CAMBRIDGE

INTERACTIVE TEXTBOOK INCLUDED

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Stage 4

Cambridge science for the NSW Syllabus

CAMBRIDGE UNIVERSITY PRESS

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Contents

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How to use this resource

Elements in the print book

You will see the following types of boxes throughout this book.

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

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

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

Did you know?
These are short facts that contain interesting information.

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

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

Section questions
Question sets at the ends of sections are categorised under the following headings: Remembering, Understanding, Applying, Analysing and Evaluating. Action verbs have been bolded. These questions are also available as Word document downloads in the Interactive Textbook.

Hands-on activities

Try this
Classroom activities help explore concepts that are currently being covered.

Practicals
Classroom or laboratory activities and investigations help consolidate student understanding. These activities are also available as Word document downloads in the Interactive Textbook.

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End-of-chapter features

Chapter review

Chapter checklist

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

Success criteria		Check
2.1	**I can recall what a force is and how they are measured.** e.g. State the unit of force.	
2.1	**I can describe the impact of balanced and unbalanced forces on an object.** e.g. If a car is travelling at a constant speed in a straight line down the Hume Highway, what can you infer about the drag and the force of the engine?	
2.1	**I can draw a force diagram to indicate the forces acting on an object.** e.g. Illustrate a force diagram of you running on the athletics track.	
2.2, 2.3	**I can describe the difference between contact and non-contact forces.** e.g. Identify two contact forces and two non-contact forces.	

SCORCHER

Chapter checklists help students check that they have understood the main concepts and learning intentions of the chapter. They come with example questions.

Data questions

Earth's Moon and the planets in our solar system have different forces of gravity on their surface than Earth because they have different masses. These forces of gravity on the surface of each are shown with respect to that of Earth in the graph below.

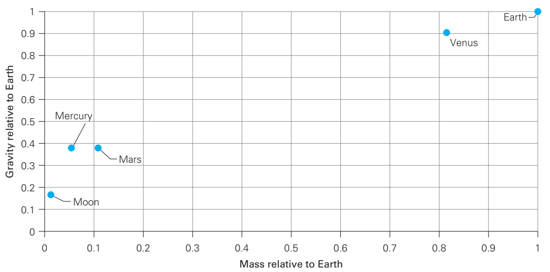

Figure 2.60 Gravity on the Moon and planets relative to that of Earth given their relative masses

1 **Identify** which planet in the graph has the lowest mass.
2 **Determine** which planet has a force of gravity closest to that on Earth.
3 If the acceleration of Earth's gravity is 9.8 m/s^2, and Mars' gravity is 38% of that of Earth, **calculate** Mars' actual gravitational force.

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

STEM activity DESIGNING AND PROTOTYPING A FERRY 99

STEM activity: Designing and prototyping a ferry

Background information

Ferries are used worldwide to connect two or more points (e.g. Parramatta RiverCat or Sydney Ferries). They carry passengers, goods, and sometimes vehicles. Ferries are vital for transport in many developing countries, since highways are expensive to build and most waterways come free.

Ferries float in water as a result of buoyancy. Any object placed in water will either sink or float: if an object is denser than water, it will usually sink; and if it is less dense, it will float. But how can a steel ship, capable of carrying thousands of passengers and cars, float in the ocean when a metal ring or coin would sink in your bathtub?

It is time to investigate how design can affect the buoyancy of a ferry!

Figure 2.61 Ferries are part of the public transport system in many places in the world.

Design brief: Design and construct a ferry boat.

Activity instructions

In teams (maximum of three people), you will design and construct a ferry capable of transporting a payload (set mass) between two points (return trip). Your team has been assigned the task of designing and constructing a ferry for riverside communities to transport people and goods on the water.

As an engineer, you should investigate the science and technology of boats.

Suggested materials

- ruler and tape measure
- scissors
- cardboard
- bubble wrap
- plastic bags
- 5 × 100 g parcels of sugar/salt (payload)
- sticky tape (duct tape or gaffer tape would be good)

Research and feasibility

1 List the features that would make a useful boat.
2 Research the terms 'density' and 'buoyancy' and discuss in your group how these factors are important in boat design.

Design

3 Design a ferry that is capable of transporting your payload between two points and return.
4 Label and include measurements of your ferry.

Create

5 Build your ferry using the materials, checking as you progress that your ferry is capable of floating.

Evaluate and modify

6 Discuss the challenges you have encountered throughout this project with at least three of your peers. List the strategies or actions that allowed you to overcome it.
7 Create a list of improvements to your design that could be applied to this project to refine its performance.

STEM activities encourage students to collaboratively design and build solutions to problems and challenges.

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Links to the Interactive Textbook

- VIDEO These icons indicate that there is a video in the Interactive Textbook.
- WIDGET These icons indicate that there is an interactive widget in the Interactive Textbook.
- WORKSHEET Worksheets can be downloaded from the Interactive Textbook at the start of every section.
- QUIZ Automatically marked quizzes can be found in the Interactive Textbook for every section.
- SCORCHER Competitive questions can be found at the end of each chapter.

Overview of the Interactive Textbook (ITB)

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

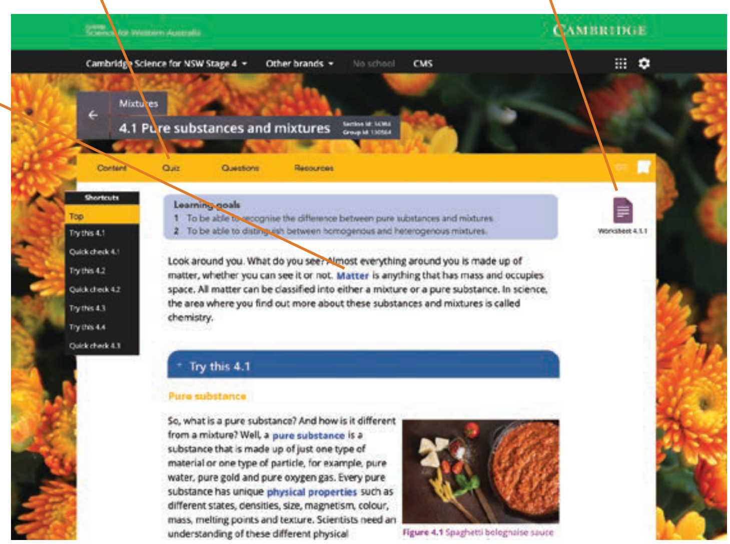
Definitions pop-up for key terms in the text.

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

Worksheets are provided as downloadable Word documents.

Videos summarise, clarify or extend student knowledge.

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



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

Practical 2.1

Using a spring balance

Aim

To select the most appropriate spring balance.

Materials

- a range of spring balances (e.g. 1 N, 5 N, 10 N, 50 N)

Procedure

1 Copy the results table into your science book.
2 Determine the force needed to complete the actions in the table.

Results

Item	Force required (N)
Hold your pencil case	
Drag this textbook across the table	
Remove a piece of sticky tape from your desk	
Open the lab door	
Drag your stool across the floor	
Hold your school bag	

Discussion

1 State whether the forces applied to the items are push or pull forces.
2 Name the forces involved when hanging and dragging an item.
3 Sequence the items in order from most to least force required to drag them.
4 Explain why the same spring balance could not be used for all of the actions.

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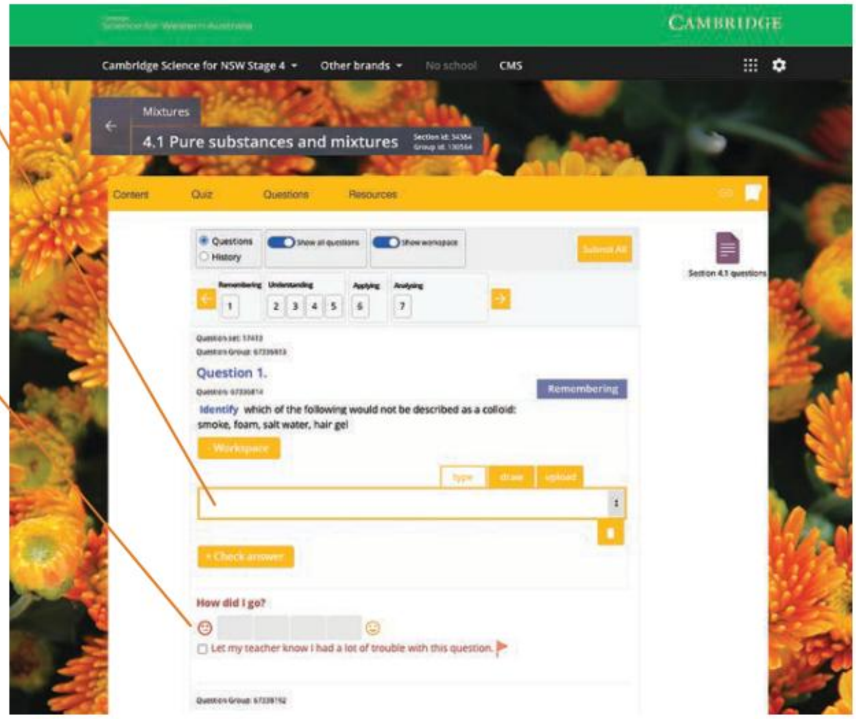
Workspaces enable students to enter working and answers online and to save them. Input is by typing, handwriting and drawing, or by uploading images of writing or drawing.

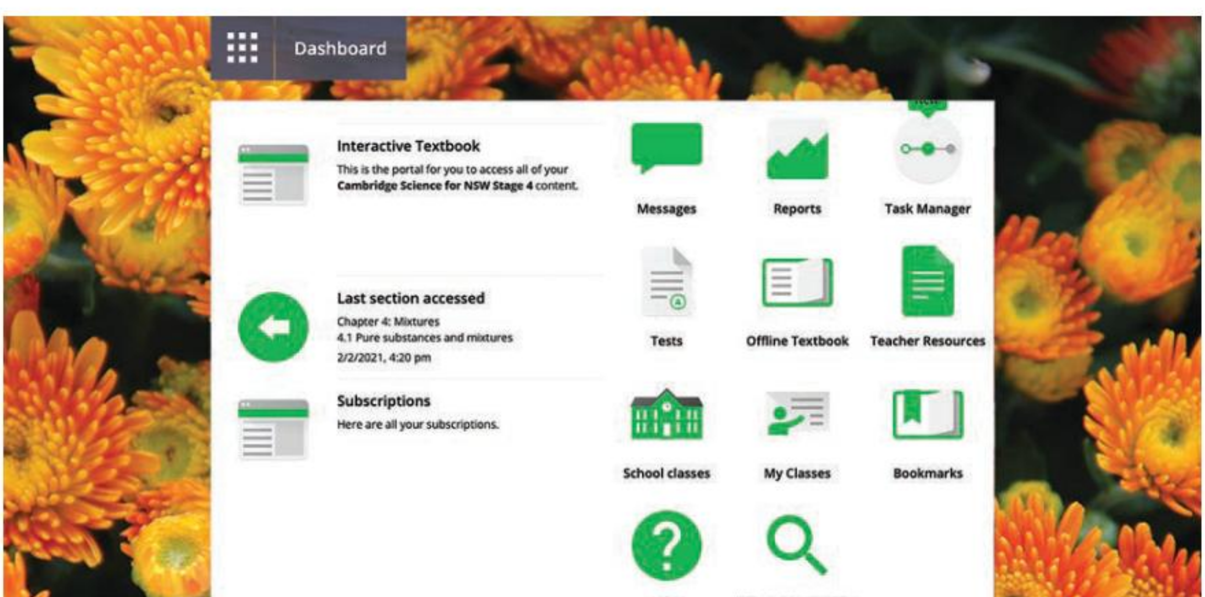
Self-assessment tools enable students to check answers, mark their own work, and rate their confidence level in their work. This helps develop responsibility for learning, and communicates progress and performance to the teacher. Student accounts can be linked to the learning management system used by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



Overview of the Online Teaching Suite (OTS)

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

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



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Chapter 1
Being scientific

PRE-TEST

Chapter introduction

You may have heard of certain famous scientists and studied aspects of science in primary school, although you might not have realised it. Science is a field of study that tries to make sense of the world around us. In this chapter, you will learn more about what a scientist does, who they work with, and the rules and principles that govern their work. It is important that all scientists have a set of similar processes that they follow to make sure their findings are valid. You also learn how to carry out research and analyse sources of data, how to record and process your own experimental data, and how to communicate your scientific findings to the world.

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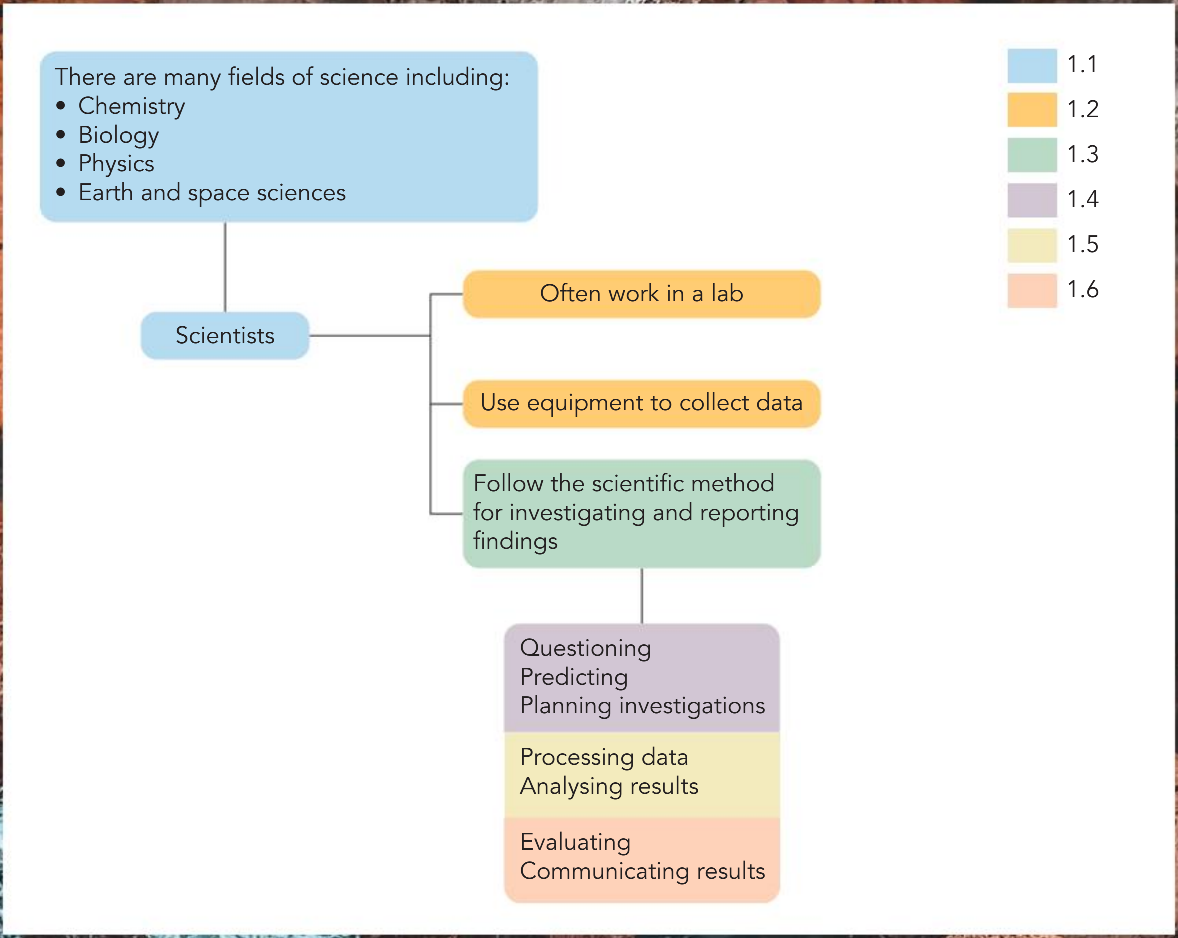
Chapter map



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1.1 What is science?

Learning goals

1 To explain what science is.
2 To describe the different fields of science.

DOC WORKSHEET

The word for 'science' comes from the Latin word for '**knowledge**', *scientia*. Science is a collection of knowledge that we have already gathered. Science is also the process of gaining new knowledge. This process is used every day to answer questions about how things work, solve problems and create new amazing technologies.

knowledge
the understanding of information

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

data
facts or statistics gathered to answer a question or for further analysis

In science, you are constantly asking questions about the universe, how things work, why they work that way and what happens if you change things. By collecting and analysing information about the world around us, scientists can produce answers about each question asked.

For example, you might be trying to grow broccoli. Your plants are looking great and then all of a sudden, they are filled with holes. You wonder why this is happening, so you watch your plants and observe that white moths are landing on the leaf. By analysing this data, you realise that the moths are laying eggs on your plants. These eggs are hatching into caterpillars that are eating your plants! You then place a net over your plants to solve the problem of the moths. This is science in action!

Figure 1.1 Caterpillars eating a broccoli plant

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

Aboriginal and Torres Strait Islander perspectives in science

Aboriginal and Torres Strait Islander peoples have been asking scientific questions and collecting observational data on the Australian continent for thousands of years. Their knowledge of Country/Place is extremely helpful in understanding the unique location that is Australia.

For example, over thousands of years, Aboriginal and Torres Strait Islander peoples have developed a deep understanding of:

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

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

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Fields of science

Just as there are many types of questions, there are many fields of science. Science groups together different areas of science depending on what is being studied. The main areas of science that are covered in Years 7 to 10 Science are biology, chemistry, physics and Earth and space science.

Biology is the study of all living things. A person that studies biology is known as a biologist. Within the field of biology, there are many smaller specialised fields such as zoology (study of animals), botany (study of plants), ecology (study of ecosystems), biotechnology (study of how organisms can be used to create products of value to society) and anatomy and physiology (study of the structure and functions of living things).

These are some questions a biologist might ask.

- How do plant roots work?
- How can the number of koalas be increased in an area?
- What animals eat this plant?

Chemistry is the interaction of substances with each other and with energy. These substances make up matter and are called chemicals.

Figure 1.3 A chemist in action

A person who studies chemistry is known as a chemist. Branches of chemistry include organic chemistry (study of carbon-based chemicals such as those found in fossil fuels) and medicinal chemistry (the design and development of medicines).

These are some questions a chemist might ask.

- What will happen if I heat this substance?
- Will I get a new chemical if I mix this one with that one?
- What are the chemicals in this liquid?

Figure 1.2 Biologists taking samples from the ocean

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Figure 1.4 Physicists working on the Large Hadron Collider in Geneva

Figure 1.5 Geologists mapping an area

Physics is the study of forces, energy and matter (excluding the interactions studied in chemistry). People who become experts in physics are known as physicists and can specialise in many fields such as atmospheric physics (study of weather and climate), atomic physics (study of atoms) and astrophysics (study of space).

These are some questions a physicist might ask.

- What forces are acting on an aeroplane?
- Does light travel at a constant speed?
- What types of energy are safe to use?

Earth and space science is the study of Earth and space. These scientists study rocks, stars, volcanoes and the non-living resources around us. Geology, astronomy and climatology are just some of the many fields people can specialise in.

These are some questions an Earth and space scientist might ask.

- Where does lava come from?
- What are asteroids made of?
- Where is gold likely to be found?

There is often a lot of overlap between different fields in science. Both physics and chemistry are involved in the study of matter. Biology and chemistry are both involved in food science. Biology and Earth and space science are involved in the study of sending astronauts into space. And very many different sciences are involved in agricultural science.

Quick check 1.1

1. Recall the definition of 'science'.
2. State the name given to information gathered in science.
3. Name the controlled situation used in science to gather data.
4. Identify the field of science that would study:
   a. an endangered animal
   b. the distribution and origin of rocks
   c. the composition of a new drug.
5. Describe what you think of when you think of a scientist at work.
6. Imagine that alien life was discovered on Mars. Identify what fields of science might be involved with studying this alien life.

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Figure 1.6 Roles in groups

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Who do scientists work with?

Scientists can work individually or in groups. They may work for themselves or might work for large multinational companies. When you conduct experiments in science class, you will often be working in groups. In the real world, these groups are made up of experts from many different fields to bring their strengths together.

Working in groups:

- is an important part of life
- requires cooperation between team members
- requires sharing ideas and resources
- means team members need to understand their role in finding a solution to a problem being investigated.

A good group has:

- a clear understanding of everybody's roles
- equitable participation, with responsibilities shared between the members
- the ability to communicate and resolve problems
- the ability to complete the tasks assigned in a timely manner
- members who listen to each other.

Roles in groups

Figure 1.6 on page 7 shows some descriptions of possible roles in groups. Often people take on multiple roles in groups, but it is important that everyone in a group knows their role, focuses their effort on the things they are good at and contributes equally. It is also a good idea to try different roles occasionally as you may find that you have a skill you did not know about.

It is important to never get stuck in the same role too many times. Even though you might feel more comfortable in certain roles in groups, you should always try out new positions and develop skills that you may not be naturally strong in.

Quick check 1.2

1 Name some qualities about yourself that are strengths when you do group work.
2 Identify what roles you would be good at.
3 State a role that you do not think you would be good at and explain why.
4 Identify three goals that would allow you to be better at the role you stated in Question **3**.

Try this 1.1

Produce a paper tower

You will work in groups. Each person in the group chooses at least one role from Figure 1.6 on page 7. Your group will act as a team of consultant engineers, working towards finding a solution to a challenge.

First, brainstorm solutions together. Remember these rules.

Rules for brainstorming

Focus on quantity: Come up with as many ideas as you can.
Encourage wild ideas: Don't put down or criticise ideas that are wild. They may lead to innovative designs.
Record all ideas: Have one student be the 'scribe' and write everything down.
Combine and build ideas: Discuss and elaborate on the ideas of other students.
Focus: Stay on topic.

Challenge

You are to design and create a newspaper tower that can support this textbook at least 20 cm off a table.

Criteria

1 The tower must not be taped to the table and cannot be supported by any other item.
2 Your teacher will set a time limit for the task.

continued…

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...continued

3 The group can only use these materials:
- two pieces of newspaper
- scissors
- 50 cm sticky tape

Instructions

1 Allocate a role to each person in the group as outlined in Figure 1.6.
2 Brainstorm all possible solutions to the problem, including drawings of your design.
3 Create and test a prototype.
4 Improve your prototype.
5 Discuss the process you followed.

Evaluation

Present your designs with the rest of the class.

1 Explain the process of how you came up with your design.
2 Identify the roles each group member played.
3 Discuss how you would approach the research and design process the next time you conduct a similar task.

Section 1.1 questions

QUIZ

Remembering

1 **State** a question that a biologist might ask.
2 **Outline** what a physicist would study.
3 **Outline** how scientists collect data.

Understanding

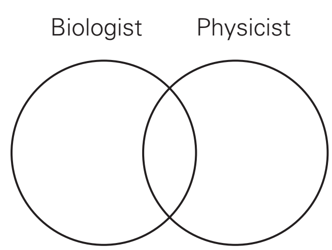
4 **Explain** how science has affected your day so far.

Applying

5 **Propose** the field of science that would study asteroids.

Analysing

6 **Compare**, using a Venn diagram, the work of a biologist to that of a physicist.



Evaluating

7 Some fields of science can overlap. **Suggest** what fields of science a biochemical engineer might study.

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1.2 Working in a laboratory

Learning goals

1. To explain the safety rules.
2. To identify some common equipment.

DOC WORKSHEET

Exploring the laboratory

Not all scientists work in laboratories, of course! Depending on the area of science, they may work 'in the field' such as out and about in the natural environment, on land or in the sea, and they can work in organisations like zoos, private companies or for the government. However, all scientists have spent at least some of their time in a 'lab'. The controlled environment and access to special equipment makes it an ideal place for conducting experiments. Now that you are studying science, you will get to participate in many exciting scientific experiments in the laboratory.

Lab safety basics

The laboratory can be a fun and safe place if the safety rules are followed. However, it can be a dangerous place if you do not follow the safety rules, or if you misuse the equipment or forget to use safety gear. Throughout your science career in school, you could get burned, be exposed to dangerous chemicals or cut yourself on broken equipment. Therefore, it is extremely important to know some core rules.

Referring to Figure 1.8, spot the differences between the students who are ignoring the rules (top image) and those following the rules (bottom image). The class in the top image is making seven dangerous mistakes. Suggest what they might be. (The answers are below.)

Answers to the spot the difference activity: did you find all the lab safety issues?

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

Figure 1.7 It is important to wear appropriate personal protective equipment at all times when working in a lab environment.

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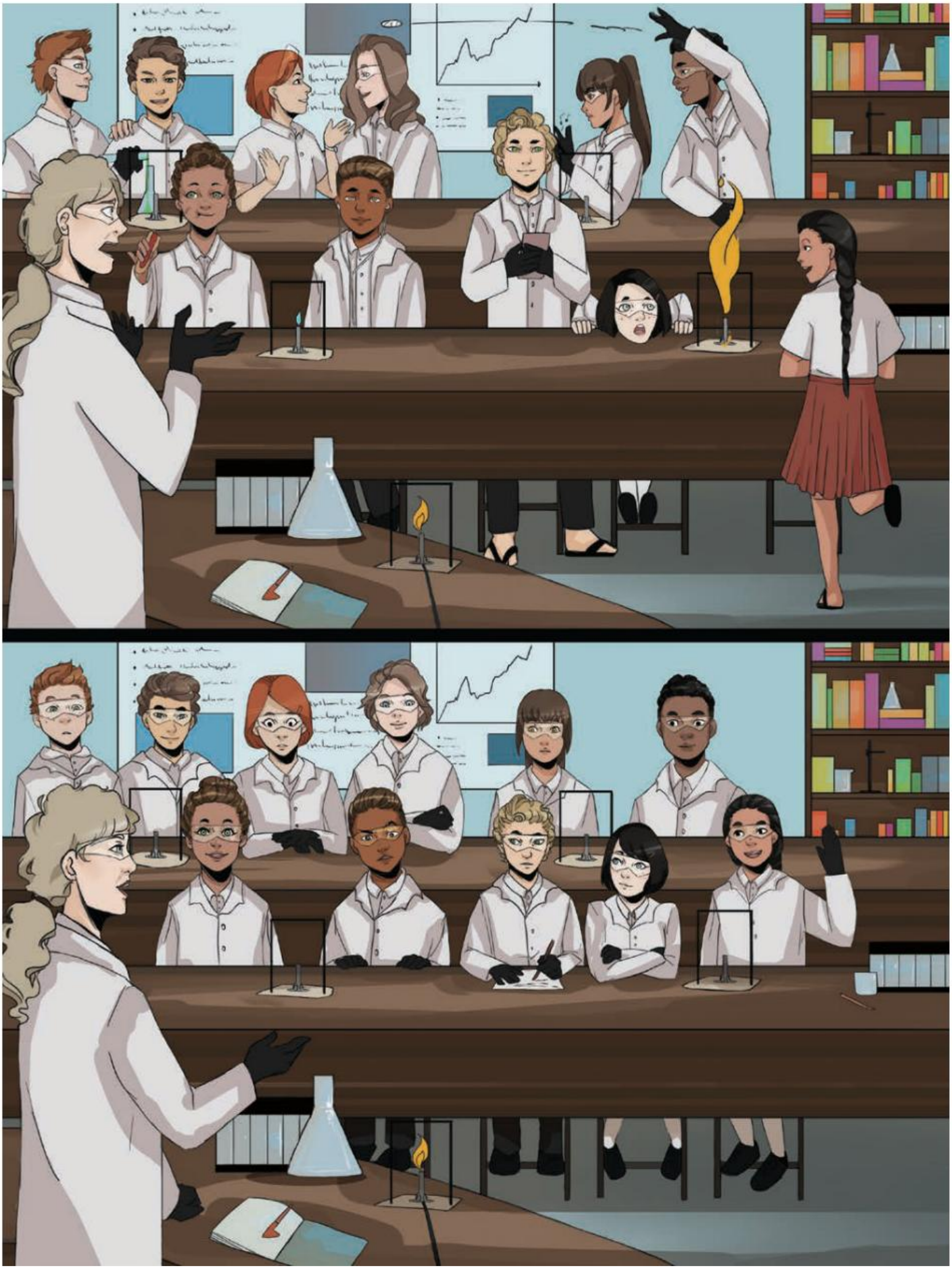

Figure 1.8 Good lab safety is essential.

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It is important to be observant in the lab and be on the lookout for any potential hazards. Common hazards in the lab are something that you could trip or slip on, or cut or burn yourself on. If you see a hazard, it is important to make your teacher aware of it as soon as possible, so they will be able to stop anyone from getting hurt.

Hazard symbols

Each time you conduct an experiment in science, there are many potential hazards to be aware of.

How do you know what chemicals are dangerous? When you use chemicals, you will see that there are often symbols on the label of the bottle (Table 1.2). These symbols tell you the possible dangers when handling any chemical.

Risk assessment

Even if you perform them carefully, all experiments carry an element of risk. Some can even be dangerous. Therefore, it is important that you write a risk assessment to show firstly, that you have considered the risks associated with the experiment, and secondly, that you know how to avoid or minimise these risks.

Many risks will be obvious to you: you will already know the hazards associated with using glassware or electricity in the lab, but you may not be fully aware of how dangerous different chemicals are.

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

Table 1.1 Risk assessment table

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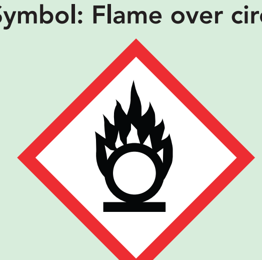
Name of hazard	Symbol	Meaning	Examples
Corrosive	**Symbol: Corrosion** 	This chemical causes skin corrosion/burns or eye damage on contact, or is corrosive to metals.	Sodium hydroxide Sulfuric acid
Health hazard/Hazardous to the ozone layer	**Symbol: Exclamation mark** 	This chemical will cause immediate skin, eye or respiratory tract irritations.	Many acids and alkalis
Flammable	**Symbol: Flame** 	This chemical will catch fire easily.	Ethanol Propanone
Hazardous to the environment	**Symbol: Dead tree and fish** 	The chemical will cause damage to all living things if it enters the waterways.	Copper sulfate
Explosive	**Symbol: Exploding bomb** 	This chemical is an explosive at risk of exploding, even without exposure to air.	Potassium Lithium
Oxidising	**Symbol: Flame over circle** 	These chemicals produce oxygen, which causes other substances to burn more.	Potassium permanganate Nitric acid

Table 1.2 Chemical hazard symbols

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

Table 1.2 (*Continued*)

Quick check 1.3

1. State the first thing you should do if you see a hazard in the science lab.
2. State when you should wear a lab coat.
3. Recall the name of the safety equipment that will protect your eyes.
4. Describe how your school labels hazardous chemicals that are being used in an experiment. Ask your teacher for an example and record how it is labelled.

When writing your risk assessment, you will have to use a safety data sheet (SDS) to provide information about the risks associated with every chemical you use. This sheet outlines any dangers the chemical presents, how you can minimise or avoid any risk to yourself when using it and the appropriate action to take should a problem arise.

Hazard	Risk	Risk management
Broken glass	Cuts from handling	Move all glassware from the edge of tables. Ensure care is taken when handling glass equipment. If any glass is broken, inform a teacher. Do not try to clear it up yourself.
Bunsen burner	Burns	Ensure appropriate personal protective equipment is worn. Do not leave the flame unattended. Ensure it is cool before handling. Check that the gas valve is off when you have finished with it.

Table 1.3 An example of how a risk assessment can be presented

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Get to know your equipment

All experiments need to be safe, fair and exact. One of the ways to ensure that this happens is to choose the correct equipment for each task. This might sound obvious, but there are several pieces of equipment that can be used for even the simple task of holding a liquid. In Table 1.4 are several pieces of equipment used to hold and work with liquids, and their purpose.

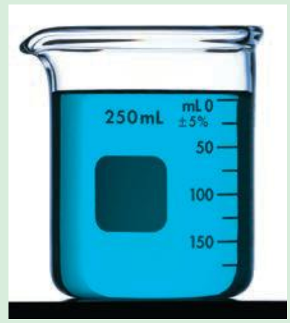
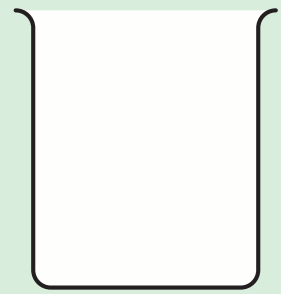
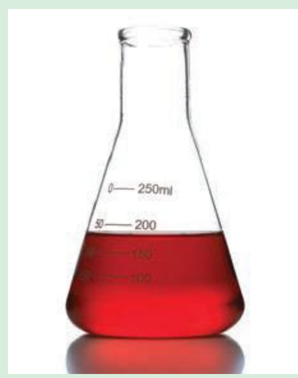
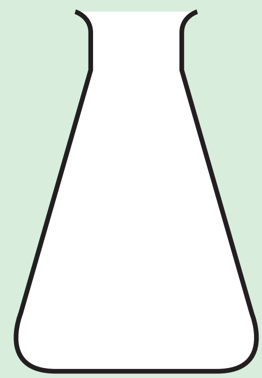
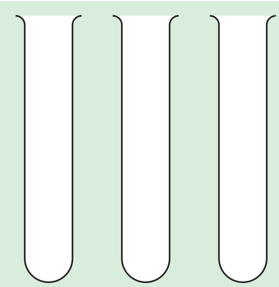
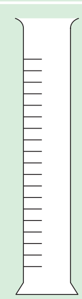
What it is used for	What it looks like	How it is drawn
A **beaker** is a common piece of equipment found in most labs. It comes in many sizes and is generally used for holding, mixing and heating liquids.		
A **conical flask** is similar to a beaker but the shape of its neck is different to reduce the likelihood of liquid spilling. It can be used to swirl liquids and prevent hot liquids from boiling over.		
Test tubes are used for holding small amounts of liquids. As they do not have a flat bottom, a test-tube rack is used to hold them.		
A **measuring cylinder** is used to accurately measure specific volumes of liquids. It must not be used to mix or heat liquids.		

