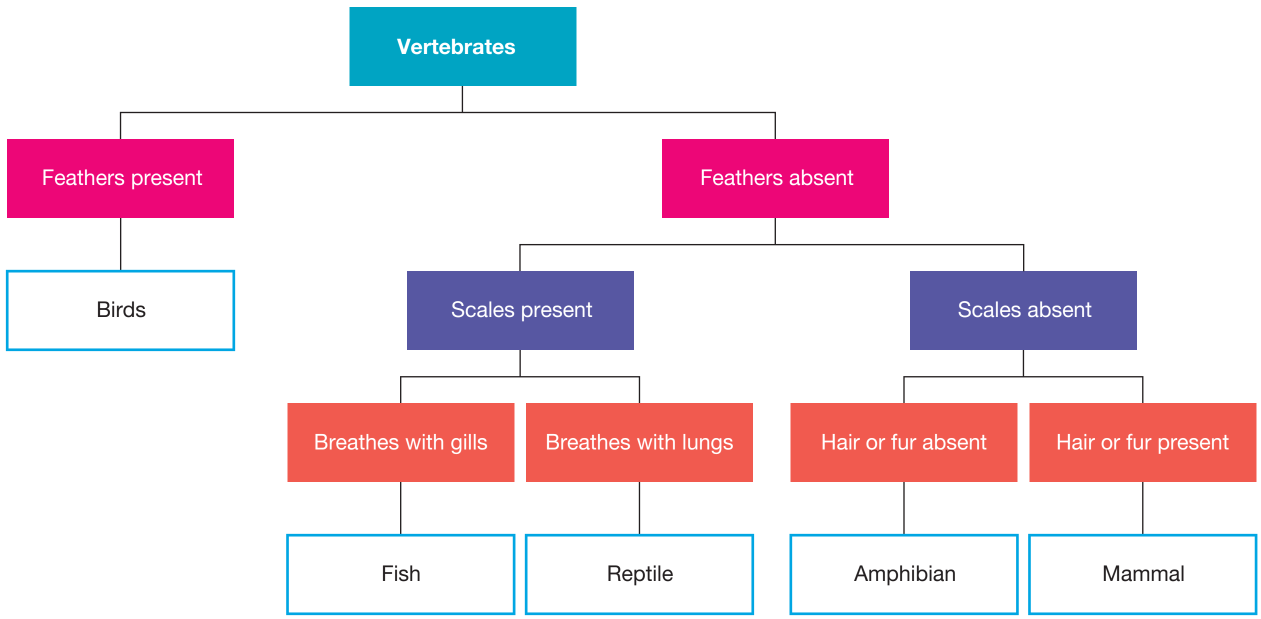


5. Suggest the identity of the missing features (A–E) in the invertebrates key shown.

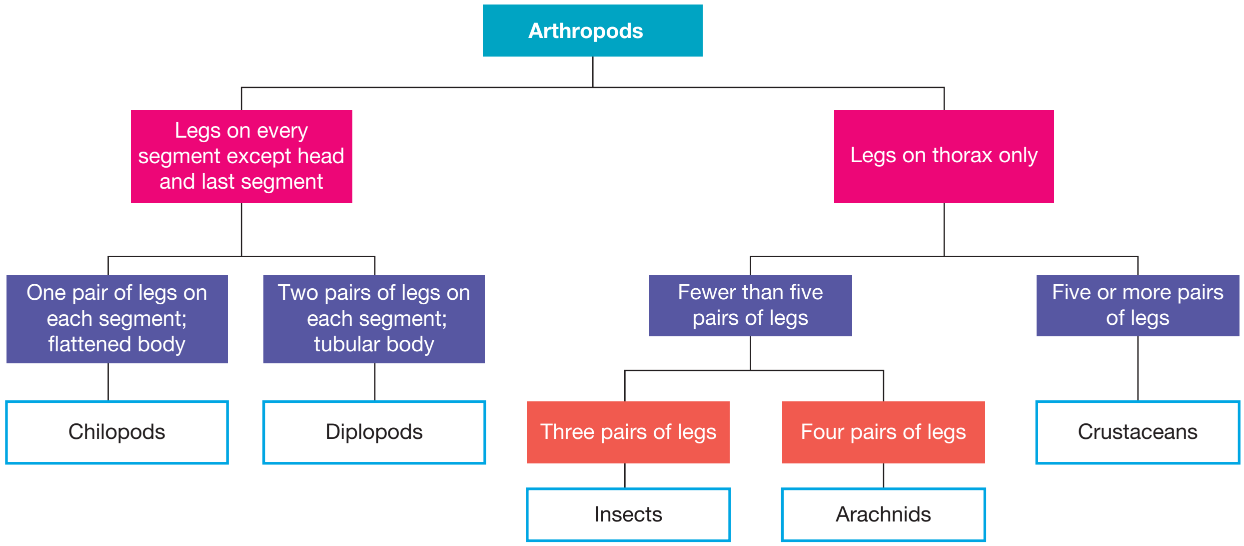


6. Identify an example for each plant phylum:
   a. Bryophytes
   b. Pteridophytes
   c. Angiosperms
   d. Gymnosperms.

7. Using the information in the vertebrates dichotomous key, 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 the arthropods key, 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 the arthropod key (in question 8) to identify the group to which each of the following arthropods belongs.

a.

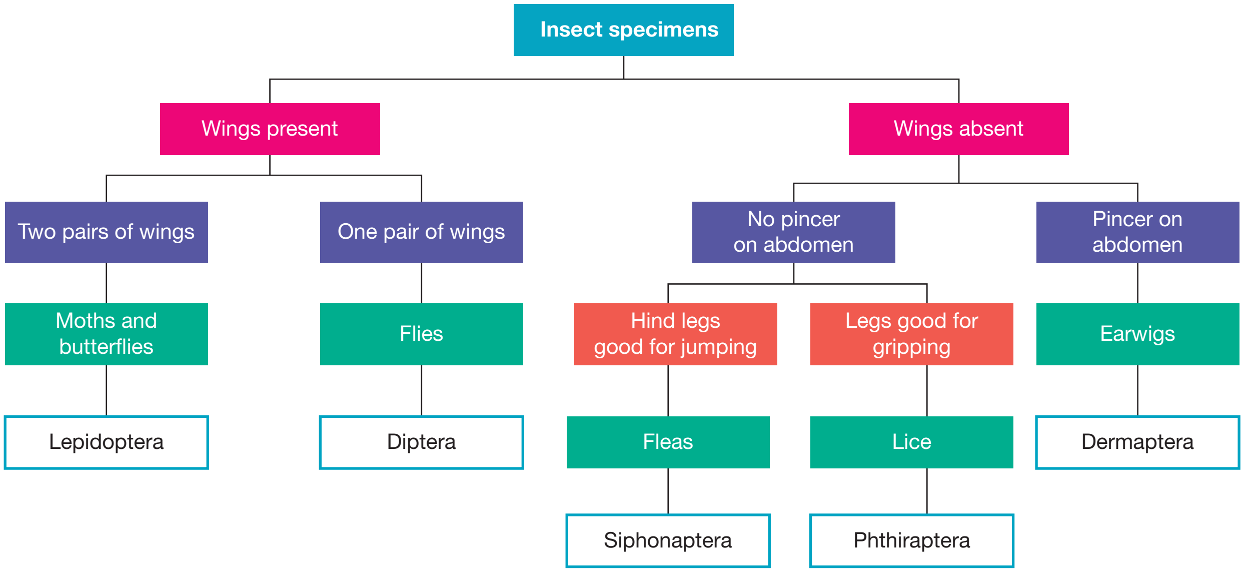

b.


c.


d.


e.


14. Use the information in the insect specimens 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 specimens a–d belong.

a.


b.


c.


d.


Evaluate and create

15. Use the information in the vertebrates dichotomous key (in question 7) 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 the arthropods dichotomous key (in question 8) to construct Venn diagrams to show the similarities and differences between each of the followinggroups.
    a. Chilopods and diplopods
    b. Insects, arachnids and crustaceans
17. Use the information in the insect specimens 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. **SIS**
    a. Construct a table with the following headings.
       - Genus or species
       - Beneficial effects
       - Description of useful plant part
       - Other details
    b. Complete the table with details on the following herbs, using the information in this lesson 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.


earwig
(Dermaptera)


dragonfly
(Odonata)


thrips
(Thysanoptera)


thysanuran
(Zygentoma)

21. Use Venn diagrams to summarise the five-kingdom classification system.

Online Resources

on Resources

Below is a full list of **rich resources** available online for this topic. These resources are designed to bring ideas to life, to promote deep and lasting learning and to support the different learning needs of each individual.

3.1 Overview

eWorkbooks
- Topic 3 eWorkbook (ewbk-11108)
- Student learning matrix (ewbk-11112)
- Starter activity (ewbk-11110)

Practical investigation eLogbook
- Topic 3 Practical investigation eLogbook (elog-1984)

Video eLessons
- Komodo dragons (eles-3274)
- The weedy seadragon (eles-2067)

Weblink
- The ruby seadragon

3.2 Classification systems

eWorkbooks
- Is it alive? (ewbk-11113)
- Labelling the kingdoms (ewbk-11115)
- Five-kingdom classification (ewbk-11117)
- Creatures from a parallel universe (ewbk-11119)

Video eLesson
- Sunflower seedlings (eles-2205)

Interactivities
- Alive, not alive or dead? (int-3422)
- Labelling the kingdoms (int-8232)
- Kingdoms (int-0204)

Weblink
- What are sea monkeys?

3.3 Patterns in scientific language

eWorkbook
- Unlocking scientific language (ewbk-11121)

Practical investigation eLogbook
- Investigation 3.1 Cryptonym game (elog-0382)

Interactivity
- The language of science (int-0935)

Weblink
- Tiny raptor tracks big discovery

3.4 Understanding scientific names

eWorkbook
- A catalogue of cats (ewbk-11123)

Interactivity
- How species are named (int-3421)

3.5 Keys to unlock identity

eWorkbooks
- My own zoo (ewbk-11125)
- Branching keys (ewbk-11127)
- Tabular and circular keys (ewbk-11129)

Practical investigation eLogbooks
- Investigation 3.2 Making a class key (elog-0384)
- Investigation 3.3 Making a class field guide (elog-0386)

Interactivities
- Dichotomous key (int-3423)
- Branching key (int-3424)
- Circular key (int-3425)

Weblink
- National field guide apps

3.6 Classifying animals

eWorkbooks
- Labelling examples of animals with endoskeletons and exoskeletons (ewbk-11133)
- Animal features (ewbk-11131)

Teacher-led video
- Investigation 3.4: Classifying animals into phyla (tlvd-10653)

Practical investigation eLogbook
- Classifying animals into phyla (elog-0388)

Interactivities
- Labelling examples of animals with endoskeletons and exoskeletons (int-8169)
- Features of animals (int-3428)

3.7 Classifying vertebrates

eWorkbooks
- Labelling the vertebrates dichotomous key (ewbk-11135)
- Classifying vertebrates (ewbk-11137)

eLesson
- Spinal cord (eles-2209)

Interactivities
- Labelling the vertebrates dichotomous key (int-0937)
- Labelling vertebrate classification (int-3429)

Weblink
- Frog ID

3.8 Classifying mammals

eWorkbook
- Looks can be deceiving (ewbk-11139)

Video eLessons
- Australian animals (eles-2211)
- The platypus (eles-2212)

Interactivities
- Classification of mammals (int-3420)
- Adaptations of kangaroos (int-3431)

Weblink
- Extinction of Australia's Megafauna (web-8365)

3.9 Classifying invertebrates

eWorkbooks
- Labelling the invertebrates dichotomous key (ewbk-11141)
- Labelling the arthropod dichotomous key (ewbk-11143)
- Labelling the insects dichotomous key (ewbk-11147)
- Classifying invertebrates (ewbk-11145)

Digital document
- Human endeavours in classification (doc-26461)

Video eLessons
- Praying mantis (eles-2208)
- The movement of invertebrates (eles-4235)

Interactivities
- Labelling the invertebrate dichotomous key (int-0938)
- Labelling the arthropod dichotomous key (int-0939)
- Labelling the insects dichotomous key (int-8170)

Weblink
- Magnified portrait of insect

3.10 Classifying plants

eWorkbooks
- Labelling the plants dichotomous key (ewbk-4034)
- Getting to know plants (ewbk-4036)

Video eLesson
- Growing plants in Australia (eles-0055)

Interactivity
- Labelling the plants dichotomous key (int-8168)

3.11 The unique flora of Australia

Interactivity
- Adaptations in *Eucalyptus* trees (int-3432)

3.12 Algae, fungi and lichens

eWorkbook
- Lichen, fungi and algae (ewbk-4038)

3.14 Project — Snakes alive

ProjectPLUS
- Snakes alive! (pro-0088)

3.15 Review

Digital document
- Key terms glossary (doc-39610)

eWorkbooks
- Topic review Level 1 (ewbk-11163)
- Topic review Level 2 (ewbk-11165)
- Topic review Level 3 (ewbk-11167)
- Study checklist (ewbk-11156)
- Literacy builder (ewbk-11157)
- Crossword (ewbk-11159)
- Word search (ewbk-11161)
- Reflection (ewbk-11155)

To access these online resources, log on to **www.jacplus.com.au**

4 Ecosystems

CONTENT DESCRIPTION

Use models, including food webs, to represent matter and energy flow in ecosystems and predict the impact of changing abiotic and biotic factors on populations (AC9S7U02)

LESSON SEQUENCE

SCIENCE INQUIRY AND INVESTIGATIONS

Science inquiry is a central component of Science curriculum. Investigations, supported by a **Practical investigation eLogbook** and **teacher-led videos**, are included in this topic to provide opportunities to build Science inquiry skills through undertaking investigations and communicating findings.

LESSON
4.1 Overview

Hey students! Bring these pages to life online

Watch videos | **Engage with interactivities** | **Answer questions and check results**

Find all this and MORE in jacPLUS

4.1.1 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 4.1. It is just one example of an ecosystem. Look closely for evidence of some of the many interactions that are occurring between the different types of **organisms**. For example, you can see different types of fish swimming close by each other among the many forms of coral.

Humans can affect these interactions between different organisms. The scuba diver might knock the coral with her flipper or catch some of the fish to eat for dinner.

FIGURE 4.1 A coral reef is one example of an ecosystem.

The picture also shows living things interacting with non-living things. 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, sometimes in a beneficial way.

organisms living things made up of one or more cells

relationships interactions with other species within an ecosystem

microorganisms microscopic (very small) life forms

on Resources

Video eLesson The beauty of the coral reef (eles-4161)

Coral reefs are one of the most diverse and beautiful ecosystems. Watch this video to see the diversity of a coral reef and the interactions between living and non-living things.

4.1.2 Think about ecosystems

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?

4.1.3 Science inquiry

Connected threads

Our planet contains a variety of different **ecosystems**. These ecosystems are made up of living and non-living things that interact with each other. The non-living things (such as temperature, water, soil and light) can determine which types of living things can survive in a particular area. These living things can affect both non-living and other living things within their ecosystem. In a similar way, interactions in one part of an ecosystem may have implications not only for one ecosystem, but also for others on our planet.

ecosystem a geographic area that consists of all the living organisms and the physical environment in which they interact

elog-1994

INVESTIGATION 4.1

Modelling interactions

Aim

To use a model to demonstrate interactions between living and non-living things within an ecosystem

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 environment' 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.
2. Comment on what happened when one part of the circle was removed.
3. Which parts were considered living? What reasons were given for these? Do you agree? What is your opinion?
4. What happened when all of the non-living parts sat down? What do you think would happen in a real ecosystem?

Conclusion

Summarise your findings for this investigation in three to four sentences, and outline how it relates to a real ecosystem.

Resources

eWorkbooks
Topic 4 eWorkbook (ewbk-11194)
Student learning matrix (ewbk-11198)
Starter activity (ewbk-11196)

Practical investigation eLogbook
Topic 4 Practical investigation eLogbook (elog-1993)

LESSON
4.2 First Nations Australians' connection to their ecosystem

LEARNING INTENTION

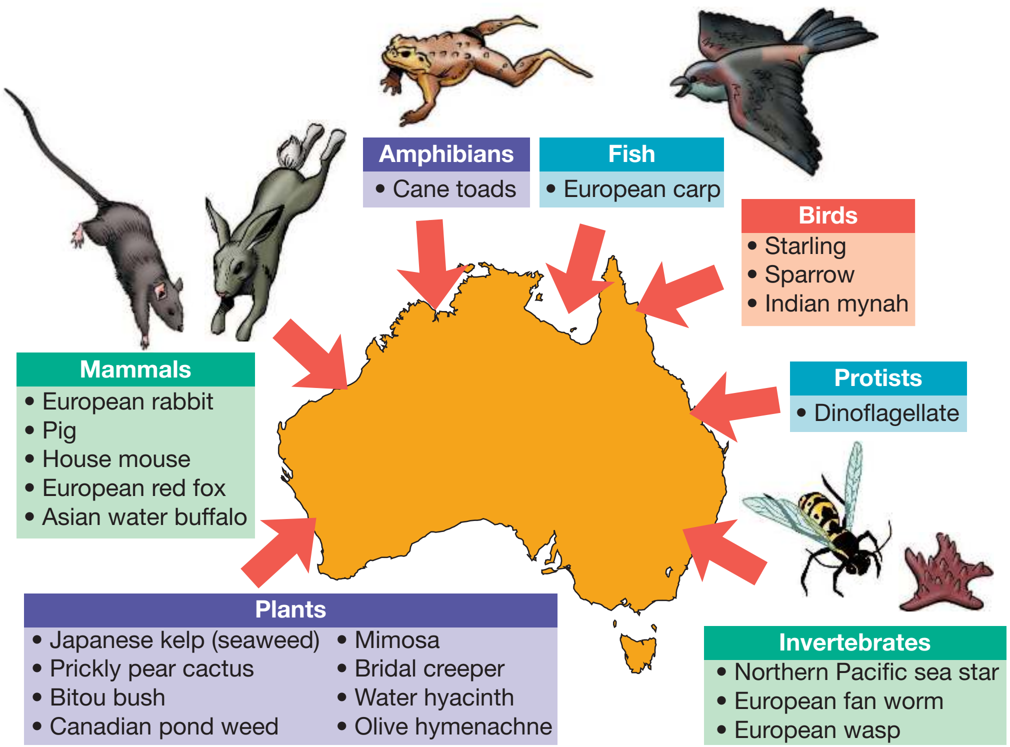
At the end of this lesson you will be able to explain how First Nations Australians have responded to invasive species and how they manage the land using fire.

4.2.1 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 significant impact on First Nations Australians' resource access and cultural practices. **Invasive species** are those plants and animals that are introduced in a certain area and then spread to a point that they damage the environment.

invasive species an organism that is not native to an area and has a negative impact on an ecosystem

FIGURE 4.2 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 sugarcane 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 and they need little water for breeding. In one season, the female toad can lay up to 40 000 eggs, which take only three 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.

First Nations Australians rely upon many native plants and animals as a source of food, medicine, materials, other life necessities and, most importantly, for personal identity and culture.

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, such as 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 50 other species of Australian animals that are now extinct.

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 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 like 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 First Nations Australians' communities to protect these endangered species. The Queensland government swiftly decided to provide protection to turtles and dugongs under the Queensland Animal Care and Protection Act.

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 fishermen 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.

First Nations Australians, 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 4.3), which can feed hotter and more intense bushfires. Some areas of First Nations Australian lands have not been notably affected, while other areas are now considered at risk of losing their biodiversity, as more intense bushfires could transform the vegetation there and thus affect the ecosystems in those lands.

FIGURE 4.3 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 Rob, weed management is part of caring for Country. However, it also takes up a lot of resources and time, which are already scarce, as 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 First Nations Australians are also involved in other management techniques, such as biocontrol.

Weeds of National Significance (WONS) weeds that have been identified based on their invasiveness, potential for spread, and environmental, social and economic impacts

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.

FIGURE 4.4 **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.

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.

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 one year the lake was completely rid of it.

In the Kimberley region (Western Australia), which is is now 93.5 per cent native title land, First Nations Australians are deeply involved in weed management, and the sector of conservation and land management offers opportunities for long-term careers for First Nations Australians in remote communities.

4.2.2 Land management by First Nations Australians

Bushfires have always been a common part of the Australian environment because of its dry and arid climate. Bushfires can be deliberately or accidentally lit by humans, but they can also happen naturally (due to lightning strikes, for instance).

First Nations Australians have deep connections to the lands, waterways and seas they have been caring for more than 65 000 years. They have made frequent and planned use of fire for effective land management. Burning the land was considered as 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, as well as 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 4.5 Warlpiri Peoples burning spinifex in the Tanami Desert (Northern Territory)

Firestick farming is also used for burning the 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.

First Nations Australians' 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.

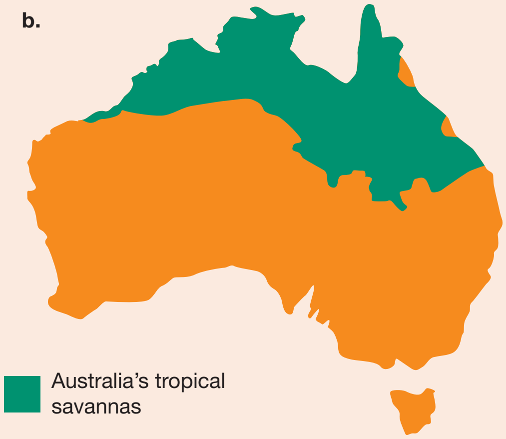
SCIENCE AS A HUMAN ENDEAVOUR: Fire management in northern Australia

First Nations Australian community-based ranger groups leading the way

For thousands of years, the First Peoples of Australia 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 First Nations Australian groups, First Nations Australian Elders oversee the process of controlled burns.

In northern Australia, the tropical savannas (see figure 4.6) 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 First Nations Australian 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.

FIGURE 4.6 a. Savanna landscape in the Kimberley region, WA **b.** The tropical savannas in the north of 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



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.

4.2.3 Bush medicine

Archaeological studies have shown that prehistoric humans practiced 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 First Peoples of Australia are no exception. They studied their environment over thousands of years and developed treatments and remedies using native plants.

SCIENCE AS A HUMAN ENDEAVOUR: First Nations Australians' medicine

Medicinal and endemic plants

First Nations Australians' 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.

First Nations Australians used crushed tea tree leaves for wounds. Scientists in the 1920s found that tea tree oil (see figure 4.7a) 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 professionals. Kangaroo apples (see figure 4.7b) 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 4.7 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.

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 First Nations Australians.

4.2.4 Bush tucker

Bush tucker, or bush food, refers to the food native to Australia that First Nations Australians 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.

SCIENCE AS A HUMAN ENDEAVOUR: Bush tucker

Ancient knowledge

Managing food sources and ecosystems is an important part of First Nations Australian 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'.

To live from the land, people knew the habits of local animals, and kept a close watch on changes in the weather and how it 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. First Nations Australians 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 (raised or nurtured) specific plant crops and created systems to manage food sources such as fish.

FIGURE 4.8 Bush tucker includes a range of plant energy storage organs such as nuts, fruits and roots.

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. The First Peoples of Australia 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 *(Endoxyla leucomochla)*

Witjuti grubs *(Endoxyla leucomochla)* were regarded as a delicacy in drier areas (shown in figure 4.10). They could be obtained from the roots and stems of trees, especially the witjuti bush, after which they are named. Witjuti grubs are the white larvae of beetles and can be up to 13 cm long. They live off the sap of the trees that they live in. Witjuti grubs are very nutritious and are rich in protein, fat and sugars (shown in figure 4.9). They are also good sources of iron, calcium and water.

FIGURE 4.9 The average body composition of a witjuti grub

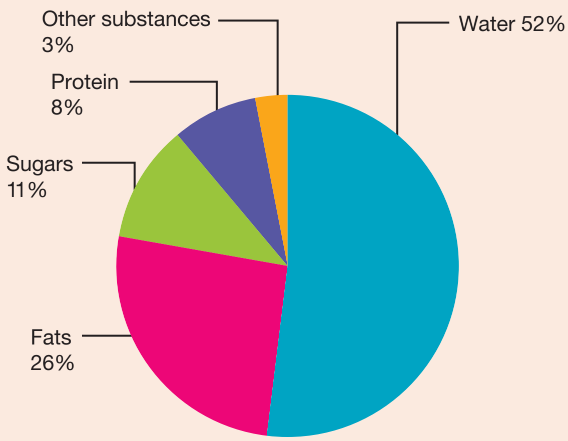


FIGURE 4.10 A witjuti grub — regarded as a delicacy in drier areas

Impacts of European colonisation: Dugongs

Dugongs are marine animals, with a flattened tail and cow-like appearance. They feature in the creation stories of many First Nations Australians across northern Australia.

For some coastal First Nations Australians, 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 First Nations Australians 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 store materials for future use, often in special storage areas that are formed. The stems, roots or leaves may be involved in storage.

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 4.1 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		✓	✓	

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 on where you live.

on Resources

eWorkbook Bush tucker (ewbk-11199)

Weblink Indigenous ecological knowledge
Fire management

4.2 Activities

learnon

4.2 Quick quiz on | **4.2 Exercise**

Select your pathway

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

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Remember and understand

1. Briefly outline the knowledge and skills that First Nations Australians traditionally used to help them 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 First Nations Australian communities living in arid areas find enough water to survive.
4. SIS Use the internet or other resources to research dugongs, and write a small paragraph answering the following questions.
   a. Suggest reasons 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. carbohydrate   c. fats and oils.
6. SIS Refer back to figure 4.9.
   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 and why might this be important for people living in dry environments?
7. Use the information in table 4.1 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. Find out and report on research into Australian native plants as a source of food or medicine. State the species name and summarise the plant's habitat.

Evaluate and create

9. Research and 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. Other examples of native foods include tanjong, lady apple, cluster fig, finger lime and the ruby saltbush. Research and summarise features of these.
12. What do you think about hunting dugongs? Who should be allowed to hunt them? How many should be taken, when and why? Research dugong hunting, then summarise your findings and opinions.
13. Dugongs feature in the creation stories of many First Nations Australian cultures across northern Australia. Find out more about one of these stories and present it in a creative way.
14. SIS First Nations Australians 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. Investigate how First Nations Australians recognised relationships in ecosystems in your area.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
4.3 What are ecosystems?

LEARNING INTENTION

At the end of this lesson, you will be able to describe ecosystems, including the way that living and non-living things interact, and the conditions that are best suited to specific living and non-living things.

4.3.1 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**.

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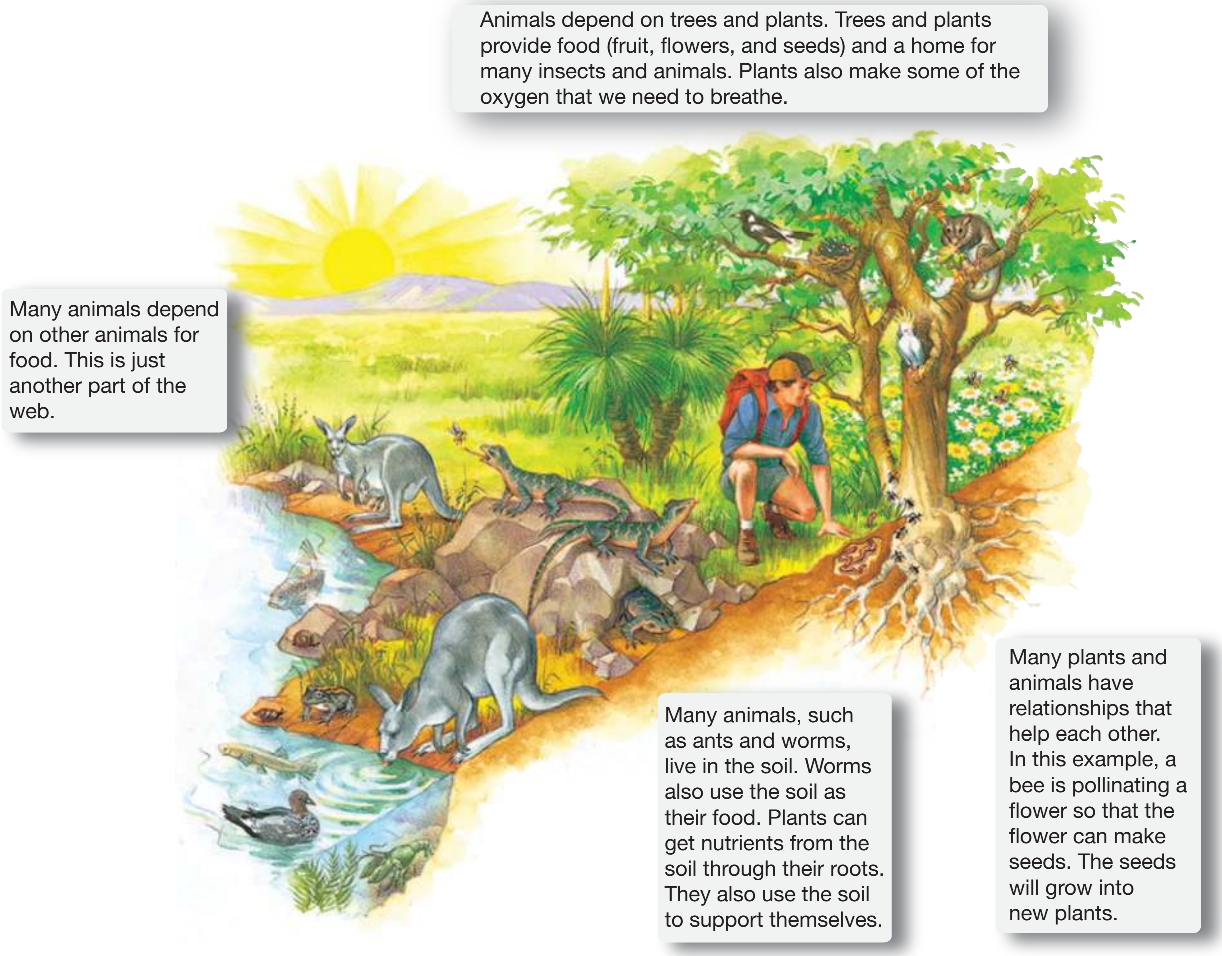
FIGURE 4.11 Organisms in an ecosystem depend on each other.



4.3.2 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 4.12.

Examples of biotic factors include:
- bacteria
- worms
- plants
- snakes.

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

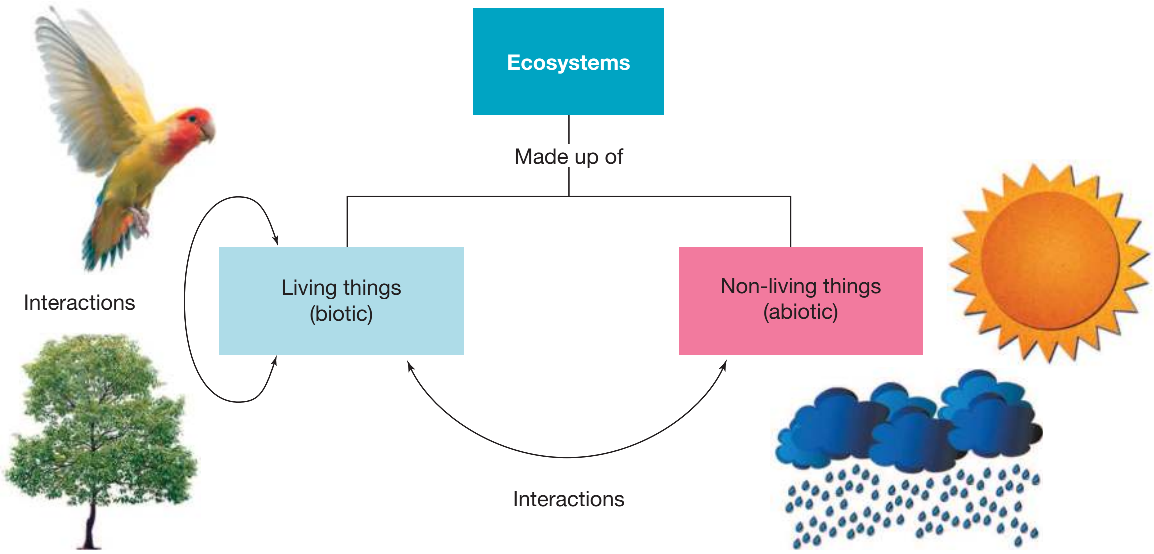
biotic factors the living things in an ecosystem

abiotic factors the non-living things in an ecosystem

Examples of abiotic factors include:

- water
- temperature
- salt levels (salinity)
- light intensity
- oxygen levels
- pH (acidity).

FIGURE 4.12 Biotic and abiotic factors in an ecosystem interact with each other.



4.3.3 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, 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 like a target, as shown in figure 4.13.

species a group of organisms with many features in common, that can mate with each other to produce fertile young under natural conditions

tolerance range the range of environmental conditions in which a species can survive

optimum range the range of environmental conditions in which a species can thrive

FIGURE 4.13 Organisms want to live in the centre of the target: the optimum conditions.

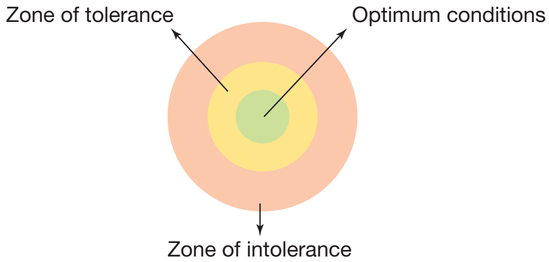
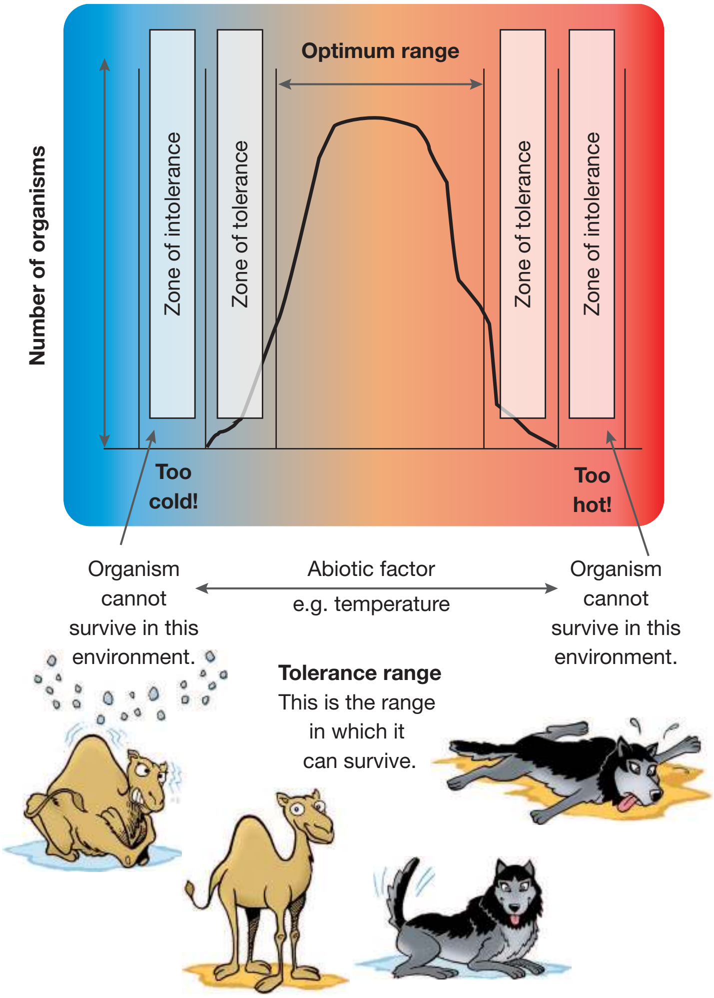


Figure 4.14 is a graph showing the optimum temperature for a camel and a dog. As organisms are most comfortable at the optimal temperature, a majority of organisms in the species will be found living within these temperatures.

DISCUSSION

What is a human's tolerance range and optimum range for different abiotic factors?

FIGURE 4.14 Abiotic factors can affect the survival of an organism within an ecosystem.



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.

4.3.4 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 can include parasites, pathogens (disease-causing organisms) and decomposers like 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 4.15. 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.

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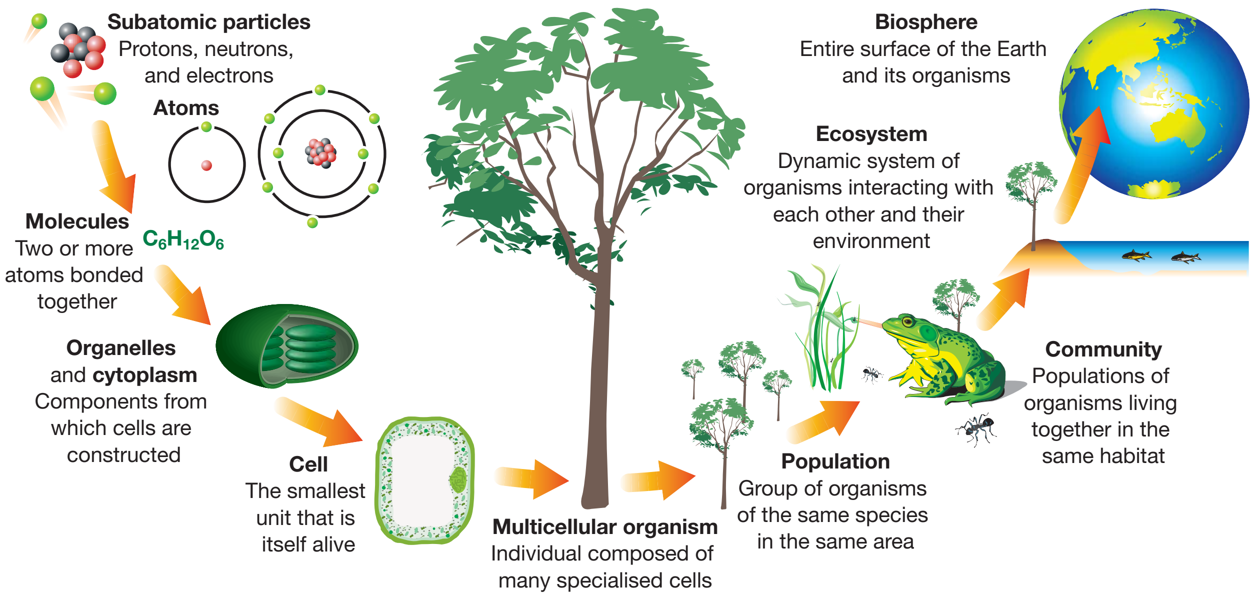
FIGURE 4.15 Levels of biological organisation



Do you make it or take it? 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 4.4.

producers organisms that use photosynthesis to make their own food from the Sun's energy

consumers organisms that rely on other organisms for food

food chain a diagram showing feeding relationships in an ecosystem

food web a number of food chains joined together

FIGURE 4.16 Members of a community

ACTIVITY: More than one school community?

How many different habitats and ecosystems are there in 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.

Living levels of organisation within ecosystems

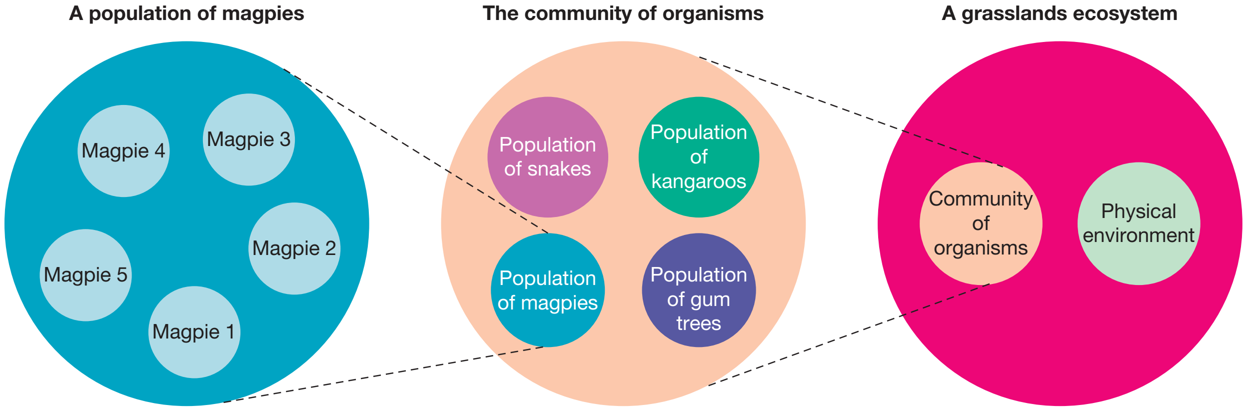
In order to explore these feeding relationships, you need to be able to distinguish between the terms 'organism', 'species', 'population' and 'community', as shown in figure 4.17. An organism is the simplest form of life. It may be made up of a single cell (unicellular) or many cells (multicellular). 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 4.18.

population organisms of one particular species in a given area at one time

community populations of various species living in a given area at the same time

FIGURE 4.17 An ecosystem is a complex level of organisation.

FIGURE 4.18 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.



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INVESTIGATION 4.2

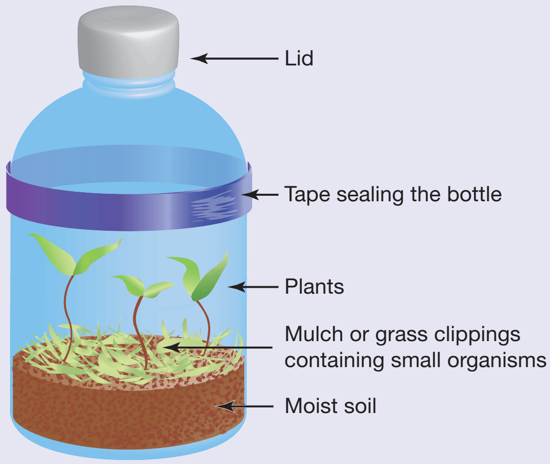
Ecosystem in a bottle

Aim

To create your own ecosystem

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

1. Record your observations for your mini ecosystem each lesson for the duration of the topic.
2. Summarise your results in a table. Remember to give your table a name; for example, 'Observations of ecosystem over 2 weeks'.

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. List three strengths in the design of this investigation.
7. Suggest how this investigation could be improved.

Conclusion

Summarise your findings from your bottle ecosystem investigation.

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INVESTIGATION 4.3

Measuring abiotic factors that can affect biotic factors

Aim

To measure abiotic factors that may influence the survival of organisms within habitats

Materials

- Water samples A, B and C (provided by your teacher)
- Thermometer
- Dropper bottle of silver nitrate solution (0.1 mol/L)
- Dropper bottle of universal indicator solution and universal indicator colour chart, or universal pH indicator paper

Method

1. Collect your three samples of water — ensure they are labelled as A, B and C.
2. Use the thermometer to measure the temperature of each sample.
3. Test the pH using either of the following methods.
   Method 1
   - Pour 5 mL of water sample A into a test tube.
   - Add three drops of universal indicator.
   - Compare the colour of the water with the colour chart and record the pH of the water sample. Repeat for the other samples.

   Method 2
   - Dip a small piece of universal pH indicator paper into water sample A.
   - Use the colour chart to match the pH of the water sample.
   - Record the pH in your table. Repeat for the other samples.
4. Test the salinity using the following method.
   - Pour 5 mL of water sample A into a test tube.
   - Add three drops of silver nitrate solution.
   - Observe the changes and use these to determine the salinity by using the table 'Salinity observations for the silver nitrate test'. Repeat for the other samples.

5. Record all your results for each sample.

TABLE Salinity observations for the silver nitrate test

Description	Salinity
Clear	Nil
Slightly cloudy	Low
Completely white/grey	High

Results

1. Complete the following table.

TABLE Abiotic measurements of three different water samples

Abiotic factor	Sample A	Sample B	Sample C
Temperature (°C)			
pH			
Salinity			

2. Of the abiotic factors measured, which factor varied between the samples: (a) the most and (b) the least?

Discussion

1. Within aquatic (water) ecosystems, temperature is very important because it can influence dissolved oxygen levels and the rate at which plants capture light energy to convert it into chemical energy that they and others can use.
   a. If you had measured the temperatures of your water samples in their original environments, do you think that they would be the same? Explain.
   b. Which of your water samples had the highest temperature and which had the lowest temperature?
   c. Suggest the impact of increasing water temperature on organisms living in aquatic habitats.
2. A pH less than 7 is considered acidic. The lower the pH, the more acidic the sample is.
   a. Which of your samples was the most acidic?
   b. What types of organisms could survive this habitat?
   c. Suggest reasons for the differences in pH between your samples.
3. While salt is a natural component of our Australian landscape, a number of our freshwater ecosystems are becoming increasingly threatened by increasing salinity.
   a. Which of your water samples had the highest salinity and which had the lowest salinity?
   b. Suggest reasons for the differences in salinity between your samples.
4. Answer the following questions about your investigation.
   a. Identify which of the tests were qualitative and which were quantitative. Quantitative data is measured, so it has a number. Qualitative data describes the information, so it is in words.
   b. Which variables were controlled in the salinity test?
   c. List two experimental design strengths.
   d. Suggest two ways in which the experiment investigation could be improved.

Conclusion

Summarise your findings for this investigation in three to four sentences, about the differences in abiotic factors between your three samples.

4.3.5 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.

habitat the place in which a particular organism lives

FIGURE 4.19 The different habitats of three organisms: **a.** a frog **b.** a scorpion **c.** coral

Resources

eWorkbook Biotic and abiotic factors (ewbk-11203)
Ocean explorations (ewbk-11205)

Video eLesson The parts of an ecosystem (eles-4256)

4.3 Activities

learnon

4.3 Quick quiz on | **4.3 Exercise**

Select your pathway

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

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Remember and understand

1. Match each term with its meaning.

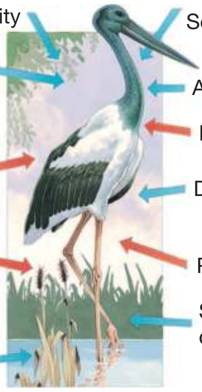
Term	Meaning
a. Ecology	**A.** The location of a population and its spread across an area
b. Ecosystem	**B.** Non-living things
c. Biotic factors	**C.** Populations of organisms living together in the same habitat
d. Abiotic factors	**D.** Groups of organisms of the same species in the same area
e. Population	**E.** The study of how living things interact with their environment
f. Habitat	**F.** Organisation made up of living things and non-living things interacting
g. Community	**G.** The range in which the organism functions best
h. Tolerance range	**H.** Living things
i. Optimum range	**I.** Place where an organism lives
j. Distribution	**J.** The number of particular organisms in an area
k. Density	**K.** 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. Fill in the blanks in 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. Find a photograph or draw an image of an animal and use two different-coloured arrows, one for abiotic and one for biotic factors (as shown in the example with the ibis), to add examples of factors that can affect its survival.
8. Select an abiotic factor from the list below and find out more about how it affects the survival of a particular organism.
   - pH (acidity)
   - Salinity
   - Temperature



Evaluate and create

9. SIS Find out more about the effects of rising salinity on our ecosystems and then suggest why rising salinity has been described as a 'white plague'.
10. SIS Human activity can result in changes in abiotic factors that may have an impact on the survival of organisms within ecosystems.
    a. Find out why rising salinity is an issue in Australia.
    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.
    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.
11. SIS
    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), collecting your data in appropriate formats.
    d. Discuss and explain your results, relating them back to your research question.
12. SIS 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.
    a. Investigate and report on acid rain and its impact on aquatic ecosystems.
    b. Report on research or strategies to reduce the production or impact of acid rain.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
4.4 Relationships in ecosystems

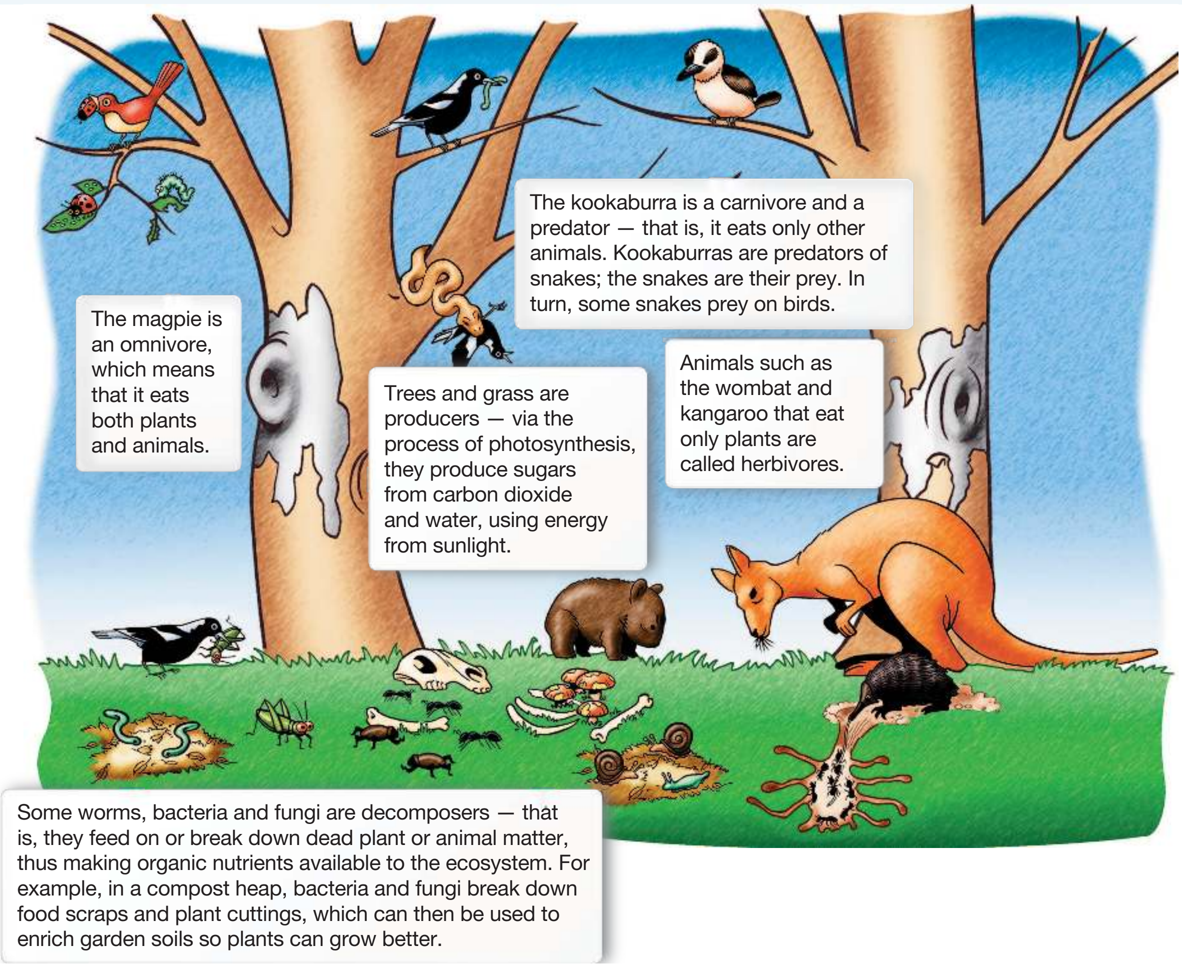
LEARNING INTENTION

At the end of this lesson, you will understand that ecosystems are made of living things interacting with each other through feeding relationships, and be able to identify and classify producers, consumers and relationships.

4.4.1 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 4.20. How many different types of interactions can you see occurring?

FIGURE 4.20 Within an ecosystem, organisms interact with each other and with their non-living environment.



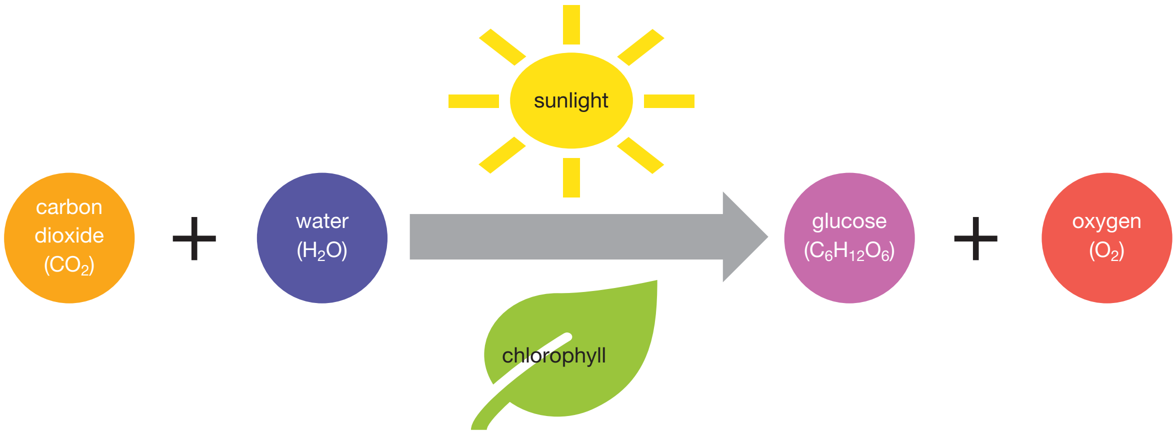
Ecosystems are made up of living (biotic) and non-living (abiotic) things that interact with each other. For example, plants use energy from the Sun, some animals eat the plants, and some animals eat other animals. It is through feeding relationships that energy flows through ecosystems and matter can be recycled.

4.4.2 Producers

Producers within ecosystems are essential as they are at the base of the food chain. They are organisms that can make their own food from their non-living environment, for example, plants. Many producers achieve this by using a process called **photosynthesis**. This process is summarised in figure 4.21.

photosynthesis a process in which carbon dioxide, water and energy from the Sun produce food in the form of sugar

FIGURE 4.21 The inputs and outputs of photosynthesis



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 cholorophyll (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.

Plants can convert glucose produced by photosynthesis into other essential organic substances. This means that they do not need to feed on other organisms. It is for this reason that 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**.

chlorophyll the green-coloured chemical in plants that absorbs the light energy used in photosynthesis to make food from carbon dioxide and water

inorganic material that is not carbon-based

organic carbon-based material derived from living things, such as plant mass

autotrophs organisms that can produce their own nutrients

cellular respiration the chemical reaction involving oxygen that moves the energy in glucose into the compound ATP

elog-1999

INVESTIGATION 4.4

Do all leaves contain the same pigments?

Aim

To extract and compare pigments, such as chlorophyll, from different types of plant leaves

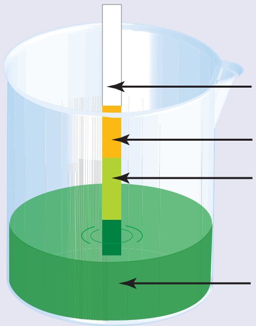
Materials

- 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, iPad 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 with the following headings and use it to summarise your detailed observations.

TABLE Chromatography observations of different leaves

Chromatography strip observations	Leaf A	Leaf B	Leaf C
Colours observed and distance each colour moved up strip			
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? Which were they?
   b. Which colour was the most dominant? Did all 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. List two strengths of the experimental design.
   d. Suggest two ways in which the experiment 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 procedures you're following in this investigation.

Conclusion

Summarise your findings for this investigation in three to four sentences, about the different pigments in plants.

4.4.3 Consumers

Consumers lack the chlorophyll required for photosynthesis; animals are unable to make their own food and are called **heterotrophs** ('other-feeders'). As 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 (figure 4.22).
- **Carnivores** eat other animals and are described as secondary or tertiary consumers in food chains or webs; for example, Tasmanian devils (figure 4.23).
- **Omnivores** eat both plants and animals; for example, humans.
- **Detritivores** feed on the tissue of dead or decaying organisms; for example, dung beetles.

heterotrophs organisms that depend on another organism to supply their complex molecules and energy

herbivores animals that eat only plants

primary consumer an organism that eats plants

carnivores animals that eat other animals

omnivores animals that eat plants and other animals

detritivores organisms that consume detritus; that is, decomposing plant and/or animal parts or faeces

FIGURE 4.22 The koala is a herbivore.

FIGURE 4.23 The Tasmanian devil is a carnivore.

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.

decomposers small organisms that break down dead and decaying matter

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 4.24 Detrivores, such as dung beetles, and decomposers, such as fungi and bacteria, play an important role in ecosystems.

on Resources

Video eLessons Dung beetle relocating his dung house (eles-2649)
Decomposers (eles-2650)

4.4.5 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).

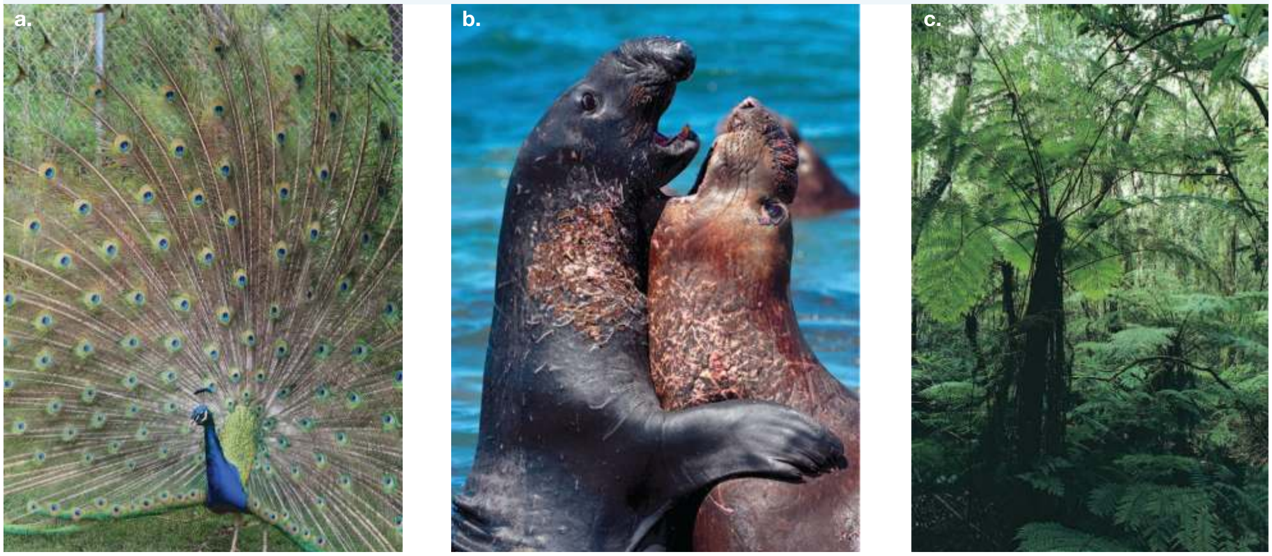
Competition, predator–prey and symbiotic relationships are all examples of different types of interactions between organisms.

ecological niche the role or position of a species or population in its ecosystem in relation to others
relationships interactions with other species within an ecosystem
interspecific between members of different species
intraspecific between members of the same species

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 4.25 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 4.26 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 4.2 and figure 4.27, 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**).

symbiosis an ongoing relationship between members of different species

parasitism a relationship between two organisms in which one benefits by using the host's nourishment

mutualism a relationship between two organisms in which both benefit

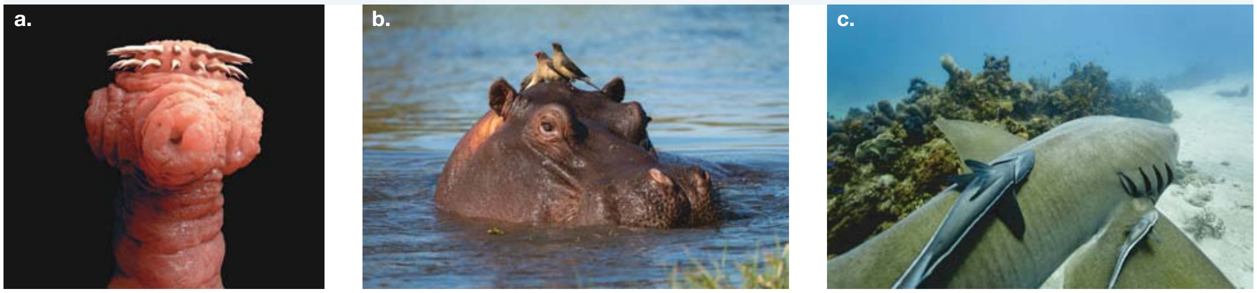
commensalism a relationship where one organism benefits without affecting the other

TABLE 4.2 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 4.27 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.

parasite an organism that lives on or within another organism, to get all or some of its nourishment

host the organism on which a parasite feeds

Mutualism

A relationship in which both species benefit is called mutualism. In a lichen, fungi and algae grow together, as seen in figure 4.29. While the fungi provide water and protection for the algae, the algae provide food for the fungi.

FIGURE 4.28 A non-pollinating fig wasp parasitoid

FIGURE 4.29 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 4.30.

FIGURE 4.30 Commensal clownfish and host anemone

on Resources

- **eWorkbook** Relationships in ecosystems (ewbk-11207)
- **Interactivity** Some animal species found in Antarctica (int-8190)
- **Video eLesson** Relationships between species (eles-4239)

4.4 Activities

learnon

4.4 Quick quiz on | **4.4 Exercise**

Select your pathway

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

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Remember and understand

1. Match each term with its meaning.

Term	Meaning
a. Producers	A. Organisms that break down dead organisms
b. Omnivores	B. Animals that eat only plants
c. Herbivores	C. Consumers that eat both plants and animals
d. Carnivores	D. Organisms that can produce their own food
e. Decomposers	E. 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 either 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. Find out how this may protect them against being eaten.
14. SIS Find examples of ways that Australian plants try and protect themselves from being eaten by herbivores.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
4.5 Food chains and food webs

LEARNING INTENTION

At the end of this lesson, you will be able to 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.

4.5.1 Food chains

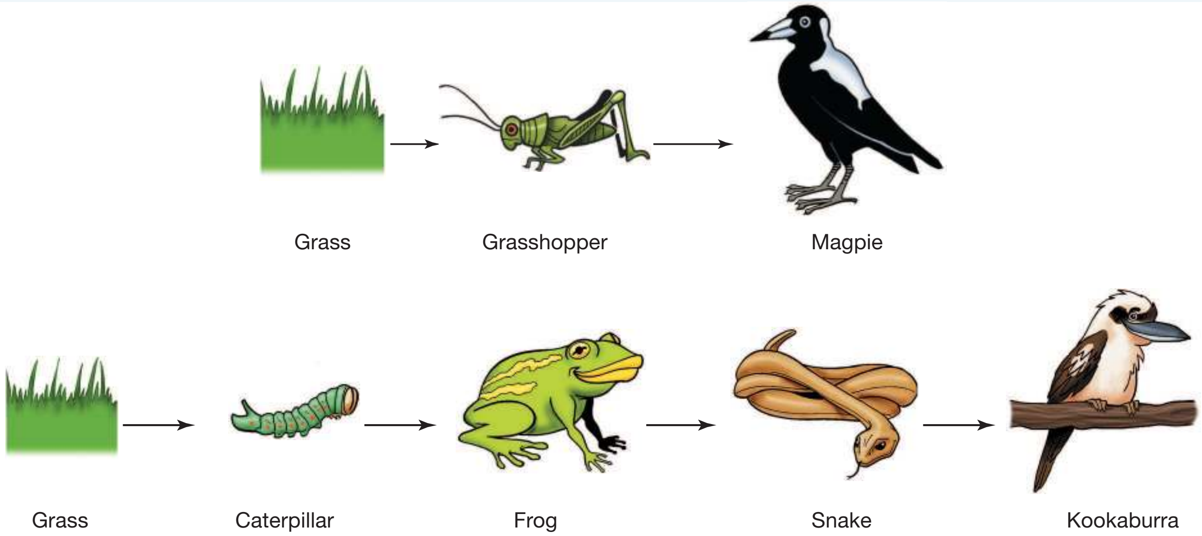
A food chain is a linear chain that starts with a producer and ends with a decomposer. It represents 'who eats whom'. To describe a food chain, the names of these organisms are linked by arrows. The arrow in a food chain indicates 'is eaten by' and describes the direction of the flow of energy. The arrow points to the animal that will be eating it. In figure 4.31 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.

4.5.2 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.

int-8174

FIGURE 4.31 Two examples of food chains



In the food chain in figure 4.31:

- grass is the producer
- the consumer that eats the producer is called a **primary consumer** (for example, the grasshopper)
- the consumer that eats a primary consumer is called a **secondary consumer** (for example, the frog)
- the consumer that eats the secondary consumer is a **tertiary consumer** (for example, the snake).

primary consumer an organism that eats plants

secondary consumer an organism that eats primary consumers

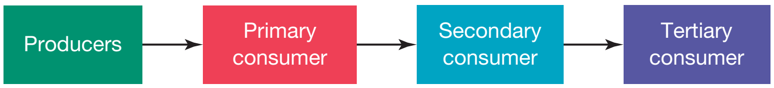
tertiary consumer an organism that eats secondary consumers

biomass the total amount of mass of living organisms

The relationship between producers, primary, secondary and tertiary consumers can be seen in figure 4.32. We can also use the term first-order, second-order and third-order to describe primary, secondary and tertiary consumers.

Note that primary consumers can also be called secondary producers, since they produce **biomass** for their predators, the secondary consumers. These secondary consumers can in turn also be called tertiary producers, as 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.

FIGURE 4.32 The food chain runs from producer through to tertiary consumer.

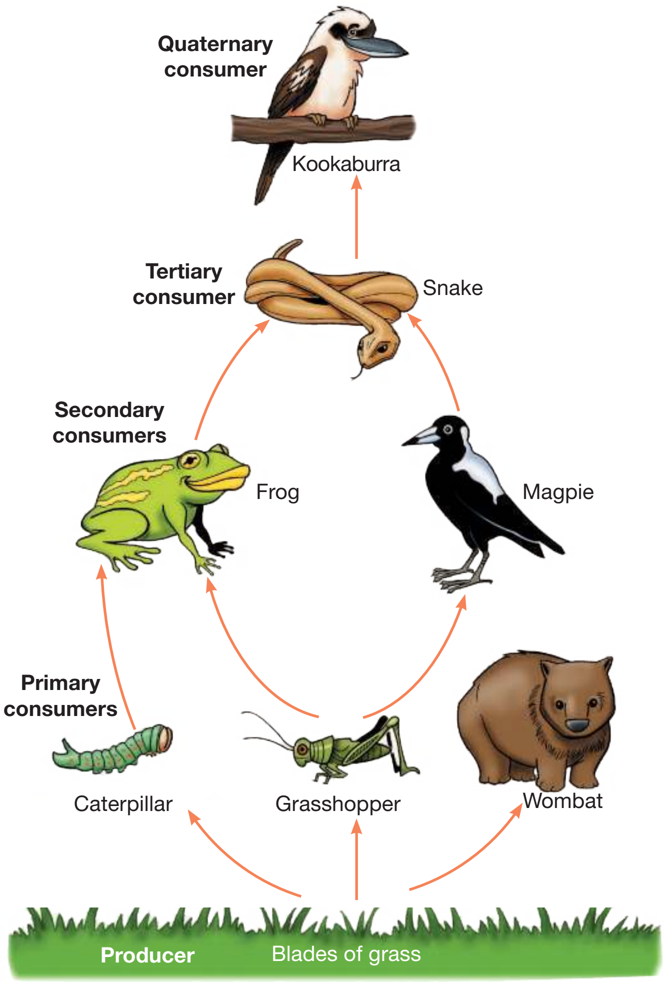


4.5.3 Food webs

Interconnecting or linked food chains make up food webs. In the food web in figure 4.33:

- 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 4.33 Each of the steps in a food chain is described as a trophic level. 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:

1. What do you think the effect might be if the grasshoppers were removed from this ecosystem?
2. What if all of the kookaburras died?
3. What do you think may happen to the numbers of snakes?
4. What implications might this have on the other organisms in this food web?

DISCUSSION

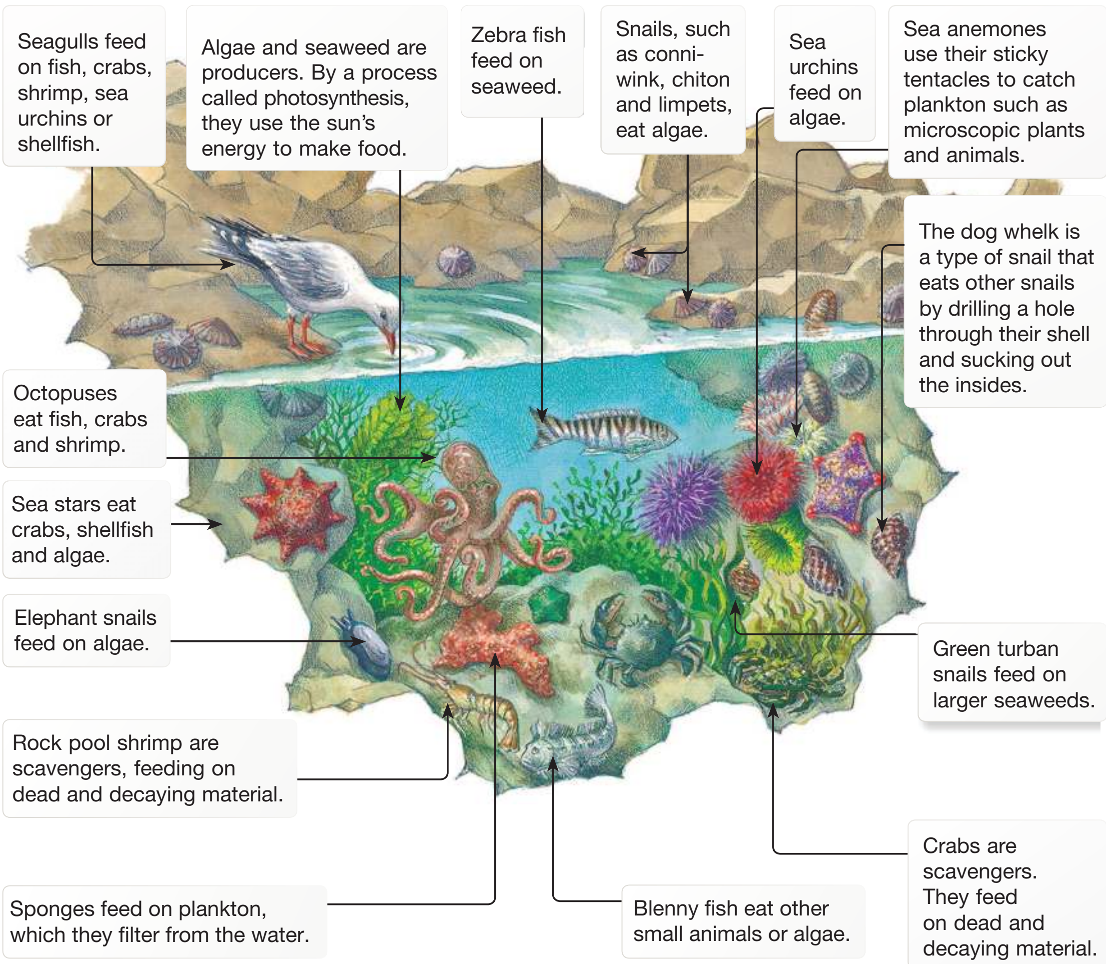
Consider the feeding relationships between the organisms in the food web in figure 4.33. How many different food chains can you see between the organisms in this ecosystem?

4.5.4 Visiting a rock pool

Carefully study the rock pool picture in figure 4.34. There are many different feeding relationships within this ecosystem. Two examples of food chains are shown in figure 4.35.

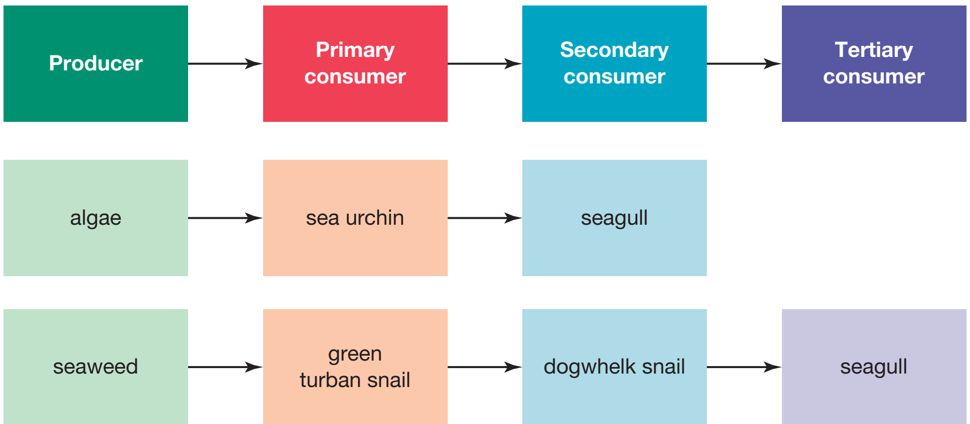
int-3454

FIGURE 4.34 Different relationships in a rock pool



int-3462

FIGURE 4.35 Two examples of food chains in a rock pool



elog-2001

INVESTIGATION 4.5

Make a food web

Aim

To model your own food web

Materials

- String
- Paper

Method

1. Construct a food web using students connected by pieces of string. You can use one of the food webs described here, or make up one of your own by discussing it in a group and planning it out on a large piece of paper.
2. 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.

Results

1. Draw your food web. Give it a number and title, such as Figure 1: Food web.
2. Label the first string tugged. List the 'organisms' in the food web that felt the tug on the string.
3. List the 'organisms' that did not feel anything.

Discussion

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.
4. Suggest a way in which this investigation could be improved to better model or simulate food web interactions.
5. Try out your suggestion to see how it works, making more modifications if required.

Conclusion

Summarise your findings for this model food web investigation in three to four sentences.

on Resources

eWorkbooks Food webs (ewbk-11209)
Nature pyramids (ewbk-11211)
Food chains and food webs (ewbk-11213)

Interactivities Food web in an Antarctic ecosystem (int-3465)
A food web showing the flow of chemical energy through different organisms in an ecosystem (int-3463)

Weblink Food chain challenge — Savannah

4.5 Activities

learnon

4.5 Quick quiz on	4.5 Exercise

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Select your pathway

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

Remember and understand

1. Match each term with its meaning.

Term	Meaning
a. Food chain	**A.** A herbivore (eats plants or algae) in an ecosystem
b. Food web	**B.** An animal that eats primary consumers
c. Primary producer	**C.** Shows the interconnected feeding relationships within an ecosystem
d. Primary consumer	**D.** An utotroph, such as plants or algae, which collectively make up the first trophic level in an ecosystem
e. Secondary consumer	**E.** 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
   c. First trophic level and third trophic level

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% 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.
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

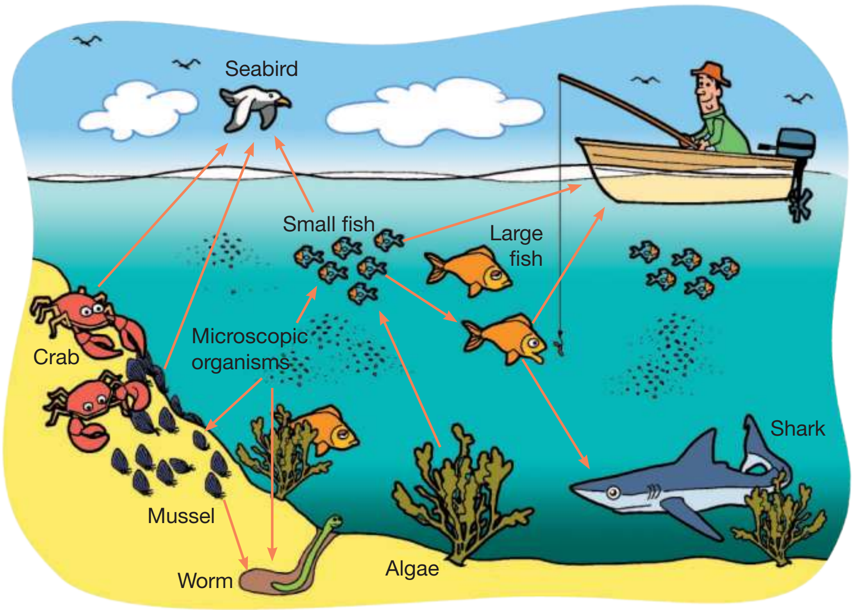
11. Use information in the picture of the rock pool ecosystem in figure 4.34 to:
    a. identify a primary producer
    b. identify two secondary consumers
    c. identify two tertiary consumers
    d. identify a detritivore or scavenger
    e. construct two food chains
    f. construct a food web.
12. SIS 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.