Table 1.4 Some common lab equipment

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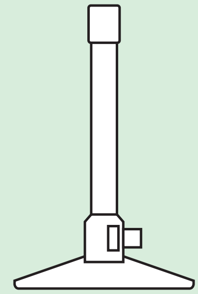
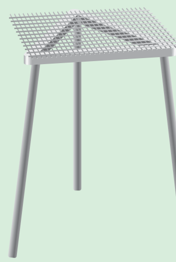
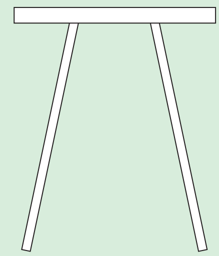
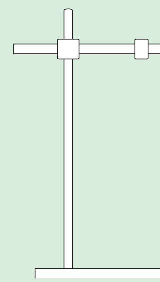
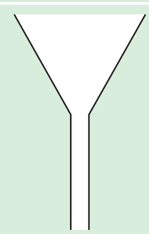
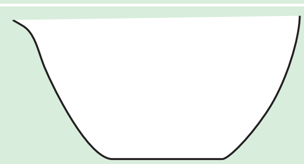
What it is used for	What it looks like	How it is drawn
A **Bunsen burner** is a common device used to add a controlled amount of heat to an object.		
A **tripod** is used to hold an object above a Bunsen burner flame while it is being heated. A wire gauze mat usually sits on top of the tripod.		
A **retort stand** and **bosshead clamp** are used to hold objects in place while testing.		
A **funnel** can be used to separate mixtures or make it easier to transfer liquids from one container to another.		
An **evaporating dish** is used to heat up and evaporate small amounts of liquid.		

Table 1.4 *(Continued)*

You may have noticed that next to each image of the equipment in Table 1.4, you will see a two-dimensional drawing. Two-dimensional, or 2D, drawings show the dimensions of length and width but do not show depth. All 2D drawings are made up of shapes. These are called scientific drawings and you use these drawings when you draw the set-up for an experiment. Use the following rules when creating a scientific drawing.

- Use a sharp pencil.
- Use a ruler to draw a straight line (no freehand).
- Only draw in 2D.

Heating equipment

In many of the experiments you will conduct in your science classes, you will need to heat different objects. This can be done using a water bath, hotplate or microwave oven but one of the most common heating tools in the lab is the Bunsen burner. A Bunsen burner is a heating tool that uses gas and a flame of controlled intensity. Although not all Bunsen burners look the same, they all have the same parts, as shown in Figure 1.9.

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Be careful

Remember these important safety points when using a Bunsen burner.

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

The Bunsen burner

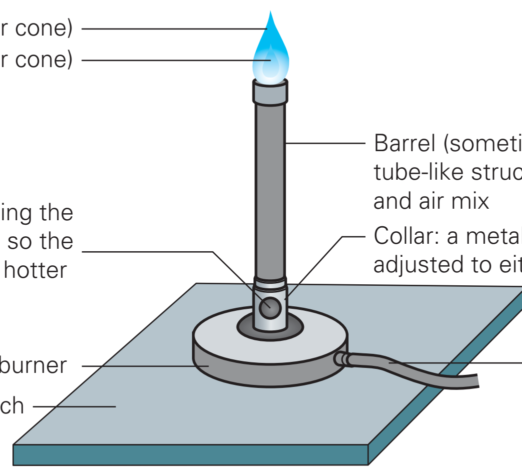

Figure 1.9 A Bunsen burner

Controlling the flame

You can control the type of flame and the temperature of the Bunsen burner by changing the size of the airhole. The airhole size is adjusted by twisting the collar.

When you first light a Bunsen burner, you must close the airhole to produce a bright yellow 'safety flame'. This yellow flame is not as hot and can be easily seen. The flame is yellow because the gas does not mix in the barrel with oxygen from the air when the airhole is closed. Oxygen is necessary to produce a more intense flame. When the collar is turned and the airhole is open, more oxygen can mix with the gas and so this produces a much more powerful blue flame.

Figure 1.10 Blue flame, or roaring Bunsen flame, is produced when the airhole is fully open. It allows oxygen from the air to mix with the gas in the barrel.

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Practical 1.1

Using a Bunsen burner

Be careful
Ensure that you follow measures to ensure general fire safety.

Aim
To practise the safe procedure for lighting a Bunsen burner.

Materials
- Bunsen burner
- matches
- heatproof mat

Planning
Consider the following questions while doing your risk assessment.
1 Explain why the airhole is closed before turning on the Bunsen burner.
2 Explain why the match is struck away from the body.

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

Practical 1.2

Heating water

Be careful
Ensure general fire safety measures are observed.
Ensure appropriate personal protective equipment is used when handling hot equipment.

Aim
To identify and use the appropriate equipment for heating water.

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

Planning
Read the procedure below and create a risk assessment for this experiment.

Procedure
The diagrams in Figure 1.11 show how to set up your equipment for each test.

Set-up 1
1 Add 50 mL of water to a beaker.
2 Place the beaker on the gauze mat over the tripod.
3 Light the Bunsen burner and measure the time taken for the water to reach boiling point.

Set-up 2
4 Fill the evaporating dish with water and pour into the measuring cylinder. Record the volume of water it can hold.
5 Repeat steps **1–3**, replacing the beaker with an evaporating dish.

continued…

...continued

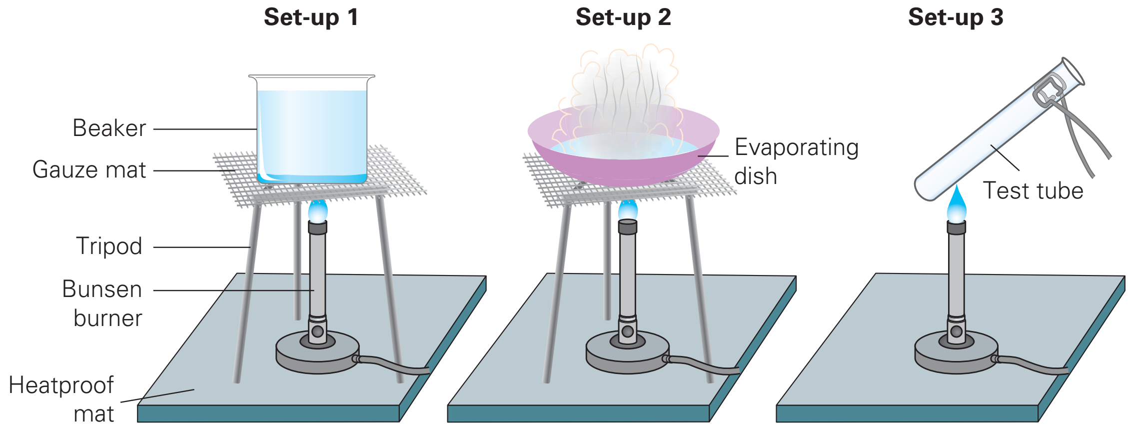

Figure 1.11 Experimental set-ups

Set-up 3

6 Fill the test tube with water and pour into the measuring cylinder. Record the volume of water it can hold.
7 Add 50 mL of water to a large test tube.
8 Hold the test tube over a blue flame using wooden tongs. Point the test tube opening away from yourself and anyone else and move it in a circular motion above the flame until the water boils.
9 Record the time it takes for the water to boil.

Results

Copy and complete the following results table.

Container	Maximum volume of equipment (mL)	Time taken to reach boiling point (s)
Beaker		
Evaporating dish		
Test tube		

Discussion

1 Describe any trends or patterns in your results.
2 Identify the best piece of equipment for holding and heating a small sample of substance.
3 Identify the best piece of equipment for removing some of the water.
4 Identify any limitations in the method.

Section 1.2 questions

Remembering

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

Understanding

2 **Explain** the steps involved in safely lighting a Bunsen burner.

Applying

3 **Organise** the lab equipment featured in this chapter into categories: Containers; Heating equipment; Measuring tools, and Others.

Analysing

4 **Compare** when you would use a conical flask and a beaker.

Evaluating

5 Billy wanted to test the absorbance of different paper towels. **Design** a risk assessment and equipment list for a possible experiment he could conduct.

QUIZ

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1.3 What do scientists do?

Learning goals

1. To identify the different types of data that can be collected in an experiment.
2. To state the steps involved in the scientific process.
3. To identify appropriate tools used to gather different types of data.

DOC WORKSHEET

Science can be thought of as a systematic way of investigating. It involves making observations, asking questions, making **predictions**, conducting experiments, collecting and **analysing** data and forming conclusions. However, one scientist may not be involved in every step of the process.

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

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

hypothesis
a proposed explanation or prediction of an event (e.g. an experiment) based on research and current knowledge

observe
use senses and tools to notice something significant

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

For example, the government might collect some health data about the population and task a scientific organisation with finding a solution to the problem. An epidemiologist (a person who tracks diseases) might come up with a **hypothesis** about the cause of the problem.

A public health advisor might design a program to test the hypothesis, and a team of health professionals, such as doctors and exercise physiologists, might conduct the experiment; for example, an exercise program. Biomedical research scientists might **observe** the experiment, collect the data and analyse it, while a pathologist might collect blood samples from the patients and test these. In the end, a nominated person would gather all the findings and publish the results in a scientific journal. Science is a team effort!

The scientific method

The process referred to above is known as the scientific method.

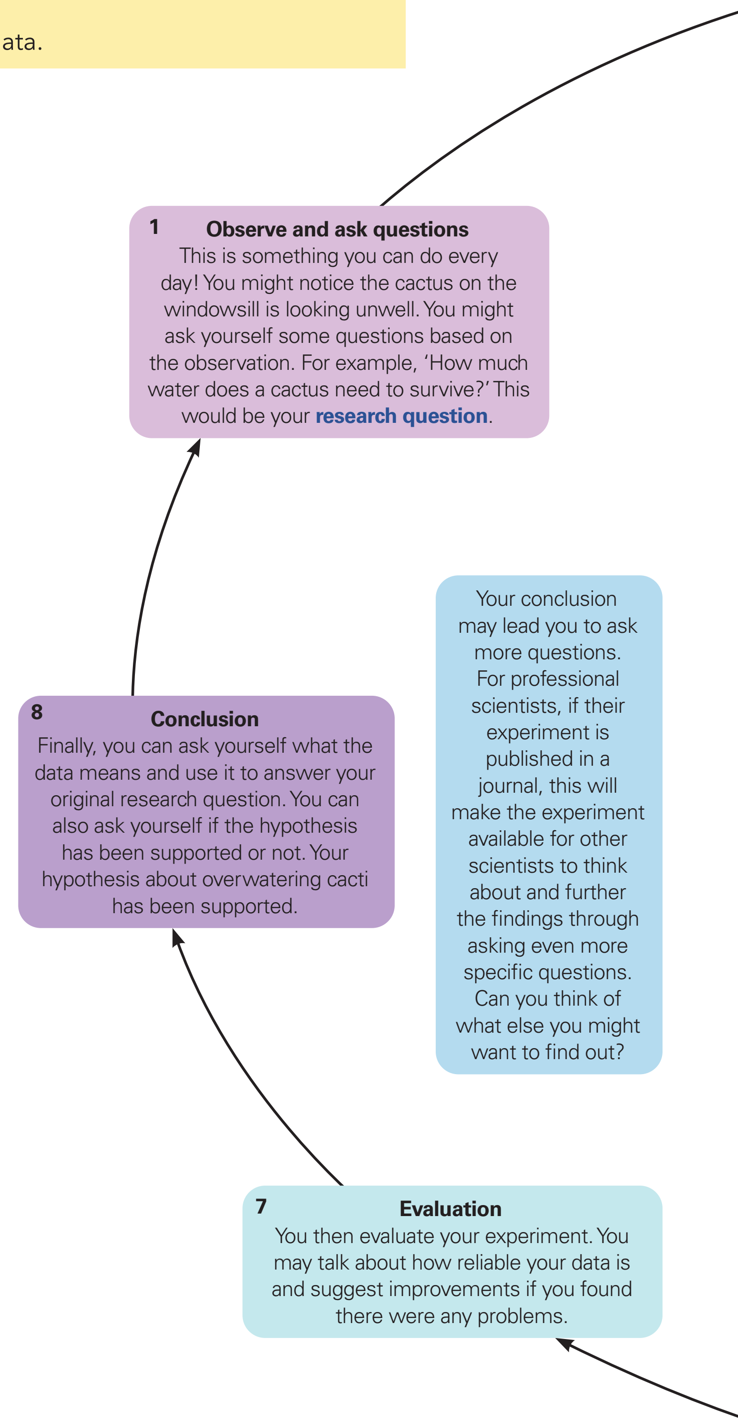

Figure 1.12 The scientific method

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The scientific method may differ slightly from one area of science to another, but will start with observing the world around you. Here is a basic outline of how the scientific method works.

2 Do background research

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

3 Hypothesis

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

4 Test the hypothesis

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

5 Processing of data

You then record and present the results. For example, you may keep track of how the cacti are doing every day. This can be quantitative or qualitative. You might want to record the colour and shape of the cacti or measure how much the cacti grow each week. The results can be presented in tables and graphs.

6 Analyse data

You then analyse the data that you have gathered to find any **trends**, patterns or relationships, and then summarise what you have found, including any problems with your data. Three of the overwatered cacti looked pale and shrunken, while all the cacti watered correctly produced small cacti pups.

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

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

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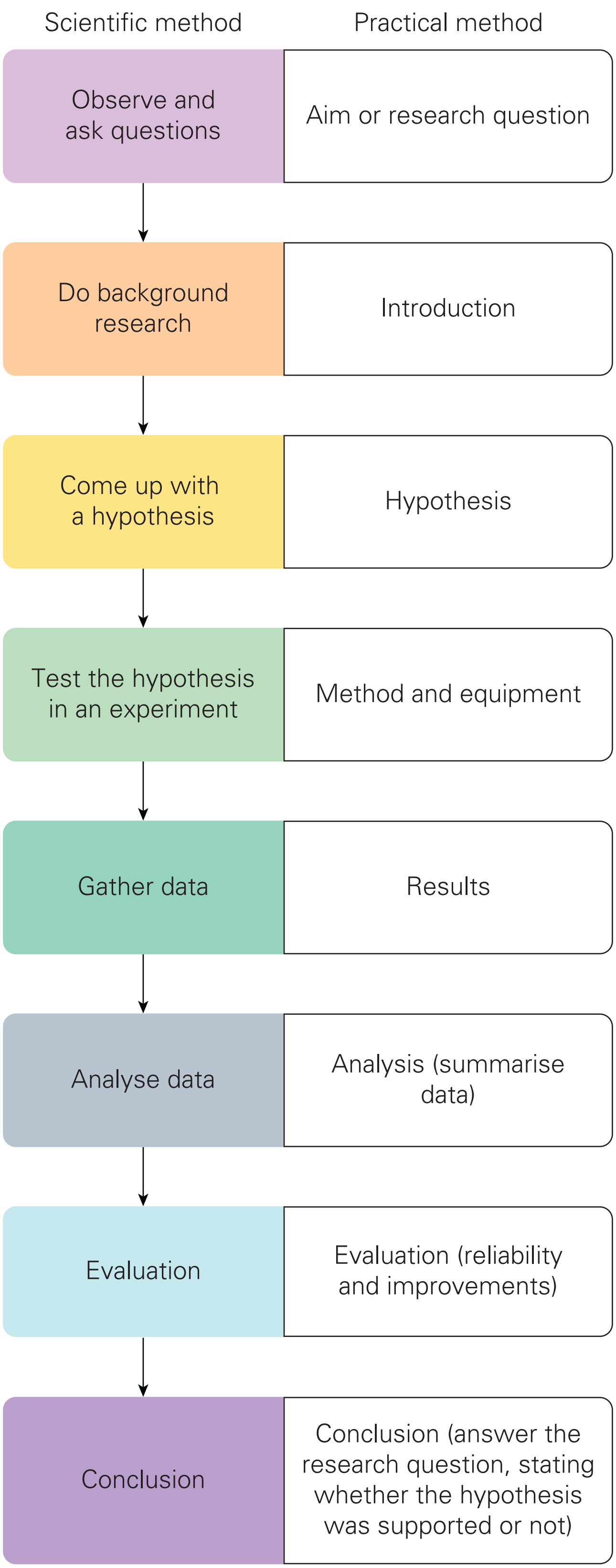

Figure 1.13 The scientific method matched to sections of a lab report

The steps in the scientific method also provide a good framework for how you should report on your findings. Each step in the process can be documented in a practical report and allows other people to understand your findings and replicate (repeat) the experiment.

Observe and ask questions

The first step in the process is often based on an observation. Scientists continually observe the world around them to gather information. These observations come from using our senses: sight, hearing, smell, taste and touch.

You use some senses for gathering information more than others. Sight is very important for making observations. However, you often use several senses together.

What is an observation?

Observations are statements about information gathered from your senses. An observation does not include predictions or assumptions about what is being observed.

These are some examples of observations.

- The sky is blue.
- The pool water is cold.
- The food smells spicy.

What is an inference?

After a scientist has made an observation, they often make an **inference** to explain the observation. This is like a conclusion or possible explanation they can form based on the observation. Inferences are based on your past experiences and knowledge you have gathered throughout your life.

Here are some examples. The first part of the sentence is an observation; the second part is an inference.

- Trent beat Lewis in a race; you **infer** that it is because he trains more.
- The ice cream melted quickly; you infer that it was a hot day.

inference
applying a reason or explanation to an observation based on past experiences and known facts

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

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These observations and inferences allow research questions to be asked. These questions should be able to be investigated scientifically. For example:

- Do more training hours improve race performance?
- What effect does temperature have on the melting time of ice cream?

Quick check 1.4

1. Define the term 'inference'.
2. State three observations about the room you are in.
3. Sally observed that the plants in her garden that grew the most were closest to the sprinkler. State an inference that Sally might make based on this observation.

Collecting data: Types of data

When something is observed, the information can be split into two types of categories. These categories are **qualitative** and **quantitative** observations.

qualitative
a form of data that is a descriptive measurement

quantitative
a form of data that is a numerical measurement

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

Table 1.5 Comparing qualitative and quantitative observations

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Quick check 1.5

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

Try this 1.2

Quantitative data versus qualitative data

Pair up with someone else in the class. Try to describe your partner both qualitatively and quantitatively. Some ideas have been suggested in the table below, but you may have your own ideas.

Feature	Qualitative observation	Quantitative observation
Hair		
Height		
Eyes		
Pets		
Siblings		

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

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

Practical 1.3

Vitamin C in fruit juices

Be careful

Ensure appropriate signage is displayed during and after hotplate usage.

Aim

To develop observations and inferences based on a simple task.

Research question

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

Materials

- beaker × 2
- test tubes – enough to test each variety of juice
- pipette
- cornstarch
- iodine
- water
- various fruit juices (e.g. orange, lemon, pineapple, tomato, apple, blueberry, kiwi)
- hotplate

Planning

1 You need to provide some background information to the investigation. Complete some research and write a brief paragraph to explain the importance of vitamin C in a balanced diet.
2 Explain why you need to leave the equipment to cool after you have used it.
3 Identify the independent variable (the thing that is changed) in this investigation. See section 1.6 for more information on variables.
4 Identify the dependent variable (the thing that is tested or measured) in this investigation.
5 Identify the controlled variables (the things that are kept the same) in this investigation.

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Procedure

1 Add 1 tablespoon of cornstarch to a beaker.
2 Mix with enough water to make a paste-like consistency.
3 Add 250 mL of water to the beaker and bring to the boil on a hotplate. This is your starch solution.
4 Add 75 mL of distilled water and 10 drops of starch solution to another beaker.
5 Add drops of iodine to this solution until it turns a dark blue-black. This is now your vitamin C indicator.
6 Add 5 mL of the indicator solution to a test tube.
7 You can now add the different fruit juices drop by drop to the indicator solution. The more vitamin C present in the juice, the lighter the colour of the indicator solution. Count the number of drops of each type of juice that it took to cause a colour change. Record your results in the table shown in the results section.
8 If time permits, repeat each experiment once or twice. Do you get the same results?
9 Now make inferences to explain each observation based on your prior knowledge or experience.

Results

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

Discussion

1 Plot a column or bar graph of the number of drops vs. type of fruit juice. See section 1.6 for more information on graphs.
2 Describe any trends in your results. Is there any pattern between the type of fruit (e.g. citrus vs. non-citrus) and the number of drops needed for a colour change? Or is there another pattern present, such as the colour of the fruit?
3 Another variation is to add the same volume of juice to each test tube and compare. Using your results from the drop-wise experiment, predict what you think the results of that experiment would be.
4 Evaluate your method and suggest any improvements that you could make if you were to do it again. See section 1.6 for more information on methods.

Conclusion

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

Collecting data: Measuring tools

When scientists use tools to collect data, it's important that the results are accurate. **Accuracy** is the closeness of a measurement to the true value and there are many pieces of equipment available to help increase this. The choice of equipment will depend on how small or large the thing is that you want to measure.

Length

You can use rulers to measure the length of a straight object. You can also use measuring tape for a non-straight object or even a trundle wheel for large distances.

accuracy
how close a measurement is to the true value

It is important to use the most appropriate tool and unit when measuring. For example, if you are measuring the size of a snail, you would use a ruler and millimetres. If you are measuring the size of a person, you would use a measuring tape and centimetres, and if you are measuring the length of the school grounds, you would use a trundle wheel and metres.

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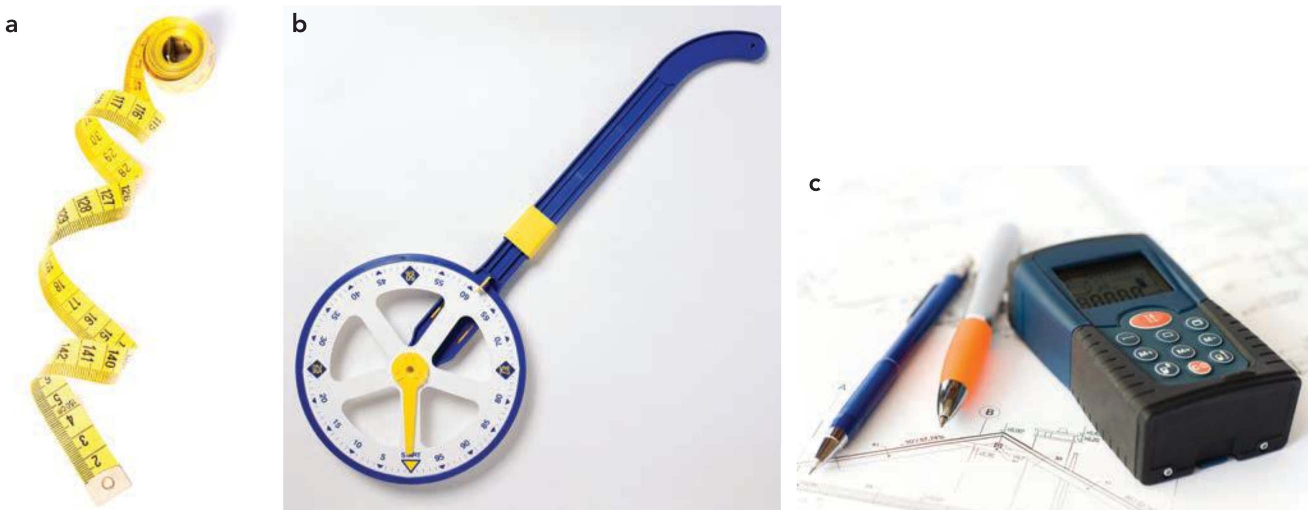

Figure 1.14 (a) A measuring tape, **(b)** a trundle wheel and **(c)** a laser distance measure for precise distances. Generally, to measure the length of an object, you use the units millimetre (mm), centimetre (cm), metre (m) or kilometre (km).

The ruler has smaller markings and greater **precision** than the trundle wheel.

Some professions use a laser distance measuring tool. This tool uses a laser to make even more precise distance measurements. (In science, the precision of a measuring system may also refer to reliability – see page 29.)

precision
(referring to measuring tools) the size of the units of measurement that are capable of being read on a measuring tool (e.g. millimetres versus metres)

Volume

Volume is measured in cubic units such as cubic millimetres (mm^3), cubic centimetres (cm^3) or cubic metres (m^3). Volume of a liquid is measured using different-sized measuring cylinders in millilitres (mL) and litres (L).

The liquid measurement of 1 mL is the same volume as 1 cm^3 and 1 L is the same volume as 1 dm^3 (1000 mL^3). Analytical scientists who require a high degree of accuracy and precision in volume measurements could also use a pipette. This piece of laboratory equipment is commonly used when a very small, but accurate, amount of liquid is required.

Figure 1.15 (a) A measuring cylinder and **(b)** a scientist using a pipette for dispensing a volume of liquid

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Figure 1.16 A data logger probe

Temperature

Digital thermometers, liquid in glass thermometers and data logger probes are used to measure the temperature of different objects. The unit of degrees Celsius (°C) is used to measure temperature. Thermometers generally have a maximum temperature of around 110°C and a minimum temperature of –10°C; however, it would be extremely rare that you would conduct an investigation in school where temperatures exceed these numbers.

Figure 1.17 The liquid in the glass thermometer shown uses the measurement unit Celsius (°C), but in some parts of the world, degrees Fahrenheit (°F) is used. What are the differences? When did Australia start using the Celsius scale?

Time

Stopwatches are an accurate way of gathering data about time. The units of seconds (s) and milliseconds (ms) are used most in science; however, minutes, hours and days could also be recorded for long-term experiments.

Practical 1.4

Reading equipment

Aim

To practise taking readings using specific pieces of equipment.

Materials

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

Station 2
- 3 sugar cubes
- electronic balance

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

Station 4
- stopwatch

Station 5
- ruler
- A4 sheet of paper

Procedure

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

Station 1

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

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Station 2

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

Station 3

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

Station 4

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

Station 5

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

Results

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

Discussion

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

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Mass

Electronic balances and spring balances are used to measure mass in science. Electronic balances can give an extremely precise mass reading. The units of milligrams (mg), grams (g) and kilograms (kg) are used to measure mass. Larger masses can be measured in tonnes (1 tonne = 1000 kg).

Minimising error

Errors are differences between the values we observe and what is actually true. Errors can cause results that are inaccurate, or even completely false. **Random errors** are unpredictable and are generally made by the experimenter, such as not timing something correctly. These will affect the **reliability** of your investigation. **Systematic errors** are consistent and may be caused by faulty equipment or a problematic method. These will affect the accuracy of your results.

Meniscus

When you try to measure liquid in a container, you will notice that the sides of the liquid are curved. As discussed earlier, it is important to take accurate measurements in science, so you need to know how to measure the curve of the top of the liquid in the container. This curve is called the **meniscus** and it can go up at the sides of the container, making a **concave** shape, or down at the sides of the container, making a **convex** shape.

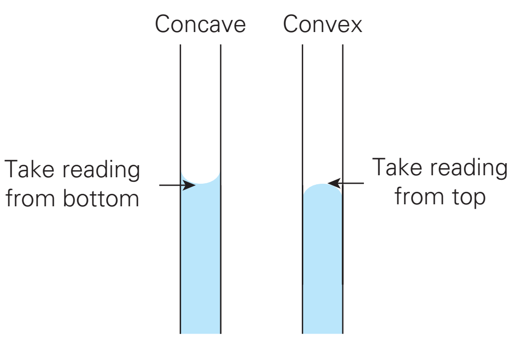

Figure 1.18 Reading a meniscus

Concave and convex meniscus

Water and water based fluids such as milk produce a concave meniscus. This is because the molecules in the fluid are more attracted to the container than they are to themselves. A convex meniscus is formed when fluid molecules are more attracted to themselves than the container they're in. This happens to mercury when placed in glass.

It is important to take the reading of the meniscus from the lowest part of the curve when the curve is concave and the highest part of the curve when the curve is convex.

If you ensure that your readings are from the correct part of the meniscus each time, you will increase the accuracy of the data you are gathering.

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

reliability
the degree of consistency of your experimental measurements. A test is reliable if it gives the same result when it is repeated under the same conditions.

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

meniscus
the surface of a liquid in a container

concave
a surface that curves inwards

convex
a surface that curves outwards

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

Parallax error

When taking a reading from the meniscus of a liquid, you can also encounter a problem known as **parallax error**. This happens when the measurement is different from the true value because of your eye being positioned at an angle to the measurement markings. If you are looking at the measuring line from above,

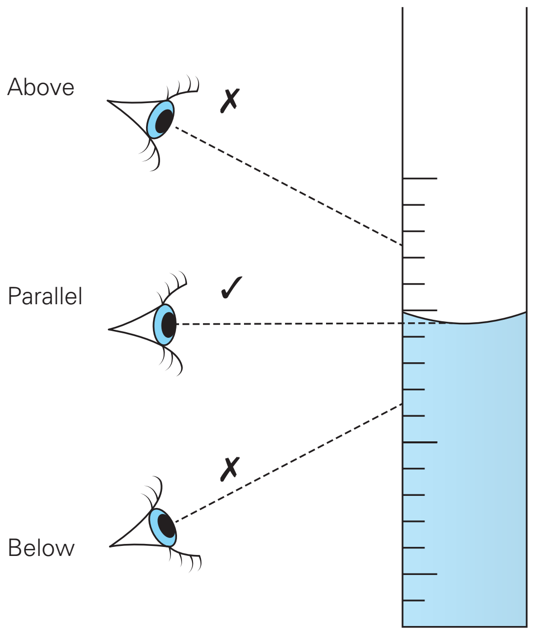

Figure 1.19 Example of parallax error

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you will not be able to accurately measure the meniscus as you need to be at eye level or parallel with the line you are measuring. This also happens when you are using other instruments such as thermometers.

Quick check 1.6

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

Section 1.3 questions

QUIZ

Remembering

1 **Describe** how an observation is different from an inference.
2 **Define** qualitative data and quantitative data.

Understanding

3 **Classify** the following pieces of data as qualitative or quantitative.
   a Tami scored 74% on the test, Aidan scored 90% on the test.
   b Teachers rated their students' behaviour for 'Submits work on time' as Rarely, Sometimes, Often, Always.
   c Students mixed two chemicals and recorded what they saw. Aaron wrote down, 'The mixture went blue'. Hannah wrote down, 'The mixture went a dark greenish-blue. The test tube felt warm to the touch. Small bubbles appeared.'
   d The number of times a gorilla ate in a 24-hour period was recorded.

Applying

4 Look around you. **Record** one observation and make one inference from this observation.

Analysing

5 A scientist undertook the following experiment.
   1: *Observed* that a pot plant seems to grow better the closer it is to a window.
   2: *Conducted an experiment* where a flowering plant was placed in the window and a cactus was placed in a dark room. The flowering plant was watered and the cactus was not. The flowering plant was also given fertiliser but the cactus was not.
   3: *Collected the data* and concluded that plants grow better when they are exposed to more sunlight.
   a **Identify** the error in the scientist's method.
   b **Describe** the effect this has on the findings.

Evaluating

6 For the pot plant experiment detailed in Question **5**, **propose** what the scientist could have done differently to ensure the experiment was fair.
7 **Propose** what a meniscus would look like if the molecules of a liquid inside a container were equally attracted to themselves and the container.

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1.4 The scientific method: Questioning, predicting and conducting

Learning goals

1. To understand how to develop a research question.
2. To identify experimental variables.
3. To develop a hypothesis.
4. To write an experimental procedure.

Asking research questions

Asking questions is the first step in the scientific process, as there needs to be a question asked before we can try to find an answer. You probably just google most questions you have, but the answers you find online are often the result of a lot of scientific research. A question to research can be about anything, such as: 'Why do people prefer red food over green food?' or 'Does listening to music help students focus in class?' Both of these questions can lead to a possible experiment.

WORKSHEET

Brainstorming can be a great way to draw out all possible questions that might be tested.

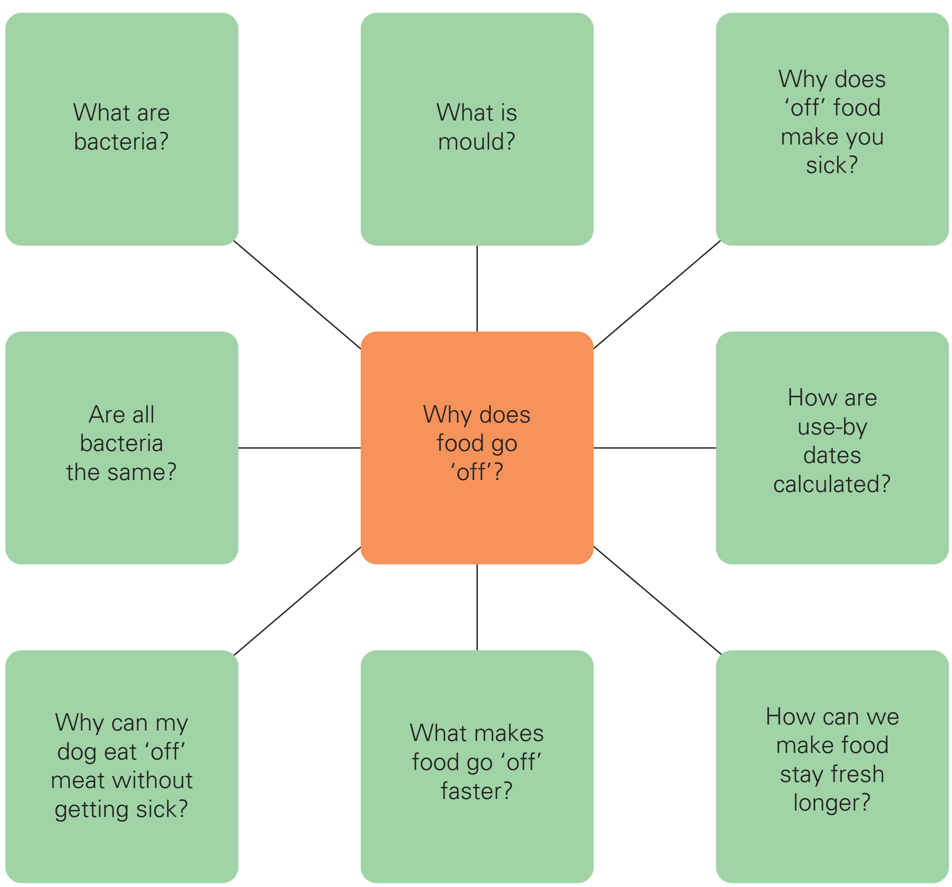

Figure 1.20 Brainstorming can help you develop questions.