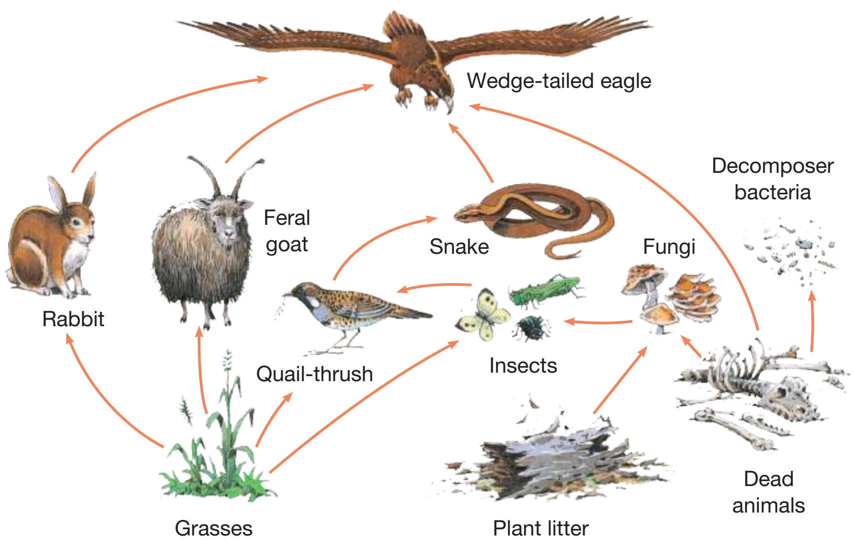
    a. Construct a food web using the information provided. Start with the producers at the bottom and work upwards. Make sure your arrows face the right way.
    b. Which organisms are the producers?
    c. Which organisms are primary consumers?
    d. Which organisms are both secondary and tertiary consumers?
    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?
13. Draw a food chain that contains a fifth-order consumer.
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 4.35?
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 lots of colour and diagrams to your map.

17. For each of the food webs shown:
   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.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
4.6 Energy flows

LEARNING INTENTION

At the end of this lesson, you will be able to explain how energy flows into and out of an ecosystem via the pathways of food webs, and how ecosystems have their own system of recycling.

Energy flows through an ecosystem and as it moves, it changes from one form to another, and no new energy is created.

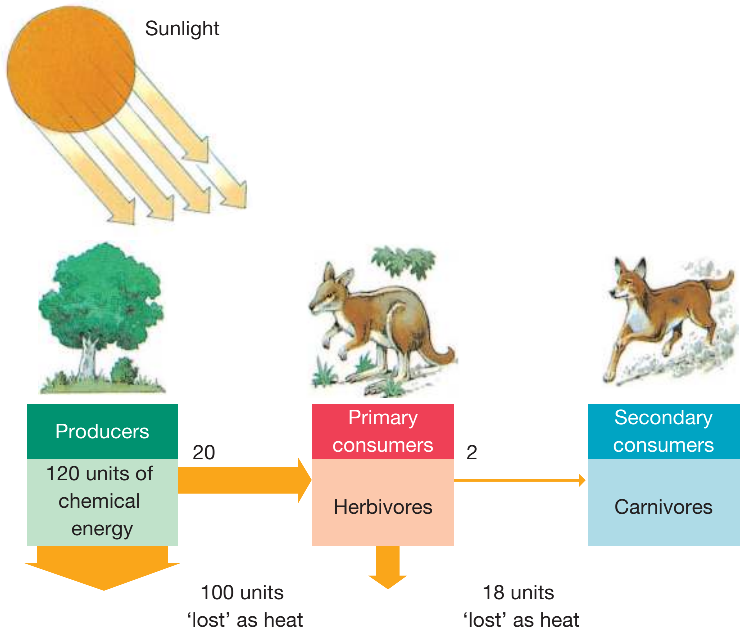
4.6.1 Energy flow in an ecosystem

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 4.36 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.



REMEMBER

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.

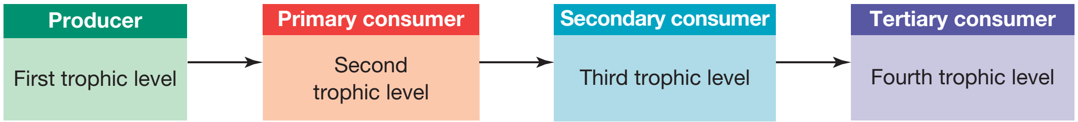
4.6.2 Trophic levels

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**.

trophic level a feeding level within a food chain

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.

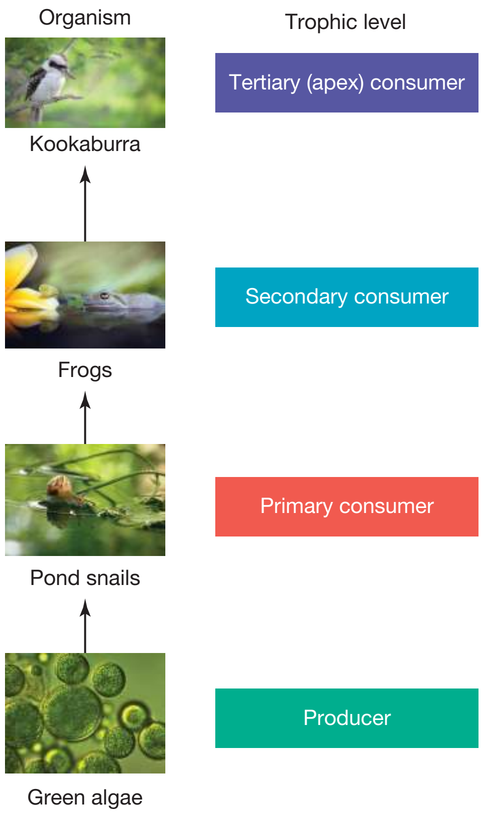
FIGURE 4.37 Trophic levels in an ecosystems



Organisms can occupy more than one trophic level. These categories are not fixed, since many organisms feed on several trophic levels.

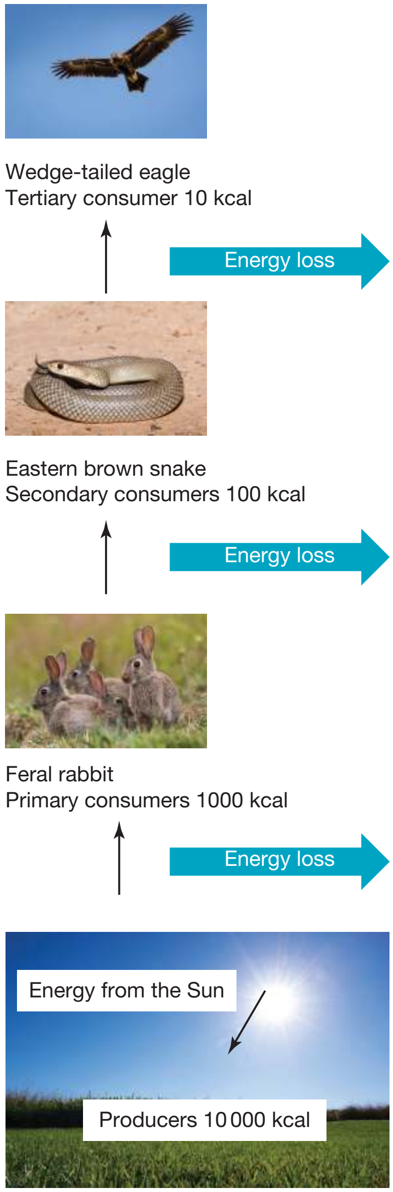
Figure 4.38 shows an example of trophic levels. Algae occupy the first trophic level since they are producers. Pond snails feed on the algae, so they occupy the second trophic level and are primary consumers. The snails are eaten by frogs, which are secondary consumers occupying the third trophic level. The kookaburra eating the frogs occupies a fourth trophic level.

FIGURE 4.38 An example of trophic levels in a pond in someone's backyard



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 4.39. As 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 4.39 An example of energy flow and trophic levels



4.6.3 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

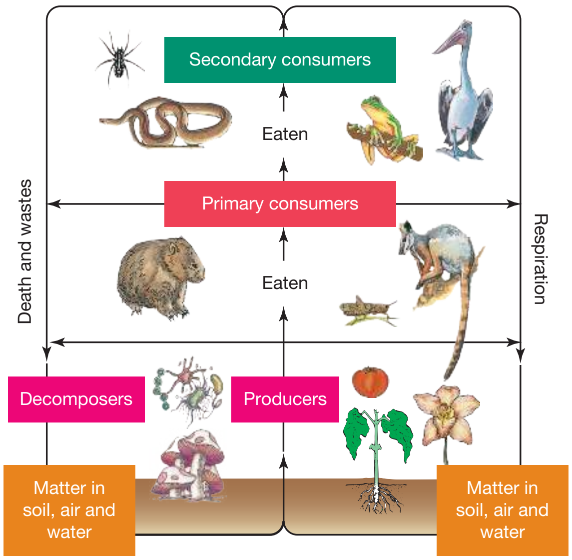
All living things contain atoms. They make up our body cells, are in the food that we eat, and are involved in essential chemical reactions that keep us alive. The set of all of these chemical reactions is called **metabolism**. Throughout these reactions, atoms are rearranged; some are used or retained 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 4.40. 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.

ewbk-11215

int-8097

FIGURE 4.40 Various components are recycled through ecosystems.



metabolism the chemical reactions occurring within an organism that enable the organism to use energy and grow and repair cells

Decomposers — nature's recyclers

Decomposers (as introduced in section 4.3.4) 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 break down the matter chemically, using enzymes, 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.

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.

saprophytes organisms such as fungi that obtain nutrients from dead organic matter

FIGURE 4.41 The role of decomposers in breaking down organic matter

Animal dies → Flies lay eggs on decaying body → Eggs hatch and become maggots → Maggots eat large parts of animal → Maggots grow quickly, becoming flies → Young flies lay eggs or become food themselves

elog-2003

tlvd-10654

INVESTIGATION 4.6

Looking at decomposers

Aim

To observe decomposers

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 one 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

Summarise your findings for this investigation about decomposers in three to four sentences.

Are people biodegradable?

If something can be broken down by decomposers then it is said to be **biodegradable**. This is very useful as 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.

biodegradable able to break down or decompose easily in the environment

non-biodegradable not able to break down or decompose in the environment

SCIENCE AS A HUMAN ENDEAVOUR: Entomology

An entomologist is a scientist who studies insects. Sometimes entomologists are asked to provide information to help solve crimes. After a person or animal dies, insects are attracted to the corpse and feed on it. They lay their eggs in the corpse, and larvae eventually emerge from the eggs and develop into adult insects.

Over time, different types of insects colonise the body. By looking at the types of insects and what stage of their life cycle they are at, it is often possible to work out the time of death. It is sometimes also possible to find out other information about the crime from the types of insects that have colonised the body. If a body spent some time in a dry cool area before being buried in dry sandy soil, the insects living on it would be different from those that would be present if it had been buried in dry sandy soil straight after death.

If you are interested in learning more about how insects can help us to solve crimes, investigate the different insects used to solve crimes, or find out more about the role of an entomologist in forensics.

FIGURE 4.42 Professor Jerry Butler, an entomologist, examining hairy maggot blowfly larvae retrieved from a murder victim

elog-2005

INVESTIGATION 4.7

Investigating decomposition

Aim

To investigate how different materials decompose

Materials

- Samples of different types of plant matter, such as grass clippings, leaves, vegetable peels, cuttings from a shrub or hedge, straw
- 250 mL beakers
- Cling wrap
- Temperature probes and a data logger

Method

1. Half-fill each beaker with a different type of plant matter.
2. Cover each beaker with cling wrap.
3. Connect the temperature probes to the data logger (one probe for each beaker) and set up the data logger to collect a temperature reading every 10 minutes for 24 hours.
4. Push each temperature probe into a different type of plant matter (you will need to pierce a hole in the cling wrap) and start the data logger.

Results

After 24 hours (or during your next Science lesson), collect the results from the data logger and observe the plant matter in each beaker.

Discussion

1. Study the graph produced by the data logger. Which type of plant matter released the most heat as it decomposed?
2. Describe some improvements that could be made to this experiment to make it a fairer test.
3. What are the advantages of using temperature probes connected to a data logger rather than thermometers for this experiment?

4. Apart from the rise in temperature, what other evidence is there that the plant matter has started to decompose?
5. Microbes decompose the plant matter. Explain why keeping the plant matter moist accelerates its decomposition.

Conclusion

Summarise your findings in three to four sentences on decomposition.

elog-2007

INVESTIGATION 4.8

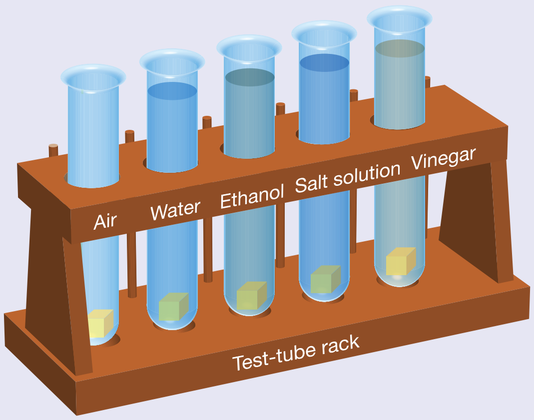
Preserving apples

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 two 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 designed. Give your table a title.

Discussion

1. Why do you think certain substances were able to preserve the food (stop the food from decaying)?
2. List some examples of foods that are preserved using:
   a. salt
   b. sugar
   c. alcohol
   d. vinegar.

Conclusion

Summarise your findings in three to four sentences on preserving foods.

on Resources

eWorkbook Cycles in nature (ewbk-11217)

Video eLesson Fungi help break down food (eles-2748)

4.6 Activities

learnon

4.6 Quick quiz on | 4.6 Exercise

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Select your pathway

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	**A.** Release enzymes to break down complex organic matter into simple inorganic material to be absorbed
b. Detritivores	**B.** Organisms that feed off dead and decaying matter (detritus)
c. Saprophytes	**C.** Heterotrophs that consume the remains of dead organisms and their wastes
d. Decomposers	**D.** 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 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. **SIS** Find out why some of the bones of the dinosaurs were not decomposed by microorganisms.
10. **SIS** 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. **SIS** Find out more about the field of forensic entomology. Report your findings as a job advertisement.
12. **SIS** Research examples of forensic succession and prepare your findings as a police report.
13. **SIS** Research an issue related to Earth cycles, recycling or sustainability, and create a written report, multimedia presentation, web page, poster or drama script to present your findings.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
4.7 Ecological pyramids

LEARNING INTENTION

At the end of this lesson, you should be able to identify and describe the different ecological pyramids used to represent relationships between organisms at different trophic levels.

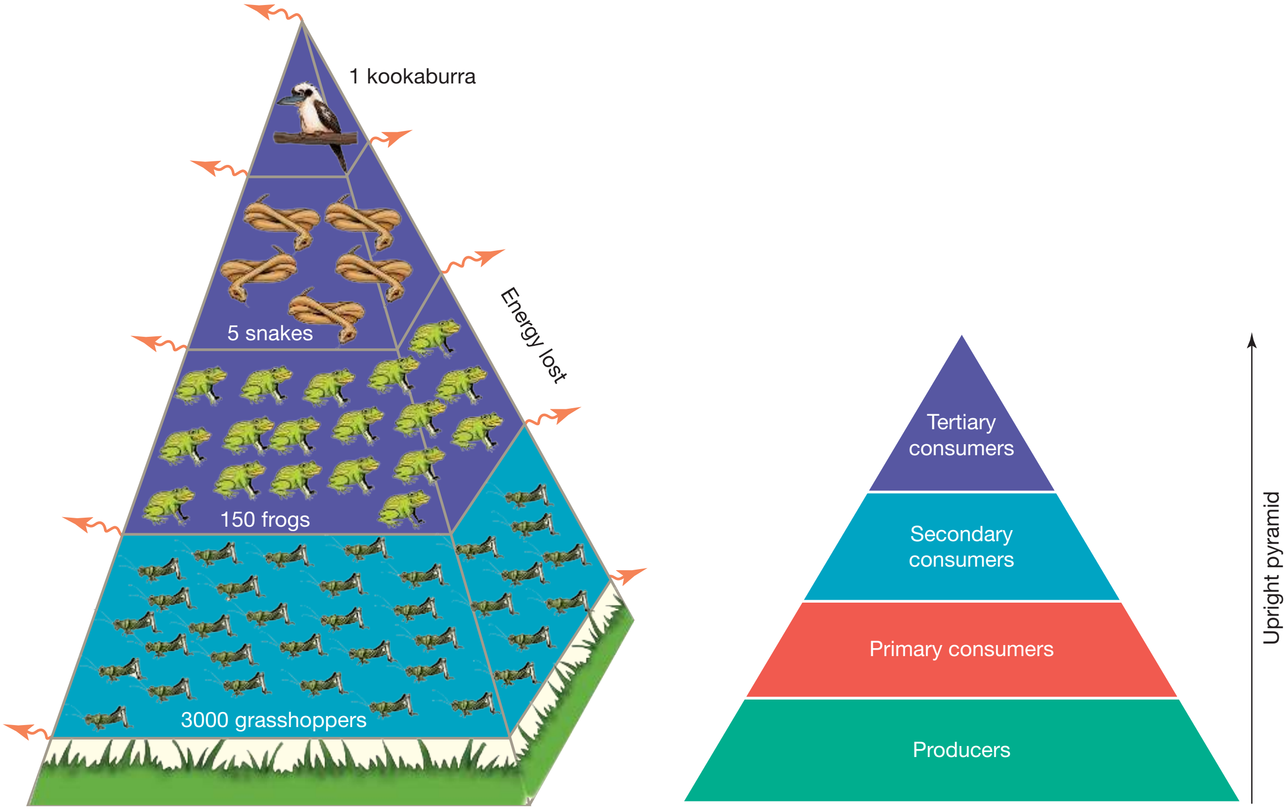
4.7.1 What are ecological pyramids?

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.

FIGURE 4.43 Pyramids showing the number of organisms in a food web and the general shape of a pyramid of numbers



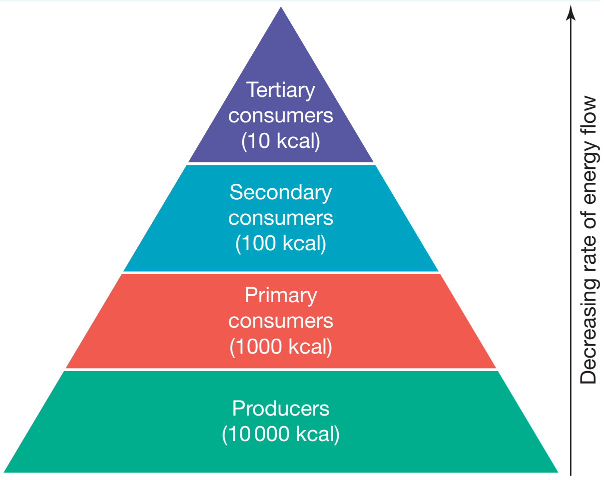
Pyramid of number

A pyramid of number (see figure 4.43) 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.

Pyramid of energy

A pyramid of energy (see figure 4.44) represents the total energy available at each trophic level of the food chain. As 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 4.44 A pyramid of energy, showing the total energy available at each trophic level



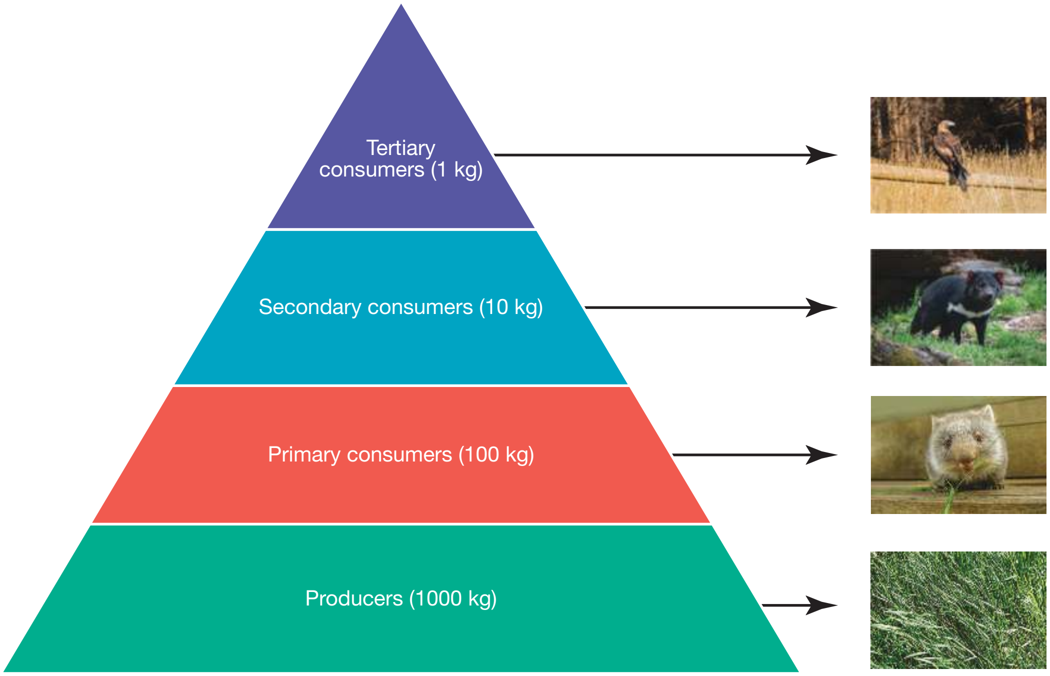
Pyramid of biomass

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.

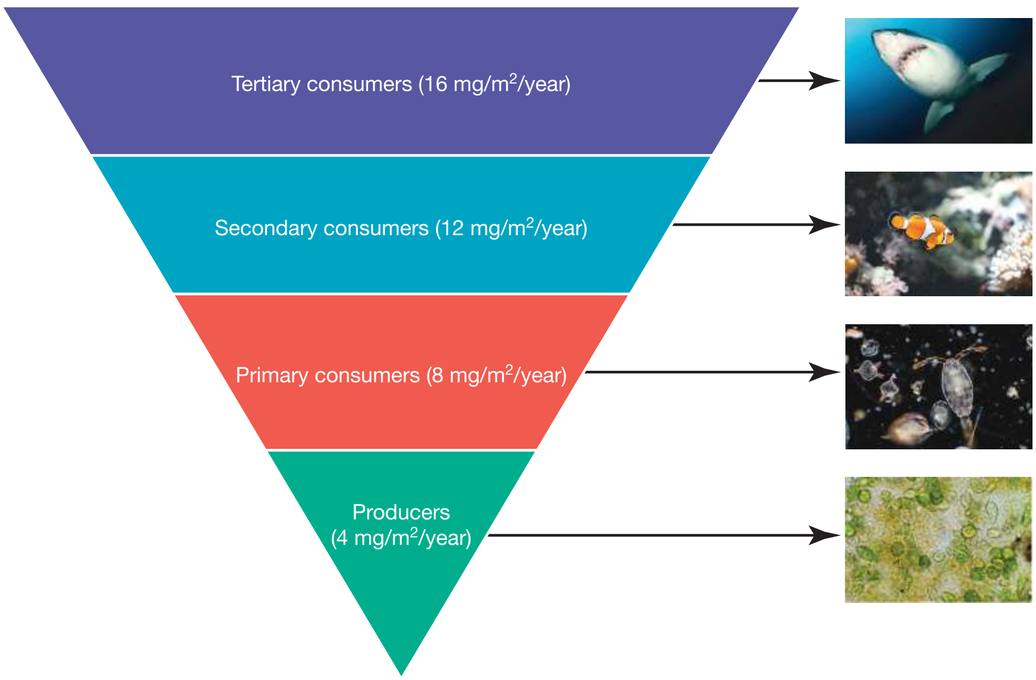
Terrestrial biomass pyramids are usually upright because the biomass decreases as we move up from the second trophic level to the final trophic level. Terrestrial ecosystems have much more biomass in plants, such as trees and grass. If you have less biomass you move up the trophic levels.

FIGURE 4.45 An example of an upright pyramid of biomass



However, the pyramids of biomass of aquatic ecosystems like ponds, lakes, rivers and oceans are inverted, as 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 4.46 An example of an inverted pyramid of biomass



on Resources

interactivity Trophic levels (int-3464)

Weblink How wolves changed rivers

4.7 Activities

learnon

4.7 Quick quiz on	4.7 Exercise

Select your pathway

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

These questions are even better in jacPLUS!
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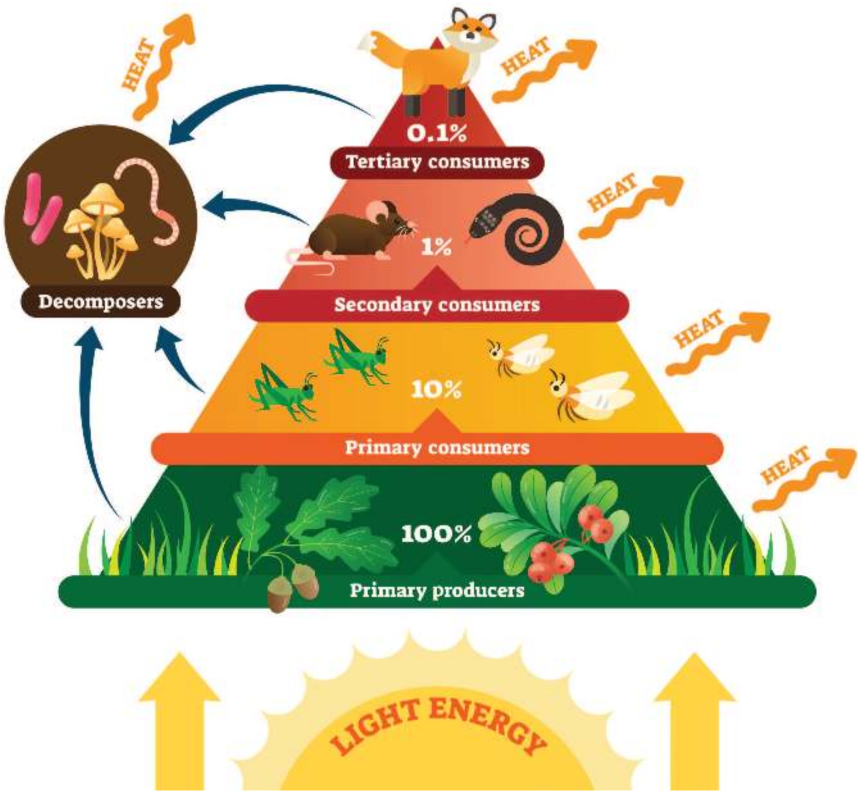
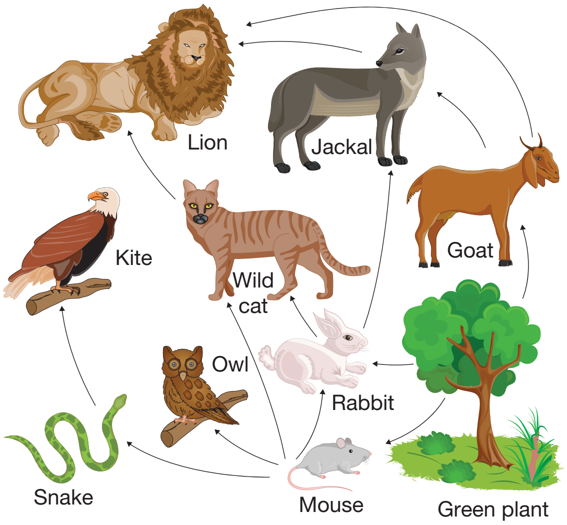
Remember and understand

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.



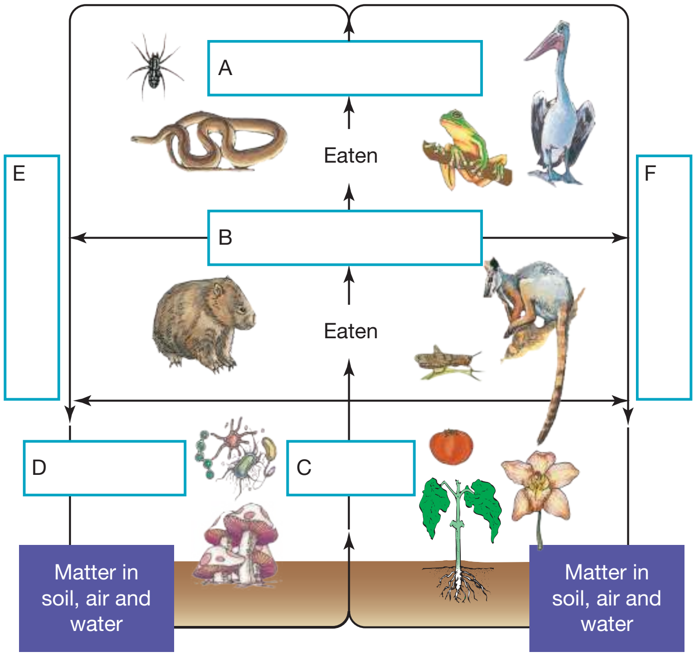
5. MC The image shown is an example of which one of the following?
A. Food chain
B. Food web
C. Pyramid of biomass
D. Trophic level



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.
producers, decomposers, secondary consumer, death and wastes, respiration, primary consumer



9. Complete the following table.

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.

LESSON
4.8 Changes in ecosystems

LEARNING INTENTION

At the end of this lesson, you will be able 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

4.8.1 Seasonal changes

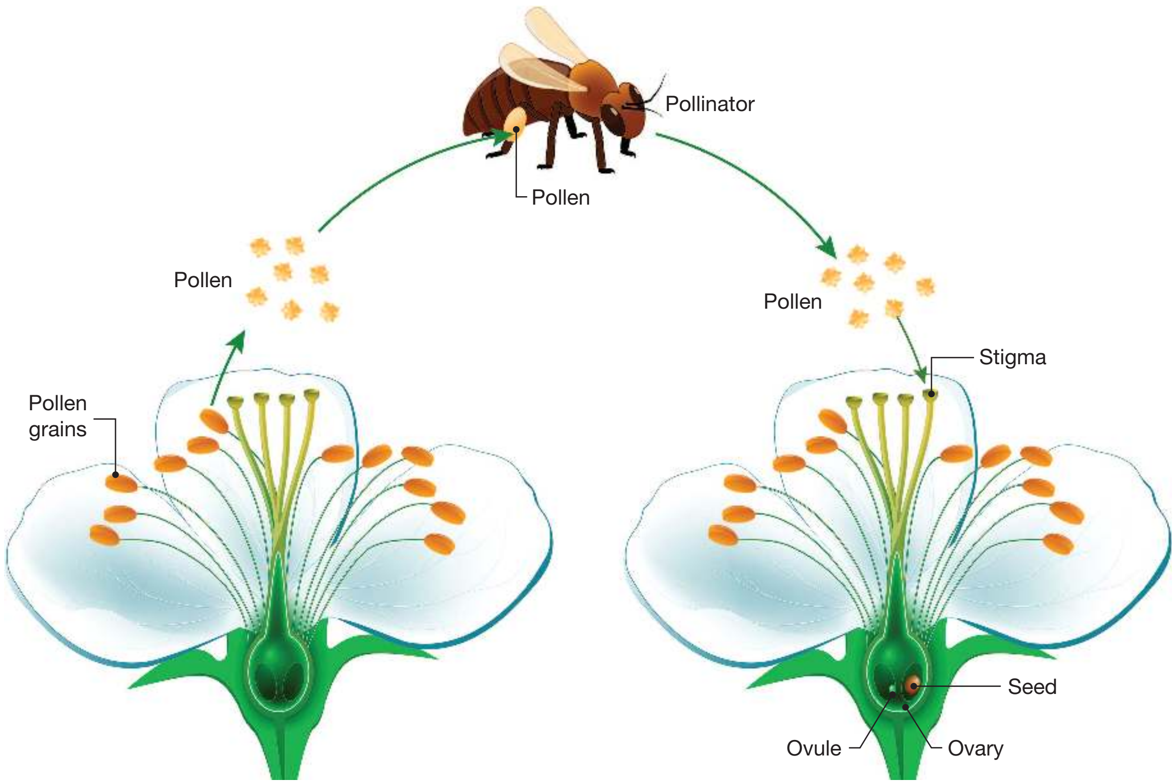
Seasonal changes can affect the timing of many life-cycle events, such as when flowers bloom or when pollinators emerge. They also affect the type and amount of food available.

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.

seed the product of a fertilised ovule

pollination the transfer of pollen from the male part of a flower to the female part of a flower

FIGURE 4.47 Cross-pollination by a bee



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.

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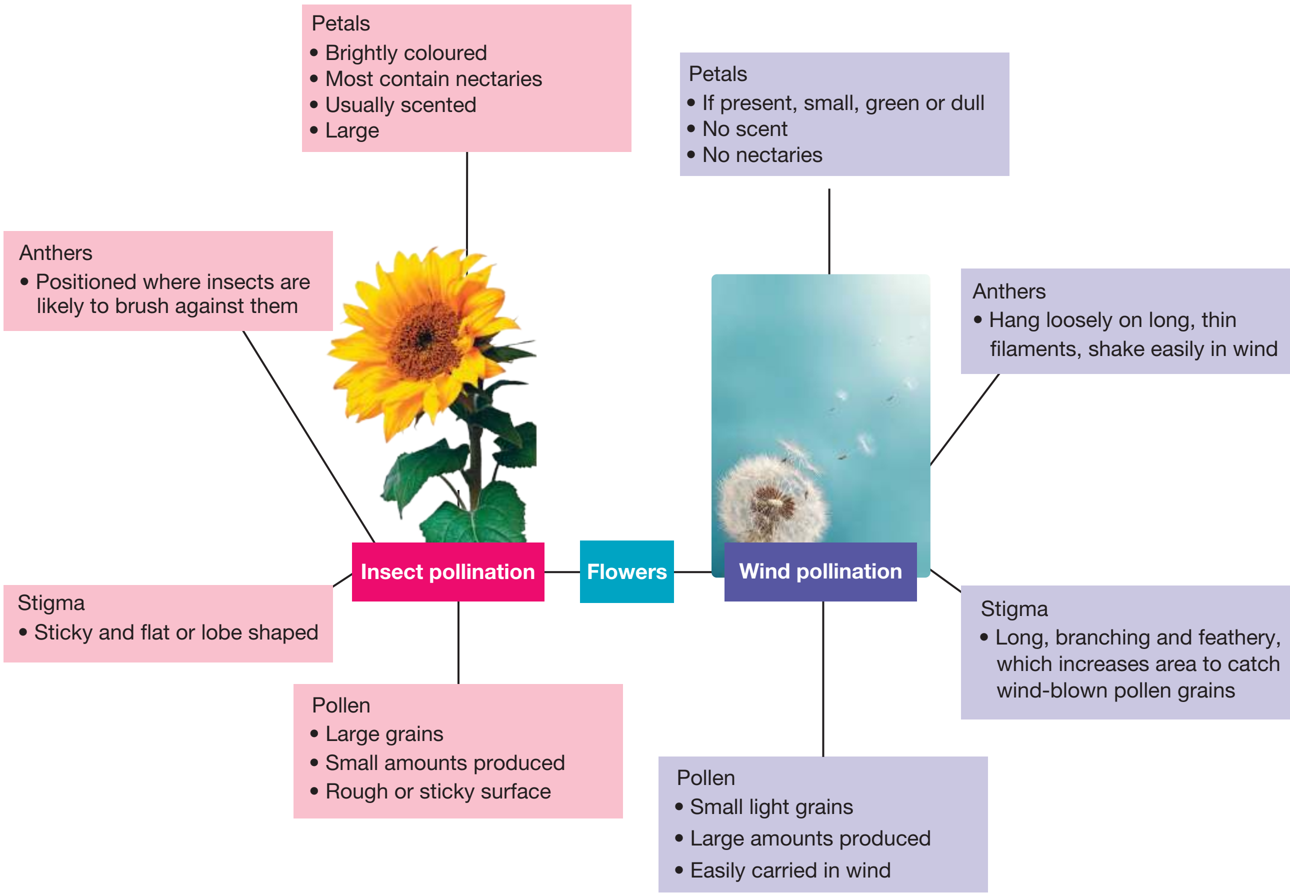
FIGURE 4.48 Some plants can pollinate themselves, while others rely on animals or the wind for successful pollination.



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 4.49.

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.

pollen fine powder containing the pollen grains (the male sex cells of a plant)

stigma the female part of a flower, that catches the pollen during pollination

pollinators organisms such as bees, flies and other organisms that carry pollen between flowering plants

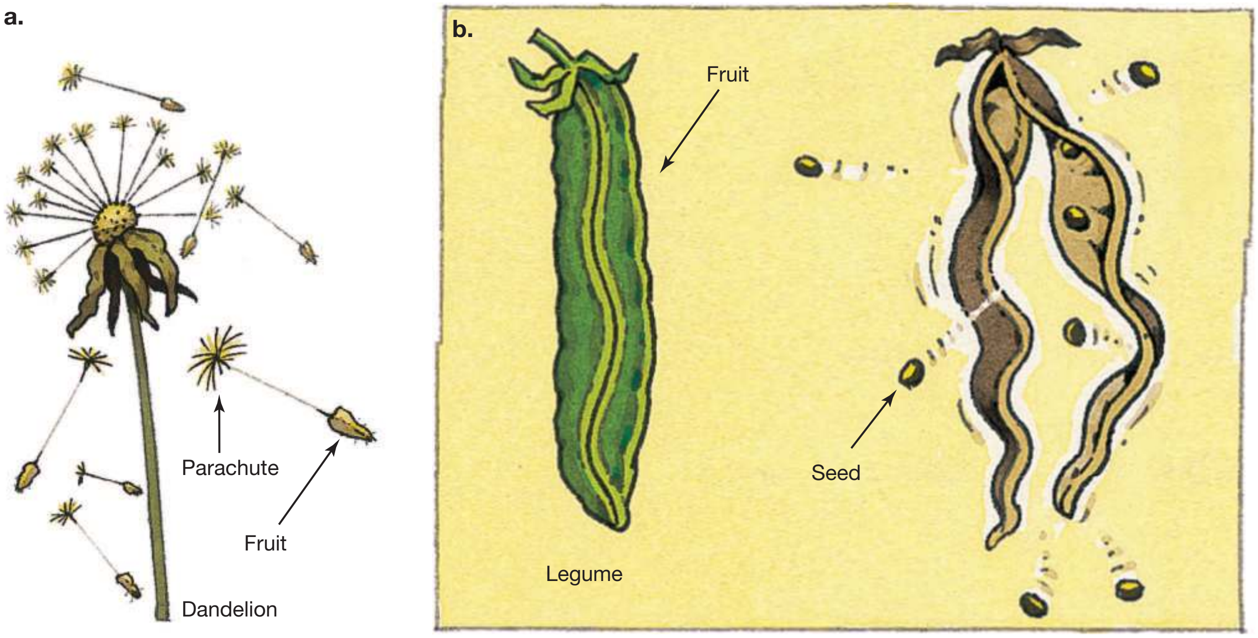
FIGURE 4.49 Three examples of feeding relationships between animals and plants

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.

FIGURE 4.50 a. Dispersal of fruit from a dandelion b. Seeds dispersing from a legume



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, dispersing their seeds themselves.

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 4.51 Animals consume brightly coloured fruits and help disperse the seeds.

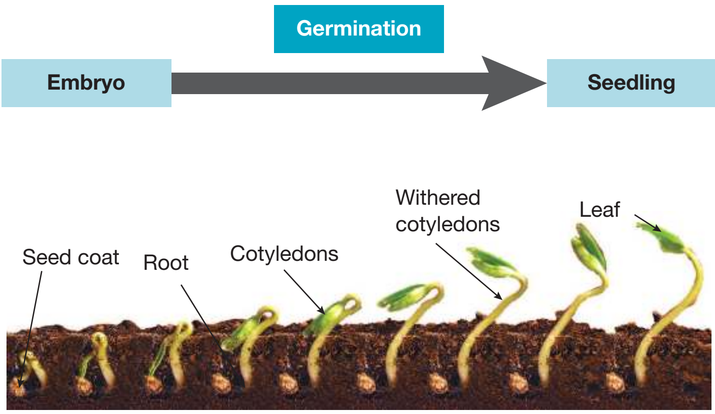
DISCUSSION

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 4.52).

FIGURE 4.52 The germination process



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).

Although light is not necessary for 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.

4.8.2 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.

germination the first sign of growth from the seed of a plant

agriculture the use of land to grow crops or raise farm animals

SCIENCE AS A HUMAN ENDEAVOUR: Laboratory-grown meat

Reducing impacts on ecosystems

Increased meat consumption around the world is of great concern as 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 into 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 4.53 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 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.

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, sugarcane or some other single crop. Such crops are called **monocultures** and can lead to reduced biodiversity.

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.

FIGURE 4.54 Areas planted with only one crop are called monocultures.

monocultures crops grown on land used for one kind of crop only

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.

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. As this would reduce the future production of crops, **fertilisers** are often added to replace these 'lost' nutrients.

FIGURE 4.55 Modern agriculture provides large amounts of food, but at a cost to the environment.

Eutrophication

Some of these fertilisers may, however, 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.

Carefully observe figures 4.57 and 4.58. The diagram in figure 4.57 shows how phosphorus is normally cycled within ecosystems. The diagram in figure 4.58 shows the effect of excess phosphorus on populations of organisms. Eutrophication is like suffocation of a waterway. It can result in the death of organisms, and so it creates an inbalance in the food chains and webs.

FIGURE 4.56 High levels of phosphorus from fertiliser in water can lead to eutrophication.

fertilisers chemicals added to soil to provide the nutrients needed for plant growth

eutrophication a form of water pollution involving an excess of nutrients leaching from soils

FIGURE 4.57 A simplified view of how phosphorus is cycled within an ecosystem

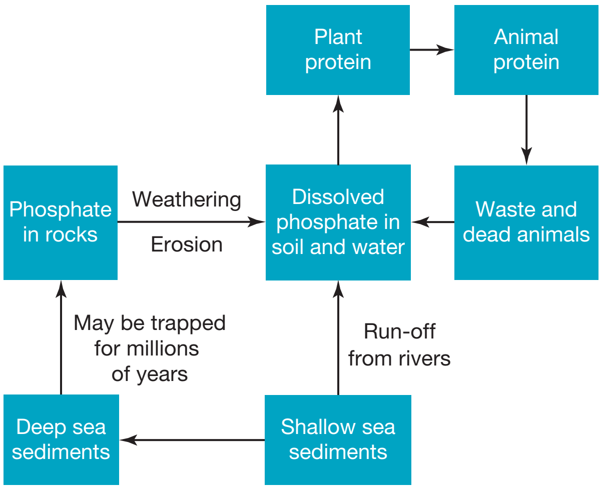
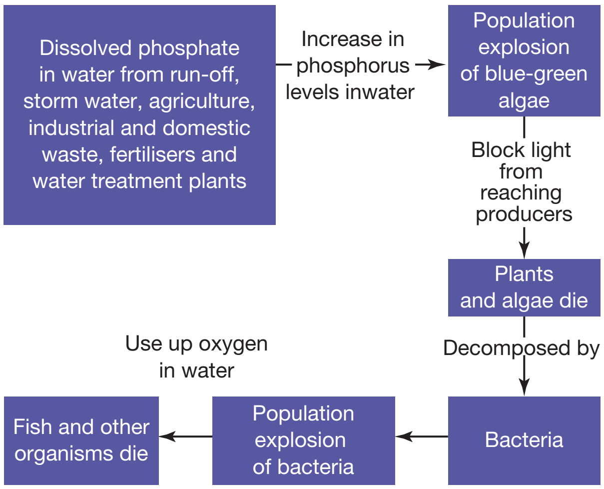


FIGURE 4.58 Eutrophication can result in the death of organisms within the ecosystem.



SCIENCE AS A HUMAN ENDEAVOUR: Desalination plants

Impact on marine ecosystems

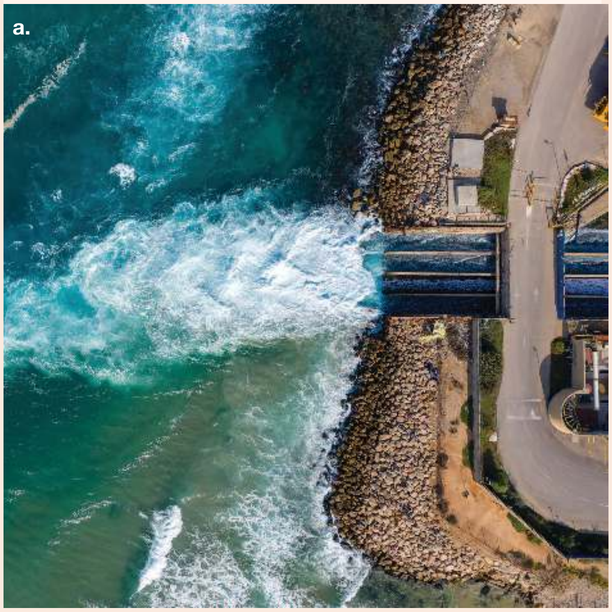
Over the past few decades, significant growth in the human population and industries has increased the demand of fresh water. Reductions in water quality and quantity have negative impacts on ecosystems. Therefore, to meet the demands of fresh water, desalination can be considered as an option.

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 takein 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.

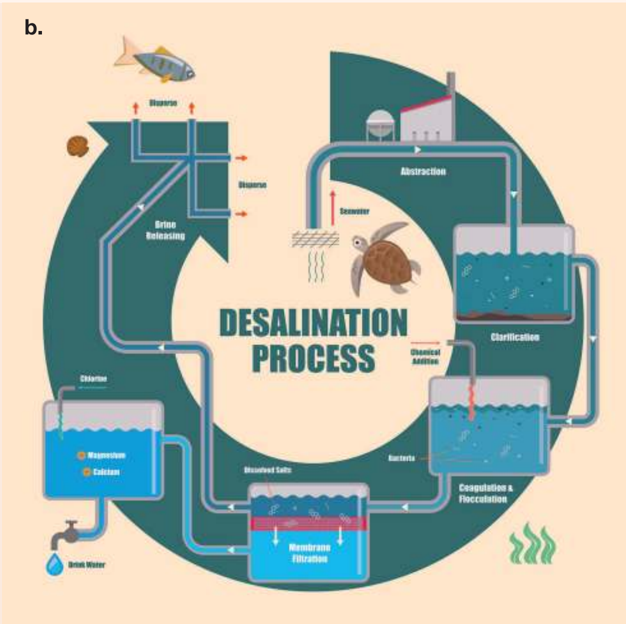
Also, significant energy consumption in the desalination process — in order to produce electricity and heat — would lead to increased greenhouse gas emissions into the atmosphere.

FIGURE 4.59 a. The desalination process



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.

FIGURE 4.59 b. Brine rejected into the Mediterranean Sea at the world's largest desalination facility in Hadera, Israel.



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.

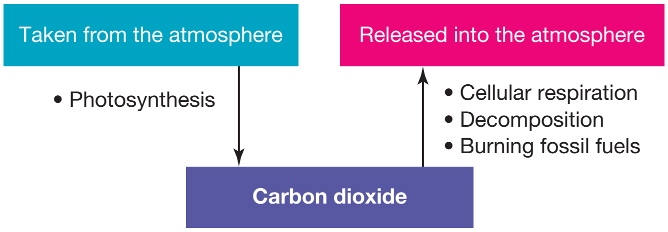
Deforestation greatly harms ecosystems. It severely impacts, or even destroys, the food chains and food webs that are in delicate balance, and many organisms lose their food source with the loss of important producers. The habitat of numerous organisms is also changed or lost completely.

FIGURE 4.60 The deforestation and clearing of huge part of a 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 4.61. 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 4.61 Deforestation and removing trees can result in more carbon dioxide in the atmosphere as less is absorbed for use in photosynthesis.



Our way of life also adds greenhouse gases into the environment; hence 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 early 2020.

FIGURE 4.62 Polar bears surrounded by melting polar ice caps

4.8.3 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.

introduced species species that are not native to an ecosystem

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

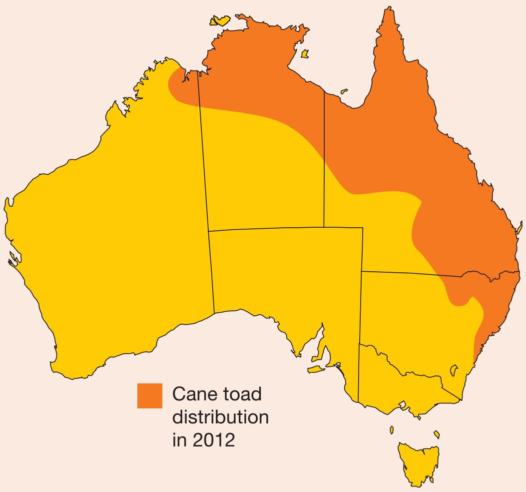
CASE STUDY: Cane toads

History

The cane toad (*Bufo marinus*) was introduced into Australia in 1935 to control the sugarcane beetle, which was destroying sugarcane 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 three 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



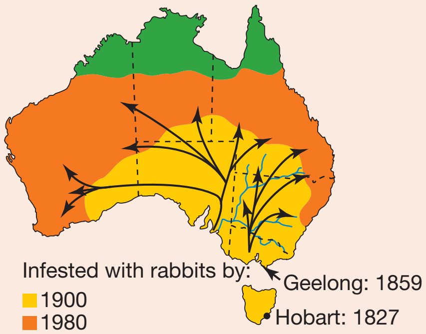
CASE STUDY: Rabbits

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 NSW 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, flood 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.

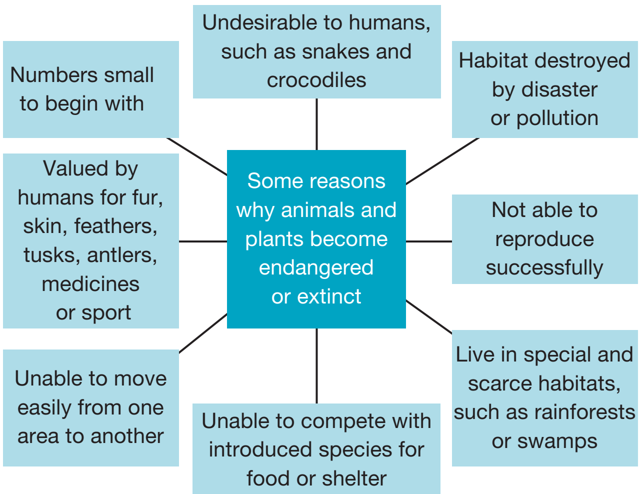
During the 200 years since the European colonisation of Australia, over 125 different species of Australian native plants and animals have become extinct. This includes over 10 per cent of all native mammals. Many more species are in danger of extinction.

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 4.63 Reasons for extinction

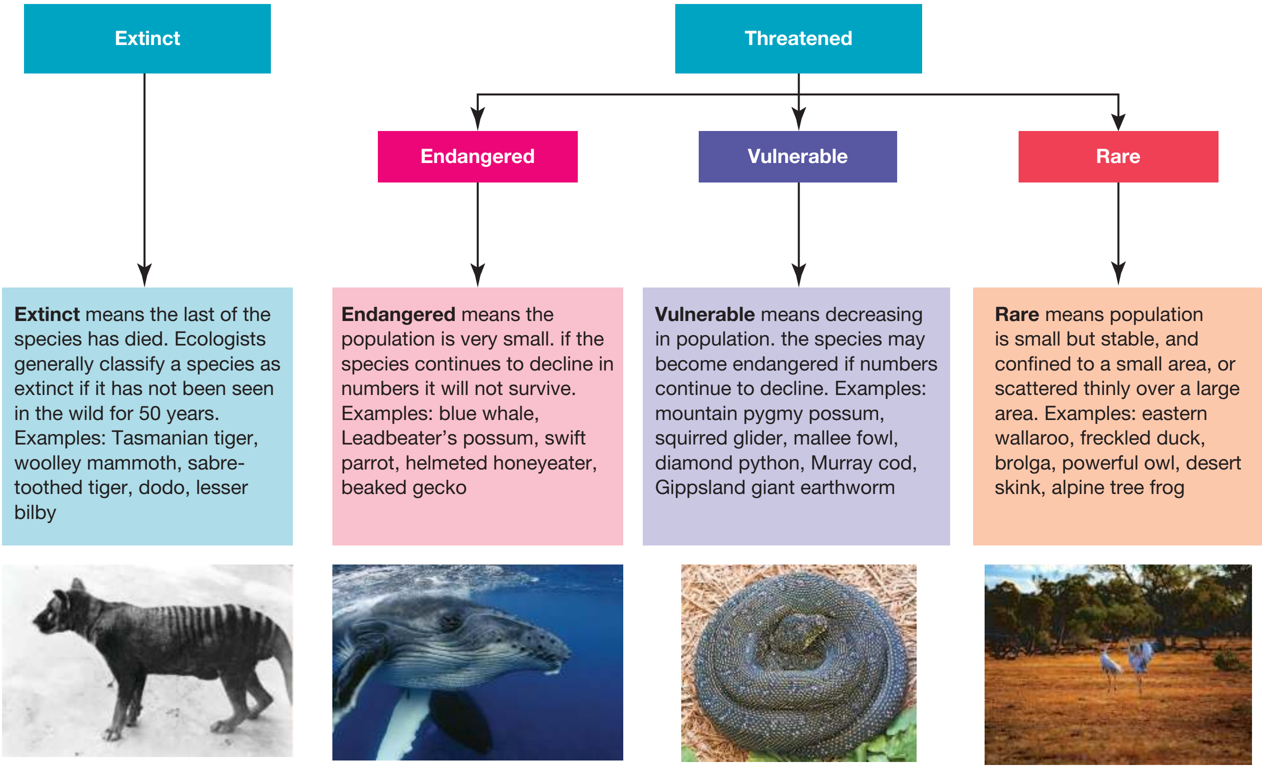


Some of the solutions put into practice to reduce the threat to endangered species include:

- 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 4.64).

FIGURE 4.64 Extinct and threatened species



on Resources

Interactivity Pesticides (int-3458)

Weblink Invasive species in Australia

4.8 Activities

learnon

4.8 Quick quiz on | 4.8 Exercise

Select your pathway

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

Remember and understand

1. Match each term with its meaning.

a.

Term	Meaning
a. Angiosperms	**A.** the fusion (joining together) of male and female sex cells
b. Pollen	**B.** when pollen grains attach to the stigma
c. Pollination	**D.** produced in the anthers of a flowering plant
e. Seed dispersal	**E.** the process in which the seed bursts open and the embryo plant becomes a seedling
f. Fertilisation	**F.** plants that produce flowers
g. Germination	**G.** the spreading of seeds

b.

Term	Meaning
a. Monoculture	**A.** 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	**B.** A chemical used to kill insects that compete with humans for food crops
c. Eutrophication	**C.** The control of plant or animal pests through the use of chemicals
d. Insecticide	**D.** Results from the addition of very high levels of phosphorus into waterways, which can reduce levels of oxygen available in the water
e. Herbicide	**E.** A crop that contains only one species
f. Chemical control	**F.** A species that has been released into an ecosystem in which it does not occur naturally
g. Introduced species	**G.** 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 harms living things
D. Anything added to the environment that harms people

3. Identify whether a plant with the following features is more likely to be insect or wind pollinated.
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 listed terms.
   a. *Terms:* 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. *Terms:* 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 4.60. Should forests be protected? If so, how many of them? If not, why not? Give reasons for your answers.
11. **SIS** Population statistics of several animals were collected in two areas over five 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.

TABLE Area 1: populations of native animals over five 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

TABLE Area 2: populations of native animals over five 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

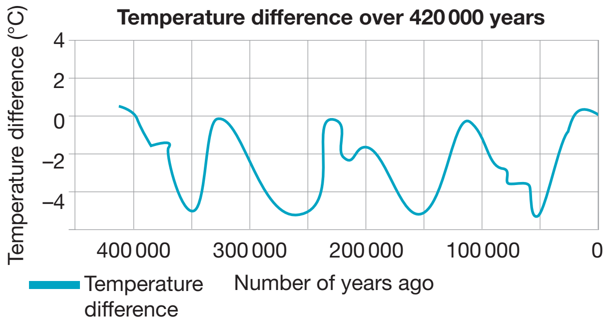
   a. Draw two separate food webs: one of the native animals only, and the other one including the introduced species.
   b. Plot two population graphs from the two tables, using a different colour for each animal. Join the points with straight lines.
   c. i. Which native animal was most affected by the introduction of the rabbit into the second area?
      ii. Which animals were least affected?

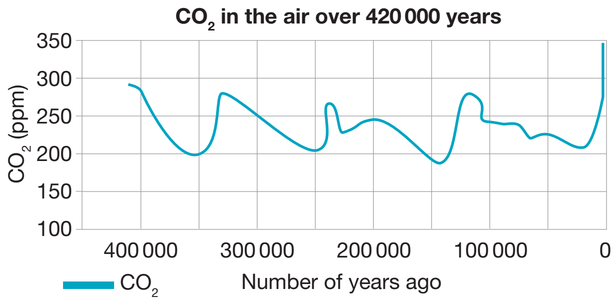
d. i. What happened to the number of rabbits in the first two years?
   ii. What happened to the number of rabbits after the first two years?
   iii. Can you explain why this happened?
e. i. What effect did the introduction of the rabbits have on the wallaby population?
   ii. Why do you think the rabbits had this effect?
f. Did the rabbits have any effect on the dingo and bandicoot populations? Explain.
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. SIS Suggest projects that governments, communities, scientists and farmers can work collaboratively on.

Evaluate and create

13. SIS Find out more about the seed dispersal of five different types of plants and report your findings visually.
14. SIS 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.
       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 to be a weed.
       vi. Suggest ways to control or eliminate this weed in Australia.
       vii. Suggest possible consequences of removing this weed from Australian ecosystems.
15. SIS 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
16. Find out more about the impact of one of the following introduced plants and animals: horse, camel, cat, fox, goat, hare, sparrow, rat, garden snail, starling, water buffalo, deer, ferret, housefly, European wasp, thistle, blackberry, serrated tussock, Paterson's curse, ragwort.
    Explain why it was introduced and what effect this had.
17. SIS Research and report on one of the following:
    - different scientific responses to rabbit plagues in Australian agricultural areas
    - the use of fire by traditional Aboriginal peoples
    - the effects of palm oil harvesting in Sumatra and Borneo.
18. SIS Scientists have drilled into ice on 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.





Fully worked solutions and sample responses are available in your digital formats.

LESSON
4.9 Thinking tools — Relational diagrams

4.9.1 Tell me

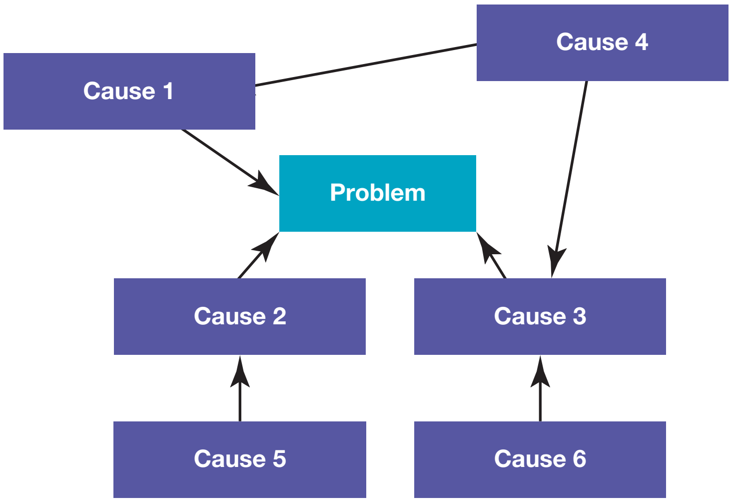
What is a relational diagram?

A relational diagram is used when you need to work out the possible reasons that a difficult situation or problem happened. They are also called multi-flow maps or process maps.

A relational diagram shows a sequence of events and how each event is related. Think of this kind of diagram as a map that shows the events that led to a specific problem or event happening.

Relational diagrams are different to tree diagrams or mind maps, because instead of showing how one event or topic branches out into its parts, a relational diagram shows how a series of different events led to one end point or action.

FIGURE 4.65 Show links between your secondary causes



What is a relational diagram for?

A relational diagram is a way of analysing the causes of a problem or situation. It is like thinking backwards from a problem to see how it happened.

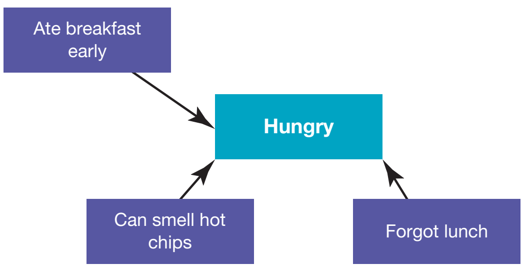
This is a great way of analysing which things were the *primary* causes of a problem, and which were *secondary* causes. The secondary causes are the things that didn't help to cause the *main* problem directly but did lead to some of the primary causes occurring, which then led on to the problem. This kind of analysing will also allow you to show which of the causes were connected.

4.9.2 Show me

To create a relational diagram:

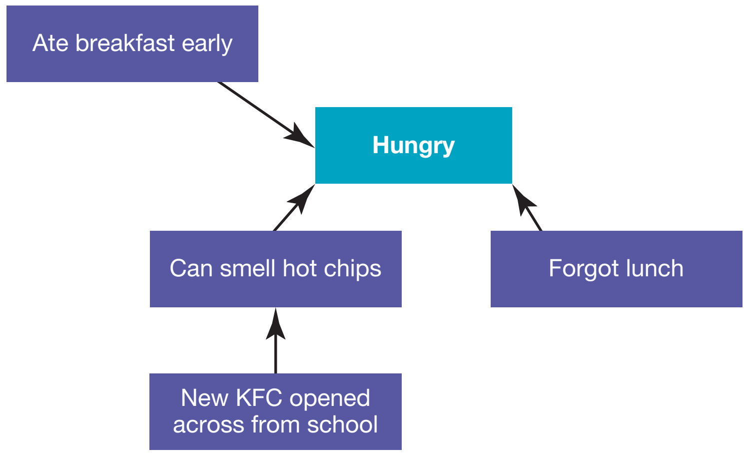
1. Write the problem or situation that you are analysing in the middle of a piece of paper.
2. Ask yourself the possible reasons that might have led to that problem happening. Write each of these answers (causes) around the problem. Add an arrow pointing to the problem to show that these are its *primary* causes.

FIGURE 4.66 Consider some causes of the problem.



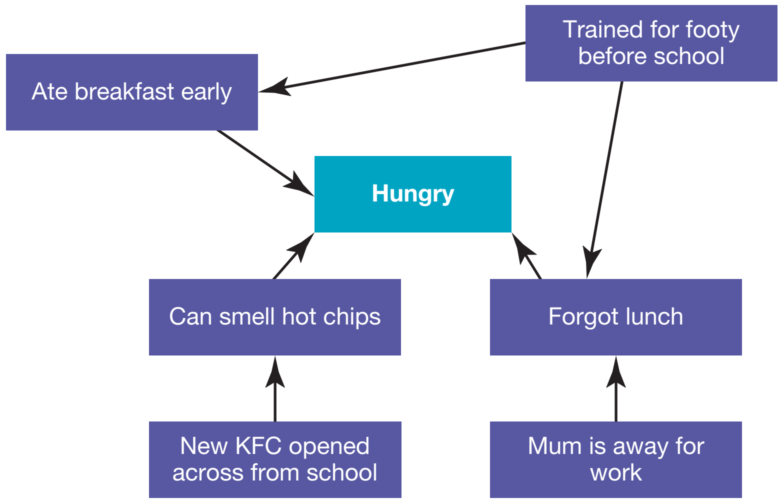
3. Think about each primary cause individually. Ask yourself why each primary cause occurred. This is asking 'what causes the cause?' These are your *secondary* causes. List as many as you can for each primary cause. Add arrows to show the secondary causes led to the primary cause.

FIGURE 4.67 Add secondary causes off your primary causes.



4. Look for other links between your secondary causes. Draw in arrows to show these relationships. For example, if you analysed the primary and secondary causes of why you are hungry, you might come up with a relational diagram like the one in figure 4.68.

FIGURE 4.68 Relational diagrams involve a problem and causes.



4.9.3 Let me do it

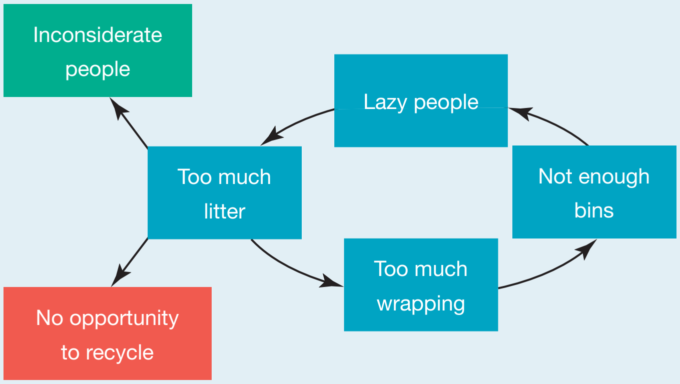
4.9 Activities

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

1. Select one problem about an ecosystem that you observe in your everyday life. Research at least five reasons that may cause this and show your results in a relational diagram.
2. The hunting and fate of whales is of great concern to many Australians. Find out more about the issues associated with the hunting of whales.
   Construct a relational diagram to show the reasons for the hunting of whales.
3. Use relational diagrams to capture possible causes of, or reasons for:
   a. Australians having large 'ecological footprints'
   b. rubbish/litter on our beaches
   c. the ecological impact of introduced species
   d. species becoming endangered.
4. a. Brainstorm possible causes of litter in your school. Summarise your discussion into a relational diagram.
   b. Compare your relational diagram with that shown. Comment on any similarities or differences.



Fully worked solutions and sample responses are available in your digital formats.

LESSON
4.10 Project — Small acts, big changes

Scenario

Climate change is an issue that is very important to us all. Nearly every day we hear statistics about what the world will be like by 2050 if we don't make dramatic changes to our lifestyles. In recent years we have seen young people take action. Now you can take action by to making a positive change. Your task is to and create a persuasive video that will inform households and local communities of actions they can take personally to help stop the consequences of climate change.

Your task

Your task is to create a three-minute internet video to be distributed online. You're aim is for this video to go 'viral' — for it to be good enough that people want to pass it on to their friends. Your video should provide the viewer with practical advice on reducing their carbon footprint, but it should also be entertaining enough to appeal to a wide range of people who use the internet. Remember, the consequences of climate change have already begun, so your video should not only create a sense of urgency about the seriousness of the problem, but also be persuasive enough to encourage its viewers to take immediate action. Your video needs to include science that the public can understand and engage with. Therefore, you need to provide convincing and accurate facts while appealing to the emotional and intellectual capacities of your audiences.

on Resources

ProjectsPLUS Small acts, big changes (pro-0036)

LESSON
4.11 Review

Hey students! Now that it's time to revise this topic, go online to:

- Review your results
- Watch teacher-led videos
- Practise questions with immediate feedback

Find all this and MORE in jacPLUS

Access your topic review eWorkbooks

on Resources

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-11229	ewbk-11231	ewbk-11233

4.11.1 Summary

The connection of First Nations Australians to their ecosystems

- First Nations Australians have a rich understanding of their ecosystems, allowing the ecosystems to remain balanced while providing for dietary requirements.

What are ecosystems?

- Ecosystems are made up of living things (biotic factors) and non-living things (abiotic factors).
- A habitat in an ecosystem is the location where an organism lives.
- Abiotic factors affect which types of organisms can survive in the environment — organisms have tolerance ranges for different abiotic factors.

Relationships in ecosystems

- Organisms of the same species live together as a population.
- Groups of different populations form a community.
- Producers are organisms that can make their own food from their non-living environment.
- Consumers are organisms that eat other organisms or their products — consumers include decomposers, carnivores, herbivores and omnivores.
- Competition can exist between organisms where they compete for the same resources.
- Other relationships include predator–prey relationships and symbiotic relationships.

Food chains and food webs

- Food chains describe the feeding relationships between organisms and the flow of energy.
- Primary consumers eat plants, secondary consumers eat primary consumers and tertiary consumers eat secondary consumers.
- A food web shows interconnecting food chains.

The importance of flowering plants

- Plants that produce flowers are known as angiosperms.
- Pollination involves the transfer of pollen from the male part to the female part of the flower — some plants self-pollinate, others rely on other animals (such as bees), and others rely on abiotic factors such as the wind.
- Germination is the process in which a seed bursts open, and relies on many different abiotic factors such as oxygen and water availability.

Decomposition and nature's recycling

- Decomposers are an important part of this recycling, breaking down complex material into simple substances that can be used by other organisms.

Human impact on ecosystems

- Humans impact ecosystems in many ways, often causing them to be unbalanced.
- Some examples of this include through agriculture, deforestation, pollution and the introduction of foreign species.

Extinction

- Extinction is when the last of a species has died.
- Many organisms that are endangered, vulnerable and rare are at risk of extinction.

4.11.2 Key terms

abiotic factors the non-living things in an ecosystem
agriculture the use of land to grow crops or raise farm animals
autotrophs organisms that can produce their own nutrients
biodegradable able to break down or decompose easily in the environment
biomass the total amount of mass of living organisms
biotic factors the living things in an ecosystem
carnivores animals that eat other animals
cellular respiration the chemical reaction involving oxygen that moves the energy in glucose into the compound ATP
chlorophyll the green-coloured chemical in plants that absorbs the light energy used in photosynthesis to make food from carbon dioxide and water
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
consumers organisms that rely on other organisms for food
decomposers small organisms that break down dead and decaying matter
detritivores organisms that consume detritus; that is, decomposing plant and/or animal parts or faeces
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
eutrophication a form of water pollution involving an excess of nutrients leaching from soils
fertilisers chemicals added to soil to provide the nutrients needed for plant growth
food chain a diagram showing feeding relationships in an ecosystem
food web a number of food chains joined together
germination the first sign of growth from the seed of a plant
habitat the place in which a particular organism lives
herbivores animals that eat only plants
heterotrophs organisms that depend on another organism to supply their complex molecules and energy
host the organism on which a parasite feeds
inorganic material that is not carbon-based
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
metabolism the chemical reactions occurring within an organism that enable the organism to use energy and grow and repair cells
microorganisms microscopic (very small) life forms
monocultures crops grown on land used for one kind of crop only
mutualism a relationship between two organisms in which both benefit
non-biodegradable not able to break down or decompose in the environment
omnivores animals that eat plants and other animals

organic carbon-based material derived from living things, such as plant mass
optimum range the range of environmental conditions in which a species can thrive
organisms living things made up of one or more cells
parasite an organism that lives 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
photosynthesis a process in which carbon dioxide, water and energy from the Sun produce food in the form of sugar
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
population organisms of one particular species in a given area at one time
primary consumer an organism that eats plants
producers organisms that use photosynthesis to make their own food from the Sun's energy
relationships interactions with other species within an ecosystem
saprophytes organisms such as fungi that obtain nutrients from dead organic matter
secondary consumer an organism that eats primary consumers
seed the product of a fertilised ovule
species a group of organisms with many features in common, that can mate with each other to produce fertile young under natural conditions
stigma the female part of a flower, that catches the pollen during pollination
symbiosis an ongoing relationship between members of different species
tertiary consumer an organism that eats secondary consumers
tolerance range the range of environmental conditions in which a species can survive
trophic level a feeding level within a food chain
Weeds of National Significance (WONS) weeds that have been identified based on their invasiveness, potential for spread, and environmental, social and economic impacts

on Resources

Digital document	Key terms glossary (doc-39621)	
eWorkbook	Study checklist (ewbk-11222)	Crossword (ewbk-11225)
	Reflection (ewbk-11221)	Word search (ewbk-11227)
	Literacy builder (ewbk-11223)	
Practical investigation eLogbook	Topic 4 Practical investigation eLogbook (elog-0497)	

4.11 Activities

learn**on**

4.11 Review questions

Select your pathway

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

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

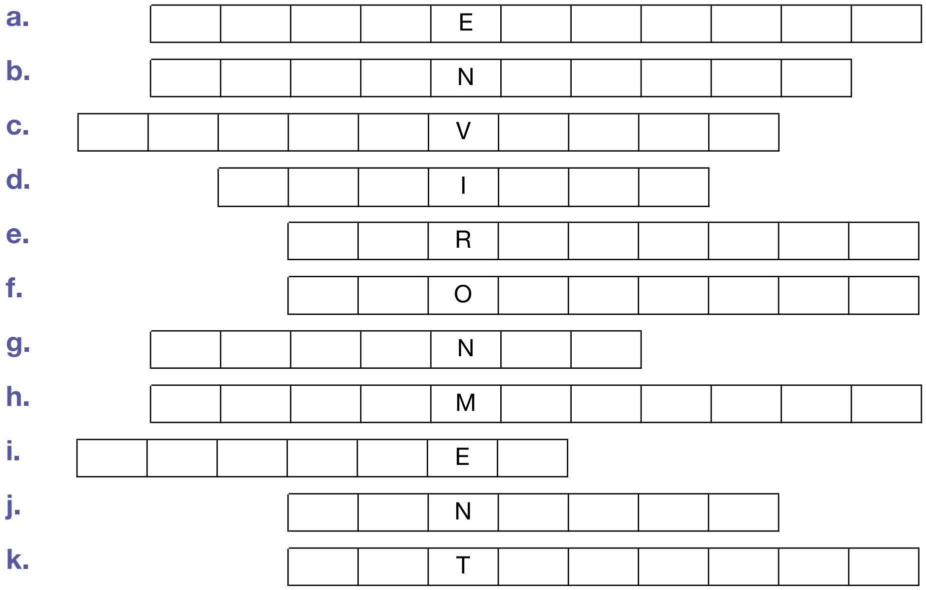
Find all this and MORE in jacPLUS

Rememember and understand

1. Match each term to its meaning.

Term	Meaning
a. Herbivores	**A.** Organisms that produce their own food
b. Producers	**B.** Animals that eat plants
c. Consumers	**C.** Organisms that live in or on other organisms and obtain their food from them
d. Parasites	**D.** Organisms that break down dead plants and animals
e. Decomposers	**E.** Animals that eat other organisms

2. Copy and complete the puzzle, using the clues provided.



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.

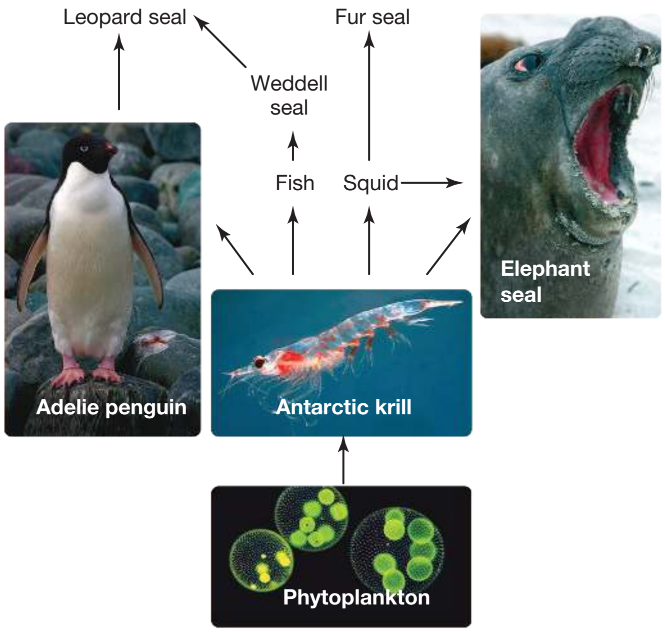
Apply and analyse

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 First Nations Australians 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.

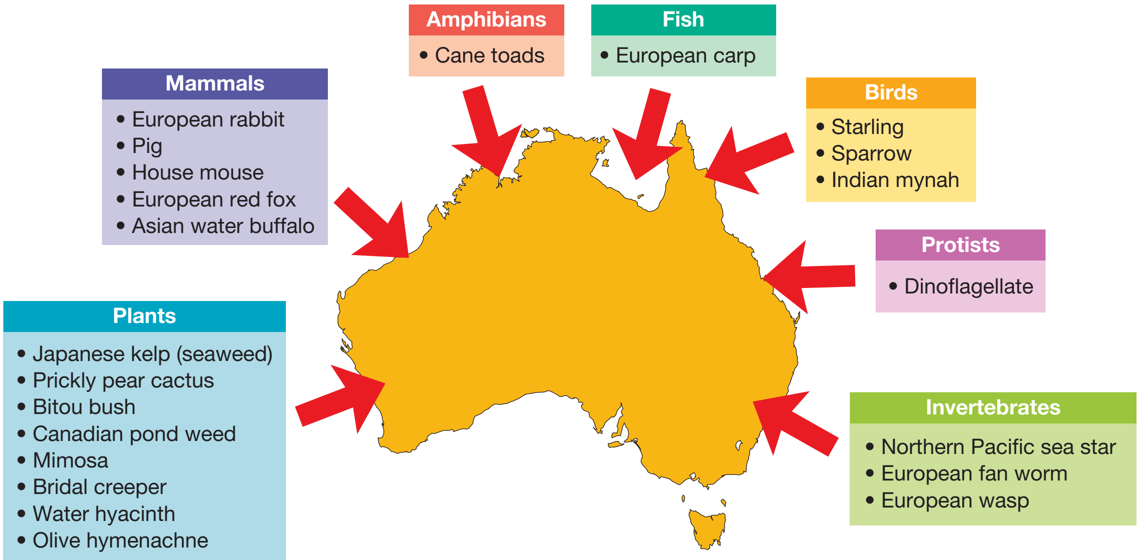
Evaluate and create

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. **SIS** Select one of the introduced organisms shown in provided map of Australia. Find out and report on:
a. where they came from and how they arrived in Australia
b. the effects that they have had on Australian ecosystems.