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Explore! 1.1

Think of a question you would love to know the answer to. The question could be anything at all. Use the following question starters to help you:

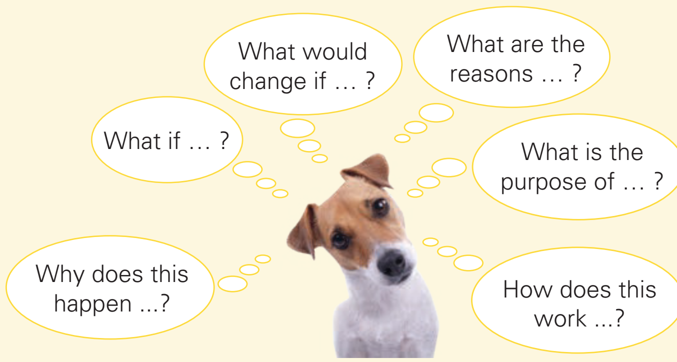

Figure 1.21 Begin by thinking of a question.

1 Identify key words

↓

2 Develop questions to answer

↓

3 Search for sources of information

Figure 1.22 You can follow these steps when conducting background research.

1 Identify key words

A simple technique you can use to break down a research question is reading with a pen. See *Try this 1.3* for ways to do this.

Try this 1.3

Reading with a pen

While reading about your research question, keep a pen handy.

Underline key words or phrases.

Circle words or phrases you don't understand.

? Put this next to something that raises a question.

! Put this next to something that surprises you.

Write important thoughts in the margin or around the question.

For example:

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

2 Develop specific and relevant questions to answer

Questions you could investigate from the inquiry question shown in *Try this 1.3* are:

1. What is palm oil?
2. What is palm oil used for?
3. Who farms palm oil?
4. Where is Indonesia?
5. Why is palm oil farmed in Indonesia?
6. What is the age range of the 'young people' we are focusing on?
7. How can farming in another country affect Australia?
8. What are the effects of palm oil farming?
9. How do these effects relate to me?

3 Search for sources

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

A **primary source** of information is one that comes from your own findings and experiments. A **secondary source** is when you search for other people's research and use their findings.

There are many types of resources that you can use to gather secondary data.

specific
clearly defined or identified

relevant
connected to the topic being investigated

primary source
a source of information that comes from your own findings or experiments

secondary source
a source of information that comes from someone else's research or findings

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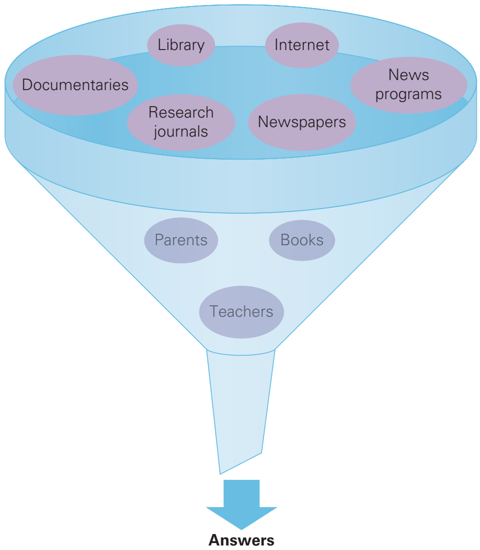

Figure 1.23 Resources for gathering secondary data

Using the internet

The internet is an amazing tool filled with lots of information. The problem is, there is so much information that sometimes it can be hard to find exactly what you are looking for. It can also be hard to decide whether the information you are reading is actually correct and free of **bias**. Information is biased if the writer has let their personal opinion or their own agenda influence their judgement. For example, if you search the website of a coffee company for information about the effects of caffeine, you are more likely to get information that is biased in favour of drinking coffee – there might be less information about the negative effects of caffeine and more about the positive effects.

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

Searching

When searching for information, there are techniques you can use to help refine your search. For example, if you were researching the question, 'What are the effects of palm oil farming?', you might use the techniques listed in Table 1.6.

Search technique	How?	Example
Group words together	Use quotation marks to group search words together	"palm oil farming"
Search for titles or headings	Type: intitle:'search word'	intitle:'farming palm oil'
Search for a file type (see Table 1.7)	Type: filetype:*abbreviation for file type*'search word'	filetype:pdf'palm oil'
Try different spellings	Sometimes words are spelled differently on US websites, so try spelling search words the American way.	*colour* (on Australian and UK websites) is spelled *color* on US websites
Try a variety of sources	Google is not designed to bring the most scientific pages to the front of your search, so try other search engines and databases.	Google Scholar Library search engines Worldbook Databases your school subscribes to

Table 1.6 Search techniques

Use	File type
Presentations	.ppt, .key, .pez
Images	.jpeg, .psd, .png, .tiff
Documents	.pdf, .docx, .pub, .pages

Table 1.7 Common file types and their uses

Referencing

Once we have searched and found enough information relating to a topic that is being studied, it is important to make notes on where that information came from. This is so the sources can be fact checked at a later date or used by readers for more in-depth study. We do this by creating a reference list. There are many types of reference list formats but all of them will contain:

- a title
- an author
- the date of publication.

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One of the most common reference formats is the Harvard Reference System. If you used the Harvard format to reference this textbook, it would look like this:

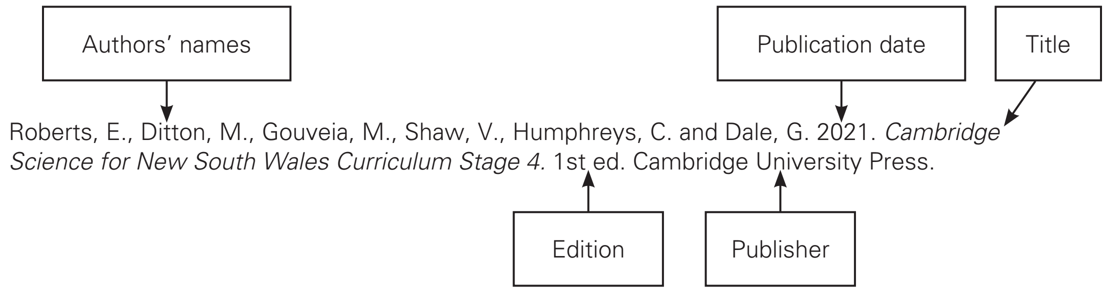

Figure 1.24 Harvard reference system

It is important to make sure that you use the correct format for your school and place your references in an alphabetical list at the end of any research assignment.

Independent, dependent and controlled variables

Once an observation has been made and a research question generated, the next step is often to conduct an experiment. Experiments are conducted in controlled situations that a scientist creates to test only one thing. This allows the scientist to measure the effect that changing this one thing will have. The things that will be changed are called **variables**.

variable
a component of an experiment that changes or can be changed

independent variable
the variable that is changed during an experiment

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

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

For example, a boy wants to see if changing the place where a towel is placed after a shower affects the time it takes to dry. Will laying it on the ground or hanging it on a rack decrease the drying time?

In this example, the boy is:

- changing the place where the towel is left. This is the **independent variable**.
- measuring the time it takes for the towel to dry. This is the **dependent variable**.

Both the independent and dependent variables may need to be measured in an experiment. In an experiment, we would predict that a change in the independent variable causes a change in the dependent variable.

To show that only the position of the towel changes the time it takes to dry, all other factors must be kept the same, such as the temperature of the room, amount of water on the towel and the towel used. These are the **controlled variables**.

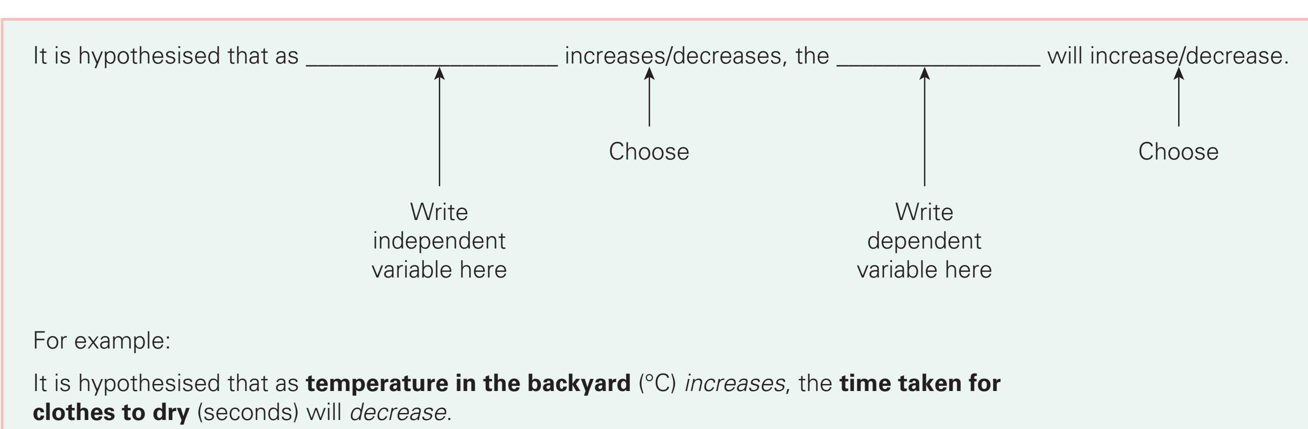

Figure 1.25 Setting out a hypothesis: Example 1

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Designing an experiment

Writing a hypothesis

The variables in an experiment are used to make a prediction – this prediction is called the hypothesis. The hypothesis is a short statement about the expected effect of the *independent variable* on the *dependent variable*. You do not need to give a reason for your prediction. Two good ways to set out a hypothesis are shown in Figures 1.25 on page 34 and 1.26.

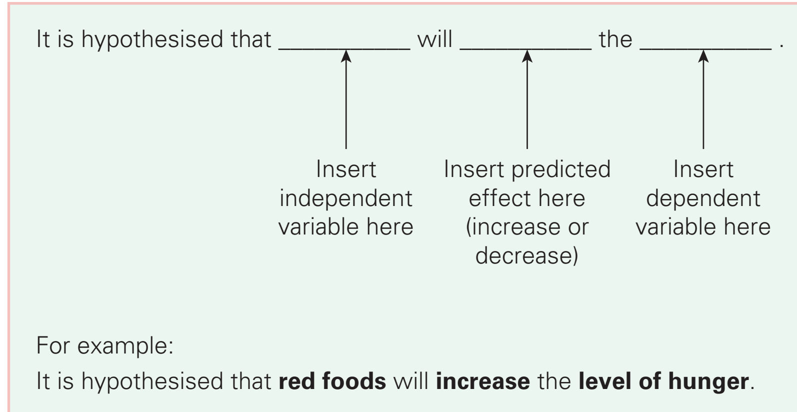

Figure 1.26 Setting out a hypothesis: Example 2

Remember these points when writing a hypothesis.

1. A hypothesis is a prediction about the outcome of the experiment.
2. It must be written as a statement that can be tested.
3. It must include a prediction about how the independent variable will affect the dependent variable.
4. Do not use 'I think …'

Quick check 1.7

1. Sequence these steps in the order in which they should be done.
   - Conduct the experiment.
   - Record and process the results (data).
   - Ask a research question.
   - Do background research.
   - Construct a hypothesis.
   - Analyse the data.
   - Evaluate the data and draw conclusions.
2. Define these terms.
   a. Independent variable
   b. Dependent variable
   c. Controlled variables
3. Recall what a hypothesis must contain.

Writing a procedure

When designing an experiment, a procedure is a detailed description of the process involved in an experiment. It is a set of step-by-step instructions that will enable the experiment to be repeated exactly as it was originally conducted. When you write up your scientific report, you will rewrite your procedure in the past tense for the 'Method' section of your report.

It is important to be as detailed as possible, as this will allow you to identify any flaws in your process when you look at your results.

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

Points to remember when writing a procedure:

1. Write the steps in order.
2. Start each step with a verb.
3. Include specific names and sizes of equipment used and quantities measured.
4. Outline what results will be measured and how this will be done.
5. Identify how the results will be presented.
6. Include the number of repeats that will be carried out.
7. Write in the third person (do not use 'you'/'I'/'we').

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When you are writing your procedure, it is important to decide how many trials you will undertake. A reliable and fair experiment should have at least three trials, so that the mean (average) can be calculated to minimise the uncertainties of measurements in the results.

You should also consider how many different levels or situations of the independent variable you want to test. For example, timing how long a substance takes to melt in the fridge, at room temperature, in direct sunlight and in a flame uses four different levels of 'temperature', which is the independent variable. This experiment is therefore said to have four experimental conditions.

Practical 1.5

Writing a procedure to test the strength of shapes

Background

In this experiment, you will be measuring the strength under compression of different shapes of paper. You may choose any shapes you wish, but they all have to be the same height and made of the same materials (one sheet of A3 paper).

Aim

To measure the strength under compression of different shapes of paper

Materials

- 3 A3 sheets of paper
- 1 piece of cardboard
- several 50 g masses
- sticky tape
- scissors

Procedure

1 Define your variables for this experiment and list them in a table.

Independent variable	
Dependent variable	
Controlled variable	

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

3 Design an experiment to test your prediction by writing out the procedure (or steps) you will follow.

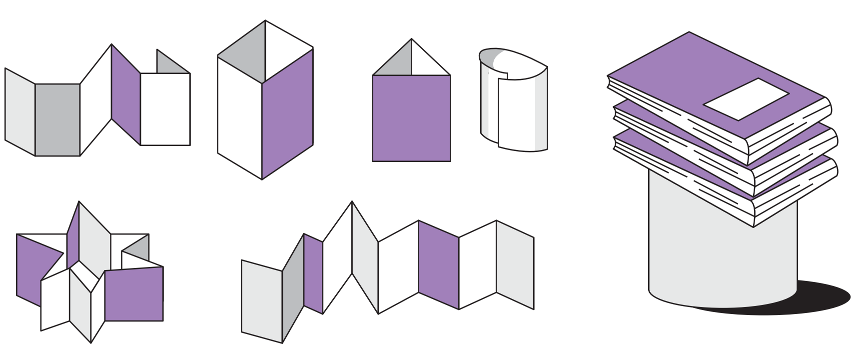

Figure 1.27 Some possible shapes to use (shown on left) and one way to test their strength (shown on right)

Results

Record your results in a table, using the following table as a guide.

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...continued

Independent variable	Dependent variable			
	Trial 1	Trial 2	Trial 3	Mean

Discussion

1 Identify the strongest shape you tested.
2 Did anyone in the class have a stronger shape?
3 Suggest one more variable you controlled or should have controlled.
4 Explain why you would add more trials and calculate the mean (average) of the results.

Conclusion

Draw a conclusion regarding the strength of different shapes using data to support your statement.

Section 1.4 questions

QUIZ

Remembering

1 **Define** the three types of experimental variables.
2 **State** the purpose of the aim.
3 **List** three starters you could use to develop a question.

Understanding

4 **Explain** why variables have to be controlled.

Applying

5 **Explain** why a procedure that includes quantitative measurements should be carried out as accurately as possible.
6 A student wants to see if writing all homework in his diary every day will increase his homework scores. For one term, he records all homework in his diary daily. In the next term, he does not record any homework. He compares his homework scores for each term.
Identify the:
a independent variable in this experiment
b dependent variable in this experiment.

Analysing

7 **Contrast** a primary source of data with a secondary source of data.

Evaluating

8 Erika says her scientific research satisfies the scientific method, because she performed all the steps of the method. She carried out the following steps.
1 She asked a question.
2 She conducted an experiment.
3 She recorded her data.
4 She analysed her data and created some graphs.
5 She did some background research to explain her data.
6 She came up with a hypothesis.
7 She evaluated the data and found that it supported her hypothesis (she drew a conclusion).
8 She published a report to communicate her findings.
Assess Erika's claim. Do you agree that she has followed the scientific method? **Explain** your answer.

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1.5 The scientific method: Processing and analysing results

Learning goals

1. To display raw data in an appropriate table.
2. To choose appropriate graphs to display different types of data.
3. To recognise trends in graphs.

DOC WORKSHEET

As you have already learned, the early steps of the scientific method involve asking a question, doing background research, constructing a hypothesis, and designing and conducting the experiment to test the hypothesis.

Hopefully, the experiment will yield some interesting data. You will need to:

- collect and record the data during the experiment
- process the data by calculating the mean (average), and then displaying your results in tables and graphs
- analyse the data by looking for patterns.

Displaying data in tables

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

All tables have:

- a title that describes what is in the table (do not use 'Results table').
- lines ruled in pencil (if on paper)
- column headings showing the unit that is measured.

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

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

Example of how to set up a table

An example of a table of data is shown in Figure 1.28. The title of this table is: 'How the mass of bicarb added to vinegar affects the height of bubbles produced over time.'

The values in a table should all be written to the same number of decimal places. In Figure 1.29, the table on the left is wrong, because the third value, 139, is not given to the same number of decimal places as the other data.

Once you have recorded your data in a table, it is good practice to write a short sentence summarising what the table shows.

For example, from the table in Figure 1.29, you could say:

'The results show that as time (s) increases, the volume of liquid (mL) also increases.'

Evaluating your data

Before you pack away the equipment, check your data to make sure you do not have any gaps or outliers. An **outlier** is a measurement that is very different from the data gathered in your other trials. If you see an outlier, perform that trial again, as the outlier could be the result of faulty procedure.

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Table How the mass of bicarb added to vinegar affects the height of bubbles produced over time

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

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

There should be no units in the data cells.

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

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

Figure 1.28 How to set up a table of data for how the mass of bicarb added to vinegar affects the height of bubbles produced over time

✗

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

✓

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

Figure 1.29 Data values in a column should all have the same number of decimal places.

Quick check 1.8

1 Identify the mistake in each of the following tables.

Table 1

Time seconds	Temperature
0	40°C
60	50°C
120	60°C
180	70°C

Table 2

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

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

3 Anna places a bottle of water in a freezer set at different temperatures and measures how long it takes the water to freeze at each temperature. She records her results in the table opposite.
Identify the mistake in the table.

Time to freeze (hr)	Freezer temperature (°C)
6	−2
4	−4
3	−6
2	−8

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Try this 1.4

Testing paper planes

In this activity you will test how the size of a paper aeroplane affects the distance it can travel. You will record the data from multiple trials in an appropriate results table.

Materials

- A4 paper
- scissors
- measuring tape

Instructions

1. Define the following for your experiment: independent variable, dependent variable and controlled variables. Create a table of results for your experiment.
2. Construct a hypothesis for your experiment. Predict how the independent variable will affect the dependent variable.
3. Follow the steps shown in Figure 1.30 to produce a paper aeroplane.
4. Choose four different sizes of paper to make different sized paper aeroplanes. Planes made from bigger pieces of paper will have a bigger mass and a bigger wing span.
5. Throw the first aeroplane and measure the distance travelled until it hits the ground.
6. Record your measurement in your results table.
7. Repeat throwing this plane for two more trials, recording your result each time.
8. Repeat steps **5–7** for each of the four different planes.
9. Calculate the mean for each set of results.

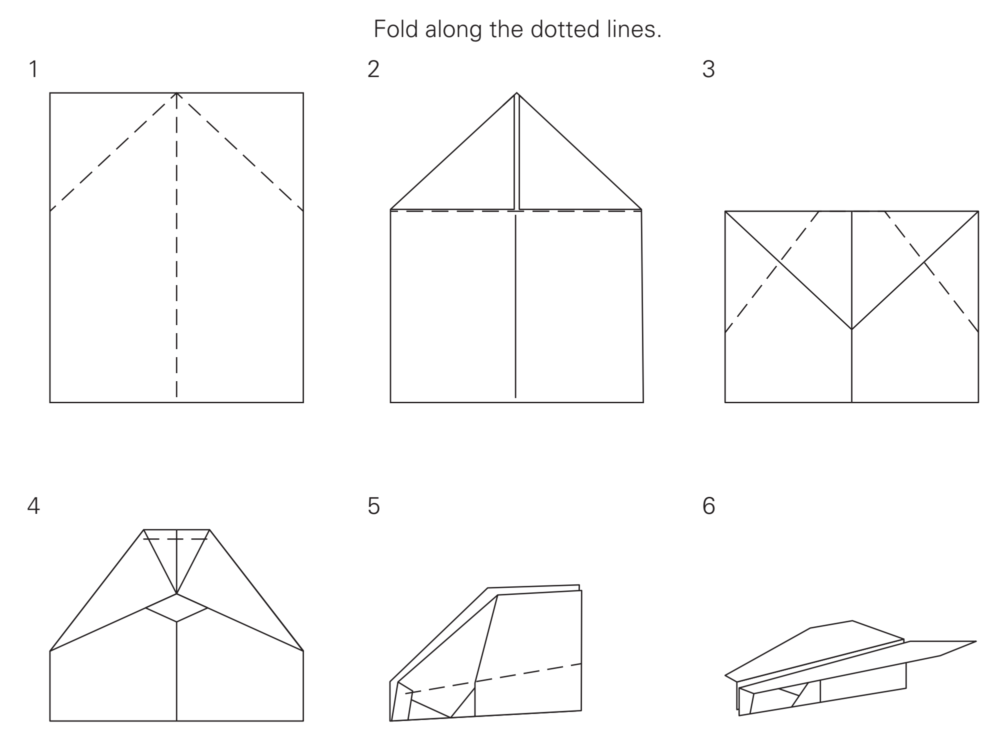

Figure 1.30 How to make the paper aeroplane

continued...

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...continued

Write a short summary of what your data shows.

Evaluation

1 Identify other variables that you should have controlled during the experiment.
2 Identify one variable that you were not able to control, that could have affected your results (one potential source of error).
3 Suggest two other independent variables that you could change, other than the size of the aeroplane.
4 Explain the reason for conducting multiple trials and calculating the mean of your results.

Displaying your data in graphs

Now that you have raw data from your experiment, it is important to display the data in a way that shows any possible patterns, trends or relationships that your experiment has uncovered.

The type of graph that is appropriate depends on the type of data you have collected. **Quantitative data** (numbers) is classified as either **continuous** or **discrete**. **Qualitative data** (descriptions or worded categories) is classified as either **ordinal** or **nominal**.

quantitative data
a form of data that is a numerical measurement

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

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

qualitative data
data values that are worded/descriptive/categorical in nature

ordinal data
qualitative (categorical) data where the categories have an order, e.g. small, medium, large

nominal data
qualitative (categorical) data where the categories have no order, e.g. male, female

Quantitative data: Continuous vs. discrete

Quantitative data relates to numbers. Table 1.8 lists the differences between continuous and discrete quantitative data.

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

Table 1.8 The differences between continuous and discrete quantitative data

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Line graphs

A *scatter plot* is a way of displaying how one quantitative variable changes in response to another quantitative variable, by plotting points. When the points are connected, it is called a **line graph**. Line graphs are generally used with continuous data, as they show how the data points continue on from one another.

> **line graph**
> a type of graph used to display how a continuous quantitative variable changes over time or in reference to another variable

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

Time (s)	Speed (m/s)
0	0.0
2	1.4
4	2.6
6	4.4
8	5.6
10	6.6
12	8.2
14	9.6

The speed of a car over a period of time

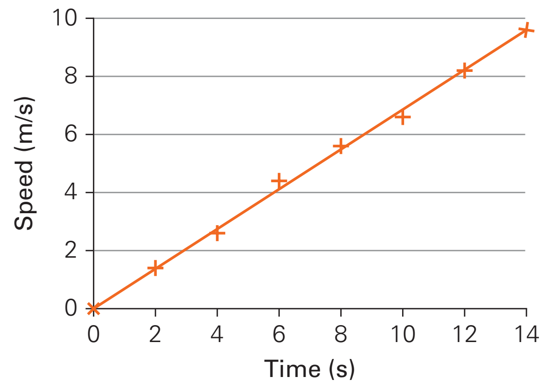

Figure 1.31 Note that in the graph representation of this table, very small crosses have been used to mark the data points.

Practical 1.6

Pendulum swing

Background information

In this practical, you will gather continuous data and convert it into a line graph.

Aim

To test the effect of string length on the time it takes a pendulum to complete one swing.

Materials

- retort stand
- bosshead and clamp
- 120 cm of string
- weight for pendulum
- protractor
- stopwatch
- Blu Tack
- graph paper or graphing application such as *Excel*

Planning

1 Define your variables for this experiment and record them using the table below.

Independent variable	
Dependent variable	
Controlled variables	

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

3 Write a risk assessment for this experiment.

continued…

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...continued

Procedure

1 Attach the weight to the bottom of the piece of string.
2 Tie the string to the bosshead and clamp attached to the retort stand, and measure 20 cm from the join of the bosshead to the base of the weight, as shown in Figure 1.32.
3 Using the protractor, hold the string tight at 45 degrees and release the pendulum.
4 Start the stopwatch as soon as you release the pendulum and count three full swings (across and back), as shown in Figure 1.32.
5 When the pendulum returns for the third time, stop the stopwatch and divide the time by 3.
6 Record the time for one swing in the results table.

Results

1 Create a results table for your experiment.
2 Use the mean of each of your trials to produce a line graph. Remember the following points when constructing your graph.
   - Plot the independent variable on the *x*-axis.
   - Plot the dependent variable on the *y*-axis.
   - Label each axis with the variable name and the unit of measurement.
   - Write a title for the graph.
   - Use an even scale (equal spaces between the numbers on the axes).

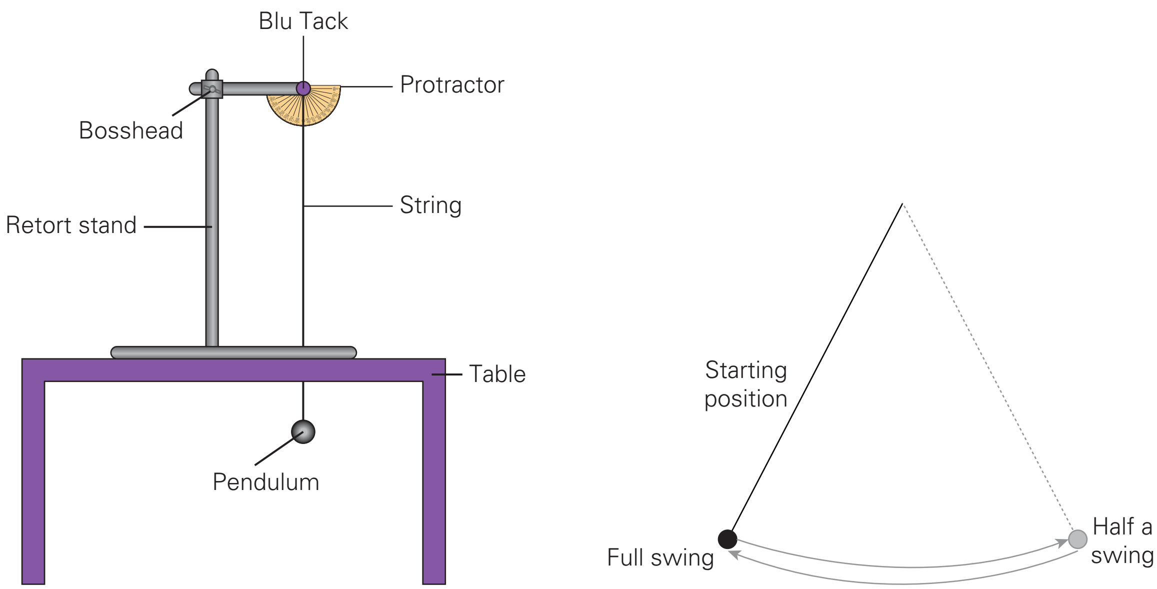

Figure 1.32 Experimental set-up. Left: setting up the pendulum. Right: timing the swing of the pendulum

Conclusion

1 Identify any trends you see in your graph.
2 Explain whether your results supported or refuted your hypothesis.

Qualitative data: ordinal vs. nominal

Qualitative data involves categories, scales or descriptions. This type of data is in the form of words (rather than numbers). The differences between ordinal and nominal data are listed in Table 1.9.

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	Ordinal data	Nominal data
Features	Categories have a natural order.	Categories do not have a natural order.
Examples	A chemical reaction is performed and the amount of product produced is described as 'low', 'medium' or 'high'. Five trials are completed and the data looks like: low, high, medium, low, low. These categories make sense if they are displayed in a certain order. *Other examples:* month of the year, size of the test tube (small, medium, large), the participant's response on a scale (strongly agree, agree, neutral, disagree, strongly disagree)	A survey is completed for background research and participants are asked to choose their favourite colour from a list. The data might look like: pink, yellow, green, blue. The categories could be displayed in any order. *Other examples:* gender (male, female), blood type (A, B, O, AB), eye colour (blue, brown, green)

Table 1.9 Differences between ordinal and nominal qualitative data

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

origin
the point (0, 0) where the *x*-axis and *y*-axis intercept

Bar graphs

A **bar graph** (or column graph) is a way of displaying how a quantitative dependent variable (for example, heart rate) changes in response to a qualitative independent variable (for example, breed of animal). Categories are listed along the *x*-axis and numbers along the *y*-axis.

Bar graphs have spaces between the bars – the bars are not positioned next to each other. An example is shown in Figure 1.33.

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

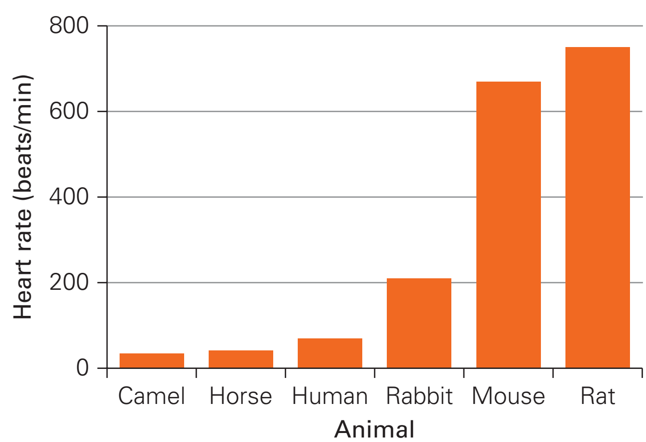

Figure 1.33 Data table and bar graph showing heart rates of different mammals

Guidelines for drawing graphs

- Always use a sharp, dark pencil (if drawing on paper).
- Usually the independent variable goes on the *x*-axis and the dependent variable on the *y*-axis. However, sometimes you may be asked to plot variables on specific axes in a way that contradicts this rule.
- Axes should be labelled with the quantity being measured and the units. The units should be in brackets after the quantity name – for example, time (s) or volume (L).
- Use the full width of the graph paper (if drawing on paper) and choose a scale that spreads the data points out over most of the grid. If you are measuring quantities where 0 does not mean 'no quantity' (for example, temperature), then you do not have to start the axes at zero. If the range of values does not go to zero (for example, 85–115), then don't start the axes at zero. In this example, you could start the axis at 80 and continue the numbers to 120. If the quantities on both axes go to zero, then the **origin** (where the axes meet) should be at (0, 0).

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- The scale needs to increase evenly, preferably with each grid square used to represent multiples of 1, 2, 5 or 10. Do not have breaks in the scale – for example, you can't show 0 to 20 in intervals of 5 and then skip straight to 60.
- Data points can be marked with an 'x', not a dot, because dots (unless surrounded by a small circle) often disappear under a line of best fit. If you are plotting multiple sets of data on the same graph, use different-coloured points for each data set and add a legend.

Practical 1.7

Insulation of water

Background information

In this practical, you will gather data in order to produce a bar graph. You will test the effect of foil, paper and cotton wool as insulating materials, and measure how this affects the cooling rate of water.

Aim

To test the effect of different materials on the cooling rate of water.

Materials

- 4 × 250 mL beakers
- kettle
- thermometers
- foil
- cotton wool
- paper
- stopwatch
- elastic band

Planning

1 Complete some background research to write a brief summary on insulation.
2 Define your variables for this experiment and record them using the table below. Also include the type of data that each variable will yield.

		Variable yields what type of data?
Independent variable		
Dependent variable		
Controlled variables		N/A

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

Procedure

1 Cover the sides of three beakers with either cotton wool, paper or foil, and use elastic bands to secure the covers in place. Leave one beaker without covering.
2 Place one thermometer in each of the beakers.
3 Boil the kettle and pour 100 mL of boiling water into each of the beakers. Start the stopwatch immediately.
4 Time for 5 minutes using the stopwatch, and then measure and record the temperature of the water in each beaker.
5 Gather data from two more trials, from other groups in your class. Add these to the results table and calculate the mean temperature after 5 minutes for each insulating material.

Results

1 Copy and complete the following table to record your results.

continued…

...continued

Cover material	Temperature after 5 minutes (°C)			
	Trial 1	Trial 2	Trial 3	Mean
Foil				
Paper				
Cotton wool				
No cover				

2 Create a bar graph for the mean data in your results table. Put the independent variable (insulating material) on the *x*-axis and the dependent variable (temperature after 5 minutes) on the *y*-axis.

Discussion

1 Explain whether your results supported or refuted your hypothesis.
2 Suggest a reason for using a beaker with no cover material.
3 Suggest a reason for putting your data into a bar graph, rather than just leaving it in a table.
4 Identify potential sources of measurement uncertainties or experimental faults in this experiment.
5 Suggest one way you could improve the experimental design if you were to repeat this experiment in the future.

Analysing data

Analysing data involves examining the tables and graphs and looking for patterns and relationships.

The graph in Figure 1.34 shows a steady increase. You would describe this by saying, 'As the age of the child (in years) increases, the size of clothing also increases'.

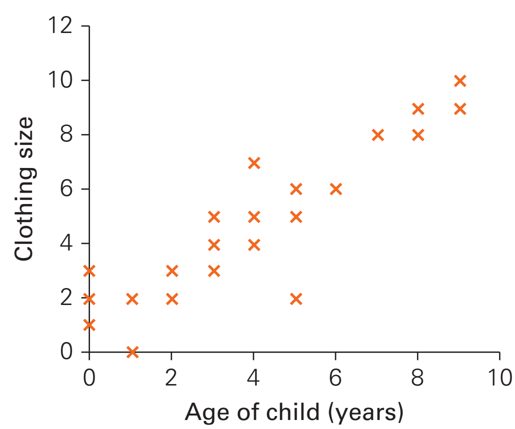

Figure 1.34 The effect of child age on clothing size

Describing patterns

We refer to patterns in graphs as trends. The following graphs show some common trends you might observe and describe.

The graph in Figure 1.35 shows a rapid increase that reaches a plateau (flat line) and then remains constant. You would describe this by saying, 'Initially during the first 60 months or so, as the number of months increases, the number of customers increases rapidly from 0 to 2000. Then, for the next 100 months, the number of customers remains fairly constant at around 2000'.

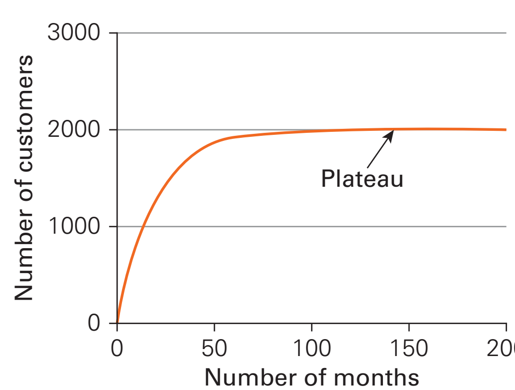

Figure 1.35 The total number of customers over months

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Figure 1.36 shows an **exponential** increase. For the first 10 hours, the number of bacteria increases slowly from 10 000 to 30 000. After 10 hours, the number of bacteria increases more rapidly.

Figure 1.37 doesn't show a clear pattern. There are seemingly random fluctuations over time.

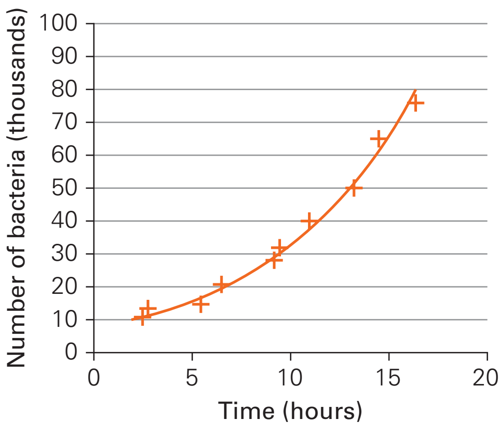

Figure 1.36 The number of bacteria over a period of time

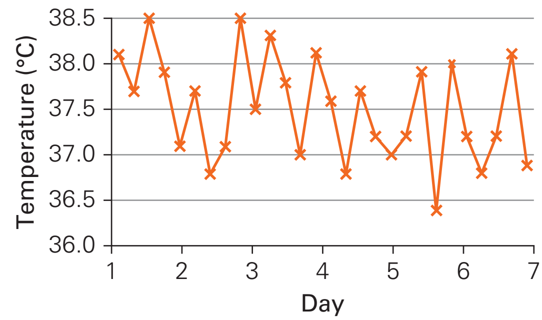

Figure 1.37 Temperature fluctuations over a 7-day period

Drawing a line of best fit

Once you have plotted your data, you may see a pattern (trend) in the results, such as a straight line or a curve. To highlight this pattern, we can use a curve or line of best fit. Connecting every data point suggests that there are absolutely no errors in the data, whereas a line of best fit approximates the relationship between the two variables. You can also use the line of best fit to predict missing measurements. If you make predictions inside the data set you originally collected, this prediction is called **interpolation**. This can be reliable in some circumstances, but not always. Care should be taken. If you predict outside the original data set, this prediction is called **extrapolation** and is less reliable.

When drawing a line of best fit, make sure that there are as many points on one side of the line as on the other. You do not need to join each data point with the line. The line of best fit is like an 'average' that runs smoothly through the middle of the data points and makes the trend obvious.

A line of best fit:

- should be continuous
- can be straight, curved or any other shape that fits the data points. Do not try to draw a straight line of best fit over data that is clearly curved
- should not be forced through a (0, 0) origin if one is used on the graph
- should not be drawn beyond the range of the data points. It can, however, be linked back to the axes with a dotted or dashed line, as shown in Figure 1.38.

exponential
a population that grows at a rate proportional to its size

interpolation
using existing data (such as a line of best fit) within the original data set to make a reliable prediction

extrapolation
using existing data (such as a line of best fit) outside the original data set to make a prediction

Figure 1.38 is a scatter plot with a line of best fit, drawn in red. Note how the line runs through the 'middle' of the data, like an average.

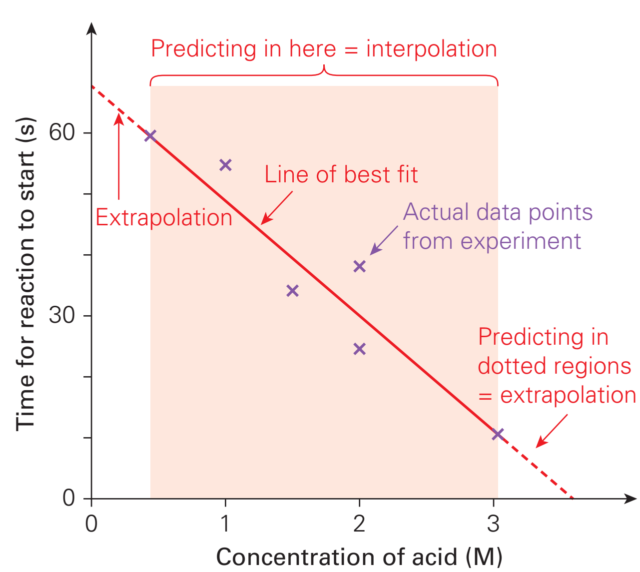

Figure 1.38 The effect of acid concentration on the time taken for a reaction to start

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The dotted regions are where the line has been continued past the original data set. If you use the line in these regions (for example, to predict the reaction time for 0.1 M acid), then it is extrapolation and is less reliable.

The line of best fit is not always a straight line. The graph in Figure 1.39 shows how 100 mL of water cools over 100 minutes. As you can see, a straight line would not fit the dots very well. In this case, the line of best fit is a curved line.

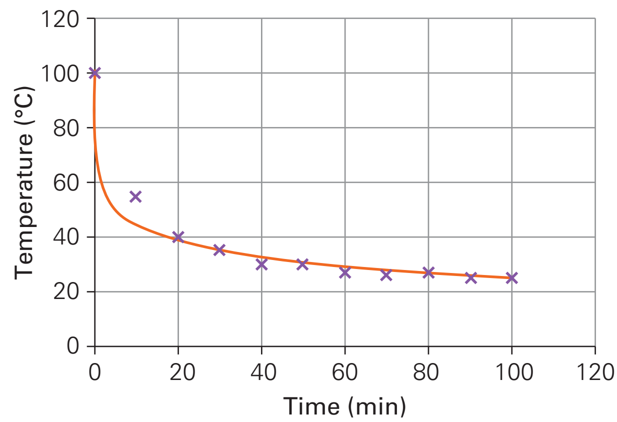

Figure 1.39 Cooling of 100 mL of water over time

Practical 1.8

Balloon popping

Background information

In this practical, you will gather data that can be turned into a scatter graph.

Be careful

Safety glasses are essential for this practical.

Aim

To test the effect of number of breaths on the circumference of a balloon.

Materials

- balloon
- string
- permanent marker
- ruler
- safety glasses

Procedure

1. Do this activity in groups of two. Lay the balloon as flat as possible on the workbench. Using the string, measure the circumference at the widest part of the balloon. Use the ruler to measure the string.
2. Using a permanent marker, draw a line on the balloon to indicate where you took the first measurement.
3. Use one breath to inflate the balloon. Without tying the balloon, measure the circumference along the line you have already drawn. (First measure the circumference using the string, and then measure the length of the string using the ruler.)
4. Repeat step **3**, adding more volume to the balloon by one breath at a time, recording your results until the balloon pops.
5. Use your results to draw a line graph.

Results

1. Create a results table for this experiment.
2. Draw a line graph. Number of breaths should be on the *x*-axis and balloon circumference is on the *y*-axis.

Discussion

1. Identify one trend that you observed in your graph.
2. Suggest possible experimental uncertainties and faults in this experiment.
3. Suggest one way to improve the experimental design if you were to conduct this experiment again in the future.

Conclusion

Draw a conclusion from this experiment. Justify your answer with data.

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Section 1.5 questions

QUIZ

Remembering

1 **State** where units of measurement go, in a results table.
2 **List** four features of a correctly drawn results table.
3 **Recall** the term used when a measurement is repeated.

Understanding

4 **Explain** what to look for when evaluating your data.
5 **Describe** where the independent and dependent variables should be placed, in a table.
6 **Describe** where the independent and dependent variables should be placed, on a graph.

Applying

7 **Compare** qualitative and quantitative data.
8 **Compare** continuous and discrete data.

Analysing

9 **Identify** two things wrong with the following table.

Height dropped	Bounce height (cm)			
	Trial 1	Trial 2	Trial 3	Average
1 m	20	20	20	20
2 m	40.5	41	40	40.5
3 m	80	90	85	85

Evaluating

10 Martin had a bag of lollies of different colours. He found that, when he offered them to friends, he was always left with black lollies. He decided to conduct an experiment to test people's favourite lolly colours. He shared a bag that had 20 of each colour and recorded what was left at the end. From this he worked out how many of each colour had been eaten. The results are shown in the table.

Lolly colour	Number of lollies eaten
Black	4
Green	13
Yellow	18
Red	20

a **Suggest** the type of graph that should be used to represent this data.
b **Identify** which column would be used as the dependent variable.
c **Identify** the independent variable in this experiment.

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1.6 The scientific method: Evaluating and communicating

Learning goals

1. Evaluate the reliability, validity and accuracy of an experiment.
2. Draw conclusions based on the data gathered from an experiment.

DOC WORKSHEET

After you have conducted an experiment, recorded the data in a table and presented the data in a graph, it is time to explain what the data is showing. This is done in the analysis and conclusion sections of a scientific report. The reliability of your experiment is considered in the evaluation section.

Analysis

Once you have presented your data in a graph, you will need to analyse and interpret it. You need to state if there is any pattern, trend or relationship between the independent and dependent variable. This should be applicable to your research question. You can also include some scientific theory that you found out during your initial research to explain your results.

validity
a measure of how closely the results of an experiment reflect what they should

Evaluation

The evaluation section of your scientific report is where you outline any problems you faced during the experiment and offer suggestions for improvements or extensions to the method.

Any suggested improvements should include the following information:

- a brief description of the problem encountered
- a description of how the problem affected the results
- a description of how you could improve the experimental method (e.g. use different equipment or change the order of the steps)
- an explanation of how this would improve the reliability, **validity** and accuracy of the measurements. The Table 1.10 provides more detail on the difference between reliability and validity.

	Reliability	Validity
What does it tell you?	The extent to which the results can be reproduced when the research is repeated under the same conditions.	The extent to which the results really measure what they are supposed to measure.
How is it assessed?	By checking the consistency of results across time, across different observers, and across parts of the test itself.	By checking how well the results correspond to established theories and other measures of the same concept.
How do they relate?	A reliable measurement is not always valid: the results might be reproducible, but they're not necessarily correct.	A valid measurement is generally reliable: if a test produces accurate results, they should be reproducible.

Table 1.10 The difference between reliability and validity

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Figure 1.40 Does salt affect the boilting point of water?

Here is an example.

Some students conducted an investigation into the effect of salt on the boiling point of water. They used a thermometer to measure the temperature at boiling point after salt had been added.

Description of the problem

The thermometer did not allow accurate readings, because the boiling point is found when the temperature stays the same for a period of time even though more heat is added. Depending on the type of thermometer and the size of the gradations, it may be difficult to see changes on a thermometer.

How the problem affected the results

It was unclear whether the temperature was staying the same, so the students had to make a judgement about when this occurred. This judgement could vary from person to person.

How it could be improved

Using a temperature probe, a data logger or an electronic thermometer could allow more accurate measurements.

Explanation of how this would improve accuracy, reliability and validity.

The data collected would be digital and more accurate, as there would be fewer measurement uncertainties.

Writing a conclusion

A conclusion is a short paragraph in a scientific report, and should always include three key ideas:

- what claim can be made from the experiment regarding the independent and dependent variables
- the evidence from your data that supports this claim
- an explanation of whether the data supports or disproves the hypothesis.

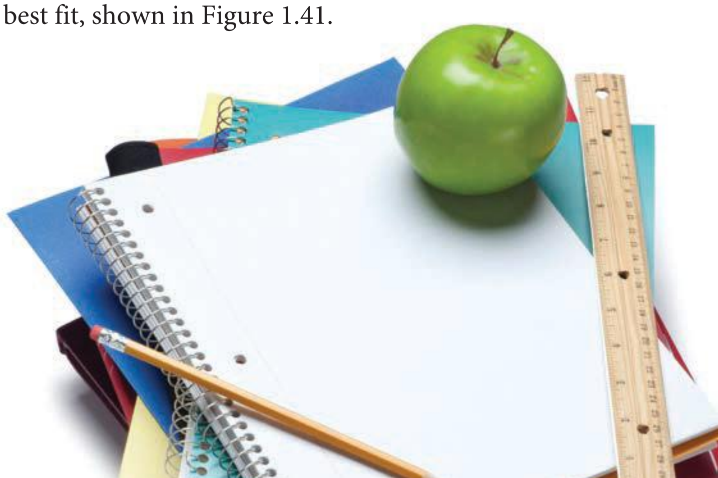
Remember, a hypothesis is never right or wrong. It is only supported or not supported which leads to more questions that need to be answered.

Here is an example.

Stuart conducts an experiment to see if taking his dog Jimmy for more walks reduces the number of socks Jimmy destroys.

Stuart's hypothesis is: 'It is hypothesised that the more walks Jimmy has per day, the fewer socks he will destroy.'

Stuart put his results into a graph and produced a line of best fit, shown in Figure 1.41.



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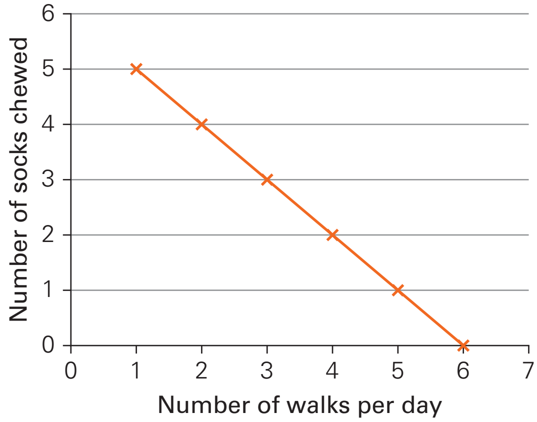

Figure 1.41 The effect of walks on the number of socks chewed

From the graph, Stuart developed the following conclusion:

'This experiment suggests that there is a relationship between the number of walks Jimmy has per day and the number of socks he destroys. The data shows that as the number of walks per day increased, there was a decreasing trend in the number of socks chewed, with five socks being chewed with one walk and no socks being chewed when there were six walks. This supports the hypothesis.'

Try this 1.5

Gen conducted an experiment to see if the distance from a window would affect the growth of her potted plants.

Gen's hypothesis was: 'It is hypothesised that, as distance from the window increases, the growth of the plants will decrease.'

Gen measured her plants before the experiment, placed them at different distances from the window and measured them two months later. She then graphed her results and obtained a line of best fit.

1 Develop a conclusion based on Gen's results.
2 Suggest three controlled variables that Gen would have used, to make this a fair test.
3 Propose two possible causes for the increase in plant height for the plant that was placed 6 m from the window.

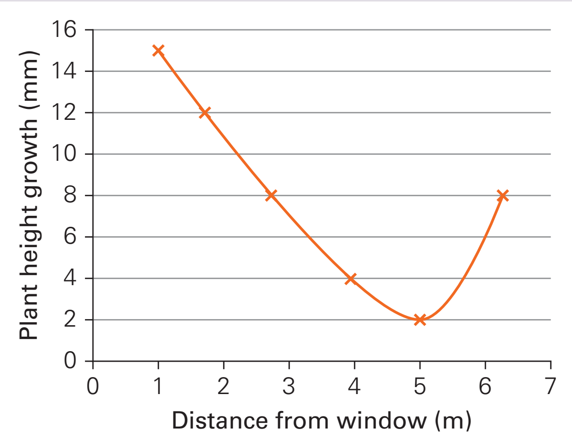

Figure 1.42 How the distance from a window affects plant height growth

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Section 1.6 questions

QUIZ

Remembering

1 **Name** the part of a scientific report that states whether the hypothesis was supported.

2 **Name** the part of a scientific report where you can talk about problems you faced and changes you would make.

Understanding

3 **Explain** how to draw a line of best fit.

4 **Explain** why graphs are used in a scientific report.

Applying

5 **Compare** the use of a scientific report with that of a scientific poster.

Analysing

6 **Identify** the general trend shown in the graph in Figure 1.43.

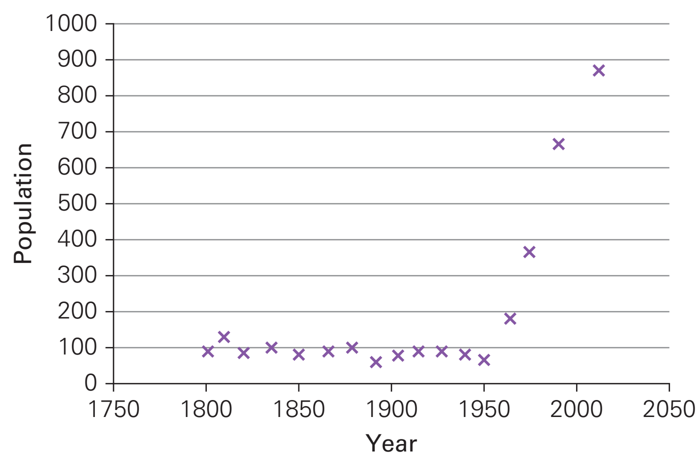

Figure 1.43

7 **Identify** the general trend in the graph shown in Figure 1.44.

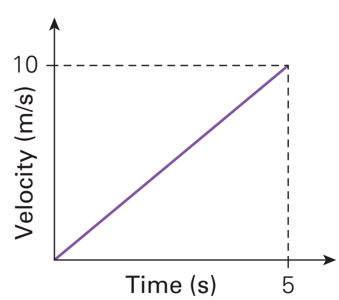

Figure 1.44

Evaluating

8 Use this table of data to answer the questions below.

a **Calculate** the average for the results in the table.

b **Identify** the outlier in the results.

c **Draw** an appropriate graph for the average data presented above.

Time (s)	Temperature (°C)			
	Trial 1	Trial 2	Trial 3	Average
60	80	83	82	
120	63	66	65	
180	30	32	65	

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Chapter review

Chapter checklist

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

SCORCHER

Success criteria		Check
1.1	**I can name different fields of science and what is studied in them.** e.g. Name the study of living things.	
1.2	**I can name the type of equipment that should be used to gather data for an experiment.** e.g. Name the equipment that can be used to measure a short amount of time.	
1.2	**I can identify hazards in the laboratory and control them.** e.g. Describe what could be done to prevent slipping.	
1.3	**I understand how to read a meniscus.** e.g. Describe how to read a meniscus.	
1.3	**I can describe each stage in the scientific process.** e.g. Observation and questions, background research, hypothesis, __________, process data, analyse data, __________, conclusion	
1.4	**I can identify the different types of variables in an experiment.** e.g. Distinguish between the independent and dependent variables.	
1.5	**I can distinguish between quantitative and qualitative data.** e.g. List two examples each of qualitative and quantitative data.	
1.5	**I can select the most appropriate type of graph for a set of results.** e.g. Name the graph that should be used for showing changes in temperature over time.	
1.5	**I can interpret trends in graphs.** e.g. Name the word used to describe a flattening out of data.	
1.6	**I can write a conclusion for the experiment.** e.g. Describe how the results from the experiment support or do not support the hypothesis.	

Reflections

1. What **connections** come to mind when you think about being scientific and your everyday life?
2. What new concepts have **extended** your thinking about being scientific?
3. What information did you find **challenging** or confusing?

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Data questions

You can measure 100 mL of water in a measuring cylinder by filling the glassware to the 100 mL line and making sure that the water level is read correctly from the bottom of the meniscus. Some Year 7 students measured out 100 mL of water in a measuring cylinder and weighed the amount of water on an electronic balance. They repeated this experiment 10 times and the results are shown in Table 1.11.

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

Table 1.11 Mass of 100 mL of water measured in a measuring cylinder and weighed on an electronic balance

1 1 mL of water has a mass of 1 g. Use this information to **determine** what should be the accurate value for the mass of 100 mL of water.
2 **Identify** two results which are considered furthest away from the accurate value.
3 Use the data in Table 1.11 to **describe** the differences in the collected results.
4 **Deduce** whether the differences in results identified in Question **3** could be from the measuring cylinder or the electronic balance or both.
5 **Infer** why there might be considerable differences in the collected data.
6 If the students were to repeat this experiment 10 more times, **predict** whether the results would change.

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Chapter 2
Forces

Inquiry questions

Why do forces cause objects to move?
How can objects respond to forces?
How do non-contact forces work?

PRE-TEST

Chapter introduction

When you travel to school, you might use a train, car, bus, bicycle or even walk, all of which use forces. At school, you open doors, use a pen to write, open your lunch box, carry your bag and play sport, all of which involve forces. Even if you are just sitting still, the chair you are using provides a force to support your weight, which stops you falling down. In this chapter, you will learn how to identify, measure and classify forces. You will also see how two or more forces may be combined to make a stronger force or to cancel each other out completely. In the final part of the chapter, you will learn about gravity and how its effects can be felt on Earth and in space.

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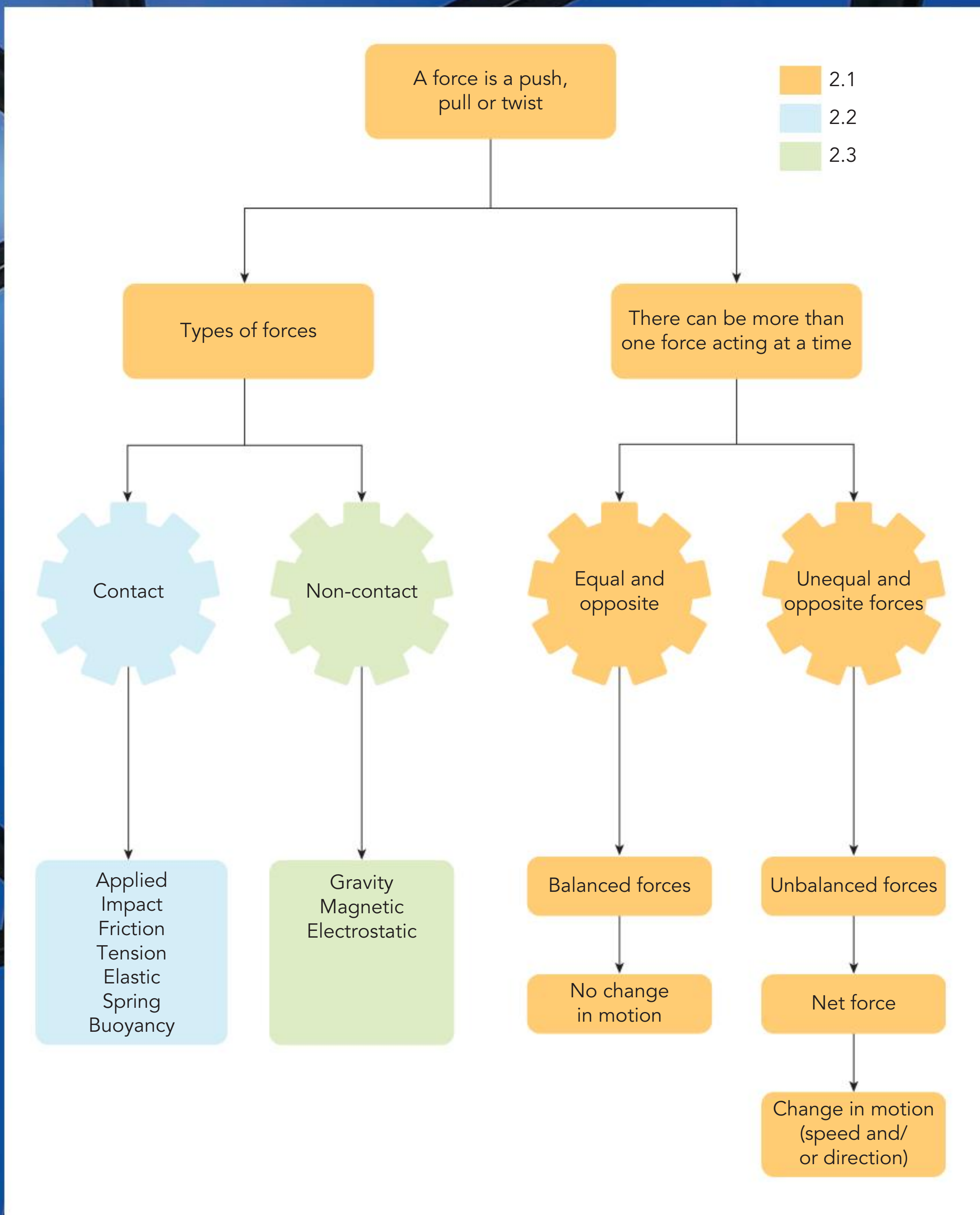
Chapter map



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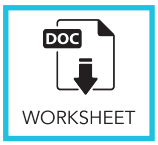
2.1 Applying forces on objects

Learning goals

1. To identify forces, how they are measured and how they are represented in diagrams.
2. To be able to discuss the effects forces have on objects.



A **force** is being applied whenever something is given a **push** or a **pull**, or is rotated or **twisted**. Forces are part of our everyday life. They are found in sport, music, transport, at home and in the work place. For example, when you push your pen across the paper to write, strum guitar strings or slam dunk a basketball … those are all forces! In nature, the forces from the flap of a bird's wings allows it to soar in the air, and the push in a grasshopper's legs lets it jump.

force
a push, pull or twist in a specific direction

push
to exert a force away from something

pull
to exert a force towards something

twist
to turn something

Try this 2.1

The following picture demonstrates forces in action. Make a list of all the pushing and pulling forces you can see in the following image, and if you can, describe what it is in each case that is doing the pushing or pulling.

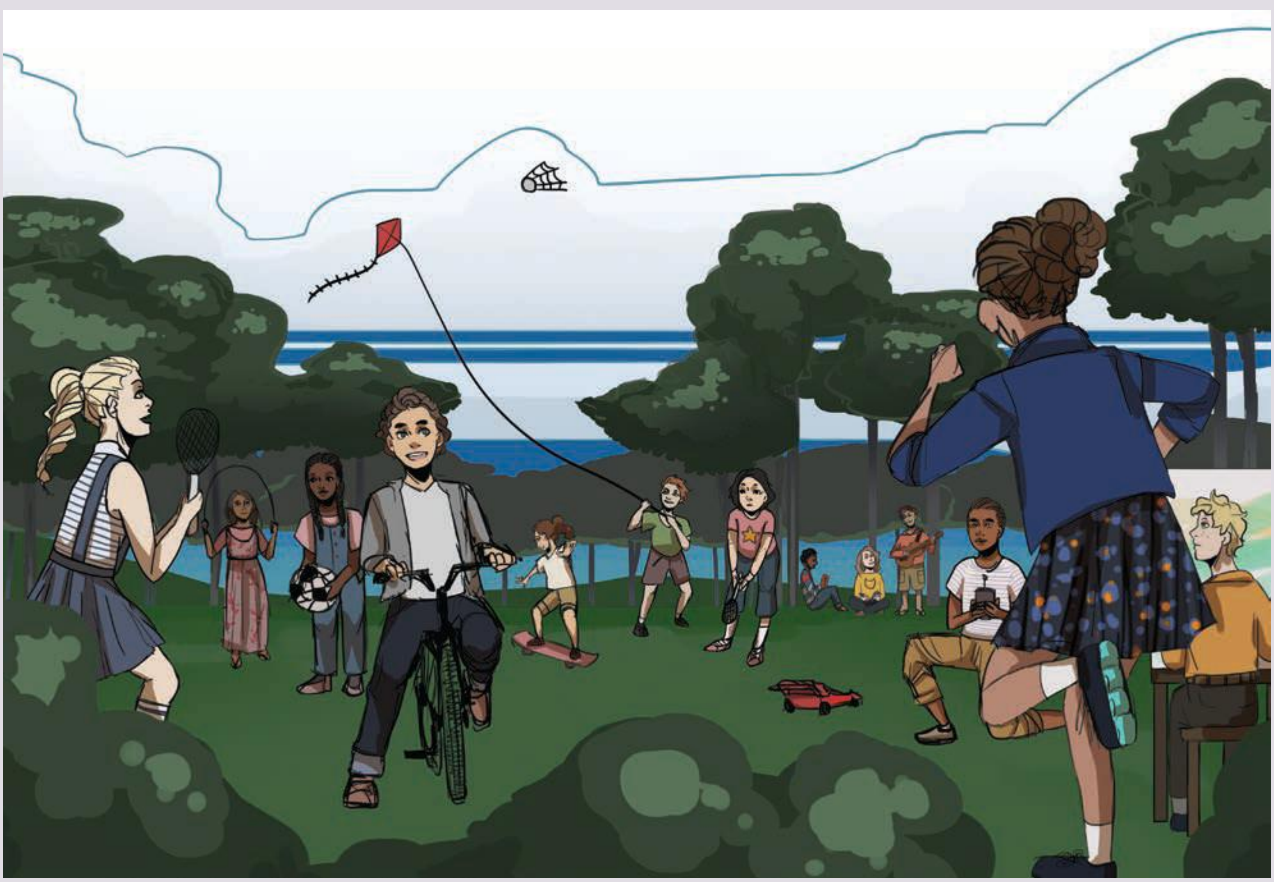


Figure 2.1 Having fun in the park means many forces are in action.

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Table 2.1 gives a summary of some of the forces and associated terms.

Contact or non-contact	Type of force	Description	Example
Contact forces	Pushing	One object moves or tries to move another that it is touching, away from it	Pushing a trolley
	Pulling	One object moves or tries to move an object which it is attached to, towards it	Pulling on a lead to move an animal
	Impact	The force of one object hitting another	Action of a bat on a ball
	Friction	The force between two things rubbing together that makes them (or tries to make them) slow down relative to each other	Brake pads rubbing on the wheel of a bike
Non-contact forces (acting at a distance)	Gravity	The apparent force of attraction when one thing moves near something that has mass	The force that keeps you on the ground
	Magnetic	The attraction or repulsion of magnetically charged objects	A magnet picking up bits of iron
	Electrostatic	The attraction or repulsion of objects that have an electric charge	Attraction of pieces of paper to a rubbed balloon

Table 2.1 Forces summary

How are forces measured?

Forces are measured using a unit called the **newton** (N). One newton is approximately the force you need to keep a large apple from falling.

Springs are usually used to measure forces because a spring will stretch when a pulling force acts on it, and will be squashed or compressed when a pushing force acts on it. In your classroom, you may use something called a spring balance or newton meter, which can measure pulls. At home, you may use kitchen or bathroom scales to measure the force of a push. The bigger the force you are measuring, the stronger the spring will need to be.

You may wonder why you are using scales and spring balances to measure forces, when in homes and stores they measure **weight**. But **mass** and weight are not the same thing in science, though in daily life the terms are used interchangeably. An object's mass is related to the amount of material that it contains, measured in grams or kilograms, and it is the same everywhere in the universe. Its weight, on the other hand, depends on its mass **and** the strength of gravity at its location. The weight of an object is the force with which gravity pulls it towards the centre of the Earth, whether it is falling or pressing down on the surface that it is resting on. So, scales and balances really measure a force – weight – even though they may be labelled in units of mass such as kilogram or grams.

On Earth's surface, an object with a mass of 1 kilogram has a weight of about 9.8 newtons (N). So, if a spring balance is labelled in N, it can also be used to measure mass in kilograms (kg), approximately, with a conversion rate of 1 N = 0.102 kg. Your kitchen or bathroom scales can measure forces (approximately) if you use a conversion of 1 kg = 9.8 N.

newton
the unit of force; one newton is roughly equal to the force you need to keep a 102 g apple from falling

weight
the force of gravity on an object; it is measured in newtons and changes in space

mass
the amount of substance in an object; mass never changes, even in space

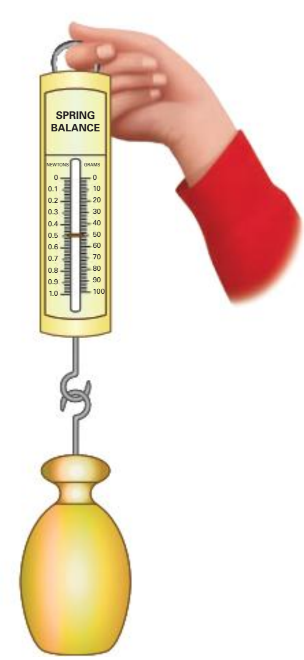

Figure 2.2 A spring balance or newton meter can be used to measure a pulling force such as the weight of an object hanging from it. For some scales, you would need to convert kilograms to newtons to obtain the weight.