Fully worked solutions and sample responses are available in your digital formats.

Online Resources

on Resources

Below is a full list of **rich resources** available online for this topic. These resources are designed to bring ideas to life, to promote deep and lasting learning and to support the different learning needs of each individual.

4.1 Overview

eWorkbook
- Topic 4 eWorkbook (ewbk-11194)
- Student learning matrix (ewbk-11198)
- Starter activity (ewbk-11196)

Practical investigation eLogbook
- Investigation 4.1: Modelling interaction (elog-1994)
- Topic 4 Practical investigation eLogbook (elog-1993)

Video eLesson
- The beauty of the coral reef (eles-4161)

4.2 First Nations Australians' connection to their ecosystem

eWorkbook
- Bush tucker (ewbk-11199)

Weblink
- Indigenous ecological knowledge
- Fire management

4.3 What are ecosystems?

eWorkbook
- Labelling the levels of biological organisation (ewbk-11201)
- Biotic and abiotic factors (ewbk-11203)
- Ocean explorations (ewbk-11205)

Practical investigation eLogbook
- Investigation 4.2: Ecosystem in a bottle (elog-1996)
- Investigation 4.3: Measuring abiotic factors that can affect biotic factors (elog-1997)

Video eLesson
- The parts of an ecosystem (eles-4256)

Interactivities
- How living things interact (int-8189)
- Labelling the levels of biological organisation (int-8095)

4.4 Relationships in ecosystems

eWorkbook
- Relationships in ecosystems (ewbk-11207)

Practical investigation eLogbook
- Investigation 4.4: Do all leaves contain the same pigments? (elog-1999)

Video eLessons
- Relationships between species (eles-4239)
- Dung beetle relocating his dung house (eles-2649)
- Decomposers (eles-2650)

Interactivity
- Some animal species found in Antarctica (int-8190)

4.5 Food chains and food webs

eWorkbook
- Food webs (ewbk-11209)
- Nature pyramids (ewbk-11211)
- Food chains and food webs (ewbk-11213)

Practical investigation eLogbook
- Investigation 4.5: Make a food web (elog-2001)

Interactivities
- The organisms in a food chain (int-8174)
- What can you see in the rockpool? (int-3454)
- A food chain (int-3462)
- Food web in an Antarctic ecosystem (int-3465)
- A food web showing the flow of chemical energy through different organisms in an ecosystem (int-3463)

Weblink
- Food chain challenge — Savannah

4.6 Energy flows

eWorkbook
- Labelling recycling through ecosystems (ewbk-11215)
- Cycles in nature (ewbk-11217)

Teacher-led video
- Investigation 4.6: Looking at decomposers (tlvd-10654)

Practical investigation eLogbook
- Investigation 4.6: Looking at decomposers (elog-2003)
- Investigation 4.7: Investigating decomposition (elog-2005)
- Investigation 4.8: Preserving apples (elog-2005)

Video eLesson
- Fungi help break down food (eles-2748)

Interactivity
- Labelling recycling through ecosystems (int-8097)

4.7 Ecological pyramids

Interactivity
- Trophic levels (int-3464)

Weblink
- How wolves changed rivers

4.8 Changes in ecosystems

eWorkbook
- Labelling methods of pollination (ewbk-11219)

Interactivity
- Pesticides (int-3458)
- Labelling methods of pollination (int-8175)

Weblink
- Invasive species in Australia

4.10 Project — Small acts, big changes

ProjectPLUS
- Small acts, big changes (pro-0036)

4.11 Review

eWorkbooks
- Topic review Level 1 (ewbk-11229)
- Topic review Level 2 (ewbk-11231)
- Topic review Level 3 (ewbk-11233)
- Study checklist (ewbk-11222)
- Reflection (ewbk-11221)
- Literacy builder (ewbk-11223)
- Crossword (ewbk-11225)
- Word search (ewbk-11227)

Digital document
- Key terms glossary (doc-39621)

To access these online resources, log on to **www.jacplus.com.au**

5 States of matter

CONTENT DESCRIPTION

Use particle theory to describe the arrangement of particles in a substance, including the motion of and attraction between particles, and relate this to the properties of the substance (AC9S7U05)

LESSON SEQUENCE

SCIENCE INQUIRY AND INVESTIGATIONS

Science inquiry is a central component of Science curriculum. Investigations, supported by a **Practical investigation eLogbook** and **teacher-led videos**, are included in this topic to provide opportunities to build Science inquiry skills through undertaking investigations and communicating findings.

LESSON
5.1 Overview

Hey students! Bring these pages to life online

Watch videos | Engage with interactivities | Answer questions and check results

Find all this and MORE in jacPLUS

5.1.1 Introduction

Everything around you and in you is made of matter. Your desk, your mobile phone, 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 and it is interesting to note that it 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 5.1 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 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.

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
water vapour water in the gaseous state

on Resources

Video eLesson Three states of water (eles-3524)

Water naturally occurs on Earth in three states: solid (ice), liquid and gas (vapour). Watch this video to explore the properties of water as it changes states.

5.1.2 Think about states of matter

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?

5.1.3 Science inquiry

Bathroom science

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.
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?

FIGURE 5.2 Does the bathroom mirror fog up when you have both hot and cold showers?

elog-2009

INVESTIGATION 5.1

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 state 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

3. Take the beaker of water and draw a small amount up into the syringe. Place your finger over the opening at the end of the syringe and press down on the plunger.
4. Place the beaker on the balance and zero the balance, release the water back into the beaker and record the mass.

Gas

5. Partially inflate a balloon with air and hold the opening tightly closed. Try to squeeze the balloon.
6. Release your hold on the opening of the balloon.
7. Place 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

TABLE Properties of solids, liquids and gases

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 its 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.

on Resources

eWorkbooks Topic 5 eWorkbook (ewbk-11235)
Student learning matrix (ewbk-11239)
Starter activity (ewbk-11236)

Practical investigation eLogbook Topic 5 Practical investigation eLogbook (elog-2010)

LESSON
5.2 States of matter

LEARNING INTENTION

At the end of this lesson you will be able to compare the properties of different states of matter.

5.2.1 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 for instance.

solid state of matter that has a fixed shape and volume

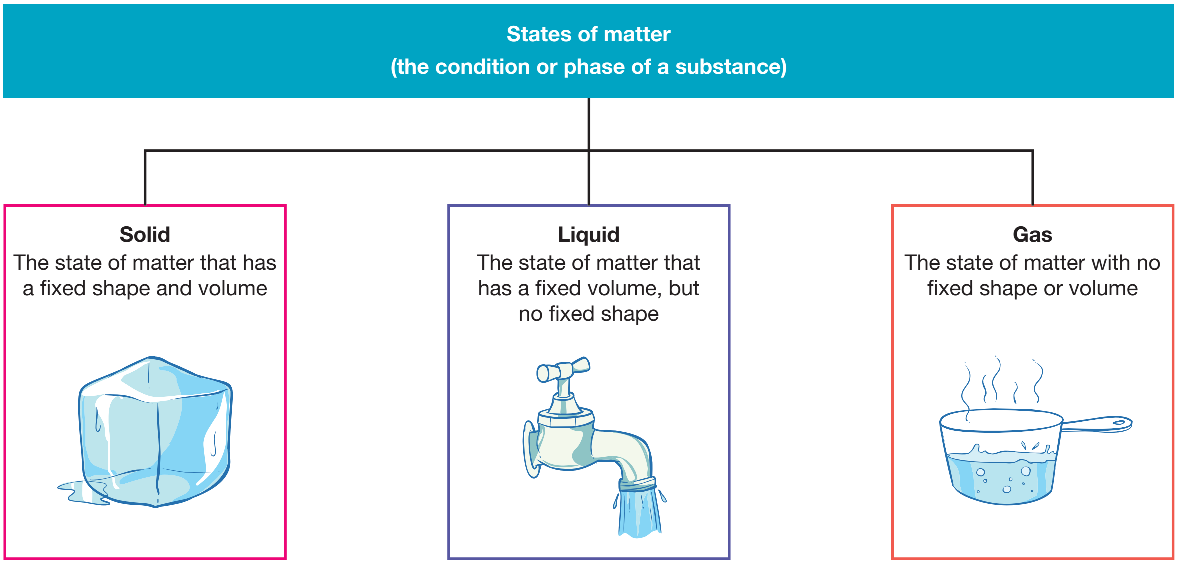
liquid state of matter that has a fixed volume, but no fixed shape

gas state of matter with no fixed shape or volume

properties the qualities and characteristics of materials and the substances that they are composed of

plasma superheated, charged gas that is the fourth state of matter

FIGURE 5.3 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 5.4 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 5.5 Liquid pouring from a cup and overflowing

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 5.6, iodine gas is being formed and is spreading, or diffusing, throughout the gas jar.

Gases, unlike solids and liquids, can be compressed, making them take up less space. An inflated balloon can be compressed by squeezing it.

DISCUSSION

Salt crystals are able to be poured and also take up the shape of their container. Are salt crystals liquid or solid?

diffusion movement of one substance through another due to a movement of particles, for example from a region of higher concentration to lower concentration

FIGURE 5.6 The iodine gas will diffuse to take up the space inside the glass jar.

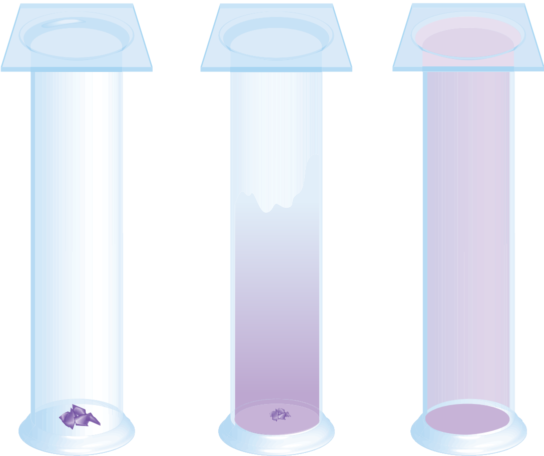


FIGURE 5.7 For safety, iodine gas is being diffused in a fume cupboard.

on Resources

Video eLesson Diffusion (eles-2035)

elog-2013

INVESTIGATION 5.2

Ranking substances

It is useful to refer to 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

TABLE Results of investigation 5.2

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 solid, liquid or gas.
2. Rank the following 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

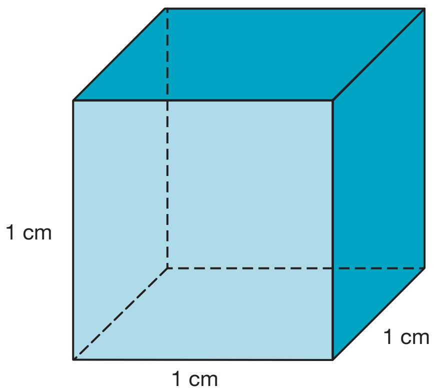
Which substances were most difficult to classify as solid, liquid or gas? Explain why they were difficult to classify. Your conclusion should be no longer than three or four sentences.

5.2.2 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 5.8 This cube has a volume of 1 cm^3 and can hold 1 mL of a fluid.



$$1\ \text{mL} = 1\ \text{cm}^3$$
$$1\ \text{L} = 1000\ \text{cm}^3$$
$$1000\ \text{L} = 1\ \text{m}^3$$

volume the amount of space taken up by an object or substance

fluid a substance that flows and has no fixed shape. Gases and liquids are fluids.

on Resources

Interactivity Volume (int-3791)

elog-2014

INVESTIGATION 5.3

Measuring the volume of an irregular-shaped solid

Aim

To investigate the volume of an irregular-shaped solid

Hypothesis

If a beaker and a measuring cylinder are used to measure the volume of an object, then the results will be different.

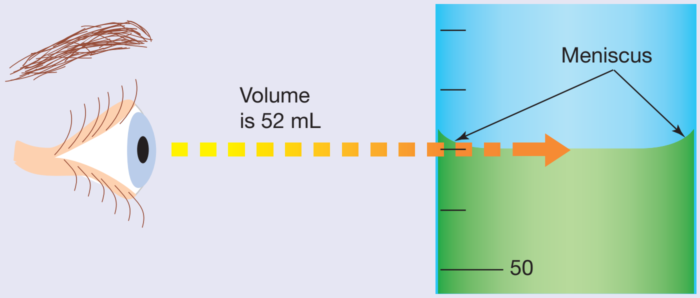
Materials

- 100 mL beaker
- 100 mL measuring cylinder
- Stone or pebble that will fit into the measuring cylinder

Method

1. Half fill (approximately) a 100 mL beaker with water.
2. Carefully pour the water into the measuring cylinder and accurately record the volume.
3. Carefully place the pebble into the measuring cylinder. Take care not to spill any displaced water and accurately record the new volume.

The curved upper surface of the liquid is called the meniscus. When you are reading the volume of a liquid in a measuring cylinder, your eye should be level with the flat part in the centre of the meniscus.



Results

1. Accurately record the volume of water in the measuring cylinder using the technique shown in the diagram. Do not forget to include units.
2. Accurately record the new volume once the pebble has been added.

Discussion

1. What was the volume of the solid in mL?
2. What was the volume of the solid in cm^3?
3. Suggest another way of measuring the volume of the solid object.
4. Which is the more accurate piece of equipment for measuring volume: a 100 mL beaker or a 100 mL measuring cylinder? Explain why.

Conclusion

Summarise your findings in three or four sentences.

5.2 Activities

learnon

5.2 Quick quiz on	5.2 Exercise

Select your pathway

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

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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 three headings, Solids, Liquids and Gases, or into a cluster, mind or concept map. You can list items between columns if they displayed properties of both states.

Solids	Liquids	Gases

4. **a.** Identify three properties 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.** What is the unit used to measure small volumes, such as for liquid medicines?
   b. How could you measure such a volume?

Apply and analyse

6. Describe, in terms of their properties, how gases differ to liquids.
7. Both steel and chalk are solids. 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 the petrol station, the safety sign asks 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. **SIS** There is a fourth state of matter known as plasma, which is not very common on Earth. Research and report on:
    a. how plasma is different from solids, liquids and gases
    b. where plasma can be found
    c. how plasma can be used on Earth.
13. **SIS** 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.
14. Make up a short poem about the properties of solids, liquids and gases.
15. **SIS** Olivia says that when a candle burns it is a solid that burns, Henry says that it is a liquid that burns and Zahra says that 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 watch it on Youtube). Decide who is correct and write a summary of your findings.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
5.3 Changing states

LEARNING INTENTION

At the end of this lesson you will be able to 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.

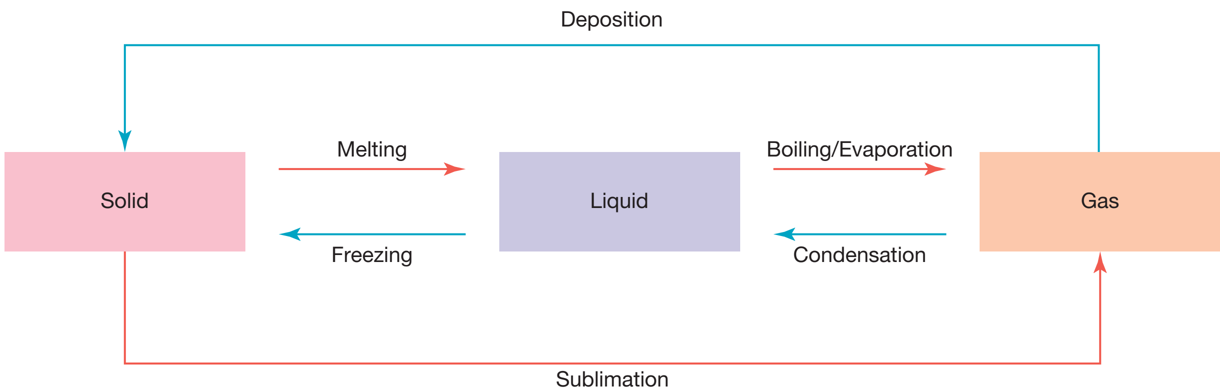
5.3.1 Changing states

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.

To change the state of any substance, including water, it must be heated or cooled, or the pressure changed.

FIGURE 5.9 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 5.10 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.

state of matter condition or phase of a substance. The three main states of matter are solid, liquid and gas.

pressure the force exerted per unit area

temperature a measure of how hot or cold something is

melting point the temperature at which a solid substance turns into a liquid (melts) or a liquid turns into a solid (freezes)

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 5.1.

TABLE 5.1 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 under –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 (to remove warts, for instance) 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 windowpane, 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.

boiling point the temperature at which a liquid changes to a gas

evaporation the change in state from a liquid to a gas. Evaporation occurs only from the surface of a liquid.

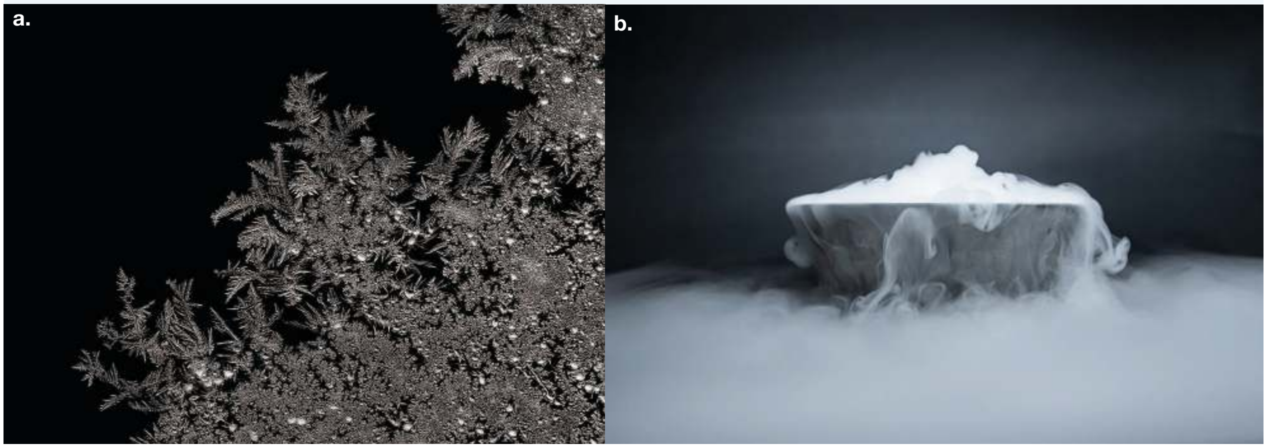
condensation the change in state from a gas to a liquid

deposition the change in state from a gas into a solid without first becoming a liquid

sublimation the change in state from a solid into a gas without first becoming a liquid

asphyxiation a condition caused by not having enough oxygen

FIGURE 5.11 **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.



on Resources

Video eLessons Gold melting (eles-2075)
Sublimation (eles-2038)

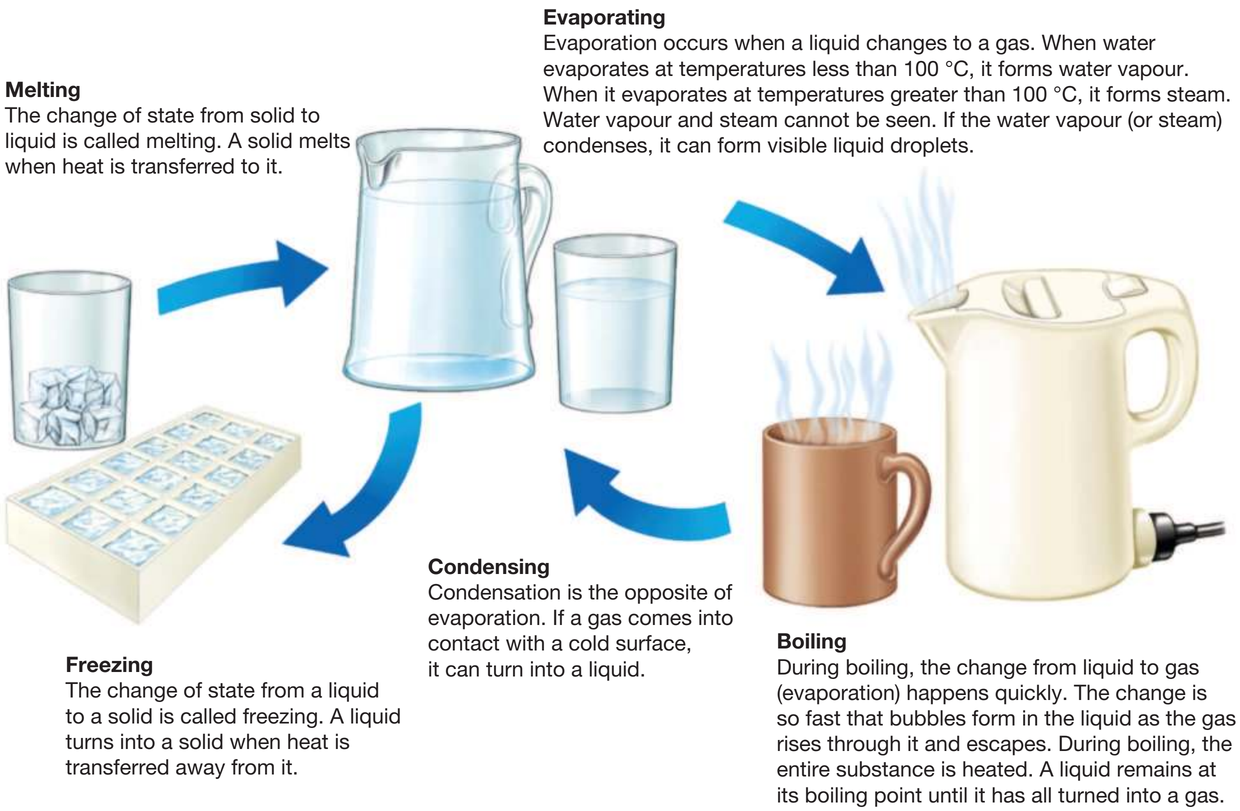
DISCUSSION

When butter is melted in a frying pan before putting the food in to fry, why doesn't the frying pan melt as well?

ewbk-11240

int-7684

FIGURE 5.12 The changing states of water in the kitchen



The state of an object depends on its temperature and the pressure surrounding the object.

on Resources

eWorkbook Changing the boiling point of water (ewbk-11241)

5.3 Activities

learnon

5.3 Quick quiz on	5.3 Exercise

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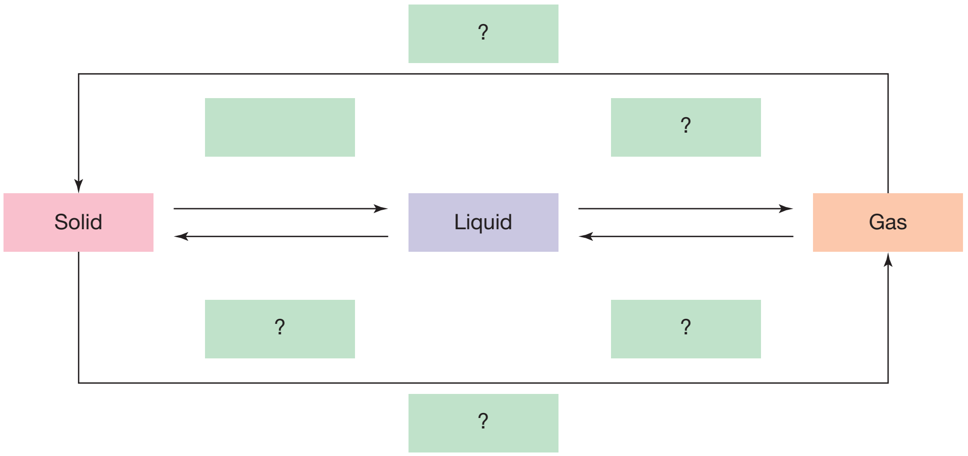
Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
1, 3, 6	2, 4, 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. Complete the diagram shown, by labelling the changes of state.



4. **MC** At higher altitudes, why does water boil at a temperature less than 100 °C?
   A. Because temperature at higher altitudes is low.
   B. Because atmospheric pressure is low.
   C. Because temperature at higher altitudes is higher.
   D. Because atmospheric pressure is high.
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. **SIS** Examine the data recorded in the table.

TABLE 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. Which substance — oxygen or nitrogen — would freeze first if the temperature were gradually lowered?
9. **SIS** Dry the outside of a very cold can of soft drink or carton of milk and allow it to stand on a table or bench for about 10 minutes. (Don't forget to put it back in the fridge afterwards.)
   a. What change occurred on the outside of the can/carton?
   b. Where did the water come from?
   c. What change of state has occurred?

Fully worked solutions and sample responses are available in your digital formats.

LESSON
5.4 The state of the weather

LEARNING INTENTION

At the end of this lesson you will be able to describe the differences between different forms of precipitation such as rain, hail, snow and sleet. You will also be able to recognise how scientists predict the weather. You will also examine how global reporting on high-impact weather events has led to the development of warning systems and evacuation policies.

5.4.1 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.

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.

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 may fall as a fine mist known as drizzle.

FIGURE 5.13 Clouds are formed by tiny droplets of water, kept up by air currents.

Hail

If drops of rain freeze, they may 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 cause extensive damage.

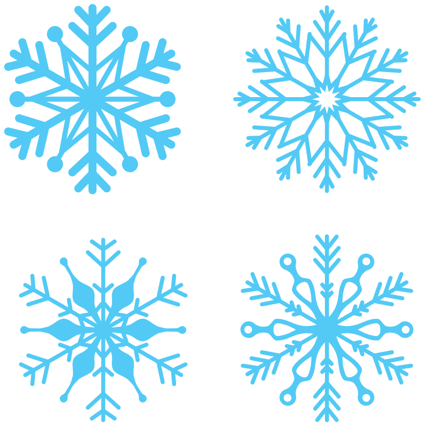
FIGURE 5.14 In summer, warm rising air helps to keep the hailstones in the clouds for longer, forming even more layers of ice than usual. These hailstones can reach masses of over 1 kg before they fall.

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.

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.

FIGURE 5.15 Snowflakes form many shapes and patterns but always have six 'sides'.



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.

5.4.2 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 5.16 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.

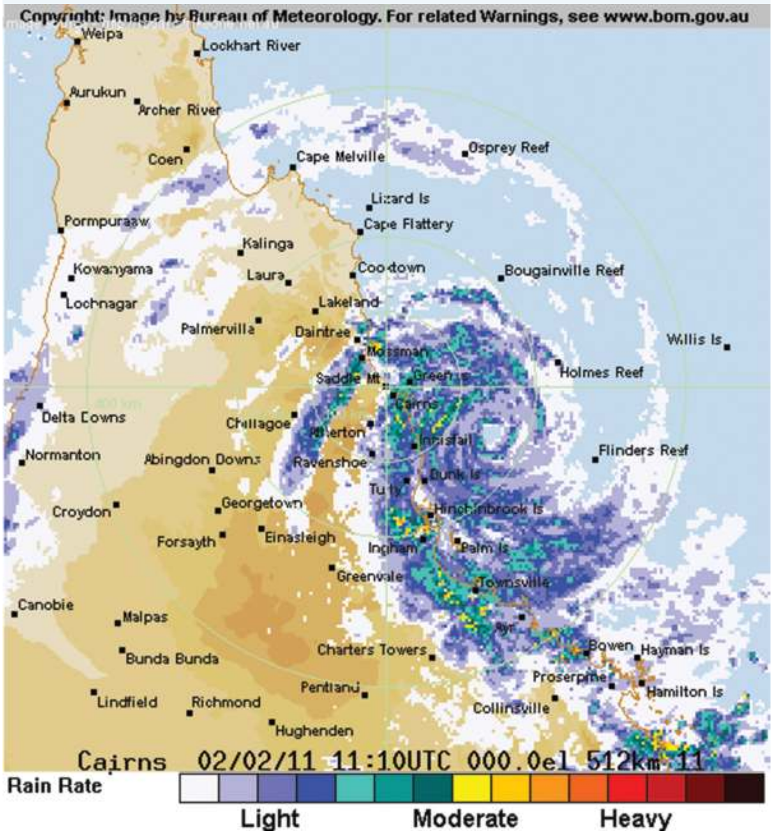
5.4.3 Advances in warning systems for high-impact weather events

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.

meteorologist a scientist who uses observations of the atmosphere to predict or explain the weather

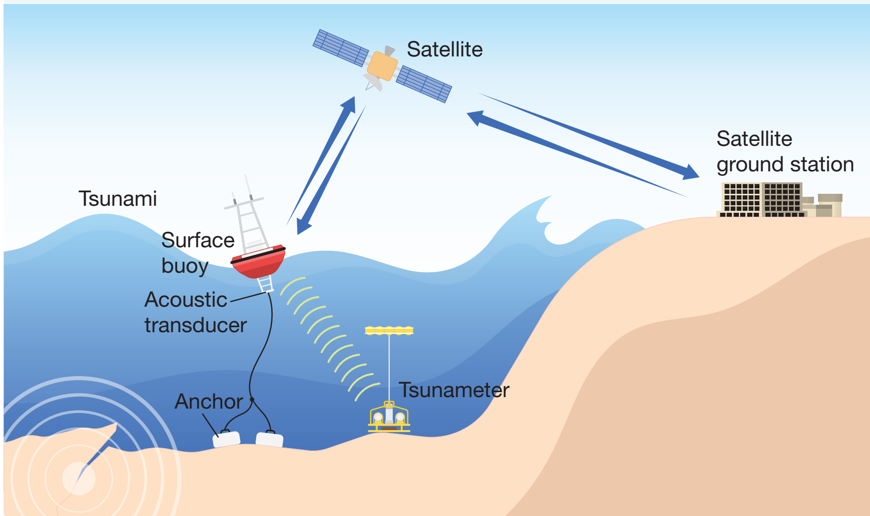
FIGURE 5.17 Bureau of Meteorology radar image of severe tropical cyclone Yasi



But it is not just high-impact weather events that are closely scrutinised. For instance, 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 are used to immediately alert people; for example, through SMS texts or TV and radio broadcasts. At-risk communities can then evacuate if necessary.

FIGURE 5.18 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 them and prepare for it.

Disasters such as the Black Summer bushfires of 2019–20 in NSW or the 2022 floods in Queensland are recent illustrations of the importance of disaster risk reduction and community preparedness.

The Australian Warning System, which is a new national approach to warnings for high-impact weather events such as bushfires and floods, aims to better prepare Australians for these types of disasters; and the Australian Institute for Disaster Resilience aims for a more disaster-resilient Australia.

DISCUSSION

What are the weather hazards where you live?

Do you know the types of warning systems in place?

DISCUSSION

Why is it that in social situations people so frequently discuss the weather?

on Resources

Video eLesson Understanding a weather forecast (eles-0161)

Weblinks Australian warning system
Australian Institute for Disaster Resilience

5.4 Activities

learnon

5.4 Quick quiz on | **5.4 Exercise**

Select your pathway

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

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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 air D. The expected rainfall
4. Explain how hailstones are formed.
5. Identify the differences between snow and sleet.
6. How can hailstones get as large as the one in figure 5.14 (the photograph in section 5.4.1)?
7. Suggest why extra-large hailstones are more common in summer than in winter.

Apply and analyse

8. Make a list of leisure activities that rely on predictions about the weather.
9. Ski resort operators suffer when there is a shortage of snow in some years. What conditions would they look for to predict coming snowfall?

Evaluate and create

10. In which occupations do each of the following types of weather prevent activity?
    a. Extreme heat
    b. Heavy rain
    c. Thunderstorms
11. **SIS** Record the predictions of the maximum temperature of your nearest capital city 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 on the Bureau of Meteorology website (www.bom.gov.au), on the TV news or in daily newspapers.

    Then record the actual maximum temperature for each day as reported on the evening news or www.bom.gov.au. Use a table like the one provided to record your data.

TABLE 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. How does the accuracy of the 7-day forecast compare with the accuracy of the previous day's forecast?
    b. State your opinion about the accuracy of the forecast made on the day before.
    c. Apart from temperature, what other aspects of the weather forecast are reported in newspapers and on the TV 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. **SIS** Find out what relative humidity is, and with which instrument it is measured.
13. **SIS** Research and report on what a hydrologist does.
14. **SIS** Find out and describe the difference between weather and climate.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
5.5 The particle model

LEARNING INTENTION

At the end of this lesson you will be able to 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. You will be able to explain properties of materials such as density, melting point and compressibility in terms of particle arrangement. You will also be able to explain the process of diffusion in a liquid and a gas in terms of particles.

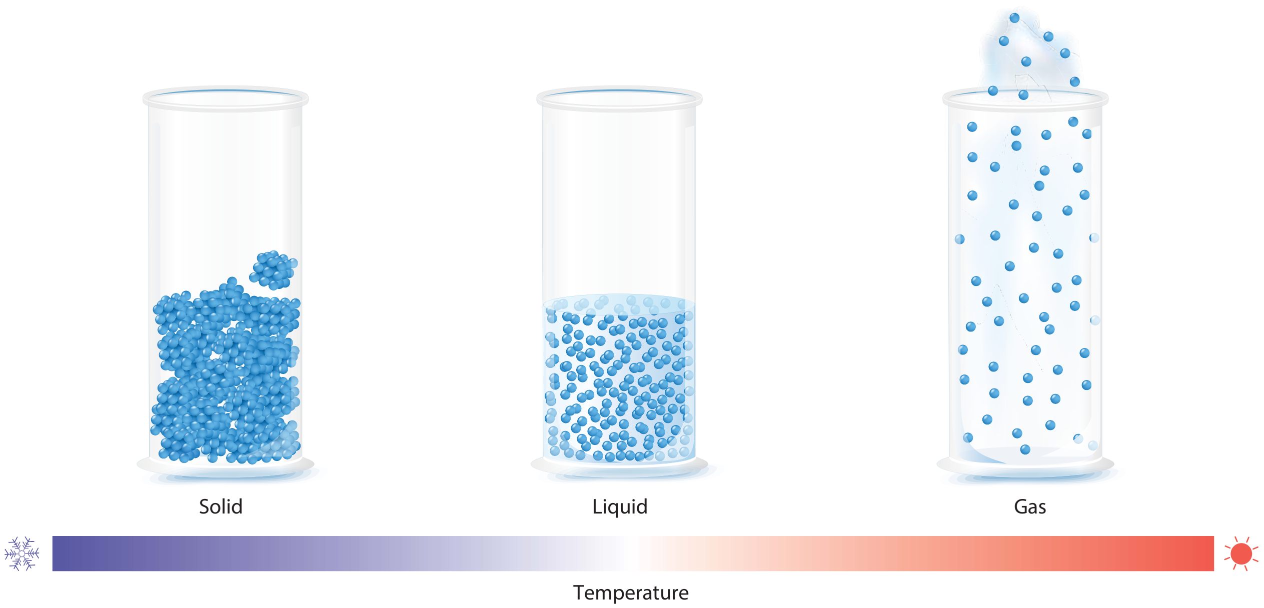
5.5.1 The particle model

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**.

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

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 5.19 A particle model for different states — solid, liquid and gas



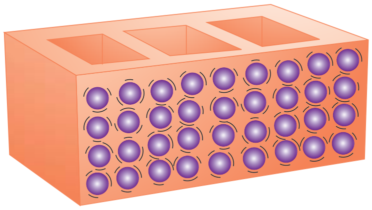
What does it mean?

The word particle comes from the Latin word *particula*, meaning 'part'.

5.5.2 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.

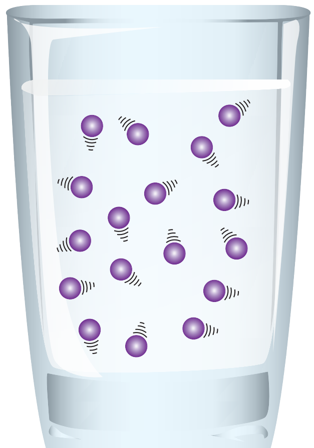
FIGURE 5.20 Particles in a solid



5.5.3 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.

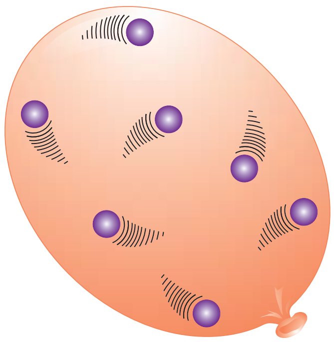
FIGURE 5.21 Particles in a liquid



5.5.4 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.

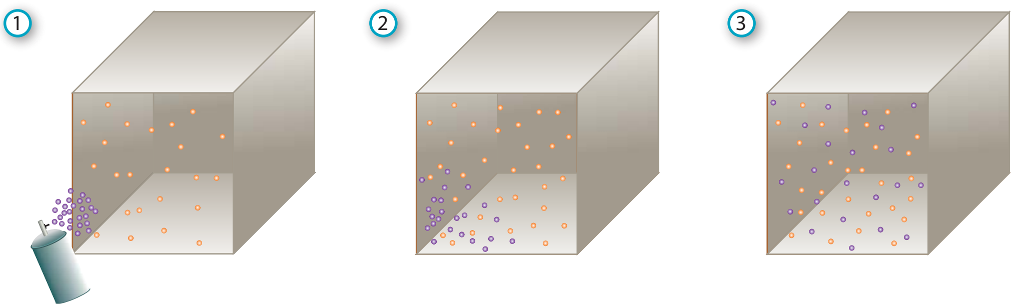
FIGURE 5.22 Particles in a gas



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 5.23 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**.

elog-2017

INVESTIGATION 5.4

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 liquid (water) and in a gas (air).
   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.

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 where the particles are more spread out. Hence, a gas would have the least density.

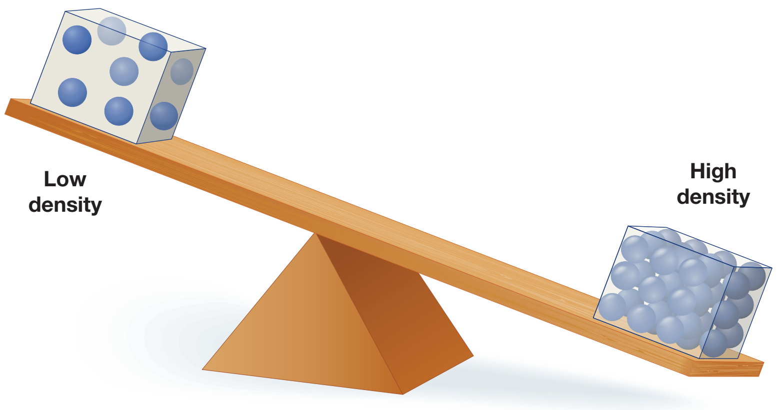
expand increase in size due to particles moving apart

contract shorten or become smaller in size

density mass per unit volume

FIGURE 5.24 When placed in water, substances that are more dense than water sink and substances that are less dense than water float.

FIGURE 5.25 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.

elog-2019

INVESTIGATION 5.5

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 into 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. Using your results, tabulate which items appeared to sink or float in the water or oil. Use the table below as a guide.

TABLE Results

Item	Sink	Float
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 your experimental findings in three or four sentences.

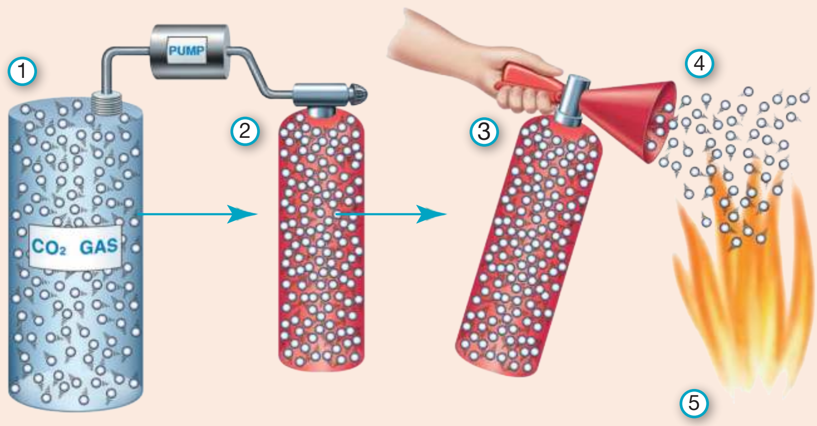
5.5.5 Gases under pressure

The fire extinguishers used to put out electrical fires are filled with carbon dioxide gas. Carbon dioxide can be used in this way only because huge amounts of it can be compressed, or squeezed, into a container. Gases can be compressed because there is a lot of space between the particles. Gases compressed into cylinders are used for barbecues, scuba diving, natural gas in cars and aerosol cans.

CASE STUDY: How fire extinguishers use compressed gas

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.

FIGURE 5.26 Carbon dioxide gas under pressure is used to extinguish fires.



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.

on Resources

eWorkbooks Fire! Fire! (ewbk-11244)
Particles in our lives (ewbk-11245)

Video eLesson Under pressure (eles-0058)

5.5 Activities

learnon

5.5 Quick quiz on	**5.5 Exercise**

Select your pathway

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

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- Receive immediate feedback
- Access sample responses
- Track results and progress

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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. SIS 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.

Evaluate and create

10. 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.
11. a. Draw labelled diagrams of three containers with solid particles in the first, liquid in the second and gas in the third.
    b. How does this model of particles compare with the particles in an actual container?
12. Use the internet to investigate the safe storage of gas cylinders. Make a list of requirements and state the reason for each of them.
13. Use the internet or other resources to research why cold water sinks but ice floats on warmer water, and write one or two sentences with an explanation relating to density.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
5.6 Energy matters

LEARNING INTENTION

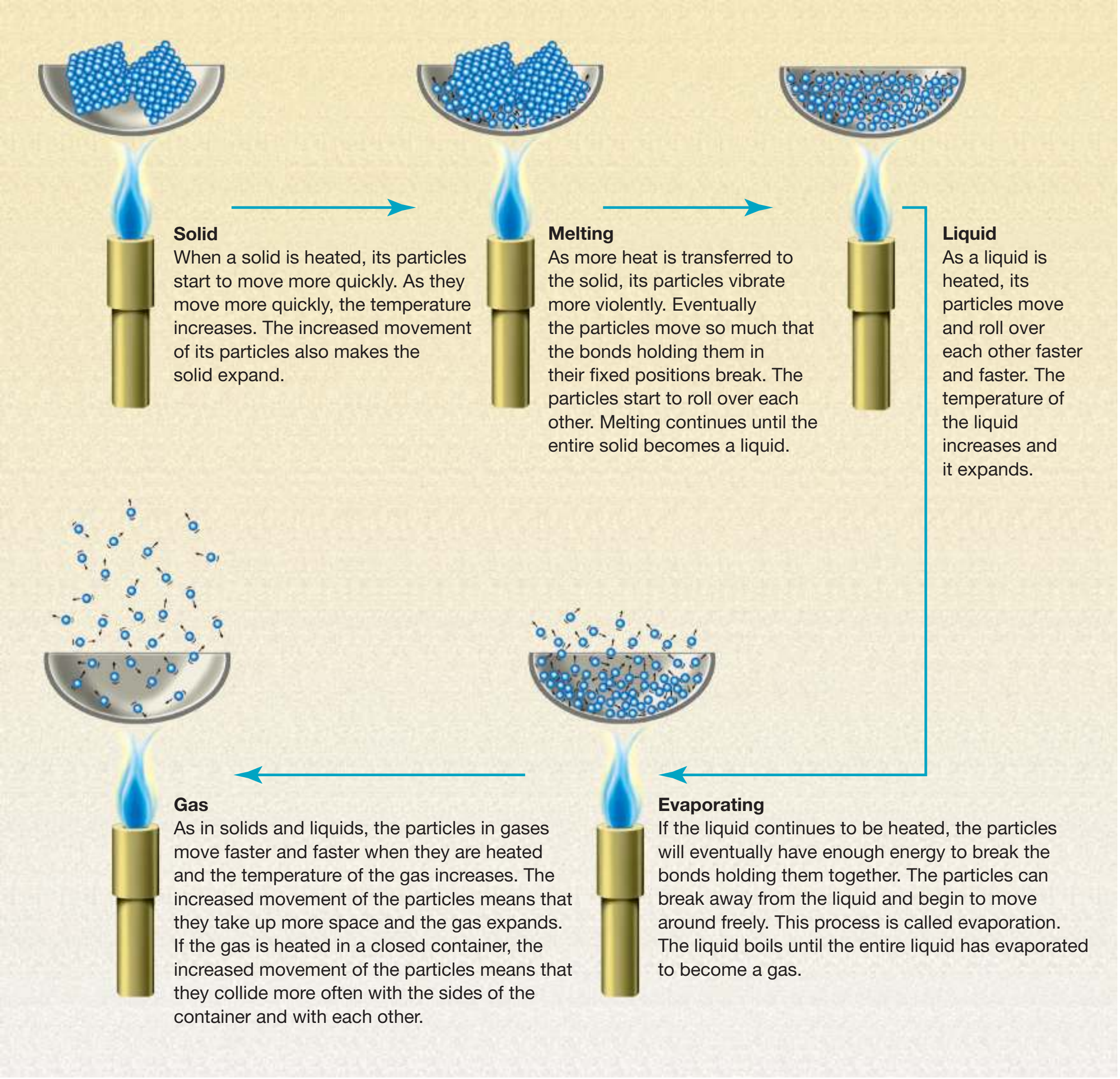
At the end of this lesson you will be able to explain how the changing motion and energy of particles is affected by the amount of heat energy absorbed or released.

5.6.1 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 5.27 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.



elog-2021

INVESTIGATION 5.6

Explaining gases

Aim

To investigate the expansion and contraction of a gas

Hypothesis

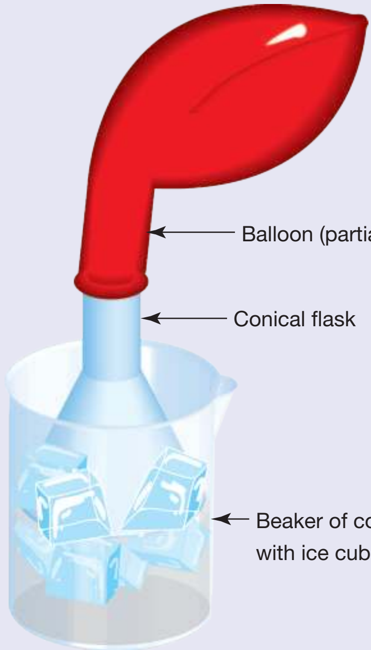
If the temperature of a gas is increased then it will expand because the energy causes the particles in the substance to move faster.

Materials

- Balloon
- Ruler
- Two large beakers
- Hot and cold water
- Piece of string
- Small conical flask
- Ice cubes

Method

1. Ensure you have a copy of the results table to fill in for this task.
2. 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 your table.
3. 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.
4. Put some hot water into the second beaker. Take the conical flask from the ice water and place it into the hot water.
   - Leave for a few minutes, then measure and record the balloon's circumference.



Results

TABLE Effect of temperature on air

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.

elog-2022

INVESTIGATION 5.7

Investigating melting points

Aim

To investigate the melting points of various materials

Hypothesis

If a solid is heated, then it will change into a liquid at a specific temperature, which can be measured using a thermometer.

Materials

- 15 g chocolate
- 15 g butter
- 15 g wax
- Thermometer
- Beaker
- Hot water

Method

1. Place the first of your materials (for example, chocolate) in a beaker.
2. Gently heat the beaker, either by flame or by placing over hot water. Check with your teacher first for their preferred method.
3. Using a thermometer, record the temperature at which the material starts to melt.
4. Repeat steps 1–3 for each material.

Results

Record the melting points of each material. Use the table below as a guide.

TABLE Melting points of selected substances

Item	Melting point (°C)
Chocolate	
Wax	
Butter	

Discussion

1. Which item had the highest melting point?
2. Can you explain why the materials melt, relating this to the particle theory?
3. Were your results what you expected?
4. Can you give a reason why your items have different melting points?

Conclusion

Summarise your experimental findings in three or four sentences.

5.6.2 Examples of heating and cooling

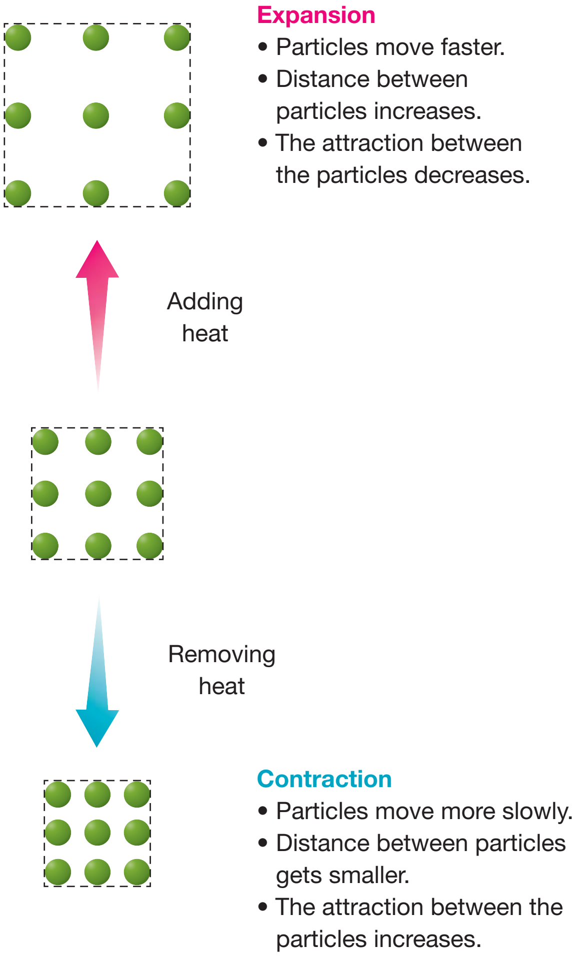
When a substance is heated, the particles gain energy, move faster, become further apart and take up more space, and a substance expands as the temperature increases.

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.

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.

FIGURE 5.28 These hot air balloons rise when the air inside them expands. How do they get back down to the ground?

FIGURE 5.29 The volume of a substance changes, expanding as heat is added and contracting as heat is removed.



on Resources

Interactivity Heating and cooling (int-3413)

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 that material will expand or contract. The table *Expansion of materials* in 5.6 Activities, question 9 shows how much some commonly used materials expand when the temperature increases by 10 °C.

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 5.30 Oops! The reason why you shouldn't put a bottle full of water in the freezer

elog-2023

INVESTIGATION 5.8

Expansion of solids

Aim

To investigate the expansion of a solid

Hypothesis

If a metal is heated, then it will expand.

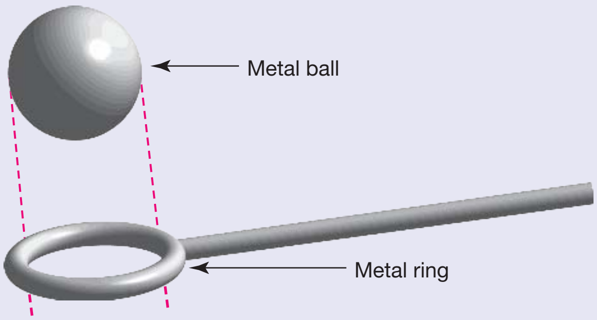
Materials

- Metal ball and ring set
- Bunsen burner and heatproof mat
- Tongs

Method

1. Try to put the ball through the ring. Record your observations.
2. Use the Bunsen burner to heat the ring and use tongs to try to put the ball through it. Take care not to touch the hot metal.
3. Let the ring cool and try to put the ball through the ring again.

A ball and ring set



Results

Record your observations of the ball and ring before heating and after heating.

Discussion

1. Describe what happened to change the size of the ring.
2. Use the particle model to explain the change that took place in the ring.

Conclusion

Summarise the findings of the experiment in three or four sentences.

5.6.3 Thermometers

Bulb thermometers, like the one pictured in figure 5.31a, 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.

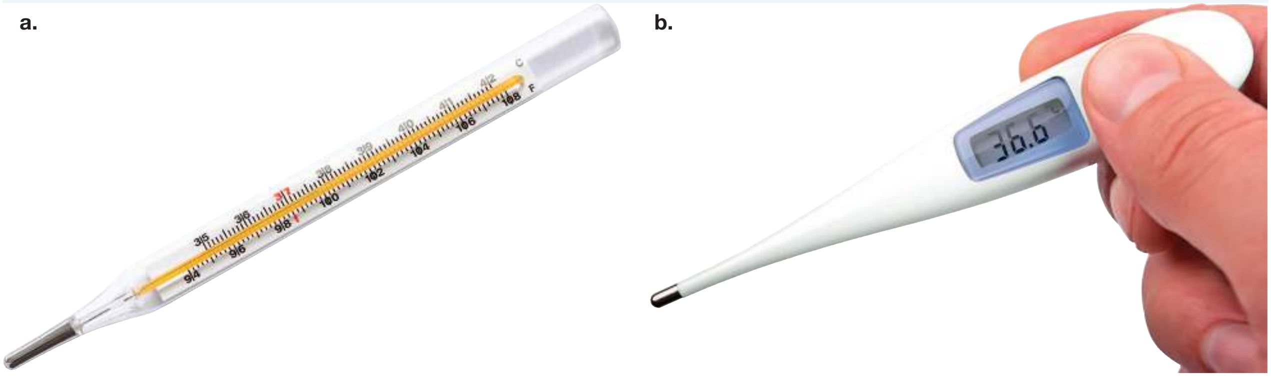
The two most commonly used liquids in thermometers are mercury and alcohol. Mercury has a low **freezing** point (−39 °C) and a high boiling point (357 °C). Alcohol, however, is much more useful in very cold conditions because it does not freeze until the temperature drops to −117 °C. On the other hand, alcohol boils at 79 °C, so it cannot be used for measuring higher temperatures.

freezing the change in state from a liquid to a solid

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 5.31a 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 5.31 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).

elog-2024

tlvd-10655

INVESTIGATION 5.9

Expansion of liquids

Aim

To investigate the expansion of a liquid

Hypothesis

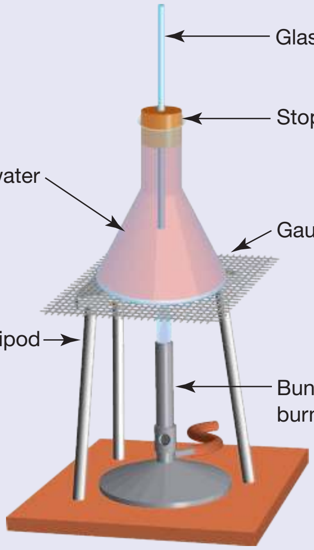
If a liquid is heated, it will expand and rise.

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 five 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

TABLE Results of investigation 5.9

Change in height of water level when heated from initial height (cm)	
Change in height of water level after cooling (cm)	

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.

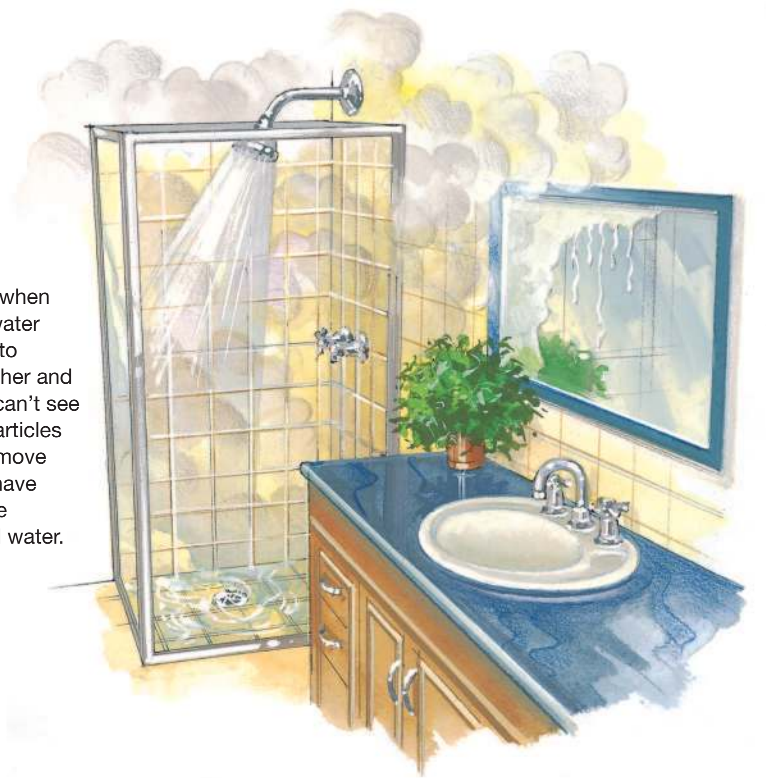
5.6.4 Foggy mirrors

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 5.32 Different states of water found in your bathroom



Resources

eWorkbooks Changes of state (ewbk-11249)
Expansion of liquids (ewbk-11248)

Interactivity Changes of state (int-0222)

5.6 Activities

learnon

5.6 Quick quiz on	5.6 Exercise

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Select your pathway

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 overhead electric power lines are not hung tightly.
9. SIS Use the table to answer the following questions.

TABLE 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

a. If a steel rod of 10 metres 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. Why is steel 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 section 5.6.1 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. **SIS** 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 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. **SIS** List the advantages of digital thermometers over mercury bulb thermometers for measuring human body temperature.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
5.7 Review

Hey students! Now that it's time to revise this topic, go online to:

Review your results

Watch teacher-led videos

Practise questions with immediate feedback

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Access your topic review eWorkbooks

on Resources

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-11257	ewbk-11258	ewbk-11259

5.7.1 Summary

Matter

- Matter is anything that has mass and volume.
- Most matter exist as solids, liquids or gases.

Solids, liquids and gases

- Physical properties of solids:
  - Fixed volume and shape
  - Not compressible
  - Do not flow easily
- Physical properties of liquids:
  - Take the shape of the container
  - Not compressible
  - Flow easily
- Physical properties of gases:
  - Fill the container
  - Compressible
  - Flow easily
- A fluid is a substance that flows, for example gases and liquids.
- One way volume can be measured is to use a measuring cylinder.
- The volume of an irregular solid can be measured by seeing how much water is displaced by it.
- The mass of an object can be measured using a balance.

Changes of state

- Melting is a change of state from solid to liquid.
- Freezing is a change of state from liquid to solid.
- Evaporation is a change of state from liquid to gas at different temperatures.
- Boiling is a change of state from liquid to gas at the liquid's boiling point.
- Condensation is a change of state from gas to liquid.
- Sublimation is a change of state from solid to gas.
- Melting point is the temperature at which a solid substance turns into a liquid (melts) or a liquid turns into a solid (freezes).
- Boiling point is the temperature at which a liquid changes to a gas.
- Rain, hail, snow and sleet are forms of precipitation. The type of precipitation depends on the temperature.

The particle model of matter

- The four major assumptions of the particle model of matter are:
  - all substances are made up of tiny particles
  - the particles of liquids and solids are attracted towards other surrounding particles
  - the particles are always moving
  - the hotter the substance is, the faster the particles move.
- The particles of a solid are closely packed in a fixed shape and have strong bonds between them; they vibrate in a fixed position.
- The particles of a liquid are less strongly held together than solids but still relatively close together, so they cannot be compressed. They can roll over each other so liquids can take the shape of their container.
- The particles of a gas have more energy than those in liquids and solids; they move constantly and spread out to fill any container, so they do not have a fixed shape. The large space between the particles means that they can be compressed.
- Diffusion is the spreading of one substance through another due to the movement of their particles. Diffusion can occur in gases and liquids.
- When matter is heated, energy is transferred into the object causing the speed of the particles to increase.
- When a solid is heated, its particles start to move quickly and the temperature rises. The particles spread out making the solid start to expand.
- As the heating continues, the particles vibrate more strongly and the bonds holding them in position start to break until the solid becomes a liquid.
- With further heating, the particles gain enough energy to completely break the bonds holding them together and the particles continue to spread out even further to become a gas.
- If the temperature continues to increase, the particles move faster and faster taking up more space and the gas expands. If the gas is in a closed container, the particles collide more often with each other and with the sides of the container, increasing the pressure.

Science as a human endeavour

- Meteorologists are scientists who observe, explain and predict the weather.
- Engineers and architects design structures with allowances for expansion and contraction of materials.
- Risk assessments, which include evacuation procedures, permit effective early warning systems that are essential in reducing the danger and the death toll of high-impact weather events.

5.7.2 Key terms

asphyxiation a condition caused by not having enough oxygen
boiling point the temperature at which a liquid changes to a gas
condensation the change in state from a gas to a liquid
contract shorten or become smaller in size
density mass per unit volume
deposition the change in state from a gas into a solid without first becoming a liquid
diffusion movement of one substance through another due to a movement of particles, for example from a region of higher concentration to lower concentration
evaporation the change in state from a liquid to a gas. Evaporation occurs only from the surface of a liquid.
expand increase in size due to particles moving apart
fluid a substance that flows and has no fixed shape. Gases and liquids are fluids.
freezing the change in state from a liquid to a solid
gas state of matter with no fixed shape or volume
liquid state of matter that has a fixed volume, but no fixed shape
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
melting the change in state from a solid to a liquid
melting point the temperature at which a solid substance turns into a liquid (melts) or a liquid turns into a solid (freezes)
meteorologist a scientist who uses observations of the atmosphere to predict or explain the weather

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
physical property property that you can either observe using your five senses — seeing, hearing, touching, smelling and tasting — or measure directly
plasma superheated, charged gas that is the fourth state of matter
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.
pressure the force exerted per unit area
properties the qualities and characteristics of materials and the substances that they are composed of
solid state of matter that has a fixed shape and volume
state of matter condition or phase of a substance. The three main states of matter are solid, liquid and gas.
sublimation the change in state from a solid into a gas without first becoming a liquid
temperature a measure of how hot or cold something is
volume the amount of space taken up by an object or substance
water vapour water in the gaseous state

on Resources

eWorkbooks	Study checklist (ewbk-11256) Reflection (ewbk-11252) Literacy builder (ewbk-11253) Crossword (ewbk-11254) Word search (ewbk-11255)
Digital document	Key terms glossary (doc-39581)
Practical investigation eLogbook	Topic 5 Practical investigation eLogbook (elog-2010)

5.7 Activities

learn**on**

5.7 Review questions

Select your pathway

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

These questions are even better in jacPLUS!

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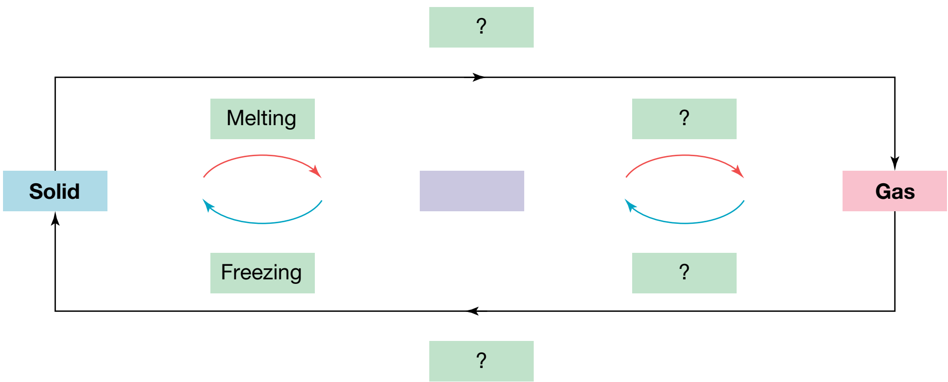
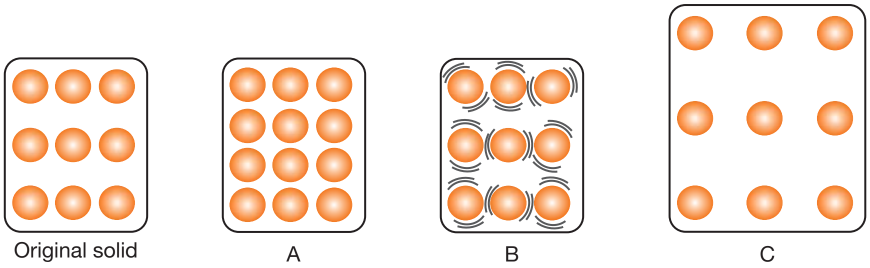
Remember and understand

1. Complete the diagram shown, labelling the missing state and changes of state.



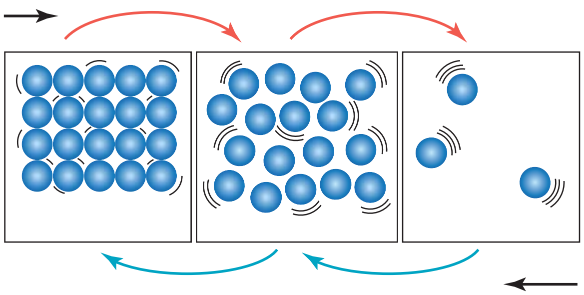
2. **MC** What happens during a change of state?
   A. Heat energy is always absorbed.
   B. The temperature remains constant until the change is complete.
   C. The temperature increases at a constant rate as the heat energy is absorbed.
   D. Heat energy is neither absorbed nor lost.
3. **MC** What 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. In which state — solid, liquid or gas — do the particles have:
   a. the most energy
   b. the least energy?
5. In which state are the forces of attraction between the particles likely to be greatest?
6. Describe the changes of state involved in the formation of rain and hail.
7. Which of the diagrams shown (A, B or C) best represents the particles of a solid after heating?



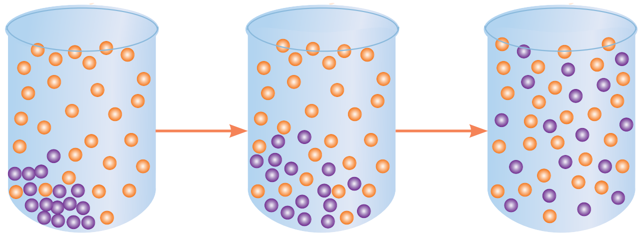
8. Use the particle model to explain why steam takes up more space than liquid water.

Apply and analyse

9. Label the three diagrams to show which represents a solid, liquid or gas. Label each image and identify whether energy is added or removed on the black arrows. Identify which properties are shown by each of these diagrams.



10. Name the process that is taking place in the following diagram and explain why it occurs only in liquids and gases.

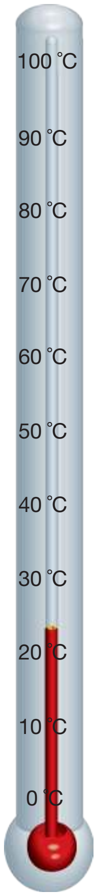


11. Complete the table provided to summarise the properties of solids, liquids and gases. Use a tick to indicate which properties each state *usually* has.

TABLE 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 this 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. **SIS** 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 if 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. **SIS** Julia and Chris did an investigation about the rate of evaporation of ethanol in three different pieces of equipment. The containers used were a flat Petri dish, 100 mL beaker and 100 mL conical flask, and 10.0 mL of ethanol was used in each.
    The volume in each container after 45 minutes was as follows: Petri dish 9.3 mL, beaker 9.8 mL, and conical flask 9.6 mL.
    a. State the aim.
    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.

Fully worked solutions and sample responses are available in your digital formats.

Online Resources

on Resources

Below is a full list of **rich resources** available online for this this topic. These resources are designed to bring ideas to life, to promote deep and lasting learning and to support the different learning needs of each individual.

5.1 Overview

eWorkbooks
- Topic 5 eWorkbook (ewbk-11235)
- Student learning matrix (ewbk11239)
- Starter activity (ewbk-11236)

Practical investigation eLogbooks
- Topic 5 Practical investigation eLogbook (elog-2010)
- Investigation 5.1: Investigating the properties of solids, liquids and gases (elog-2009)

Video eLesson
- Three states of water (eles-3524)

5.2 States of matter

Video eLesson
- Diffusion (eles-2013)

Practical investigation eLogbooks
- Investigation 5.2 Ranking substances (elog-2013)
- Investigation 5.3: Measuring the volume of an irregular-shaped solid (elog-2014)

Interactivities
- Volume (int-3791)

5.3 Changing states

eWorkbooks
- Changing the boiling point of water (ewbk-11241)
- The changing states of water in the kitchen (ewbk-11240)

Video eLessons
- Gold melting (eles-2075)
- Sublimation (eles-2038)

Interactivity
- The changing states of water in the kitchen (int-7684)

5.4 The state of the weather

Video eLesson
- Understanding a weather forecast (eles-0161)

Weblinks
- Australian warning system
- Australian Institute for Disaster Resilience

5.5 The particle model

eWorkbooks
- Fire! Fire! (ewbk-11244)
- Particles in our lives (ewbk-11245)

Practical investigation eLogbooks
- Investigation 5.4: Investigating diffusion (elog-2017)
- Investigation 5.5: Investigating density (elog-2019)

Video eLesson
- Under pressure (eles-0058)

5.6 Energy matters

eWorkbooks
- Changes of state (ewbk-11249)
- Expansion of liquids (ewbk-11248)

Teacher-led video
- Investigation 5.9: Expansion of liquids (tlvd-10655)

Practical investigation eLogbooks
- Investigation 5.6: Explaining gases (elog-2021)
- Investigation 5.7: Investigating melting points (elog-2022)
- Investigation 5.8: Expansion of solids (elog-2023)
- Investigation 5.9 Expansion of liquids: (elog-2024)

Interactivities
- Heating and cooling (int-3413)
- Changes of state (int-0222)

5.7 Review

eWorkbooks
- Topic review Level 1 (ewbk-11257)
- Topic review Level 2 (ewbk-11258)
- Topic review Level 3 (ewbk-11259)
- Study checklist (ewbk-11256)
- Reflection (ewbk-11252)
- Literacy builder (ewbk-11253)
- Crossword (ewbk-11254)
- Word search (ewbk-11255)

Digital document
- Key terms glossary (doc-39581)

To access these online resources, log on to **www.jacplus.com.au**

6 Separating mixtures

CONTENT DESCRIPTION

Use a particle model to describe differences between pure substances and mixtures and apply understanding of properties of substances to separate mixtures (AC9S7U06)

LESSON SEQUENCE

SCIENCE INQUIRY AND INVESTIGATIONS

Science inquiry is a central component of Science curriculum. Investigations, supported by a **Practical investigation eLogbook** and **teacher-led videos**, are included in this topic to provide opportunities to build Science inquiry skills through undertaking investigations and communicating findings.

LESSON
6.1 Overview

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6.1.1 Introduction

Think about your school bag on your first day of school. It possibly contained some graphite pencils and some folders, but also a variety of other useful objects such as a ruler, coloured markers, highlighters, exercise 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**.

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 actually made of lots of different colours. Mixtures are found in everyday life. How mixtures can be separated will be explored in this topic.

FIGURE 6.1 Are the objects in your school bag pure substances or mixtures?

on Resources

Video eLesson: Separating coloured markers (eles-3526)

Some markers are made by combining different colours of ink together. Watch this video to see these colours from a few lines of black marker separate out through a process called chromatography.

pure substance a form of matter that cannot easily be separated into its components

mixture a substance that is made by a combination of two or more components, which are easy to separate

6.1.2 Think about mixtures

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?

6.1.3 Science inquiry

A world of mixtures

The ground that you stand on, the air that you breathe and the oceans of Earth are all mixtures. For example, air is a mixture of many gases, including nitrogen, oxygen and carbon dioxide. Ocean water is a mixture of pure water, salt and many other substances. Even the fresh water in lakes and rivers is not pure and always contains small amounts of other substances.

DISCUSSION

Is drinking water really a pure substance? What substances are present in small amounts of drinking water?

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 can't 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 a substance that is attracted to magnets, but the sand is not attracted to magnets.

What if plastic beads had been dropped into the sandpit instead of nails? They can't 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 don't.

FIGURE 6.2 Nails can be separated from sand with a magnet.

DISCUSSION

What other methods could be used to separate the nails from the sand? What difference in properties might other methods use to separate the substances?

properties the qualities and characteristics of materials and the substances that they are composed of

elog-2029

INVESTIGATION 6.1

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/'dead' matches
- Small pebbles (about 500 mL)
- Steel paperclips
- Water as required

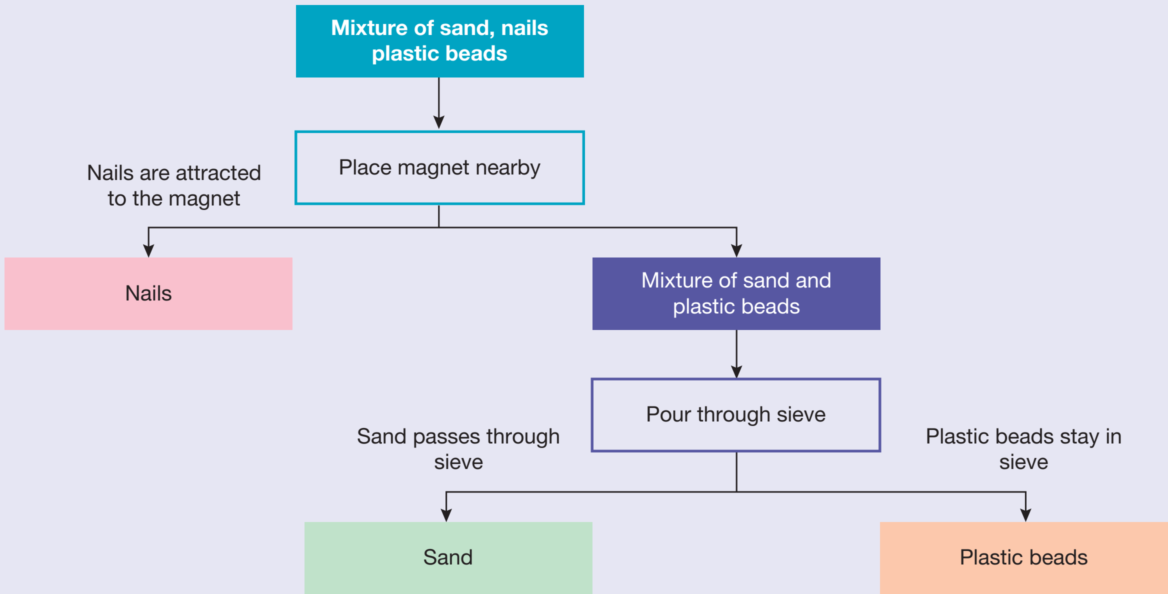
Method

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 of 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 flowchart similar to the one in part 1 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.

on Resources

eWorkbooks Topic 6 eWorkbook (ewbk-11266)
Student learning matrix (ewbk-11268)
Starter activity (ewbk-11269)

Practical investigation eLogbook Topic 6 Practical investigation eLogbook (elog-2031)

LESSON
6.2 Mixtures and solutions

LEARNING INTENTION

At the end of this lesson you will be able to use representations of particles to show the difference between samples of pure substances and mixtures, and identifying examples of each. You will be able to examine different solutions, identify the solvent and solute and describe the difference between concentrated and dilute when referring to solutions.

6.2.1 Pure substances and mixtures

Matter makes up everything in our universe. It is any substance that has mass and volume, whether this be miniscule, like that of an atom, or vast, like the entire volume of the Pacific Ocean.

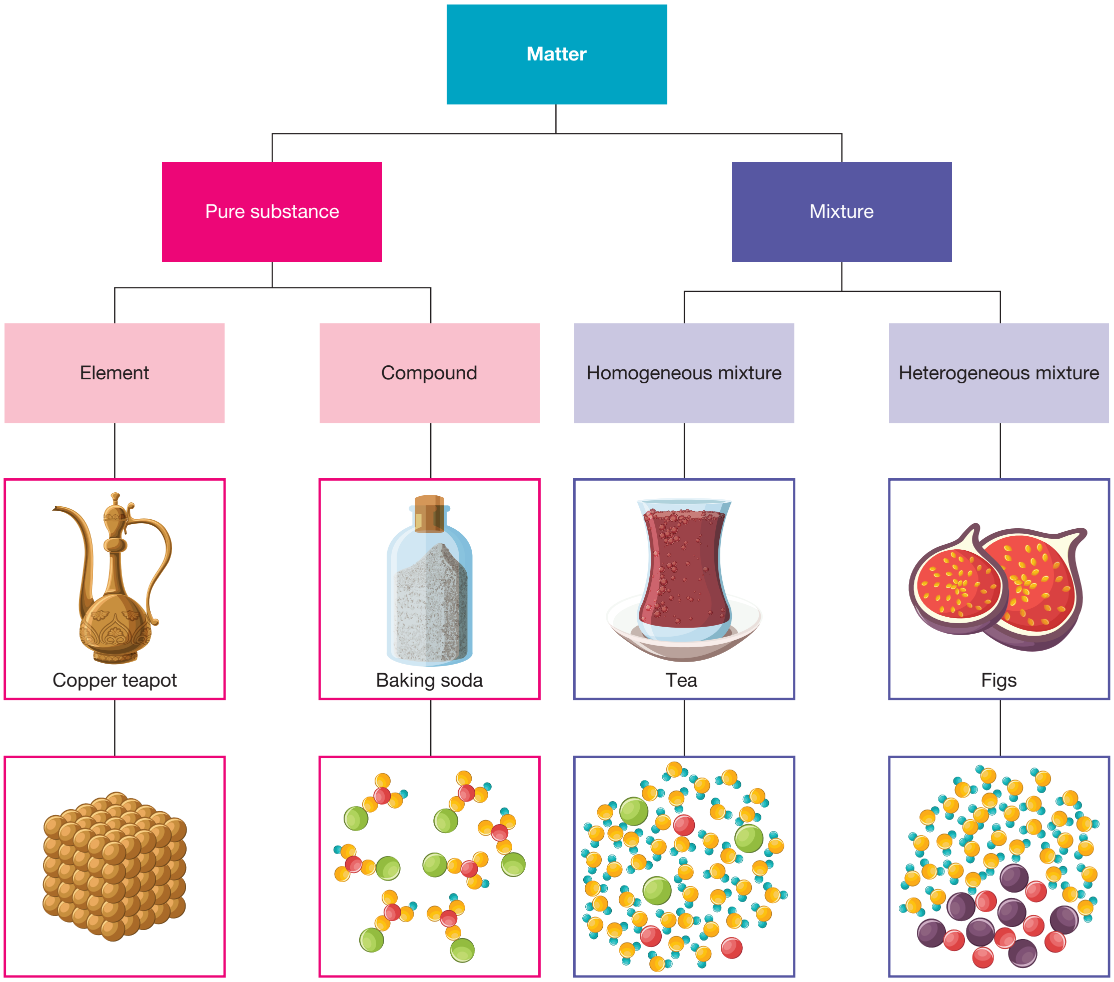
Matter can be split into two main components:
- pure substances
- mixtures.

matter all physical material; anything that takes up space and can be weighed

ewbk-11271

int-8050

FIGURE 6.3 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, if you were given a piece of pure salt (sodium chloride), it 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.

Mixtures can be classed as homogeneous mixtures or heterogeneous mixtures:

- **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, as the different gases particles are distributed uniformly.
- **Heterogeneous mixtures** are those in which the different components are scattered unevenly throughout the mixture; they appear as more than one state. An example is a mixture of oil and water.

In this topic, we will explore three main types of mixtures and different ways that these can be separated.

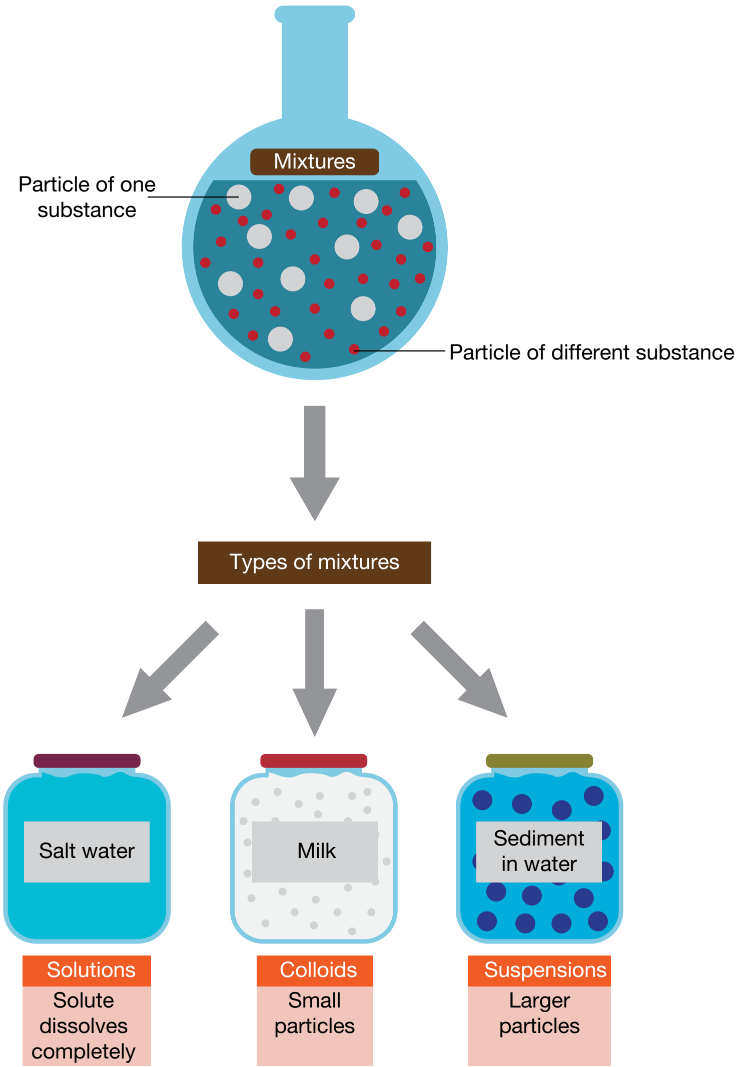
homogeneous mixture a mixture in which particles are spread evenly

heterogeneous mixture a mixture in which particles are spread unevenly

The three main types of mixtures:

- Solutions — contain particles that completely dissolve
- Suspensions — contain larger particles
- Colloids — contain small particles

FIGURE 6.4 The three main types of mixtures



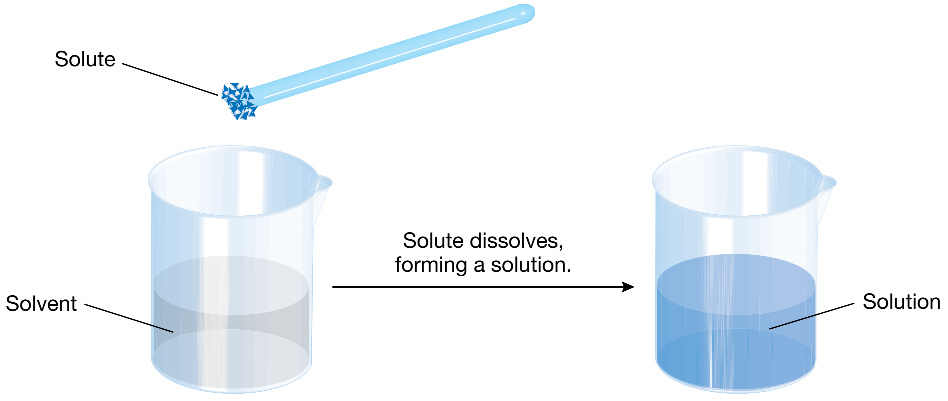
6.2.2 What is a solution?

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.

ewbk-11273

int-8051

FIGURE 6.5 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.

6.2.3 ‘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 6.6, 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

pressure the force exerted per unit area

dissolved a substance that has mixed completely with a liquid so that it is no longer visible

solution a mixture of a solute dissolved in a solvent

solute a substance that is dissolved in a solvent to form a solution

solvent a substance in which a solute dissolves to form a solution

aqueous solutions solutions in which water is the solvent

soluble a substance that will dissolve in a liquid

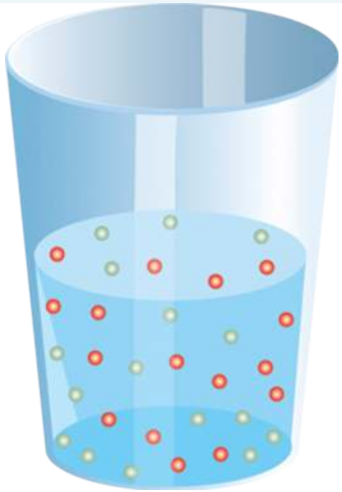
transparent see-through; allowing light to pass through so objects behind can be seen distinctly

insoluble a substance that will not dissolve in a liquid

chemical reaction a chemical change in which one or more new chemical substances is produced

FIGURE 6.6 When you open the bottle, dissolved carbon dioxide is visible.

FIGURE 6.7 In a solution, the particles of one substance (the solute) are spread evenly throughout the other (the solvent).



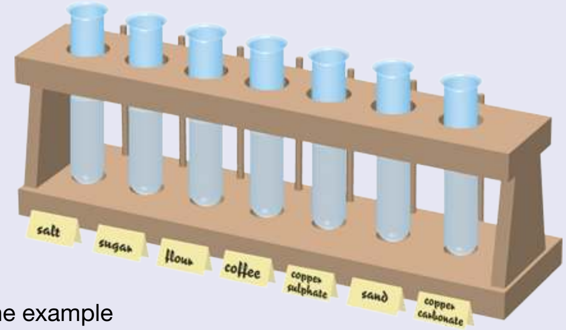
elog-2033

INVESTIGATION 6.2

What is soluble in water?

Aim

To investigate a range of substances for solubility



Materials

- Heatproof mat
- Seven test tubes in a test-tube rack
- Spatula
- Samples of salt, sugar, flour, coffee, sand, copper sulfate and copper carbonate

Method

1. Draw up a table with eight rows and three columns, like the example in the results section.
2. Predict which of the seven substances in the table you think will be soluble. Highlight these substances in the first column.
3. Half-fill each of the test tubes with cold water.
4. Label the test tubes: salt, sugar, flour, coffee, sand and copper.
5. Use a spatula to add a very small amount of each substance to its labelled test tube. (Do not add more than a quarter of a spatula to each test tube.)
6. Hold each test tube up to the light. Decide whether the mixture is clear or cloudy. Record your results in column 2 of your table.

Results

TABLE The solubility of different substances in water

Substance mixed with water	Clear or cloudy?	Soluble or insoluble?
Salt		
Sugar		
Flour		
Coffee		
Sand		
Copper sulfate		
Copper carbonate		

Discussion

1. Identify:
   a. the independent variable in this investigation
   b. the dependent variable in this investigation
   c. the controlled variables in this investigation.
2. a. Explain how can you tell if a substance has dissolved.
   b. Explain how can you tell that a substance has not dissolved.
3. You might find that students in other groups have obtained different results from your own group. Explain why this might have happened.

Conclusion

Summarise your findings from the investigation in three or four sentences. State which substances dissolved in water and were soluble and which substances were insoluble and link your findings back to the aim and hypothesis.

on Resources

Interactivity A solute dissolves in a solvent and creates a solution (int-3435)

elog-2035

INVESTIGATION 6.3

Froth and bubble

Aim

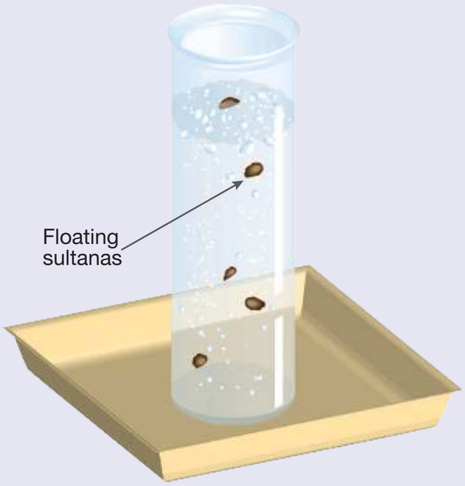
To investigate the separation of carbon dioxide from fizzy drinks

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. When the sultanas get to the surface why do they drop back to the bottom?
3. Try other things in the gas jar to see whether they can be carried to the surface.

Conclusion

Summarise the findings of thei nvestigation in three or four sentences.

6.2.4 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**.

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.

FIGURE 6.8 The cordial in these glasses is a coloured solution. Can you tell which has the greatest concentration of cordial syrup?

DISCUSSION

Discuss some concentrated and dilute solutions that you use in your everyday life. Compare this to your classmates.

on Resources

eWorkbooks Solutions and solubility (ewbk-11277)
Mail room mayhem (ewbk-11275)

concentrated a solution containing a large amount of solute

saturated unable to dissolve any more solute

dilution the process of adding more solvent to a solution to make it less concentrated

6.2 Activities

learnon

6.2 Quick quiz on	6.2 Exercise

Select your pathway

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

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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. Outline what homogeneous means.
   c. Identify which mixture is homogeneous.
2. MC A fizzy soft drink is which of the following?
   A. Solution B. Solvent C. Solute D. Pure substance
3. MC 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 What leaves a fizzy drink to cause it to go flat?
   A. Water B. Sugars C. Carbon dioxide D. Solvents
5. MC Which substance is added to cordial to make it more dilute?
   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. Complete this table by filling in the 'Solvent' and 'Solutes' columns.

TABLE Solvents and solutes in different solutions

Solution	Solvent	Solutes
a. Soft drink		
b. Sea water		
c. Swimming pool water		
d. Cup of coffee		

Apply and analyse

8. Complete the passage to describe the difference between a concentrated solution and a saturated solution, using the following words. (*Hint*: You won't need to use all of the words.)

   Word bank: 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. What substance could you add to salt water to make it:
   a. more concentrated
   b. less concentrated?
10. A bottle of soft drink left lying in sunlight may burst open. Complete the passage using the following terms to explain why. (*Hint*: You won't need to use all the terms; carbon dioxide should be treated as one single term.)

    Word bank: higher lower temperature carbon dioxide oxygen solute solution pressure liquid solid 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. SIS Research what happens when you place an unopened can of soft drink and an unopened can of diet soft drink of the same type in a sink of water:
    a. Which can floats?
    b. Which can sinks?
    c. What does this tell you about the sugar in soft drinks and diet soft drinks?

Evaluate and create

13. SIS Conduct a survey of at least five food and drink products. Use the list of ingredients to determine what is in them. What are the most common chemicals added to food and drink products?
14. SIS It is claimed by manufacturers that some washing powders work just as well in cold water as in hot water.
    Design an experiment to show how you would investigate washing powders to find out whether they dissolve as well in cold water as they do in hot water. Include the aim, materials, method, and dependent and independent variables.

15. SIS Design an experiment to test whether a fizzy drink will go flat faster when it's cold or when it's warm. Remember to use a **fair test**. You must keep everything the same except the one thing that you want to test.
16. SIS Find out how much sugar can be dissolved in 200 mL of water at room temperature and what difference an increase in temperature of 10 °C makes. Describe your observations and write a conclusion.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
6.3 Separating solids from mixtures

LEARNING INTENTION

At the end of this lesson you will be able to describe differences between suspensions, colloids and emulsions and a range of physical separation techniques such as filtration, decantation and sieving.

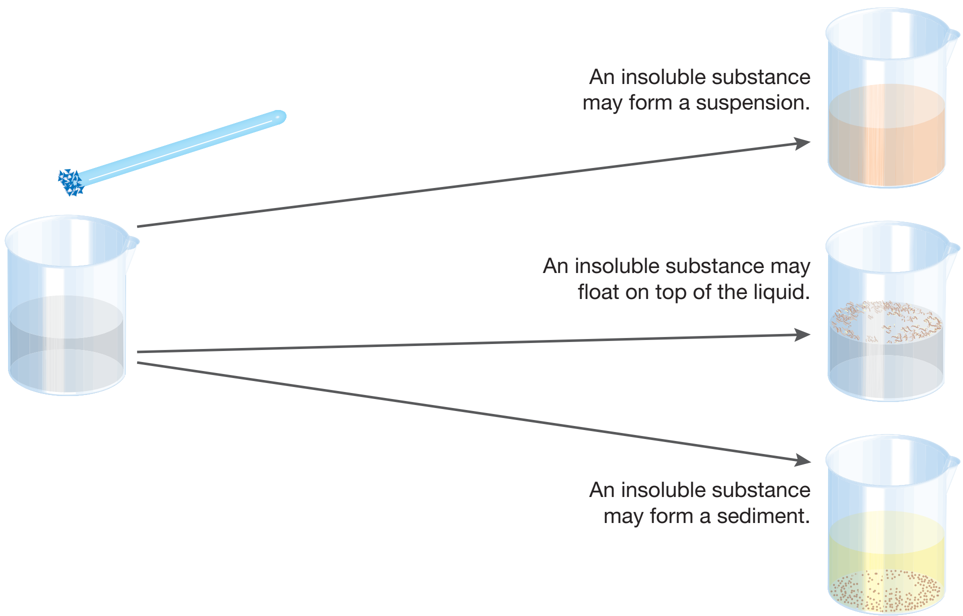
6.3.1 Filtering insoluble materials

There are many ways of separating mixtures in a laboratory. Some methods are simple and quick and others need expensive equipment and take time.

No matter how hard you try, you can't dissolve sand in water; sand is insoluble. If you shake up the sand and water in a sealed jar, the sand spreads through the water, forming a cloudy **suspension**, which is a heterogeneous mixture. When you stop shaking the jar, the particles of sand are suspended in the water briefly, but they soon settle to the bottom, forming a **sediment**. Muddy water is also a suspension, but most of the particles in mud are smaller than sand particles so it takes much longer for them to settle to the bottom. Some insoluble substances don't form suspensions but float on top of the liquid.

int-3436

FIGURE 6.9 Adding an insoluble substance to a liquid



suspension a mixture of an insoluble substance in a liquid or gas

sediment the insoluble material that collects at the bottom of a container when suspensions are left to stand

filtration the process of separating suspended particles from fluid through a filter

filter a device that allows some materials to pass through; blocks particles too large to fit through the holes or pores

residue the material remaining as a solid on a filter paper after a liquid passes through in the filtration procedure

filtrate liquid that has passed through a filter

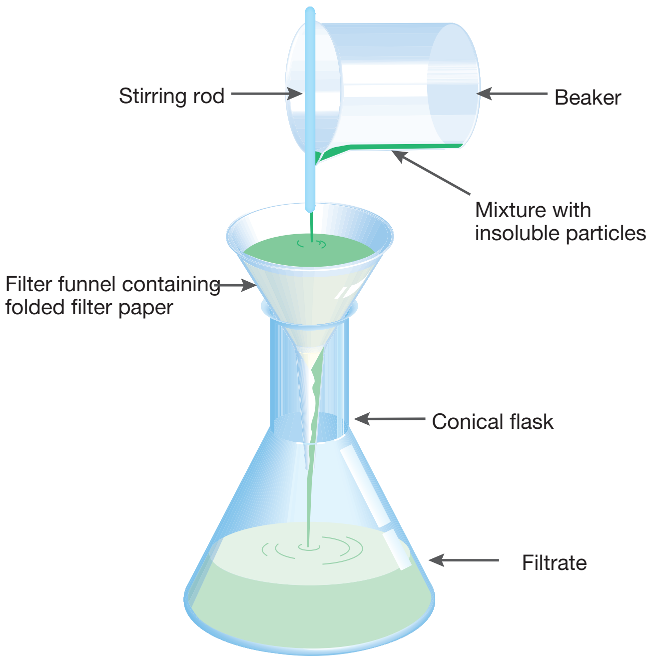
What do a vacuum cleaner, tea strainer and protective face mask have in common? They are all devices for separating particles from suspensions by **filtration**. In the laboratory, filtration is carried out using filter paper, but there are many other useful methods of filtration that are used in the home and in industry.

In filtration, solutions, solvents or gases pass through the **filter** but particles that cannot fit through the filter are trapped by it. Insoluble particles can be separated from a mixture using filter paper in a funnel as shown in figure 6.10. 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**.

ewbk-11279

int-8052

FIGURE 6.10 Equipment used to filter a mixture that contains insoluble particles



elog-2037

INVESTIGATION 6.4

Filtration in the laboratory

Aim

To investigate filtration to separate substances in a mixture

Hypothesis

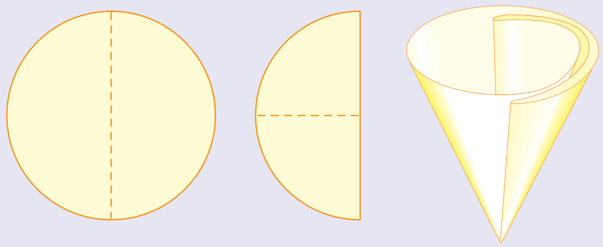
If a substance is insoluble in water, then it can be filtered out.

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 6.10.
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

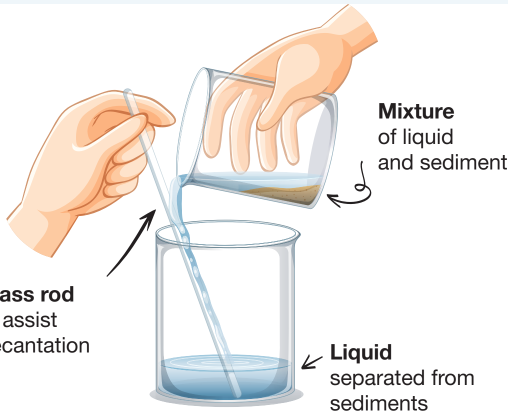
Summarise the findings of the investigation in three or four sentences using correct scientific terms.

6.3.2 Decanting

There are a number of ways of separating mixtures that are not solutions. If sediment sinks to the bottom of a container and the water can be poured off, this is called **decanting**. This is the simplest method of separating a mixture of a liquid and an undissolved solid.

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.

FIGURE 6.11 Separating a mixture by decanting



ACTIVITY: Decanting muddy water

Collect some muddy water and try to see how well you can decant the water. Compare your results to others in your class. Do you think the water would be safe to drink?

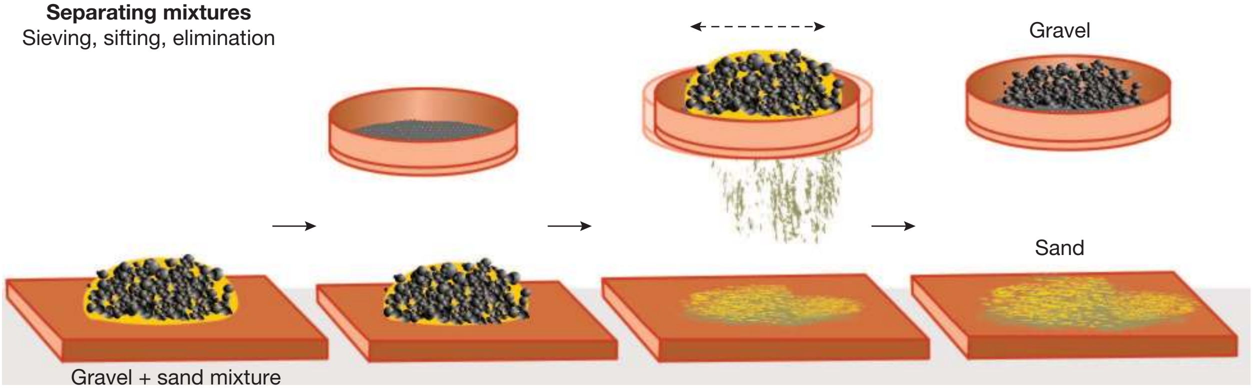
6.3.3 Sieving

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 also very efficient at separating larger particles from finer particles, as seen in figure 6.12.

decanting pouring liquid off the top when sediment has settled to the bottom of the container

sieving separating particles of different sizes by allowing the smaller particles to fall through holes in a container

FIGURE 6.12 Sieving can be used to separate gravel from sand



on Resources

Video eLesson Decanting (eles-2214)

Interactivity Sieving and decanting (int-8053)

6.3.4 Colloids and emulsions

Some mixtures are neither solutions nor suspensions. A mixture that contains suspended particles too small to settle or be removed by filtering is called a **colloid**. Unlike solutions, which are clear, colloids are cloudy. Colloids can be formed by solids, liquids or gases. Examples of colloids include mist, cappuccino froth, whipped cream and paint.

An **emulsion**, which is a heterogeneous mixture, is a specific type of colloid involving two or more **immiscible liquids**. In emulsions, one liquid is able to spread evenly through another liquid, rather than settling into layers as it usually would. Unhomogenised milk (as seen in figure 6.13), is not an emulsion due to the layer of cream floating on the milk. Homogenised milk and mayonnaise are examples of emulsions, as is the liquid spread through water in figure 6.14.

colloid a mixture in which extremely small particles of one substance are spread evenly throughout another substance

emulsion a colloid where droplets of one liquid spread evenly through another

immiscible liquids liquids that will not mix, such as oil and water

FIGURE 6.13 Unhomogenised milk forms layers and is not an emulsion.

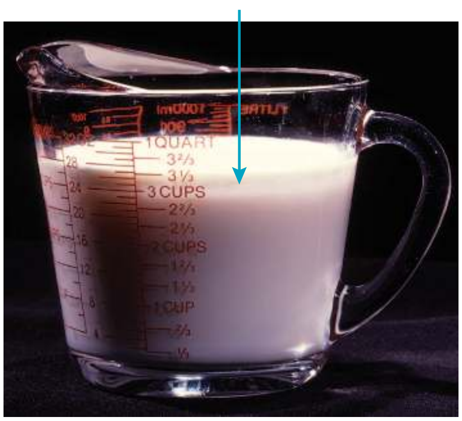
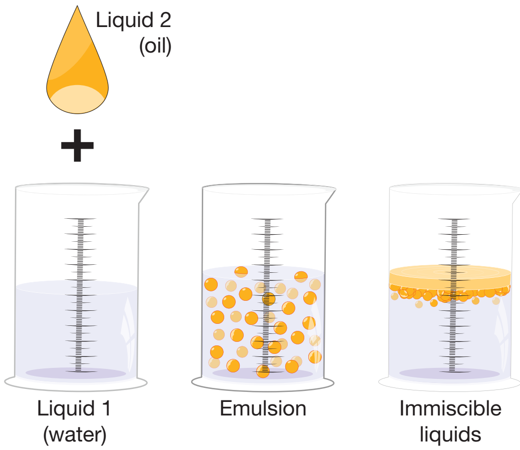


FIGURE 6.14 Emulsions involve one liquid spreading evenly throughout another liquid, rather than forming into layers, which occurs in immiscible liquids.



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:

- suspension, sediment, emulsion, colloid
- filtration, sieving, decanting
- solute, solvent, solution.

on Resources

eWorkbooks	Sieving, filtering or decanting (ewbk-11281)
	The pool shop (ewbk-11283)
Video eLesson	Density (eles-2546)
Interactivity	Mixtures (int-0224)

6.3 Activities

learnon

6.3 Quick quiz on | **6.3 Exercise**

Select your pathway

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

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Remember and understand

1. Match each of the following terms with their descriptions.

Term	Description
a. Sediment	**A.** A process where liquid is carefully poured off the sediment
b. Filtration	**B.** Insoluble particles dispersed in a liquid
c. Residue	**C.** Liquid passing through filter paper
d. Colloid	**D.** A type of colloid, where droplets of one liquid are spread through another
e. Filtrate	**E.** A mixture where extremely small particles spread through another substance
f. Emulsion	**F.** Material deposited on a filter
g. Suspension	**G.** An insoluble substance that sinks to the bottom
h. Decanting	**H.** A process of separating suspended particles using a filter

2. MC What happens to a suspension if it is left to stand?
   A. The suspension separates and the soluble sediment sinks to the bottom of the vessel.
   B. The suspension separates and the insoluble sediment sinks to the bottom of the vessel.
   C. The suspension separates and the insoluble sediment rises to the top of the vessel.
   D. The suspension stays the same no matter how long it stands.
3. Complete the passage using the following terms to explain how to distinguish a colloid and a solution.

   Word bank: colloids cloudy clear suspended solutions separate

   _______________ are _______________ and the _______________ colloidal particles do not sediment out quickly. _______________ are _______________ and do not _______________.
4. MC Identify which types of substances mix with each other to form emulsions.
   A. Soluble powders
   B. Insoluble liquids
   C. Salt and fresh water
   D. Solids and gases

Apply and analyse

5. Think of two more filters or sieves used in the home. Construct a four-column table like the following to describe the filters.

TABLE The function of different filters

Filter	Mixture	Residue	Filtrate
Vacuum cleaner	Air and dust	Dust	Air
Food strainer	Chips and hot oil	Chips	Oil

6. The air filter and oil filter in a car engine have to be replaced occasionally. Why do you think this is done?
7. The following steps in a recipe are examples of separating mixtures in the kitchen. Label 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.
8. Explain why filtering is preferable to decanting when separating a suspension from a mixture.
9. SIS 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.
10. Imagine you're camping at the beach with friends, when a strong wind disturbs your dinner preparation. You need to separate the following substances (in bold) 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

11. SIS What types of paper can be used to filter a suspension? Research or carry out an investigation that tests different papers (such as newsprint, tissue paper, brown paper, kitchen towel and so on) for their suitability as filter paper. Write a report on your findings.
12. SIS The kidneys act as filters to remove wastes from our blood. Find out more about how the kidneys filter wastes from the blood.
13. 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.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
6.4 Other separating techniques

LEARNING INTENTION

At the end of this lesson you will be able to explain how a separating funnel and centrifuge separate mixtures, and the type of mixtures they are used to separate.

6.4.1 The separating funnel

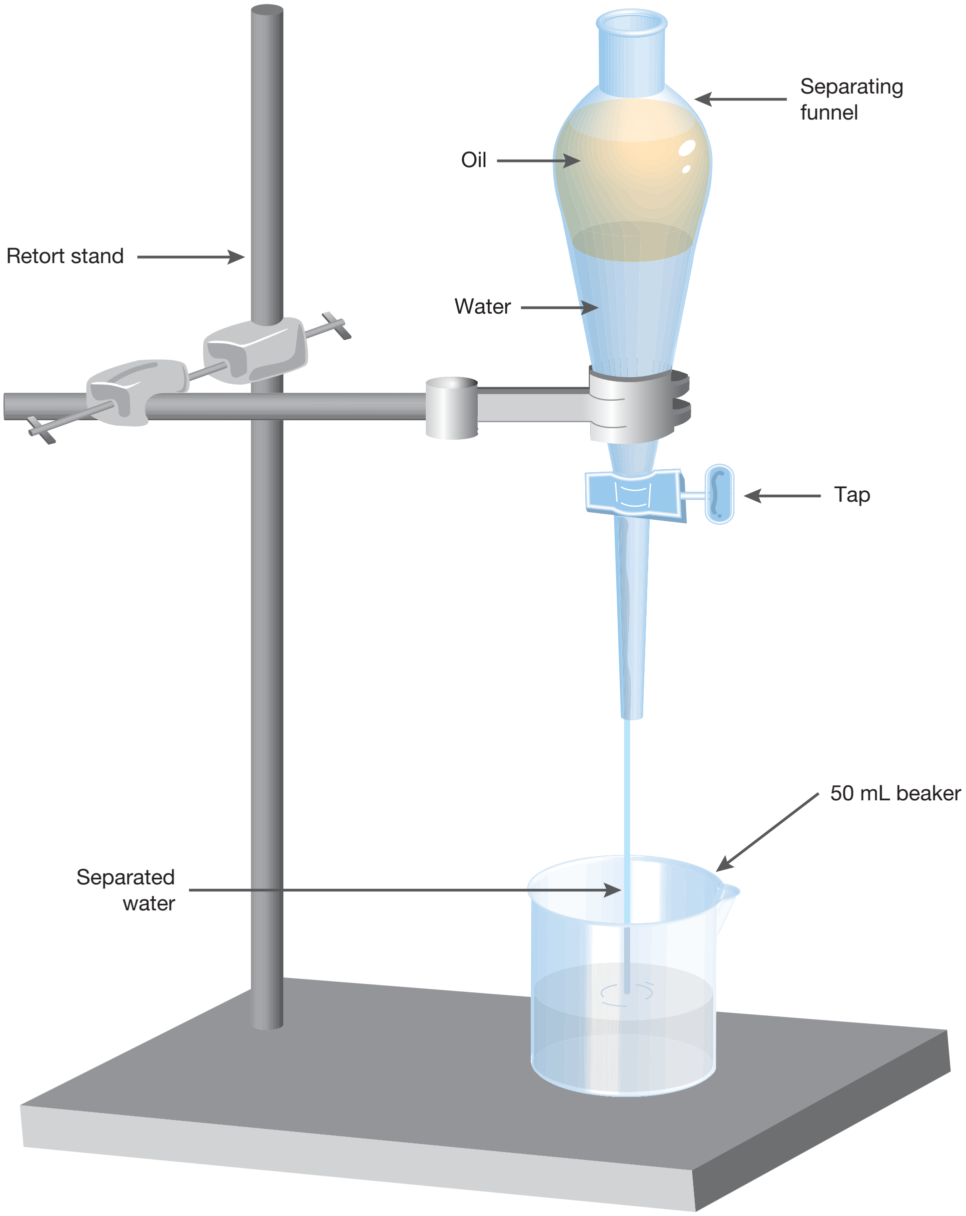
When one liquid does not mix with another but floats on top of it, a **separating funnel** can be used to separate the two liquids. Oil floats on water because oil is less dense than water. This mixture can be separated using a separating funnel as shown in figure 6.15.

separating funnel a pear-shaped glass container, with a tap at its base, used to separate two liquids that do not mix

ewbk-11285

int-8055

FIGURE 6.15 Using a separating funnel to separate oil from water



6.4.2 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 it 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 6.16 A centrifuge

on Resources

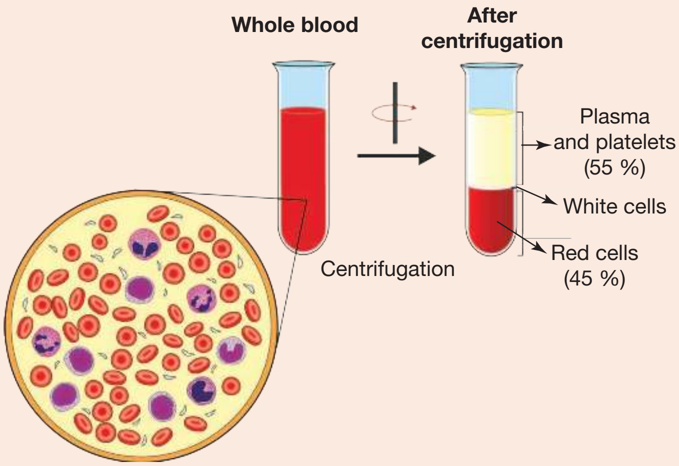
eWorkbook	Centrifuging and separating (ewbk-11287)
Video eLesson	Centrifuging (eles-0061)

centrifuging separating a mixture by rotating the container quickly so the heavier parts of the mixture move to the outside of the spinning container

SCIENCE AS A HUMAN ENDEAVOUR: 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.

FIGURE 6.17 Centrifuging 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 6.17 and 6.18.

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 6.1. 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 the Australian Red Cross Blood Service. Separation allows doctors to treat a larger number of patients and save many lives.

FIGURE 6.18 Blood is collected and separated by the Australian Red Cross Blood Service.

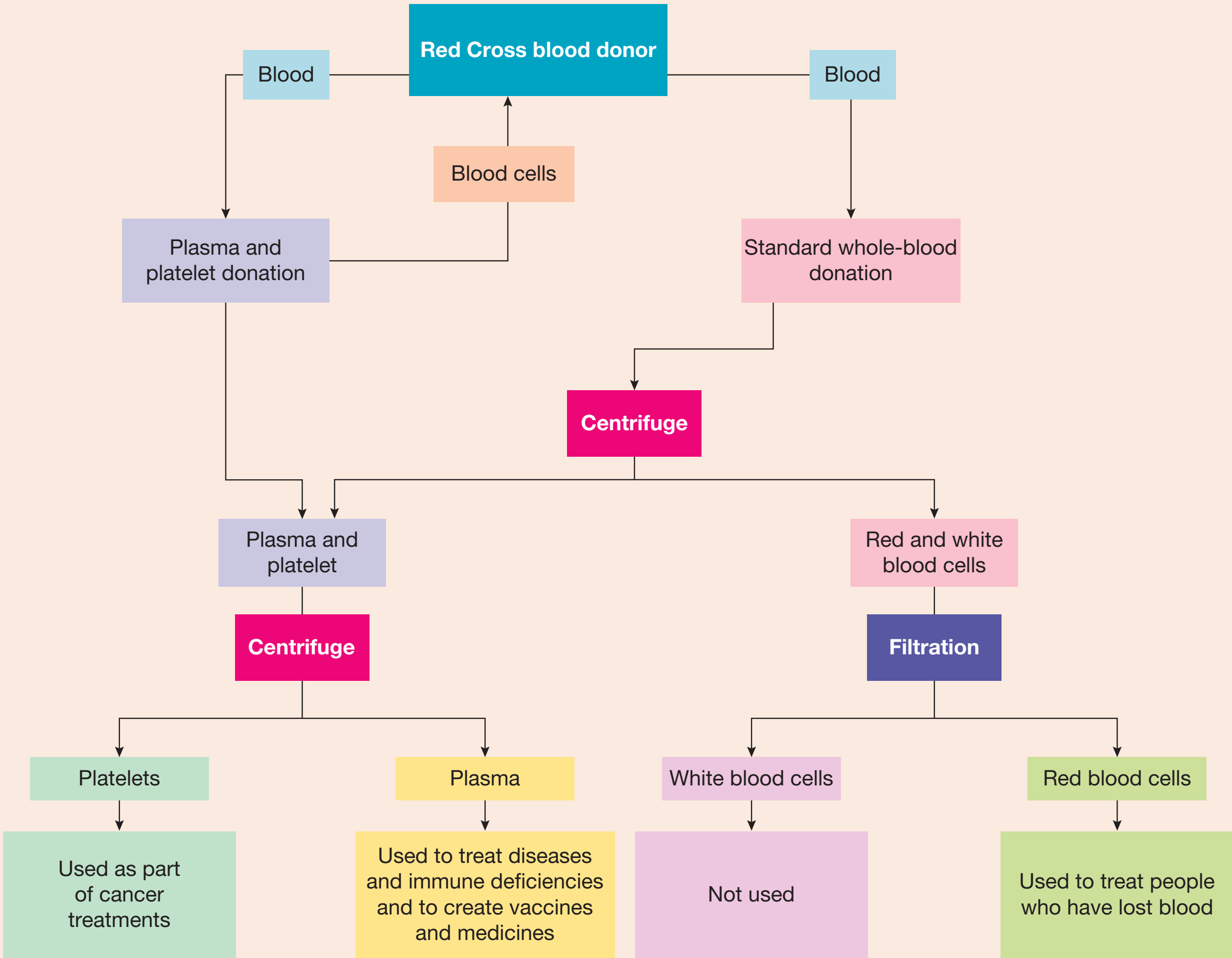


TABLE 6.1 Blood types and main uses

Blood type	Percentage of population	Most useful donations	Main uses
AB	3%	Plasma	AB plasma can be given to any blood type.
A	38%	Whole blood, plasma or platelets	Common blood type, so there is a high demand for these products
B	10%	Plasma	Particularly useful for people with blood diseases, severe burns or trauma
O–	9%	Whole blood or platelets	All products can be given to any blood type.
O+	40%	Whole blood, plasma or platelets	Most common blood type; 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.)

DISCUSSION

In an average week, the Australian Red Cross Blood Service needs about 21 000 blood donations to meet the demand for blood and blood products. Research and report on the following questions.

Why are you not allowed to donate blood if you have recently had a tattoo?

What ethical considerations does a person who recently had a tattoo have to think about before a blood donation?

on Resources

Interactivity Blood donation in Australia (int-3439)

Weblink Follow the blood bag: How Australian Red Cross processes life-saving donations

6.4 Activities

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6.4 Quick quiz on | **6.4 Exercise**

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

Remember and understand

1. MC Complete the sentence: 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.

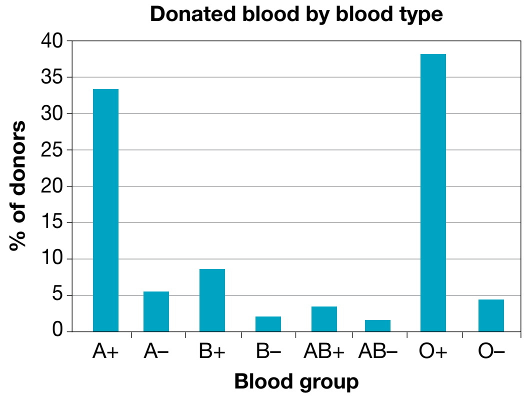
   plasma, white blood cells, filters, dishlets, blood type, red blood cells, aqueous blood cells, platelets

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 Why is blood 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.

Apply and analyse

7. Explain how blood is separated into different parts. Ensure you use the correct scientific terminology.

8. Refer to the bar graph and answer the questions that follow.
   a. The highest percentage of blood donors have what type of blood?
   b. What does the vertical axis show?
   c. Provide a title for this graph.
   d. State the total percentage of donors who have B group blood.
   e. Why is there a high demand for O+ group blood?



Evaluate and create

9. In an average week, the Australian Red Cross Blood Service needs about 21 000 blood donations to meet the need for blood and blood products. Research and report on the following questions.
   a. How old do you need to be to donate blood?
   b. What is the minimum body weight required of blood donors?
10. SIS 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.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
6.5 Separating solutions

LEARNING INTENTION

At the end of this lesson you will be able to explain the physical separation techniques such as evaporation, distillation, crystallisation and chromatography, and outline examples of where they are used. You will be able to describe separation techniques used by First Nations Australians, such as hand picking, sieving, winnowing, yandying, filtering, cold-pressing and steam distilling.

6.5.1 Reviewing solutions

Imagine being stranded on a small, sandy island with no fresh water to drink. You are surrounded by the sea. But you can't 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?

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 won't work — the dissolved particles are too small. Neither will decanting or centrifuging. You can't 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 and boils away, leaving the salt behind as solid crystals.

6.5.2 Distillation

In the laboratory, pure water can be produced by a process called **distillation**. Tap water is poured into a boiling flask (see figure 6.19) 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.

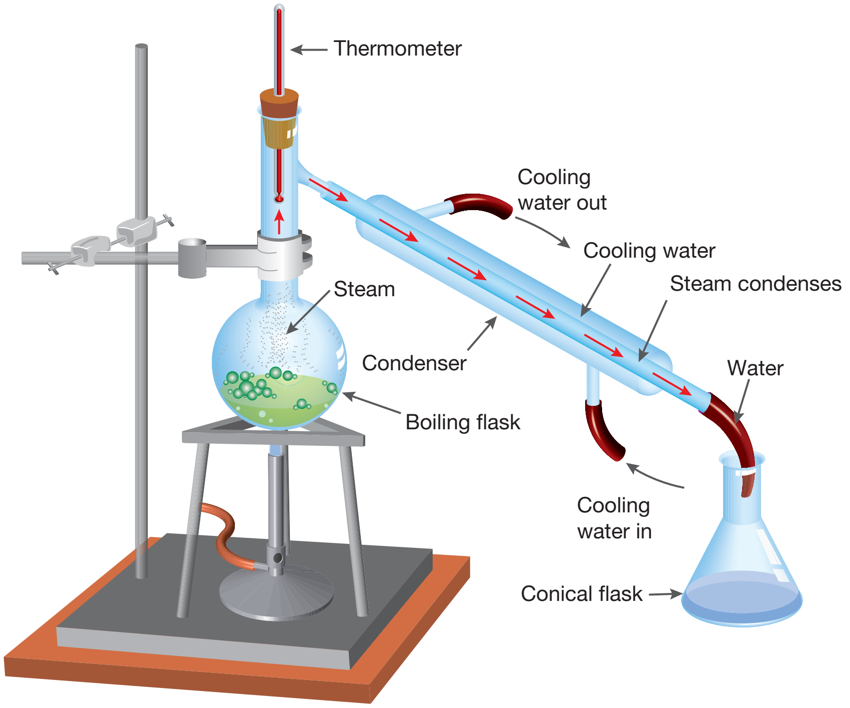
The pure water collected in the conical flask is called the **distillate** and can be rightly labelled **distilled water**. The impurities in the water are left behind in the boiling flask.

distillation a separation technique that uses evaporation to separate substances
evaporate change state from liquid to gas
condense change state from gas to liquid
distillate the liquid collected during distillation when the evaporated substance condenses
distilled water pure water collected by condensing steam

ewbk-11289

int-8056

FIGURE 6.19 Equipment used for distillation in the laboratory



Distillation 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 can easily turn to vapour, and have a low boiling point. Liquids with a low volatility cannot easily become a gas, and have a high boiling point. 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.

on Resources

Video eLesson Distillation (eles-0060)

6.5.3 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 6.20, could be used to produce small amounts of pure water from salt water.

When evaporation is used to separate pure water from salty 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.

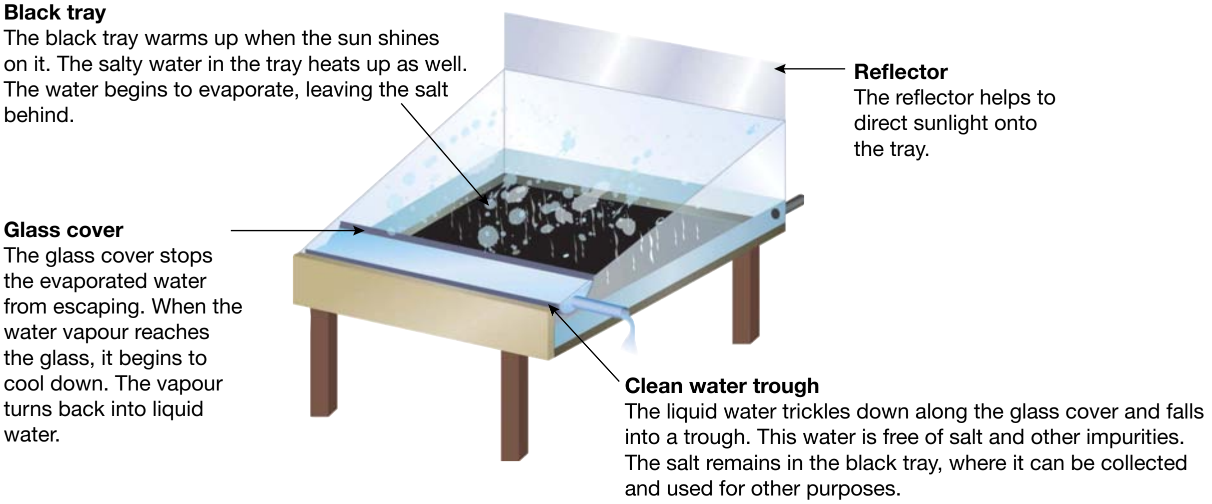
volatility how readily a substance evaporates or becomes a vapour

crystallisation a separation technique that uses evaporation to separate the parts of a solution, leaving the solute as crystals

ewbk-11291

int-8057

FIGURE 6.20 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.

elog-2039

INVESTIGATION 6.5

Making a simple water still

Aim

To investigate a simple still to separate salt from salt water

Hypothesis

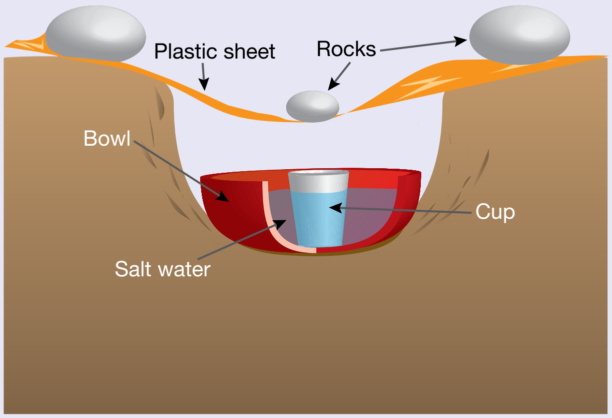
If a solution of salt water is distilled using a simple water still, then the salt and water will be separated, with water falling into the cup and salt remaining in the bowl.

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 a few centimetres deeper than the height of the cup and 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. How has the water level in the bowl changed?
2. Is there any residue on the walls of the bowl? What do you expect this is made of?
3. Describe how the water in the cup is different from the water in the bowl.

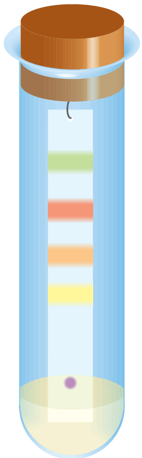
Conclusion

Summarise the findings of the investigation in three or four sentences.

6.5.4 Chromatography

int-3442

FIGURE 6.21 Filter paper being used in the process of 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 6.21. Chromatography relies on the differences in solubility of substances in a mixture.

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.

Chromatography can separate parts of mixtures according to their different solubilities in a particular solvent.

on Resources

eWorkbook Chromatography (ewbk-11293)

Video eLesson Paper chromatography (eles-2548)

paper chromatography method of separating a mixture of different colours positioned on filter paper using a solvent

elog-2041

INVESTIGATION 6.6

Separating colours

Aim

To investigate the use of paper chromatography to separate substances in food colouring

Hypothesis

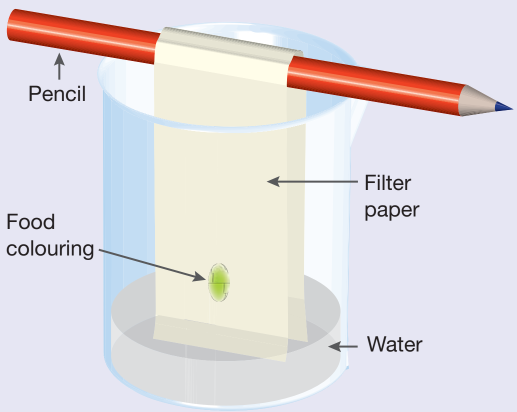
If a sample of water soluble food colouring is made of a mixture of different dyes, then these will be separated using paper chromatography, since some colours will move further up the paper than others.

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. How are the colours actually separated using this method?
2. Explain if you think that the colours would separate in the same way if a different solvent was used.
3. a. State if any of the separated colours are the same distance from the pencil line. For example, was the yellow part in the different food colours the same distance from the pencil line?
   b. What does this suggest about the particular 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.

FIGURE 6.22 A high-performance liquid chromatography (HPLC) machine automatically separates mixtures by chromatography.

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.

pollution the introduction of harmful substances or products into the environment

forensic scientists people who use methodical gathering and analysis of scientific evidence to establish facts that can be presented in a legal proceeding

6.5.5 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.

elog-2043

tlvd-10656

INVESTIGATION 6.7

Crystallisation

Aim

To investigate separation by crystallisation

This investigation must be done in class with your teacher.

Materials

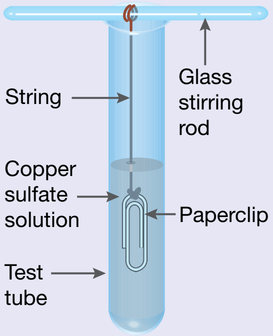
- Test tube
- Solid copper sulfate (or alum)
- A balance
- 150 mL beaker
- Glass stirring rod
- Hot water
- String
- Test tube rack
- Piece of filter paper
- Filter funnel
- Conical flask or beaker
- Paperclip

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.

6.5.6 First Nations Australians' separation techniques

Separation techniques have been used by First Nations Australians for thousands of years. These include hand picking, sieving, **winnowing**, **yandying**, filtering, **cold pressing** and **steam distilling**. These separation methods played a major role in their everyday lives for medicines, food and water.

One of the most commonly used separation techniques is hand picking, which is simply using hand and eye coordination to select a desirable product by distinguishing it by its shape, colour, size and so on. This 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 6.23).

For cultivating food crops, the planting of seeds is required. Seeds have to be separated from their outer layer and other debris before they can be planted in the soil. This method of seed separation is known as winnowing, and it involves a **coolamon** (see figure 6.24a). This allows the lighter outer layer of the seed and debris to be removed by the wind as the components are tossed in the air, while the denser seeds are retained in the koolamon.

winnowing using an air current to separate seeds from their outer layer and other debris

yandying process that removes less dense particles, such as sand, ash and dirt, from denser desirable seeds

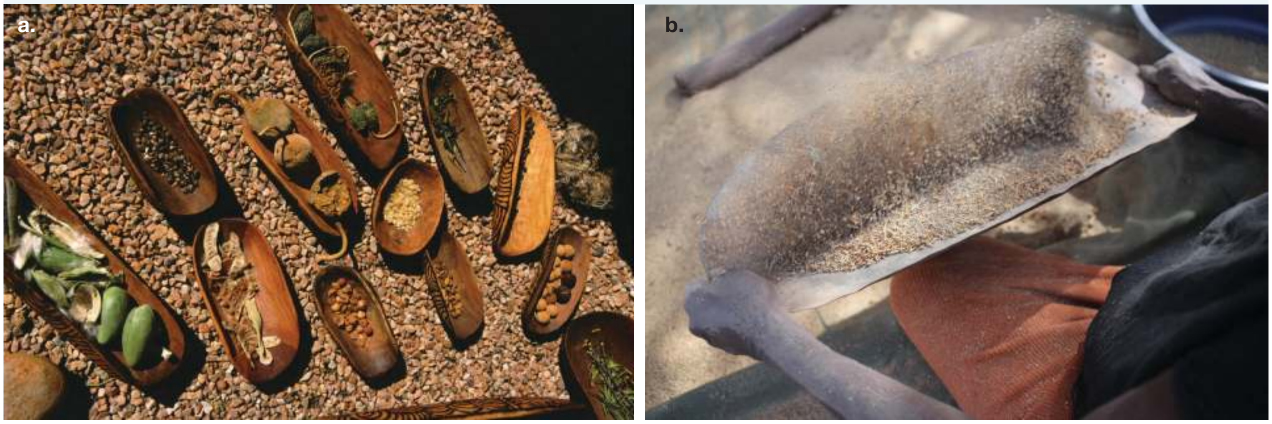
cold pressing pressing at low temperatures to produce oils/pulp

steam distilling process of using water vapour to extract aromatic oils and other substances from plant matter

coolamon First Nations Australians' vessel for carrying objects

FIGURE 6.23 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?

FIGURE 6.24 a. An assortment of native bush foods (kakadu plums, acacia seeds, desert quandong, bush coconuts) in coolamons. How many of these foods have you tried? **b.** Yandying kalaru seeds



Yandying, originating from the Pilbara region of Western Australia, is another density-based separation process for selecting denser seeds from debris such as sand and dirt. It uses a wooden shallow yandy, which is a dish, in a similar manner to that used for winnowing. The yandy and its contents are gently shaken, causing the denser seeds to collect at the bottom.

First Nations Australians combine sieving and decanting to prepare native yams, some of which are toxic unless prepared properly. The yams are boiled and placed into a dilly bag (bag woven from plant fibres). The bag is squashed, and the softer parts of the yam are strained through the bag into a can of water. The bag acts as a sieve, allowing some substances to pass through, but not others. The skins and harder parts of the yam that are left in the bag are thrown away. The water is decanted from the can, and repeated washing with water removes more of the toxic substance. The yam is then placed into another dilly bag and hung up overnight before being ready to eat.

FIGURE 6.25 Flowering honeysuckle banksia

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.

Cold pressing has been employed by First Nations Australians to extract oils from plant matter, by grinding it to a pulp and then pressing the pulp, extracting the watery and oily components. Oil, being less dense than water, will accumulate in a separate layer on top of the water. Macadamia nuts, for instance, can be cold pressed.

Aromatic oils, generally used for medicinal purposes, can be extracted from plant matter using steam distillation, which involves boiling the components in hot water to release the oils. Aromatic oils are generally volatile, meaning that they will easily evaporate, and the steam, rich in aromatic components, can then be inhaled, or wafted near the body part to treat. For instance, eucalyptus oil can be used to treat sore throats.

on Resources

eWorkbook Crystallisation and distillation (ewbk-11295)

Weblink Separating mixtures

6.5 Activities

learnon

6.5 Quick quiz (on)	6.5 Exercise

Select your pathway

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

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Remember and understand

1. MC Which separating technique is 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. Add the correct names for each piece of equipment used in the distillation process.

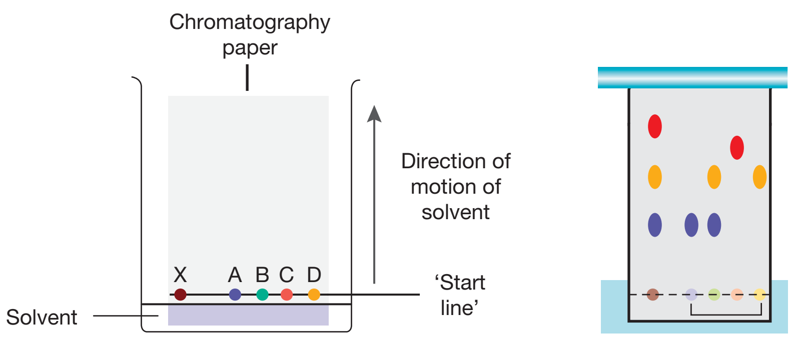
TABLE The equipment used in distillation

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. Explain the following separation techniques used by the First Nations Australians. 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 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 one centimeter 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 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 a biro 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. SIS 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 as 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. **SIS** Zoe performs a paper chromatography experiment on waterproof markers, using water as a solvent. Will her experiment work? Explain your answer.
14. **SIS** 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.
15. **SIS** Investigate how to distill perfume. Summarise this process.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
6.6 Separation in industry

LEARNING INTENTION

At the end of this lesson you will be able to describe how important separation processes are in the mining, dairy and wine industries and how they are used to clean up oil spills.

6.6.1 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.

SCIENCE AS A HUMAN ENDEAVOUR: 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 to a fine powder before the copper ore and gangue can be separated. Crushing takes place in a ball mill. This 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.

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

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 (as shown in figure 6.25) while the lighter gravel and sand swirl out of the pan with the water.

FIGURE 6.25 Gold separated from unwanted rock

gravity separation separation of heavier particles in a mixture, by shaking or spinning them

on Resources

Video eLessons Gold panning (eles-2547)
Gravity separation and plants (eles-2215)

elog-2045

INVESTIGATION 6.8

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.

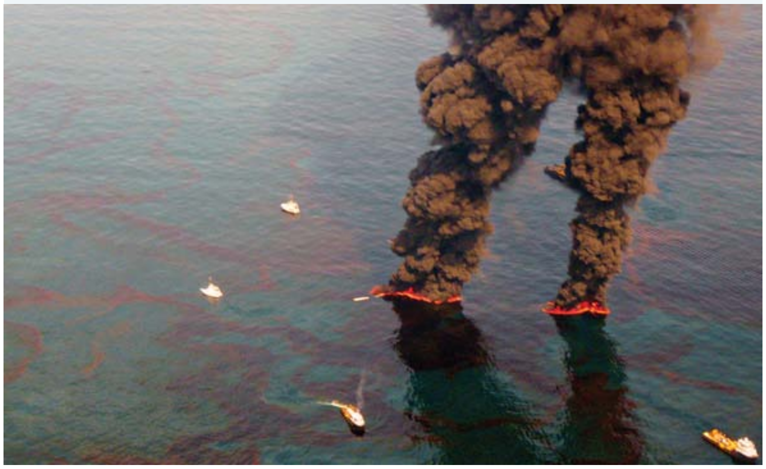
Conclusion

Summarise the findings of the investigation in three or four sentences.

6.6.2 Cleaning up oil spills in the ocean

On 20 April 2010, an explosion on the BP Deepwater Horizon drilling rig caused a massive oil spill into the waters of the Gulf of Mexico (see figure 6.26). The slick covered thousands of square kilometres of ocean. Another smaller oil spill occured in the East China Sea in 2018, when an oil tanker collided with a cargo ship. Oil spills cause significant harm to many living organisms, including birds, fish and mammals. Such a slick can be cleaned up by considering some of the different properties of oil and sea water, as outlined in figure 6.27.

FIGURE 6.26 Controlled burns of oil gathered from the surface of the Gulf of Mexico following the BP Deepwater Horizon oil spill disaster



Biodegradation of the oil occurs when microorganisms in the ocean break the oil down to use as a source of nutrients. This removes the oil from the water naturally. However, this process may take many years.

Oil spill dispersants can be sprayed onto the oil by helicopters, planes or boats. Dispersants contain substances called **surfactants** that can break up the oil into much smaller droplets. The detergent that you use to break up the grease on your dishes is also a surfactant. The smaller oil droplets are then more easily broken down by bacteria, algae and decomposers in the ocean.

As oil is **flammable** but water is not, the oil can be removed from the water by burning it off the water surface. The oil is ignited by a **helitorch**, which is lowered to the spill surface from a helicopter. However, while fresh crude oil burns well, oil that has been on the surface of the water for a while becomes weathered and is harder to ignite. Also, if a spill has spread too far, the oil layer may have become too thin to ignite. The smoke produced from burning the oil can cause pollutants and toxins to enter the air.

Biostimulants can be added to the ocean. These are chemicals, such as fertilisers, that increase the numbers of microorganisms in the ocean and so speed up the rate of biodegradation of the oil.

Booms are used to control the spread of oil. These float on the ocean surface and extend into the water below the level of the oil. Booms are made of **buoyant** materials such as neoprene.

Skimmers are dragged by boats across the top of the oil spill and scrape the oil from the water surface. The oil is then sucked into storage tanks on board the boats.

biodegradable able to break down or decompose easily in the environment

oil spill dispersants chemicals that when sprayed onto an oil spill, can break the oil into smaller particles

surfactants substances that can break up substances such as oil into smaller particles

flammable substances such as methylated spirits that burn easily

helitorch a device used to drop flaming fuel onto another substance in order to ignite it

biostimulants substances that stimulate processes of living organisms to enhance their growth

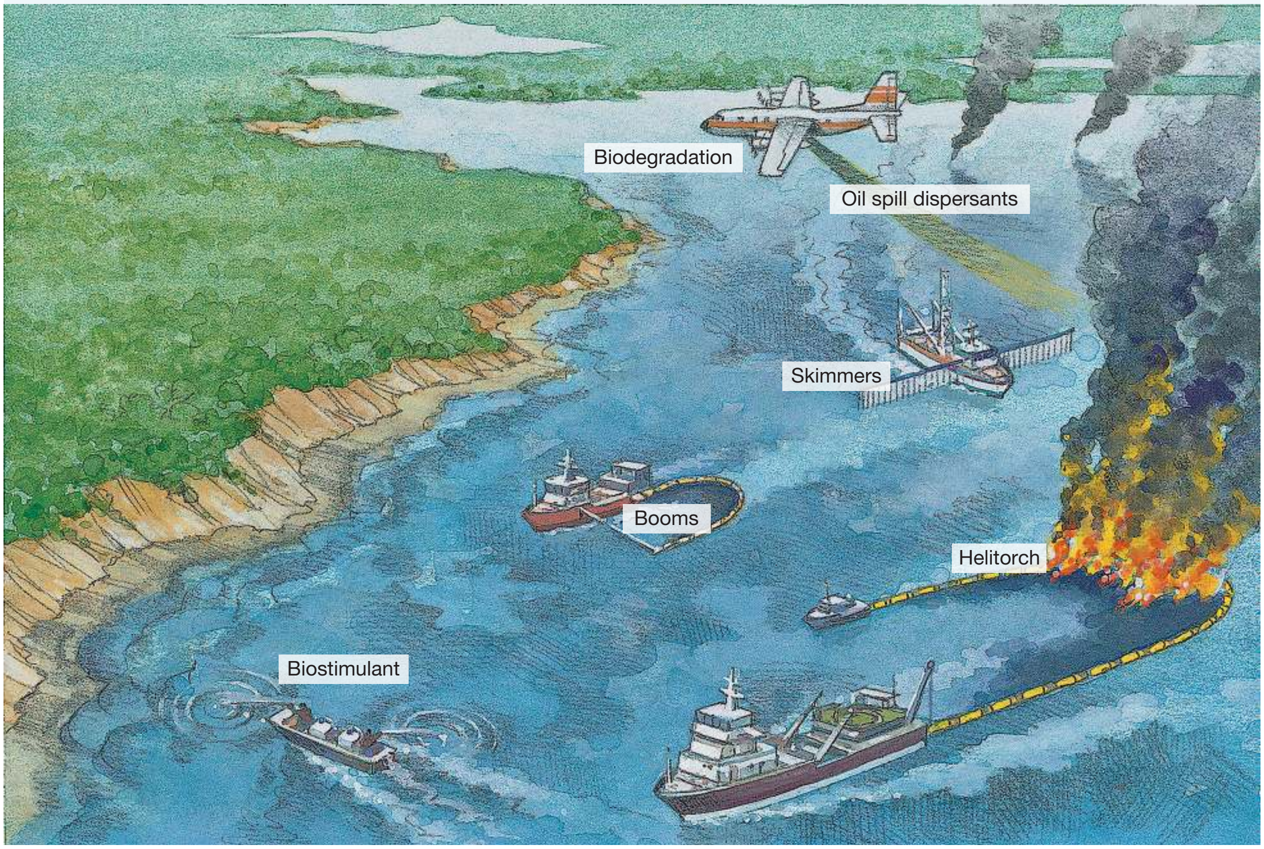
booms devices that float on the surface of the ocean and assist in containing oil spills by extending below the oil spill

buoyant able to float on a liquid

skimmers devices dragged by boats that scrape the oil off the surface

int-3438

FIGURE 6.27 How to clean up an oil spill



Resources

Weblink How do we clean up oil spills?

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 6.28 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.

SCIENCE AS A HUMAN ENDEAVOUR: Separating mixtures in the wine industry

Winemakers use a variety of separation techniques in the production of wine. Presses are used to separate the juice from the grapes. A large plate is lowered onto grapes in a container, pressing until the juice is forced out of the grape skins. Some winemakers still use the ancient method of pressing using a large wooden basket. A plate is lowered onto the grapes and the juice flows out through the openings in the basket.

FIGURE 6.29 A variety of separation techniques can be used to make wine.

Filtration is used to remove solid impurities in wine, but the microscopic particles in wine that make it cloudy are separated by a process winemakers refer to as 'fining'. They add agents such as egg white, gelatin (an animal protein) and casein (a protein found in milk) that bond with the particles, making them larger so that they sink to the bottom of the tank or barrel. The remaining wine is clear.

Fortified wines such as apera (originally called sherry) and muscat are made by distilling wine to separate and remove water from alcohol and other dissolved substances that give the wine its flavour. The remaining mixture is called spirit, which is added to other wines to fortify, or strengthen, them and make them sweeter.

on Resources

eWorkbook Separation in industry (ewbk-11297)

Interactivity The homogenisation process (int-3437)

6.6 Activities

learnon

6.6 Quick quiz on | **6.6 Exercise**

Select your pathway

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

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Remember and understand

1. MC What type of separation is used when panning for gold?
   A. Crystallisation B. Gravity separation C. Centrifuging D. Distillation
2. MC Froth flotation is used when the impurities are ____________________ the ore particles.
   A. similar to B. lighter than C. heavier than D. mixed in
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 Which of the following 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. **SIS** Smoke stacks are used in many production plants and power stations to release waste gases and hot particles into the atmosphere. In some of these smoke stacks, an electrostatic precipitator is used to separate smoke, dust and other small particles and droplets from the waste gases before they are released into the atmosphere. Research and report on how electrostatic precipitators work.
9. **SIS** Investigate the processes used to separate olive oil from the other liquids and solids in olives. Prepare a fact sheet with suitable images and text.
10. **SIS** An oil spill at sea can ruin the local environment and kill wildlife. Research and report on each of the following.
    a. Find out how environmental and other authorities clean up oil spills at sea. List the properties of oil that allow each method to succeed.
    b. When and where did the worst oil spill disaster occur and how was the oil separated from the sea water?

Fully worked solutions and sample responses are available in your digital formats.

LESSON
6.7 Removing contamination from water

LEARNING INTENTION

At the end of this lesson you will be able to 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.

6.7.1 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.

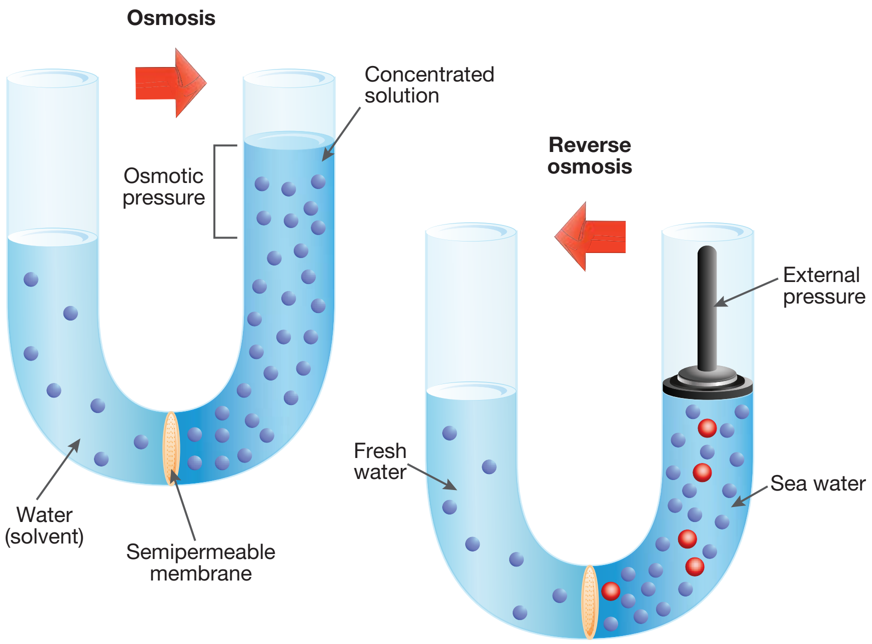
contaminated when a useful substance contains one or more other substances that affect its use

- 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.

6.7.2 Desalination: making the sea safe to drink

The processes of distillation and evaporation are not suitable for purifying sea water on a scale large enough to supply drinking water to large communities. Desalination plants have been built in New South Wales, Victoria, Western Australia and South Australia. In all of these plants, a process called **reverse osmosis** is used to separate salt from large quantities of sea water, as shown in figure 6.30.

FIGURE 6.30 The processes of osmosis and reverse osmosis



In the process of **osmosis**, water moves through a very thin membrane from an area of low salt concentration to an area of high salt concentration. This continues until the concentration of salt is the same on both sides of the membrane. The membrane has tiny holes that allow water to pass through without the salt. In reverse osmosis, the water is forced under very high pressure to flow through the membrane in the opposite direction.

In desalination plants (such as that in figure 6.31), sea water is pumped under high pressure through thin membranes in coils. The pure water that has passed through is directed to drinking water supply tanks. The very salty water left behind is pumped back into the sea.

The use of desalination plants is controversial. There are two major concerns about their use.

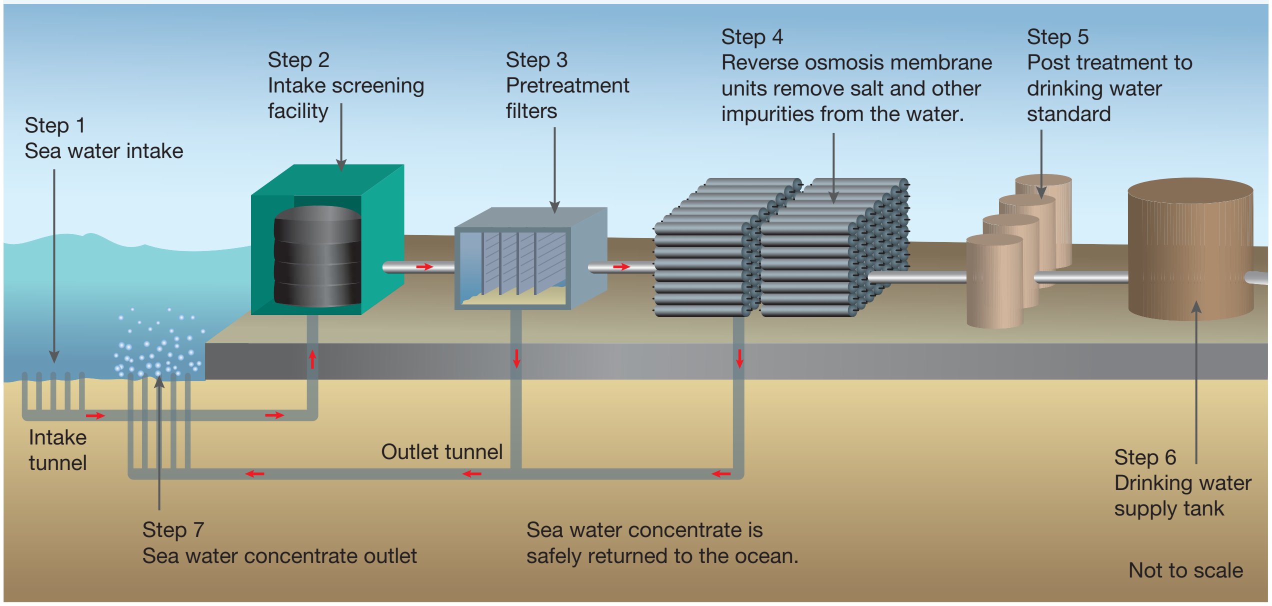
- Desalination uses a lot of energy, which is usually supplied by coal-fired power plants. With this energy source, the use of these plants causes pollution and overall the process is not **sustainable**; that is, using them now affects the environment and needs of future generations. In some cases, the large amounts of energy used are offset by constructing wind farms or by supporting other renewable sources of energy.
- The water flowing back to the sea contains much more salt than sea water. It is also warmer. This poses a threat to marine animals and plants that live near the desalination plant. The threat can be reduced by choosing suitable locations for the salty water outlet. This requires scientific studies by marine biologists and other scientists. In the case of the Wonthaggi plant in Victoria, the outlet is around 1 km offshore.

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

osmosis the process of separating using a membrane through which one constituent cannot pass

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

FIGURE 6.31 Example of a desalination plant



on Resources

Weblink Australia Water Association — desalination plants

6.7.2 SCIENCE AS A HUMAN ENDEAVOUR: Keeping water safe

The water supplies of most of Australia's biggest cities come from very large protected catchment areas. In the catchment areas surrounding dams and reservoirs, human habitation is not allowed and public access to these areas is strictly controlled. This reduces contamination of the water as it flows through and over the ground and into the dam or reservoir. The water is stored for up to five years in the major reservoirs. During this time it is purified by settling and other natural processes.

FIGURE 6.32 Wivenhoe Dam supplies potable water (drinking water) to the Brisbane and Ipswich regions.

Some chemicals are commonly added to major city water supplies to make drinking water safe and healthy.

- Chlorine is added in very small amounts to kill harmful microorganisms, which might cause diseases. It keeps the water safe to drink up to the moment it reaches your tap.
- Fluoride is added to protect your teeth from decay.
- Lime is added to balance the acidity of the water caused by adding chlorine and fluoride.

DISCUSSION

Would you like your water to come out of the tap looking like the water in the glass in figure 6.33? Would you bathe or shower in it? Imagine your clothes after washing them!

The cloudiness of the muddy water is caused by tiny clay particles. Muddy water is an example of a colloid. Recall that a colloid is a cloudy mixture that contains suspended particles too small to be removed by filtering.

FIGURE 6.33 Would you drink this water?

6.7.3 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, and 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.

flocculation the process of adding a chemical to a suspension to create flocs, which settle to the bottom

floc a clump of particles heavy enough to sink to the bottom rather than remain floating in a liquid

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.

elog-2047

INVESTIGATION 6.9

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.

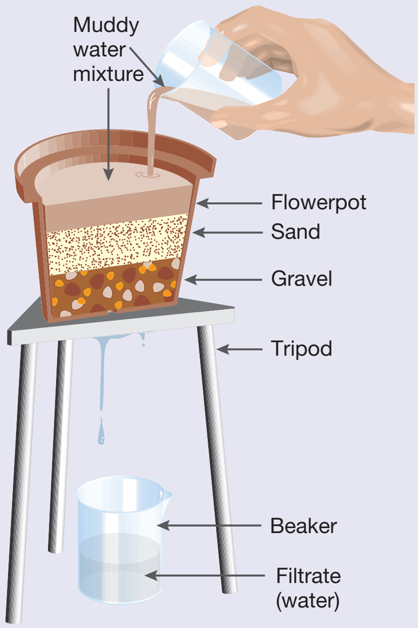
Materials

- 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. Draw up a table like the one provided to record your observations.
2. Describe the water at each stage of the process. Include the appearance and odour of the water.

TABLE Water after different stages of treatment

Treatment stage	Description of water
Untreated water	
Water after flocculation	
Water after filtration	
Water after chlorination	

Discussion

1. Which separation techniques did you use to purify the water?
2. Which step do you feel was 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.

on Resources

eWorkbook Clean and clear? (ewbk-11299)

6.7 Activities

learnon

6.7 Quick quiz on	6.7 Exercise

Select your pathway

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

These questions are even better in jacPLUS!

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Remember and understand

1. MC 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 are added to many city water supplies. Why are the following substances added to drinking water supplies?

TABLE The addition of substances to water

Substance	Reason added to water supplies
a. Lime (calcium)	
b. Chlorine	
c. Fluoride	

4. Complete the passage using the following terms to explain why alum is added to country water supplies.
   Word bank: sediment gravity cloud colloids flocculate turbidity
   Alum is added to some country water supplies to __________the clay _________ in the ___________ water. This produces larger particles that will ___________ under ____________ and thus reduce the ____________ of the water.

Apply and analyse

5. You live in a country town that does not fluoridate the water. Research how you could obtain your fluoride.
6. Among the swimming pool products that are claimed to clarify pools or make them 'crystal clear' are super-floc, power floc and supa-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?
7. The building of desalination plants is controversial. Explain two reasons for this.