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Practical 2.1

Using a spring balance

Aim
To select the most appropriate spring balance.

Materials
- a range of spring balances (e.g. 1 N, 5 N, 10 N, 50 N)

Procedure
1 Copy the results table into your science book.
2 Determine the force needed to complete the actions in the table.

Results

Item	Force required (N)
Hold your pencil case	
Drag this textbook across the table	
Remove a piece of sticky tape from your desk	
Open the lab door	
Drag your stool across the floor	
Hold your school bag	

Discussion
1 State whether the forces applied to the items are push or pull forces.
2 Name the forces involved when hanging and dragging an item.
3 Sequence the items in order from most to least force required to drag them.
4 Explain why the same spring balance could not be used for all of the actions.

Advances in science 2.1

A new device to measure the force of a bird's wings while flying

In 2015, research came out about a new device that is going to help scientists understand the forces birds generate while flying. You know that a bird flaps it wings to fly, but determining how a bird generates lift has been a problem for scientists. The device is called an aerodynamic force platform, and it works like the force platforms that have allowed bioengineers to study the forces that humans exert to walk or run. Essentially, it is a box the size and shape of a large birdcage, with supersensitive force sensors attached to the bottom of the box. As the bird flies, each beat of its wings pushes against the air, which in turn pushes against the bottom of the box. These forces are recorded to produce a precise measurement for each stroke of the bird's wings.

Figure 2.3 Identifying how a bird generates lift has been an issue for scientists.

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How do you draw forces?

When you want to indicate the forces acting on an object, you draw a force diagram. This diagram uses arrows to show both the direction and size of the force. For example, look at the image of a hanging plant held by a hook in Figure 2.4. The plant is being pulled down due to **gravity**, and the length of the arrow on the diagram represents the size of this force. What stops the plant from falling is a force called **tension**, which comes from the chain. The size of the tension force must be the same as that of gravity, and work in the opposite direction, to hold the plant in place. In other words, the forces of gravity and tension are equal and opposite, so they are balanced. On the diagram, the arrow for the tension force is drawn with the same size as the arrow for gravity, but pointing up.

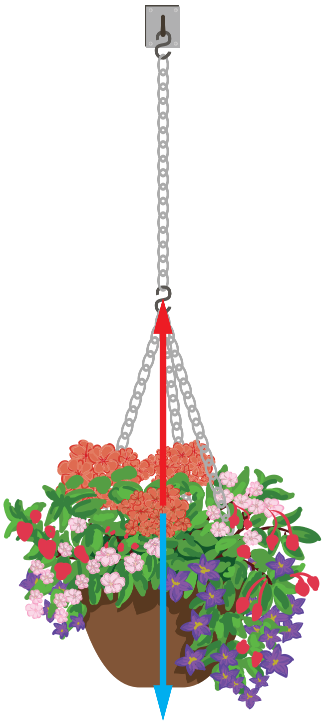

Figure 2.4 The tension in the chain pulling up (red) balances the pull down (blue) of the plant due to gravity.

In Figure 2.5, there are three plants and you can draw a force of gravity arrow for each one, with length proportional (corresponding) to their weight. The size of the tension force to hold the three plants up must equal the total of all their gravity forces. So on the diagram, the tension arrow is drawn as long as the three gravity arrows added together.

Interactions of forces

Forces can either work together or against each other. For example, in a tug of war, the two teams apply forces in opposite directions. If the forces are equal in size, there will be no change in the movement (in this case, because there is no movement then there will continue

Figure 2.5 The tension in the chain pulling up (red) is equal to the sum of the pull down (blue) of the three plant baskets due to gravity.

to be no movement). Equal and opposite forces are said to be **balanced**.

Forces can also be **unbalanced**, meaning that one force is bigger than another. For example, if you have a tug-of-war with all the people having the same strength, and one side has more people, then that side will pull with a greater force, so the forces are said to be unbalanced, and the stronger team will move the other team (Figure 2.6 on page 62). Unbalanced forces cause a change in movement. This change in movement can be seen by something slowing down, speeding up, changing direction, changing shape or rotating.

gravity
a non-contact force describing the pull of any object with mass

tension
the force in a wire, cable or string when being stretched

balanced forces
forces of the same size but that act in opposite directions

unbalanced forces
a combination of one or more forces that has an overall effect, and which changes an object's motion

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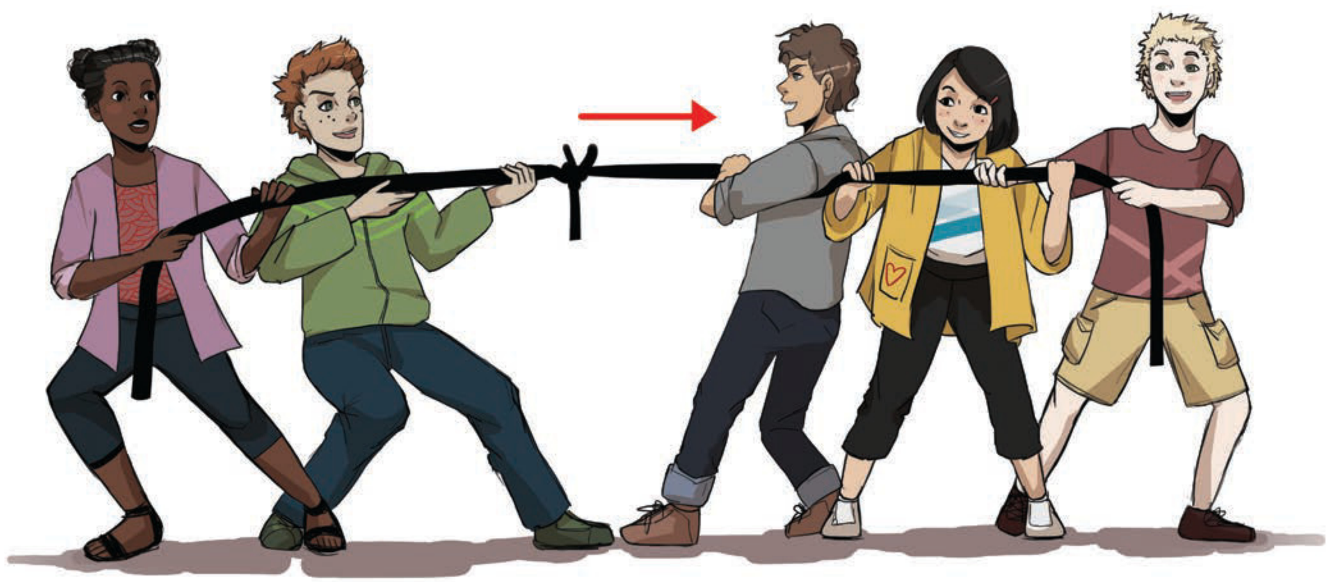

Figure 2.6 Unbalanced forces exist when there are not equal-sized forces pulling in opposite directions, which causes change in movement.

WIDGET
Fly a helicopter

Quick check 2.1

1 Define the following key terms in your own words: force, newton, balanced, unbalanced.
2 Identify which of the following activities use a push force and which use a pull force.
   a catching a fish on a fishing rod
   b dragging your toboggan behind you in the snow
   c cutting up salad vegetables for lunch
   d writing in your exercise book
   e typing on your computer
   f lifting a heavy school bag
   g hitting a hockey ball
   h putting on your slippers at night.

Figure 2.7 A hiker carrying a backpack

3 Explain how a spring can be useful in measuring force.
4 Match each force to its approximate value.

Weight of an apple	700 N
Weight of a car	1 N
Weight of an adult	100 N
Weight of a dog	7000 N

5 The hiker in Figure 2.7 exerts an upward force on her bag when she carries it, while the downward force is gravity.
   a Decide if these forces are acting together or working against each other.
   b Communicate where and what size the arrows should be on the image.

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What are the results of applying a force?

You may have noticed that a force can be applied to change the motion of an object, but this is not always the result. There are four main changes that can occur due to a force acting on an object, and it depends on whether the forces are balanced or unbalanced.

1 A force can balance another force so there is no change in its motion.

2 A force can change an object's speed to make it go faster or slower, including starting from rest when its speed was zero.

3 A force can make an object **rotate** or change its direction of motion.

4 A force can change an object's shape by moulding, bending, stretching or breaking it.

VIDEO How do you know a force is acting on an object?

rotate
to turn or spin on an axis

Try this 2.2

Observing forces

Use the materials listed to perform the tasks in the table below.

- rubber band
- lump of modelling clay
- tennis ball
- bar magnet
- paperclip
- inflated balloon
- plastic counter

Draw the table in your book and record your observations.

Task	Observations	
	Change in motion or shape	Force that caused the change
Stretch a rubber band		
Squash a lump of modelling clay		
Drop a tennis ball and catch it when it bounces		
Bring a bar magnet close to a paperclip		
Use your hands to compress an inflated balloon (be careful not to pop it)		
Rub an inflated balloon against your head and then hold it near your hair		
Use your fingers to flick a plastic counter across a table		

1 A force can balance another force.

You saw earlier that two forces that are equal in size and are applied in opposite directions balance each other out and so have no overall effect on the movement of an object. When forces are balanced, a stationary object remains stationary. If an object is moving, it keeps moving at the same speed and in the same direction.

Let's have a look at just a few examples. What forces act on a book when it is resting on a surface such as a shelf? The weight of a book is balanced by the shelf pushing up on it. This force is equal and opposite to the weight, so they are balanced. If the pull of gravity on the book was bigger than the push up of the shelf, the book would fall through the shelf. What would happen if the shelf pushed up more than the book is pulled down?

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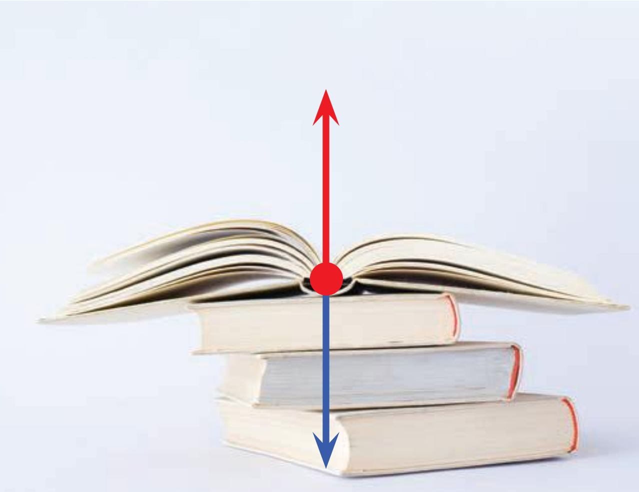

Figure 2.8 The weight of the book (blue) is pulling down towards Earth due to gravity. This is balanced by the force of the other books pushing back at it (red).

An object floating in water, like the ball in Figure 2.9, has an upwards **buoyancy force** that balances the pull of gravity on the ball down (its weight). Consider what would happen if the pull of gravity was larger than the buoyancy force.

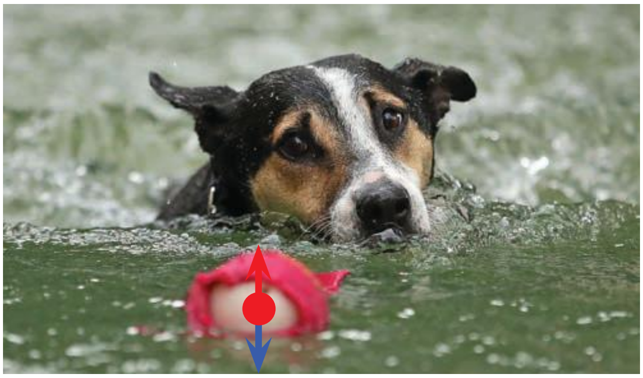

Figure 2.9 The weight of the ball (blue) is balanced by the buoyancy force of the water (red).

Just because a force is balanced, does not mean there is no movement going on. Look at the example of the car in Figure 2.10. There four forces acting on the car. The thrust from the engine pushes the car forward, while **air resistance** and a force called **friction** (the force of the road against the wheels) slow it. The weight of the car pulls it down and the road surface pushes it back up. If these forces are balanced the **net force** acting on the car is zero, therefore it will continue to move at a constant speed. If the car starts to speed up or slow down, then there is an unbalanced force applied to the car. This causes the net force to change from zero.

buoyancy force
the force experienced by an object that is partially or fully submerged in a fluid, e.g. water or air

air resistance
the frictional force of the air

friction
a contact force opposing motion due to the interaction between two surfaces

net force
the sum of all forces acting on an object

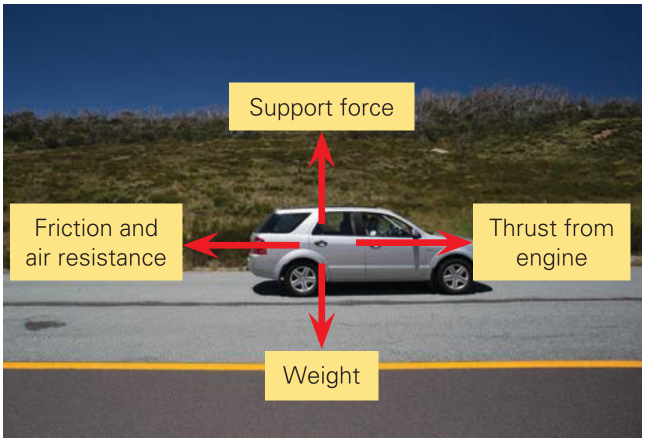

Figure 2.10 The forces on the car are balanced and the car travels at a constant speed.

Try this 2.3

These rocks at Stonehenge in England have been exerting forces on each other for around 5000 years. Begin by identifying where the forces are acting. Then explain whether they are balanced or unbalanced. What is the evidence that allowed you to come to this conclusion?

Figure 2.11 Stonehenge is one of the wonders of the world.

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Quick check 2.2

1. A painting is hanging on a wall from a nail. Decide if the forces on it are balanced or unbalanced.
2. A drone is hovering in the sky. Its weight is pulling it downwards and the force of its rotors is pulling it upwards. Decide if these two forces are balanced.
3. A swimmer is racing from one end of the pool to the other at a constant speed. Explain what must be true of the forces on the swimmer.
4. Draw a truck that is changing its speed and going faster as it travels along a highway. Add force arrows to your drawing, showing how the forces are acting on the truck change.

2 A force can change an object's speed.

Sports are great activities to look for unbalanced forces. Can you think of some examples in sports of when something has sped up due to a force? A golf club hitting a golf ball is a very sudden and quick change in the speed of the ball, and for this reason is classed as an **impact force**. Many ball sports involve impact forces, because the ball is hit by a tennis racquet, hockey stick or cricket bat.

Figure 2.12 The force of the golf club changes the speed of the golf ball from zero to extremely fast in a matter of milliseconds.

Objects changing speed can get slower as well. Brakes on a bicycle and car apply forces to reduce the speed in this way. You may have noticed if you stop pedalling your bicycle on a flat road, even if the wind is minimal, you will slow down and eventually stop. This is because friction has been working in the opposite direction of your travel the entire time. When you stop applying force via pedalling, friction is now the larger force and will slow you until you stop.

impact force
a contact force that sometimes only lasts for a short time; often impact forces change an object's speed

turning force
a force that makes an object start or stop rotating

3 A force can make an object rotate or change its direction.

As well as changing the speed of an object, unbalanced forces can make objects rotate, change direction or spin. Think of all the vehicles that use force to turn their wheels, and you will realise that rotating forces are very common. **Turning forces** are not just found in transport, but also bathroom taps, door handles and even doors themselves, which turn when a force is applied to open them.

Figure 2.13 In the bathroom, the force of your hand results in the top of the tap rotating.

Figure 2.14 In the workshop, screwdrivers and drills require a force to make them turn.

Figure 2.15 In the kitchen, a food mixer uses turning forces.

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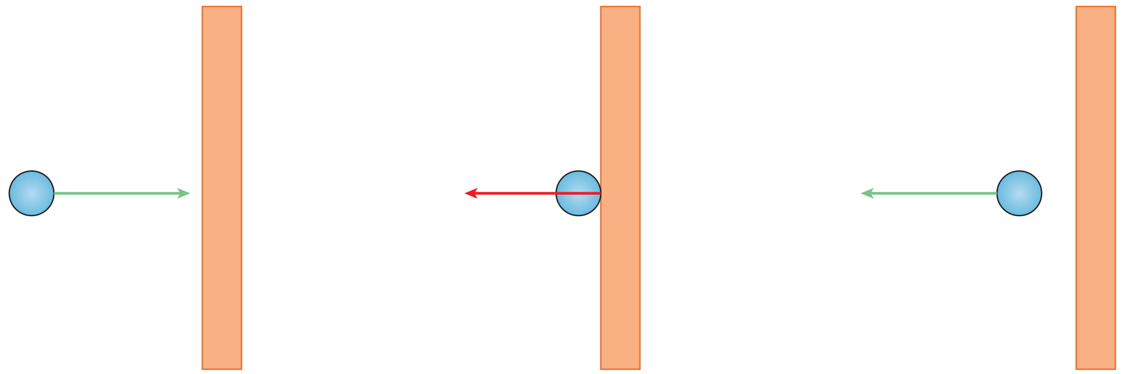

Figure 2.16 What about changing the direction of an object using force? When a ball directly hits a wall, the direction of the rebound will be in the opposite direction to how it was thrown. The green arrows indicate the direction of the ball, and the red arrow represents the force of the wall on the ball.

Quick check 2.3

1. Name some sports where a force can change the speed of an object or a person.
2. Name some sports where a force can change the direction of an object or a person.
3. Name some sports where a force can change the rotation (spin) of an object or a person.
4. Explain if it is possible for an object to speed up or change direction without a net force.
5. Decide if two forces that speed up, slow down, or change the direction of an object are called balanced or unbalanced. Explain your answer.

4 A force can change an object's shape by moulding, bending, stretching or breaking it.

When bread is made by hand, a baker uses forces to mix the ingredients and to mould the dough into a new shape.

mouldable
soft enough to be shaped

Potters use forces to mould clay spinning on a wheel to create bowls. In these examples, the material is soft and is easily moulded into a new shape. Plasticine and Play-Doh are examples of materials that children enjoy moulding. A material that can be moulded easily is called **mouldable**.

Figure 2.17 Dough is moulded by forces into a new shape.

Figure 2.18 Potters use a wheel to spin the clay as they shape it to form a bowl.

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Figure 2.19 Glass can shatter if a large impact is applied.

Figure 2.20 Once the clay has been fired in a kiln, pottery becomes very brittle.

Elastic materials, such as rubber bands and springs, change shape while a force is being applied but return to their original shape once the force is removed. However, not all substances can change their shape easily when subjected to a force. Substances that tend to break instead of bending are called **brittle**. Two examples are glass and pottery, which break into pieces if they are subjected to a large enough force.

brittle
a material that is likely to break or snap when subject to a big enough force

Figure 2.21 The spring on this park ride will allow the tortoise to move around while staying upright.

Practical 2.2

Investigating forces

Aim

To measure some everyday forces.

Materials

- a range of spring balances (e.g. 1 N, 5 N, 10 N, 50 N)
- a selection of masses (e.g. 10 g, 20 g, 50 g, 100 g, 1 kg, 2 kg)

Planning

1. Identify the independent variable.
2. Identify the dependent variable.
3. Develop a hypothesis by predicting how a change in the mass will affect the dependent variable.
4. Identify the controlled variables and describe how these will be managed.

continued…

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...continued

Procedure

1 Copy the results table into your science book.
2 Record the masses you have selected in the first column.
3 Hook each mass onto an appropriately scaled spring balance and measure the force required to hang (suspend) it against gravity. Record the measurement in your results table.
4 Place each mass on a bench, attach a spring balance near the base, and record the force required to get it moving.
5 Then drag the mass steadily at constant speed (drag each mass at roughly the same speed) along the laboratory bench. Record the force reading when it is moving at a steady rate. Write it in your results table.

Results

Mass (g)	Force required to suspend the mass (N)	Force required to get the mass moving (N)	Force required to drag mass at constant speed (N)

1 Plot a graph showing the relationship between mass and the force required to suspend it. Draw a single straight line so that it best fits through the average line of all the data points.
2 Plot another graph showing the relationship between mass and the force required to drag the mass at a constant speed. Again, draw a line of best fit for the data points you have.

Discussion

1 Identify the relationship between the mass and the force required to suspend it.
2 Identify the trend in your second graph.
3 Identify any outlier results in your second graph.
4 Extrapolate your second graph to find out how much force would be required to drag a 4 kg mass at the same constant speed you used previously.
5 If you had any outlier results, explain how these may have been caused.

Conclusion

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

Quick check 2.4

Match each word to its correct description.

1 Brittle	A Can be stretched but always returns to its original shape when the force is removed.
2 Elastic	B Can be made into a new shape.
3 Mouldable	C Breaks into pieces when a force is applied.

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Section 2.1 questions

QUIZ

Remembering

1 **State** the units for mass and weight.
2 **Recall** five contact forces.
3 **Recall** the name given to two forces that cancel each other's effect.
4 **Identify** four examples of impact forces.
5 **List** the different things that forces can do to an object.
6 **Describe** the features of balanced and unbalanced forces. Include an example where possible.
7 **Define** the term 'net force'.

Understanding

8 **Name** an everyday example of each of the following results caused by forces.

Result of the force	Everyday example
No change in motion	
Speeding up of object	
Slowing down of object	
Rotating of object	
Changing direction of object	
Changing shape of object	

9 If a boat is travelling at a constant speed in a straight line on the water, what can you **infer** about the drag and the force of the engine?
10 **Provide** an example from everyday life for each of the following types of force.
  a A force that changes the motion of an object
  b A force that changes the shape of something
  c A force that stretches or bends something.
11 **Provide** examples of materials that are:
  a able to be moulded
  b brittle
  c elastic.
12 Can water exert a force? **Explain** your answer.
13 There are many forces between the parts of Sydney Harbour Bridge. Are all the forces between the parts balanced or unbalanced? **Explain** your answer.

Figure 2.22 The Sydney Harbour Bridge

14 **Identify** the pair of equal and opposite forces on each of the Moroccan tree-climbing goats in Figure 2.23.

Figure 2.23 Moroccan tree-climbing goats only climb argan trees.

15 **Explain** how a spring balance can be used to measure force.

Applying

16 You push a door, and find it is locked and will not open. **Apply** your knowledge of forces to decide if you still exerted a force even though the door did not move.

17 If you hold a carton of milk at arm's length in front of you, **determine** whether you are still exerting a force on it if the milk carton is not moving.

18 You are sitting on the couch at home after a big day at swimming sports. Sketch yourself and **draw** arrows to represent the forces acting on you (alternatively, you can just describe it). **Examine** whether the forces balanced.

19 In Figure 2.24, the weight (force of gravity) of the gymnast is balanced by the tension in the ropes. **Draw** a sketch of the gymnast and include arrows to represent the forces acting on him (alternatively, you can just describe where the arrows would be and what direction they point).

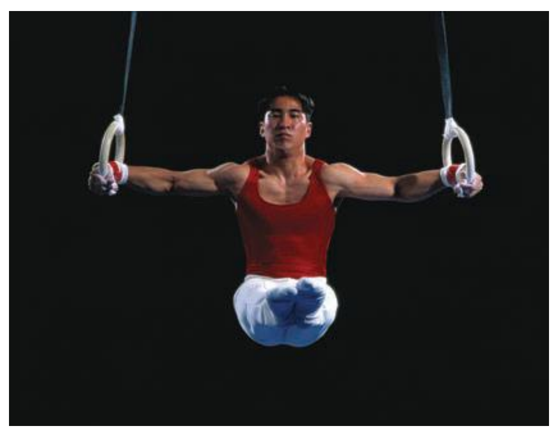

Figure 2.24 A gymnast

Analysing

20 **Analyse** Figure 2.25 and describe or draw the forces on the cyclist. Assume they are moving at constant speed in a straight line.

21 You know force is measured in newtons. How could you **explain** to a friend in a different class how big a 30 N force is?

Evaluating

22 Three cycling triplets are identical in every way, including their size, mass and clothing, and they have identical bikes. They start a sprint race side by side at the same time. After 10 seconds, Albert has gone 200 m, Ben has gone 160 m and Charlie has gone 120 m. Was the average force each exerted on the pedals the same during the 10 seconds, or different? Who exerted the highest force, and who exerted the lowest? Was it a fair comparison? **Justify** your reasoning.

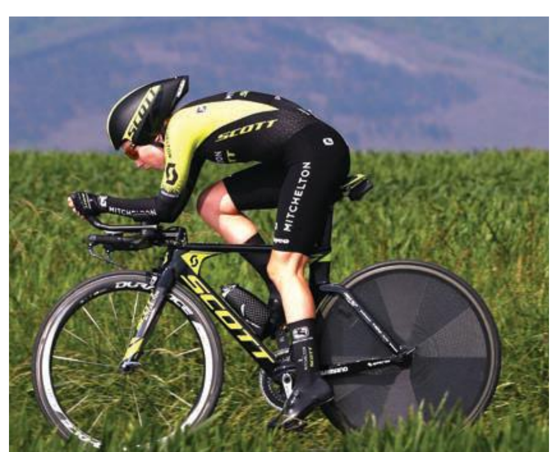

Figure 2.25 A cyclist

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2.2 Types of forces: Contact

Learning goals

1. To identify and describe types of contact forces.
2. To describe the effects of friction.
3. To be able to discuss how the effects of everyday forces can be reduced.

You have learned that forces can have a number of different effects. Using the definition that a force is a push, pull, twist or rotation, you will now learn that there are many types of forces and you will learn how to classify the forces you encounter at school and at home.

Contact forces are pushes, pulls and rotations which require the objects to be in contact with each other. A contact force that is part of everyday life is friction. You will look at this and some of the other contact forces caused by ropes, chains, levers, pulleys, motors and human muscles.

Friction forces

Friction is a force that is part of everyday life. Friction is a contact force and occurs whenever surfaces rub together, or when a liquid or gas flows over a surface. It happens when one object tries to move over another object it is in contact with, like trying to move an armchair across the floor. Friction always acts in the opposite direction of relative motion and so it either slows down or stops moving objects.

DOC WORKSHEET

VIDEO Give examples of contact forces

Imagine life without friction. Walking would be difficult because your shoes would have no grip on the floor. Normally you push your foot backwards against the ground and the ground pushes back on you (note: the friction is pushing you forward here), but if there were no friction, it would feel like everything was covered in a thin film of slippery soap. This type of friction is called traction. Without friction, car brakes would not work and without the grip of the tyres on the road, cars would not be able to move in any direction; backwards, forwards, nor around corners.

Try this 2.4

Push and pull

In groups, take a few moments to think of different pushes or pulls (i.e. forces) you have experienced in the last few days. (Leave aside twists and rotations for the time being as they tend to be trickier.) You may like to choose one from a sport, and one from playing a musical instrument, from home or at school, or even on public transport – are there any forces involved? When all the groups have finished, create a list for your class and, if you can, try to give the forces names and to classify them into groups. How did you go? There are lots of possible forces that you could have included in your list, so keep your list handy and now you will start looking at some of the categories of forces that exist in our world.

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Practical 2.3

Surfaces and friction

Aim

To observe the effect of various surface types on the frictional force on a moving object.

Materials

- large block of wood with hook attached
- spring balances (10 N, 20 N and 100 N)
- a variety of different surfaces (e.g. vinyl floor, carpet, concrete, polished concrete, sandpaper, grass or bitumen in a safe area).

Procedure

1. Copy the results table into your science book. Ensure the independent variable is in the left-hand column and the dependent variable trials and mean sit at the right of the table. Don't forget units in the headers.
2. Place the block of wood on the first surface and attach the appropriate spring balance. (Hint: Which spring balance would be the best for each surface? How would this be determined?)
3. Pull the block of wood at a constant speed across the surface and read the force on the spring balance. The force on the spring balance will be equal to the force of friction. Record this reading in your results table.
4. Repeat the measurement four more times and record in your table.
5. Repeat steps 1–4 on three other different surfaces.

Results

Surface	Friction force			
	Trial 1 (N)	Trial 2 (N)	Trial 3 (N)	Mean (N)

Discussion

1. Why was it necessary to measure the friction of each surface three times? Find the mean.
2. List your surfaces in order of lowest to greatest friction force.
3. Explain why some surfaces create more friction than others.

Friction between surfaces

As you would have found completing the practical activity, friction depends on the surfaces that are rubbing together. Rough surfaces tend to produce more friction than smooth ones. Friction also depends on the weight of an object. Think about the earlier example of trying to move an armchair across the floor. If the chair is extremely heavy, there will be more friction opposing the push you are giving. Friction also depends on the speed at which an object is moving. It increases as the speed increases. This is why it is important to use the same constant speed in an experiment.

So, you have seen that friction can be a very useful force, but it can also have an unwanted consequence. When two surfaces rub against each other the friction force can transfer energy which increases the temperature. On a cold day you may have rubbed your hands together to make them warm, or maybe you have rubbed sticks together at high speed to start a fire. However, higher temperature is not always welcome because it can represent wasted energy or be dangerous.

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Figure 2.26 Petrol engines need oil to lower the friction inside.

Minimising friction between surfaces

One way to reduce friction between two surfaces is to polish them or to use lubrication such as oil or graphite. This allows the surfaces to move over each other with less friction and thus generate less wasted energy. In Figure 2.26, clean oil is put into an engine to lower the friction between the moving parts. If there is no more oil, the extra frictional forces will destroy the engine because the metal expands as the temperature increases.

Another way friction can be reduced, especially when moving heavy loads from one place to another, is to use a wheel and axle (Figure 2.27). This is one of the earliest and most widely used inventions ever made.

Figure 2.27 The wheel and axle allows objects to be moved over a surface with very little friction.

By using a wheel and axle, trains, cars, trucks and even aircraft taking off and landing can all move with little friction. Wheels are used all over the world. The only exception is on snow and ice, where surfaces have low friction and it is better to use skis or sledges on runners. Skis and runners do not sink into the snow and get stuck like a wheel would. Additionally, being long and thin, they tend to run straight where wheels would slide sideways.

Wheels also do not work well if the ground is very rough, so trains need tracks and cars work best on roads. Wheels do not work on water, so seaplanes designed to land on water use long thin hollow floats or pontoons, shaped like closed canoes, in place of wheels.

Figure 2.28 Seaplanes use floats instead of wheels to land on water.

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Try this 2.5

Use a spring balance to measure the force required to pull a wooden block across your bench. Next, lay out pencils or pens that are perfectly round and about the same thickness next to each other and measure the force required to pull the block on top of them. How does the force required differ? Can you explain your observations?

Friction in gases and liquids

In this section, you will learn about friction between solid surfaces and gases or liquids, which is also called **drag**. However, friction can also occur between liquids and gases, or even within liquids and gases. In the air, drag is also called air resistance. Friction in liquids and gases is very similar and the two are often treated together as fluid friction.

drag
the frictional force of a liquid or gas

streamlined
designed to minimise air resistance or drag

As an arrow moves through the air, air resistance will act to slow it down, but because arrows are **streamlined**, the force slowing the arrow is small.

Fish have a streamlined shape that helps them move through water easily. The same shapes are used by the designers of boats and submarines to reduce drag and to enable them to travel at high speed in water.

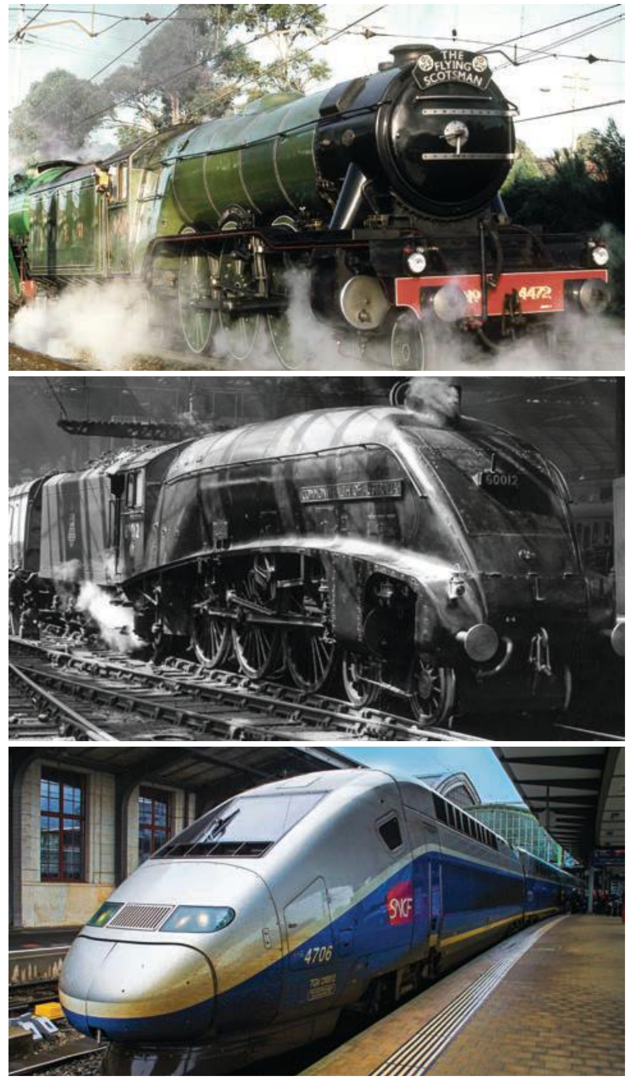

Figure 2.30 Trains have become more streamlined as their speeds have increased.