Evaluate and create

8. SIS Home swimming pools are vacuumed using a pool vacuum cleaner. Research and explain how this type of vacuum cleaner works.
9. SIS Seal pools at Melbourne Zoo and Taronga Zoo are kept free from contamination by a combination of filtration, chemical treatment with ozone, and a process called foam fractionation. Foam fractionation is used to remove solid seal waste, food waste, algae and other small particles from the pool without the use of a flocculant. Find out and describe how a foam fractionator works.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
6.8 Separating our waste

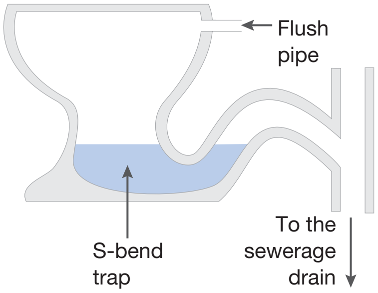
LEARNING INTENTION

At the end of this lesson you will be able to describe how human waste water is treated and how materials in household waste are separated to be recycled.

6.8.1 Waste water treatment

Every time you flush the toilet, have a shower, wash the dishes or your clothes, or even clean your teeth, the waste water travels into an underground **sewerage** system. This usually passes through an S-bend trap before passing into the sewerage system, as shown in figure 6.34.

FIGURE 6.34 The S-bend trap in the toilet fills with clean water to prevent smelly gases from the sewerage travelling back into the house.



The waste water is a mixture of human body waste flushed down the toilet, detergent, dirt, toothpaste, food scraps and other materials washed down the drains. The mixture, which is mostly water, is called **sewage**.

If you live in a major city, the sewage in the drain under your house flows into a larger drain under your street and travels through the sewerage system to a treatment plant. The waste water needs to be treated before it can be returned to the environment.

The design of treatment plants normally involves consultation between your state or territory government, engineers, scientists including biologists and environmental scientists, and local community groups. In country centres, treatment plants are usually located on the edge of the town. If there is no local treatment plant, the waste water flows into a personal sewage treatment system — a **septic tank** buried in the backyard, as shown in figure 6.35.

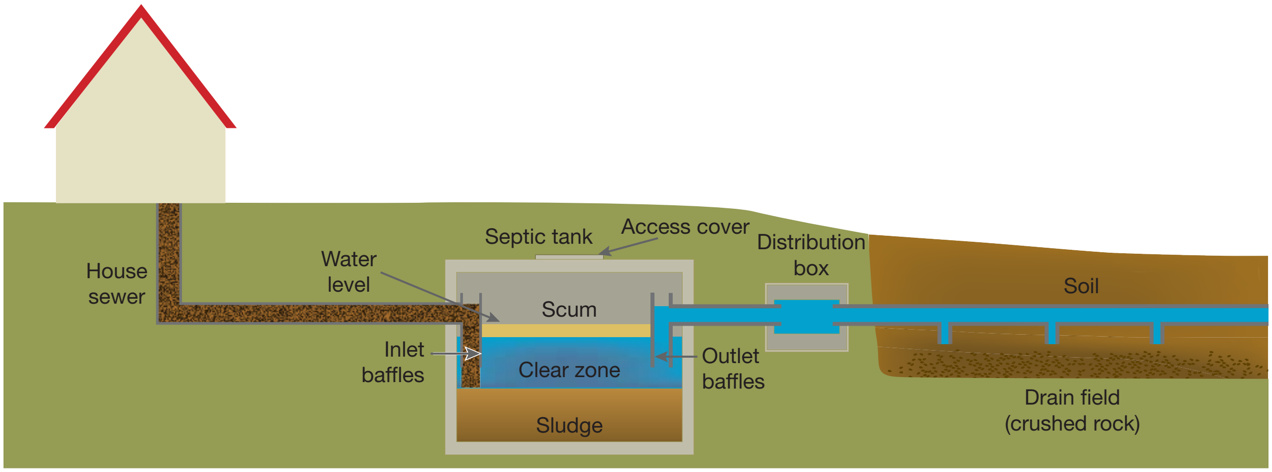
A septic tank contains bacteria that break down the sewage. A thick, smelly sludge is formed. The sludge sinks to the bottom of the tank and clear water flows out into the surrounding area. The sludge needs to be removed from time to time.

sewerage the system of drains and pipes that takes sewage away from a property

sewage a mixture of water and substances that flow from laundries, bathrooms, kitchens and toilets

septic tank a sewage treatment system placed underground in backyards of houses not connected to town sewage treatment plants

FIGURE 6.35 A typical septic tank system, where bacteria breaks down the sewage.



on Resources

Video eLesson	Treating sewage (eles-0059)
Weblinks	Wastewater treatment process Melbourne Water — what is sewage?

6.8.2 The separation process

Waste water contains **suspended** solids such as bacteria, grit and dirt as well as some larger items that do not break down easily and may have washed or been flushed down drains. It also contains many dissolved substances.

suspended hanging, not falling or sinking

floatables substances that are less dense than water so can float on water

When the waste water arrives at the sewage treatment plant for primary treatment, it passes through a screen (a wire mesh filter) that removes the larger items. The sewage then flows into settling tanks where it is kept for about two hours. In the settling tanks, suspended solids settle to form a sediment, and **floatables** such as oil and plastic collect on top of the sewage and are removed.

The watery part of the sewage flows from the settling tank into secondary treatment. This waste water still contains dissolved substances and bacteria. Secondary treatment takes place by filtering the water through soil and grass or by storing it in a series of one-metre-deep lagoons for two to four months. The bacteria in the waste water break down the dissolved substances to purify the water further. In the lagoons, sedimentation also takes place. The treated water looks clear but it is still not safe to drink.

FIGURE 6.36 The lagoon system at Melbourne Water's Western Treatment Plant in Werribee

The advanced lagoon sewage treatment system shown in figure 6.36 is part of Melbourne Water's Western Treatment Plant in Werribee, which covers 11 000 hectares in area. Some of this treated water is recycled and used for agriculture, horticulture and other applications.

Pollution from the sewerage system

There are many materials that should not be tipped down kitchen, bathroom, laundry or school laboratory sinks. The treated water is eventually released into the sea, but there are many substances that the sewerage system is not designed to treat. Such substances include:

- chemicals such as oven cleaners and insect sprays that are poisonous
- substances like fat and oil that don't dissolve in water.

These substances can eventually find their way to the sea, polluting it and killing or harming animals, plants and other living things (such as algae) that live there. Substances like these should be saved for collection by local councils.

Small objects such as cotton buds and tampons should not be flushed down the toilet because they can block the filters at treatment plants. These objects can be put out with other household garbage. This is also the case with paper towels, tissues and baby wipes, which do not break down as toilet paper does. The effect of flushing these objects was seen during the coronavirus pandemic in 2020, when a shortage of toilet paper meant baby wipes and tissues were used and flushed instead. This lead to significant plumbing and sewerage issues caused by blockages from these items.

Play it safe

The best policy at home is to avoid putting anything solid or oily down the sink, or that you suspect may be poisonous or harmful to living things. 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.

int-3434

SCIENCE AS A HUMAN ENDEAVOUR: Recycling to reduce waste

Individuals can play a greater role in reducing both our waste and our carbon footprint (which affects climate change). Earth's resources are finite, and everyone has a role to play in being waste-vigilant.

For instance, people can become better consumers by not over-consuming and by establishing a circular economy in which products are shared, leased, repaired when broken and used again, until finally the materials they are made of are recycled to make new products. Aluminium, for example, can be infinitely recycled, while most plastics will end up in landfill (and in the oceans). Using biodegradable products made from biobased materials, using renewable energy and avoiding single-use products (such as plastic cups) are steps that can be taken to avoid depleting Earth's resources at such an alarming rate.

The 8Rs — Rethink, Refuse, Reduce, Reuse, Repair, Refurbish, Repurpose and Recycle — can help you make better choices.

FIGURE 6.37 The many Rs of waste management

To preserve resources for future generations, the **recycling** of materials is essential. Items such as paper, plastic bottles and containers, glass, aluminium and steel can be recycled and made into new products. Recycling reduces the amount of waste that goes to **landfill** and saves precious natural resources such as trees and bushland. Many **manufacturing processes** pollute the environment. Recycling and reusing materials reduces the need to manufacture from **raw materials**. Fortunately, most local councils have a recycling program.

recycling treating items such as glass, paper, plastic, aluminium and steel so that new products can be made from them

landfill an area set aside for the dumping of rubbish

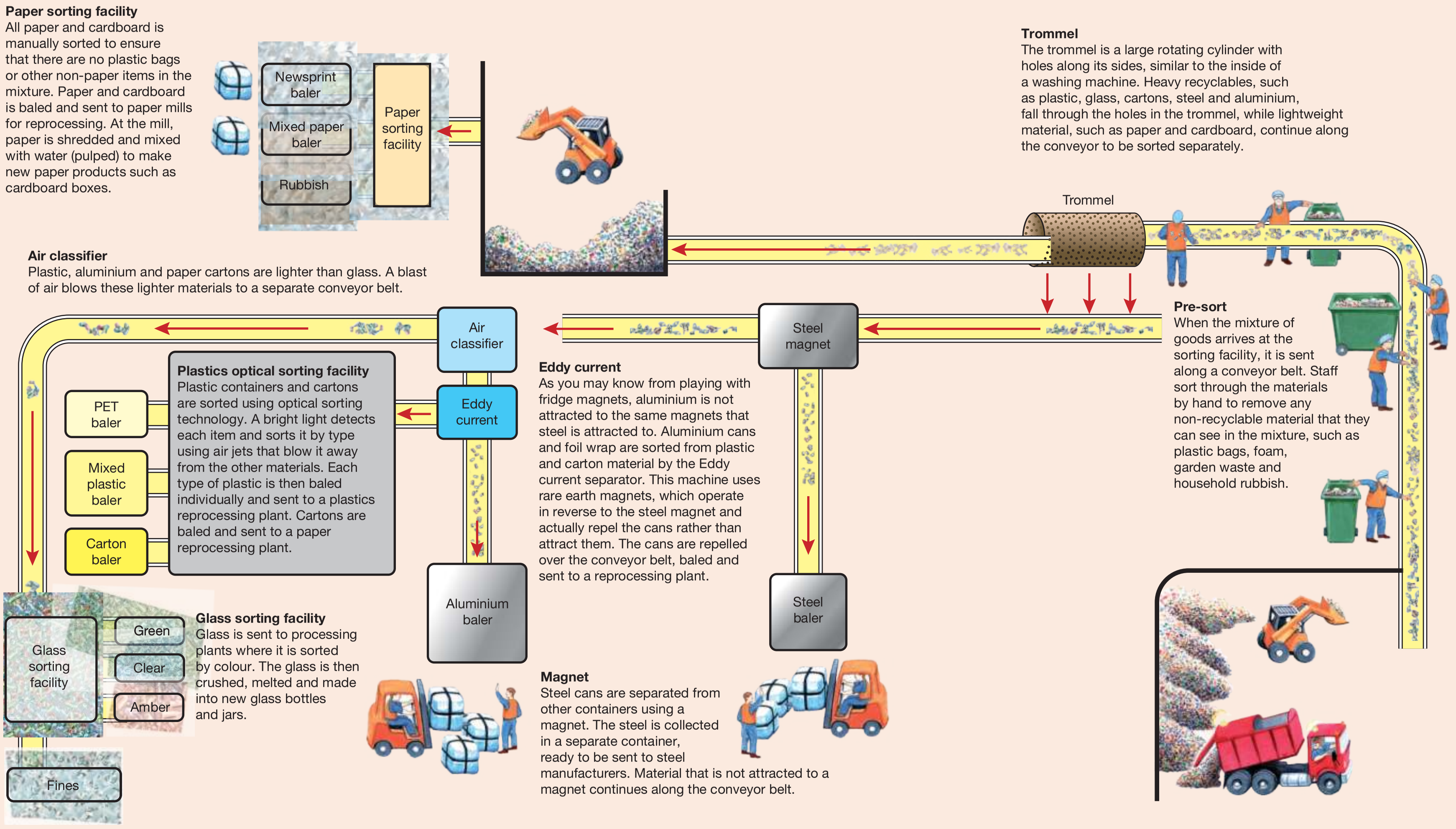
manufacturing processes processes used to make products

raw materials materials before they are made into a final form

Separating by sight

Household rubbish is usually a mixture of food scraps, recyclable materials and other waste. The first step in recycling is to separate the recyclable items from other household rubbish. This is most easily done by hand — that is, separating by sight. We can see the differences between the types of rubbish, and we know which items can be recycled.

FIGURE 6.38 Recycling centres sort through waste so it can be made into new products.



ACTIVITY: Examining waste in schools

What type of waste is produced in your school? What do you think is the most common waste that is deposited in the school waste bins? Perhaps you could examine the rubbish using gloves and protective gear, and then write a report. Consider what measures you could take to decrease the amount of waste produced.

DISCUSSION

How does the recycling of cans and bottles save oil, coal and gas? It takes energy from fossil fuels to run the equipment that mines and processes the materials that make new cans and bottles. Recycling also reduces the amount of raw materials that need to be taken from the ground and processed.

How would you encourage or help people around the world to recycle more of their cans and bottles? Would different methods convince people in different places in Australia to recycle more? How else could we reduce the number of cans and bottles that are produced?

on Resources

eWorkbook Treating waste water (ewbk-11301)

6.8 Activities

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6.8 Quick quiz on | 6.8 Exercise

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Select your pathway

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

Remember and understand

1. MC Identify which of the following substances is likely to be found in waste water.
   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.
   1. Bacteria in the tank breaks the sewage down.
   2. Clean water flows out of the tank.
   3. The sewage becomes a thick, smelly sludge.
   4. The sludge sinks to the bottom of the tank.
   5. Sewage enters the septic tank.
3. Complete the passage, which describes the processes involved in the primary and secondary treatment of sewage, using the following words. (*Hint:* You won't need to use all of the words.)

   Word bank: 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. Waste water may be stored in a series of one-metre-deep __________ for two to four months, where suspended solids can __________. Bacteria in the water break down dissolved substances and __________ the water further.

4. Make a list of 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 Why can't the same type of magnet be used for separating both aluminium and steel cans when recycling materials?
   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 aluminum and steel.

Apply and analyse

7. A certain type of shower provides water at a rate of 11 L per minute.
   a. If you have a five-minute shower, how much water do you use?
   b. If you showered once a day, how much water would you use from showering in a year?
   c. How much water would a family of four use showering in one year (assuming each has a 5-minute shower every day)?
8. Describe how paper and cardboard are separated from other recyclable materials.
9. What happens to recycled glass after it is separated from other materials in a recycling plant?
10. Suggest why disinfectants that kill bacteria should not be poured down a septic system.
11. Why do people, rather than machines, manually separate some of the recycling mixture?
12. Complete a table to show the following information about separating recyclable rubbish. For each method, identify:
    a. the material removed from the flow of rubbish
    b. the properties of the recycled material that allow it to be separated from the mixture.

TABLE Comparing different methods of separating recyclable rubbish

Method	What is removed	Properties
a. Sorting by hand		
b. Magnet		
c. Air classifier		
d. Lasers		
e. Electricity		

13. What roles might engineers, biologists and environmental scientists 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

14. SIS Find out the kind of treatment (primary or secondary) that is used for the sewage treatment system in the capital city of your state or territory. Where does the treated water go? How suitable do you think this system is for a large city?
15. SIS Find out who is responsible in your area for the collection of waste that cannot be tipped down the kitchen, bathroom or laundry sinks, and how often it is collected.
16. SIS Design a poster or summary that explains which plastics can be recycled, including an explanation of symbols and images. Check with your local council for its recycling guidelines. Compare the properties of plastics that can be recycled with those that can't.

Fully worked solutions and sample responses are available in your digital formats.

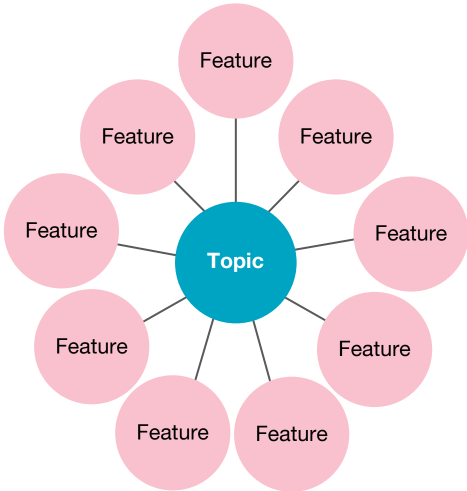
LESSON
6.9 Thinking tools — Single bubble maps

6.9.1 Tell me

What is a single bubble map?

A single bubble map is used to show the characteristics or features of a single topic. They are sometimes called sunshine wheels or spider diagrams. A bubble map is used when you want to show how one idea can be broken down into subtopics or features that all have the same weighting, or when showing a hierarchy (or order) isn't needed.

FIGURE 6.39 You can summarise what you know about a single idea with a single bubble map.



What is a single bubble map used for?

Single bubble maps are a good tool to use for summarising what you know about a single idea and remembering the main parts of a bigger topic. If you need to divide your topic into more than one level, a single bubble map is not the right tool. (For showing more than one level of information coming from your topic, try using a concept map.)

For example, you might use a single bubble map to show:
- the types of chocolate in a box
- the substances that are mined at a specific mine site
- the physical features of an animal.

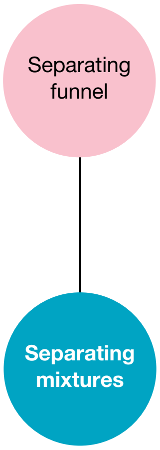
Because single bubble maps show the parts of one idea, they are a great tool for summarising — for example, summarising the subtopics in this chapter to help with revision.

6.9.2 Show me

Follow these steps to create a single bubble map.
1. Draw a circle (or square) in the centre of a sheet of paper. Write your main idea or topic in the shape.
2. Think of an example, part or feature that relates to your main idea. Write that in a circle (or shape) attached to your main topic with a line.

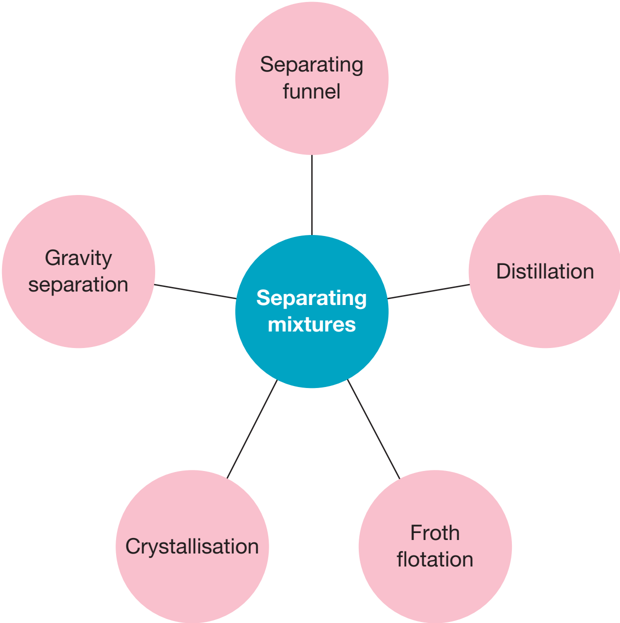
FIGURE 6.40 Creating a single bubble map — Step 1

FIGURE 6.41 Creating a single bubble map — Step 2



3. For each new example, part or feature, attach a new circle to your central topic. Figure 6.42 shows a single bubble map of the methods of separating mixtures.

FIGURE 6.42 A single bubble map — Step 3



6.9.3 Let me do it

6.9 Activities

1. Create your own single bubble map to show what you have learned about one aspect of separating mixtures. Remember, this kind of diagram is for showing the basic or most important idea only. Create a bubble map for each of the following.
   a. Common kitchen products that are not safe to tip down the kitchen sink
   b. Different components of blood that the Australian Red Cross separate
   c. Different substances in your favourite fizzy drink
   d. Common chemicals added to drinking water

Fully worked solutions and sample responses are available in your digital formats.

LESSON
6.10 Project — The diamond flush

Scenario

Having only just been toilet-trained, your little brother seems fixated on dropping stuff into the toilet and flushing it away. He has flushed away all sorts of things — Lego blocks, shopping lists, dog biscuits and even the occasional goldfish get put down the U-bend. It all seemed very funny until one day when he flushed away some really valuable things including a diamond ring, a pair of tiny diamond stud earrings, a wallet and a cultured pearl necklace. Your mum is absolutely frantic; but maybe, if you can track down where in the sewerage system they went, you have a chance of getting some things back for her!

Your task

Choose one of the valuable items and determine the most likely place that the missing object would be found. To do this you will need to do the following:

1. Research the pathway taken by the sewage after it leaves your house and the different processes that the sewage (and the object) would be subjected to as it undergoes treatment.
2. Put together a PowerPoint presentation that:
   a. explains the pathway along which the object would have travelled once it left the house
   b. explains the pathway through the sewage treatment systems that it would have passed through
   c. identifies where in the treatment system it is most likely to be found.

FIGURE 6.43 How would you find something accidentally flushed down the toilet?

on Resources

ProjectsPlus The diamond flush (pro-0070)

LESSON
6.11 Review

Hey students! Now that it's time to revise this topic, go online to:

Review your results

Watch teacher-led videos

Practise past VCAA exam questions

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Access your topic review eWorkbooks

on Resources

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-11311	ewbk-11313	ewbk-11315

6.11.1 Summary

Pure substances and mixtures

- All the parts of a pure substance are the same, whereas a mixture is made up of two or more different pure substances. Examples of pure substances include oxygen, silver, water and carbon dioxide. Examples of mixtures include salty water, milk, air and soil.
- A mixture can be separated according to specific properties of its components.

Types of mixtures

- A solution consists of solute dissolved in a solvent. An example is when salt (solute) dissolves in water (solvent) to form a salt solution.
- Solutes can be solids, liquids or gases.
- Solutions where water is the solvent are described as aqueous solutions.
- Solubility refers to the amount of solute that dissolves in a particular amount of solution.
- A concentrated solution has a large amount of solute dissolved whereas a dilute solution has a small amount of solute dissolved.
- Solids that do not dissolve in a liquid form suspensions. They either settle to form a sediment or float on top of the liquid.
- The particles in a colloid are too small to settle.
- An emulsion is a type of colloid that has one liquid spread evenly through another. Mayonnaise is an example of an emulsion.

Separating mixtures

- The processes of filtering (solid from liquid), sieving (smaller particles from larger particles), decanting (liquid from solid or denser liquid), distillation (liquid from solution or liquids with different boiling points), evaporation (liquid from solution), crystallisation (solid from solution), chromatography (for example, liquids from liquids) and using a separating funnel (less dense from more dense liquid) can be used in separating mixtures.
- Filtering (red and white blood cells) and centrifuging (heavier substances sink to the bottom of a container when spun) can be used in the isolation of blood products,
- Distillation and evaporation may be used to purify water. Pure water can be obtained after evaporation, using a condenser which converts the water vapour back to liquid water to be collected.
- Separation techniques used by First Nations Australians include winnowing, yandying, filtering, cold pressing and steam distilling.
- Winnowing is using an air current to separate seeds from their outer layer and other debris.

- Yandying is a process that removes less dense particles, such as sand, ash and dirt, from denser desirable seeds.
- Cold pressing involves pressing at low temperatures to produce oils or pulp.
- Steam distilling uses water vapour to extract aromatic oils and other substances from plant matter.

Science as a human endeavour

- Separation processes used in industry include methods such as distillation, centrifuging and chromatography. Other examples include:
  - froth flotation in the separation of copper ore
  - gravity separation for gold
  - evaporation to produce skim milk
  - filtration to remove solid impurities in wine.
- Salt is separated from sea water in desalination plants by reverse osmosis.
- Common contaminants found in water include animal waste, pesticides, detergents, chemicals and salt.
- Water is made safer by adding chlorine, fluoride and lime, and through flocculation.
- Sewage is household waste water, whereas sewerage is the process by which sewage is removed.
- The processes by which sewage is treated involves filtering, settling, removing floatables, filtering through soil, breakdown by bacteria and further settling over time.

6.11.2 Key terms

aqueous solutions solutions in which water is the solvent
biodegradable able to break down or decompose easily in the environment
biostimulants substances that stimulate processes of living organisms to enhance their growth
booms devices that float on the surface of the ocean and assist in containing oil spills by extending below the oil spill
buoyant able to float on a liquid
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 reaction a chemical change in which one or more new chemical substances is produced
cold pressing pressing at low temperatures to produce oils/pulp
colloid a mixture in which extremely small particles of one substance are spread evenly throughout another substance
concentrated a solution containing a large amount of solute
condense change state from gas to liquid
contaminated when a useful substance contains one or more other substances that affect its use
coolamon First Nations Australians' vessel for carrying objects
crystallisation a separation technique that uses evaporation to separate the parts of a solution, leaving the solute as crystals
decanting pouring liquid off the top when sediment has settled to the bottom of the container
dilution the process of adding more solvent to a solution to make it less concentrated
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
emulsion a colloid where droplets of one liquid spread evenly through another
evaporate change state from liquid to gas
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 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
forensic scientists people who use methodical gathering and analysis of scientific evidence to establish facts that can be presented in a legal proceeding
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
gravity separation separation of heavier particles in a mixture, by shaking or spinning them
helitorch a device used to drop flaming fuel onto another substance in order to ignite it
heterogeneous mixture a mixture in which particles are spread unevenly
homogeneous mixture a mixture in which particles are spread evenly
immiscible liquids liquids that will not mix, such as oil and water
insoluble a substance that will not dissolve in a liquid
landfill an area set aside for the dumping of rubbish
manufacturing processes processes used to make products
matter everything that takes up space and has mass is matter
mixture a substance that is made by a combination of two or more components, which are easy to separate
oil spill dispersants chemicals that when sprayed onto an oil spill, can break the oil into smaller particles
osmosis the process of separating using a membrane through which one constituent cannot pass
paper chromatography method of separating a mixture of different colours positioned on filter paper using a solvent
pollution the introduction of harmful substances or products into the environment
pressure the force exerted per unit area
properties the qualities and characteristics of materials and the substances that they are composed of
pure substance a form of matter that cannot easily be separated into its components
raw materials materials before they are made into a final form
recycling treating items such as glass, paper, plastic, aluminium and steel so that new products can be made from them
residue the material remaining as a solid on a filter paper after a liquid passes through in the filtration procedure
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
saturated unable to dissolve any more solute
sediment the insoluble material that collects at the bottom of a container when suspensions are left to stand
separating funnel a pear-shaped glass container, with a tap at its base, used to separate two liquids that do not mix
septic tank a sewage treatment system placed underground in backyards of houses not connected to town sewage treatment plants
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
skimmers devices dragged by boats that scrape the oil off the surface
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
steam distilling process of using water vapour to extract aromatic oils and other substances from plant matter
surfactants substances that can break up substances such as oil into smaller particles
suspended hanging, not falling or sinking
suspension a mixture of an insoluble substance in a liquid or gas
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
transparent see-through; allowing light to pass through so objects behind can be seen distinctly
volatility how readily a substance evaporates or becomes a vapour
winnowing using an air current to separate seeds from their outer layer and other debris
yandying process that removes less dense particles, such as sand, ash and dirt, from denser desirable seeds

Resources

eWorkbooks
Study checklist (ewbk-11304)
Reflection (ewbk-11303)
Literacy builder (ewbk-11305)
Crossword (ewbk-11307)
Word search (ewbk-11309)

Digital document Key terms glossary (doc-39589)

Practical investigation eLogbook Topic 6 Practical investigation eLogbook (elog-2031)

6.11 Activities

learnon

6.11 Review questions

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
1, 2, 4, 5, 7, 10, 12, 17, 20, 22	3, 6, 9, 13, 14, 16, 18, 23, 25, 27	8, 11, 15, 19, 21, 24, 26, 28, 29, 30

These questions are even better in jacPLUS!

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- Access sample responses
- Track results and progress

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Remember and understand

1. Categorise the following substances according to whether they are pure substances or mixtures.

TABLE Comparing pure substances and mixtures

Substance	Pure substance	Mixture
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. Match the ingredients of a cup of coffee to their part in the mixture.

TABLE Ingredients in black instant coffee

Component	Ingredient
a. Solute	
b. Solvent	
c. Solution	

3. **MC** How can you tell whether a mixture in water is a solution or a suspension?
   A. A solution will be cloudy, and a suspension will be clear.
   B. Both are the only mixtures that are clear.
   C. A solution will be clear, and a suspension will be cloudy.
   D. A solution is solid, and a suspension is gas.
4. **MC** Identify which of the following substances is a mixture.
   A. Silver **B.** Distilled water **C.** Smoke **D.** Nitrogen gas
5. **MC** A water sample taken from a river that shows a brown colour is most likely to be which of the following?
   A. Solution **B.** Colloid **C.** Suspension **D.** Emulsion
6. Identify the emulsions from the following list.

TABLE Identifying emulsions

Substance	Emulsion	Not an emulsion
A. Mayonnaise		
B. House paint		
C. Water		
D. Sand		
E. Hair conditioner		
F. Soft drink		

7. **MC** 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
8. How would you 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

9. Match the separation techniques to their description and examples.

Method of separation	Description of how it works	An example of how it is used in the home or in industry
a. Filtration	A. 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 perfumes and wine
b. Distillation	B. A device or substance allows some substances to flow through but prevents others from flowing through.	ii. Tea strainer
c. Crystallisation	C. 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	D. 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 the bottle when red wine is poured
e. Decanting	E. 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	F. A liquid is poured off after a sediment has formed at the bottom of the container.	vi. Analysing stains, dyes and inks
g. Centrifuging	G. A solution is heated to leave a solid dissolved in a solvent behind as crystals.	vii. Separating blood cells from plasma; separating cream from milk
h. Chromatography	H. 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

10. MC A separating funnel works when two substances have different which of the following?

A. Melting points B. Colours C. Boiling points D. Densities

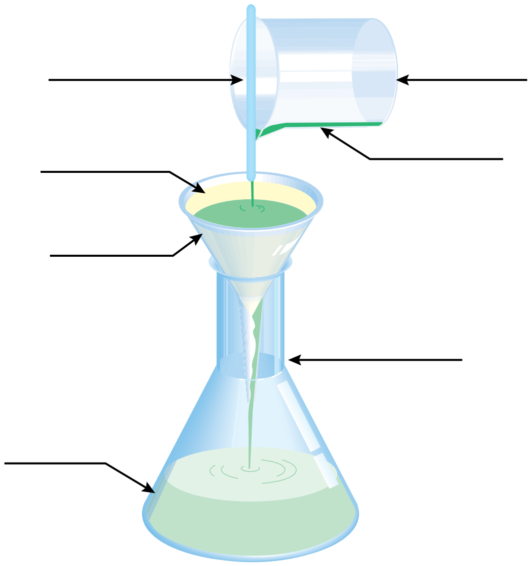
11. MC What is the purpose of the S-bend in the toilet?

A. Prevents smells escaping from the sewer into the house
B. Helps the waste move quickly down the pipe
C. Allows for a clear flow of water to move from the tank to the bowl
D. Recycling water for reuse

Apply and analyse

12. 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.
13. Imagine you dropped plastic nails in the sawdust in woodwork class. Propose three reliable, safe ways of separating the nails from the sawdust.

14. The diagram provided 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.



15. You have been asked to analyse some salt-contaminated soil and to propose a method for separating the salt from the soil.
   a. **SIS** 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.
16. Pasta is cooked by boiling it in water. It sinks to the bottom of the saucepan when it is left to stand.
   a. Which type of mixture is the pasta and water?
   b. Describe two methods that could be used to separate the pasta.
   c. Which of the two techniques is better for separating the pasta and water?

17. 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
18. **SIS** 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. How would you remove the dirt from the muddy water so that you could drink the water?
19. Explain the difference between froth flotation and flocculation.
20. Explain why chlorine is added in small amounts to the water supplies of many cities.
21. Oil floats on water. When detergent is added, the oil forms droplets in the water that do not settle. What type of mixture has been formed? Justify your answer.
22. Muddy water is an example of a colloid. Describe how a colloid is different from other suspensions.
23. Mayonnaise is an example of an emulsion, which is a type of colloid. Explain how an emulsion is different from other colloids.
24. 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

25. Use a labelled diagram to illustrate the differences between the processes of osmosis and reverse osmosis used in desalination plants.
26. **SIS** 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.
27. How does flocculation make the particles in a suspension settle out?
28. Explain why blood collected by the Red Cross Blood Service needs to be separated before it is used.

29. **SIS** Design a mixture that cannot be separated by the methods described in this chapter. Explain the basis for your design.

30. Read the story 'An ocean of salt' and use the information to answer the following questions.
   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.
   Spend some time researching ancient methods of salt separation before creating your flowchart. If using the internet, use search words such as 'ancient salt production', 'Roman times salt' and 'salt evaporation'.

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 sea water. The sea water, 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 sea water.

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 sea water.

Fully worked solutions and sample responses are available in your digital formats.

Online Resources

on Resources

Below is a full list of **rich resources** available online for this this topic. These resources are designed to bring ideas to life, to promote deep and lasting learning and to support the different learning needs of each individual.

6.1 Overview

eWorkbooks
- Topic 6 eWorkbook (ewbk-11266)
- Student learning matrix (ewbk-11268)
- Starter activity (ewbk-11269)

Practical investigation eLogbooks
- Investigation 6.1 Design and separate (elog-2029)
- Topic 6 Practical investigation eLogbook (elog-2031)

Video eLesson
- Separating coloured markers (eles-3526)

6.2 Mixtures and solutions

eWorkbooks
- Labelling a flowchart — pure substances and mixtures (ewbk-11271)
- Labelling the components of a solution (ewbk-11273)
- Solutions and solubility (ewbk-11277)
- Mail room mayhem (ewbk-11275)

Practical investigation eLogbooks
- Investigation 6.2 What is soluble in water? (elog-2033)
- Investigation 6.3 Froth and bubble (elog-2035)

Interactivities
- Labelling a flowchart — pure substances and mixtures (int-8050)
- Labelling the components of a solution (int-8051)
- A solute dissolves in a solvent and creates a solution (int-3435)

6.3 Separating solids from mixtures

eWorkbooks
- Labelling the equipment used in filtering (ewbk-11279)
- Sieving, filtering or decanting (ewbk-11281)
- The pool shop (ewbk-11283)

Practical investigation eLogbook
- Investigation 6.4 Filtration in the laboratory (elog-2037)

Video eLessons
- Decanting (eles-2214)
- Density (eles-2546)

Interactivities
- Labelling the equipment used in filtering (int-8052)
- Sieving and decanting (int-8053)
- Mixtures (int-0224)
- Adding an insoluble substance to a liquid (int-3436)

6.4 Other separating techniques

eWorkbooks
- Labelling the components of a separating funnel (ewbk-11285)
- Centrifuging and separating (ewbk-11287)

Video eLesson
- Centrifuging (eles-0061)

Interactivities
- Blood donation in Australia (int-3439)
- Labelling the components of a separating funnel (int-8055)

Weblink
- Follow the blood bag: How Australian Red Cross processes life-saving donations

6.5 Separating solutions

eWorkbooks
- Labelling the equipment used in distillation (ewbk-11288)
- Labelling the components of solar distillation (ewbk-11291)
- Chromatography (ewbk-11293)
- Crystallisation and distillation (ewbk-11295)

Teacher-led video
- Investigation 6.7: Crystallisation (tlvd-10656)

Practical investigation eLogbooks
- Investigation 6.5 Making a simple water still (elog-2039)
- Investigation 6.6 Separating colours (elog-2041)
- Investigation 6.7 Crystallisation (elog-2043)

Video eLessons
- Distillation (eles-0060)
- Paper chromatography (eles-2548)

Interactivities
- Labelling the equipment used in distillation (int-8056)
- Labelling the components of solar distillation (int-8057)
- How chromatography works (int-3442)

Weblink
- Separating mixtures

6.6 Separation in industry

eWorkbook
- Separation in industry (ewbk-11297)

Practical investigation eLogbook
- Investigation 6.8 Separation by flotation (elog-2045)

Video eLessons
- Gold panning (eles-2547)
- Gravity separation and plants (eles-2215)

Interactivities
- Cleaning up an oil spill (int-3438)
- The homogenisation process (int-3437)

Weblink
- How do we clean up oil spills?

6.7 Removing contamination from water

eWorkbook
- Clean and clear? (ewbk-11299)

Practical investigation eLogbook
- Investigation 6.9 Treating your own dirty water (elog-2047)

Weblink
- Australia Water Association — desalination plants

6.8 Separating our waste

eWorkbook
- Treating waste water (ewbk-11301)

Video eLessons
- Treating sewage (eles-0059)

Interactivity
- The recycling plant (int-3434)

Weblinks
- Wastewater treatment process
- Melbourne Water — what is sewerage?

6.10 Project — The diamond flush

ProjectsPlus
- The diamond flush (pro-0070)

6.11 Review

eWorkbooks
- Topic review Level 1 (ewbk-11311)
- Topic review Level 2 (ewbk-11313)
- Topic review Level 3 (ewbk-11315)
- Study checklist (ewbk-11304)
- Reflection (ewbk-11303)
- Literacy builder (ewbk-11305)
- Crossword (ewbk-11307)
- Word search (ewbk-11309)

Digital document
- Key terms glossary (doc-39589)

To access these online resources, log on to **www.jacplus.com.au**

7 Earth in space

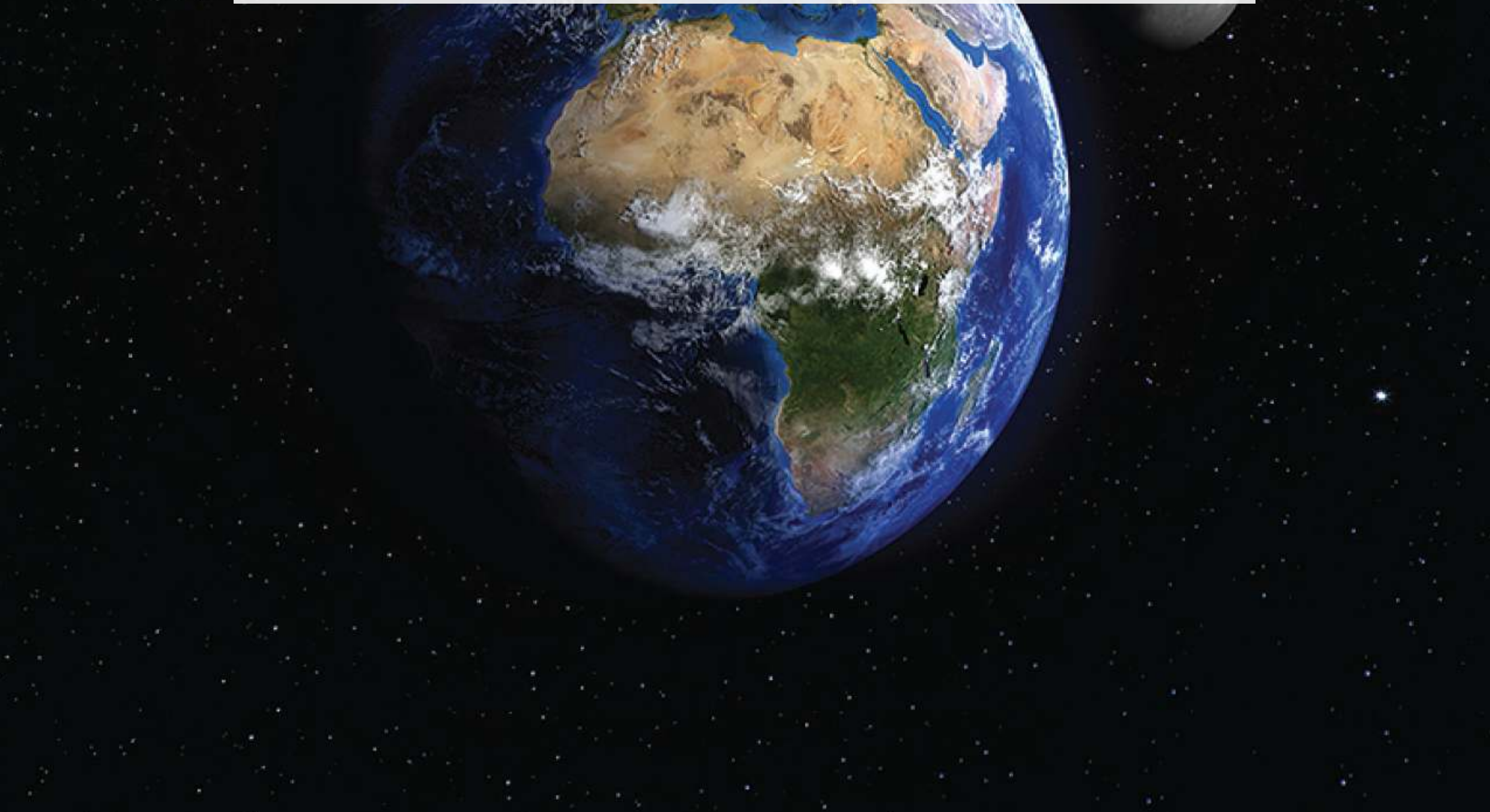
CONTENT DESCRIPTION

Model cyclic changes in the relative positions of the Earth, sun and moon and explain how these cycles cause eclipses and influence predictable phenomena on Earth, including seasons and tides (AC9S7U03)

LESSON SEQUENCE

SCIENCE INQUIRY AND INVESTIGATIONS

Science inquiry is a central component of Science curriculum. Investigations, supported by a **Practical investigation eLogbook** and **teacher-led videos**, are included in this topic to provide opportunities to build Science inquiry skills through undertaking investigations and communicating findings.



LESSON
7.1 Overview

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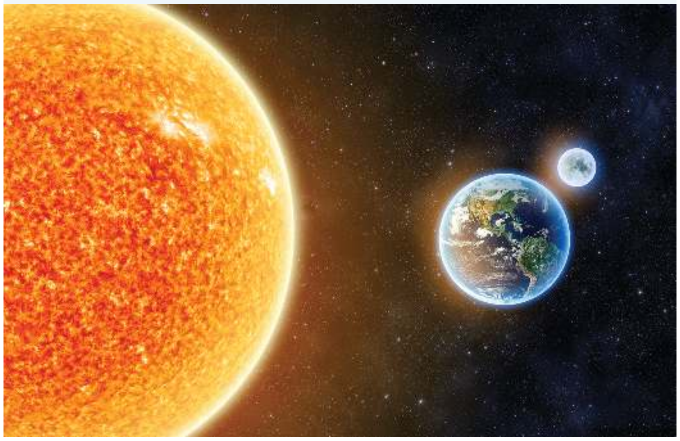
7.1.1 Introduction

Earth is just a tiny speck in a vast **universe**. It's 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.



universe all of space and the matter and energy contained in it

solar system a group of bodies that revolve around a star

on Resources

Video eLesson Earth within the universe (eles-3528)

Earth is just a tiny speck in a vast universe. Watch this video to see a fly-through space, from Earth to the edge of our Milky Way galaxy, within an even larger universe.

7.1.2 Think about Earth in space

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?

7.1.3 Science inquiry

elog-2051

INVESTIGATION 7.1

The changing Moon

Aim

To observe and explain the phases of the Moon

Method

1. Observe the Moon every third or fourth evening over a period of at least two weeks. Observations over one whole month would be best. Try to make your observations as close to sunset as possible so that you know where the Sun is.
2. Write your results in a table similar to that shown in the Results section.

Results

Record the date, the time and the shape of the sunlit part of the Moon in your table.

TABLE Observing the phases of the Moon

Date	Time	Shape of the Moon	Comment about the position of the Sun and the shape of the Moon

Discussion

1. Each time you make an observation, make a comment about the position of the Sun and suggest why the Moon has the shape that you have observed. If you live near a beach, comment about the tides at your beach. Is there a big difference between high and low tides or does the water stay at roughly the same level all day?
2. What would the Moon look like if it was viewed from somewhere in the Northern Hemisphere? Why do you think it looks that way?
3. Estimate the percentage of the Moon's 'face' which is visible. Draw a graph of your observations. Describe the shape of your graph.
4. Use your observations to predict the shape of the Moon one week from now, and one month from now.

Conclusion

Summarise how the motion of the Moon and Earth causes the phases of the Moon and how this motion helps us predict the Moon's phases.

on Resources

eWorkbook Topic 7 eWorkbook (ewbk-11325)
Student learning matrix (ewbk-11329)
Starter activity (ewbk-11327)

Practical investigation eLogbook Topic 7 Practical investigation eLogbook (elog-2050)

LESSON
7.2 First Nations Australians' astronomy knowledge and understanding

LEARNING INTENTION

At the end of this lesson you will be able to investigate First Nations Australians' knowledge systems of astronomy, including phases of the Moon, solar and lunar eclipses, seasonal calendars and tides.

7.2.1 The oldest astronomers in the world

First Nations Australians have continuously inhabited the continent for at least 65 000 years. They constitute the oldest human civilisations, and are also the oldest astronomers in the world. They developed different convenient ways of observing the celestial bodies like the Sun, Moon and stars for navigation purposes, but also for timekeeping, the harvesting of different foods and when to practice cultural burnings.

First Nations Australians' knowledge is passed down generations through oral traditions. These can include song, dance, ceremony and storytelling.

SCIENCE AS A HUMAN ENDEAVOUR: The earliest astronomers

Almost all 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 got here. First Nations Australians 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 group of stars do vary from tribe to tribe.

The emu in the sky

Rock engravings carved by the Guringai Peoples of the northern outskirts of Sydney show an emu in the sky 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 engravings, it is the emu egg-laying season. It signals that 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 7.2 The Dark Emu of First Nations Australians' sky lore rising in a moonlit sky over the Tasman Sea from a beach near Lakes Entrance, Victoria

Chopped to bits

The Yolngu 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.

Many First Nations Australians' 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 and for some First Nations Australian cultures, solar and lunar eclipses were considered negative and linked with disease and death.

Several (but not all) First Nations Australian 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.

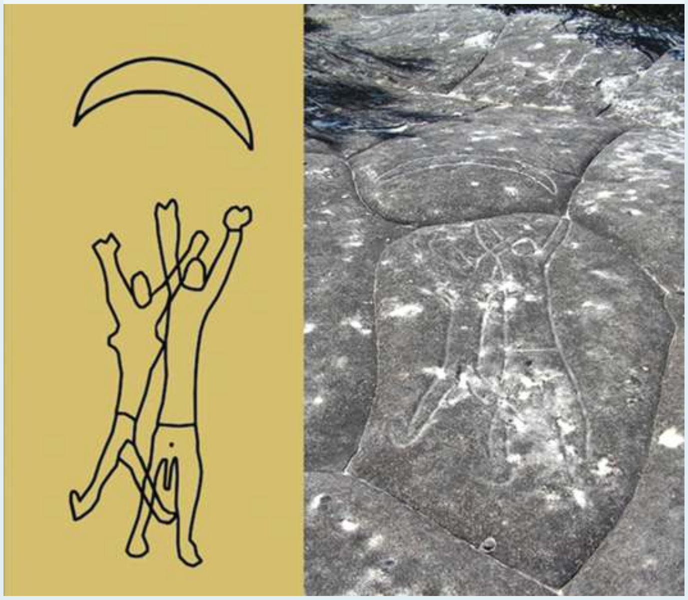
ACTIVITY: Traditional First Nations Australians' knowledge regarding solar and lunar eclipses

1. Work in pairs to research the aspects of traditional First Nations Australians' knowledge about solar and lunar eclipse. Note: information found will differ between nation groups. The following questions can be used to guide your research.
   a. How did First Nations Australians perceive the Sun and the Moon?
   b. How did First Nations Australians perceive eclipses?
   c. How did First Nations Australians explain solar and lunar eclipses?
   d. What evidence is there that First Nations Australians understood the phenomena of solar and lunar eclipses?
2. Prepare a short presentation, including visuals and diagrams, on First Nations Australians' knowledge of solar and lunar eclipses.
3. Present your findings to your class.

ACTIVITY: Deciphering the meaning of the 'eclipse' rock carving at the Basin Track, Ku-ring-gai Chase National Park, NSW

1. Observe the engraving shown in figure 7.3. What do you think the crescent shape represents?

FIGURE 7.3 A rock engraving from the Ku-ring-gai Chase National Park, NSW



a. Compare and contrast the crescent shape in figure 7.3 with the different boomerang shapes shown in figure 7.4. Does it look like a boomerang?

FIGURE 7.4 Boomerangs come in a variety of shapes. Do you know which shape(s) of boomerang the traditional owners of Ku-ring-gai used?

b. Compare and contrast it with the appearance of the Moon throughout a lunar cycle (figure 7.5a) and during a lunar eclipse (figure 7.5b). Could the crescent represent the Moon?

FIGURE 7.5 a. Appearance of the Moon throughout a lunar month **b.** Timelapse of the 2018 total solar eclipse from Thailand

a.

b.

7.2.2 Predicting seasonal changes

First Nations Australians' seasons are organised differently than the traditional four-season calendar used today. By observing the movement and position of stars, First Nations Australians developed seasonal calendars. The properties of stars, such as their brightness and colour, are also used for predicting weather and seasonal changes.

First Nations Australians monitor the life cycles of the plants and animals, and link them to the seasons. This knowledge was recorded over time and is passed on to future generations.

In many First Nations Australian 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 whales' migration but marks the ideal time to look for dingo pups, as 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.

ACTIVITY: First Nations Australian' calendars

1. Go to the **CSIRO Indigenous seasons calendars** weblink and view the different calendars available online.
2. Choose any two Indigenous calendars and compare and contrast them. The following questions might guide you:
   - Where are the peoples who created these calendars?
   - Where is their traditional land?
   - How many seasons does their calendar have?
   - How do they mark the start and the end of the seasons?
   - Are their food sources available in all seasons?
3. Write down a comparative report about the two Indigenous calendars you have selected and share it with your class.

on Resources

Weblinks Indigenous seasons
CSIRO Indigenous seasons calendars

7.2.3 Understanding the tides

First Nations Australians 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.

ACTIVITY: Stone-walled intertidal fish traps

Use the internet or other resources to research stone-walled fish traps used by First Nations Australians and write a short paragraph explaining how tides are used to trap fish.

Communities living on the coast, such as the Yolngu 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 as 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: Using solunar charts to determine when to go fishing on Murray Island, Qld

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.

1. Research on the internet the solunar charts for Murray Island and note, over a one-month period, the best days to go fishing.
2. Note the phases of the Moon on those days. Do you notice a trend?
3. Research on the internet the tide times for Murray Island and note the tidal range, which is the height difference between high tide and low tide, on those days. You can use a table like the one below to organise the data you are collecting.

Good days to go fishing	Phase of the Moon	Tidal range (m)

4. Write a short paragraph to recommend when during the Moon cycle to go fishing.

7.2 Activities

learnon

7.2 Quick quiz on | 7.2 Exercise

Select your pathway

- LEVEL 1: 1, 2
- LEVEL 2: 3, 6
- LEVEL 3: 4, 5

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. How does the position of the emu in the sky influence the Guringai Peoples of New South Wales?
2. How do the Yolngu Peoples of Arnhem Land explain the phases of the Moon?
3. Besides Dreaming stories that are still told today, suggest evidence that First Nations Australians studied the night sky.

Apply and analyse

4. Use the following solunar chart for Cairns to answer the following questions.

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 tide
9	◐	1.2	0.4	Neap tide
16	○	2.0	2.1	Spring tide
23	◑	1.5	1.1	Neap tide
30	●	1.6	2.1	Spring tide

   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. Use the internet or other resources to find out the traditional knowledge associated by Torres Strait Islanders to Baidam, the Shark Constellation.
6. Explain why it is difficult to interpret the meaning of First Nations Australians' rock art, such as that displayed in figure 7.3.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
7.3 Earth in orbit

LEARNING INTENTION

At the end of this lesson you will be able to describe how Earth's tilt and it's position in space, relative to the Sun, influences the seasons and day/night cycles.

7.3.1 Paths through space

Earth is constantly moving through space. It does not move randomly but takes a specific path around the Sun called an **orbit**.

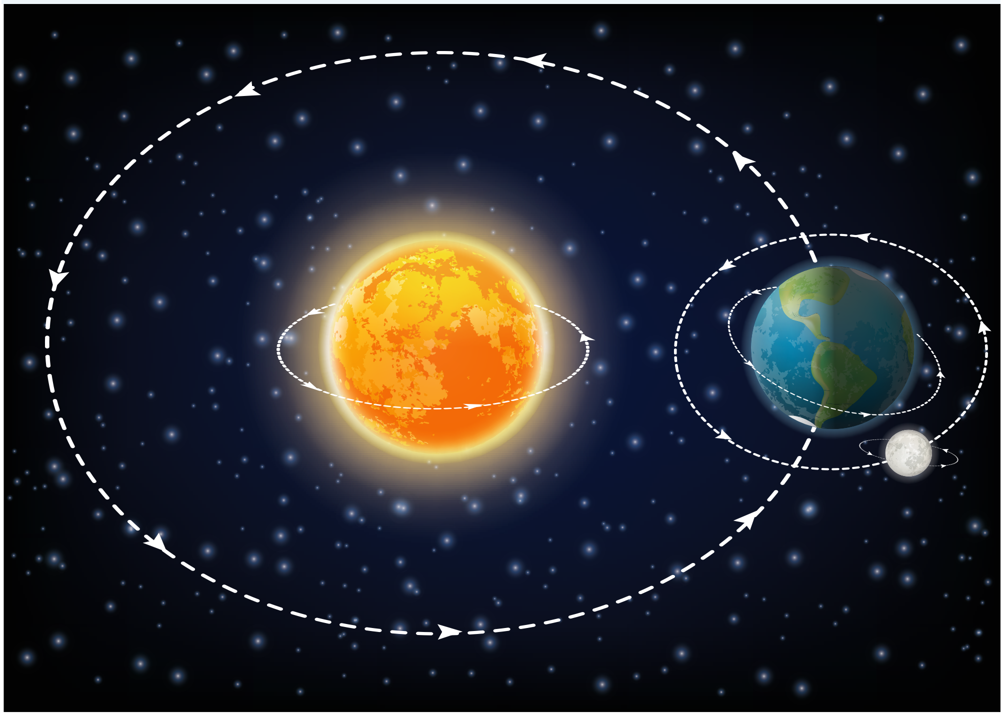
Earth's orbit is **elliptical**; it is almost, but not quite, circular. The Moon also moves in an orbit — it moves in an elliptical orbit around Earth. Other planets in our solar system also orbit the Sun. Many of these planets also have moons in orbit around them. Even the Sun follows a path through space.

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

elliptical an oval or egg shape; the shape of Earth's orbit around the Sun

eles-3529

FIGURE 7.6 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 also orbit the Sun. Earth's gravitational force on the Moon causes the Moon to orbit Earth. 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 that there are predictable cycles or patterns that repeat themselves. This allows us to measure and predict events such as day and night, the seasons, the phases of the Moon and the tides.

gravitational force an attractive force between two objects that have mass

axis an imaginary line from the North Pole to the South Pole that the Earth spins on

rotation the turning of an object about its own axis (between the North Pole and South Pole)

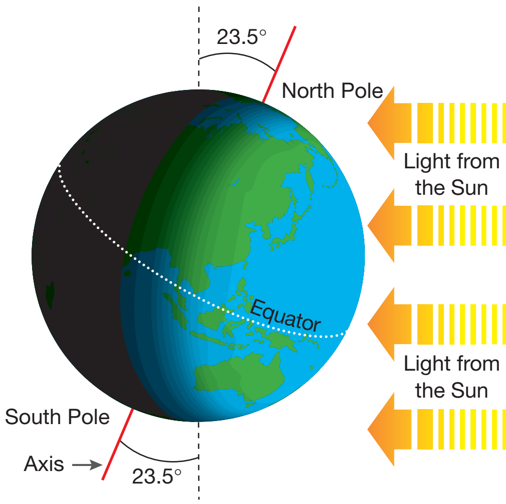
7.3.2 Night and day

In addition to orbiting the Sun, Earth also rotates on its own **axis**, as do all the other planets. 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 7.7. This **rotation** takes 24 hours to complete and results in day and night on Earth.

Earth rotates in an anticlockwise direction (opposite to the hands on a clockface) when viewed from above the North Pole, or a clockwise direction when viewed from above the South Pole. This also means that as you travel west, sunrise will happen later and later in the day. At night, the rotation of Earth makes the moons and planets appear to move in this same direction. This makes it seem like they are travelling from east to west.

As Earth rotates, the side facing the Sun receives light from the Sun and experiences day time (see figure 7.7). 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.

FIGURE 7.7 Only one half of Earth can face the Sun at any one time. This diagram shows Australia and part of East Asia in daylight.



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 because we don't feel like we are moving when we stand on the surface of Earth.

elog-2053

INVESTIGATION 7.2

Day and night

Aim

To model the cycle of day and night

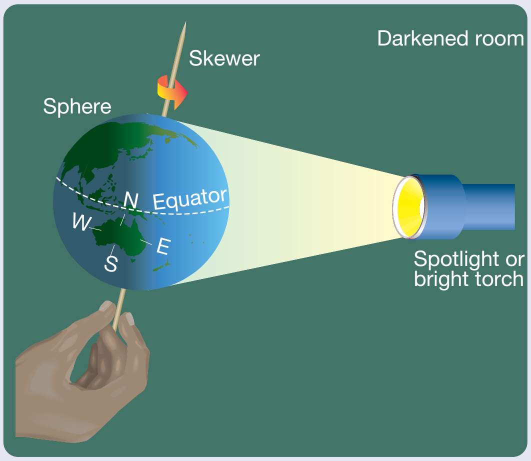
Materials

- 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 in 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 when Australia is lit up? Where is Australia when Africa is lit up? Explain why these continents experience daylight at different times.
2. How can we explain the apparent movement of the Sun across the sky?
3. How does this model help explain why night falls in Perth about two hours later than in Sydney and Melbourne?

Conclusion

Summarise your findings as to why the surface of Earth experiences day and night.

on Resources

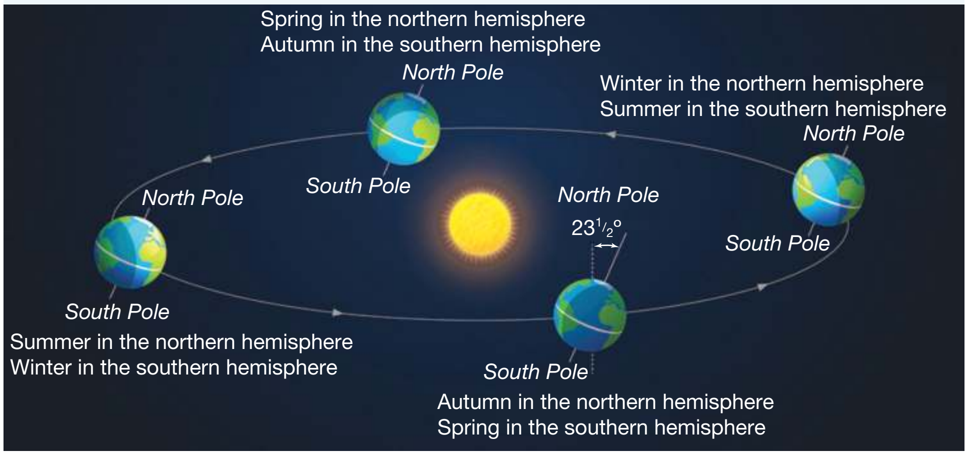
Interactivity Day, night and time zones (int-0006)

7.3.3 Earth's seasons

The seasons experienced by the Northern Hemisphere and Southern Hemisphere are different at the same time of the year. The tilt of Earth does not change; however, the part of Earth that gets the most direct sunlight changes. Figure 7.8 shows that, for one part of Earth's orbit, the Southern Hemisphere is tilted towards the Sun. For the other part of the orbit, the Southern Hemisphere is tilted away from the Sun. The opposite is true for the Northern Hemisphere.

ewbk-11330
int-8061

FIGURE 7.8 As the Earth orbits the Sun, the seasons change. This diagram shows the seasons as they are in the Southern Hemisphere.



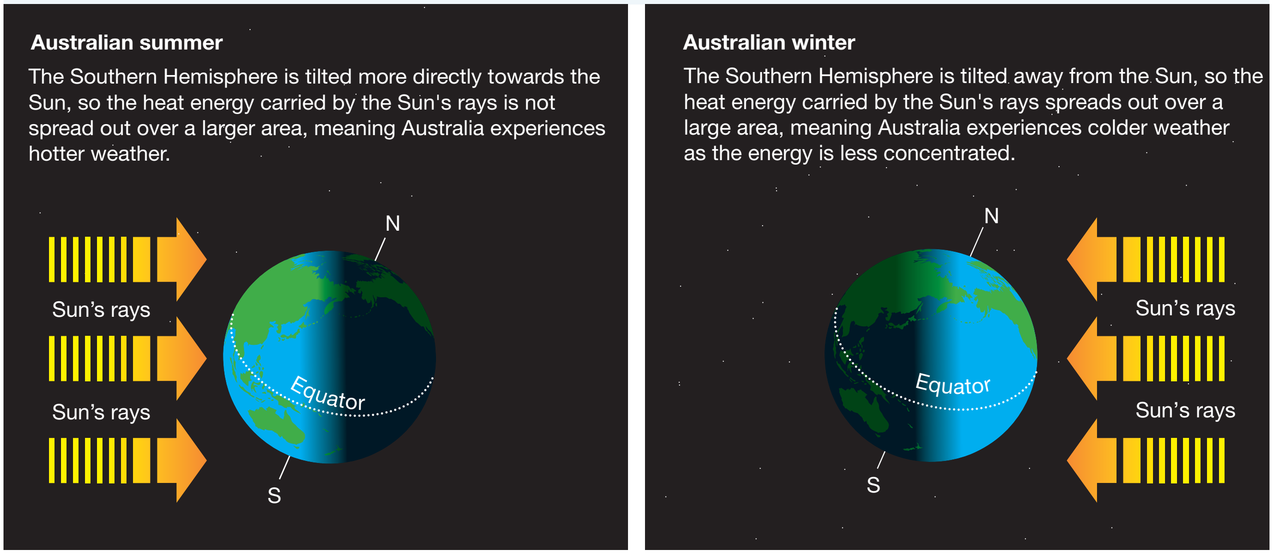
The Southern Hemisphere experiences summer when it is tilted towards the Sun. At that time, light from the Sun hits the Southern Hemisphere 'head-on'. Therefore, heat energy from the Sun is concentrated in a small area, leading to an increase in temperature, and warmer weather. At the same time, the 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, this results in lower temperatures during this time.

While it's winter in the Southern Hemisphere it's summer in the Northern Hemisphere. Between summer and winter, neither hemisphere is tilted towards the Sun. This happens during autumn and spring.

The light from the Sun is made up of many different parts. One part is visible light, which allows humans to see the world around us, and allows plants to perform photosynthesis. Sunlight also contains infrared light (or heat energy) and UV light (which can cause skin cancer). There are also small amounts of radio waves and microwaves in sunlight. The amount of each type of light reaching Earth's surface changes during a year. This leads to the different seasons and changes in day lengths; it also changes our chances of getting sunburnt!

FIGURE 7.9 The tilt of Earth's axis and its path around the Sun help explain the seasons.



on Resources

eWorkbook Sunrise, sunset and seasons (ewbk-11332)

7.3.4 Measuring time

Earth takes approximately 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. 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. Since Earth also moves, it can appear as if the Moon takes longer to complete its orbit: $29\frac{1}{2}$ days. Historically, this time period of $29\frac{1}{2}$ days is used to define a month. This time frame of $29\frac{1}{2}$ days is known as the lunar cycle (the time between one full moon to the next as observed on Earth).

Earth takes $365\frac{1}{4}$ 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 four years that averages out at $365\frac{1}{4}$ days.

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 the Sun.

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; however, that is not true. The summer solstice occurs when Earth's tilt towards the Sun is at a maximum and therefore the Sun appears at its highest point in the sky for a longer period of time.

Just like the seasons, the number of hours of daylight is determined not by the distance of Earth from the Sun, but by the angle at which the Sun's rays strike Earth. In summer, the Sun is high in the sky and provides light for a longer time.

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 in the Southern Hemisphere; this happens in June in Australia.

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, and the autumnal equinox, in March. On these days, Earth's axis is tilted neither towards nor away from the Sun.

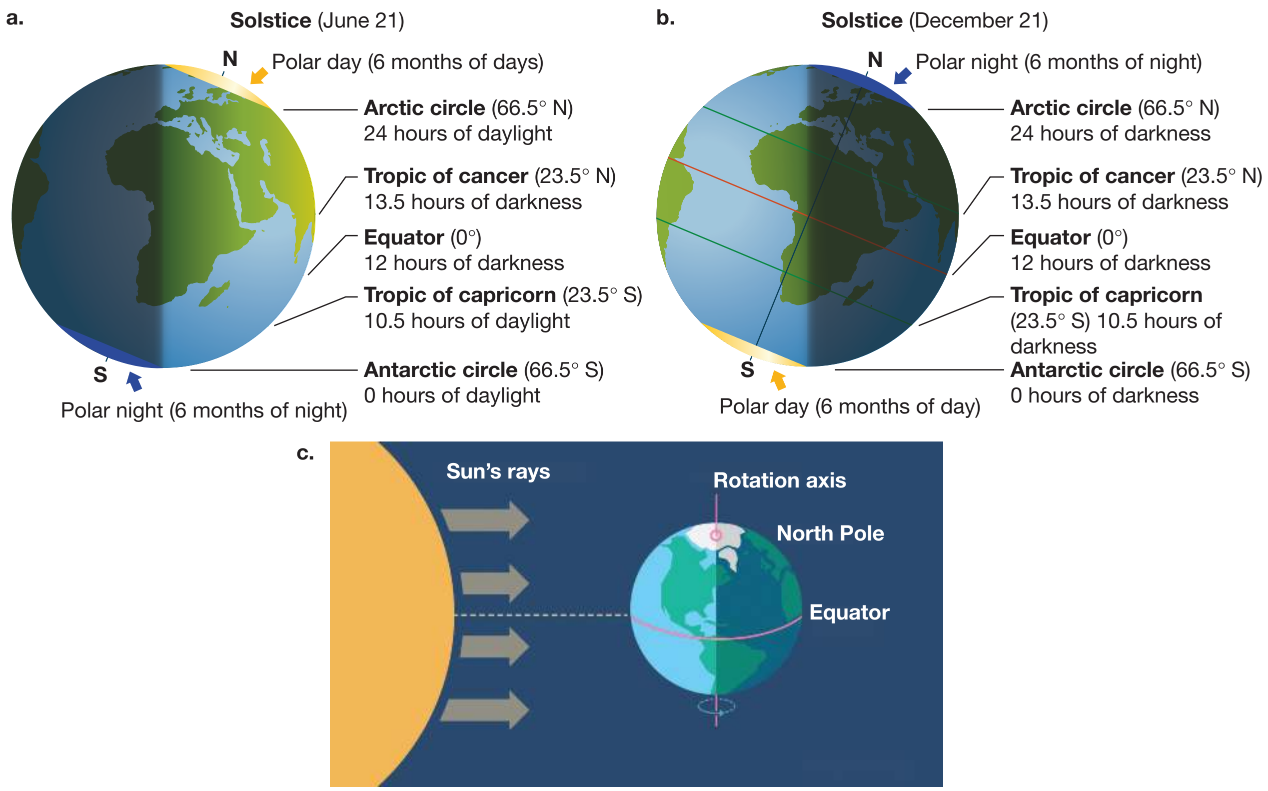
revolution movement around an orbit

summer solstice the day of the year with the most daylight hours

winter solstice the day of the year with the fewest daylight hours

equinox days with the same number of daylight hours as night hours

FIGURE 7.10 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. **c.** During the equinox, which occurs twice a year, there are equal hours of daylight and nighttime hours.



Source: https://www.timeanddate.com/

on Resources

Weblink Solstices and equinoxes in Melbourne

elog-2055

INVESTIGATION 7.3

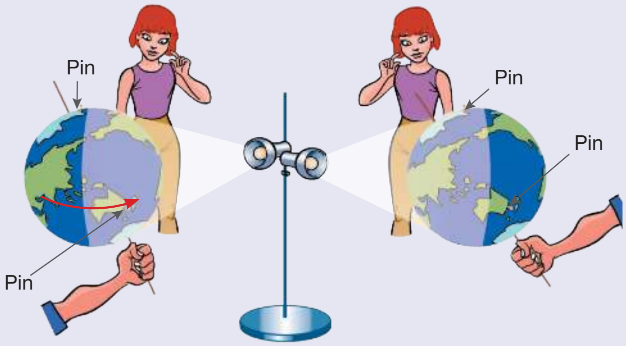
Long days, short days

Aim

To model the cycle of the seasons 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. Hold the skewer vertically. Push two pins into your sphere — one about where Sydney is and the other directly above it at the top of the sphere, near the skewer.
2. Set the spotlight up in a central place (such as on a table you can move around). Darken the room.
3. 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.
4. 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.
5. 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?
2. What does this tell you about the number of daylight hours in each hemisphere when the Southern Hemisphere tilts towards the Sun?
3. Which pin comes into the light first when the northern half of the sphere leans towards the light?
4. What does this tell you about the number of daylight hours in each hemisphere when the Northern Hemisphere tilts towards the Sun?

Conclusion

Summarise your findings in three to four sentences to explain why the seasons occur on the surface of the Earth.

7.3 Activities

learnon

7.3 Quick quiz on	7.3 Exercise

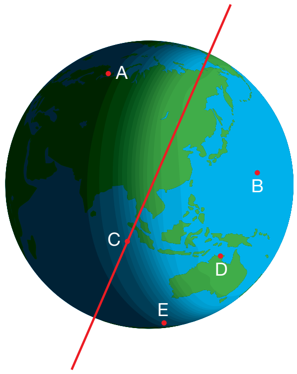
Select your pathway

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

Remember and understand

1. Explain the difference between the revolution and rotation of Earth.
2. How long does it take Earth to complete one:
   a. rotation
   b. revolution?
3. Outline why we experience day and night.
4. Explain why the Sun rises in the east and sets in the west.
5. During which season does Australia tilt towards the Sun?

Apply and analyse

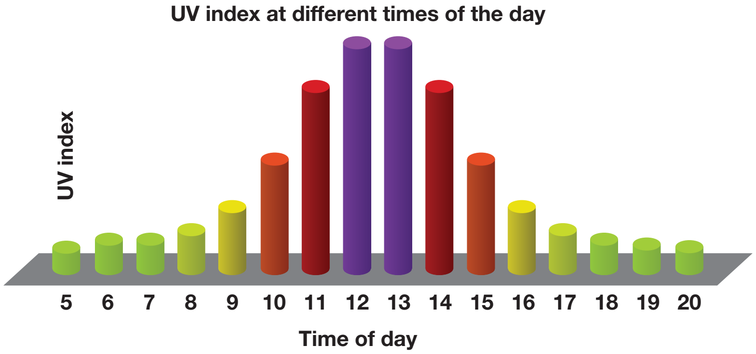


6. Use the diagram shown to answer the following questions.
   a. Identify which of the locations A, B, C, D and E:
      i. are in daylight
      ii. are experiencing summer
      iii. are experiencing the longest day
      iv. are experiencing the shortest day.
   b. In which of the locations that 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 is in darkness during the Southern Hemisphere's winter.
10. Explain why both the time and position of sunrise and sunset are not the same every day.
11. A day on Jupiter is less than 10 hours. This means it takes under 10 hours 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 kilometres every hour!
    a. Which planets in the solar system have the shortest and longest days?
    b. How long are these days?
    c. 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

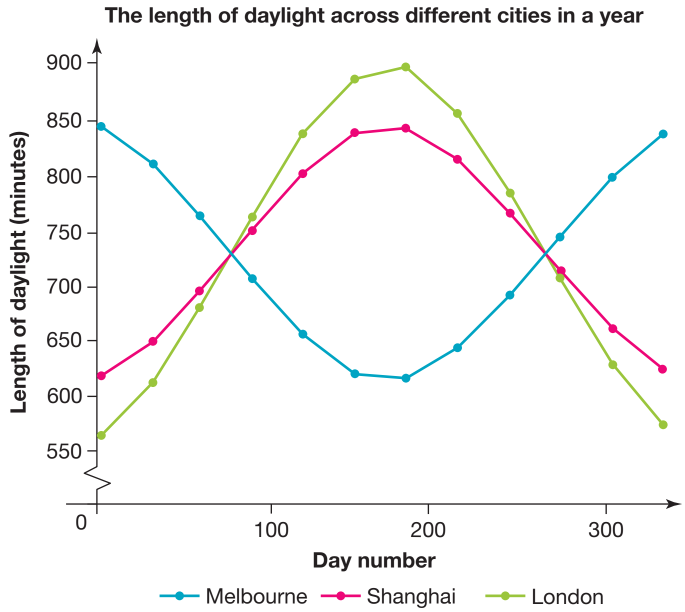
13. Observe the position of the shadow of a tree trunk or vertical pole from time to time on a sunny day.
    a. Explain how the shadow moves during the day from sunrise to sunset.
    b. How do you think prehistoric people explained the movement of the shadow?
    c. What does the shadow tell you about the Sun and Earth?
    d. How would you expect the length of the shadow to change from summer to winter?
    e. In ancient times, a vertical stick was used as a daylight clock. It was called a sundial. Describe the disadvantages of sundials.

14. SIS The following graph shows the UV index at different times on a summer day in Perth. (*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 Perth on this day.
c. Explain why the UV index varies throughout the day.

15. SIS 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?

16. SIS Use the internet or other resources to find out when and where the astronomer Al-Battānī lived and worked, and what contribution he made to understanding the seasons.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
7.4 The Moon

LEARNING INTENTION

At the end of this lesson you will be able to describe the differences between the surface of Earth and the surface of the Moon, and describe the sequence of the phases of the Moon and explain why these phases occur.

7.4.1 Looking up from Earth

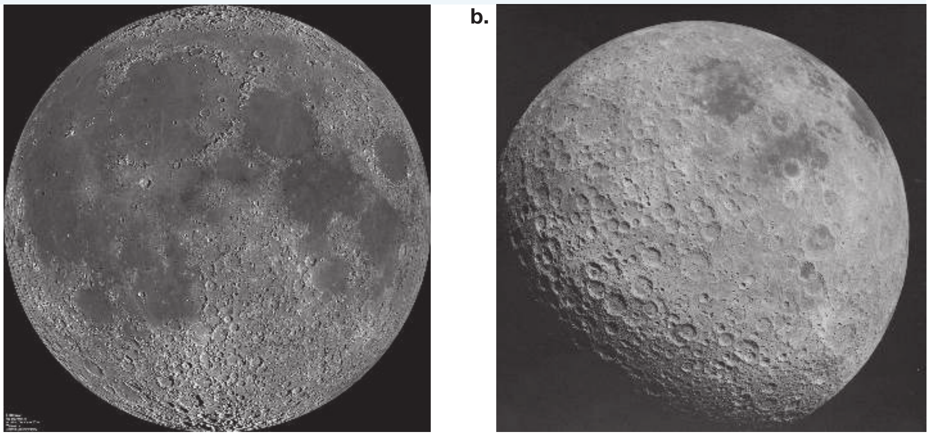
From Earth, the Moon is, by far, the brightest object in the night sky. The Moon is the only natural **satellite** of Earth. Its presence and changing appearance have raised questions, inspired myths and legends, shaped our calendar and even determined the dates of some religious holidays.

satellite a body such as a moon that orbits another celestial body of a larger size and mass

The Moon takes the same amount of time to complete one full turn about its own axis as it takes to orbit Earth, as seen from the surface of 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 — is facing 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 the edges of the far side. However, 41 per cent of its surface is never visible from Earth.

FIGURE 7.11 a. The near side and **b.** the far-side of the Moon

a. b.



Unlike Earth, the Moon has no atmosphere. 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.

Profile of the Moon

- Natural satellite of Earth
- Distance from Earth: 385 000 km (three days by spacecraft)
- Diameter at equator: 3475 km (Earth's diameter is 12 750 km)
- Period of orbit around Earth: about 27.3 days*
- Period of rotation about 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.

on Resources

eWorkbook Features of the Moon (ewbk-11334)

Video eLesson The surface of the Moon (eles-2224)

elog-2057

INVESTIGATION 7.4

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 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.

7.4.2 Phases of the Moon

The Moon is visible from Earth only because it reflects light from the Sun.

As the Moon orbits Earth, it turns so that the same side of the Moon always faces Earth. At night, when you are in darkness, the side of the Moon facing Earth is sometimes completely bathed in sunlight. You then 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. You are then unable to see the Moon.

When the side of the Moon facing Earth is partially bathed in sunlight and partially in shadow, you see only the part that is in sunlight. The different shapes of the Moon that you see from Earth are called **phases**. The diagram in figure 7.12 shows how the phases change during the $29\frac{1}{2}$-day period between one new moon and the next (as outlined in section 7.3.4, this is the length of time it takes for the Moon to complete one orbit as measured from the surface of Earth, which is linked with Earth's own rotation and orbit). This time between one full moon and the next is referred to as a **lunar month**. 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 7.12. Further south, in Adelaide or Hobart 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**. As the phases change between the full moon and the new moon, it is said to be **waning**.

full moon the view of the Moon seen from Earth when the whole of its near side is in sunlight

phases shapes observed in a repeated pattern of changes

lunar month the time period between the appearance of one new moon to the next, which equates to $29\frac{1}{2}$ days

waxing the change in the Moon's appearance between a new moon and the following full moon

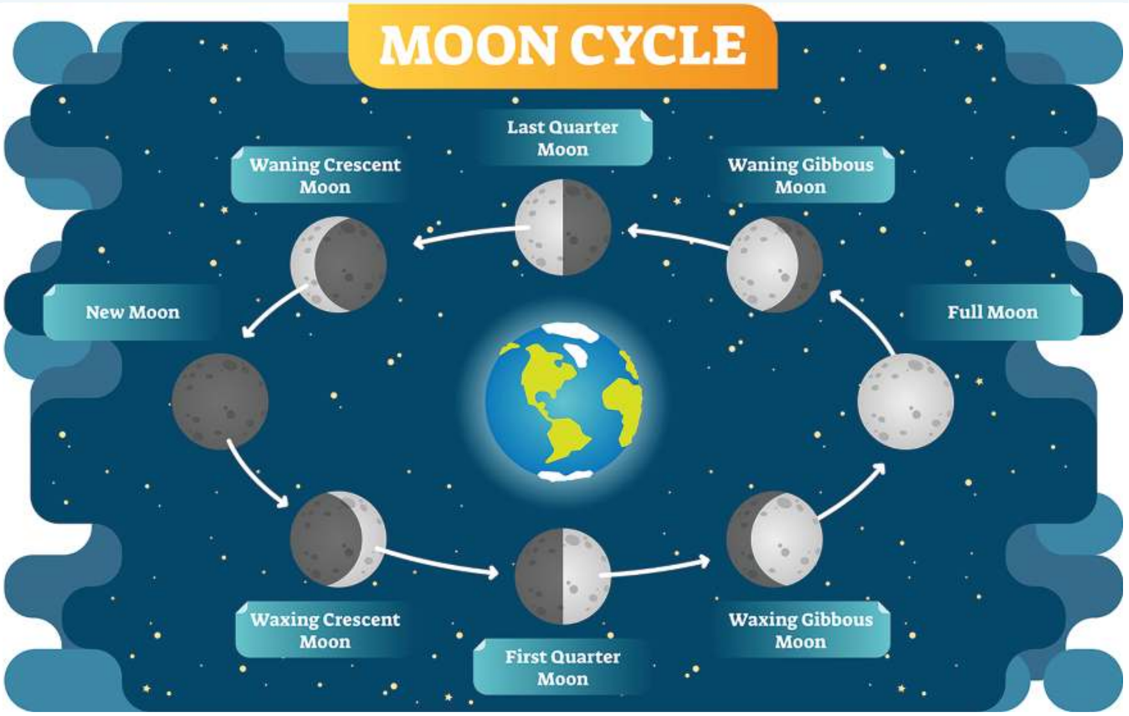
waning the change in the Moon's appearance between a full moon and the following new moon

ewbk-11336

int-8062

eles-2225

FIGURE 7.12 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.

elog-2059

INVESTIGATION 7.5

Modelling the phases of the Moon

Aim

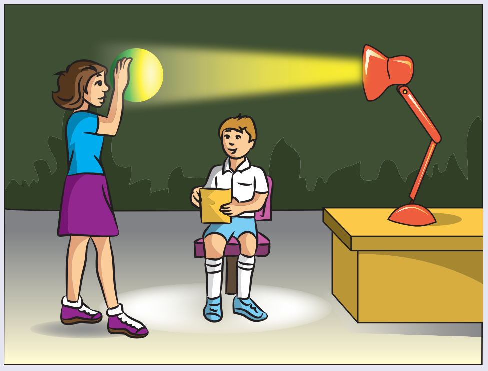
To model the phases of the Moon

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 it 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 the 'Moon' can be recorded.



Results

Draw a diagram to show the positions of the 'Sun', 'Earth' and the 'Moon' that result in:

a. a full moon
b. a gibbous moon
c. a quarter moon
d. a crescent moon
e. a new moon.

Discussion

1. Describe the positions of the Sun, Earth and the Moon when there is:
   a. a full moon
   b. a new moon.
2. Explain why the appearance of the Moon varies when we see it from Earth.

Conclusion

Summarise how this investigation allowed you to model the different phases of the Moon.

ACTIVITY: Songs about the Moon

The Moon has been the subject of many poems and songs. As a class, see how many songs you can list with the word 'Moon' in the title. Many of them are quite old, so you might need to ask music-minded adults for help.

Why do you think the Moon features in so many poems and songs?

on Resources

eWorkbook The phases of the Moon (ewbk-11338)

Video eLesson Full moon (eles-2549)

7.4 Activities

learnon

7.4 Quick quiz on	7.4 Exercise

Select your pathway

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. What is a lunar month?
3. Explain, with the aid of a diagram, how a quarter moon occurs.
4. Why is the phase in which half the Moon is visible called a quarter moon?

Apply and analyse

5. Sometimes the Moon is visible during the day.
   a. What phases of the Moon would you be most likely to see 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 flow chart to show how the phases of the Moon occur.

7. SIS a. Using the information in the table provided, draw a graph of the percentage of the Moon's surface that is visible against the day of the month.

TABLE Percentage of the Moon's surface visible from Earth

Day of the month	Percentage of the Moon's surface that is visible
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. SIS What is a blue moon? Can you find any other 'moon' names and their meaning?
9. Describe a harvest moon.

Fully worked solutions and sample responses are available in your digital formats.

LESSON 7.5 Eclipses

LEARNING INTENTION

At the end of this lesson you will be able to describe the cause of solar and lunar eclipses and will be able to 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. A **lunar eclipse** occurs when the Moon passes into Earth's shadow. The Moon no longer receives any light from the Sun and 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.

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

umbra the shadow created when light is completely blocked by an object

A total lunar eclipse is usually observed as a blood moon, in which the Moon has a red tinge (see figure 7.13). This is due to the way the red light from the Sun bends (or diffracts) around Earth and reaches the Moon. When only a section of the Moon passes through Earth's shadow, a partial lunar eclipse occurs as only a portion of the light is blocked by the Earth (also known as the **penumbra**).

penumbra the region where only a portion of light is blocked by an object

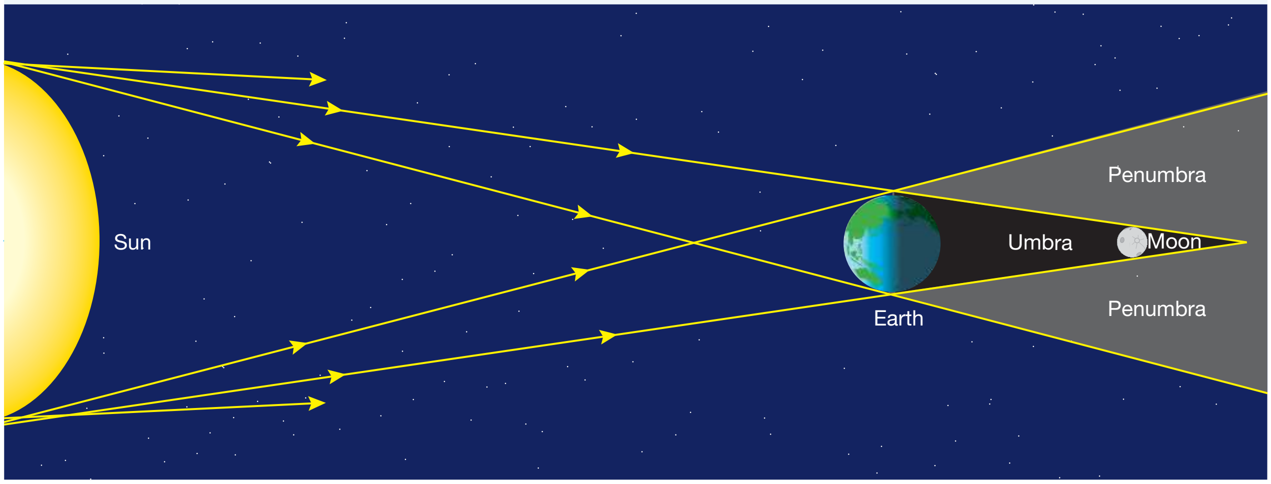
FIGURE 7.13 Earth's shadow makes the Moon appear to change phases during a total lunar eclipse. Note the red tinge of the Moon at the height of the eclipse.

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 7.14 and 7.15).

ewbk-11340

int-8063

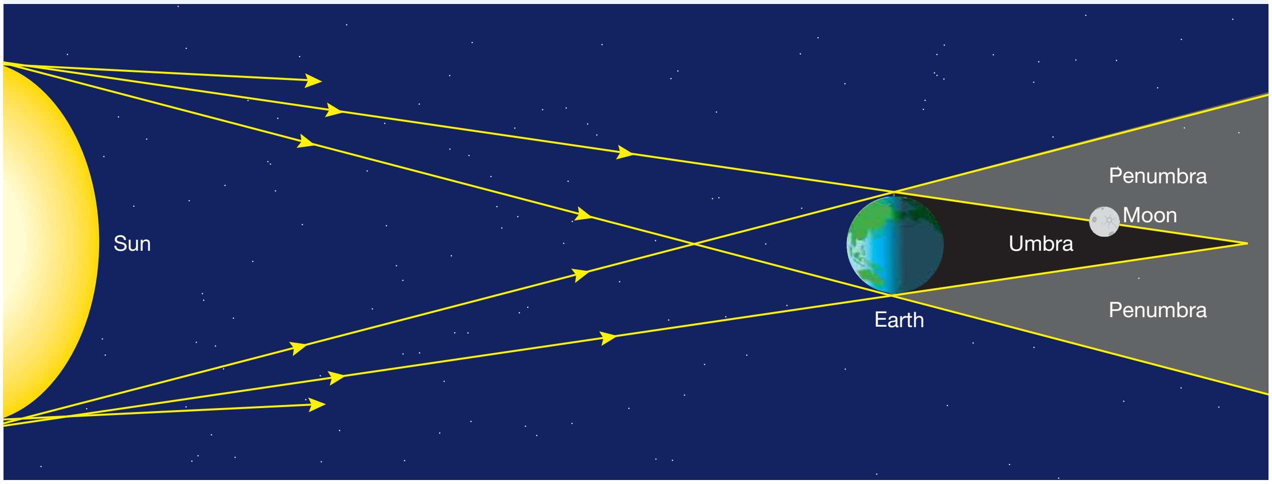
FIGURE 7.14 Total lunar eclipse



ewbk-11342

int-8064

FIGURE 7.15 Partial lunar eclipse



on Resources

Video eLesson Lunar eclipses (eles-3531)

Weblink Future lunar eclipses in Australia

7.5.2 Solar eclipses

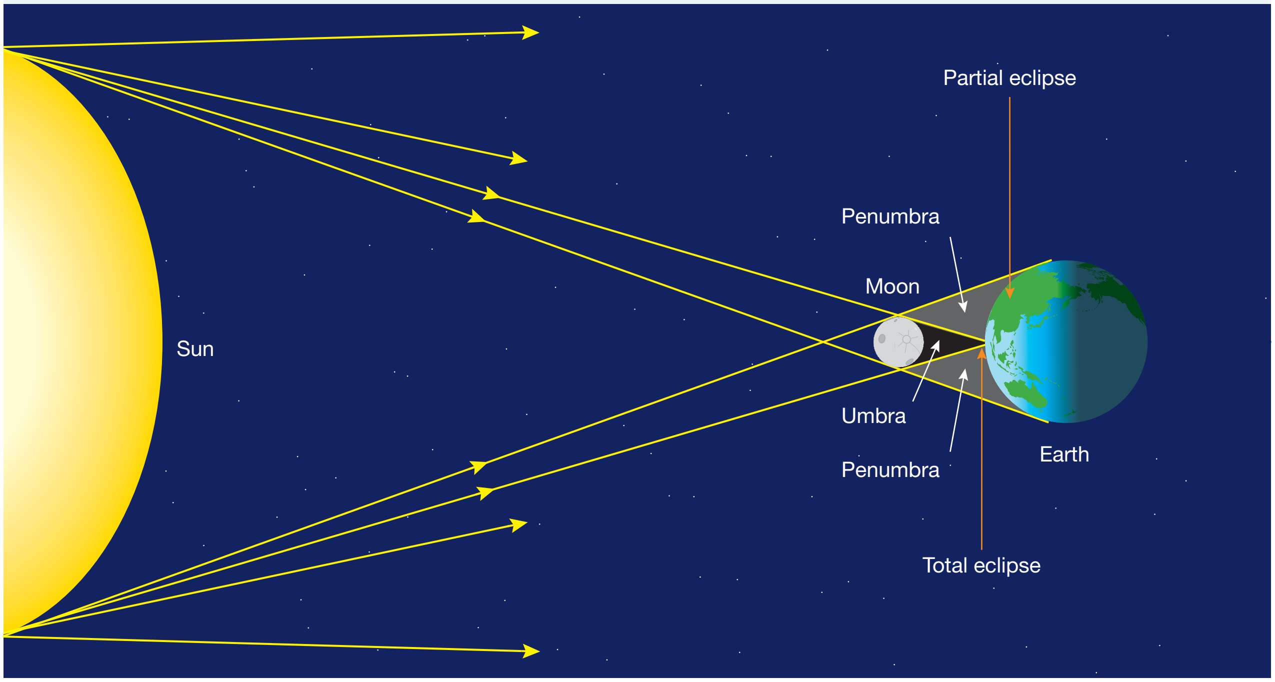
Sometimes, when the Moon passes between Earth and the Sun, the Moon's shadow falls on Earth. The part of Earth in the shadow experiences a **solar eclipse** (see figure 7.16).

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

ewbk-11344

int-8065

FIGURE 7.16 Total and partial solar eclipses

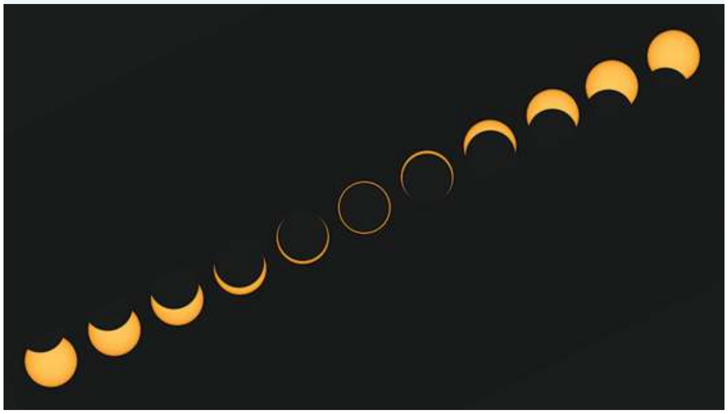


Total solar eclipse

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 $29\frac{1}{2}$ days, 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, a **total solar eclipse** is experienced.

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 7.17.

FIGURE 7.17 A total solar eclipse — the Sun's light is blocked



The last total solar eclipse to affect Australia was only observed in the southern part of Australia (mostly Tasmania and Victoria) and occurred in December 2021. The next total solar eclipse to affect Australia will touch the coast at Exmouth in Western Australia in April 2023. A further total solar eclipse in July 2028 will cross a narrow band from the Kimberley in Western Australia all the way to Sydney.

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

partial solar eclipse occurs when the Moon moves between Earth and the Sun and prevents some of the Sun's light reaching a place on Earth

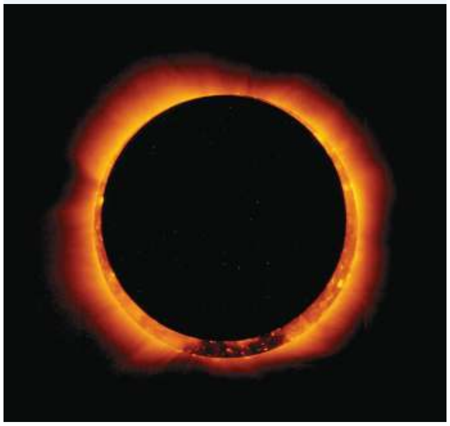
annular solar eclipse occurs when the Moon moves between the Sun and Earth

Partial and annular solar eclipses

Partial solar eclipses (see figure 7.18) and **annular solar eclipses** (see figure 7.19) are much more common than total solar eclipses. A partial solar eclipse is experienced by areas in the partially dark part of the 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 7.18 A partial solar eclipse

FIGURE 7.19 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.

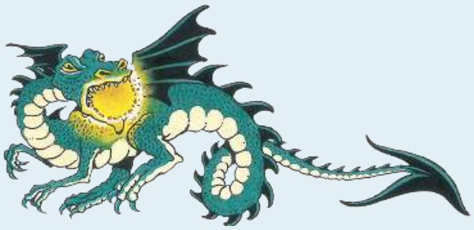
on Resources

Video eLessons Total solar eclipses (eles-3532)
Partial solar eclipse (eles-2227)

Weblink Future solar eclipses in Australia

ACTIVITY: Cultural beliefs about solar eclipses

The ancient Chinese believed that solar eclipses occurred when a giant dragon ate the Sun. They thought that if they made enough noise they could frighten the dragon. The frightened dragon would then spit the Sun out, bringing daylight back. Investigate other cultural beliefs about solar eclipses, and discuss your findings as a class.



elog-2061
tlvd-10657

INVESTIGATION 7.6

Modelling solar and lunar eclipses

Aim

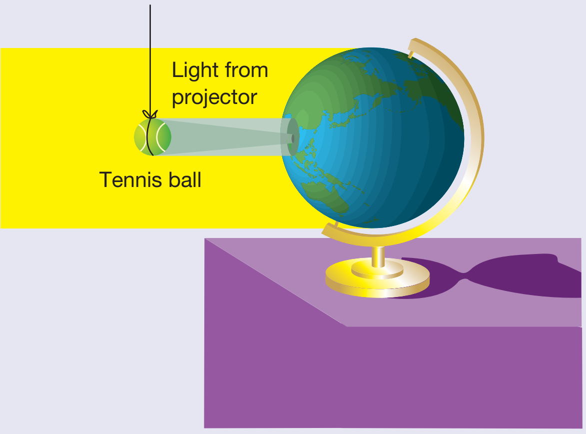
To model solar and lunar eclipses

Materials

- Projector
- Globe
- Tennis ball attached to string

Method

1. Darken the room and aim a beam of light at the globe.
2. To simulate a solar eclipse, suspend the tennis ball (the Moon) between the projector (the Sun) and the globe (Earth) as shown. Ensure that you keep your own shadow off the globe.
3. Rotate the globe a little (think carefully about which way to turn it) and note what happens to the shadow.
4. To simulate a lunar eclipse, move the tennis ball to the opposite side of the globe from the projector. Suspend it so that it is partly in the shadow of the globe.



Results

1. Draw a diagram to show the initial positions of Earth, the Moon and the Sun in your model of a solar eclipse.
2. When you rotate the globe, does the shadow move from east to west or from west to east?
3. Draw a diagram showing the positions of Earth, the Moon and the Sun in your lunar eclipse model.

Discussion

1. During which phase of the Moon does a lunar eclipse occur?
2. During which phase of the Moon does a solar eclipse occur?

Conclusion

Write a summary explaining how the motion of the Moon and the Sun create solar and lunar eclipses.

elog-2063

INVESTIGATION 7.7

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 this fuzzy shadow.

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.

on Resources

eWorkbook Eclipses (ewbk-11346)

Interactivity Eclipses (int-0207)

Weblink Earth's Moon

7.5 Activities

learnon

7.5 Quick quiz on	7.5 Exercise

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Select your pathway

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

Remember and understand

1. Outline the difference between 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 shown a lunar or a solar eclipse? Justify your response.

6. **SIS** Research solar and lunar eclipses that have been or will be observed in Australia between the years 2015 and 2025.
   a. Copy and complete the table with the information you have found.

TABLE Information on solar and lunar eclipses observed in Australia from 2015–2025

Date	Year	Solar or lunar	Type of eclipse (partial/total)	Locations visible

   b. Of these eclipses, calculate the percentage that are solar eclipses.
   c. i. Create a graph comparing the number of total and partial eclipses.
      ii. What does this graph suggest?
   d. What predictions would you make about eclipses in the year 2030?

Fully worked solutions and sample responses are available in your digital formats.

LESSON
7.6 Tides

LEARNING INTENTION

At the end of this lesson you will be able to 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 7.21 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.

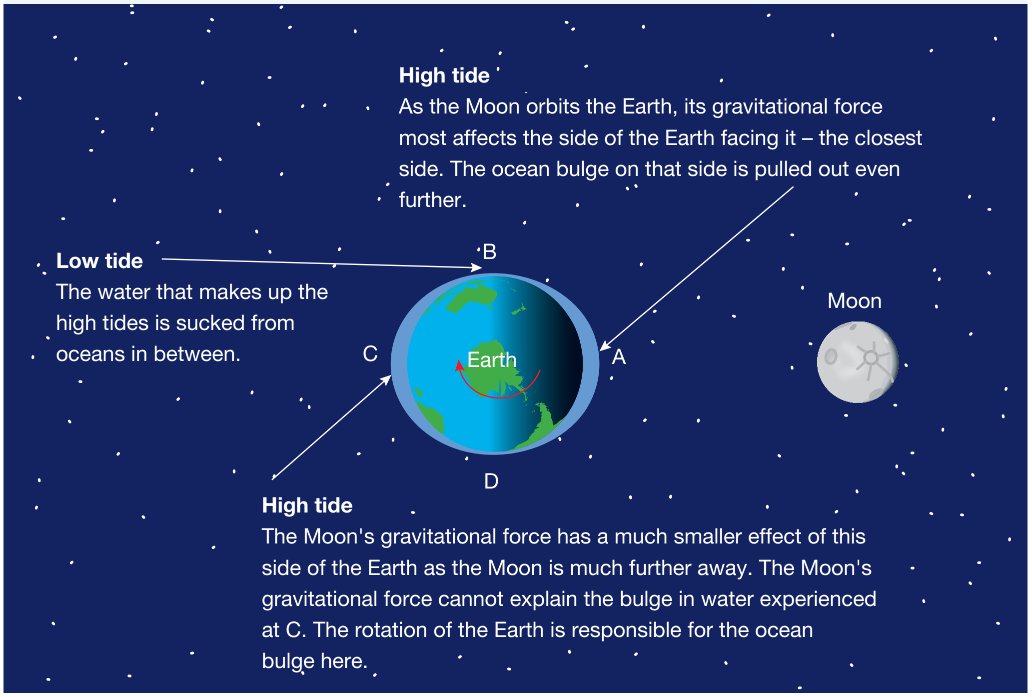
tide the regular rise and fall of water level of the ocean, in a cycle close to 12.5 hours

FIGURE 7.20 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.

ewbk-11348

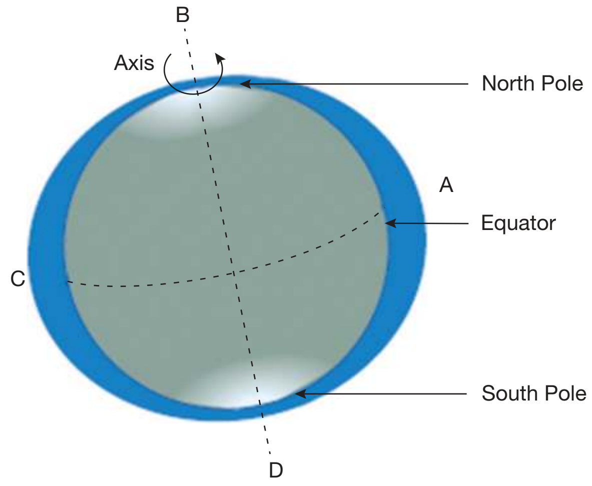
int-8066

FIGURE 7.21 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 7.22. 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 Earth. The ocean water doesn't come completely off 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 other side of Earth, creating a second high tide.

FIGURE 7.22 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.



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 Earth is greater because it is so much closer to Earth.

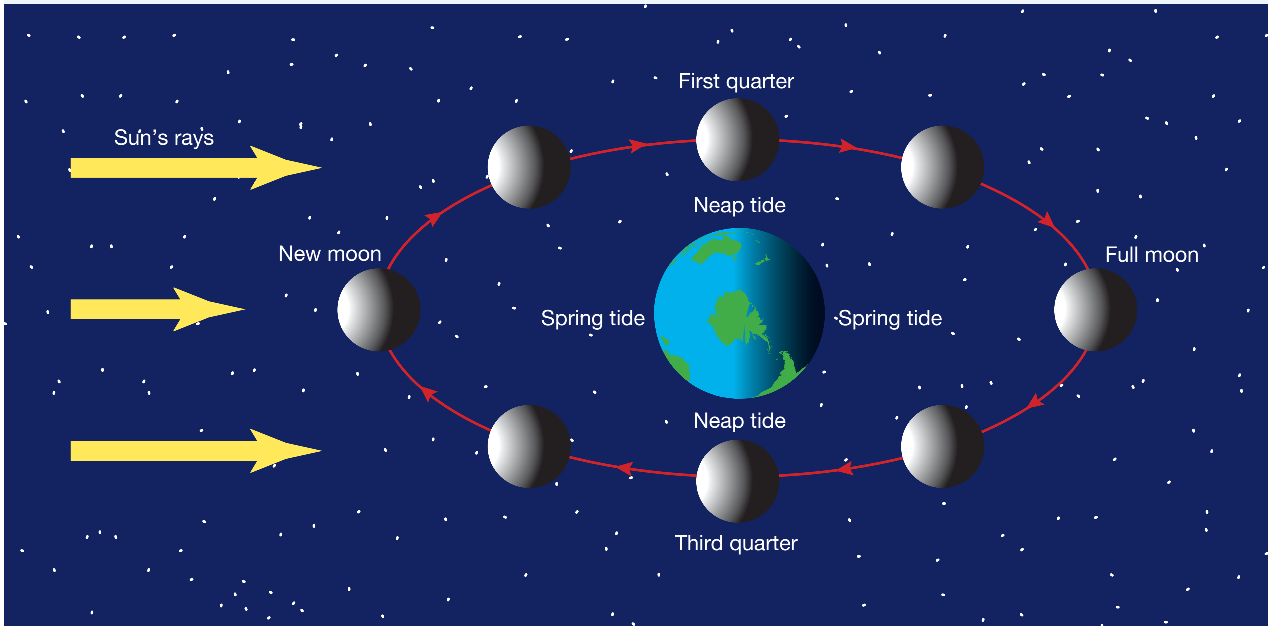
When the Sun is on the same side of Earth as the Moon, its gravitational force adds to the gravitational force of the Moon. When it is on the opposite side, its gravitational force assists the rotation of Earth in creating the second bulge of water, and higher tides than normal are experienced. These tides are called **spring tides**. They occur when there is a full moon or a new moon when the Sun, Earth and the Moon form a straight line.

spring tide a very high tide that occurs when there is a new or full moon

ewbk-11350

int-8067

FIGURE 7.23 During each orbit of the Moon around Earth ($29\frac{1}{2}$ days), there are two spring tides and two neap tides.



About seven 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.

neap tide a weaker high and low tide that occurs when the Sun and the Moon are not in the same line as Earth

on Resources

eWorkbook	Surf's up (ewbk-11352)
Video eLesson	Time-lapse video of the Floating Torii Gate on Miyajima Island (eles-2226)
Interactivity	Tides (int-0225)
Weblink	Tide predictions in Australia

7.6 Activities

learn**on**

7.6 Quick quiz **on** | 7.6 Exercise

Select your pathway

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

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Remember and understand

1. State the major cause of tides on Earth.
2. Why are there two high tides and two low tides in a day?
3. Even though the Sun is much larger than the Moon, it has much less effect on the tides. Explain the reasoning for this.

Apply and analyse

4. Explain why the highest 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 on the side of Earth closest to the Sun.
8. On any given day, one high tide is higher than the other one. Suggest a reason for this.
9. **SIS** Use the information in the table provided to plot a graph of the high and low tide levels at Portland beach during July 2020.

TABLE 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

(continued)

TABLE High and low tide at Portland beach *(continued)*

Date	Highest tide (m)	Lowest tide (m)
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 provided to answer the questions.

TABLE 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	06.27		18.11
	Height (m)	1.41	0.37		0.62
Friday 5 July	Time	03:59	10:35	16:55	22:49
	Height (m)	1.60	0.51	1.46	0.69
Tuesday 9 July	Time	07:14	01:19	19:39	13:15
	Height (m)	1.52	0.54	1.71	0.51
Saturday 13 July	Time	09:47	03:50	21:53	15:24
	Height (m)	1.41	0.49	1.76	0.61
Wednesday 17 July	Time	12:47	06:45		18:15
	Height (m)	1.28	0.60		0.79
Sunday 21 July	Time	03:48	10:20	16:42	22:41
	Height (m)	1.56	0.49	1.53	0.66
Thursday 25 July	Time	03:59	10:35	16:55	19:56
	Height (m)	1.66	0.32	2.02	0.34
Monday 29 July	Time	11:19	05:14	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 it 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.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
7.7 Explaining the night sky

LEARNING INTENTION

At the end of this lesson you will be able to describe how new evidence from people such as Al-Battānī and current day astronomers have changed people's views of the solar system.

7.7.1 Developments in astronomy

Astronomers have been recording observations of the night sky for at least 4000 years. For just as long, they have been trying to explain their observations.

Ask someone to cite a famous astronomer, and chances are they will cite 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.

ACTIVITY: Contributions to astronomy

1. Using the internet or other resources to research the information, link each of the following individuals on the left of the table to one major contribution to astronomy on the right.

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

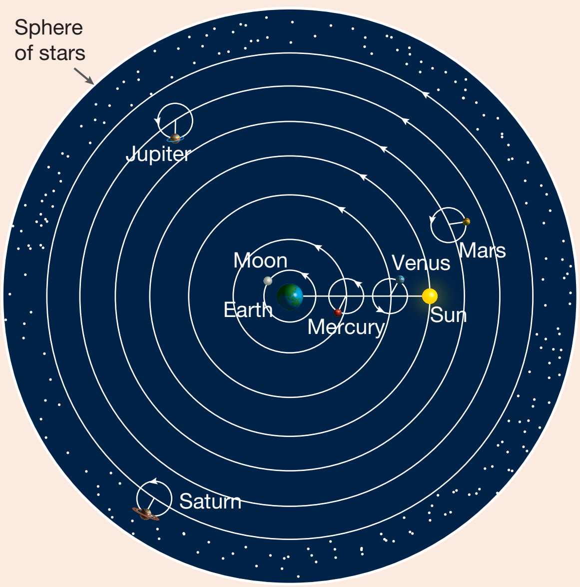
2. Select one of the individuals in the table and write a short paragraph on their contribution to astronomy.

SCIENCE AS A HUMAN ENDEAVOUR: Modelling the universe

Ptolemy's theory

The early Greek astronomer Ptolemy, in about AD 150, 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.

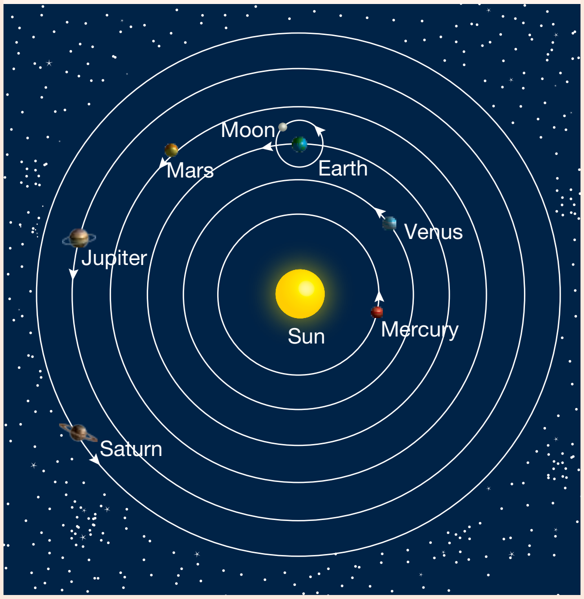
FIGURE 7.24 Ptolemy's model of planetary motion



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 (as seen in figure 7.25). 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.

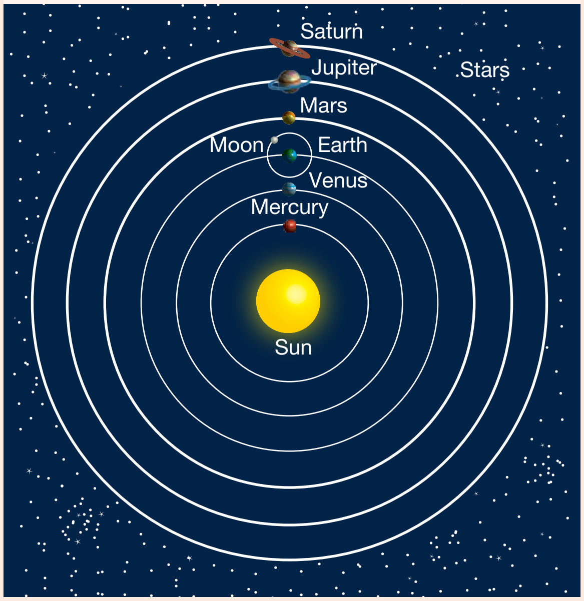
FIGURE 7.25 Aristarchus's heliocentric model



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 7.26 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.

More than 2000 years ago, the Ancient Greeks had discovered that Earth was spherical, and Eratosthenes even calculated the circumference of Earth to within a margin of error of less than 1 per cent.

During the seventh century, Indian mathematician and astronomer Brahmagupta developed methods to calculate the trajectory of astronomical objects, as well as solar and lunar eclipses.

During the tenth century, Muslim scholars such as Al-Battānī made great contributions to our understanding of astronomy and mathematics.

Chinese scholars such as Wang Zhenyi demonstrated how lunar and solar eclipses happen.

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 to 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, Sun and 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 7.27 A modern artist's impression of Wang Zhenyi's home experiment to explain a lunar eclipse

Developments in astronomy have been driven by passionate scholars for thousands of years, but from the first telescopes developed during the seventeenth century, to NASA's James Webb Space Telescope launched in 2021, technological progress has also played an important role in our pursuit of knowledge. For instance, the invention of the astronomical spectroscope enabled 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 domains (such as traditional medicine or land management), indigenous knowledge from all around the world has finally started to be recognised. In Australia, as seen in lesson 7.2, First Nations Australians possess specific knowledge and understanding of astronomy. However, this is still not widely known, and science communication can help remediate this.

SCIENCE AS A HUMAN ENDEAVOUR: Promoting First Nations Australians' astronomy knowledge and understanding

Karlie Noon

Astronomer, astrophysicist and science communicator Karlie Noon, a Gamilaraay woman, is the first female First Nations Australian in New South Wales to graduate with a double degree in maths and physics.

Noon is on a mission to explore the knowledge First Nations Australians have about the link between the land and the sky. She wants to show that First Nations Australians 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.

FIGURE 7.28 Astrophysicist Karlie Noon at the Murchison Radio-astronomy Observatory in Western Australia

Kirsten Banks

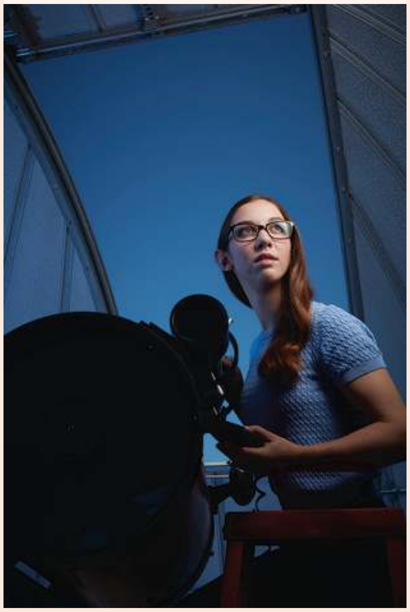
Kirsten Banks is a Wiradjuri woman who is a proud astrophysicist and science communicator at Sydney Observatory. Kirsten launched her career in astrophysics with a Bachelor of Science at the University of New South Wales.

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 First Nations Australian 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 7.29 Kirsten Banks at the University of New South Wales



on Resources

- **eWorkbook** Astronomical history (ewbk-11354)
- **Video eLesson** The Corpernican model (eles-2228)
- **Weblinks** Aboriginal astronomy — Karlie Noon
  Kirsten Banks — Astrophysics, TikTok and culture

7.7 Activities

learnon

7.7 Quick quiz on	7.7 Exercise

Learning pathways

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

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

1. 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. Explain why an Earth-centred model of the solar system made much more sense to early astronomers than a Sun-centred one.
5. Which new technology enabled Galileo to make observations that supported the idea of a Sun-centred solar system?

Apply and analyse

6. Why were the ideas of Copernicus rejected for so long?
7. Describe the limitations that ancient cultures had on 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. **SIS** Use resources from the library, internet or home to find out more about how explanations of the night sky have changed since ancient times. In your timeline, include the technology, such as telescopes and space probes, that has made new explanations possible. You might need to use separate timelines to show some of the details from 1700 BCE to 1400 BCE and from the 1950s to the present time.
12. **SIS** Research and write a report of approximately 200 words about the life and times of Omar Khayyam and the contributions he made to astronomy.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
7.8 Thinking tools — Mind maps

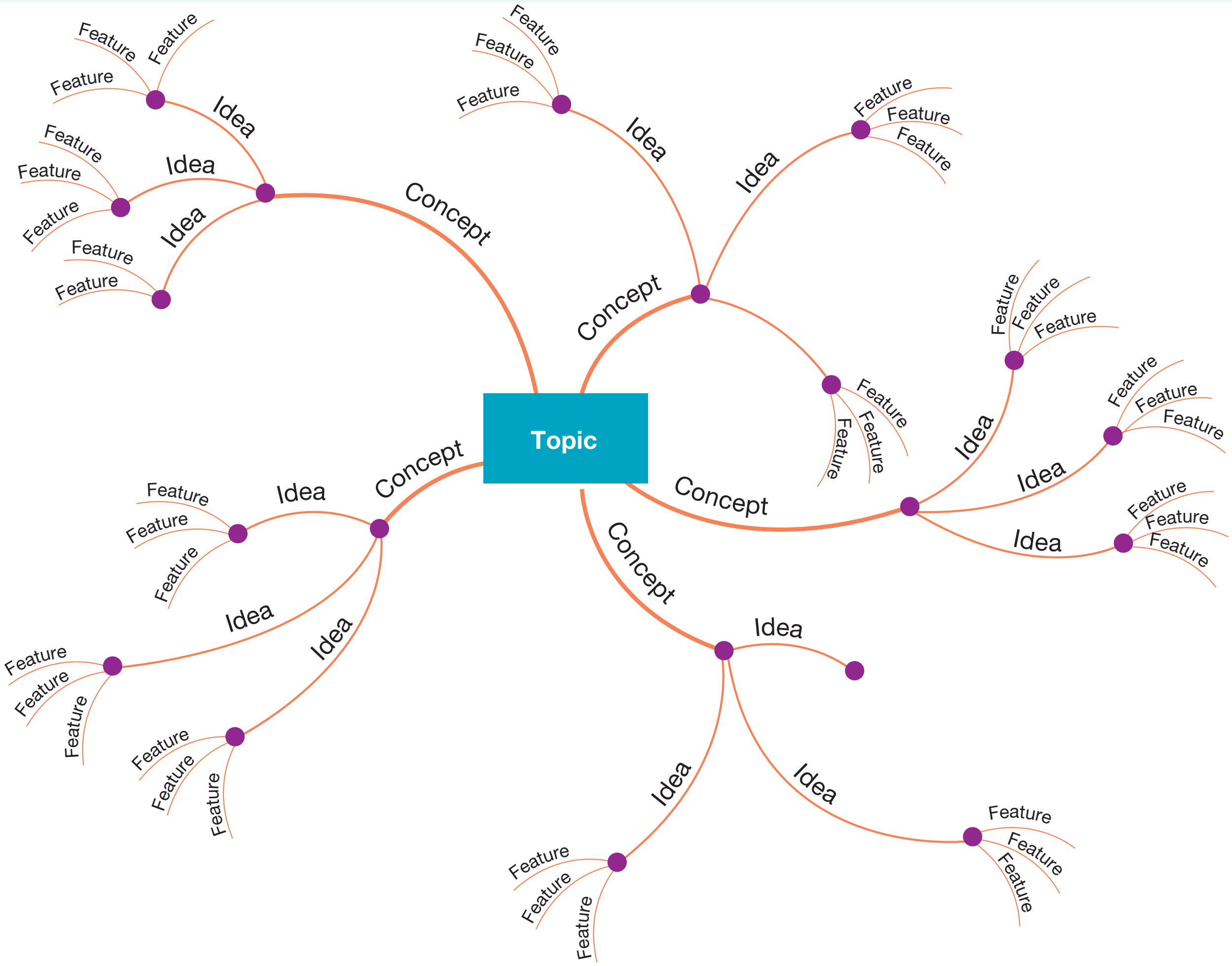
7.8.1 Tell me

What is a mind map?

A mind map is a diagram that breaks up ideas within a topic, from the main topic to the many small features or examples of its parts. They are also called model maps, memory maps or brain maps.

A mind map breaks down a topic into sections or groups of ideas, all curving out from the central topic in the middle; a mind map has a radial structure. In a mind map, there are no straight lines, horizontal organisation or ordering like you will see in a tree or concept map. Concept maps have a tree structure with many branches and clusters, and generally represent the relationship between the different ideas.

FIGURE 7.30 A mind map with fluid lines and a central topic showing that the concepts are all different



What is a mind map for?

A mind map is used for showing how different parts of a central idea can be broken down into sections or groups. They are for when you want to show connections that do not have a series of similar levels; because of this, mind maps are freer flowing and suit brainstorming and summaries well.

For example, you would use a mind map to:

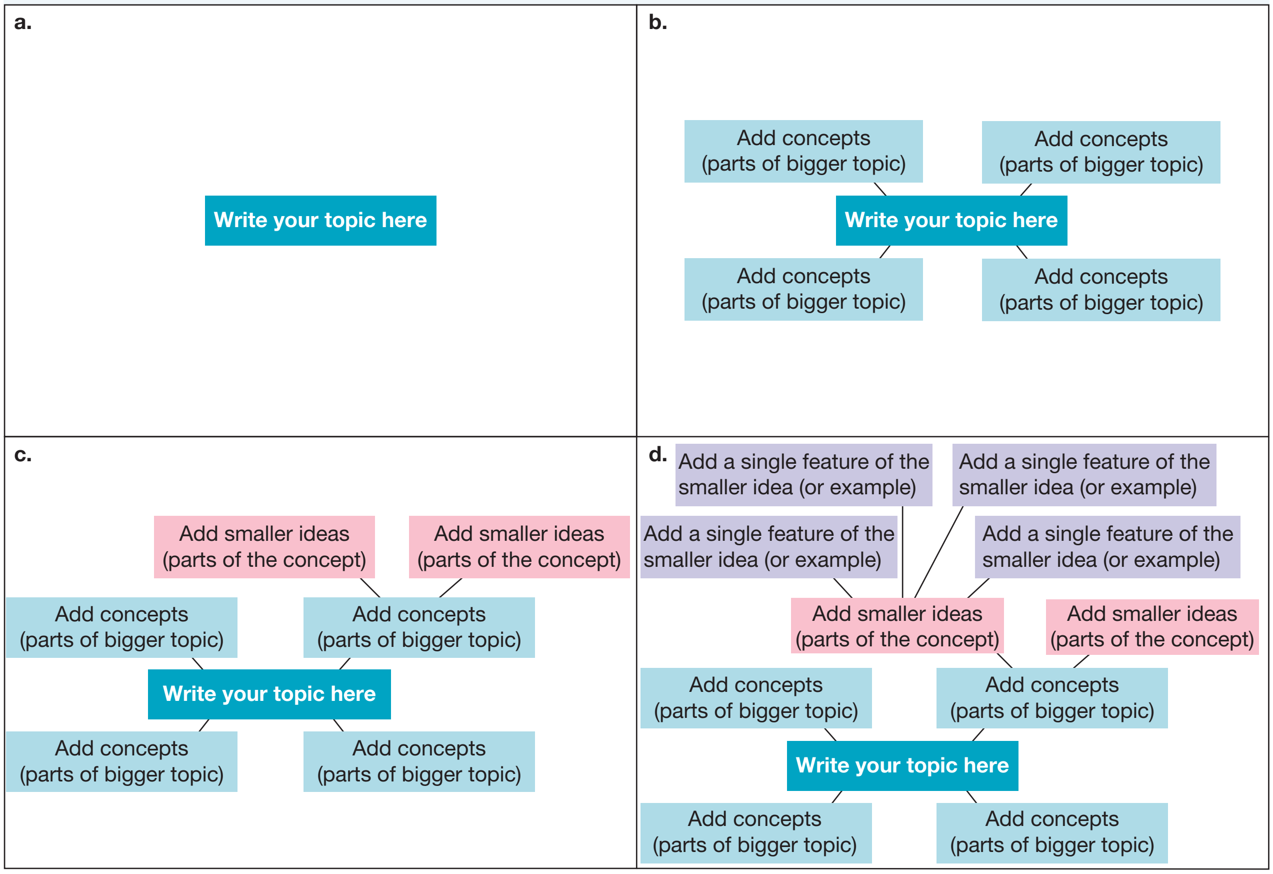
- summarise what you know about a topic
- show key terms related to a topic and lesson
- brainstorm ideas for a project or essay.

7.8.2 Show me

To create a mind map:

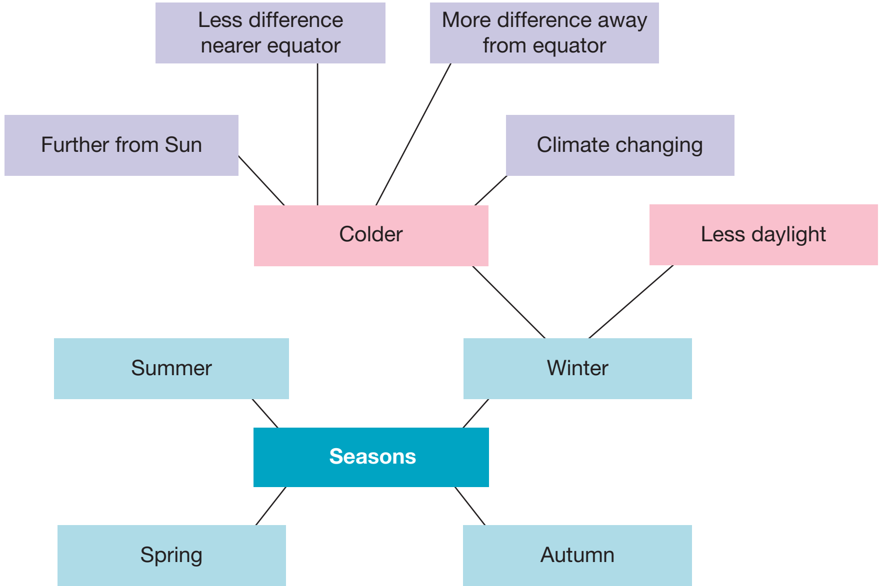
1. Write your topic in the middle of a sheet of paper.
2. Draw a number of lines branching out from it. Think of some main ideas related to the topic and write one on each branch.
3. Draw a number of lines branching from each of your main ideas. Think of words or terms related to one of your main ideas and write one on each branch.
4. Continue adding branches until you run out of ideas. You can also decorate your map with colour, drawings or photos to make the ideas and links clearer.

FIGURE 7.31 The steps involved in making a concept map. **a.** Write your topic. **b.** Add main concepts around the topic. **c.** Add branches from your main concepts. **d.** Add more branches until you run out of ideas.



An example of a mind map for the seasons is shown in figure 7.32.

FIGURE 7.32 Summarising ideas about seasons in a mind map



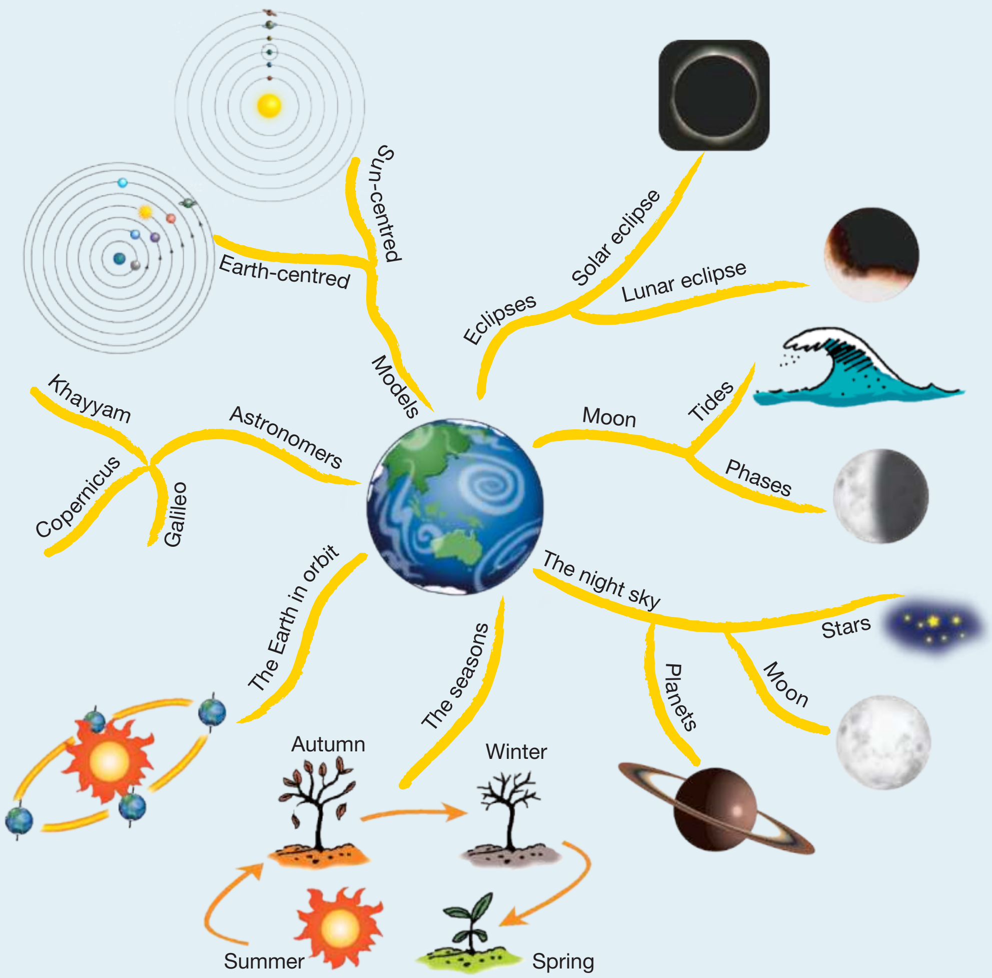
7.8.3 Let me do it

7.8 Activities

This mind map summarises what a student might remember about Earth in space in this topic.

1. Create your own mind map to show what you have learned in this topic or to brainstorm one part of the topic you have enjoyed or found interesting.
   Some examples of topics you might place in the centre include:
   - the Moon
   - systems
   - the night sky
   - ancient ideas about the universe.

   You can use branches with words or pictures flowing from the centre (or both).



Fully worked solutions and sample responses are available in your digital formats.

LESSON
7.9 Review

Hey students! Now that it's time to revise this topic, go online to:

Review your results | **Watch teacher-led videos** | **Practise questions with immediate feedback**

Find all this and MORE in jacPLUS

Access your topic review eWorkbooks

on Resources

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-11363	ewbk-11364	ewbk-11365

7.9.1 Summary

First Nations Australians' astronomy knowledge and understanding

- First Nations Australians are the oldest astronomers in the world.
- Different groups and communities used their knowledge and understanding of the celestial bodies like the Sun, the Moon and the stars to develop seasonal calendars linked to their traditional land, enabling them to predict seasonal changes.
- First Nations Australians knew about solar and lunar eclipses, and different groups and communities have different perceptions and understandings of such phenomena.
- First Nations Australians understood the relationship between different phases of the Moon and the tides and their effect on the environment around them.

The seasons, day and night

- Earth rotates in an anticlockwise direction when viewed from above the North Pole.
- Earth rotates on its own axis, which is 23.5° from the vertical. Earth takes 24 hours to complete one full rotation.
- As Earth rotates, the side facing the Sun experiences day time and the other side experiences night time.
- Earth orbits the Sun — one orbit takes $365\frac{1}{4}$ days.
- This orbit is an elliptical orbit (rather than being perfectly circular).
- Due to the tilt of Earth, during orbit the different hemispheres are tilted towards the Sun. This results in the seasons.

The Moon

- The Moon takes approximately $29\frac{1}{2}$ days to complete one revolution or orbit around Earth.
- The Moon also rotates on its axis so we usually see only one face.
- The face of the Moon we see is less mountainous and rugged compared to the other side (the far side).
- The Moon has no atmosphere, no air and no sign of water on the surface.
- The Moon is a natural satellite of Earth, with surface gravity around one-sixth of that of Earth.
- The different shapes of the Moon that are seen from Earth are referred to as phases.
- The phase of the Moon depends on its position in orbit and how much of the Sun's rays are shining on it.

Eclipses

- A lunar eclipse occurs when the Moon passes into Earth's shadow, so the Moon no longer receives light from the Sun.
- During a total lunar eclipse, the Moon appears as a red blood moon.
- During a partial lunar eclipse, only some of the Moon is covered by Earth's shadow (known as the umbra).
- In a solar eclipse, the Moon passes between Earth and the Sun.
- In a total solar eclipse, the Moon is in a location where all of the Sun's light is blocked by the Moon.
- In a partial eclipse or an annular solar eclipse, only part of the Sun is blocked by the Moon.

Tides

- The changes in water levels are referred to as tides.
- These tides are mostly due to the gravitational force or pull of the Moon.
- The side of Earth closest to the Moon experiences higher tides. A lower tide is experienced as Earth rotates away from the Moon.
- A second high tide occurs each day, as the oceans bulge at the equator.

Explaining the night sky

- Early astronomers have been recording observations of the night sky for at least 4000 years.
- Many cultures use stories to explain the night sky — including those passed on through generations by First Nations Australians.
- The Ancient Greeks provided many early ideas that developed into modern astronomy. Originally, people believed that everything revolved around Earth.
- This developed over time into the currently supported theory of the heliocentric model of the solar system, in which the planets orbit the Sun.

7.9.2 Key terms

annular solar eclipse occurs when the Moon moves between the Sun and Earth
axis an imaginary line from the North Pole to the South Pole that the Earth spins on
elliptical an oval or egg shape; the shape of Earth's orbit around the Sun
equinox days with the same number of daylight hours as night hours
full moon the view of the Moon seen from Earth when the whole of its near side is in sunlight
gravitational force an attractive force between two objects that have mass
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 $29\frac{1}{2}$ days
neap tide a weaker high and low tide that occurs when the Sun and the Moon are not in the same line as Earth
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
partial solar eclipse occurs when the Moon moves between Earth and the Sun and prevents some of the Sun's light reaching a place on Earth
penumbra the region where only a portion of light is blocked by an object
phases shapes observed in a repeated pattern of changes
revolution movement around an orbit
rotation the turning of an object about its own axis (between the North Pole and South Pole)
satellite a body such as a moon that orbits another celestial body of a larger size and mass
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 system a group of bodies that revolve around a star
spring tide a very high tide that occurs when there is a new or full moon
summer solstice the day of the year with the most daylight hours
tide the regular rise and fall of water level of the ocean, in a cycle close to 12.5 hours
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

umbra the shadow created when light is completely blocked by an object
universe all of space and the matter and energy contained in it
waning the change in the Moon's appearance between a full moon and the following new moon
waxing the change in the Moon's appearance between a new moon and the following full moon
winter solstice the day of the year with the fewest daylight hours

on Resources

eWorkbooks	Study checklist (ewbk-11360) Reflection (ewbk-11356) Literacy builder (ewbk-11361) Crossword (ewbk-11366) Word search (ewbk-11368)
Digital document	Key terms glossary (doc-39597)
Practical investigation eLogbook	Topic 7 Practical investigation eLogbook (elog-0214)

7.9 Activities

learnon

7.9 Review questions

Learning pathways

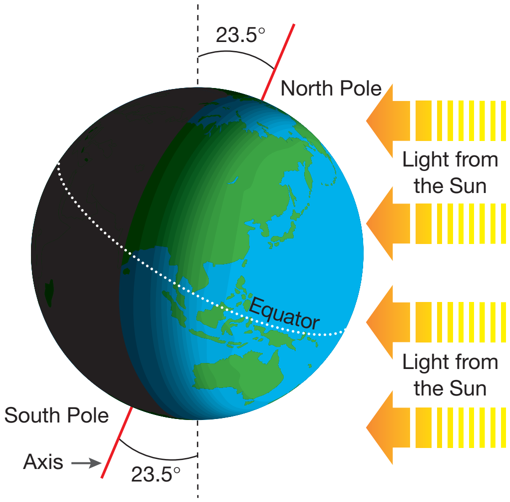
LEVEL 1	LEVEL 2	LEVEL 3
1, 4, 10, 12	2, 6, 8, 11	3, 5, 7, 9

These questions are even better in jacPLUS!
- Receive immediate feedback
- Access sample responses
- Track results and progress

Find all this and MORE in jacPLUS

Remember and understand

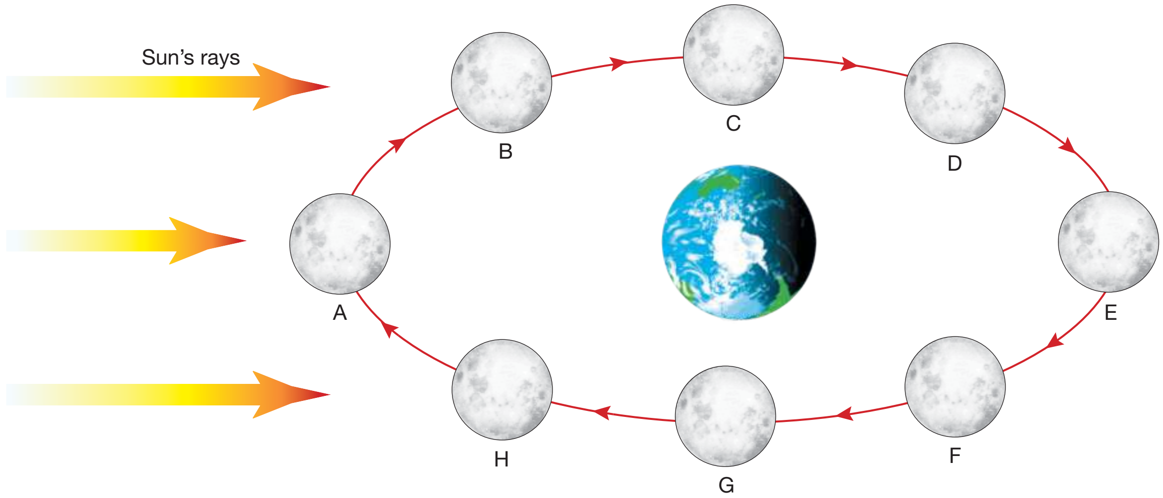
1. State the difference between the rotation and revolution of Earth.
2. The diagram shows half of Earth in sunlight while the other half is in darkness. Which Australian season is represented in this diagram? Explain how you know.



3. Explain why the position of the Sun in the sky at midday changes from day to day.
4. Explain what causes a partial solar eclipse. Explain how it is different from a total solar eclipse.

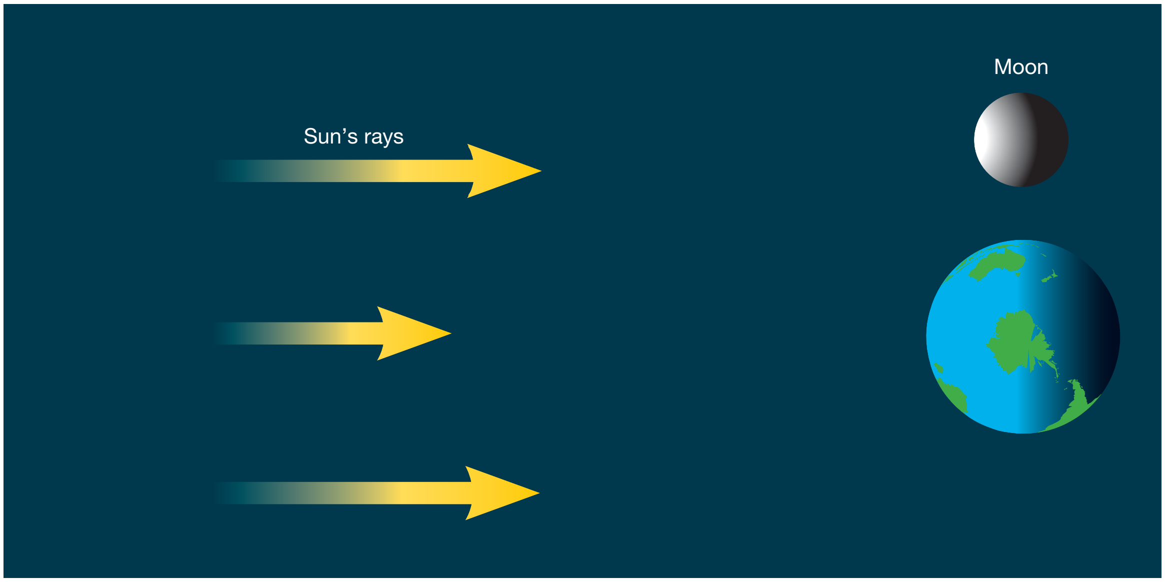
Apply and analyse

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. How long does it take the Moon to complete a single orbit?
c. Why is it not possible to see a new moon during the day?
d. Explain which one or more positions of the Moon would result in a quarter moon.
e. Explain which one or more positions of the Moon would result in a gibbous moon.
f. Explain which one or more positions of the Moon would result in a full moon.
g. How many times does the Moon rotate about its own axis while completing a single orbit of Earth?

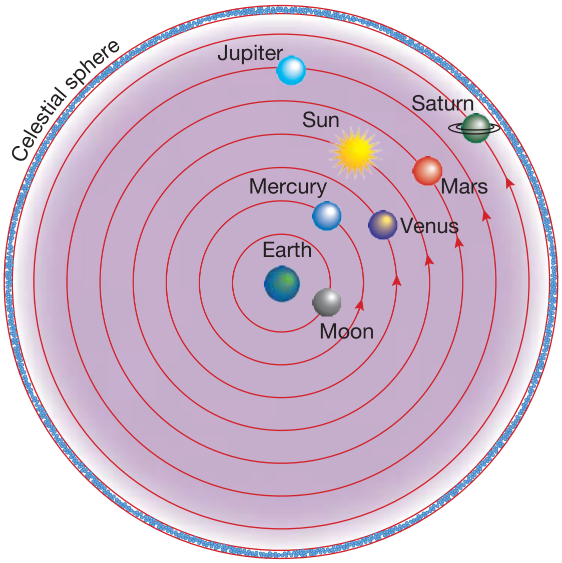
6. The length of a day on the planet Venus is 243 Earth days. The length of a year on Venus is only 225 Earth days. Explain how it is possible for a day to be longer than a year.
7. Explain which type of tide is experienced when a full moon is overhead.
8. The diagram shows the view of Earth from above the South Pole. While the Moon is in the position shown, explain which type of tide is being experienced on the east coast of Australia — high tide, low tide or neap tide.



Evaluate and create

9. The photograph 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. Does Earth have the same phases as the Moon? Draw some diagrams showing the positions of the Sun, Earth and the Moon to explain
   your answer.
   d. If you were on the Moon, how long would you expect to have to wait between Earthrise and Earthset?

10. Astronauts have already visited the Moon and may soon land on Mars. Is it likely that astronauts will one day visit a planet outside our solar system? Explain your answer and describe what a trip to a distant planet may look like.
11. a. Which astronomer developed the model of the universe shown in the diagram?
    b. Where are the stars on this model?
    c. Explain why this model of the universe was so well accepted for almost 1500 years.
    d. Name three well-known scientists or mathematicians who put an end to the popularity of this model.



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?

Fully worked solutions and sample responses are available in your digital formats.

Online Resources

on Resources

Below is a full list of **rich resources** available online for this this topic. These resources are designed to bring ideas to life, to promote deep and lasting learning and to support the different learning needs of each individual.

7.1 Overview

eWorkbook

- Topic 7 eWorkbook (ewbk-11325)
- Starter activity (ewbk-11327)
- Student learning matrix (ewbk-11329)

Practical investigation eLogbook

- Topic 7 Practical investigation eLogbook (elog-2051)
- Investigation 7.1: The changing Moon (elog-2050)

Video eLesson

- Earth within the universe (eles-3528)

7.2 First Nations astronomy knowledge and understanding

Weblink

- Indigenous seasons
- CSIRO Indigenous seasons calendars

7.3 Earth in orbit

eWorkbook

- Labelling the location of Earth in different seasons (ewbk-11330)
- Sunrise, sunset and seasons (ewbk-11332)

Practical investigation eLogbook

- Investigation 7.2: Day and night (elog-2053)
- Investigation 7.3: Long days, short days (elog-2055)

Video eLesson

- Cyclical motions of Earth, the Moon and the Sun (eles-3529)
- The surface of the Moon (eles-2224)

Interactivities

- Day, night and time zones (int-0006)
- Labelling the location of Earth in different seasons (int-8061)

Weblink

- Solstices and equinoxes in Melbourne

7.4 The Moon

eWorkbook

- Features of the Moon (ewbk-11334)
- Labelling the phases of the Moon (ewbk-11336)
- The phases of the Moon (ewbk-11338)

Practical investigation eLogbook

- Investigation 7.4: Observing the Moon's surface from Earth (elog-2057)
- Investigation 7.5: Modelling the phases of the Moon (elog-2059)

Video eLessons

- Moon phases (eles-2225)
- Full moon (eles-2549)

Interactivity

- Labelling the phases of the Moon (int-8062)

7.5 Eclipses

eWorkbook

- Labelling a total lunar eclipse (ewbk-11340)
- Labelling a partial lunar eclipse (ewbk-11342)
- Labelling a total and partial solar eclipse (ewbk-11344)
- Eclipses (ewbk-11346)

Teacher-led video

- Investigation 7.6: Modelling solar and lunar eclipses (tlvd-10657)

Practical investigation eLogbook

- Investigation 7.6: Modelling solar and lunar eclipses (elog-2061)
- Investigation 7.7: Fuzzy shadows (elog-2063)

Video eLessons

- Lunar eclipses (eles-3531)
- Total solar eclipse (eles-3532)
- Partial solar eclipse (eles-2227)

Interactivities

- Labelling a total lunar eclipse (int-8063)
- Labelling a partial lunar eclipse (int-8064)
- Labelling a total and partial solar eclipse (int-8065)
- Eclipses (int-0207)

Weblinks

- Future lunar eclipses in Australia
- Future solar eclipses in Australia
- Earth's Moon

7.6 Tides

eWorkbook
- Labelling high and low tides (ewbk-11348)
- Labelling spring and neap tides (ewbk-11350)
- Surf's up (ewbk-11352)

Video eLesson
- Time-lapse video of the Floating Torii Gate on Miyajima Island (eles-2226)

Interactivities
- Labelling high and low tides (int-8066)
- Labelling spring and neap tides (int-8067)
- Tides (int-0225)

Weblink
- Tide predictions in Australia

7.7 Explaining the night sky

eWorkbook
- Astronomical history (ewbk-11354)

Video eLesson
- The Corpernican model (eles-2228)

Weblinks
- Aboriginal astronomy — Karlie Noon
- Kirsten Banks — Astrophysics, TikTok and Culture

7.9 Review

eWorkbook
- Topic review Level 1 (ewbk-11363)
- Topic review Level 2 (ewbk-11364)
- Topic review Level 3 (ewbk-11365)
- Study checklist (ewbk-11360)
- Reflection (ewbk-11356)
- Literacy builder (ewbk-11361)
- Crossword (ewbk-11366)
- Word search (ewbk-11368)

Digital document
- Key terms glossary (doc-39597)

To access these online resources, log on to **www.jacplus.com.au**

8 Forces in action

CONTENT DESCRIPTION

Investigate and represent balanced and unbalanced forces, including gravitational force, acting on objects, and relate changes in an object's motion to its mass and the magnitude and direction of forces acting on it (AC9S7U04)

LESSON SEQUENCE

SCIENCE INQUIRY AND INVESTIGATIONS

Science inquiry is a central component of Science curriculum. Investigations, supported by a **Practical investigation eLogbook** and **teacher-led videos**, are included in this topic to provide opportunities to build Science inquiry skills through undertaking investigations and communicating findings.

LESSON
8.1 Overview

Hey students! Bring these pages to life online

Watch videos

Engage with interactivities

Answer questions and check results

Find all this and MORE in jacPLUS

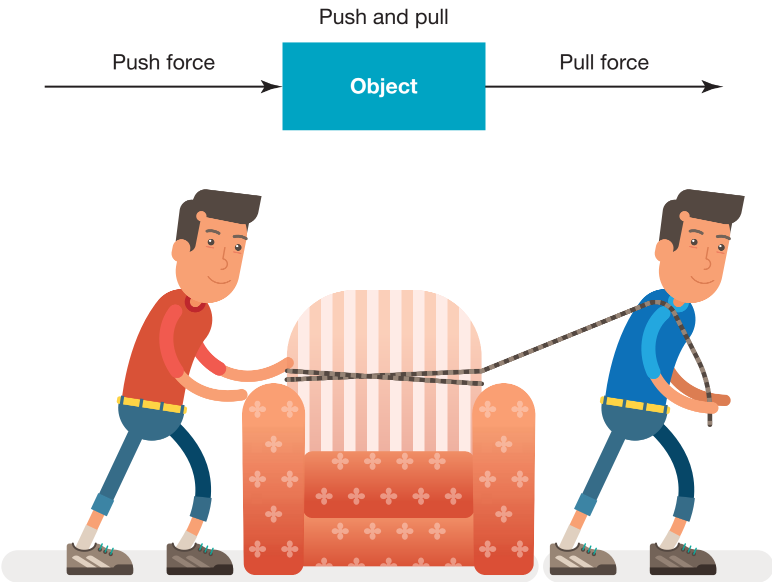
8.1.1 Introduction

The way objects move depends on what forces are acting on them. A force is 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 our everyday life. Gravitational forces ensure we do not float off into space. Frictional forces allow use 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, as shown in the topic opener, it's 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



on Resources

Video eLesson Parachutist Felix Baumgartner (eles-2229)

Watch this video to see how parachutist Felix Baumgartner jumped from the edge of space, after flying to an altitude of 39 045 metres in a helium-filled balloon. He became the first person to break the sound barrier without the aid of a vehicle. It took years of unthinkably expensive research, development and testing with industry experts to perfect the equipment. One of the most important factors for the jump was Felix's pressure suit, because if this failed he almost certainly would have died.

8.1.2 Think about forces

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. Do you weigh the same on Mars as you do 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?
9. How could you lift a 200 kg refrigerator off the ground by yourself?
10. What machine has most improved your life?

8.1.3 Science inquiry

Forces in everyday life

The introduction mentioned the importance of forces in our everyday lives. There are many types of forces — some involve direct contact, but others can occur without objects touching!

1. Using a large piece of butcher's paper or a whiteboard, draw up a table with the terms listed in the left-hand column of the table.

TABLE Examples and meanings of different terms relating to forces

Term	Meaning	Real-life examples
a. Force		
b. Friction		
c. Magnet		
d. Magnetic field		
e. Mass		
f. Gravity		
g. Weight		
h. Lubricant		
i. Buoyancy		
j. Surface tension		
k. 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 other groups in the class.
5. Examine the figure of the ice skaters. How do you think forces impact the way they are able to move?

on Resources

eWorkbooks Topic 8 eWorkbook (ewbk-11370)
Student learning matrix (ewbk-11374)
Starter activity (ewbk-11372)

Practical investigation eLogbook Topic 8 Practical investigation eLogbook (elog-2066)

LESSON
8.2 Forces

LEARNING INTENTION

At the end of this lesson you will be able to 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 a push, pull or twist. Forces are acting around you all the time and they can 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 8.2 Forces act on a tennis ball when it is hit with a tennis racquet.

force a push, pull or twist
newton the unit for measuring force

elog-2067

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.

1. Stretch a rubber band.
2. Squash a lump of plasticine.
3. Push down on the floor with one foot.
4. Drop a tennis ball. Observe what happens:
   a. at the moment that you drop it
   b. as it falls
   c. as it hits the ground
   d. as it goes up again.
5. Flick a coin with one finger so that it slides along the surface of a table. Observe what happens after the coin is flicked.
6. 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

TABLE Observations of changes in motion of different actions

Action	Change in motion or shape	What caused the change
Stretch a rubber band.		
Squash a lump of plasticine.		
Push down on the floor with one foot.		
Drop a tennis ball. Observe what happens: **a.** at the moment that you drop it **b.** as it falls **c.** as it hits the ground **d.** as it goes 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.		

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 Contact or no contact?

The changes in motion illustrated in figure 8.3 are all caused by **contact forces**. One object is in contact with another. The golf club strikes a ball (and the sand), the air pushes against the parachute to slow down the car and the tube of toothpaste is squeezed to change its shape and push out the toothpaste.

contact force force between objects that are touching

FIGURE 8.3 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.

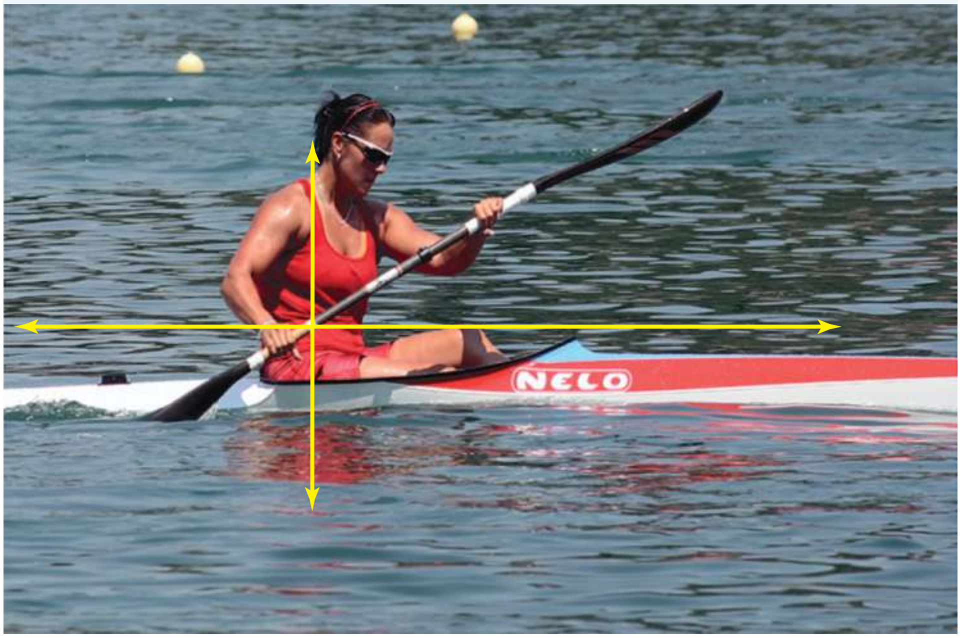
When you drop a tennis ball, it speeds up as it falls through the air. The force of **gravity** pulls it towards the ground. Gravity is a **non-contact force**. An object does not have to be touching Earth to be pulled towards it. Other forces that can work without touching are **magnetic forces** and **electrostatic forces**.

Magnets can attract each other or some metals, such as iron, from a distance. If you rub a pen with a cloth, you can pick up small pieces of paper with an electrostatic force.

8.2.3 Representing forces

Arrows can be used to represent the size and direction of forces. The length of the arrow shows how large the force is compared with another force. The arrow head shows the direction in which the force is acting. The arrows representing forces are usually drawn from the object's **centre of gravity**. This is where all of the weight of an object would be concentrated if it were in one place. Your body's centre of gravity is at about bellybutton height when you are standing.

FIGURE 8.4 Forces acting on a kayaker who is speeding up



The arrows in the figure 8.4 shows 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 and so there is no change in her upward or downward motion.

The horizontal arrow to the right represents the 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 and so the kayaker and kayak speed up.

gravity the force of attraction that exists between any two bodies in the Universe that have mass

non-contact force force between objects that are not touching

magnetic force force acting between magnets and magnetic objects

electrostatic force attractive or repulsive non-contact force of electric charges at rest

centre of gravity an imaginary point in an object that gravity appears to act around

8.2.4 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. The direction of the force is very important when calculating net force.

net force the sum of forces acting on an object

equilibrium balanced or equal

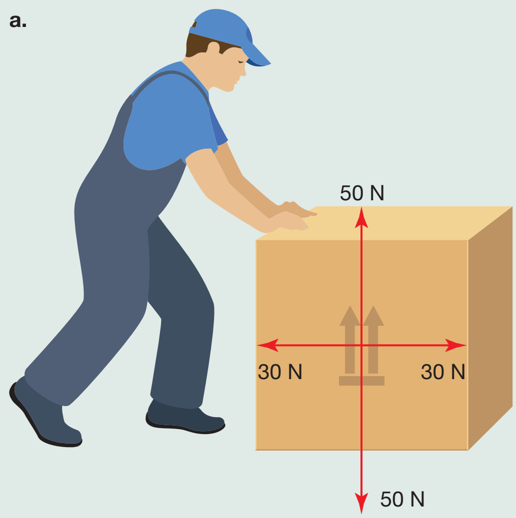
If the net force acting on an object is zero (the forces are in **equilibrium**), then the object's motion will remain unchanged. If the net force is non-zero, the object's speed and/or direction will change.