Figure 2.29 The friction force on an arrow as it flies through the air is small.

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Figure 2.31 The streamlined shape of a kingfisher is useful to minimise drag during a dive.

In the air, birds have a streamlined shape, which lets them fly with as low an air resistance as possible. Air resistance is a major consideration for the designers of cars, trains and aircraft. Have a look at the three trains in the images in Figure 2.30: their design has become more streamlined to allow them to go faster.

Quick check 2.5

1 Explain what friction is and how it works.
2 Describe two features of a car that are designed to minimise friction for better fuel economy.
3 Describe two features of a car that are designed to maximise friction for safety.
4 Define the key terms 'air resistance', 'drag' and 'streamlined'.
5 Explain why a shark's body is streamlined, whereas a koala's is not.

Practical 2.4

Stretching springs

Aim

To observe the relationship between force and extension for a spring.

Materials

- spring
- retort stand, bosshead and clamp
- set of slotted weights
- ruler

Procedure

1 Using a retort stand, hang a spring on a bar and place an empty weight holder on the end of the spring.
2 Tape a ruler to the vertical bar of the retort stand. Use the scale of the ruler to record the initial position of the bottom of the weight holder.
3 Add masses to the weight holder. Each time a new mass is added, record the new position of the bottom of the weight holder. Be careful not to overstretch the spring.

Results

Mass (g)	Extension (m)	Force (N)

1 Calculate the force applied to the spring by dividing the mass in grams by 1000 and multiplying by 9.8.
2 Draw a graph of how force affects the extension of the spring.

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Discussion

1 Identify the trend in your graph.
2 Identify any outlier results in your graph.
3 Can you use your graph to make predictions about other masses?

Conclusion

From this activity we can claim that the extension of a spring depends on _____________. This is supported through observing _____________.

Elastic/spring forces

Forces in metal springs

Springs can be pulled, pushed or bent sideways. In each case they will exert a force in the opposite direction to the force applied: this is called a spring or **elastic** force.

> **elastic**
> elastic materials bend, stretch or compress when a force is exerted on them; they exert elastic forces when this happens

Forces in elastic materials

Solid pieces of elastic or rubber can also be stretched, pulled sideways, and compressed. But a rubber band or strand of elastic cannot be compressed lengthwise, because of its shape.

Rubber and other elastic materials can be compressed when they are formed into a short, fat shape: they are used in this way to absorb bumps and shocks in doorstops, in vehicles and machines.

Long pieces of wood, plastic or metal can also exert an elastic force when they are bent. They spring back to their original position when the force is removed, as long as the force is not large enough to break or deform them permanently. Tree branches are an example of this as they can bend in the wind. If they become rotten and unable to bend, they will break in a storm.

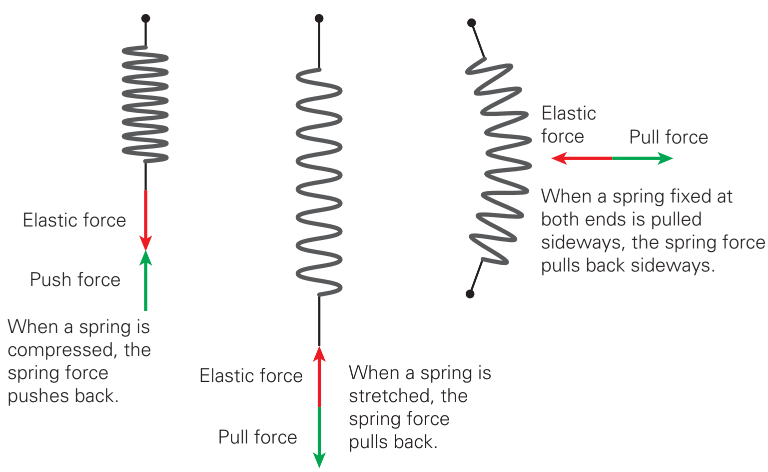

Figure 2.32 Three ways to apply a force to a spring

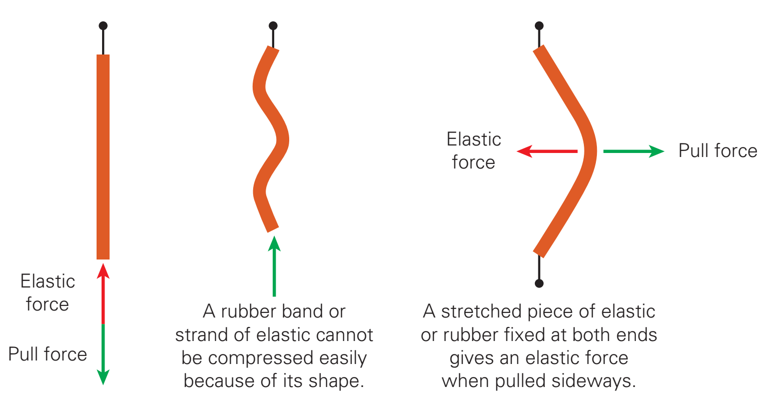

Figure 2.33 Two ways to apply a force to a rubber band

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Figure 2.34 The diver makes use of the elastic forces in a springboard.

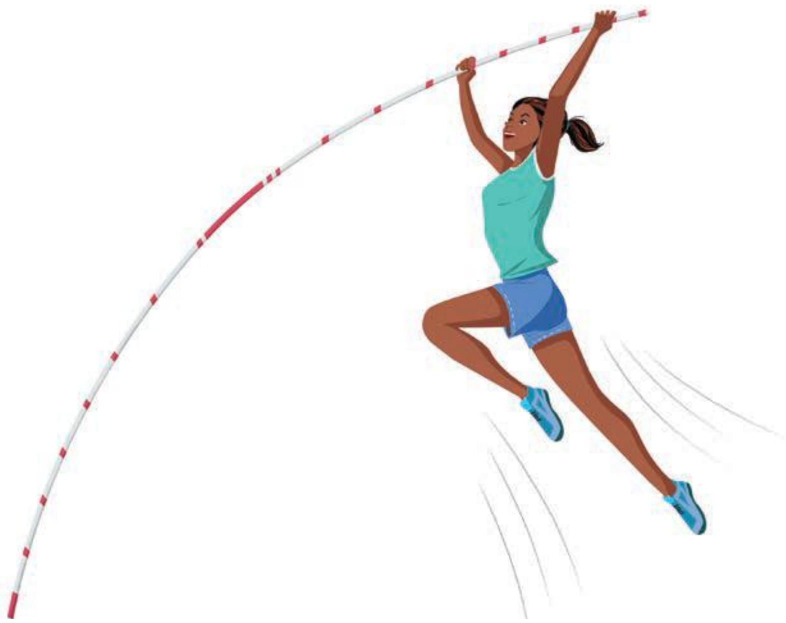

Figure 2.35 A pole vaulter uses the elastic forces in a pole to reach the top of the vault.

Elastic forces are used by divers on a springboard to gain extra height when they dive. The force exerted by a bow on an arrow is another example of an elastic force. Some of the force comes from the stretching of the string; however, most of the force comes from bending the wood or plastic of the bow.

Quick check 2.6

1. What is an elastic force?
2. Compare elastic forces on a spring and a rubber band.
3. Can you think of other sports or activities that have not been mentioned that use elastic or spring forces?

Buoyancy forces

The buoyancy force is the upward push that occurs when an object is partially or fully submerged in fluid such as water or air. If an object placed in water sinks, the buoyancy force acting upwards is smaller than the weight of the object. If it floats, the buoyancy force is equal to the object's weight.

There is also an upwards buoyancy force on an object in a gas, but it is much smaller, and can only be seen in an object that is very light compared to its size, such as a helium balloon. The air's upwards buoyancy force on a helium balloon can be greater than the balloon's weight (when it will rise) or equal to its weight (when it will float at a constant height).

Figure 2.36 Buoyancy forces allow heavy container vessels to float.

Figure 2.37 In these glasses of lemonade, the lemon floats and bubbles of gas rise to the surface due to buoyancy forces.

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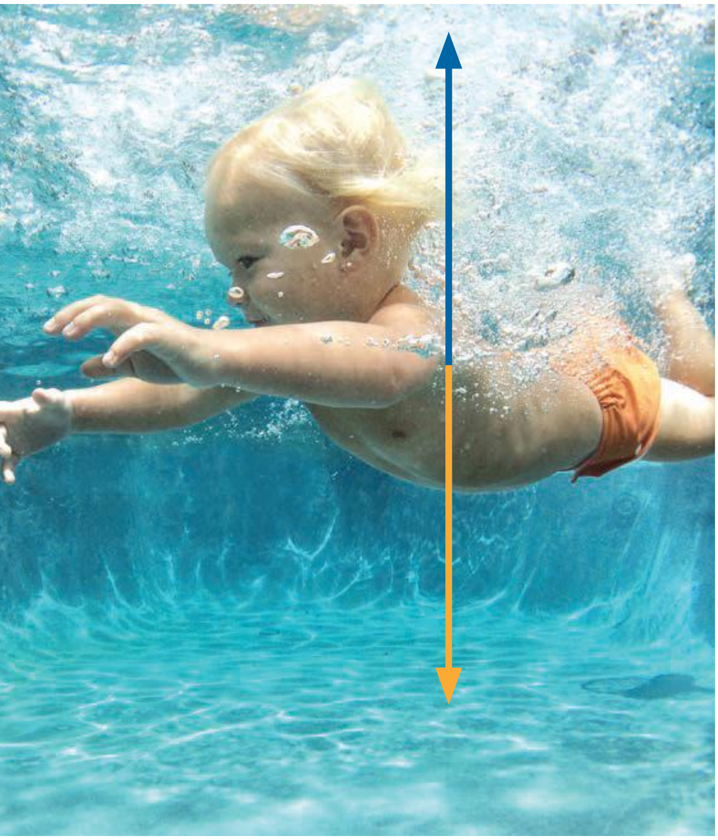


Figure 2.38 The buoyancy force on the baby is approximately equal to the baby's weight.

Did you know? 2.1

Buoyancy forces are everywhere!
Hot magma inside Earth is lighter than cooler magma, and buoyancy forces cause giant bubbles of hot magma to move towards the Earth's surface. These create volcanoes and earthquakes when they reach the crust. So, from tiny bubbles in a glass of lemonade to destructive volcanoes, you can find buoyancy forces everywhere.

You will have experienced a buoyancy force if you have been swimming: it is the force that makes you feel weightless in the water. Whether you are swimming on the surface or underwater as in Figure 2.38, the buoyancy force (blue) is approximately equal to the force of gravity (orange).

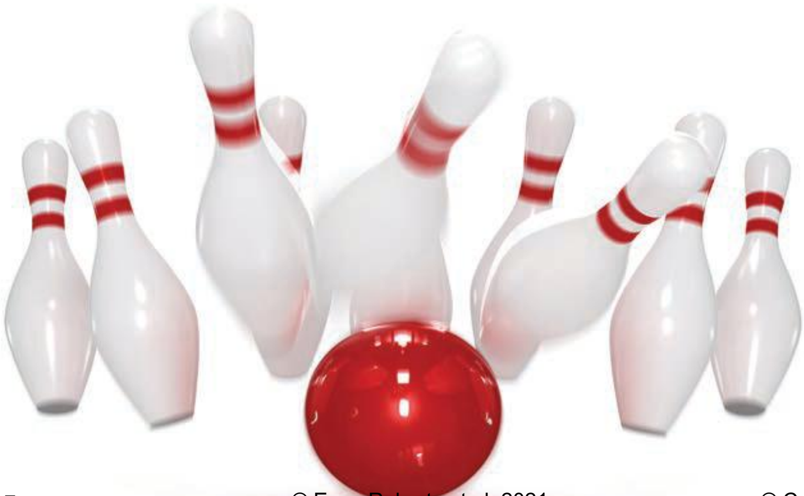
Impact forces

The contact forces you exert or experience in daily life, such as moving an object or opening a door, are called **applied forces**. When objects collide, they typically exert or experience a force that lasts just a fraction of a second. This is called an impact force, and it is a push that (usually) fast-moving objects or particles exert for the very short time that they are in contact with another object. These forces are increased if the moving objects are heavier or faster. Examples include ten-pin bowling skittles being hit by a bowling ball or a hammer hitting a nail. Can you name some other examples of impact forces?

applied force
force that is applied to an object by another object or person

Keep in mind that impact forces can be useful as well as dangerous. A pressure cleaner emits a jet of water at a high speed, and when the water hits its target, its speed changes quickly, causing the water to exert a force on the ground that can be used to clean a surface.

In car accidents, impact forces can cause serious injuries, but these can be reduced by using seat belts, crumple zones and air bags. These safety measures spread the impact force over a larger area (thus decreasing the pressure at any point) and spread the change in speed over a longer time (thus decreasing the force).



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Advances in science 2.2

Bike helmets

Australia has a proud record of leading the way when it comes to road safety. The origin of road safety legislation has its roots in evidence collected by doctors stating that road accident victims often had injuries that were preventable. The head is especially vulnerable to injury and for this reason both motorcyclists and cyclists are required to wear a helmet in Australia. The main function of the helmet is to protect the skull by stopping penetrating injuries, and to spread the force over a larger area, and to make the change in speed of the head take a longer time as the head sinks into the foam thus reducing the force on the head. Similarly, occupants of cars wear a seatbelt to absorb the energy by spreading the impact forces over the chest and preventing the head from hitting the windscreen in an accident. The forces involved in the sudden changes of speed that can happen in a collision are very large, and so injuries can be prevented if these forces can be reduced by spreading the change in speed over a longer time, and the pressure reduced by spreading the force over a larger area, so the body is protected.

Figure 2.39 Luke Bell of Australia wearing a helmet that protects his head and is also designed to minimise air friction.

A major study presented in 2016 looked at the use of bike helmets around the world. Based on more than 64 000 cyclists, the study found helmets reduce the risks for a serious head injury by nearly 70%, face injury by 33% and fatal head injury by 65%. So, regardless of whether they are compulsory, wearing head protection is highly recommended!

Explore! 2.1

Footwear design

Shoes and boots these days are used for walking, running, playing sports, work boots and as formal wear. They are used to protect your feet from injury but also must provide support and comfort. Every time you walk or run, your foot is under pressure as forces are applied. Nowadays, footwear includes design features that help reduce the impact of these forces. These features include extra cushioning in the sole of the shoe. The cushioning is very flexible as it has elastic properties (as discussed earlier). Air pockets within the sole can also help reduce impact forces.


Figure 2.40 Stability, elasticity and density are among the properties considered for sports shoes.

Conduct some research to find out the types of materials that are used in shoe soles. Describe how each of these materials helps reduce the impact force on the wearer's feet. Make sure you look at formal shoes as well as sport shoes.

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Explore! 2.2

Car safety features

Car manufacturers are continually adding safety features to car design to help reduce the impact of the forces on the occupants during a collision. When a car collides with an object, the occupants continue to move forward even though the car has stopped. They will continue to move forward until they are stopped.

Research the following car safety features and answer the questions in the table:

- seatbelts
- airbags
- crumple zones.

	Who invented this safety feature and when was it introduced into cars?	Briefly explain how this safety feature works.	Describe how this safety feature reduces the stopping force on occupants when in a collision.
Seatbelts			
Airbags			
Crumple zones			

Figure 2.41 Safety features of a car include seatbelts, airbags and crumple zones.

Quick check 2.7

1. Name the two forces acting on you when you are lying on an inflatable mattress in a swimming pool.
2. Define the term 'impact force' and provide three examples.
3. Explain why Australians are required to wear seat belts in cars and bike helmets when riding, in the context of impact forces.

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Section 2.2 questions

QUIZ

Remembering

1 **Recall** four types of contact force.
2 **Identify** which contact force can be easily used to warm up a small object or surface.
3 **Identify** the common name for friction on an object moving through a liquid or gas.
4 **State** if an object can change direction without a force.

Understanding

5 An impact force is a force that acts for a short time. **Describe** three examples of impact forces from sport.
6 The wheels of a car and some bikes are attached with springs. **Explain** using forces how the springs help give a smooth ride even on a bumpy road.
7 If an object is travelling horizontally in a straight line at a constant speed, **explain** if it needs a force to keep it moving.

Applying

8 Compare the two cars in Figure 2.42 and decide which one is designed to go faster. **Explain** your answer.

Figure 2.42 Which car will go faster?

Analysing

9 **Propose** whether a glass or plastic bottle is a better choice to carry water in a backpack.
10 The foot in Figure 2.43 belongs to a swan. Use your knowledge of forces to **analyse** the structure of the foot and explain how it is adapted to be used in water.

Figure 2.43 The foot of a swan

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11 On snow and ice, wheels with tyres are often replaced by skis and tracks on vehicles. Examine and contrast the skis and the tyre below and **describe** how their shape and friction forces relate to their use.

Figure 2.44 Skis versus tyres

12 Use your answer to the question above and knowledge of forces to **explain** how a snowmobile works and **justify** why it is preferred for snow compared to a normal motorcycle.

Figure 2.45 Snowmobiles use skis and a track instead of wheels.

Evaluating

13 Earthquakes are dangerous, and buildings in earthquake-prone places must be specially designed to withstand the shock of an earthquake. There are three types of building materials that could be used in an earthquake zone. Use your knowledge of forces to recommend how you would use or modify each material to cope with earthquakes. **Justify** your reasons and examples.

- Brittle
- Elastic
- Bendable

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2.3 Types of forces: Non-contact

Learning goals

1. To identify and describe non-contact forces.
2. To identify the usefulness of non-contact forces.
3. To identify the problems caused by non-contact forces.

Non-contact forces are forces that act at a distance, through all states of matter, and outer space. They do not require physical contact for the force to act. Did you have any non-contact forces in your list?

There are three key non-contact forces you will investigate:

- gravity
- magnetic
- electrostatic.

Gravity

Gravity is the name that we give to a force that exists when something changes its motion due to being near a body that has mass. If each body has mass, then each will change the motion of the other. You experience gravity as the force that pulls you towards the centre of Earth. There is a force of attraction between you and Earth. The effects of gravity near Earth's surface are familiar but Earth's gravity also extends into space. It holds the Moon in orbit, and keeps communication and weather satellites in orbit. But can you believe that the force of attraction between you and Earth goes both ways? You also pull Earth towards you, but because Earth is so much bigger than you, the effect of your force exerted on Earth cannot be noticed. Gravity is also the force that maintains all the planets in our solar system in orbit around the Sun.

DOC WORKSHEET

VIDEO Give examples of non-contact forces

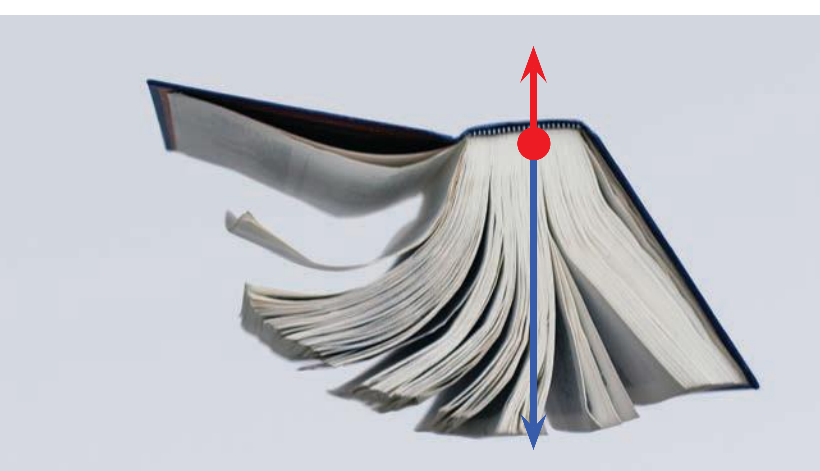

Figure 2.46 A book falls due to the force of gravity (blue arrow), which is opposed by the smaller force of air resistance (red arrow). The forces are unbalanced and there is a net force downwards.

What forces are acting on a falling object such as a book? It is moving towards the ground and speeding up as it falls, so you know that an unbalanced force is acting on it. As you have noted previously, the force pulling the book to the ground is due to gravity and is called weight. However, there is also a force pushing the book up. This force is called 'air resistance', which you can feel on your hand when you wave it quickly. But this force is much smaller than the weight of the book, so the book falls faster and faster (unless the book falls more than a few hundred metres, in which case the air resistance can be enough to limit the speed the book can reach).

Although the force of Earth's gravity gets weaker in space, the weight of an object is almost the same everywhere on Earth's surface. Remember, force is measured in newtons, so weight, which is a force, is measured in newtons, not kilograms.

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Explore! 2.3

Fields

You may not be able to see gravity but it is always there. Earth's gravity creates a **field** (an example of a force field) around it.

1 Find out and summarise what it means to say that Earth's gravity creates a field around it.
2 Find a diagram of Earth's gravitational field and describe what happens to the strength of this field as you move closer to Earth. Describe the direction of the gravitational force as well.

Different gravitational pulls

The pull of gravity is different in various locations of the universe. The Sun has the strongest gravity in the solar system, about 28 times the gravity on Earth. Do not go for a holiday to the Sun. The average person would weigh about the equivalent of two cars on the Sun, and it would require a lot of effort just to move. Neutron stars are extremely dense objects which are left behind when some stars explode. They are so dense that 1 cm of human hair on a neutron star would weigh more than all the water in an Olympic size swimming pool on Earth! Black holes have such strong gravity that not even light can escape from them.

field
a region in space in which an object is affected by a force

Try this 2.6

Jumping on planets: Mass vs. weight

Use a metre ruler and sticky tape to calculate how high you could jump on different planets.

1 Tape the ruler to a table leg or wall so that it is vertical.
2 Get a partner to kneel down so their eyes are level with the ruler.
3 Jump as high as you can while your partner records the height you achieved.
4 Repeat the jump two more times.
5 Swap roles so you are now recording the jump height of your partner. Repeat steps **2–4**.
6 Copy the table below into your book and calculate the mean jump height.

	Jump height (m)			
Student name	Jump 1	Jump 2	Jump 3	Mean

7 Calculate how high you could jump on each planet, plus the Sun and the Moon. Divide your mean height by the surface gravity of each celestial body in the table below. For example, if you jumped a mean height of 0.65 m and wanted to calculate how high you could jump on Venus, you would divide 0.65 by 0.91. This would tell you that you could jump 0.71 m if you were standing on the surface of Venus.

Member of the solar system	Ratio of the surface gravity of each location to Earth's surface gravity	The height I could jump at each location (m)
Sun	27.90	
Mercury	0.38	
Venus	0.91	
Mars	0.38	
Jupiter	2.36	
Saturn	0.92	
Uranus	0.89	
Neptune	1.12	
Pluto	0.06	
Earth's moon	0.16	

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Quick check 2.8

1 Define these key terms: gravity, mass, weight.
2 Describe the relationship between the force of gravity, mass and weight.
3 You go to the butcher's shop to buy some sausages for a school fundraiser and the butcher says your sausages weigh 2.5 kg. Compare the meaning of the word 'weight' for the butcher in this situation versus what it actually means.

Air resistance

Do all objects of the same weight fall at the same rate? If they do, then identical pieces of paper, no matter how they are folded or not folded, should fall at the same rate. See whether this is the case or not in the following activity.

Practical 2.5

Surface area vs. air resistance

Aim

To determine how surface area and mass affect air resistance.

Materials

- one piece of A4 paper
- one piece of A4 card
- metre ruler
- stopwatch

Procedure

1 Copy the results table into you science book.
2 Take the A4 paper and measure its length and width to calculate its surface area. Record this in your table.
3 Drop the paper from a height of 1.5 m and record the time it takes to reach the ground. Repeat two more times.
4 Fold the paper in half and then repeat steps 2 and 3. Continue doing this until you have folded the paper four times.
5 Repeat using the piece of card.

Results

		Time taken to drop paper (s)			
Number of folds	Surface area of paper (cm^2)	Trial 1	Trial 2	Trial 3	Mean
0					
1					
2					
3					
4					

		Time taken to drop card (s)			
Number of folds	Surface area of card (cm^2)	Trial 1	Trial 2	Trial 3	Mean
0					
1					
2					
3					
4					

continued...

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...continued

Plot both sets of results onto the same graph to compare them. Plot the surface area of each item against the mean time it takes to drop.

Discussion

Identify any trends, patterns or relationships in your results.

The experiment in Practical 2.5 demonstrates that the reason different objects hit the ground at different times is due to the interaction of the object with air: the air resistance of the object. When the flat piece of paper was used, the air resistance is much greater because it has to push more air out of the way. This is related to the area of the paper that pushes against the air. The face of the paper is a very big area, so it falls much more slowly than the folded piece of paper where a smaller area pushes the air out of the way.

If these experiments were repeated without air (in a vacuum), then all the objects released from the same height at the same time, regardless of their mass, would hit the ground at the same time.

In fact, without air resistance, objects of different weights would also fall at the same rate. It has been shown that when dropped in a vacuum, a feather and a bowling ball hit the ground at the same time.

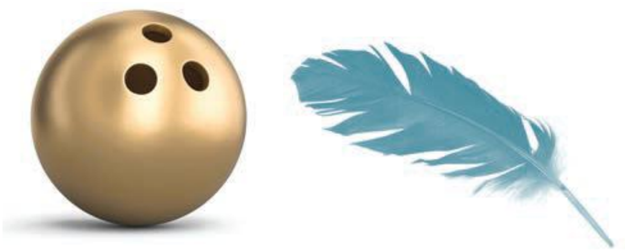

Figure 2.47 In a vacuum (without air resistance), these two objects fall at the same rate if dropped from the same location.

When air resistance is equal to the force of gravity, you will fall at a constant speed. The speed at which air resistance equals weight for a falling object is called the terminal velocity.

Parachutes are a practical application for air resistance. You can fall through the air safely if you have a parachute because the parachute increases your air resistance to the point where it overwhelms your weight, thus enabling you to slow down.

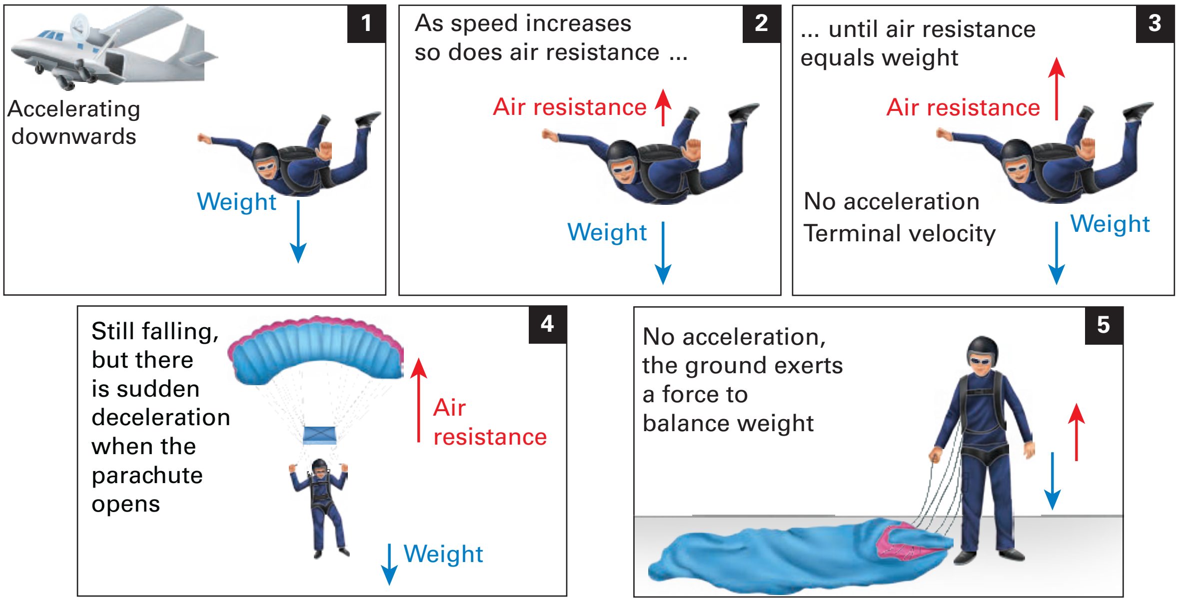

Figure 2.48 The way a parachutist falls depends on the size of the pull of gravity and the air resistance from the parachute.

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Try this 2.7

Drop time of a parachute

Materials

- plastic freezer bags
- scissors
- modelling dough
- stopwatch
- cotton or string
- metre ruler

Instructions

In small groups, use the materials listed to design and build a parachute. Compare your group's design to other groups' designs to explore the effect of one of the following variables on the drop time of a parachute:

- mass of the sky diver
- surface area of the parachute
- shape of the parachute
- length of the connecting string.

Quick check 2.9

1 Explain the meaning of the terms 'air resistance' and 'terminal velocity'.
2 Describe the relationship between the speed an object falls at, the pull of gravity and air resistance.
3 Look at Figure 2.49.
   a Identify the forces acting on the capsule.
   b Describe how these forces change before and after the parachute is opened.

Figure 2.49 When astronauts return to Earth from space, the air resistance of their parachute provides an upwards force equal to the weight of the capsule they are safely enclosed within.

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Magnetic forces

Magnetic force, like gravity, is a non-contact force. Remember, this means objects do not have to be touching to have an action. Magnetic forces are always strongest at the ends of a magnet, which are called poles. There are two types of magnetic poles, north and south, and they always occur as a pair. Even if you break a magnet in half, it will still have a north and south pole at the ends of each of the pieces.

> **magnetic force**
> a non-contact force between a magnet and another magnet or magnetic metal
>
> **repel**
> to force back or apart
>
> **alloy**
> a substance composed of two or more metals

In the *Try this 2.8* activity, if you use real magnets, you will find that north and south poles attract each other, but two like poles **repel**.

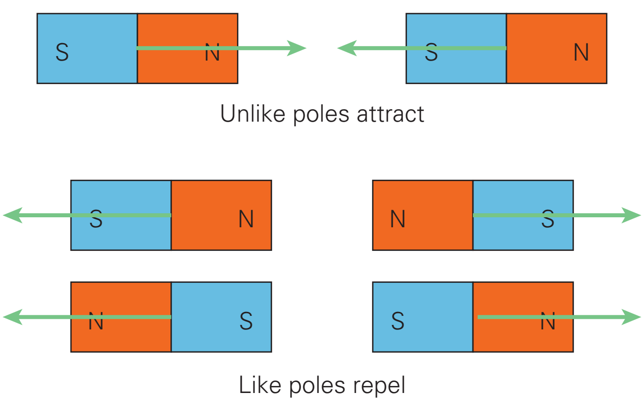


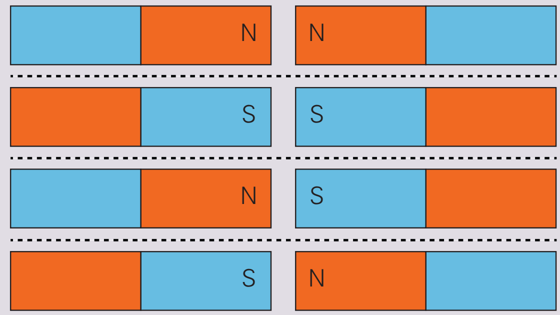
Figure 2.50 Forces between magnets

Some magnets always retain their ability to be magnetic and so they are called permanent magnets. An example would be a fridge magnet: they are always magnetic. On the other hand, metals like soft iron become magnets only when they are near a permanent magnet; they can become a temporary or induced magnet. Try hanging a paperclip from a magnet. While it is there, it will behave like a magnet and can be used to attract other paperclips.

In addition to each other, magnets also attract iron, cobalt, nickel and their **alloys**, such as steel (an alloy of iron).

Try this 2.8

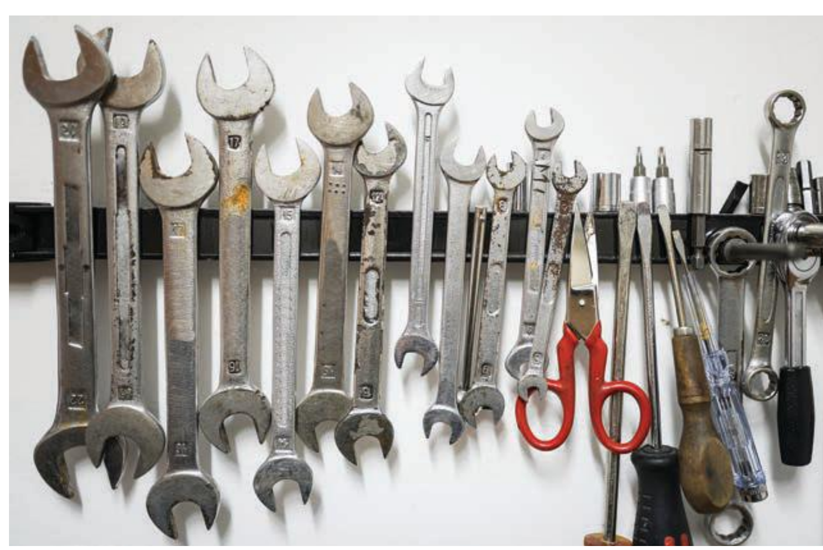
1. Which of the situations below display interactions between like poles?
2. Which situations display interactions between unlike poles?



Try this 2.9

Collect the following items: bar magnet, pencil, pen, paper, plastic straw, coins, paperclips, iron nail, metal spoon, aluminium foil, copper wire.

1. Hold the magnet close to each of the items and record whether they are attracted to the magnet. What do the objects attracted to the magnet have in common?
2. Using the bar magnet, carefully pick up paperclips one at a time, forming a chain of paperclips. How are you able to do this?