EXTENSION: Calculating net force

Consider the situation where a box is being pushed along the floor, as seen in figure 8.5.

In figure 8.5a the upward and downward (gravity) forces both are 50 N and left (friction) and right (push) forces both are 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 (as it was already moving) without changing its speed or direction.

FIGURE 8.5 a. and **b.** The forces at work when pushing a box across the floor



Now consider the situation as shown in figure 8.5b, the upward (contact force) and downward (gravity) forces both are still 50 N, however, 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. As the horizontal force on the right is bigger than the left, the box will move to the right with increasing speed.

on Resources

Interactivity	Net force (int-5894)
eWorkbook	Types of forces (ewbk-11375)
Video eLesson	Pushing force (eles-2230)

8.2 Activities

learnon

8.2 Quick quiz on | **8.2 Exercise**

Select your pathway

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

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Remember and understand

1. MC 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 force c. magnetic force d. gravitational force.
3. Complete the following sentence: The force that opposes the movement of an object through water is ____________.
4. State why drag can be referred to as a backwards force.

Apply and analyse

5. Complete the following sentence: 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 by thinking of an everyday example of a force for each of the effects of forces given. The first one has been done for you.

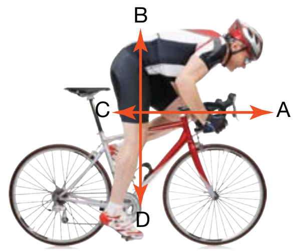
TABLE Everyday examples of forces having a specific effect

Effect	Examples in everyday life
a. Starting motion	Pushing your hands into 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. What is the name of the force that slows it down?
   b. While your finger is still pushing the coin, there are four forces acting on the coin. Draw arrows on the image of the coin to represent the direction and relative size of each force.
   c. How many forces are acting on the coin after your finger stops pushing?
   d. SIS Do you think that the mass of the coin affects how quickly it slows down? Design 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 provided diagram.
   a. Which of the four forces represented is a non-contact force?
   b. 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?



10. SIS Research Newton's First Law of Motion and state it in your own words.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
8.3 Gravity

LEARNING INTENTION

At the end of this lesson you will be able to explain what the force of gravity is, as well as the difference between mass and weight. You will also be able to 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 the force of gravity, even Earth's atmosphere would float off into space.

Every object with mass in the Universe pulls on other objects with a force of gravity. 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 8.6 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 can't see that Earth is also pulled towards us.

8.3.2 Weight

The **weight** of an object or substance is a measure of the force of gravity pulling it towards the centre of a large object such as a planet, moon or star.

Because weight is a force, it is measured in newtons. At Earth's surface, the force of gravity is about 10 newtons for every kilogram of mass. So a person with a mass of 50 kilograms has a weight of about 500 newtons on Earth. On Mars, however, the force of gravity is only about four newtons for every kilogram. So a person with mass of 50 kilograms would have a weight of 200 newtons on Mars.

mass the quantity of matter in an object (usually measured in grams or kilograms)
weight a measure of the size of the force of gravity pulling an object towards the centre of a massive body

SCIENCE AS A HUMAN ENDEAVOUR: Sir Isaac Newton and the falling apple

Sir Isaac Newton (1643–1727) was an English mathematician, physicist, astronomer and philosopher. You might know him as the guy who sat under the apple tree and, after being struck on the head by a falling apple, discovered gravity. But it probably didn't happen that way. Many scientists and historians believe that Newton was looking out of the window when he saw the apple fall.

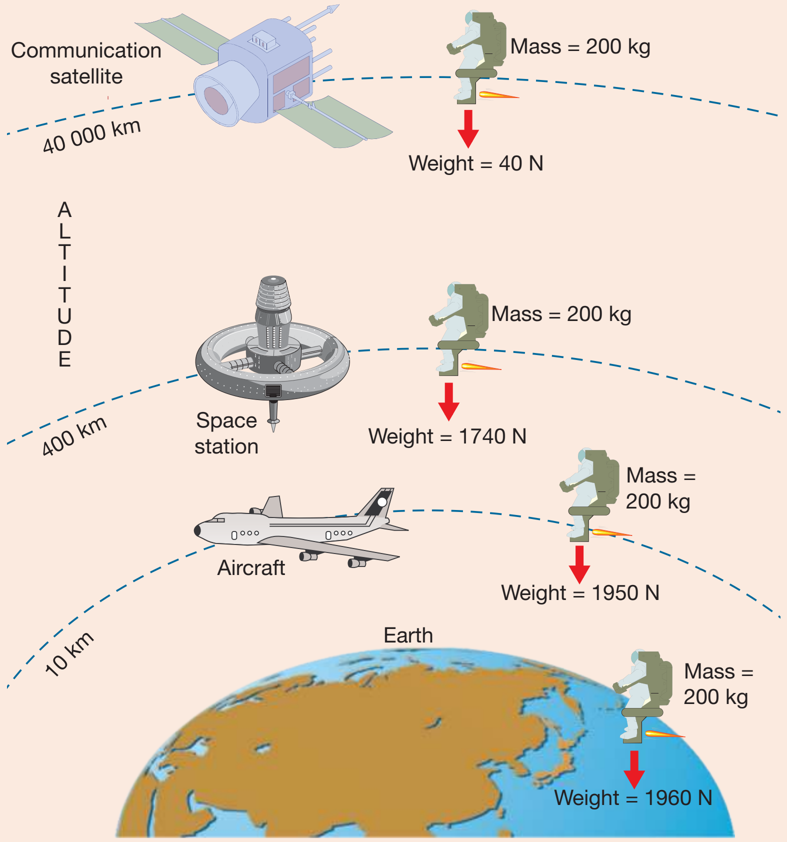
Whichever way it happened he was struck with a realisation — apples (and everything else) always fall down, not up or sideways. He wondered about the force that caused this to happen. He wondered what would happen if the tree were much taller. In fact, he was able to deduce, after much time and many calculations, that the force that caused the apple to fall was the same force (gravity) that kept the Moon in orbit around Earth. From these ideas, Newton wrote his Law of Universal Gravitation, which describes how gravity acts in all places, not just on Earth, as shown in figure 8.8.

Newton was able to explain many observations, including falling apples, tides and orbiting planets with a single law of gravity.

FIGURE 8.7 Did an apple falling on the head of Newton inspire the discovery of gravity?

int-3449

FIGURE 8.8 Weight, the force of gravity on an object, decreases as it gets further from the centre of Earth. However, the object's mass remains the same wherever it is.



8.3.3 Measuring weight and mass

Mass can be measured with a balance. Figure 8.9 shows an old-fashioned measuring scale on which the mass being measured is being compared with a known mass. A 2-kilogram bag of flour will balance the two standard kilogram masses no matter what the pull of gravity is.

A laboratory beam balance measures mass by balancing the object to be measured on one side with sliding masses on the other side.

Weight can be measured with a spring balance like the one shown in figure 8.10.

The object is fastened to the hook on the end of the spring balance. As the object falls due to the force of gravity, it pulls down on the spring and stretches it. The distance that the spring is stretched depends on the object's weight.

FIGURE 8.9 The 2-kilogram bag of flour will always balance the two standard kilogram weights.

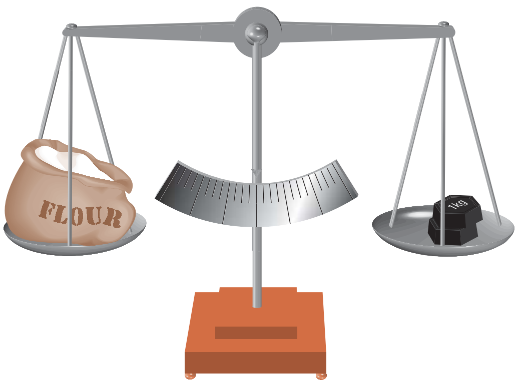


FIGURE 8.10 A spring balance can be used to measure weight.

elog-2069

INVESTIGATION 8.2

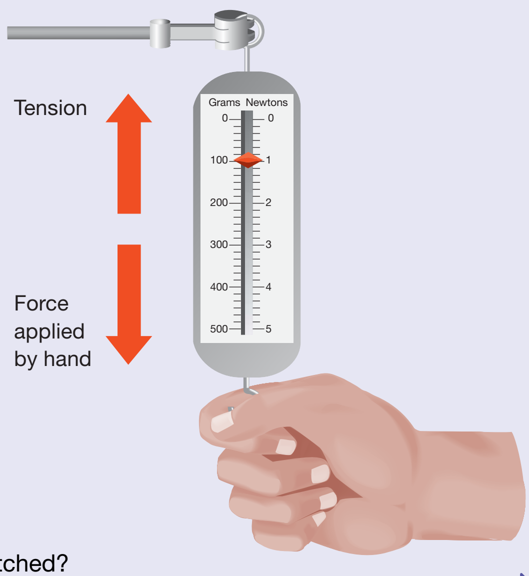
Measuring weight

Aim

To investigate the relationship between weight and mass on Earth

Background

A spring is a good force measurer because, if the pulling force on it doubles, the amount of stretch doubles. If the pulling force triples, the amount of stretch triples.



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 its weight in newtons by reading from the scale on the spring balance. Record your result in the Results table. Also 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 weight in newtons as you go.

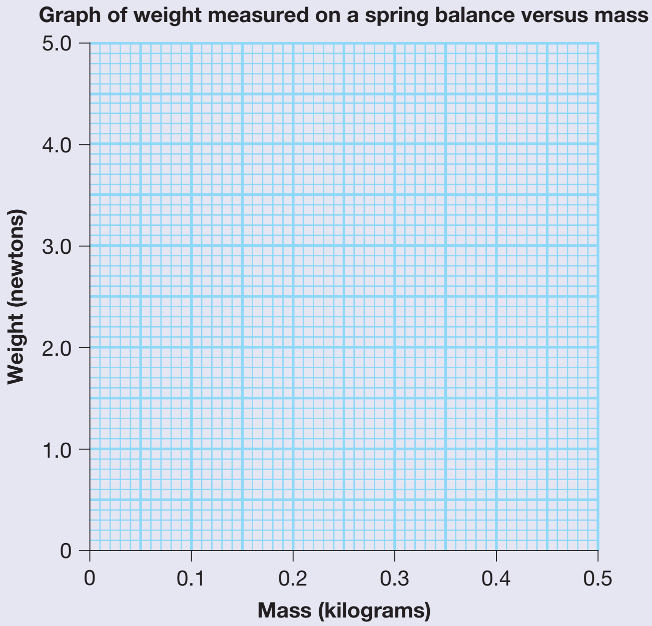
Results

1. Copy and complete the table provided.

TABLE The effect of mass on the weight measured on a spring balance

Mass (g)	Mass (kg)	Weight (N)
50	0.05	
100	0.10	
150	0.15	

2. Use your results to plot a graph of weight versus mass, using a grid like the one shown.
3. Draw a line through the points that you have plotted and continue your line to where you think it would be if you measured the weight of a mass of 500 g. This process is called extrapolation.



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 weight of 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 weight on Earth.

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**. Air resistance is an example of fluid friction.

air resistance the force of air pushing on an object as it moves through the air

elog-2071

INVESTIGATION 8.3

More than one force?

Aim

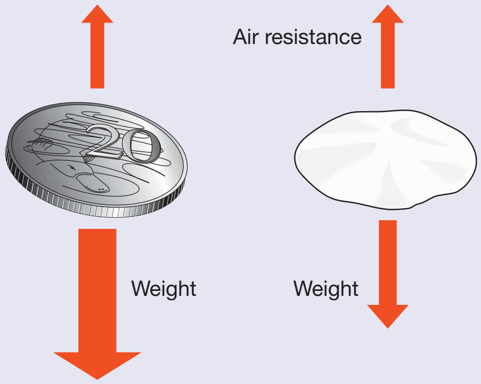
To investigate the effect of air resistance on a disc

Materials

- 20 cent coin
- Scissors
- Paper

Method

1. Drop a coin from about chest height. The force of gravity on the coin (its weight) pulls it down. It speeds up until it hits the floor.
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? 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 seperately? Explain why this occurred.

Conclusion

Summarise your findings on what occured when the coin and discs 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 don't feel the same push of air against you.

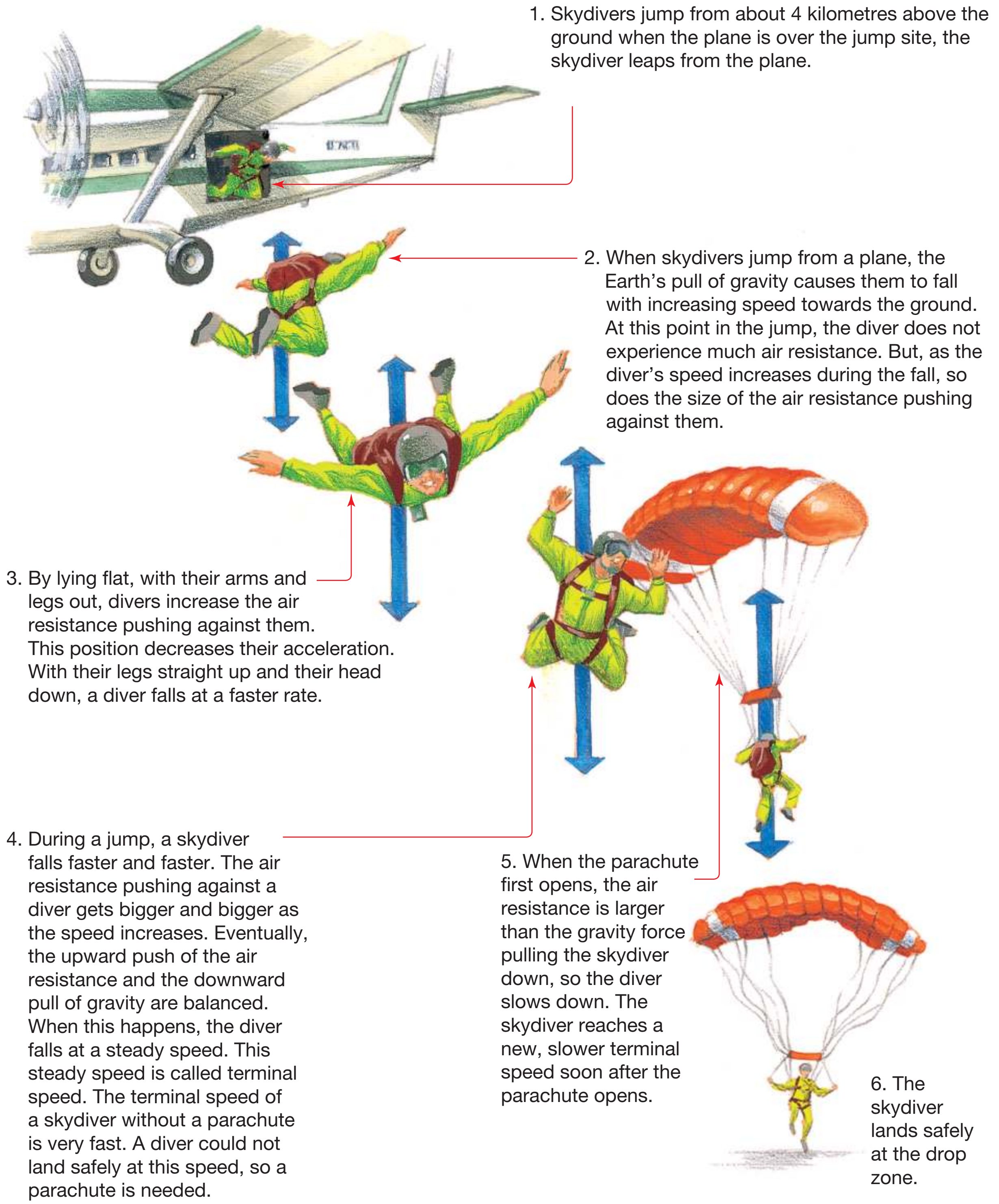
If the object travels fast enough, the air resistance can become as great as the force of gravity on the object. Once the air resistance balances the force of gravity, the net force on the object is zero and it stops speeding up. It has reached its **terminal speed**. It won't fall any faster.

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

Forces in skydiving

int-3450

FIGURE 8.11 Forces involved in skydiving



There is something about falling through the air at 200 km/h that really gets the adrenaline pumping! 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 8.11.

EXTENSION: Resistance in skydiving

Skydivers reach speeds of about 200 km/h before air resistance is great enough to balance their weight. After the parachute has opened, the air resistance is much greater than the skydiver's weight, slowing him or her down to about 20 km/h.

FIGURE 8.12 There is more than one force acting on this skydiver.

elog-2073

INVESTIGATION 8.4

The landing time of a parachute

Aim

To investigate the effect of a variable on the landing time of a parachute

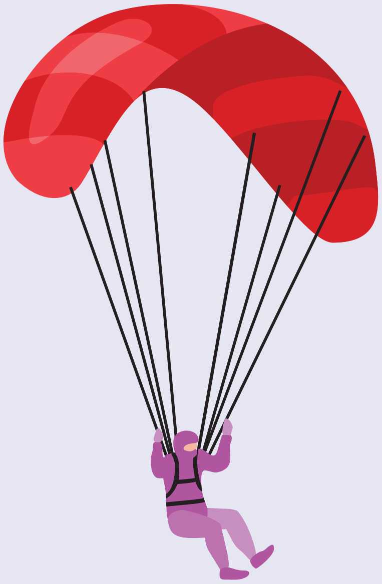
Materials

- 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

TABLE The effect of the area of a canopy on the time for a parachute to reach the ground

	Time taken to fall (seconds)			
Area of canopy (square centimetres)	**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 variable 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 longest to reach the floor with a standard load of five paperclips from a height of 2 metres.

on Resources

eWorkbooks Moon Olympics (ewbk-11377)
Gravity (ewbk-11379)

Video eLessons Isaac Newton (eles-1771)
Skydivers (eles-2554)

8.3 Activities

learn**on**

8.3 Quick quiz on | **8.3 Exercise**

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
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Remember and understand

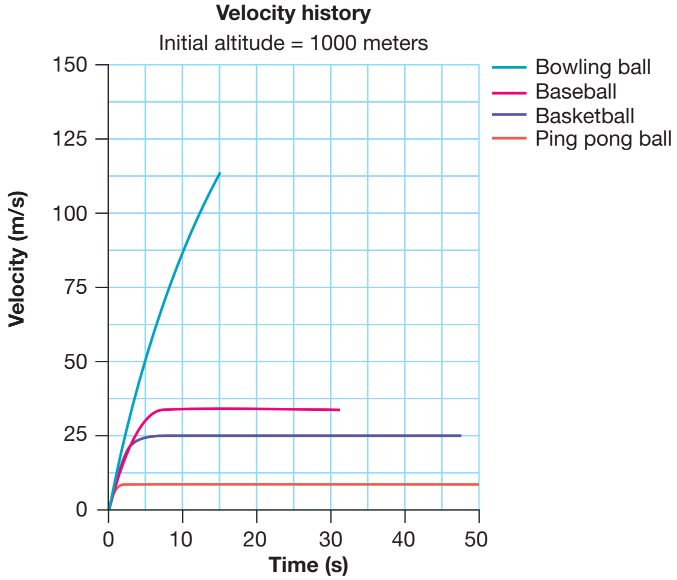
1. Describe the difference between mass and weight.
2. The force of gravity is not the same on all objects. On what property of each object does it depend?
3. If you were to land on Mars, what would change: your mass, your weight or both?
4. What is the weight on Earth of a person with a mass of 50 kilograms?
5. What is terminal speed?

Apply and analyse

6. If every object with mass pulls on other objects with a force of gravity, explain why you don't notice objects being attracted to you.
7. a. On Earth, Belinda has a weight of 450 newtons. Calculate her mass.
   b. On the Moon, the gravity is around one-sixth that of Earth. What would you expect Belinda's weight to be on the Moon?
8. a. What three forces are acting on the bungee jumper on the opening page of this topic just before reaching the water?
   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 is no air resistance acting on them, which do you think will reach the ground first?
   c. Find out how the acceleration of a falling object is related to the force due to gravity acting on a falling object in a vacuum. Use your research to explain your answer to part (b).

Evaluate and create

10. SIS Would a rubber band be as effective as a spring in a force measurer? Design an investigation that would allow you to find this out.
11. SIS 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. SIS Find out more about the contributions to science made by Sir Isaac Newton. Write a brief report about his achievements other than his Law of Universal Gravitation.
13. SIS 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.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
8.4 Friction

LEARNING INTENTION

At the end of this lesson you will be able to explain what friction is, and 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 8.13 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 8.13 Friction is needed to start skating, and to stop.

CASE STUDY: Crickets communicate with friction

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.

friction the force applied to the surface of an object when it is pushed or pulled against the surface of another object

traction a type of friction used to assist movement

8.4.2 Friction is sometimes a nuisance

Although friction is necessary for movement and 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. And 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!

FIGURE 8.14 Olympic bobsled teams spend long hours smoothing and polishing the runners of their sleds.

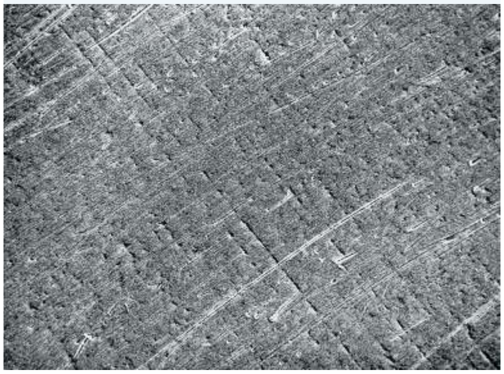
8.4.3 What causes friction?

Even very smooth surfaces are rough when you look at them under a very powerful microscope.

The photograph in figure 8.15 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 8.15 A close-up of a 'smooth', polished surface



8.4.4 Reducing friction

Ball-bearings

Ball-bearings are often used to reduce the friction on wheels as they spin around an axle, as seen in figure 8.16. 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 as they lessen the amount of contact between the surfaces.

FIGURE 8.16 Ball-bearings reduce friction between the axle and wheel hub of a skateboard.

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.

lubricant substance with large particles that can slide easily over each other

Synovial fluid is an an example of a lubricant in the human body and is found between your joints to stop your bones from scraping against each other.

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.

fluid a substance that flows and has no fixed shape. Gases and liquids are fluids.

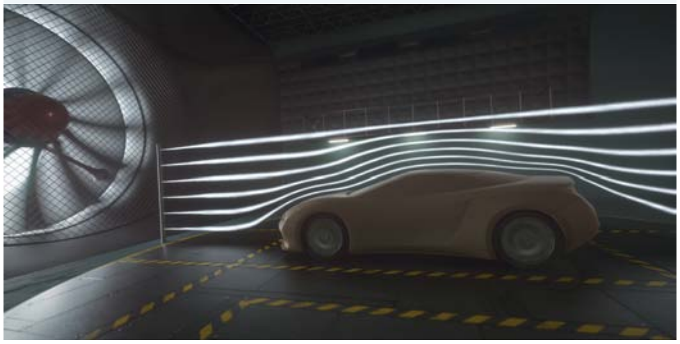
streamlined being shaped so that drag through a fluid is minimised

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, as shown in figure 8.17.

FIGURE 8.17 A racing cyclist's equipment is designed to reduce fluid friction.

FIGURE 8.18 Scientists use wind tunnels to test the effect of fluid friction on objects with different designs.



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, scientists and other crew members of the International Space Station return to Earth, the greatest danger they face is re-entry into Earth's atmosphere. Until July 2011, crew members returned on board a NASA space shuttle. Since then they have returned aboard a much smaller and differently shaped Russian *Soyuz* capsule. After travelling through space with almost no friction, both re-entry craft enter the upper atmosphere at speeds above 25 000 km/h. Because they are travelling so fast, the force of fluid friction is huge, causing temperatures on the outside of the craft to reach more than 1500 °C, enough to make them glow red hot.

The surfaces of the NASA space shuttles were covered with thousands of ceramic tiles to protect the crew. The *Soyuz* capsule has a heat shield and a surface covered with ceramic sheets. As the space shuttles slowed down, they zigzagged through the lower atmosphere, cooling down and getting into the correct landing path. It landed like a plane at speeds of about 300 km/h. The *Soyuz* capsules get rid of the heat shield on entering the lower atmosphere and are guided down by a system of parachutes. The capsule falls to the ground on the plains of Kazakhstan at about 5 km/h and its crew is assisted out of the capsule by a ground recovery team.

FIGURE 8.19 A recovery team locates the *Soyuz* capsule after a safe landing.

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 8.20 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?

elog-2075

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 differences in friction of various shoes.

on Resources

eWorkbook Friction (ewbk-11381)

Video eLessons Friction as a driving force (eles-0032)
Synovial fluid (eles-2231)
Model of a waterski (eles-2235)

Interactivities Moving boxes (int-3447)
Friction as a driving force (int-0054)

8.4 Activities

learnon

8.4 Quick quiz on | **8.4 Exercise**

Select your pathway

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

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Remember and understand

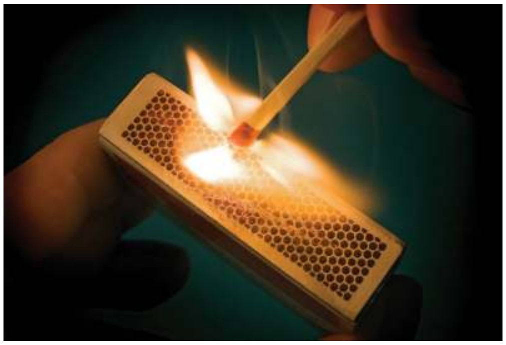
1. **MC** What is friction?
   A. A force of attraction between two objects with mass
   B. A force applied to the surface of an object when it moves against the surface of another object
   C. A force between charged particles
   D. A force of repulsion between two objects

2. Friction can cause objects to slow down. What else can it do?
3. How is traction different from other types of friction?
4. List three ways in which friction can be reduced. Give an example of each method.
5. What is fluid friction? List some examples of fluid friction.

Apply and analyse

6. For each of the 'friendly friction' photos 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 'unfriendly friction' images 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. **SIS** Olympic swimmers use to wear smooth, tight-fitting suits, streamlining their bodies to reduce friction. Some of them even shave their heads. Research at least three other sports in which athletes attempt to reduce friction and outline how they do so.
9. Write about how frictional forces would affect astronauts aboard the space capsule as it leaves from the International Space Station, re-enters Earth's atmosphere and lands.

10. **SIS** Imagine a world without friction. Make a list of things that would be:
   a. easier to do b. harder to do.
11. **SIS** Research and report on each of the following questions about car tyres.
   a. Why do tyres have tread?
   b. Are wider tyres better than narrow ones? Why?
   c. How does it affect your driving when the tread is worn away and the tyres are 'bald'?
   d. How does tread make wet weather driving safer?

Fully worked solutions and sample responses are available in your digital formats.

LESSON
8.5 Keeping afloat

LEARNING INTENTION

At the end of this lesson you will be able to 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, *Wonders of the Seas*, has a mass of about 237 million kilograms. The downward pull of gravity on this giant of the sea, its weight, is huge — over 2.3 billion newtons. Why doesn't it sink?

buoyancy an upward force acting on a floating object provided by a fluid

There must be an upward force equal to its weight. That upward force is provided by the water it is floating on. It's called **buoyancy**.

FIGURE 8.21 The force of buoyancy pushes upwards to keep this huge cruise ship afloat.

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 8.22. If the buoyancy force is greater than the weight of the balloons, they will rise into the air if the girl lets go. If the buoyancy force is greater than the weight of the girl and the balloons, they will take the girl with them.

The buoyancy force of the water in the Dead Sea is so large you can lie back and read a book, as shown in figure 8.23. The unusual size of the force is caused by the large amount of salt in the water.

FIGURE 8.22 What will happen if she lets go?

FIGURE 8.23 Buoyancy in the Dead Sea

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INVESTIGATION 8.6

Are things really lighter in water?

Aim

To measure buoyancy and its effect on the apparent weight of an object

Materials

- Stone
- Length of string
- Spring balance
- Bucket
- 500 gram mass

Method

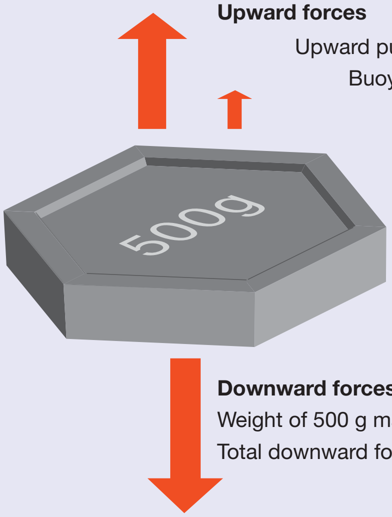
1. Tie some string around a large stone. Suspend the stone in a bucket of water without letting it touch the bottom.
2. Use a spring balance to find the weight, in newtons, of a 500 g mass and record it.
3. Without removing the mass from the spring balance, carefully lower it into the bucket so that 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 weight, in newtons, of the 500 g mass?
3. What was the weight, in newtons, of the 500 g mass when it was 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.).



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

3. Is the 500 g mass really lighter? Explain.

Conclusion

Summarise your findings from this investigation, explaining why an object feels lighter in water.

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?

surface tension the 'firmness' of the surface of a liquid created by the attraction between particles at the surface

FIGURE 8.24 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 until a certain point, you can overfill your glass with water because the surface tension of the water creates a meniscus.

a.

b.

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.

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INVESTIGATION 8.7

Water drops

Aim

To investigate how dishwashing liquid 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 liquid 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 liquid 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 liquid affects the surface tension of water.

DISCUSSION: Walking on water

The water spider can walk on water. Water spiders are certainly light, but is that the only reason that they do not sink?

Surface tension is what keeps the water spider from sinking and drowning. The small weight of the water spider is well spread out over the surface and is not large enough to push the water particles apart.

What inventions apply the same principles to allow humans to move over water? What inventions apply different principles to allow us to move over water?

FIGURE 8.25 The water spider walks on water. Why can't you?

on Resources

- **eWorkbook** Buoyancy (ewbk-11383)
- **Video eLesson** Surface tension (eles-2036)
- **Interactivity** Density (int-0221)

8.5 Activities

learnon

8.5 Quick quiz on | **8.5 Exercise**

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Select your pathway

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

Remember and understand

1. MC 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. Which fluid produces the greater buoyancy force — air or water? How do you know?
4. Name the three forces acting on a water spider when it is standing on a still pond.

Apply and analyse

5. State if an object would sink, rise to the surface or not move if plunged into a fluid where:
   a. the buoyancy force is the same as its weight
   b. the buoyancy force is less than its weight.
6. Explain in terms of gravity, buoyancy and surface tension why humans can't walk on water.

Evaluate and create

7. SIS Different fluids produce different buoyancy forces. Drop a corn kernel or pea into a glass of water and another into a glass of soda water (or research what would happen in this situation). Which liquid applies the larger buoyancy force? Explain why.
8. SIS Design an experiment to compare the buoyancy and surface tension of water, olive oil and vinegar. Write up a report using the following headings: aim, hypothesis, materials, and method. Explain your expected results and conclusion for this investigation.
9. SIS Find out what capillary action is and how it works.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
8.6 Magnetic fields

LEARNING INTENTION

At the end of this lesson you will be able to describe the magnetic fields produced by a magnet and explain how an electromagnet works.

8.6.1 Magnetic attraction

Magnets can attract certain materials without actually touching them. Magnetic forces can therefore be referred to as non-contact forces.

Magnets that retain their magnetism when removed from other magnets are called **permanent magnets**. Natural permanent magnets contain one or more of the elements iron, nickel and cobalt. The most common natural permanent magnetic substance is magnetite, also known as lodestone.

Most permanent magnets, however, are **alloys**, or mixtures, of iron, nickel or cobalt with other elements. Items made of steel are attracted to magnets because steel is an alloy of iron, carbon and other substances.

Temporary magnets are those that lose their magnetism when removed from another magnet. For example, paperclips themselves are not magnetic, but become temporary magnets while in contact with the permanent magnet. As soon as they are removed from themagnet, they lose their magnetism.

permanent magnet magnet that retains its magnetic effect for many years

alloy a mixture of a metal with other elements

temporary magnet magnet that does not stay magnetic after it has been removed from another magnet

FIGURE 8.26 Magnets that might be found at home: **a.** fridge magnets, **b.** a magnetic screwdriver and **c.** a magnetic knife holder

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INVESTIGATION 8.8

What does a magnet attract?

Aim

To investigate the magnetic attraction of a magnet

Materials

- Magnet
- Selection of materials to be tested (pencil, paper straw, plastic straw, coins, iron nail, stainless steel spoon, aluminium foil, paperclip, copper wire)

Method

1. List the materials you think will be attracted to the magnet.
2. Place a magnet close to a range of materials to find out which ones are attracted to it.
3. Record your observations in a table.

Results

Outline which materials were attracted to the magnet and which were not in a table like the following one.

TABLE The attraction of different materials to magnets

Attracted	Not attracted

Discussion

1. Are all metals attracted to magnets?
2. Of the materials that were attracted to the magnet, which one was attracted the most? Why do you think this was so?
3. Were there any forces other than the magnetic force acting on the objects? If so, what were they?
4. Were there any unexpected observations? If so, what were they?

Conclusion

Summarise your findings from the investigation, explaining which objects were attracted to the magnet.

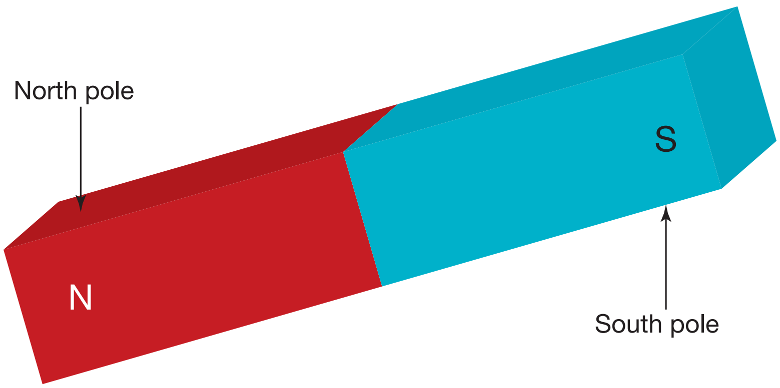
Extension

Do some materials 'block' the magnetic force? Design an experiment to find out.

8.6.2 Magnetic poles

All magnets, no matter what their shape, have a **north pole** at one end and a **south pole** at the other.

FIGURE 8.27 The north and south poles of a magnet



When a magnet is cut in half, each half still has a north pole and a south pole. If you keep cutting a magnet in half over and over again, each half always has a north pole and a south pole.

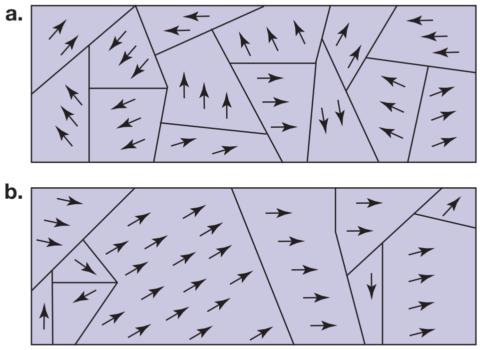
Certain materials can act like a magnet because of their **domains**. If the regions within the material line up, the material will behave like a magnet.

north pole the end of the magnet that, when free to rotate, points to the north pole of Earth

south pole the end of the magnet that, when free to rotate, points to the south pole of Earth

domains regions within the material that are aligned or facing different directions

FIGURE 8.28 The material will behave like a magnet only when the domains are lined up.



If the domains inside the material all face different directions, the material will not behave like a magnet.

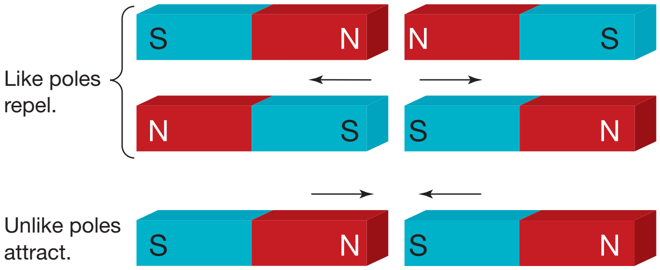
If almost all the domains are lined up facing the same direction, the material will behave like a magnet.

As seen in figure 8.29, when the north poles of two magnets are brought close together, the magnets push away (or repel) each other. This same **repulsion** force is felt between two south poles.

repulsion an opposing force in which objects are pushed away from each other

When the north pole of a magnet comes close to the south pole of another magnet, the opposite happens. They pull on each other, or attract one another.

FIGURE 8.29 In magnets, like poles repel each other and unlike poles attract.



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INVESTIGATION 8.9

Poles apart

Aim

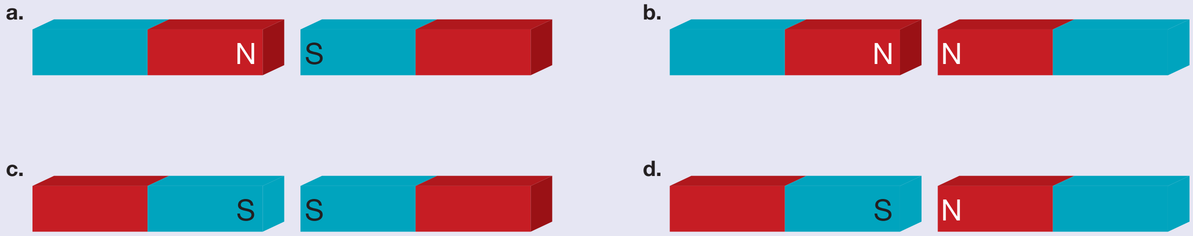
To investigate the forces of attraction and repulsion between the poles of a magnet

Materials

- Two bar magnets

Method

1. Take two bar magnets and identify the north and south pole of each.
2. Position the magnets near each other in the configurations shown.
3. Take note of whether the magnets attract or repel each other in each case.



Results

TABLE The magnetic force between different configurations of bar magnets

Configuration	Attraction or repulsion
a.	
b.	
c.	
d.	

Discussion

1. Describe what you observed in your investigation.
2. Were the forces you observed contact or non-contact forces?
3. If you were able to snap the magnets in half, would you expect similar results? Explain your answer.

Conclusion

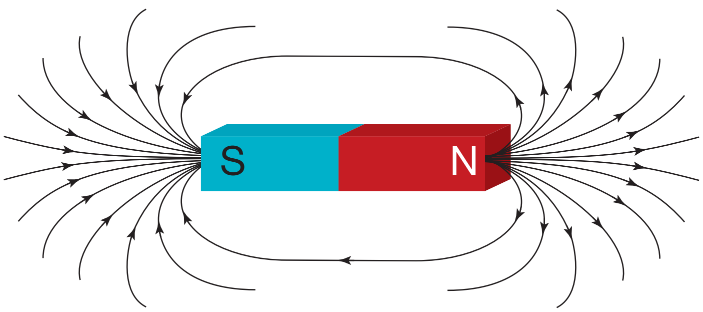
Summarise your findings from the investigation, explaining the attraction and repulsion between poles of a magnet.

8.6.3 Magnetic fields

Iron filings line up in the direction of the magnetic force around a magnet. The area where the magnetic force acts is called the **magnetic field**.

The magnetic field can be drawn like a map, as in the diagram in figure 8.30. The lines show the direction of the magnetic force. The lines are closest together where the magnetic force is greatest and furthest apart where the magnetic field is weakest. Notice that the lines of the magnetic field point away from the north pole and towards the south: that is, from north to south. The north pole of a compass points in the direction of a magnet's magnetic field.

FIGURE 8.30 Magnetic fields can be drawn as maps.



magnetic field a map of lines showing the size and direction of a magnetic force

8.6.4 Earth's magnetic field

Earth, like the Sun and some planets, has its own magnetic field. It is very much like the magnetic field of a bar magnet. Scientists are not sure why Earth has a magnetic field.

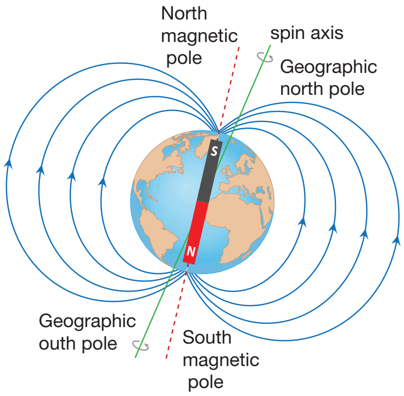
Any magnet free to turn will line itself up along the field lines. The north pole of the magnet is the pole that points towards the magnetic North Pole of Earth. In a similar way, the south pole of a magnet points towards the magnetic South Pole of Earth.

A compass is just a small magnet with its poles tapered to a point. The north pole of a compass is usually coloured or marked. This end of the compass points towards the magnetic North Pole of Earth (as shown in 8.31). However, if another magnet is brought close to a compass, the north pole of the compass points towards the south pole of the other magnet.

The direction of any magnetic field is the direction in which the north pole of a compass needle points.

FIGURE 8.31 A compass contains a small magnetic needle that aligns with Earth's magnetic field.

FIGURE 8.32 Earth's magnetic poles are not in the same location as the geographical poles.



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INVESTIGATION 8.10

Mapping the magnetic field

Aim

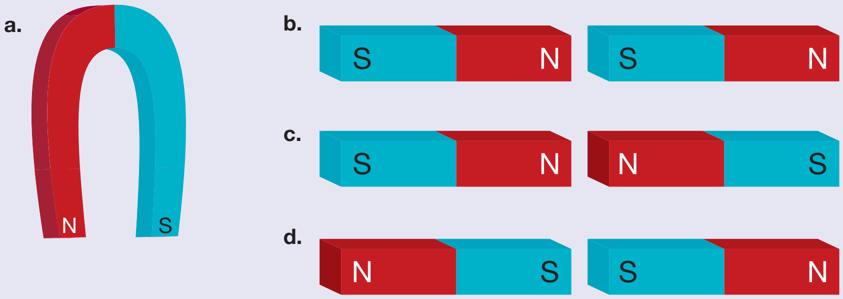
To map the magnetic field around magnets

Materials

- Horseshoe magnet in a plastic bag
- Overhead transparency
- Two bar magnets in plastic bags
- Iron filings
- Sheet of A4 paper
- Small compass

Method

1. Place a bar magnet in the centre of a sheet of white paper.
   Cover the paper and magnet with an overhead transparency.
2. Carefully sprinkle iron filings over the transparency, gently tapping it to spread the filings out. Take care not to let iron filings get under the transparency.
3. Draw a diagram of the pattern made by the iron filings. Label the north pole and south pole of your magnet on the diagram. The pattern in your diagram is a map of the magnetic field around the bar magnet.
4. Place a compass at several positions around the magnet. The direction in which the compass needle points shows the direction of the magnetic field lines. Add arrows to your diagram to show the direction of the magnetic field.
5. Use the iron filings and compass to investigate the magnetic fields around a horseshoe magnet and the pairs of magnets shown.



Results

Draw a diagram of the magnetic field (put arrows on the field lines to indicate their direction) that results from four configurations examined.

Discussion

1. Explain how the magnetic field around the horseshoe magnet is different to that of the bar magnets.
2. Does the orientation of the bar magnets affect the magnetic field? Explain your response.
3. Suggest other configurations you may explore in this investigation.

Conclusion

Summarise your findings in relation to the magnetic fields.

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INVESTIGATION 8.11

Making your own compass

Aim

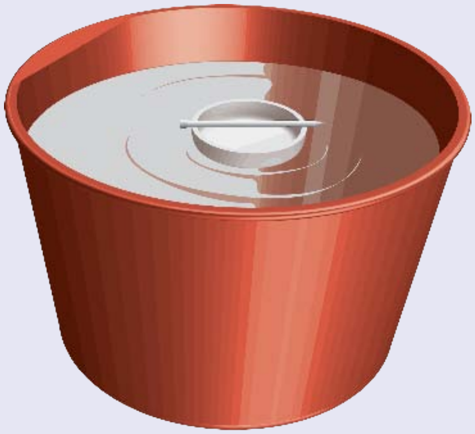
To make your own compass using an iron nail

Materials

- Large iron nail (about 75 mm long)
- Strong magnet
- Paperclips or small nails
- Sewing needle
- Polystyrene cup
- Compass
- Container of water

Method

1. Take a large iron nail and stroke it with a strong permanent magnet.
2. After each stroke, lift the magnet high above the nail before commencing the next one. You need to make sure that each stroke is in the same direction and made with the same end of the magnet.
3. After a total of 40 strokes, test your new magnet by trying to attract paperclips or small nails.
4. Compare the strength of your magnet with that of others in your class.
5. Use your magnet to make a compass like the one shown. You will need a container of water and a float. The bottom of a polystyrene cup will make a good float. Compare the direction of the nail to the direction of a compass.



Results

Did the iron nail in your homemade compass point in the same direction as the real compass? In which direction did it point?

Discussion

1. Is your magnet a permanent magnet or a temporary magnet?
2. Which end of your magnet is the north pole? How do you know?
3. Could you magnetise the sewing needle instead of an iron nail? Try it! Explain why or why not.

Conclusion

Summarise your findings for this investigation, explaining how an iron nail compass compares to a normal compass.

8.6.5 Electromagnets

An **electromagnet** is a type of magnet that only becomes magnetic when connected to an electric current. It is often a coil of wire wrapped around an iron core. When an electric current is passed through the coil, it creates magnetic fields and is made stronger by the iron core. When the current is turned off, the iron is no longer magnetised. Being able to turn a magnet on and off at will can be very useful.

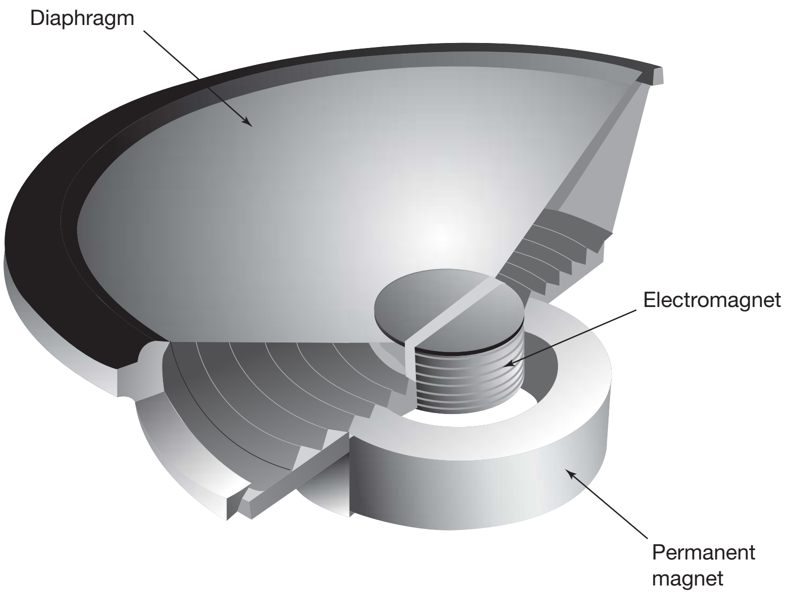
FIGURE 8.33 An electromagnet on a large crane used to lift scrap metal

Figure 8.33 shows one such use. The electromagnet is attached to a giant crane. The electric current is turned off while the electromagnet is lowered onto the load of scrap metal to be lifted. When the current is switched on, the iron or steel in the scrap is attracted to the electromagnet and lifted to a container. The electric current is switched off and the metal falls into the container. This is useful to separate iron and steel (which are attracted to magnets) from other scrap metal.

Electromagnets are also used in doorbells, metal detectors, speakers, phones, electric motors and generators.

We use electromagnets and permanent magnets every day. Computer hard drives (not solid state drives) store information by forming magnetic patterns on disks. Electromagnets are used to store and read the magnetic patterns. Phones have microphones and speakers (shown in figure 8.34) that rely on both permanent magnets and electromagnets.

FIGURE 8.34 Cross-section through a speaker



electromagnet a magnet that requires an electric current to become magnetic

DISCUSSION

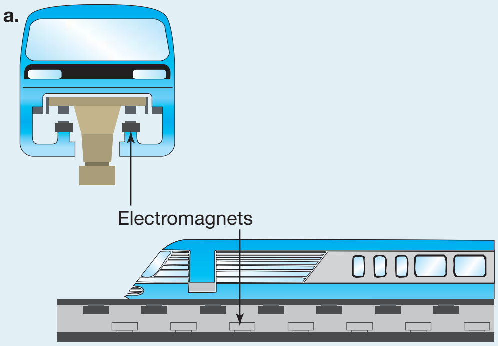
The maglev train gets its name from MAGnetic LEVitation. It carries passengers at speeds of up to 500 km/h and doesn't even need a normal engine to run! It uses pushing forces between electromagnets on the track and on the train to keep them apart.

Electromagnets also propel the train forwards. Magnets ahead of the train pull the train forwards. Magnets behind the train push it forwards.

The maglev train seems to float above the train tracks. The train touches the track only while it is building up speed before moving.

Are there other devices or transport systems that run on magnetic force? What devices that require power might be redesigned to use magnetic force? Could this technology be harnessed to reduce our reliance on fossil fuels?

FIGURE 8.35 a. Electromagnets and the maglev train **b.** The bullet trains in Japan use maglev and can reach speeds of up to 505 km/h!



EXTENSION: Solenoids

The coil of wire that is wrapped around the iron core in an electromagnet is called a solenoid. Even without the iron core inside, a solenoid produces a magnetic field. Solenoids are used in many devices, including cars, to switch things on and off.

Think about the appliances and gadgets you have at home. Predict which of them might use a solenoid to switch on and off. Research each of your predictions to determine whether your guess was correct.

elog-2088

INVESTIGATION 8.12

Making an electromagnet

Aim

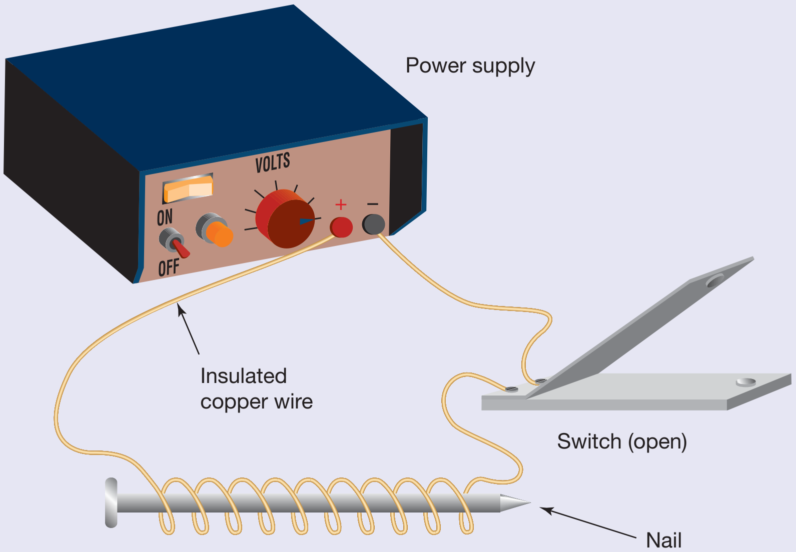
To investigate the effects of voltage and number of turns of wire on the strength of an electromagnet

Materials

- Two insulated wires: one short, the other 1.5 m long
- Power supply
- Switch
- Paperclips (many)
- Nail

Method

1. Before you begin, answer the following questions to form your hypothesis.
   - How do you think increasing the number of turns of wire will affect the strength of the electromagnet?
   - How do you think increasing the voltage will affect the strength of the electromagnet?
2. Wind 15 turns of the longer wire around the nail. There will be a lot of wire left over but do not cut it.
3. Set up the electric circuit as shown.



4. Set the power supply to 2 volts and close the switch.
5. Test your electromagnet by opening the switch and seeing how many paperclips it will pick up.
6. Wind five more turns of wire around the nail. Record the number of paperclips picked up by your electromagnet now.
7. Keep winding the wire around the nail. Record the number of paperclips picked up by 25 and 30 turns of wire.
8. Increase the voltage to 4 volts and repeat the previous steps.

Results

Copy and complete the following table:

TABLE The number of paperclips picked up at different voltages and wire turns

Voltage of power supply (V)	Number of turns of wire	Number of paperclips picked up
2	15	
2	20	
2	25	
2	30	
4	15	
4	20	
4	25	
4	30	

Discussion

1. What is the effect of increasing the number of turns around the nail?
2. What is the effect of increasing the voltage?
3. Did the iron nail retain its magnetism when the current was switched off? Explain.

Conclusion

Summarise your findings for this investigation, explaining how the strength of the electromagnet was affected by voltage and the number of turns of wire.

on Resources

eWorkbooks	Magnetic fields and forces (ewbk-11387) Electromagnetism (ewbk-11385)
Video eLessons	A Shanghai Maglev train (eles-2552) Earth's magnetic field (eles-2798) Electromagnet (eles-2234) Electromagnetism (eles-1778) The magnetic field around a bar magnet (eles-2232)

8.6 Activities

learn**on**

8.6 Quick quiz on | **8.6 Exercise**

Select your pathway

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

Remember and understand

1. MC Which of the following statements is correct?
   A. Permanent magnets never lose their magnetism.
   B. All metals are strongly attracted to magnets.
   C. Iron, steel and nickel are attracted to magnets.
   D. Iron is the only substance attracted to magnets.
2. What is the difference between a permanent magnet and a temporary magnet?
3. MC How should two bar magnets be placed on a table so that they repel each other? (*Hint:* There may be more than one correct answer.)
   A. South poles close together
   B. North poles close together
   C. One south pole and one north pole close together
   D. All of the above
4. Describe a magnetic field.

Apply and analyse

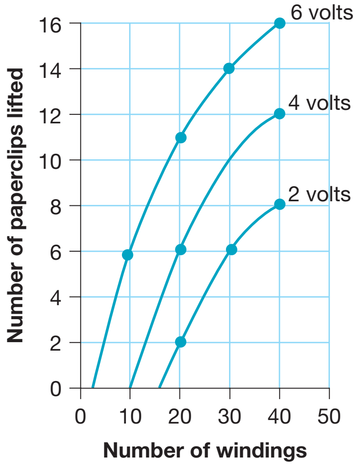
5. a. Describe what an electromagnet is and explain how it works.
   b. What is the advantage of an electromagnet over a permanent magnet?
6. The magnetic North Pole of Earth can be considered as one pole of a bar magnet. Is it a south pole or a north pole? Research this and explain your answer.
7. Explain which way the coloured end of a compass would point, if you were in a plane flying directly above Earth's magnetic North Pole?

Evaluate and create

8. SIS Design an experiment to measure the strength of different magnets. Write a clear method for your experiment and outline your expected results.

9. **SIS** Arianna made her own electromagnet to find out how the number of windings around a nail affected the number of paperclips that the nail could pick up. She used the circuit shown in investigation 8.12 with the power supply set to 2 volts. Arianna then repeated her measurements with the power supply set to 4 volts and 6 volts. She recorded her observations in a table, then she constructed a graph as shown, which she titled 'The effect of the number of windings around a nail in an electromagnet on the number of paperclips lifted'.
   a. How many paperclips did Arianna lift with 20 windings and the power supply set to 6 volts?
   b. Arianna lifted 12 paperclips when the power supply was set to 4 volts. How many windings were there around the nail?
   c. How many paperclips could Arianna expect to lift with 50 windings around the nail and the power supply set to 2 volts?
   d. Suggest a way in which Arianna would be able to make her results more reliable.
10. **SIS** Design a device that uses an electromagnet to make a noise when you close a switch or push a button. Explain how your device works.

The effect of the number of windings around a nail in an electromagnet on the number of paperclips lifted



Fully worked solutions and sample responses are available in your digital formats.

LESSON
8.7 Electric fields

LEARNING INTENTION

At the end of this lesson you will be able to describe electrical charge and the methods used to charge an object. You will also be able to explain the behaviour of an electric field produced by a charged object and the difference between a conductor and an insulator.

8.7.1 Electric charge

All matter is made up of atoms. At the centre of each atom is a heavy **nucleus**. Inside the nucleus are two different types of particles: **protons**, which carry a positive electric charge, and **neutrons**, which carry no electric charge. Surrounding the nucleus is a lot of empty space and tiny particles called **electrons**. Electrons are constantly moving around the nucleus. Each electron carries a negative **electric charge**.

nucleus central part of the atom, made up of protons and neutrons

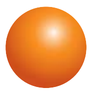
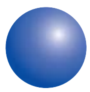
proton tiny, but heavy, positively charged particle found in the nucleus of an atom

neutron tiny, but heavy, particle found in the nucleus of an atom with no electrical charge

electron very light, negatively charged particle inside an atom

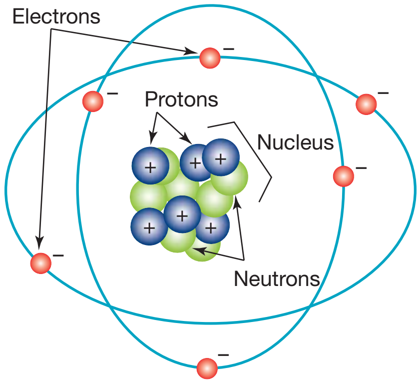
electric charge a property relating to the charge (negative or positive) on an atom or object

TABLE 8.1 Summary of the particles found inside an atom

	Electron	Proton	Neutron
			
Charge	–	+	0
Location	Around the nucleus	Inside the nucleus	Inside the nucleus

The positive electric charge of a proton exactly balances the negative charge of an electron. Any particle or substance that has more protons than electrons is said to be positively charged. Any particle or substance that has more electrons than protons is said to be negatively charged. Any particle or substance that has equal amounts of positive and negative charge is said to be uncharged or **neutral**.

FIGURE 8.36 A neutral atom contains an equal number of protons and electrons. This diagram represents a carbon atom. The number of neutrons is not always the same as the number of protons.



8.7.2 Becoming charged

Substances usually become charged by the addition or removal of electrons. This can be done in two ways: by friction or by contact.

Friction

The rubbing of one neutral substance against another adds or removes electrons. When you rub a plastic ruler with wool, electrons are moved from the neutral wool onto the neutral plastic ruler. The wool, having lost electrons, becomes positively charged. The plastic ruler, having gained electrons, becomes negatively charged.

Contact

If a neutral substance is touched by a charged object, electrons can move to or from the charged object. When the charged object is removed, the previously neutral substance has gained or lost electrons.

Electrons are the easiest particles to add to or remove from atoms, because they are not held together in the nucleus as protons are.

8.7.3 Electric fields

The area around an electrically charged object where objects experience an electric force is called an **electric field**. The strength of the electric field increases with the size of the charge producing it and decreases with distance. When two charged particles are near one another, their electric fields interact to produce forces of attraction or repulsion.

neutral having the same number of protons and electrons

electric field an area around an electrically charged object where objects experience an electric force

When two like charges (two positive charges or two negative charges) are placed near each other, they will experience a force of repulsion.

When two unlike charges (a negative charge and a positive charge) are placed near each other, they will experience a force of attraction.

8.7.4 Static electricity

The electricity that builds up on plastic rulers, balloons and the Van de Graaff generator (figure 8.37) is called **static electricity**. The word 'static' means standing still. The charge on the objects is called electrostatic charge (or static charge). Static charge can leak slowly through substances such as rubber and air. Substances through which electric charge cannot move quickly are called **insulators**. Static charge builds up easily in insulators. Substances through which electric charge flows easily are called **conductors**. Metals are good conductors of electricity. Static charge doesn't build up in conductors.

static electricity a build-up of charge in one place

insulator material that does not allow an electric charge to flow through it

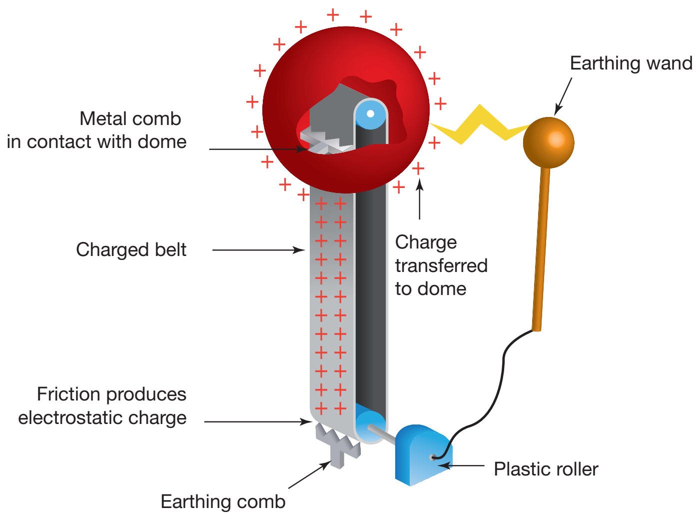
conductor material that allows an electric charge to flow through it

ewbk-11389

eles-2553

int-0031

FIGURE 8.37 a. In a Van de Graaff generator, charge is transferred from the rubber belt to the metal dome. In this Van de Graaff generator, a positive charge builds up on the dome. A spark discharge can be produced if an earthing wand is brought near the metal dome.



Objects with the same static charge repel each other while those with opposite charges attract each other. If sufficient charge builds up in oppositely charged objects, the attraction between the electric charges is so great that electrons can jump across small air gaps. Lightning is caused by the movement of electric charge between a cloud and the ground.

Charged objects and neutral objects can be attracted to each other. This effect can be seen in figure 8.38. When the negatively charged pen is close to the paper, electrons are repelled from the pen, leaving the top surface of the paper with a positive charge. Note that the whole piece of paper is still neutral. If there is enough charge and the pen is close enough to the paper, the attraction is great enough to pull the paper up. Once the paper is touching the pen, the charge moves across and arranges itself so that it is evenly spread out. This is similar to the pen and water, where the water bends towards the pen.

FIGURE 8.37 b. The effects of a Van de Graaff generator

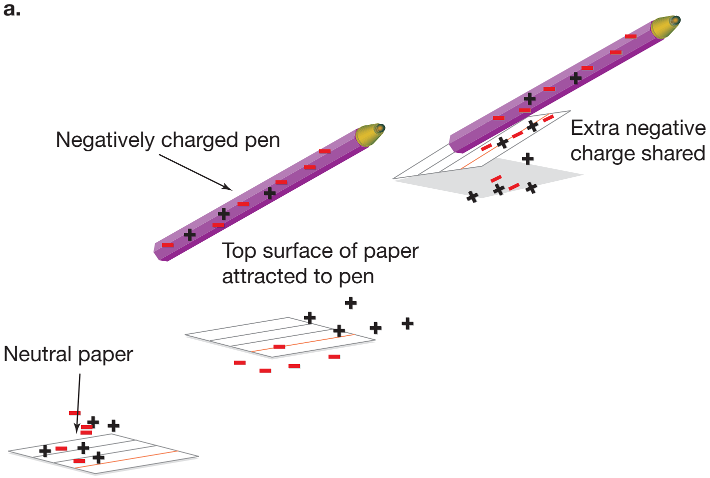
ACTIVITY: Salt and pepper

Can static electricity be used to separate a mixture of salt and pepper? Try it! Write a report using the following headings: aim, hypothesis, materials, method, results, discussion, conclusion.

int-3448

FIGURE 8.38 Charged and neutral objects can be attracted to each other, such as **a.** paper and **b.** water to a charged pen.

a.



b.

When static electricity is a nuisance

- When you clean and polish windows and mirrors with a cloth you leave the surface with an electric charge. The light, neutral dust particles nearby are attracted to the surface in the same way that the paper is attracted to the pen. Similarly, TV and computer monitor screens attract dust while they are being used.
- When you walk on carpet, the friction between the surface and your shoes gives your body an electric charge. If the air is dry and you are wearing rubber-soled shoes, the charge does not leak away but builds up. When you touch a metal object such as a door handle, the charge moves very quickly to or from your body, causing a small electric shock.
- A moving car builds up static electric charge as its tyres move along the road and its body rushes through the air. Because its driver and passengers are in contact with the car, they share the electric charge that builds up. Sometimes you will get a small electric shock when you get out of the car and touch the metal body, because the charge moves through your body to the ground.

When static electricity is useful

Static electricity is not always a nuisance. For example, photocopying machines use static electricity to make copies and electrostatic attraction can be used to separate light particles from other substances. In a chimney, smoke particles are charged as they move past a metal grid. They are then attracted to the sides of the chimney and form a layer of soot instead of passing out to pollute the air.

EXTENSION: When lightning strikes

The particles of water and ice inside clouds are constantly moving and colliding with each other. When they collide, electrons are transferred from the smaller particles to the larger particles. This leaves the lighter, smaller particles with a positive charge and the heavier, larger particles with a negative charge. Updrafts take the lighter positively charged particles closer to the top of the cloud. The larger negatively charged particles fall towards the lower part of the cloud.

The charges keep building up. Eventually there is so much charge built up that huge numbers of electrons move from the lower part of the cloud to either the upper part of a neighbouring cloud or the ground.

FIGURE 8.39 Lightning takes the easiest path to the ground.

If a bolt of lightning strikes a building, it can cause a huge amount of damage. It is known that lightning takes the easiest path to the ground, so lightning rods are attached to the tops of tall buildings. Lightning rods are made of a highly conductive metal. They are connected to a copper or aluminium cable, which conducts the charge to the ground, keeping the rest of the building safe.

elog-2091

INVESTIGATION 8.13

The attraction of electricity

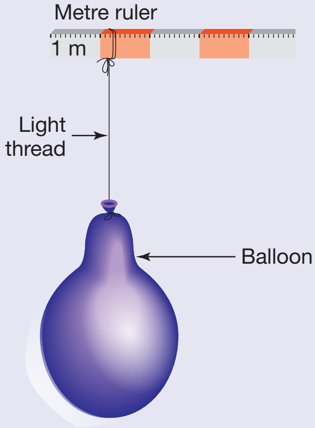
Aim

To investigate static electricity

Materials

- Two balloons
- Light thread
- Woollen cloth
- Metre ruler

Method



1. Suspend one balloon from the metre ruler with light thread, as shown in the diagram.
2. Rub the balloon with a woollen cloth.
3. Remove the woollen cloth and then place it close to, but not touching, the part of the balloon that was rubbed. Observe any movement of the balloon.
4. Suspend a second balloon from the metre ruler so that it is close to, but not touching, the first balloon.
5. Rub each of the balloons with a woollen cloth — rub on the surfaces that are facing each other.
6. Remove the cloth and position the balloons so that they are as close together as they can be without touching each other. Observe any movement of the balloons.

Results

1. Describe the movement of the single balloon. Did the balloon and the cloth attract or repel one another?
2. Describe the movement of the two balloons. Did the two balloons attract or repel one another?

Discussion

1. Do the balloons have the same charge as the woollen cloth after they are rubbed? How do you know?
2. After being rubbed with the woollen cloth, do the two balloons have like or unlike electric charges? How do you know?

Conclusion

Summarise your findings from this investigation, with reference to like and unlike charges.

elog-2093

INVESTIGATION 8.14

Defying gravity

Aim

To investigate the forces between a charged object and an uncharged object/substance

Materials

- Plastic ballpoint or felt-tip pen
- Woollen, cotton or nylon cloth
- Balloon

Method

1. Rub a plastic pen with a piece of cloth, then hold it near a thin stream of water from a tap.
2. Observe the behaviour of the water.
3. Rub an inflated balloon with the woollen cloth and place it against a wall. (If the balloon does *not* stick to the wall, try rubbing it with a different type of cloth.)

Results

1. Describe what happened to the water.
2. Did the balloon stick to the wall?

Discussion

1. Explain the behaviour of the water and balloon in your own words.
2. What is the effect of the cloth on the balloon?

Conclusion

Summarise your findings from this investigation, explaining what happens to the stream of water and the balloon on the wall, and why this occurs.

on Resources

eWorkbook Electrostatic charge (ewbk-11391)

Video eLesson Producing static electricity (eles-0067)

8.7 Activities

learn**on**

8.7 Quick quiz **on**	8.7 Exercise

Select your pathway

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

Remember and understand

1. Write down the type of electrical charge of the following particles.
   a. A proton b. A neutron c. An electron
2. State how an object containing protons and electrons may be neutral (or uncharged).
3. When you rub a plastic ruler with a woollen cloth, the plastic ruler becomes negatively charged.
   a. What happens to the atoms in the cloth and ruler to cause this change?
   b. Choose the options to complete this sentence correctly.
   As the ruler becomes negatively charged, the cloth becomes **positively/negatively** charged because it has more **protons/neutrons** than electrons.
4. Complete each of the following sentences by choosing the words 'attract' or 'repel'.
   a. Two positively charged objects would be expected to **attract/repel** each other.
   b. Two negatively charged objects would be expected to **attract/repel** each other.
   c. A positively charged object would be expected to **attract/repel** a negatively charged object.

Apply and analyse

5. Explain, with the aid of a diagram, how it is possible for a neutral object to be attracted to a charged object.
6. Two balloons are hanging on threads next to each other, but not touching. They begin to move away from each other. If one of the balloons is positively charged, what is the charge of the other balloon?

7. If you placed a charged pen near a whole A4 sheet of paper, would you expect the paper to rise and stick to the pen? Give a reason for your answer.
8. Draw a labelled diagram to show how a neutral stream of water from a tap is attracted to a charged plastic pen. Use the symbols + and – to represent positive and negative charge.

Evaluate and create

9. **SIS** Investigate why you are less likely to get an electric shock after walking on carpet in humid weather than in dry weather.
10. **SIS**
    a. As planes move through the air, they build up large amounts of static electricity. Investigate how this happens.
    b. Before refuelling, a wire is used to connect the plane to the ground. Investigate why this is important.
11. Devise a model (this may be diagrammatic) to represent positive and negative charges, to show how objects become positively and negatively charged. Use your model to demonstrate:
    a. whether a neutral object contains any electric charge
    b. what must happen to make an object:
        i. negatively charged.
        ii. positively charged
12. **SIS**
    a. Have you ever heard a crackling sound when you removed your clothes at night? What causes it?
    b. Which types of clothes are most likely to cause the crackling? Explain the reasoning behind this.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
8.8 Staying safe

LEARNING INTENTION

At the end of this lesson you will be able to apply the knowledge of forces to understand how helmets make cycling safer, airbags and seatbelts make driving safer, and how bending your knees makes landing on the ground safer.

8.8.1 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: Safer cycling

Every year in Australia, about 1200 people die as a result of road accidents. Many of the deaths and injuries can be avoided.

Bicycle riders account for well over one-third of road accident injuries in the 10–14-year-old age group. The most serious injuries tend to be to the head and face. The wearing of bicycle helmets has greatly decreased the number of head injuries to cyclists.

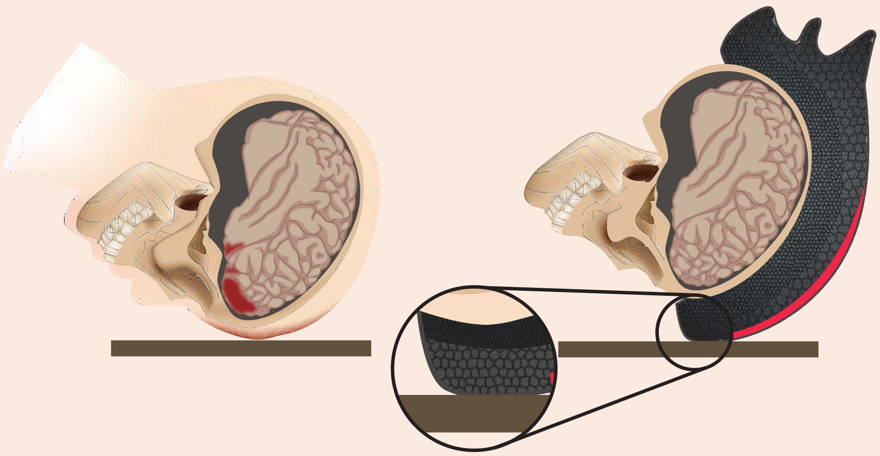
A bicycle helmet has a layer of polystyrene foam at least one centimetre thick inside a shell of hard plastic. A cyclist's head falling to the road hits the ground at speeds of up to 20 kilometres per hour. Without a helmet, the head stops suddenly when it hits the ground. The sudden impact can cause

FIGURE 8.40 The law requires that cyclists wear a bicycle helmet.

serious head injuries. With a helmet, the head stops more slowly as the plastic shell and polystyrene foam are crushed. The injuries are less severe.

Cycling isn't the only sport where you need a helmet. Other activities in which helmets soften the impact of a fall or collision include motorcycling, horse riding and a wide range of other sporting activities.

FIGURE 8.41 The plastic shell and polystyrene foam of a helmet soften the impact on the head in an accident.



elog-2095

INVESTIGATION 8.15

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.

elog-2097

INVESTIGATION 8.16

Crash test dummy

Aim

To model the effect 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.

8.8.2 Safety on four wheels

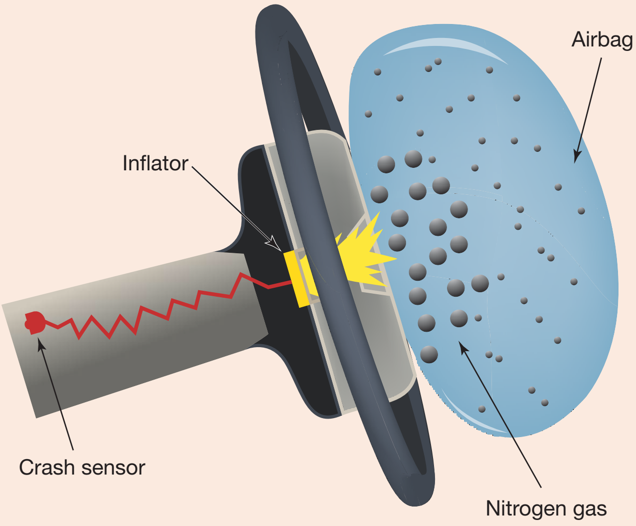
In cars and other motor vehicles, padded dashboards, collapsible steering wheels and airbags reduce injuries by allowing the upper body to slow down more gradually when a car crashes. The addition of various safety features has greatly reduced deaths and fatalities over the year.

SCIENCE AS A HUMAN ENDEAVOUR: 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 8.42.

FIGURE 8.42 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 with 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.

8.8.3 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 8.43 It's best to bend your knees when landing after a high leap.

on Resources

Interactivities How an airbag works (int-5896)
Safety features in cars (int-5895)

Weblink Car safety — RACV

8.8 Activities

learn**on**

8.8 Quick quiz on | **8.8 Exercise**

Select your pathway

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

These questions are even better in jacPLUS!

- Receive immediate feedback
- Access sample responses
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Remember and understand

1. MC How do bicycle helmets protect the head in an accident?
   A. Reduce the force of gravity on your head when it's falling
   B. Reduce the size of the force applied to your head
   C. Reduce friction between your head and the ground
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. SIS What is Newton's First Law of Motion and how is it relevant to seatbelts in cars?

Evaluate and create

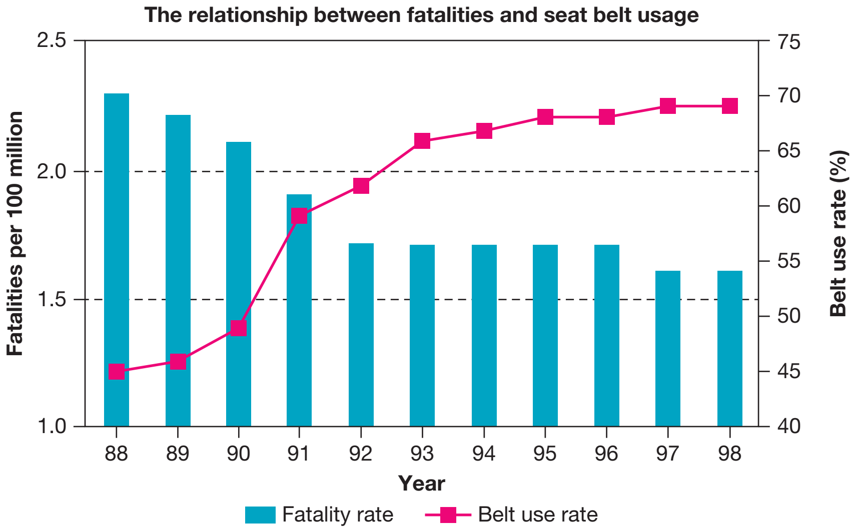
6. SIS Use the internet to research and report on the following questions.
   a. What evidence is there that the compulsory wearing of bicycle helmets in Australia has saved lives and prevented critical brain injuries?
   b. Not everybody believes that the wearing of bicycle helmets should be compulsory. Use a two-column table to list the reasons for and against the compulsory wearing of helmets.
7. Design a poster with the title 'Don't be an egghead. Wear a helmet'. Summarise the important aspects you included on your poster.
8. SIS Use the data in the table to answer the following questions.