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The way that magnets exert their force is through **magnetic fields**, that is, the space around a magnet where the magnetic force acts. The magnetic field is a force field, like the gravitational field, although the two forces are different in most other respects. Look at Figure 2.51. You can see the iron filings are strongly attracted to the south pole of the magnet and, amazingly, they are lining up in a certain way. Your job in the following activity is to investigate and explore what the shape of this magnetic field is and how it changes with different shapes of magnets.

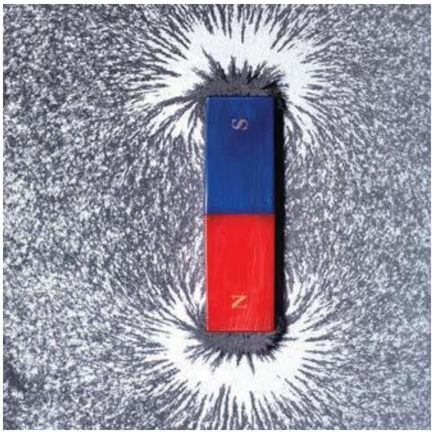

Figure 2.51 Magnetic fields around a magnet form a particular pattern.

magnetic field the space around a magnet where the magnetic force acts

Practical 2.6

Magnetic field lines

Aim

To visualise the shape of the magnetic field of different magnets.

Materials

- 2 bar magnets
- horseshoe magnet
- iron filings
- piece of A4 paper
- compass

Procedure

1. Place the bar magnet on a table and cover it with a piece of paper.
2. Sprinkle iron filings on the paper and look at the pattern formed.
3. Hold the compass at different points around the magnet. The direction that the compass points in indicates the direction of the magnetic field lines.
4. Repeat steps **1–3** with the horseshoe magnet.

Results

Draw a sketch of the pattern formed by the iron filings.

Discussion

1. Using your diagram, determine where the magnet's poles are.
2. Identify where the magnetic field appears to be the strongest.
3. Investigate different patterns formed with two or more magnets placed near each other.

Quick check 2.10

1. Explain why magnetism is considered a non-contact force.
2. Complete the following sentence: Opposite poles ___________ each other while poles that are the same ___________ each other.
3. Explain the difference between a permanent and a temporary magnet.
4. Describe a magnetic field. Draw a picture of the field around a bar magnet and indicate the direction of the magnetic field lines.

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Earth is a giant magnet with magnetic poles near the geographic poles. What is called the North Magnetic Pole is actually the south pole of Earth's magnetic field. A suspended magnet will turn until its north pole points geographically north, because of its attraction to the south pole of the internal Earth magnet. This is a property of natural magnets or lodestones and has been used by navigators for thousands of years.

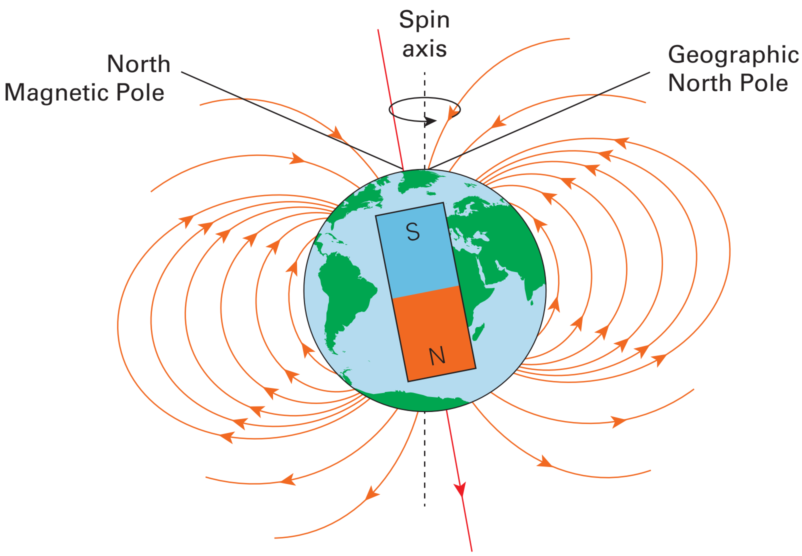

Figure 2.52 This diagram shows Earth's internal magnet. You can see that the south pole is equivalent to what geographers call the magnetic North Pole of Earth, which is close to the geographic North Pole. You know this because a compass always points north, and opposites attract, so the north of a compass is attracted to the south pole of Earth's magnetic field.

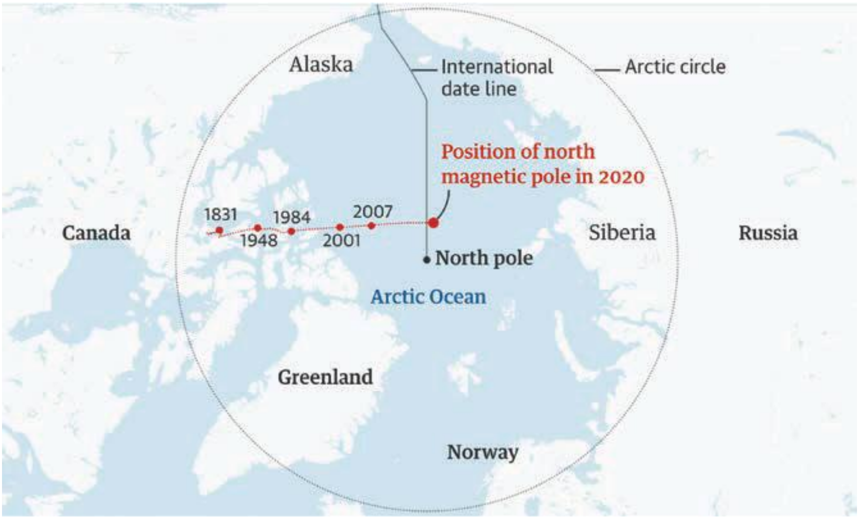

Figure 2.53 The North Magnetic Pole is rarely stationary, it is always slowly wandering or moving around. Recently, however, it has started wandering more quickly than usual. It is now moving about 55 km per year away from Canada towards Siberia in Russia. This is a problem because navigation relies on knowing where the North Magnetic Pole is.

Try this 2.10

Making a compass

Use a steel nail, a strong magnet, a piece of cork (or polystyrene foam) and a bucket of water to make a compass. Follow these instructions.

1 Stroke the steel nail with the strong magnet in one direction. After each stroke, be sure to lift the magnet away from the nail before your next stroke. Repeat this process about 50 times.
2 Test your nail to see if it has become magnetised by holding it near some paperclips.
3 Place the cork or polystyrene in the bucket of water. Then place the nail on top.
Identify which end of the nail is the north pole. How did you know this?
Check the accuracy of the homemade compass with an ordinary compass. Discuss the accuracy of the homemade compass. State one way in which the accuracy of the homemade compass could be improved.

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Did you know? 2.2

Sea turtles use Earth's magnetic field to find home

Female sea turtles always return to the beach where they were born to lay their own eggs. Sometimes this means swimming thousands of kilometres, and the way they do this is by relying on Earth's magnetic field. Scientists are unsure how turtles detect the magnetic field, but it is possible that tiny magnetic particles in their brains help the turtles navigate.

Figure 2.54 The sea turtle is guided along the coast by Earth's magnetic field.

Magnetism and electricity

Magnetism and electricity are closely related; wires carrying electricity create a magnetic field around them. Magnets called **electromagnets** are made by coiling a wire. When a battery is connected, the current flows along the wire, and a magnetic field is created. When the current stops, the magnetic field ceases. The strength of the field can be increased by wrapping the coil around a piece of iron.

electromagnet a magnet made by passing electricity through a coil of wire

Figure 2.55 How to make a simple electromagnet

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Practical 2.7

Making a simple electromagnet

Aim

To investigate how changing the number of coils on an electromagnetic will affect its strength.

Research question

How do the number of coils on an electromagnet affect its strength?

Be careful

Make sure you only turn on your electromagnet for a short time. If left on, it will get hot.

Materials

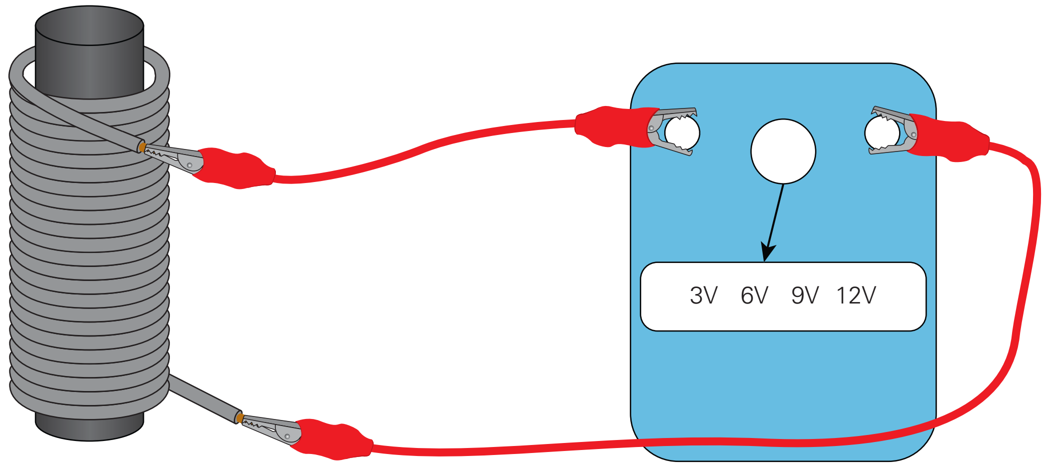
- 9 V battery or powerpack
- long nail
- compass
- 2 insulated wires with alligator clips (one short wire, one long wire)
- switch
- paperclips

Planning

1 You need to provide some background information to the investigation. Research electromagnets. Write a brief paragraph to explain how electromagnets work and the factors that can affect their strength.
2 Identify the independent variable in this investigation.
3 Identify the dependent variable in this investigation.
4 Develop a hypothesis by predicting how the independent variable will affect the dependent variable.
5 Identify the controlled variables in this investigation.
6 Create a risk assessment for this investigation.

Procedure

1 Draw the table shown in the results section into your science book.
2 Set the DC powerpack to 6 V and make sure the switch is OFF.
3 Carefully wrap the long wire around the nail 10 times, ensuring to only wind in one direction and avoiding any overlap of wires.
4 Connect the powerpack both ends of the long wire using the insulated wires with alligator clips.
5 Turn the powerpack ON.
6 Test your electromagnet by seeing how many paperclips it picks up. Record this number in the results table.
7 Retest the electromagnet two more times and record.
8 Repeat steps **2–7**, increasing the number of coils each time, according to the results table.



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...continued

Results

Independent variable: Number of coils	Dependent variable: Number of paper clips				
	Trial 1	Trial 2	Trial 3	Mean	Range
10					
20					
30					
40					

Use a spreadsheet application, such as Excel or Google sheets, to create a digital graph that displays the mean for each group. Label each axis appropriately and add an appropriate title.

Peer review

1 Swap graphs with a peer. Give each other feedback on how easily the graph can be used. Feedback should identify if the graph displays only the mean results, has appropriate labels, units and title, and any other features that could be improved to enhance how well the experimental results are communicated, such as scale or formatting.
2 After receiving feedback, make alterations to the graph to address the identified issues.

Discussion

1 Identify the trend in your graph.
2 Identify any outlier results in your graph.
3 Extrapolate your graph to find out how many paperclips could be picked up if there were 80 coils.
4 If you had any outlier results (ones that were much different from the others), explain how these may have been caused.
5 Describe how the investigation could be improved if you had the chance to do it again.

Conclusion

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

Explore! 2.4

Uses of magnets

You may not realise it, but electromagnets and permanent magnets are used everywhere and every day. Electric motors, door bells, computer hard drives, MRI machines, phone speakers and microphones, drills, hair dryers, bank cards and credit cards!

Research any two of these examples and write a short report on each. Include a picture and details of how an electromagnet or permanent magnet is involved in how the object functions.

Quick check 2.11

1 Discuss the reasons why we think that Earth acts like a big magnet.
2 Explain how an electromagnet is different from a bar magnet.
3 Name some examples of electromagnets used every day.
4 Describe the advantages of an electromagnet over a permanent magnet.

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Electrostatic forces

Try this 2.11

Take a piece of paper and rip it up into small pieces on your table. Rub a plastic pen against woollen material or a jumper. Bring the pen near the pieces of paper. What happens? Can you explain what you observe?

electrostatic force
a non-contact force between positive and negative charges, opposite charges attract, like charges repel

static electricity
a build-up of electric charge

The third non-contact force you need to know about is **electrostatic force**. This is that pesky force that can give you a small electric shock when you close a car door or drag your feet on carpet. It can be used to pick up pieces of paper with a balloon after rubbing it on your hair or clothes. On a much larger scale, electrostatic charges cause lightning to flash during a storm!

Like magnets, electrical charges attract and repel each other. There are two types of charge: positive (+) and negative (–). Opposite charges attract each other and like charges repel.

Like gravity and magnetism, objects with an electric charge also create a field around them. The electrostatic field is the region in which charged particles will feel the electrostatic force.

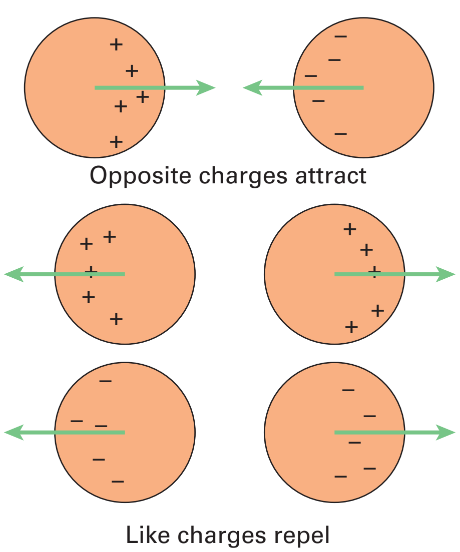

Figure 2.56 Forces between charges

Look at Figure 2.57. The machine the girl is touching is called a Van de Graaff generator, and essentially it separates positive and negative charges. The negative charges go down to the ground; meanwhile the positive charges in the metal dome stay in place. Because the girl is touching the dome, the negative charges from her hair flow to the dome, making her hair positively charged. Remember, like charges repel, so with all her hair turning positively charged, they all try to get away from each other!

So why do you get these small electric shocks after dragging your feet on the carpet? When electrical charges build up, like they do in the Van de Graaff generator, it is called **static electricity**. Usually this charge leaks away, but when it builds up a lot, the charge can jump to an object that conducts electricity like a metal door handle or stair railing. So dragging your feet on the carpet moves negative electric charges onto you; if they do not leak away they can jump to the door handle and this is the shock you feel.

Figure 2.57 Electrostatic forces can make your hair stand on end.

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Try this 2.12

Observing static electricity

Materials

- 2 balloons
- string
- a metre ruler
- woollen cloth

Instructions

1. Rub the inflated balloon with the woollen cloth and place it against a wall. Record your observations.
2. Suspend the balloon from the metre ruler using the string.
3. Suspend the second balloon so it is close to, but not touching, the first balloon.
4. Rub both balloons with the woollen cloth on the sides that are facing each other.
5. Record any observations of any movement in the balloons.

Evaluation

Discuss the following questions with your classmates.

1. What is the purpose of rubbing a balloon with a woollen cloth?
2. Did the balloon stick to the wall? Propose reasons as to why or why not.
3. Describe the movement of the two balloons when hung next to each other.
4. Does the movement indicate that the balloons had like or unlike charges? How do you know?

Explore! 2.5

Lightning formation

Lightning is a natural phenomenon. It is a sudden discharge of electrostatic charges that have formed in a cloud.

Research lightning to answer the following questions.

1. Describe how clouds become electrically charged.
2. Explain why the electrical discharge that causes lightning happens.
3. Are there any ways that the build-up of electrostatic charges in clouds can be avoided?

Figure 2.58 Fear of lightning and thunder is known as astraphobia.

Quick check 2.12

1. Define the key terms 'electrostatic force' and 'static electricity'.
2. Complete the following sentence: Opposite charges ______________ and like charges ______________.
3. Explain how a Van de Graaff generator works.
4. Explain why you sometimes get a small electric shock even though you have not touched a supply of electricity.

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Section 2.3 questions

QUIZ

Remembering

1 **Identify** which forces are acting on a dropped book that falls to the floor.
2 **Recall** the force which a magnet exerts.
3 **Identify** some objects which use electromagnets.
4 **Recall** three magnetic materials.
5 **Define** the term 'magnetic field' and illustrate with a picture.
6 **Identify** the two types of electric charge.

Understanding

7 A falling object is pulled down by Earth. Earth is pulled up toward the object. **Explain** why the movement of Earth cannot be detected.
8 **State** whether the mass of an object changes as it moves around the universe.
9 If you travelled to the Moon, **state** whether your weight would increase, decrease or stay the same.
10 **State** what your weight would be in deep space.
11 **State** which ball will hit the ground first: a wood ball, a plastic ball or a metal ball, if air resistance is ignored.
12 The north pole of a magnet points north if it is free to move. **Clarify** what magnetic pole must be near the North Pole.
13 **Distinguish** which types of forces have a force field.

Applying

14 **Calculate** the weight of a 5 kg cat on Earth (g = 9.8 N/kg) and on Mars (g = 3.7 N/kg).
15 Which would take longer to fall, a rock dropped from 1 metre on the Moon (gravity is about one-sixth of Earth's) or a rock dropped from 1 m on Mars (gravity is a little over one-third of Earth's)? **Explain** your answer. You can ignore air resistance on both planets.
16 **Describe** three situations where air resistance is useful and one situation where it is not useful.
17 **Summarise** how you can visualise the magnetic fields that surround a bar magnet.
18 Two balloons are hanging loosely near each other. One balloon is given a negative charge and the balloons start to move away from each other. **Explain** what is happening and what the charge on the other balloon must be.
19 **Describe** how charged objects and magnets are similar.

Analysing

20 Would a hammer and a feather hit the ground together if dropped from the same height at the same time on the planet Mercury where there is no atmosphere? **Justify** your answer.
21 **Examine** how a compass works. Why is it useful?
22 Parachutes have large pieces of material. **Explain** what the purpose of it is and distinguish between how it makes an object speed up or slow down.
23 Figure 2.59 shows a scientist inspecting seagrass. Around his waist he is wearing a heavy belt made of metal. Apply your knowledge of forces to **explain** the function of this belt.
24 Metal recycling takes place in most cities, and aluminium, copper and steel are the most common metals that are recycled. After collection, the first step is to flatten the metal and then cut it into small pieces. The second step is to separate the iron and steel from the aluminium and copper before finally melting the metals ready to be used again. **Identify** a way that could be used to easily carry out the second step.

Figure 2.59 Diver wearing a weight belt

Evaluating

25 **Evaluate** the effects of living in a low gravity environment for a long time.

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Chapter review

Chapter checklist

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

Success criteria		Check
2.1	**I can recall what a force is and how forces are measured.** e.g. State the unit of force.	
2.1	**I can describe the impact of balanced and unbalanced forces on an object.** e.g. If a car is travelling at a constant speed in a straight line down the Hume Highway, what can you infer about the drag and the force of the engine?	
2.1	**I can draw a force diagram to indicate the forces acting on an object.** e.g. Illustrate a force diagram of you running on the athletics track.	
2.2, 2.3	**I can describe the difference between contact and non-contact forces.** e.g. Identify two contact forces and two non-contact forces.	

SCORCHER

Reflections

1 What **connections** come to mind when you think about forces and your everyday life?
2 What new concepts have **extended** your thinking about forces?
3 What information did you find **challenging** or confusing?

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Data questions

Earth's Moon and the planets in our solar system have different forces of gravity on their surface than Earth because they have different masses. These forces of gravity on the surface of each are shown with respect to that of Earth in the graph below.

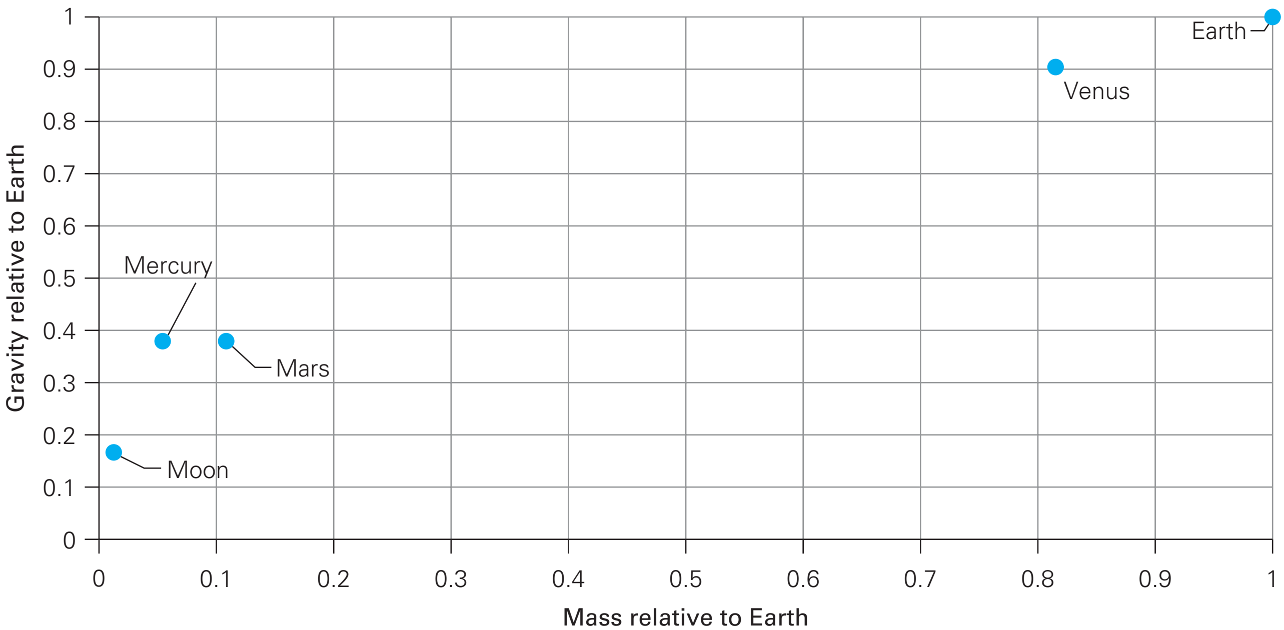

Figure 2.60 Gravity on the Moon and planets relative to that of Earth given their relative masses

1. **Identify** which planet in the graph has the lowest mass.
2. **Determine** which planet has a force of gravity closest to that on Earth.
3. If the acceleration of Earth's gravity is 9.8 m/s^2, and Mars' gravity is 38% of that of Earth, **calculate** Mars' actual gravitational force.
4. **Identify** the general relationship between the mass of a planet and the force of gravity.
5. Use the data presented in the graph to **contrast** the gravitational force of Earth and Mercury.
6. **Deduce** why the Moon orbits Earth, instead of Earth orbiting the Moon.
7. The mass of Jupiter is approximately 318 times that of Earth. **Predict** whether the gravitational force on Jupiter would be greater or less than that of Earth.
8. Among the planets shown, two of them are such that a person standing on their surface would weigh about the same. **Infer** which two planets they are.
9. Pluto has a relative force of gravity of 0.06 to that of Earth. Use the relationship identified in Question **4**, to **justify** that Pluto will have a mass less than that of Earth's moon.

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STEM activity: Designing and prototyping a ferry

Background information

Ferries are used worldwide to connect two or more points (e.g. Parramatta RiverCat or Sydney Ferries). They carry passengers, goods, and sometimes vehicles. Ferries are vital for transport in many developing countries, since highways are expensive to build and most waterways come free.

Ferries float in water as a result of buoyancy. Any object placed in water will either sink or float: if an object is denser than water, it will usually sink; and if it is less dense, it will float. But how can a steel ship, capable of carrying thousands of passengers and cars, float in the ocean when a metal ring or coin would sink in your bathtub?

It is time to investigate how design can affect the buoyancy of a ferry!

Figure 2.61 Ferries are part of the public transport system in many places in the world.

Design brief: Design and construct a ferry boat.

Activity instructions

In teams (maximum of three people), you will design and construct a ferry capable of transporting a payload (set mass) between two points (return trip). Your team has been assigned the task of designing and constructing a ferry for riverside communities to transport people and goods on the water.

As an engineer, you should investigate the science and technology of boats.

Suggested materials

- ruler and tape measure
- scissors
- cardboard
- bubble wrap
- plastic bags
- 5 × 100 g parcels of sugar/salt (payload)
- sticky tape (duct tape or gaffer tape would be good)

Research and feasibility

1 List the features that would make a useful boat.
2 Research the terms ‘density’ and ‘buoyancy’ and discuss in your group how these factors are important in boat design.

Design

3 Design a ferry that is capable of transporting your payload between two points and return.
4 Label and include measurements of your ferry.

Create

5 Build your ferry using the materials, checking as you progress that your ferry is capable of floating.

Evaluate and modify

6 Discuss the challenges you have encountered throughout this project with at least three of your peers. List the strategies or actions that allowed you to overcome it.
7 Create a list of improvements to your design that could be applied to this project to refine its performance.

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Chapter 3
Energy

Inquiry questions

Where does energy come from?
How is energy changed from one form to a more useful form?
How is energy made useful to meet our needs?

PRE-TEST

Chapter introduction

This chapter provides an introduction to the different forms of energy that we encounter in our everyday lives. Your senses can detect several types of energy – your eyes detect light, your ears detect sound, and your skin can feel hot and cold. You use your muscles to move, gaining kinetic energy, or to lift things, giving them gravitational potential energy. The food you eat contains chemical energy, which allows you to move and keep warm.

Our homes are full of machines that use energy for lighting, cooking, cleaning, heating, cooling and entertainment. You will learn about how energy can be converted from one form to another, always leaving the total amount of energy the same.

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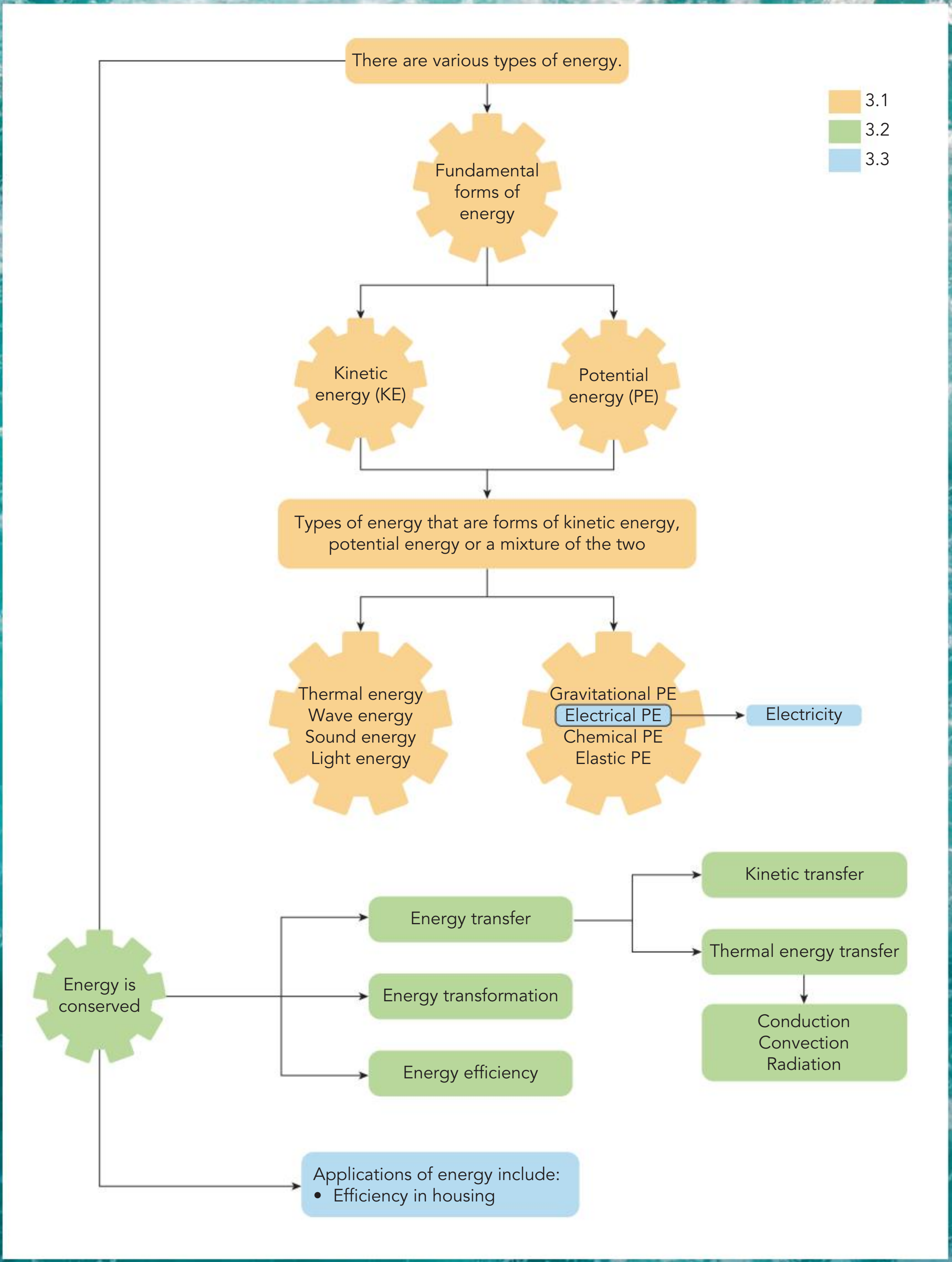
Chapter map



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3.1 What is energy?

Learning goals

1. To define energy and its units.
2. To identify the different types of energy.

DOC WORKSHEET

VIDEO Types of stored energy

Energy is the ability to do work or make things happen. It can't be created or destroyed; that is, the amount of energy in our universe is always the same. However, energy can change form, be transferred from one object to another, or it can be stored for later use. For all the different types of energy, the unit of measurement is the **joule** (J).

energy
the capacity to do work; the total amount of energy is conserved in any process

joule
the unit of energy or work done

kinetic energy
the energy of moving matter

potential energy
the energy stored in something because of its height above the ground, or because it is stretched or compressed, or in chemical form, etc.

There are just two fundamental forms of energy: **kinetic energy** and **potential energy**. All the other forms are one or other of these, or a mixture of the two.

Kinetic energy

The energy an object has when it is moving is called kinetic energy (KE or K). The amount of energy depends on the mass of the object and its speed.

Figure 3.1 Fast-moving cars have a lot of kinetic energy.

Potential energy

Some objects can store energy until it is ready to be used. This stored energy is called potential energy, because it has the potential to do work or make things happen. For example, a stretched rubber band has stored elastic potential energy. The energy is not being used at that point, but it has the potential to make something happen. Some forms of stored energy are summarised in Table 3.1.

Form of potential energy	Description
Gravitational potential energy (GPE or U_g)	Energy stored when an object is lifted off the ground; energy released when the object falls
Electrical energy	Energy stored in electrostatic situations (e.g. thunderclouds, capacitors); energy released when current flows (includes sparks like lightning)
Chemical potential energy	Energy stored in chemicals such as fuel and in batteries (when connected to an electric circuit, the chemical energy is converted to electrical energy)
Elastic potential energy	Energy stored when an object is stretched or compressed; energy released when an object returns to its original size and shape
Nuclear energy	Energy stored in unstable (radioactive) atoms; energy released when atoms decay or undergo fission or fusion in unstable (radioactive) atoms

Table 3.1 Potential energy is a form of energy that can be stored.

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Forms of energy we can detect with our senses

We can detect kinetic energy with our senses, and other types we can sense are listed in Table 3.2.

Form of energy	Description
Thermal energy	Energy in an object due to the random motion of its particles
Wave energy	Energy carried by a wave
Sound energy	Energy carried by a sound wave
Light energy	Energy carried by light waves (electromagnetic energy)

Table 3.2 Types of energy, other than kinetic energy, that we can sense

Forms of energy

Thermal energy

Heat is related to the vibration and movement of the particles of matter. So heat is related to the kinetic energy of particles of matter. In this chapter, we will use the more technical term for 'heat' and that is **thermal energy**. To change an object's **temperature**, thermal energy needs to be either added (to raise it, i.e. heating) or removed (to lower it, i.e. cooling). The amount of thermal energy in an object depends on three things:

- temperature – objects with higher temperature have more thermal energy than identical cold objects
- mass – large objects at a lower temperature can have more thermal energy than small objects at high temperatures
- material – some materials are better at storing thermal energy than others.

The total thermal energy depends on all three factors. For example, a warm bath contains a lot more thermal energy than a burning match. This is because, even though the match has a higher temperature, the hot bath is much bigger, and water is very good at storing thermal energy.