TABLE Comparing the use of seatbelts and no seatbelts in car crash survivals and fatalities

	Seat belt	No seat belt	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. Display your results from (a) and (b) in a pie graph.
   d. What can you conclude from the data shown in this table?

9. **SIS** 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?

Fully worked solutions and sample responses are available in your digital formats.

LESSON
8.9 A world of machines

LEARNING INTENTION

At the end of this lesson you will be able to investigate how simple machines such as levers and pulleys are used to change the magnitude of force needed to perform a task.

8.9.1 Simple machines

What do you think of when you hear the word 'machine'? Maybe you think of a car engine. Or a car-building **robot** in a factory, or even a computer. And you would be right — these are all examples of machines. But machines aren't always complicated things made up of lots of moving parts. A machine can also be something as uncomplicated as a spear thrower (see figure 8.44), a screwdriver, a bow or an axe. The earliest machines used by humans were simple ones, such as the wedge and the wheel, or a hunting boomerang.

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. Machines help us by changing the direction in which a force acts, changing the size of a force, or both.

FIGURE 8.44 The atlatl (spear thrower) is a tool that has been used for thousands of years by humans. It uses leverage to dramatically increase the velocity and range of the projectile.

robot complex combination of machines designed to perform tasks without human assistance

on Resources

Video eLesson Robots assembling a car in fast motion (eles-2555)
Watch this video to observe the amazing ability of machines when assembling a car. The speed in which robots can complete assembly is much faster, improving every day as machines continue to advance.

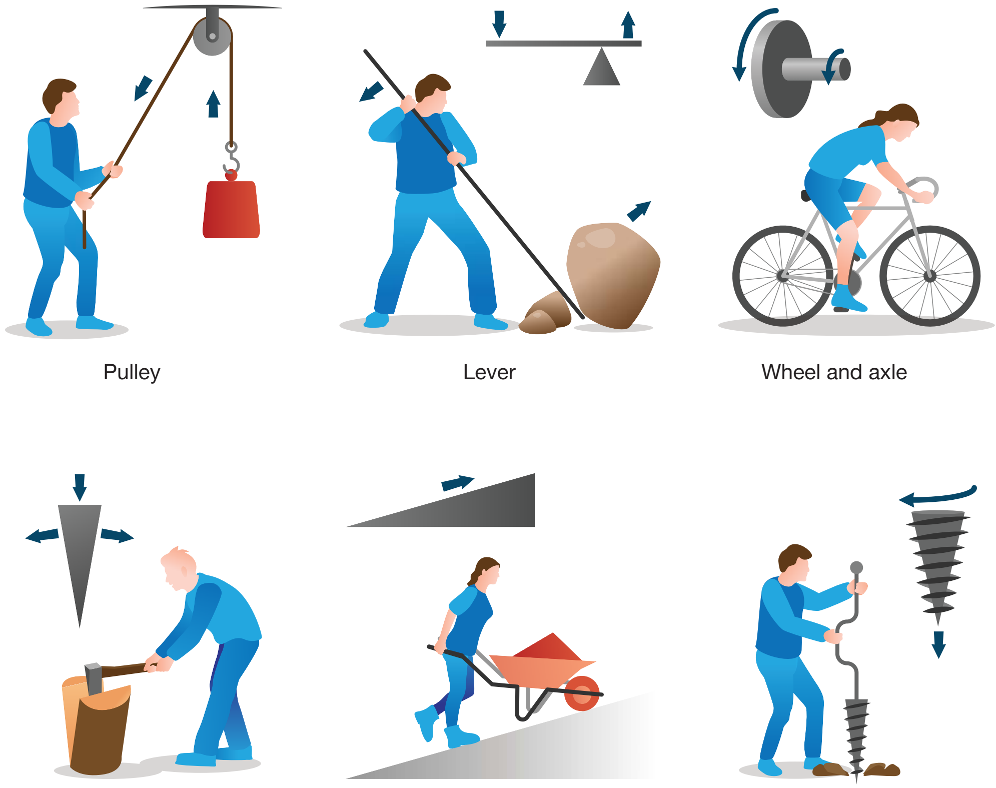
Exploring simple machines

A **machine** is a device that makes a physical task easier. That means that cars, bikes, cranes, lifts and escalators are machines. But machines like these are actually made up of many smaller machines called **simple machines**. Simple machines transfer energy from one object to another to make it move or change direction.

machine device that makes a physical task easier by converting energy

simple machine device with minimal components such as levels and wedges designed to make work easier

FIGURE 8.45 Some simple machines to make tasks easier



elog-2099

INVESTIGATION 8.17

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 Milo can 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

5. Try to remove the nail from the block of wood without the hammer. Take care that you don't hurt your hand.
6. Now use the hammer to remove the nail.

Results

Copy and complete the table with your observations.

TABLE Observations of the uses of teaspoons and hammers as simple machines

	Observations without using a simple machine (no teaspoon/hammer)	Observation 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.

8.9.2 Using 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**.

There are three types (or 'classes') of lever. Levers are categorised depending upon where the fulcrum is placed relative to the load and the effort. This is shown in figure 8.46.

lever simple machine usually consisting of a long, rigid object that moves around a turning point when a force is applied

fulcrum point around which a lever turns

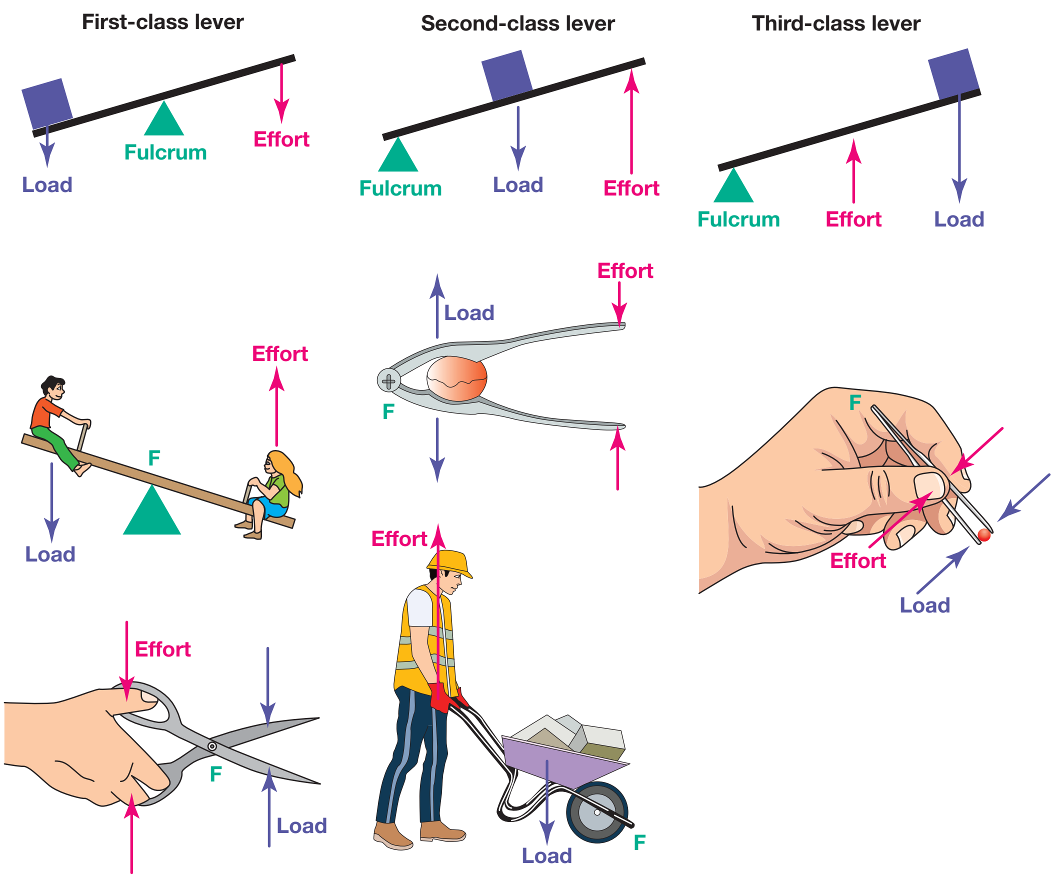
load force, such as the weight of an object, resisting motion against which a lever works

effort force used to cause movement

ewbk-11393

int-7685

FIGURE 8.46 The three classes of lever differ depending on the relative positions of the fulcrum, effort and load.

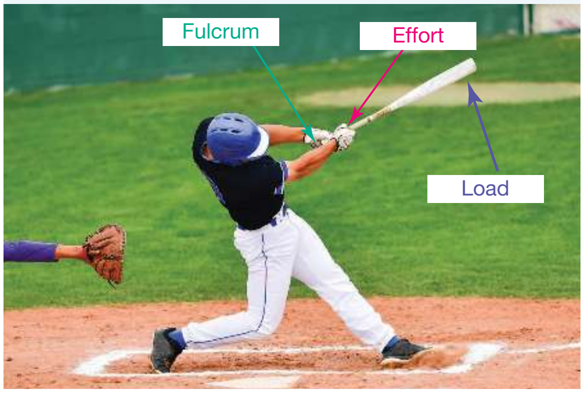


Types of levers

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 softball bat shown in figure 8.47 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 8.47 A softball bat is a third-class lever designed to move a small load quickly.



First-class and second-class levers are force multipliers. Third-class levers are speed multipliers.

What's the advantage?

The advantage of force-multiplying levers is that they allow you to move a heavy load with a small effort.

The **mechanical advantage** of a force-multiplying lever is defined as:

$$\text{mechanical advantage} = \frac{\text{load}}{\text{effort}}$$

force multiplier simple machine that supplies a greater force than the effort used

speed multiplier simple machine that increases the speed of an object

mechanical advantage the advantage of force-multiplying levers or other machines as defined by the load divided by the effort

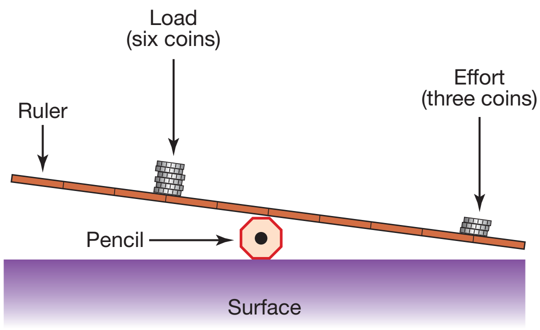
For example, when you use the lever in figure 8.48 to raise a load of six coins with an effort of only three coins, the mechanical advantage is given by:

$$\textbf{mechanical advantage} = \frac{\textbf{load}}{\textbf{effort}}$$

$$= \frac{6}{3} = 2$$

In other words, the lever lifts a load that is two times greater than the effort.

FIGURE 8.48 The mechanical advantage of this lever is 2.



elog-2101

INVESTIGATION 8.18

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
- Six identical coins or 50-gram 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

TABLE The relationship between effort, load and distance

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

Summarise the relationship between the effort and its distance from the fulcrum.

The Law of Conservation of Energy

Although levers can 'multiply' a force or speed, the Law of Conservation of Energy is never broken. The Law of Conservation of Energy states that energy cannot be created or destroyed. It can only be transferred to another object or transformed into a different form. You can never get more energy out of a lever than you put in.

Levers in your arm

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 8.49).

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 8.50).

FIGURE 8.49 When you bend your arm to lift a load, your forearm acts as a third-class lever.

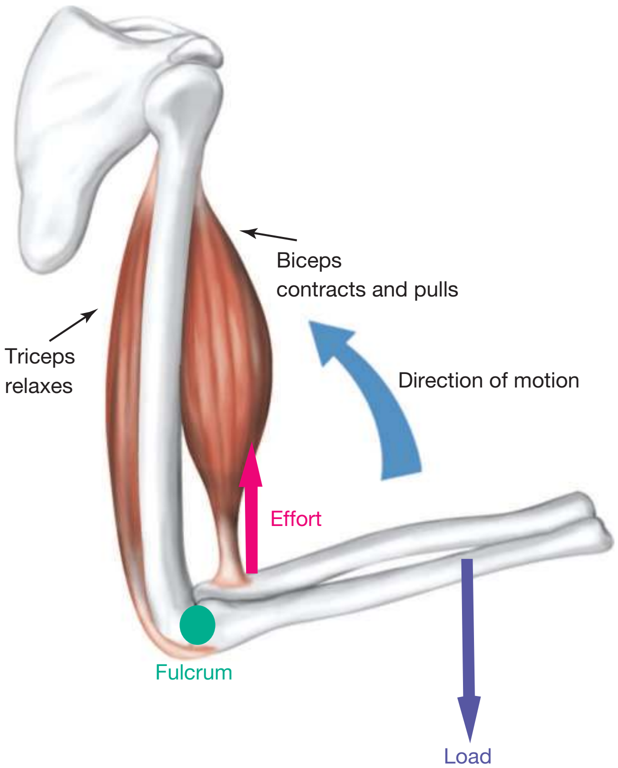
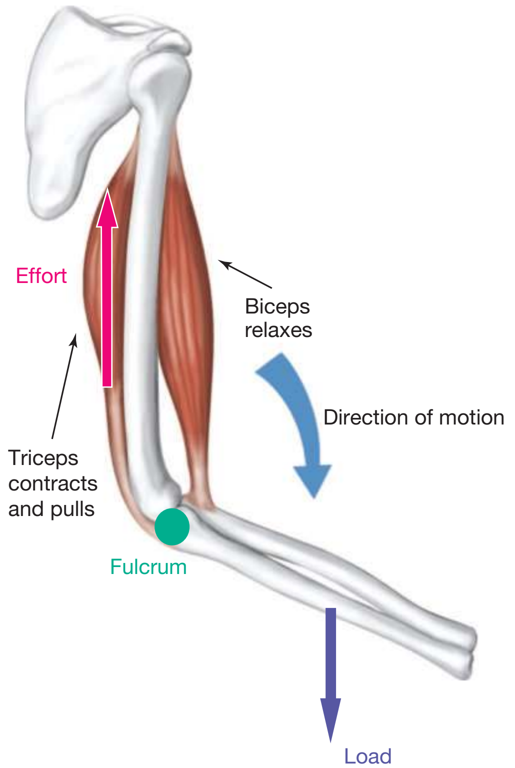


FIGURE 8.50 When you straighten your arm to push down loads, your forearm acts as a first-class lever.



Kicking a ball

When a football is kicked, bones in the lower leg act as a third-class lever (see figure 8.51). 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.

FIGURE 8.51 The knee acts as a fulcrum in the kicking motion.

Anyone for tennis?

In ball games such as tennis, cricket, baseball, golf and hockey, racquets, bats, clubs and sticks are used as third-class levers. 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.

When a tennis ball is served, the lever consists of your whole arm and the tennis racquet (see figure 8.52). 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 8.52 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.

8.9.3 Inclined planes — Using 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 8.53). 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 shown in figure 8.54 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.

When an object is pushed up an inclined plane, energy is transformed from the energy of movement (kinetic energy) into stored energy (potential energy). If an object at the top of an inclined plane is allowed to slide or roll down, some of its potential energy is transformed back into kinetic energy.

ramp simple machine, called an inclined plane, that reduces the effort required to raise objects to a higher level

inclined plane simple machine that uses a sloping surface to reduce the effort required for a task

FIGURE 8.53 Lifting a heavy object is made much easier with a ramp.

FIGURE 8.54 This winding mountain road is a ramp. How does this make driving easier?

elog-2103

INVESTIGATION 8.19

Inclined to make it easier

Aim

To investigate how an inclined plane changes the force and work required to complete a task

Materials

- Three textbooks
- 500-gram 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-gram 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-gram 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 wish to add lines if you test multiple heights.

TABLE The effect of ramps on force

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 pulled 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 8.9.2). What is the mechanical advantage of your ramp?

Conclusion

Summarise your findings about the force and work required when using an inclined plane.

8.9.4 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.

wedge simple machine that reduces the force required to cut through objects or stop them from moving
screw curved inclined plane
thread curved ridge of a screw formed by a winding inclined plane
pitch the distance between two turns of the thread of a screw

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 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. Most car jacks use a large screw to lift a huge load with little effort.

FIGURE 8.55 A participant employs a wedge to cut through a log in a wood-chopping competition.

FIGURE 8.56 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.

elog-2105

INVESTIGATION 8.20

Inclined planes on the move

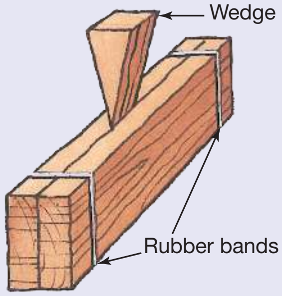
Aim

To investigate how wedges and screws are used to make tasks easier to complete

Materials

- Wooden door wedge
- Two rubber bands
- Two 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.

on Resources

eWorkbook Inclined planes (ewbk-11395)

8.9.5 Wheels and axles

If a lever is fixed at one end and rotated, it becomes a simple machine called a **wheel and axle**, as 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 8.57).

wheel and axle a type of lever that can rotate when an effort applied at the wheel produces a greater force on the axle

The doorknob in figure 8.58 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. There is, however, a penalty; you pay for the extra force with extra distance. The wheel (handle) moves further than the axle. Imagine how difficult it would be to turn the axle without a handle though.

Bathroom taps and car steering wheels (see figure 8.59) are also force-multiplying wheels and axles. Can you think of any others?

FIGURE 8.57 The components of a wheel and axle

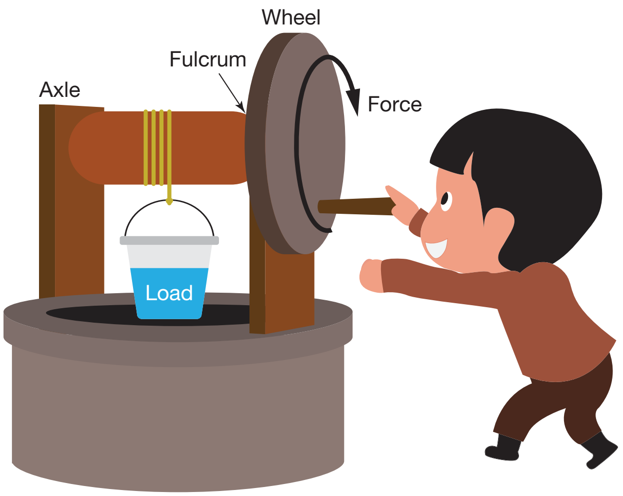


FIGURE 8.58 This doorknob is a wheel and axle machine.

FIGURE 8.59 Steering wheels are force-multiplying levers.

on Resources

eWorkbook Labelling a wheel and axle (ewbk-11397)

Interactivity Labelling a wheel and axle (int-8098)

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. Does your model change energy from one form to another? If so, describe the change in detail.

Speed it up

Wheel and axle machines can be used to make things move faster. The ceiling fan in figure 8.60 is a wheel and axle machine. A large force is applied to the axle and each time the axle turns, the fan blades move a much greater distance in the same amount of time and trace out a complete circle. It is a speed multiplier.

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 8.61). 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 tank. The chain connecting the wheels allows one engine to create a lot of force and easily move a tank.

eles-3262

FIGURE 8.60 This ceiling fan is a speed-multiplying wheel and axle machine.

FIGURE 8.61 These wheels and axles are joined by a belt to operate heavy machinery.

elog-2107

INVESTIGATION 8.21

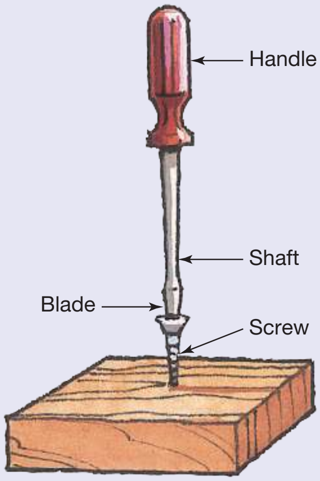
Investigating wheels and axles

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.

elog-2109

INVESTIGATION 8.22

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 shown.

TABLE Exploring different machines

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.

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 single 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 as 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 8.62 is using the pulley to **transfer** energy from herself to the weight to make it move. In order to move the load, her muscles need to **transform** the chemical energy that she has stored by eating food into movement energy of her arms.

transfer move energy from one object to another using simple machines

transform change one form (of energy) into another

FIGURE 8.62 A pulley changes the direction the effort is needed to lift a load, making it easier.

elog-2111

tlvd-10658

INVESTIGATION 8.23

Lifting that load

Aim

To compare the mechanical advantage of three pulley arrangements

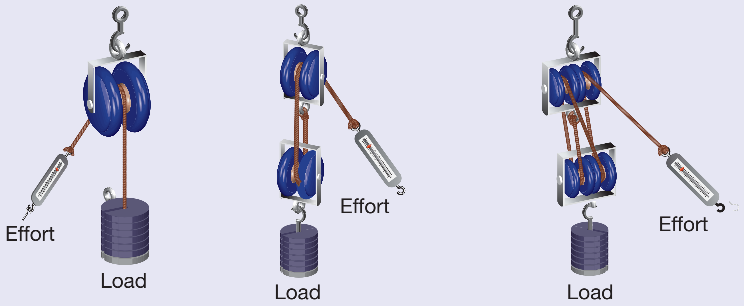
Materials

- Two single pulleys
- Two double pulleys
- 1-metre length of string
- Set of slotted 50-gram masses
- 5.0 newton spring balance
- Meter ruler
- Hook from which to suspend pulleys

Method

1. Load the slotted masses to a mass of 400 grams 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 your table in 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 5.0 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 5.0 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 5.0 cm.

10. Repeat the previous two steps using the system with the two double pulleys shown in diagram (c).



Results

Draw up a table for your results like the one shown.

TABLE The effect of different pulley arrangements on load and effort

Pulley arrangement	Load (N)	Load distance (cm)	Effort (N)	Effort distance (cm)	Mechanical advantage (load/effort)
Single pulley		5.0			
Two single pulleys		5.0			
Two double pulleys		5.0			

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 5.0 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 5.0 cm?

Conclusion

Summarise your findings about the three pulley systems and differences in their mechanical advantage.

on Resources

eWorkbook Loaded levers (ewbk-11399)

8.9 Activities

learnon

8.9 Quick quiz on	8.9 Exercise

Select your pathway

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

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Remember and understand

1. Is a circular doorknob a force multiplier or a speed multiplier? How do you know?
2. **MC** Which two of the things listed are inclined planes?
   A. Playground slides
   B. Tables
   C. Ski slopes
   D. Doorways
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. How is a single fixed pulley useful even though it does not decrease the size of the force needed to lift a load?
6. Outline why first-class and second-class levers are called force multipliers.

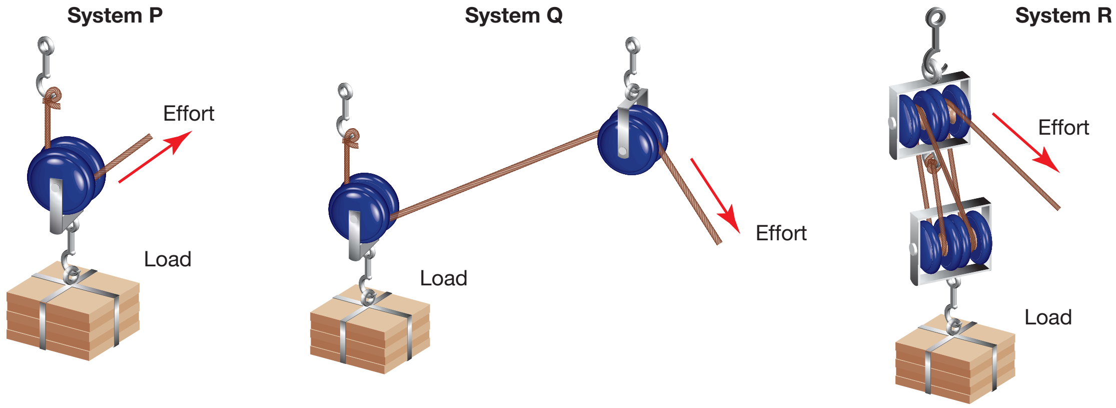
Apply and analyse

7. Explain why you can't get more energy out of a lever than you put in.
8. Is height an advantage to tennis players and cricket bowlers? Explain your answer.
9. Explain why inclined planes are classified as force multipliers.
10. Explain how a ramp is able to produce a mechanical advantage.
11. Explain why a ceiling fan is called a speed multiplier.

Evaluate and create

12. With reference to inclined planes, explain why it is important to sharpen kitchen knives when they become blunt.
13. **SIS** Research ramps designed for wheelchair use and answer the following questions.
    a. What standards are required to be met when designing a ramp for wheelchair use?
    b. Why do there need to be regulations for ramps?
    c. Examine a location in your school (or even your home) that has stairs. Make a list of recommendations on where a ramp could be placed, what it needs to look like and why it would be important to install.

14. Explore the systems P, R and Q shown in the provided diagram.



Identify and explain in which of the systems P, Q and R 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.

15. SIS

a. What is the mechanical advantage of a lever when one coin is used to lift a load of three coins?
b. In nature there is a wide variety of jaw shapes. Some are rather short, like a human jaw, and some jaws are long and slender, like a fish jaw. Based on what you have learned, identify whether or not an animal is a speed or force multiplier based on the shape of its mouth, and explain how this might provide an advantage.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
8.10 Thinking tools — Cluster maps

8.10.1 Tell me

What is a cluster map?

A cluster map is used to generate new ideas and the follow-on consequences or impacts of those ideas. It is like a collection of single bubble maps joined together to show connections around a single, central topic. While a single bubble map only has one level from the central bubble, a cluster map can have many levels from the centre. Cluster maps are also known as brainstorm maps or spider diagrams.

What is a cluster map for?

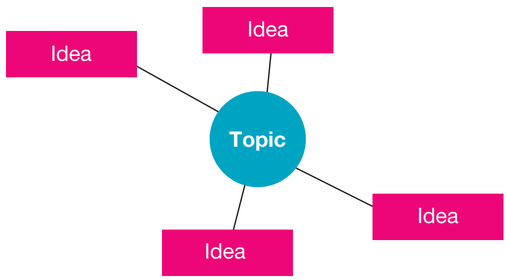
A cluster diagram is a way of brainstorming. It helps you to think about how a central idea might be divided into smaller ideas or effects.

For example, you might use a cluster diagram to brainstorm:
- possible consequences of a specific action or decision
- smaller parts of one central idea.

8.10.2 Show me

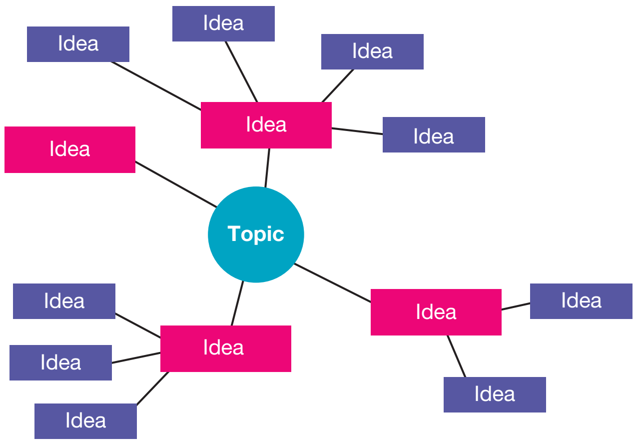
To create a cluster map:
1. Write your topic in the middle. Around your topic, write any ideas that link with it. Draw lines from the ideas to your topic.

FIGURE 8.63 Start buildings ideas around your topic.



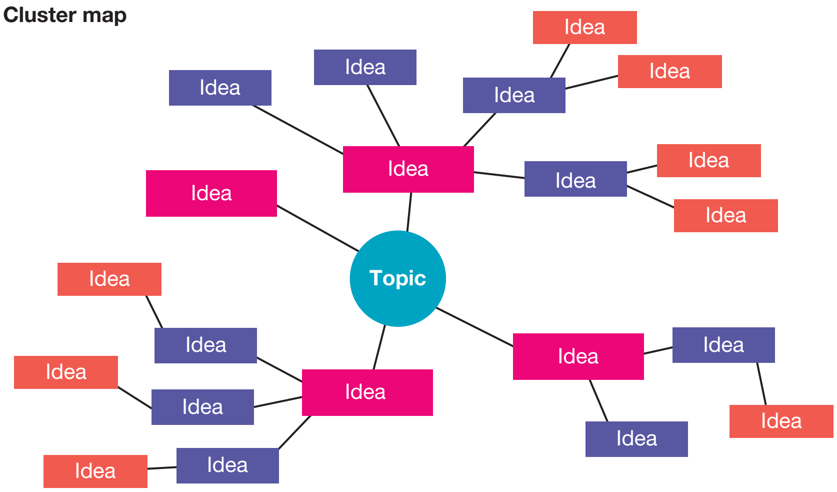
2. Write new ideas that are related to your first ideas, and link them with lines.

FIGURE 8.64 Add any related ideas.



3. Keeping building levels of ideas from each new idea.

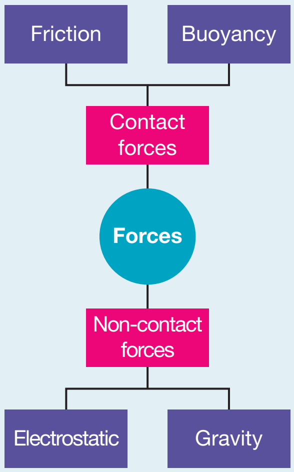
FIGURE 8.65 Continue building new ideas.



8.10.3 Let me do it

8.10 Activities

1. a. Copy and complete the cluster map to show the links between the types of forces described in this topic. Add as many links as you can to the map. Don't forget that you can sometimes make links between the different 'arms' of your cluster map.



   b. Suggest a different way of dividing the six forces into two groups and draw a new cluster map starting with these two groups branching from the title.
2. Create a cluster map outlining and showing the links of the different forces acting on you while you are walking between your classes during the day.
3. Create your own cluster maps to brainstorm the following topics:
   - wearing bike helmets
   - going into space.

Fully worked solutions and sample responses are available in your digital formats.

LESSON
8.11 Project — Paper, scissors, robot

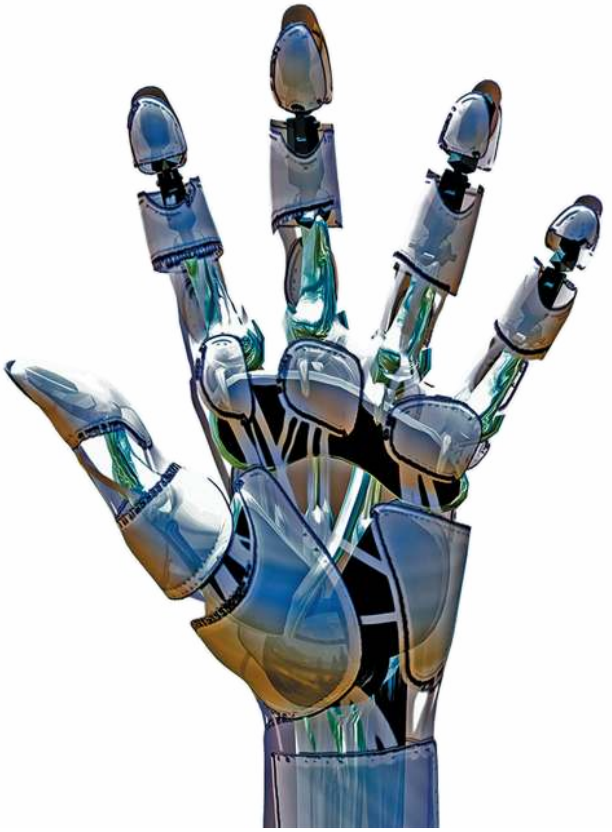
Scenario

Robots are highly advanced electrical machines that can be programmed to perform specific tasks. Like all compound machines, they are made up of many smaller interacting devices that are referred to by engineers as simple machines. In general, there are considered to be seven types of simple machine — lever, screw, inclined plane, gear, pulley, wheel and axle, and wedge.

Our bodies are able to move around because the muscles, bones, tendons and ligaments also act like simple machines. For example, an incisor is really an organic form of a wedge, while the movement of your forearm is possible because it is a lever, with your elbow acting as the fulcrum.

The robotic hands that prosthetic engineers design are the result of combining processed materials such as metal alloys and polymers to create systems of simple machines that imitate the motion of a real hand as closely as possible.

FIGURE 8.66 A robotic hand imitates a human hand.



Your task

- You are going to design and build a robot hand that is capable of performing all of the hand motions used in the game of Paper, scissors, rock. You will then use your robot hand to compete with those created by other student groups in your class to find the Paper, scissors, robot champions. This tournament will be done as a round-robin competition, with each group playing every other group once. Your robot hand must be sturdy enough to keep functioning throughout the tournament.
- You will also create a user's manual that goes with your robot hand. This will provide a detailed diagram/plan of your robot hand, including an explanation of how it is constructed and how the user makes it move into the three different positions required. In the back of the manual there should also be a 'Troubleshooter' table that will tell the user what the most common problems are that they may experience when using the hand and provide solutions to fix those problems.

on Resources

ProjectsPlus Paper, scissors, robot (pro-0089)

LESSON
8.12 Review

Hey students! Now that it's time to revise this topic, go online to:

Review your results | **Watch teacher-led videos** | **Practise questions with immediate feedback**

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Access your topic review eWorkbooks

on Resources

Topic review Level 1	Topic review Level 2	Topic review Level 3
ewbk-11409	ewbk-11411	ewbk-11413

8.12.1 Summary

Forces and their effects

- A force is a push, pull or twist.
- Forces are represented in diagrams using arrows.
- Forces can be contact forces (when one object is in contact with another) or non-contact (when objects are not in contact).
- There is almost always more than one force acting on an object. All forces acting on an object are added together to determine the net force acting on the object.

Gravity

- Every object with mass in the universe pulls on other objects with a force of gravity.
- Mass is a measure of the amount of material in an object or substance (measured in kilograms, kg).
- The weight of an object or substance is a measure of the force of gravity pulling it down (measured in newtons, N).

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 friction that assists movement is called traction.
- Friction also exists in fluids (fluid friction) which affects objects moving through the air and water.

Keeping afloat

- Buoyancy is a force that keeps objects floating.
- Surface tension is the pulling of particles in a liquid towards each other.

Magnetism

- Magnetism is a non-contact force.
- Magnets that retain their magnetism when removed from other magnets are called permanent magnets. Temporary magnets are those that lose their magnetism when removed from another magnet.
- All magnets have a north pole at one end and a south pole at the other.
- The area where the magnetic force acts is called the magnetic field.

Electric forces

- All matter is made up of atoms. Electrons and protons are both charged particles in the nucleus (negative and positive respectively).

- Substances usually become charged by the addition or removal of electrons. This can be done in two ways: by friction or by contact.
- The area around an electrically charged object where objects experience an electric force is called an electric field.
- The electricity that builds up is called static electricity. The charge on the objects is called electrostatic charge (or static charge).

Staying safe

- Helmets are vital to protect from injury. Without a helmet, the head stops suddenly when it hits the ground. The sudden impact can cause serious head injuries.
- Airbags and seatbelts are vital for safety in cars. In a crash, a seatbelt prevents the occupants from moving forwards through the windscreen or into other parts of the inside of the car, while airbags help slow the upper body down more gradually.

Using levers

- Simple machines are devices that transfer energy from one object to another to make it move or change direction, helping make tasks easier.
- Levers are simple machines that consist of a long rigid object that moves around a turning point.
- The turning point is known as the fulcrum, the resistance to motion is the load and the force applied is the effort.
- First and second-class levers are force multipliers that increase the effect of the force.
- Third-class levels are speed multipliers that increase the speed of an object.

Pushing uphill using ramps, wedges and screws

- A ramp or inclined plane is a simple machine that reduces the effort to raise objects to a higher level.
- Wedges are inclined planes that reduce the force to movement (like a door wedge) or to cut through objects (like an axe).
- Screws are curved inclined planes which are pushed down onto an object.

Wheels, axles and pulleys

- Wheels and axles are simple machines where a level is fixed at one end and rotated.
- The circular part (which acts as the lever) is the wheel and the turning point (fulcrum) is attached to an axle.
- Some wheels and axles act as force multipliers (like a doorknob). Others act as speed multipliers (like a ceiling fan).
- Pulleys are a type of wheel and axle used to help lift a load.

8.12.2 Key terms

air resistance the force of air pushing on an object as it moves through the air
alloy a mixture of a metal with other elements
buoyancy an upward force acting on a floating object provided by a fluid
centre of gravity an imaginary point in an object that gravity appears to act around
conductor material that allows an electric charge to flow through it
contact force force between objects that are touching
domains regions within the material that are aligned or facing different directions
effort force used to cause movement
electric charge a property relating to the charge (negative or positive) on an atom or object
electric field an area around an electrically charged object where objects experience an electric force
electromagnet a magnet that requires an electric current to become magnetic
electron very light, negatively charged particle inside an atom
electrostatic force attractive or repulsive non-contact force of electric charges at rest
equilibrium balanced or equal

fluid a substance that flows and has no fixed shape. Gases and liquids are fluids.
force a push, pull or twist
force multiplier simple machine that supplies a greater force than the effort used
friction the force applied to the surface of an object when it is pushed or pulled against the surface of another object
fulcrum point around which a lever turns
gravity the force of attraction that exists between any two bodies in the Universe that have mass
inclined plane simple machine that uses a sloping surface to reduce the effort required for a task
insulator material that does not allow an electric charge to flow through it
lever simple machine usually consisting of a long, rigid object that moves around a turning point when a force is applied
load force, such as the weight of an object, resisting motion against which a lever works
lubricant substance with large particles that can slide easily over each other
machine device that makes a physical task easier by converting energy
magnetic field a map of lines showing the size and direction of a magnetic force
magnetic force force acting between magnets and magnetic objects
mass the quantity of matter in an object (usually measured in grams or kilograms)
mechanical advantage the advantage of force-multiplying levers or other machines as defined by the load divided by the effort
net force the sum of forces acting on an object
neutral having the same number of protons and electrons
neutron tiny, but heavy, particle found in the nucleus of an atom with no electrical charge
newton the unit for measuring force
non-contact force force between objects that are not touching
north pole the end of the magnet that, when free to rotate, points to the north pole of Earth
nucleus central part of the atom, made up of protons and neutrons
permanent magnet magnet that retains its magnetic effect for many years
pitch the distance between two turns of the thread of a screw
proton tiny, but heavy, positively charged particle found in the nucleus of an atom
ramp simple machine, called an inclined plane, that reduces the effort required to raise objects to a higher level
repulsion an opposing force in which objects are pushed away from each other
robot complex combination of machines designed to perform tasks without human assistance
screw curved inclined plane
simple machine device with minimal components such as levels and wedges designed to make work easier
south pole the end of the magnet that, when free to rotate, points to the south pole of Earth
speed multiplier simple machine that increases the speed of an object
static electricity a build-up of charge in one place
streamlined being shaped so that drag through a fluid is minimised
surface tension the 'firmness' of the surface of a liquid created by the attraction between particles at the surface
temporary magnet magnet that does not stay magnetic after it has been removed from another magnet
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
thread curved ridge of a screw formed by a winding inclined plane
traction a type of friction used to assist movement
transfer move energy from one object to another using simple machines
transform change one form (of energy) into another
wedge simple machine that reduces the force required to cut through objects or stop them from moving
weight a measure of the size of the force of gravity pulling an object towards the centre of a massive body
wheel and axle a type of lever that can rotate when an effort applied at the wheel produces a greater force on the axle

Resources

Digital document	Key terms glossary (doc-39605)
eWorkbooks	Study checklist (ewbk-11402) Reflection (ewbk-11401) Literacy builder (ewbk-11403) Crossword (ewbk-11405) Word search (ewbk-11407)
Practical investigation eLogbook	Topic 8 practical investigation eLogbook (elog-2066)

8.12 Activities

learnon

8.12 Review questions

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
2, 3, 4, 8, 9, 10, 13, 17, 22	1, 5, 7, 14, 16, 18, 19, 23, 26	6, 11, 12, 15, 20, 21, 24, 25, 27, 28, 29, 30, 31

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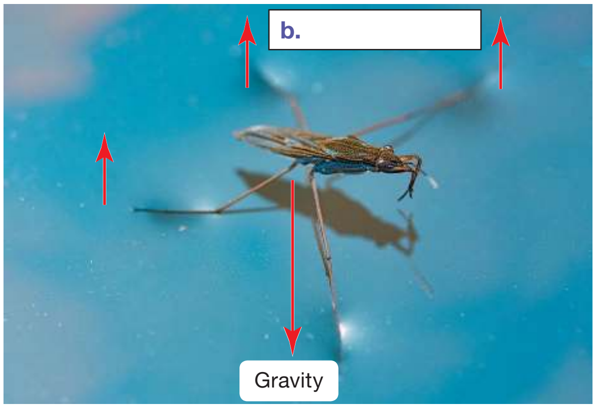
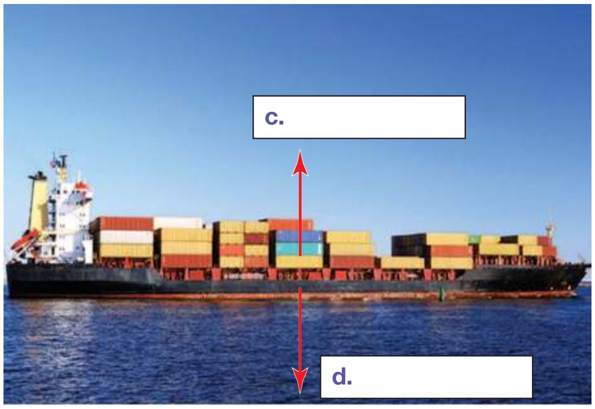
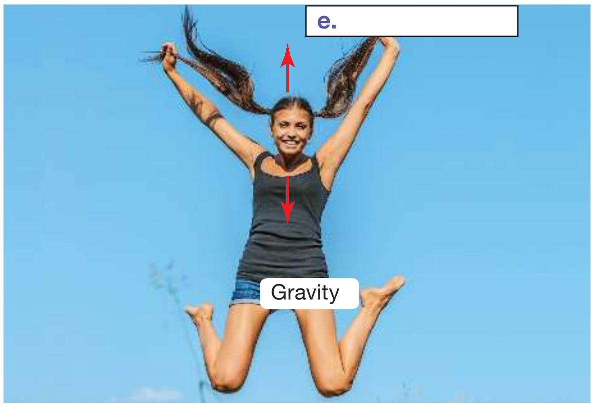
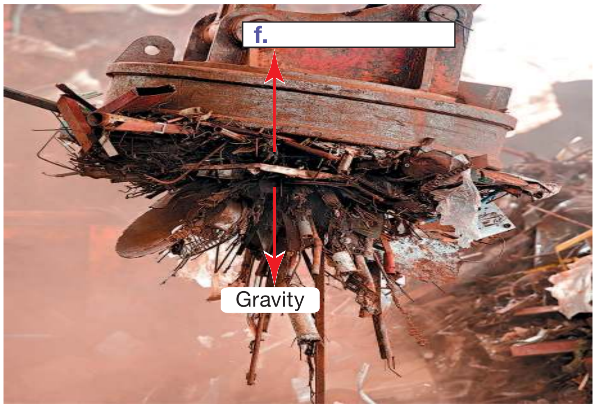
Remember and understand

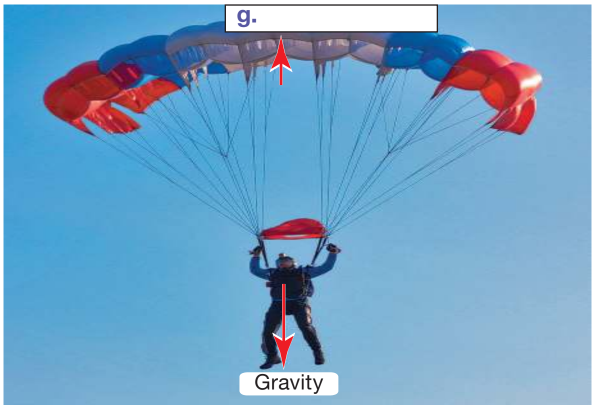
1. Identify the forces missing in each of the images.







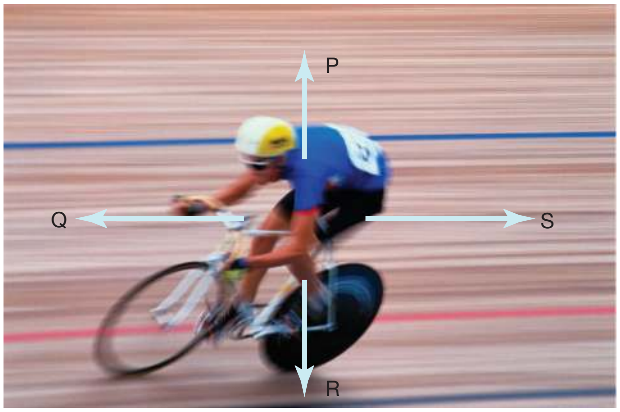




2. Match the force to the effect it creates.

Effect	Force
a. Pushes you up when you are swimming underwater	A. Friction
b. Causes all objects with mass to attract each other	B. Buoyancy
c. Acts on an object when it moves across the surface of another object	C. Surface tension
d. Resists the motion of all objects moving through the air	D. Gravity
e. Pushes up on objects on the surface of water, but not on objects below the surface	E. Magnetic force
f. Can lift a paperclip from a desktop	F. Air resistance

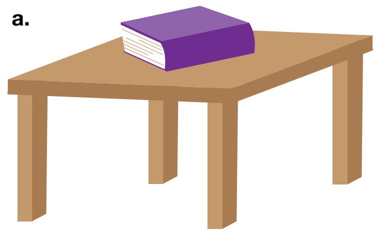
3. State the units used to measure:
   a. mass
   b. weight
   c. force.
4. Complete the following sentence:
   Like charges **attract/repel** and unlike charges **attract/repel.**
5. The arrows in the image of the cyclist represent four of the forces acting on the cyclist riding on a smooth, flat surface.



   a. Which two forces are equal in size?
   b. Which arrow could represent air resistance?
   c. Is the cyclist speeding up, slowing down or travelling at a steady speed? Explain your answer.

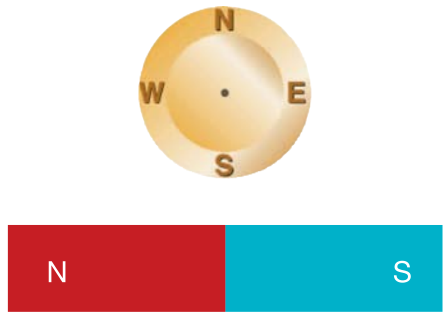
6. Draw arrows on the following diagrams to represent the forces acting on the book:
   a. while it is at rest on the desk
   b. while it is falling towards the floor.

a.



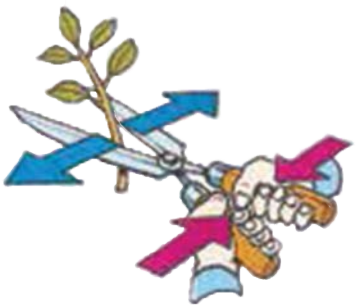
b.

7. MC The compass needle is not shown in the diagram. If the needle was included in the diagram, in which direction would it point?
   A. North
   B. South
   C. East
   D. West



8. Which part of a circular doorknob is the wheel? Which part is the axle?
9. a. Copy the following diagrams and label the fulcrum, load and effort on each of the levers. The first diagram has the load (blue arrows) and effort (pink arrows) labelled.
   b. For each diagram, identify what type of level it is.

i.



ii.

iii.

iv.

Apply and analyse

10. Explain why streamlining an object reduces fluid friction.
11. Electricians use screwdrivers and long-nosed pliers with handles that are coated with plastic. Suggest a reason for this.
12. When you rub your shoes on some types of carpet, your body becomes negatively charged. Explain what will happen to the extra negative charge on your body if you:
    a. stand still for a few minutes
    b. touch a metal door handle immediately after rubbing your shoes on the carpet
    c. place the palm of your hand near a negatively charged balloon hanging from a thread
    d. place the palm of your hand near a positively charged balloon hanging from a thread.
13. Use a labelled diagram to explain how a positively charged balloon can be attracted to an uncharged plaster wall.
14. Explain why the pull of gravity is less on the Moon than it is on Earth.
15. MC When a package of emergency supplies is first dropped from a plane, it gains speed rapidly. Why does the package eventually stop 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
16. Explain how lubricants such as grease and oil reduce the production of heat in the moving parts of car engines and other mechanical devices.
17. 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.

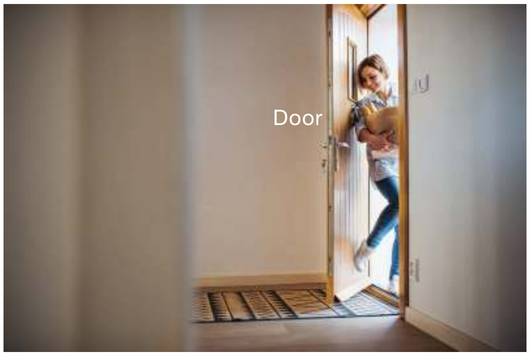
18. In cricket, the arm acts as a lever when the ball is bowled.
    a. Which class of lever is the arm acting as?
    b. Is the arm acting as a speed multiplier or a force multiplier? Explain your answer.
    c. MC Which part of the body acts as the fulcrum?
        A. The elbow
        B. The muscle
        C. The shoulder
        D. The hand
19. Investigate the following four examples of levers and answer the questions for each.
    a. Label the load, effort and fulcrum on a copy of each of the levers in a–d.
    b. Which of the levers are speed multipliers? Explain your response.
    c. Which of the levers are second-class levers? Explain your response.

i.

ii.

iii.

iv.

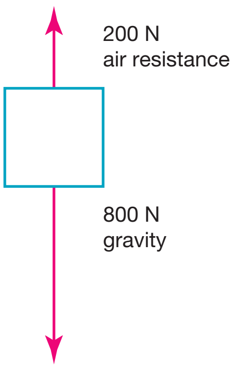


20. A ramp makes it easier to push or pull objects upwards. What is the 'penalty' for making the task easier?
21. Why is a system of two single pulleys better than one single pulley for lifting very heavy loads?

Evaluate and create

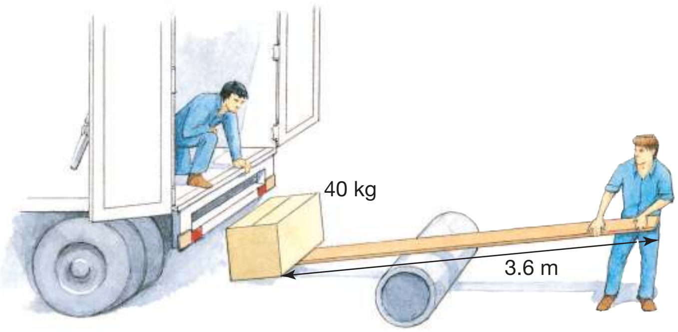
22. MC Which of the following are ways in which racing cyclists reduce the effect of air resistance on their motion? Select all possible answers from the options listed.
    A. Using an aerodynamic helmet
    B. Wearing tight-fitting, streamlined clothing
    C. Wearing loose clothing
    D. Position their body to become more streamlined
    E. Use tyres with more grip
    F. Shaving body hair
23. Scuba divers wear very heavy belts when they are diving. What difficulty would be caused if a heavy belt wasn't used? Use the terms buoyancy, gravity and net force in your answer.

24. SIS Investigate some investigations that sports scientists could undertake to improve performance in each of the following sports:
    a. tennis
    b. golf
    c. cricket.
25. 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.
26. 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.
27. 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.

28. Explain why door handles are placed as far away from the hinges as possible.
29. SIS Pulleys are important in the functioning of rollercoasters. Explain what the purpose of pulleys in rollercoasters is, and describe in what part of the ride they are most important.
30. A student uses a pencil and ruler to model a first-class lever. It is tested by lifting 20 cent coins placed at one end of the ruler.
   a. Draw a diagram to show how a pencil and ruler 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 four coins to lift 12 coins.
   c. If the 12 coins are placed six centimetres from the fulcrum, how far should the four coins be from the fulcrum to lift the larger pile of coins?
31. The plank shown is 3.6 metres long. It is being used as a lever to lift a 40-kilogram box. This represents a load of 400 newtons.



   a. If the fulcrum were placed in the centre of the plank, what downward effort would the man on the right of the diagram 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. how far along the plank should the fulcrum be?
      ii. what would the mechanical advantage of the lever be?
   c. How could the mechanical advantage of the lever be increased?
   d. Is the plank being used as a speed multiplier or a force multiplier? Explain your answer.
   e. Suggest a different way of using the plank as a simple machine to get the box into the truck.

Fully worked solutions and sample responses are available in your digital formats.

Online Resources

Resources

Below is a full list of **rich resources** available online for this topic. These resources are designed to bring ideas to life, to promote deep and lasting learning and to support the different learning needs of each individual.

8.1 Overview

eWorkbooks
- Topic 8 eWorkbook (ewbk-11370)
- Student learning matrix (ewbk-11374)
- Starter activity (ewbk-11372)

Practical investigation eLogbook
- Topic 8 Practical investigation eLogbook (elog-2066)

Video eLesson
- Parachutist Felix Baumgartner (eles-2229)

8.2 Forces

eWorkbook
- Types of forces (ewbk-11375)

Practical investigation eLogbook
- Investigation 8.1: Forces (elog-2067)

Video eLesson
- Pushing force (eles-2230)

Interactivity
- Net force (int-5894)

8.3 Gravity

eWorkbooks
- Moon Olympics (ewbk-11377)
- Gravity (ewbk-11379)

Practical investigation eLogbooks
- Investigation 8.2: Measuring weight (elog-2069)
- Investigation 8.3: More than one force? (elog-2071)
- Investigation 8.4: The landing time of a parachute (elog-2073)

Video eLessons
- Isaac Newton (eles-1771)
- Skydivers (eles-2554)

Interactivities
- Weight decreases with altitude while mass stays constant (int-3449)
- Skydiving (int-3450)

8.4 Friction

eWorkbook
- Friction (ewbk-11381)

Practical investigation eLogbook
- Investigation 8.5: Friction (elog-2075)

Video eLessons
- Friction as a driving force (eles-0032)
- Synovial fluid (eles-2231)
- Model of a waterski (eles-2235)

Interactivities
- Moving boxes (int-3447)
- Friction as a driving force (int-0054)

8.5 Keeping afloat

eWorkbook
- Buoyancy (ewbk-11383)

Practical investigation eLogbooks
- Investigation 8.6: Are things really lighter in water? (elog-2077)
- Investigation 8.7: Water drops (elog-2079)

Video eLesson
- Surface tension (eles-2036)

Interactivity
- Density (int-0221)

8.6 Magnetic fields

eWorkbooks
- Magnetic fields and forces (ewbk-11387)
- Electromagnetism (ewbk-11385)

Practical investigation eLogbooks
- Investigation 8.8: What does a magnet attract? (elog-2090)
- Investigation 8.9: Poles apart (elog-2082)
- Investigation 8.10: Mapping the magnetic field (elog-2084)
- Investigation 8.11: Making your own compass (elog-2086)
- Investigation 8.12: Making an electromagnet (elog-2088)

Video eLessons
- A Shanghai Maglev train (eles-2552)
- Earth's magnetic field (eles-2798)
- Electromagnet (eles-2234)
- Electromagnetism (eles-1778)
- The magnetic field around a bar magnet (eles-2232)

8.7 Electric fields

eWorkbooks
- Electrostatic charge (ewbk-11391)
- Labelling a Van de Graaff generator (ewbk-11389)

Practical investigation eLogbooks
- Investigation 8.13: The attraction of electricity (elog-2091)
- Investigation 8.14: Defying gravity (elog-2093)

Video eLessons
- Producing static electricity (eles-0067)
- A Van de Graaff generator (eles-2553)

Interactivities
- The Van de Graaff generator (int-0031)
- Charged and neutral objects can be attracted to each other (int-3448)

8.8 Staying safe

Practical investigation eLogbooks
- Investigation 8.15: Egghead (elog-2095)
- Investigation 8.16: Crash test dummy (elog-2097)

Interactivities
- How an airbag works (int-5896)
- Safety features in cars (int-5895)

Weblink
- Car safety — RACV

8.9 A world of machines

eWorkbook
- Loaded levers (ewbk-11399)
- Inclined planes (ewbk-11395)
- Labelling a wheel and axle (ewbk-11397)
- Labelling the three classes of levers (ewbk-11393)

Teacher-led video
- Investigation 8.23: Lifting that load (tlvd-10658)

Practical investigation eLogbooks
- Investigation 8.17: Exploring simple machines (elog-2099)
- Investigation 8.18: Get a load of this (elog-2101)
- Investigation 8.19: Inclined to make it easier (elog-2103)
- Investigation 8.20: Inclined planes on the move (elog-2105)
- Investigation 8.21: Investigating wheels and axles (elog-2107)
- Investigation 8.22: Wheels and axles at work (elog-2109)
- Investigation 8.23: Lifting that load (elog-2111)

Video eLessons
- Robots assembling a car in fast motion (eles-2555)
- Ceiling fan spinning (eles-3262)

Interactivities
- The three classes of lever differ depending on the relative positions of the fulcrum, effort and load. (int-7685)
- Labelling a wheel and axle (int-8098)

8.11 Project — Paper, scissors, robot

ProjectPLUS
- Paper, scissors, robot (pro-0089)

8.12 Review

eWorkbooks
- Topic review Level 1 (ewbk-11409)
- Topic review Level 2 (ewbk-11411)
- Topic review Level 3 (ewbk-11413)
- Study checklist (ewbk-11402)
- Literacy builder (ewbk-11403)
- Crossword (ewbk-11405)
- Word search (ewbk-11407)
- Reflection (ewbk-11401)

Digital document
- Key terms glossary (doc-39605)

To access these online resources, log on to **www.jacplus.com.au**

PERIODIC TABLE OF THE ELEMENTS

Alkali metals → Group 1

Alkaline earth metals → Group 2

Key

Period 1		
	1 Hydrogen **H** 1.0	2 Helium **He** 4.0

- 2 ← **Atomic number**
- Helium ← Name
- He ← **Symbol**
- 4.0 ← Relative atomic mass

Transition metals (Groups 3–9)

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9
Period 1	**1** Hydrogen **H** 1.0								
Period 2	**3** Lithium **Li** 6.9	**4** Beryllium **Be** 9.0							
Period 3	**11** Sodium **Na** 23.0	**12** Magnesium **Mg** 24.3							
Period 4	**19** Potassium **K** 39.1	**20** Calcium **Ca** 40.1	**21** Scandium **Sc** 45.0	**22** Titanium **Ti** 47.9	**23** Vanadium **V** 50.9	**24** Chromium **Cr** 52.0	**25** Manganese **Mn** 54.9	**26** Iron **Fe** 55.8	**27** Cobalt **Co** 58.9
Period 5	**37** Rubidium **Rb** 85.5	**38** Strontium **Sr** 87.6	**39** Yttrium **Y** 88.9	**40** Zirconium **Zr** 91.2	**41** Niobium **Nb** 92.9	**42** Molybdenum **Mo** 96.0	**43** Technetium **Tc** (98)	**44** Ruthenium **Ru** 101.1	**45** Rhodium **Rh** 102.9
Period 6	**55** Caesium **Cs** 132.9	**56** Barium **Ba** 137.3	**57–71** Lanthanoids	**72** Hafnium **Hf** 178.5	**73** Tantalum **Ta** 180.9	**74** Tungsten **W** 183.8	**75** Rhenium **Re** 186.2	**76** Osmium **Os** 190.2	**77** Iridium **Ir** 192.2
Period 7	**87** Francium **Fr** (223)	**88** Radium **Ra** (226)	**89–103** Actinoids	**104** Rutherfordium **Rf** (261)	**105** Dubnium **Db** (262)	**106** Seaborgium **Sg** (266)	**107** Bohrium **Bh** (264)	**108** Hassium **Hs** (267)	**109** Meitnerium **Mt** (268)

Lanthanoids

57 Lanthanum **La** 138.9	**58** Cerium **Ce** 140.1	**59** Praseodymium **Pr** 140.9	**60** Neodymium **Nd** 144.2	**61** Promethium **Pm** (145)	**62** Samarium **Sm** 150.4	**63** Europium **Eu** 152.0

Actinoids

89 Actinium **Ac** (227)	**90** Thorium **Th** 232.0	**91** Protactinium **Pa** 231.0	**92** Uranium **U** 238.0	**93** Neptunium **Np** (237)	**94** Plutonium **Pu** (244)	**95** Americium **Am** (243)

- Alkali metals
- Alkaline earth metals
- Transition metals
- Lathanoids
- Actinoids
- Unknown chemical properties
- Post-transition metals
- Metalloids
- Non-metals
- Halides
- Noble gases

Noble gases

Non-metals

Group 10	Group 11	Group 12	Group 13	Group 14	Group 15	Group 16	Group 17	Group 18
								2 Helium **He** 4.0
			5 Boron **B** 10.8	**6** Carbon **C** 12.0	**7** Nitrogen **N** 14.0	**8** Oxygen **O** 16.0	**9** Fluorine **F** 19.0	**10** Neon **Ne** 20.2
			13 Aluminium **Al** 27.0	**14** Silicon **Si** 28.1	**15** Phosphorus **P** 31.0	**16** Sulfur **S** 32.1	**17** Chlorine **Cl** 35.5	**18** Argon **Ar** 39.9
28 Nickel **Ni** 58.7	**29** Copper **Cu** 63.5	**30** Zinc **Zn** 65.4	**31** Gallium **Ga** 69.7	**32** Germanium **Ge** 72.6	**33** Arsenic **As** 74.9	**34** Selenium **Se** 79.0	**35** Bromine **Br** 79.9	**36** Krypton **Kr** 83.8
46 Palladium **Pd** 106.4	**47** Silver **Ag** 107.9	**48** Cadmium **Cd** 112.4	**49** Indium **In** 114.8	**50** Tin **Sn** 118.7	**51** Antimony **Sb** 121.8	**52** Tellurium **Te** 127.6	**53** Iodine **I** 126.9	**54** Xenon **Xe** 131.3
78 Platinum **Pt** 195.1	**79** Gold **Au** 197.0	**80** Mercury **Hg** 200.6	**81** Thallium **Tl** 204.4	**82** Lead **Pb** 207.2	**83** Bismuth **Bi** 209.0	**84** Polonium **Po** (210)	**85** Astatine **At** (210)	**86** Radon **Rn** (222)
110 Darmstadtium **Ds** (271)	**111** Roentgenium **Rg** (272)	**112** Copernicium **Cn** (285)	**113** Nihonium **Nh** (280)	**114** Flerovium **Fl** (289)	**115** Moscovium **Mc** (289)	**116** Livermorium **Lv** (292)	**117** Tennessine **Ts** (294)	**118** Oganesson **Og** (294)

Metals

64 Gadolinium **Gd** 157.3	**65** Terbium **Tb** 158.9	**66** Dysprosium **Dy** 162.5	**67** Holmium **Ho** 164.9	**68** Erbium **Er** 167.3	**69** Thulium **Tm** 168.9	**70** Ytterbium **Yb** 173.1	**71** Lutetium **Lu** 175.0
96 Curium **Cm** (247)	**97** Berkelium **Bk** (247)	**98** Californium **Cf** (251)	**99** Einsteinium **Es** (252)	**100** Fermium **Fm** (257)	**101** Mendelevium **Md** (258)	**102** Nobelium **No** (259)	**103** Lawrencium **Lr** (262)

GLOSSARY

abiotic factors the non-living things in an ecosystem
accurate describes a measurement that is close to the true value
acoustics the study of sound and how the design of a room or theatre affects what is heard
agriculture the use of land to grow crops or raise farm animals
aim a statement outlining the purpose of an investigation
air resistance the force of air pushing on an object as it moves through the air
algae aquatic photosynthetic organisms that are often unicellular
alloy a mixture of a metal with other elements
angiosperms vascular plants that produce seeds and flowers
annular solar eclipse occurs when the Moon moves between the Sun and Earth
aqueous solutions solutions in which water is the solvent
arthropod an animal that has an exoskeleton, a segmented body and jointed legs (e.g. insects, crabs)
asphyxiation a condition caused by not having enough oxygen
assimilate take in and process
asymmetry lack of symmetry
auditory learning learning through listening
autotrophs organisms that can produce their own nutrients
axis an imaginary line from the North Pole to the South Pole that the Earth spins on
bar chart a diagram using the lengths of rectangles (bars) to show the size of the same property for different objects or at different times
beaker container for mixing or heating substances
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
biochemist a scientist who studies the composition and interaction of substances in living things
biodegradable able to break down or decompose easily in the environment
biomass the total amount of mass of living organisms
biomechanics the study of how animals, including humans, move
biophysicist a scientist who studies the forces, energy and electrical processes in living things
biostimulants substances that stimulate processes of living organisms to enhance their growth
biotic factors the living things in an ecosystem
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
botany the study of plants
buoyancy an upward force acting on a floating object provided by a fluid
buoyant able to float on a liquid
carnivores animals that eat other animals
categorical data related to categories or non-numerical values; also known as qualitative
cellular respiration the chemical reaction involving oxygen that moves the energy in glucose into the compound ATP
centre of gravity an imaginary point in an object that gravity appears to act around
centrifuging separating a mixture by rotating the container quickly so the heavier parts of the mixture move to the outside of the spinning container
cerebrum the largest part of the brain, responsible for higher order thinking and decision making
chemical reaction a chemical change in which one or more new chemical substances is produced
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
classification grouping animals and plants according to their similarities
cold pressing pressing at low temperatures to produce oils/pulp
colloid a mixture in which extremely small particles of one substance are spread evenly throughout another substance
column graph *see* bar chart
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
concentrated a solution containing a large amount of solute
concept map a visual thinking tool that shows the connection between ideas
conclusion a general statement that sums up the observations or results of an experiment
condensation the change in state from a gas to a liquid
condense change state from gas to liquid
conductor material that allows an electric charge to flow through it
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
continuous numerical data that can be measured and be any value in a range, including decimals
continuum a visual thinking tool that shows extremes of an idea or where people 'stand' on a particular idea or issue
contract shorten or become smaller in size
control group a group that is not affected by the independent variables and is used for comparison
controlled a parallel experiment where everything is the same as the test set-up except the variable
coolamon First Nations Australians' vessel for carrying objects
corrosive describes a chemical that wears away the surface of substances, especially metals
crystallisation a separation technique that uses evaporation to separate the parts of a solution, leaving the solute as crystals
cycle a visual thinking tool that shows order and sequence
data observations or measurements made and recorded during an investigation
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
density mass per unit volume
dependent variable a variable that 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 key a diagram 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
dilution the process of adding more solvent to a solution to make it less concentrated
discrete numerical data that can be counted and can only be certain values
discussion detailed area of a scientific report that explains the results and how they link back to the relevant concepts. It also includes suggestions for improvements to the experiment.
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
domains regions within the material that are aligned or facing different directions
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
electric charge a property relating to the charge (negative or positive) on an atom or object
electric field an area around an electrically charged object where objects experience an electric force
electromagnet a magnet that requires an electric current to become magnetic
electron very light, negatively charged particle inside an atom
electrostatic force 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
emulsion a colloid where droplets of one liquid spread evenly through another
endoparasite a parasite that lives inside its host
endoskeleton a skeleton or shell inside the body
endotherm an animal that can maintain its internal body temperature in a constant range
entomology the study of insects
equilibrium balanced or equal
equinox days with the same number of daylight hours as night hours
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
evaporate change state from liquid to gas
evaporation the change in state from a liquid to a gas. Evaporation occurs only from the surface of a liquid.
excrete get rid of waste
exoskeleton a skeleton or shell that lies outside the body
expand increase in size due to particles moving apart
experimental group test group that is exposed to the independent variable
fair test a test that changes only *one* variable and controls all other variables when attempting to answer a scientific question
falsifiable able to be proven false
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
filter funnel used with filter paper to separate solids from liquids
filtrate liquid that has passed through a filter
filtration the process of separating suspended particles from fluid through a filter
fishbone diagram a visual thinking tool that identifies causes of an event
flammable 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
flowchart a visual thinking tool that shows order and sequence
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 a push, pull or twist
force multiplier simple machine that supplies a greater force than the effort used
forensic psychology a branch of psychology dealing with the law
forensic scientists people who use methodical gathering and analysis of scientific evidence to establish facts that can be presented in a legal proceeding
freezing the change in state from a liquid to 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
fungi eukaryotic organisms that generally use spores to reproduce, and contain cell walls made of chitin
gas state of matter with no fixed shape or volume
germination the first sign of growth from the seed of a plant
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
grow undergo development
gymnosperms vascular plants that produce seeds in woody cones, but do not produce flowers
habitat the place in which a particular organism lives
habits of mind types of thinking behaviours promoted by Bena Kallick and Arthur Costa
helitorch a device used to drop flaming fuel onto another substance in order to ignite it
herbivores animals that eat only plants
heterogeneous mixture a mixture in which particles are spread unevenly
heterotrophs organisms that depend on another organism to supply their complex molecules and energy
histogram a graph with equal intervals marked on the x-axis for the values of a quantity, and frequency of occurrence of each value shown by the height of adjoining columns
homogeneous mixture a mixture in which particles are spread evenly
host the organism on which a parasite feeds
human error mistakes made by the person performing the investigation
hypothesis a testable statement from an observation, usually written in *if* ... *then* ... format, that acts as a prediction for the investigation
immiscible liquids liquids that will not mix, such as oil and water
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
inference a suggested logical explanation for an event or occurrence
inorganic material that is not carbon-based
insoluble a substance that will not dissolve in a liquid
insulator material that does not allow an electric charge to flow through it
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
kinaesthetic learning using touch or manipulating materials to learn
kingdom a scientific classification referring to a group of related phyla with similar features and distinctive characteristics
landfill an area set aside for the dumping of rubbish
lever simple machine usually consisting of a long, rigid object that moves around a turning point when a force is applied
lichen a mutualistic symbiotic relationship of a fungus with an alga and/or a cyanobacterium
line graph a graph made by plotting pairs of data as points and joining the points together
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
lobe one of the four primary areas of the cerebrum
lubricant substance 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 $29\frac{1}{2}$ days
machine device that makes a physical task easier by converting energy
magnetic field a map of lines showing the size and direction of a magnetic force
magnetic force force acting between magnets and magnetic objects
manufacturing processes processes used to make products
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)
matrixes thinking tools that can be used to compare properties of multiple topics
matter everything that takes up space and has mass is matter
measuring cylinder container used to measure volumes of liquids accurately
mechanical advantage the advantage of force-multiplying levers or other machines as defined by the load divided by the effort
melting the change in state from a solid to 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 curve seen at the top of a liquid, when in contact with a surface, specifically within a tube
metabolism the chemical reactions occurring within an organism that enable the organism to use energy and grow and repair cells
meteorologist a scientist who uses observations of the atmosphere to predict or explain the weather
microbiology the study of microorganisms, living things too small to see without a microscope
microorganisms microscopic (very small) life forms
microscopy the use of microscopes to view structures that can't be seen with the naked eye
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
multiple intelligences eight types of intelligences suggested by Howard Gardner
mutualism a relationship between two organisms in which both benefit
neap tide 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
neuron cell designed to carry electrical impulses by which the nervous system functions nerve cells
neutral having the same number of protons and electrons
neutron tiny, but heavy, particle found in the nucleus of an atom with no electrical charge
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
north pole the end of the magnet that, when free to rotate, points to the north pole of Earth
nucleus central part of the atom, made up of protons and neutrons
numerical data related to numbers; also known as quantitative
observations information obtained by the use of our senses or measuring instruments
oil spill dispersants chemicals that when sprayed onto an oil spill, can break the oil into smaller particles
olfactory learning using the sense of smell to learn
omnivores animals that eat plants and other animals
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
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
palaeontology the study of fossils
paper chromatography method of separating a mixture of different colours positioned on filter paper using a solvent
parallax error a reading error in which, when scales are read from a different angle, the reading is not accurate
parasite an organism that lives 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 eclipse 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
penumbra the region where only a portion of light is blocked by an object
permanent magnet magnet that retains its magnetic effect for many years
pharmacology the study of the effect 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
physical property property that you can either observe using your five senses — seeing, hearing, touching, smelling and tasting — or measure directly
pie chart a diagram using sectors of a circle to compare the size of parts making up the whole; also called a sector graph
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
PMI chart a thinking tool that helps you visualise and reflect on an idea, consisting of three columns headed 'plus', 'minus' and 'interesting'
poikilothermic having a body temperature that fluctuates and is similar to the temperature of its environment (as in cold-blooded organisms)
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
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.
pressure the force exerted per unit area
primary consumer an organism that eats plants
prions infectious proteins that can cause disease
priority grid a thinking tool that helps quantify or rank ideas
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
proton tiny, but heavy, positively charged particle found in the nucleus of an atom
pteridophytes vascular plants that produce spores usually located on the underside of their leaves
pure substance a form of matter that cannot easily be separated into its components
radial symmetry symmetrical about the centre axis
radiochemistry the study of radioactive substances
ramp simple machine, called an inclined plane, that reduces the effort required to raise objects to a higher level

raw materials materials before they are made into a final form
recycling treating items such as glass, paper, plastic, aluminium and steel so that new products can be made from them
relationships interactions with other species within an ecosystem
reproduce create offspring
repulsion an opposing force in which objects are pushed away from each other
research question a question that is the focus of the investigation, which the experiment aims to answer
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
results the details or data that are recorded from the outcome of an investigation
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 glasses plastic glasses used to protect the eyes during experiments
sample size the number of repeated observations in an experiment
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
scientific method the process of making an observation, developing a hypothesis and testing this through scientific investigation
screw curved inclined plane
secondary consumer an organism that eats primary consumers
sector graph *see* pie chart
sediment the insoluble material that collects at the bottom of a container when suspensions are left to stand
seed the product of a fertilised ovule
seismology the study of earthquakes
separating funnel a pear-shaped glass container, with a tap at its base, used to separate two liquids that do not mix
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
social learning collaborating and sharing with peers to learn
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 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
south pole the end of the magnet that, when free to rotate, points to the south pole of Earth
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 psychology the study of how athletes train their minds to help improve sporting prowess
spring tide 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.
static electricity a build-up of charge in one place
steam distilling process of using water vapour to extract aromatic oils and other substances from plant matter
STEM acronym: stands for the disciplines of science, technology, engineering and mathematics
stigma the female part of a flower, that catches the pollen during pollination
storyboard a visual thinking tool that shows order and sequence
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
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
suspension a mixture of an insoluble substance in a liquid or gas
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
SWOT analysis chart a visual thinking tool that helps classify or organise thoughts
symbiosis an ongoing relationship between members of different species
symmetry the quality of being a mirror image across an axis
target map a visual thinking tool that analyses and compares
taxonomy the study of the classification of organisms
technology the application of science to the design of a device or process
temperature a measure of how hot or cold something is
temporary magnet magnet that does not stay magnetic after it has been removed from another magnet
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 consumer an organism that eats secondary consumers
test tube thin glass container for holding, heating or mixing small amounts of substances
testable able to be supported or proven false through the use of observations and investigation
thermometer a device which measures temperature
thinking hats a thinking tool developed by Edward de Bono using different coloured hats for different types of thinking
thinking keys a tool developed by Tony Ryan to help unlock thinking
thread curved ridge of a screw formed by a winding inclined plane
tide the regular rise and fall of water level of the ocean, in a cycle close to 12.5 hours
timeline a visual thinking tool that helps sequence thoughts
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
transfer move energy from one object to another using simple machines
transform change one form (of energy) into another
transparent see-through; allowing light to pass through so objects behind can be seen distinctly
trophic level a feeding level within a food chain
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
variables quantities or conditions in an experiment that can change
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
Venn diagram a visual thinking tool that analyses and compares
vertebrates animals with backbones
viroid the smallest infectious known pathogen, comprised solely of a short single-stranded piece of RNA
virus a non-cellular pathogen that uses the host cells in order to reproduce
visual learning using text or images to learn
volatility how readily a substance evaporates or becomes a vapour
volume the amount of space taken up by an object or substance
vulcanology the study of 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
weight a measure of the size of the force of gravity pulling an object towards the centre of a massive body
wheel and axle a type of lever that can rotate when an effort applied at the wheel produces a greater force on the axle
winnowing using an air current to separate seeds from their outer layer and other debris
winter solstice the day of the year with the fewest daylight hours
***x*-axis** the horizontal axis on a graph
xylem vascular tissue that carries water and minerals from the roots up to the leaves
Y chart a visual thinking tool that helps you visualise and reflect
***y*-axis** the vertical axis on a graph
yandying process that removes less dense particles, such as sand, ash and dirt, from denser desirable seeds
zoology the study of animals

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