Increasing the temperature of water is one of the most expensive energy costs in the home, because heating water requires a lot of energy.

heat
thermal energy that is in transit due to differences in temperature

thermal energy
the energy contained within a material that is responsible for its temperature

temperature
a measure of the average random kinetic energy of the particles in a substance

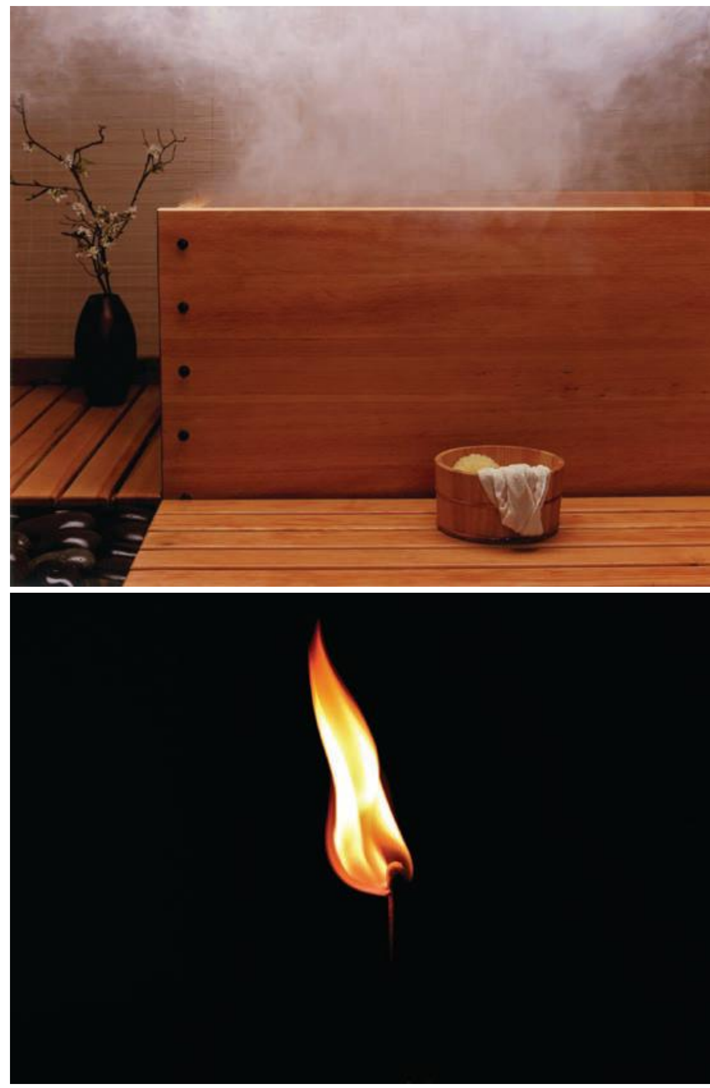

Figure 3.2 A warm bath contains more thermal energy than a burning match.

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Practical 3.1

Investigating thermal energy

Aim

To investigate the thermal energy of different volumes of water.

Materials

- glass beaker
- Bunsen burner
- gauze mat
- tripod
- heatproof mat
- thermometer
- beaker tongs

Be careful

Ensure safety equipment is worn at all times. Do not lean over or touch the beaker once it has been heated.

Planning

1 Write a rationale about thermal energy.
2 Write a specific and relevant research question for your investigation.
3 Identify the independent, dependent and controlled variables.
4 Write a hypothesis for your investigation.
5 Write a risk assessment for your investigation.

Procedure

1 Put 200 mL of water in a beaker and measure the temperature. Record this in your results table.
2 Heat this water using a Bunsen burner for 1 minute. Refer to Practical 1.2 for guidance on how to set this up.
3 Stir the water and measure the final temperature after it has been heated. Record in your results table.
4 Repeat steps **1–3** using 300 mL, 400 mL and 500 mL of water. Make sure the glass beaker is cooled between experiments, so that the initial temperature is the same. It might save time to start with four identical beakers with water at room temperature.

Results

1 Complete the following table with your results.

Volume (mL)	Initial temperature (°C)	Final temperature (°C)	Change in temperature (°C)	Energy (J)
200				
300				
400				
500				

2 Calculate the thermal energy in each volume of water by using the equation:
Thermal energy = mass in kg × specific heat capacity × change in temperature
The specific heat capacity of water is 4200 J/kg/°C.

Discussion

1 Describe any patterns, trends or relationships in your results.
2 Explain any trends you have identified.
3 How did the change in temperature differ between volumes of water?
4 Complete some research regarding specific heat capacity. What do you think would happen if a different liquid was used? Explain the reasoning behind your prediction.
5 Identify any limitations in your investigation.
6 Propose another independent variable that could have been tested, to expand on your results.
7 Suggest some improvements to this experiment.

Conclusion

Draw a conclusion from this experiment, using data to support your statement.

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Quick check 3.1

1 Recall the unit for energy.
2 Look at Figure 3.3 and identify some of the different forms of energy you can see.

Figure 3.3 Birthday parties always involve energy!

3 Define the term 'thermal energy'.
4 Recall three factors that the total thermal energy of any object depends on.
5 Explain why a warm bath contains more thermal energy than a burning match.

Wave energy

Water waves carry **wave energy** as the waves move on the surface of the water. The waves can vary in size from small ripples formed when a stone is thrown into water, all the way up to ocean swell – long waves that travel along the surface of the ocean. Because waves in water are generally able to move from place to place, they are called **travelling waves**.

wave energy
the energy carried by a travelling wave (e.g. an ocean swell) or trapped in a standing wave (e.g. a guitar string)

travelling wave
a wave that can carry energy from one place to another

sound energy
a form of travelling wave; sound consists of vibrations in the air

Waves can travel underground after an earthquake. They occur when the ground suddenly moves, and can transmit a huge amount of energy.

Sound energy

Sound energy is a form of wave energy; it consists of vibrations in the air.

Figure 3.4 Water waves can have a lot of energy.

Figure 3.5 Major earthquakes can cause severe damage to infrastructure, like this road in New Zealand.

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Advances in science 3.1

Printing using sound

Researchers at Harvard University have developed a method of printing using sound waves. The researchers used sound to control the size of the droplet being ejected from the printer nozzle, regardless of the viscosity (thickness) of the liquid. A higher amplitude of sound wave makes a smaller droplet. A wide range of liquids can be used, which means this technology has applications in many different industries, from pharmaceuticals to food.

Figure 3.6 Using sound waves in printing

Quick check 3.2

1. Provide five examples of objects that could have kinetic energy.
2. Give two types of wave energy.

Light energy

Light energy is a kind of wave that is in the visible part of the **electromagnetic spectrum**. Light can travel through air or through a vacuum (such as space).

Did you know? 3.1

Light waves

A light wave is made up of energy in the form of magnetic and electric fields. These fields vibrate at right angles to the wave's direction of movement and at right angles to each other.

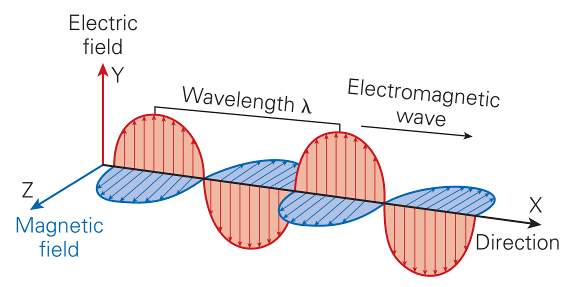

Figure 3.7 A light wave has an electric field and a magnetic field.

Gravitational potential energy

When an object is lifted, it gains **gravitational potential energy**. 'Gravitational' means the energy related to Earth's pull, and 'potential' means the energy is stored for later. Gravitational potential energy (GPE or U_g) depends on three things: the strength of gravity, the mass of the object, and the height the object is lifted. As an object loses gravitational potential energy, it begins to move because it gains kinetic energy.

light energy
a form of energy that we can see with our eyes; also called visible light; a part of the electromagnetic spectrum

electromagnetic spectrum
a way of organising electromagnetic waves according to their frequency

gravitational potential energy
a type of potential/stored energy; the energy an object has because of its height; GPE = mgh where m is the mass of the object in kg, g is acceleration due to Earth's gravity and h its height in metres

Figure 3.8 Rock climbers gain gravitational potential energy as they climb.

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Did you know? 3.2

Tiny charges

An electron is so small that the unit we use for charge represents 6.24 million million million electrons.

Electrical energy

Electrical energy is carried by tiny, negatively charged particles, called *electrons*, that can move from one atom in a wire to the next, carrying energy as they do. Voltage (V) is related to the amount of electrical energy each electron carries. For example: AAA batteries supply 1.5 joules of electrical energy per unit of charge, so they have a voltage of 1.5 volts; mobile phones operate at 5 volts; car batteries are 12 volts; in Australia, electricity in the home is 230 volts.

electrical energy energy carried by electricity moving in a wire; voltage is used to measure how much energy is carried by each unit of electricity

chemical potential energy the energy stored in the bonds between atoms

Chemical potential energy (chemical energy)

Many substances contain stored **chemical potential energy**, which can be released in a chemical reaction. Here are two examples you are familiar with.

- When fireworks are lit, chemical potential energy is released as heat, sound and light.
- The food we eat contains chemical potential energy, which is released slowly in our bodies, giving us the energy we need to keep warm and move around.

Quick check 3.3

1 State some types of energy that can be stored.

2 Look at the following image of a playground. Explain where you would stand to have the greatest gravitational potential energy.

Figure 3.9 Where is GPE greatest?

3 Figure 3.10 shows a roller-coaster. Roller-coasters are a great example of GPE. Answer the following questions, remembering that as an object loses GPE, it gains KE (kinetic energy).

  a Identify the position (A, B, C, D or E) where the cart would have the greatest GPE.

  b Identify the position where the cart would have the greatest KE.

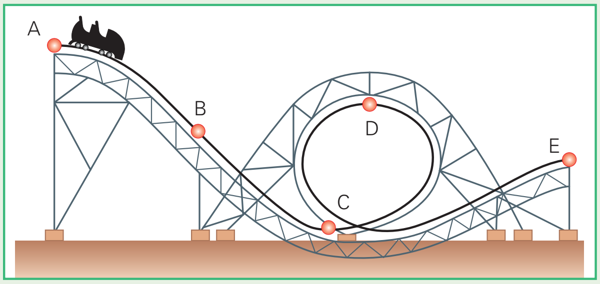

Figure 3.10 A roller-coaster

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elastic potential energy the energy stored when an elastic material is compressed or stretched

nuclear energy a non-renewable source of energy that uses the energy released by the nucleus of radioactive atoms

radioactive having or producing the energy that comes from the breaking up of atoms

Elastic potential energy

Elastic potential energy is energy that is stored whenever an elastic material is either stretched or compressed by a force. For example, energy is stored in a rubber band when it is stretched, and in a rubber ball when it is compressed. Trampolines, bungee cords and metal springs are all examples of objects that can store elastic energy.

Figure 3.11 New Year's Eve fireworks in Sydney

Try this 3.1

Investigating energy with a bouncy ball

Take a bouncy ball and hold it higher than your head. Allow the ball to fall onto the floor and continue bouncing until it comes to rest.

Describe the transformations involved as GPE changes to KE until the ball stops. Explain where elastic potential energy fits in.

Try this 3.2

Exploring elastic potential energy

Take a rubber band and stretch it as tightly as possible. Explain how the stretched rubber band is an example of potential energy. Point the rubber band at the wall and let it go. Explain how the potential energy stored in the band was converted to a different form of energy.

Nuclear energy

The *nucleus* (plural *nuclei*) of an atom contains **nuclear energy**, a form of potential energy. Most nuclei are stable and don't release energy, but the **radioactive** nuclei of some elements break down, emitting electromagnetic wave energy and/or particles with kinetic energy. The energy released shows up as a change in temperature when absorbed by the surrounding material.

Figure 3.12 A bungee cord stores elastic potential energy when it is stretched.

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Quick check 3.4

1 State two examples of chemical potential energy.
2 Explain what is happening to a material if elastic potential energy is being stored.
3 Explain where nuclear energy comes from.

Try this 3.3

A world without energy

Think about a world in which there is no electrical energy. Suppose there was no light or sound energy either. Could life exist in such a world? Write down a few sentences to say if you think it could, and what it would be like. Now imagine that there is no potential or kinetic energy of any type. What would that world be like? Discuss and collate your ideas as a class and see if you agree.

Section 3.1 questions

QUIZ

Remembering

1 **Identify** the missing words in the table below.

Form of energy	Definition	Is this an example of potential energy?
Kinetic energy		
	Energy an object possesses when it is lifted	
Chemical potential energy		Yes

2 **Describe** a situation that involves elastic potential energy.
3 **Describe** how sound energy travels.
4 **Recall** the three factors that determine how much thermal energy is present in an object.

Understanding

5 **Identify** the forms of energy contained in a piece of wood.
6 **Identify** the forms of energy a piece of wood gives out when it burns.
7 **Explain** what is meant by the term 'potential energy'.
8 **Explain** why it is harder to stop a bicycle when it is going downhill than when it is going uphill.
9 **Identify** the form of energy other than heat gained when a person climbs stairs (Figure 3.13).
10 **Name** the forms of energy emitted by lightning (Figure 3.14).
11 **Describe** a form of energy that is *not* a form of wave energy.
12 **Outline** the forms of energy possessed by a hot air balloon when it is aloft (Figure 3.15).
13 **Identify** the main form of energy that peanuts contain.

Figure 3.13

Figure 3.14

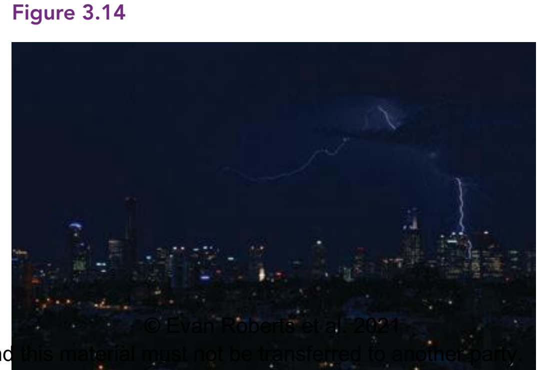
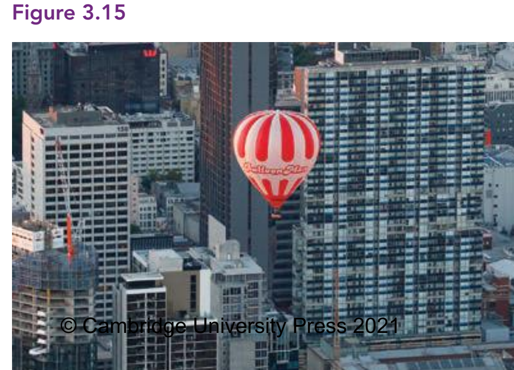


Figure 3.15



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Applying

14 Look at the diagram in Figure 3.16 and use it to answer the following questions.

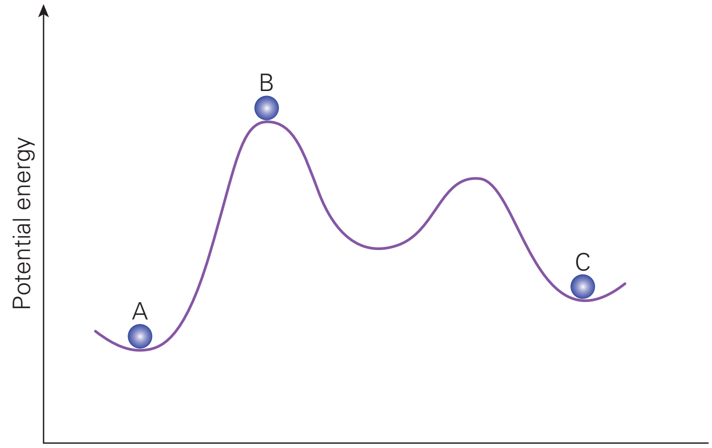

Figure 3.16 Positions of a ball above the ground

a **Determine** the letter that represents the position where the ball has the most GPE.

b If the ball moved from C to A, **determine** whether there would be an overall gain or loss of GPE.

15 **Explain** which balloon in Figure 3.17 has the most elastic potential energy.

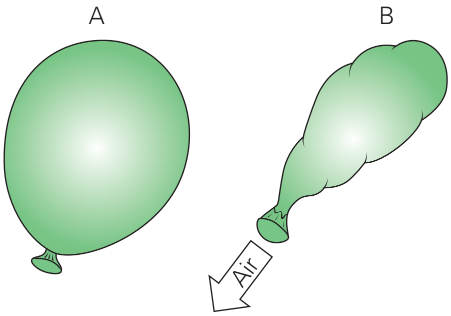

Figure 3.17

Analysing

16 **Analyse** the following list of energy sources, and rank them from most used to least used in your household.

- Electrical energy
- Chemical energy
- Sound energy
- Light energy
- Thermal energy

17 **List** all the different forms of energy that you can see evidence of in Figure 3.18.

Evaluating

18 **List** the devices in your home that use energy, two devices that don't use electricity, and at least one manual (unpowered) device. For each device, state the form of energy used as the input and the forms of energy that they output as well as the wasted energy outputs.

Figure 3.18

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3.2 Energy transfer, transformation and efficiency

Learning goals

1 To identify that energy can be passed from one object to another.
2 To understand that energy can change forms, giving examples.

WORKSHEET

Objects possess energy, and energy can be changed from one form to another. When energy changes from one form to another, it obeys the **law of conservation of energy**: energy can neither be created nor destroyed. In any process, the amount of energy present at the beginning must equal the amount of energy present at the end. In everyday life this law always holds. But energy is also lost when it is transformed from one form to another form. The process of transforming energy from one form to another form is not efficient, there is always some energy lost.

Figure 3.20 When a golfer hits a golf ball, they transfer kinetic energy from the golf club to the ball, causing the ball to move.

Quick check 3.5

1 State the law of conservation of energy.
2 In your own words, describe how this law applies in everyday life.

Figure 3.19 City lights in Sydney. The law of conservation of energy means the amount of electrical energy used by each light is exactly the same as the amount of light energy and thermal energy given out.

Energy transfer

law of conservation of energy the law that states that energy cannot be created or destroyed

energy transfer the movement of energy from one place or object to another

Kinetic transfer

Energy is the ability of an object to do work, and this energy can be transferred from one object to another. This is known as an **energy transfer**.

Heat transfer

Thermal energy is another type of energy that can be transferred. Heat is the term given to thermal energy in transit. If an object of high temperature is placed next to an object of lower temperature, heat will flow from the object of higher to that of lower temperature. This will continue until the objects are the same temperature. This flow of energy is always from high to low temperature, never the other way around.

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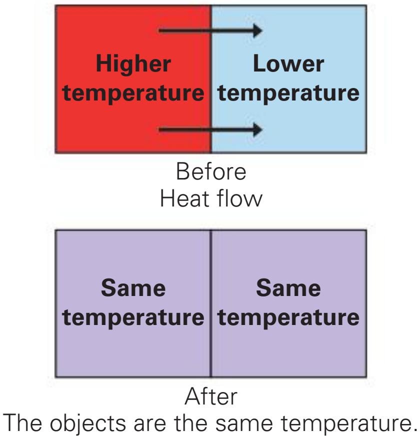

Figure 3.21 Heat (thermal energy in transit) flows from an object of higher temperature to one of lower temperature, until the objects are at the same temperature.

There are three ways heat can be transferred.

1 Conduction

Heat transfer through solid objects is called conduction.

Conduction occurs when a solid is heated. The particles where the object is being heated gain energy and begin to vibrate more rapidly. These particles bump into neighbouring particles, transferring energy, which causes them to vibrate more. This continues until the thermal energy is spread throughout the solid object, causing the cooler section to warm.

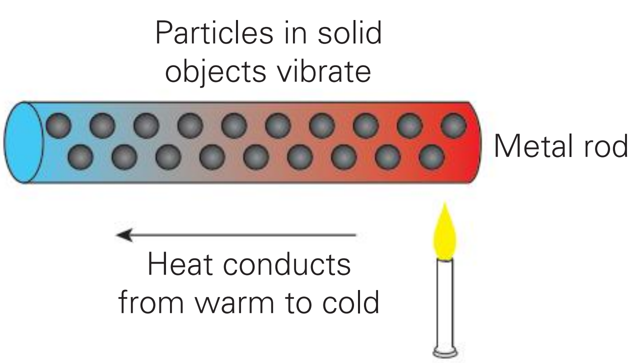

Figure 3.22 As the metal rod is heated, the particles begin to vibrate more rapidly, bumping into the nearby particles, making them move faster too. This allows heat to flow along the metal rod.

2 Convection

Heat transfer through a fluid, liquids and gases, is called convection.

Convection occurs when a fluid is heated and the warmer particles rise, while the cooler particles sink or fall. This creates currents in the fluids known as convection currents. This is happening in the atmosphere all the time as the Sun warms the air, and it is how sea breezes are formed.

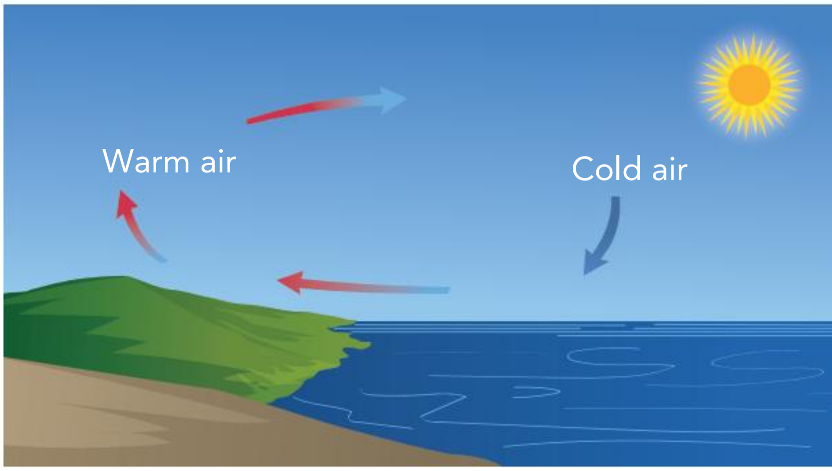

Figure 3.23 How an afternoon sea breeze is caused by convection

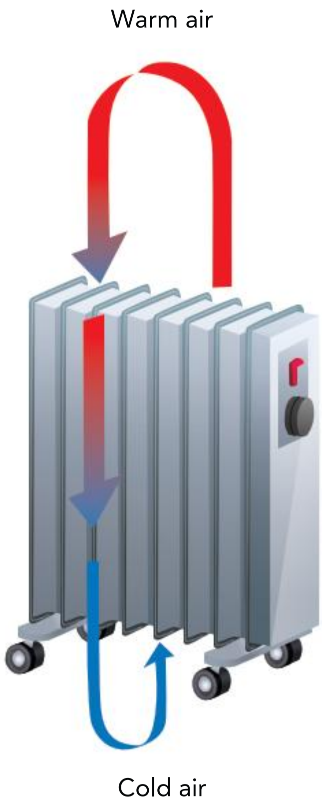

Figure 3.24 A convector heater warms a room by passing cool air from the bottom over heating elements, releasing warm air out the top.

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Practical 3.2

Heat transfer by conduction

Be careful

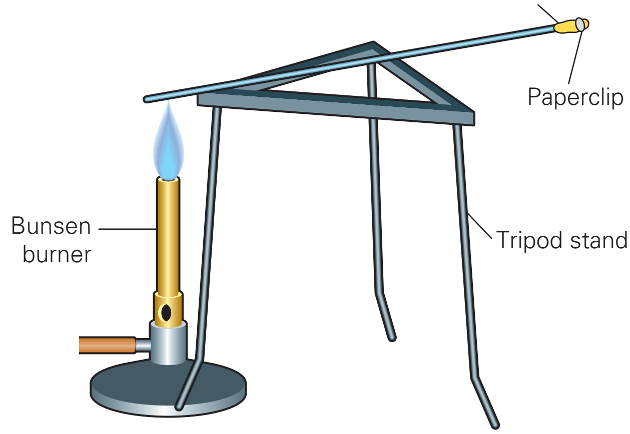
Do not touch the metal rods when they are hot. Allow time for cooling. Ensure appropriate personal protective equipment is worn.

Aim

To determine which type of metal transfers heat the quickest due to conduction.

Materials

- 4 metals rods made from different metals, e.g. iron, copper, aluminium, brass, zinc.
- Vaseline or melted wax
- timer or stopwatch
- paperclip
- tripod
- Bunsen burner



Procedure

1. Attach a paperclip to one end of each metal rod using Vaseline or melted wax.
2. Carefully balance one rod on the tripod so that the end without the paperclip is over the Bunsen burner.
3. Light the Bunsen burner.
4. Time how long it takes for the paperclip to fall from the end of the rod.
5. Record your results.
6. Repeat steps **2–5** for the other rods.

Results

Name of metal	Time for paperclip to fall (seconds)
1	
2	
3	
4	

Discussion

1. Identify the dependent and independent variables of your results.
2. List the controlled variables.
3. Why does the Vaseline or wax melt?
4. If you were to repeat this investigation, what changes would you make?
5. List the metals in order of how fast they conducted heat.

Conclusion

Write a statement that summarises your findings.

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Practical 3.3: Teacher demonstration

Heat transfer by convection

Aim

To observe convection currents in water.

Be careful

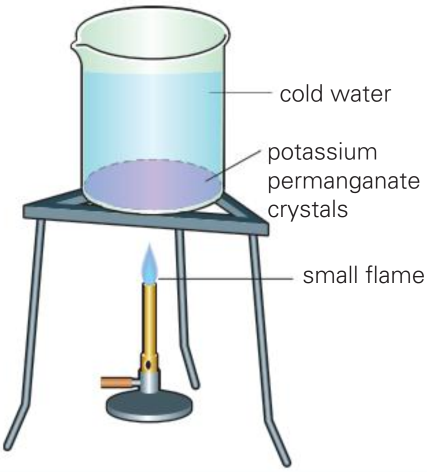
Ensure appropriate personal protective equipment is worn. Ensure Potassium permanganate is not disposed of down the drain.

Materials

- potassium permanganate crystals (grains of rice work as well)
- beaker or conical flask
- tripod
- Bunsen burner

Procedure

1 Set up your materials as shown in the diagram.
2 Light the Bunsen burner and gently heat the water.
3 Observe the motion of the coloured water.



Results

Record your observations in words and draw a series of sketches (or take photos).

Discussion

How does this activity demonstrate heat transfer by convection?

3 Radiation

Radiation is a form of heat transfer that does not rely on particles to be transferred. In other words, it can travel through space. All objects transfer some heat by radiation, even your body emits radiation thermal energy. The hotter an object is, the more heat it radiates. The radiation itself is not hot, but when an object absorbs the radiation, it causes particles in the object to vibrate quicker therefore heating the object. Warm objects usually radiate heat as infrared radiation. Heat from the Sun is an example of heat transfer by radiation.

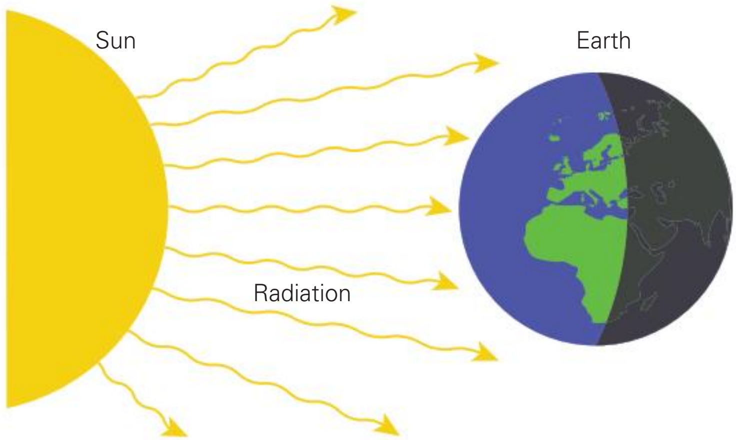


Figure 3.25 Heat transfer from the Sun by infrared radiation

The three different types of heat transfer do not have to occur in isolation from the other types.

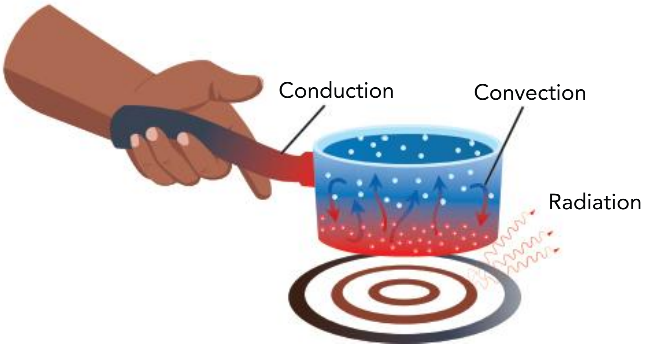


Figure 3.26 An example of the three forms of thermal transfer in the one situation

Quick check 3.6

1 Describe how heat is transferred in a liquid.
2 Give one example of heat transfer for each of the following: conduction, convection and radiation.

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Practical 3.4: Teacher demonstration

Heat transfer by radiation

Aim

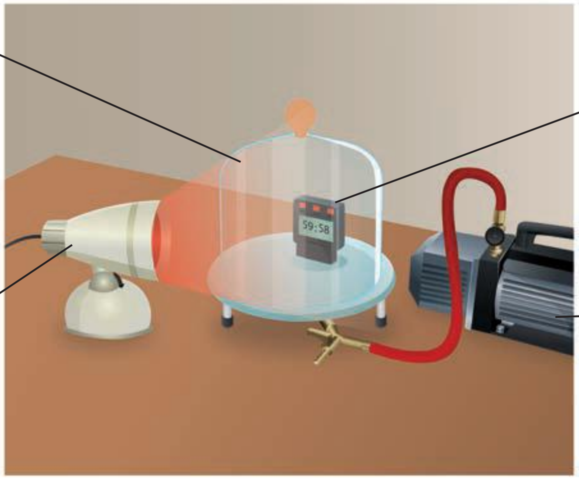
To demonstrate the transfer of thermal energy by radiation.

Materials

- infrared heat lamp
- digital thermometer (with large screen)
- vacuum chamber with vacuum pump

Procedure

1. Set up the vacuum chamber with the digital thermometer inside.
2. Take a reading from the thermometer.
3. Seal the chamber and start the pump.
4. Allow time for air to be removed from chamber.
5. Turn on the infrared lamp and aim it at the thermometer.
6. Record the temperature every 5 minutes for a whole lesson.



Result

1. Record your results below.

Time (min)	Temp (°C)	Time (min)	Temp (°C)
0		25	
5		30	
10		35	
15		40	
20		45	

2. Plot a line graph of the results.

Discussion

1. Which measurement is the dependent variable and which is the independent variable?
2. How does this demonstration show heat transfer by radiation?
3. Can you think of another way of showing heat transfer by radiation?

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Energy transformations

There are many ways in which energy can be converted from one form to another. This is called energy transformation.

Energy transformations can be represented in a flow diagram (see Figure 3.27). On the left-hand side of the flow diagram are the energy inputs. On the right-hand side are the energy outputs. **Waste energy** may be included as an energy output, but is sometimes omitted.

waste energy
the output energy that a machine creates that is not useful; waste energy is often in the form of thermal energy and sound

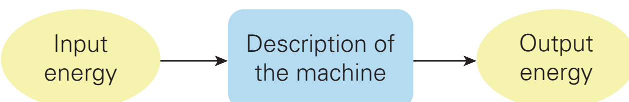

Figure 3.27 A simple energy flow diagram

For example, Figure 3.28 shows the energy flow diagram of plants converting radiant energy from the Sun into chemical energy (glucose).

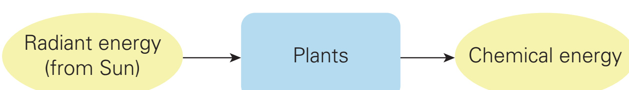

Figure 3.28 Energy flow diagram of photosynthesis in the leaves of plants. The chemical energy is stored as glucose.

useful energy
the output energy that a machine is designed to produce; an efficient machine will maximise the useful energy it creates

An electric light uses electrical energy to create light as useful energy; any thermal energy produced is waste energy.

A petrol-driven lawnmower converts chemical energy in the petrol into kinetic energy and rotational kinetic energy, with thermal energy and sound as waste forms of energy.

Figure 3.29 The chemical energy in petrol is converted into kinetic energy to move the lawnmower.

A two-step example is a battery-powered torch (see Figure 3.30). The input energy source is chemical potential energy in the battery. This is converted first to electrical energy and then to light energy in the bulb, with some waste thermal energy also.

Useful energy is the output energy the process is designed to produce. Waste energy is any other form of energy, usually thermal energy or sound, that is not wanted.

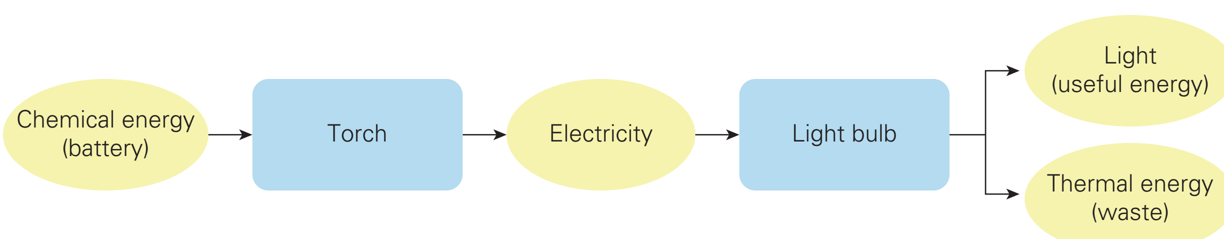

Figure 3.30 An energy flow diagram of a battery-powered torch

WIDGET
Energy forms and transformations

Quick check 3.7

1 Draw flow diagrams for the following energy transformations and indicate the waste energy.
   a A television converting electrical energy to sound, thermal and light energy
   b A light bulb converting electrical energy to light and thermal energy
   c A human converting chemical potential energy from food into kinetic energy and thermal energy when moving.

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Energy efficiency

The **efficiency** of a machine is a measure of how good the machine is at converting the input energy to useful energy. The percentage of input energy that is converted to useful energy is used to give a machine an efficiency rating. The formula used to calculate the efficiency rating is:

$$\text{Efficiency (\%)} = \frac{\text{useful output energy}}{\text{input energy}} \times 100$$

Figure 3.31 Running upstairs converts chemical energy into KE. Once the women reach the top of the stairs, energy has been converted to GPE.

Examples of efficiency calculations

efficiency
the percentage of input energy that is converted to useful energy by a machine

Example 1

A kettle uses 261 500 J of electrical energy to heat 500 mL of water. If the thermal energy of the water is 209 200 J, calculate the efficiency of the kettle.

$$\text{Efficiency (\%)} = \frac{\text{useful output energy}}{\text{input energy}} \times 100$$
$$= \frac{209\,200}{261\,500} \times 100$$
$$= 80\%$$

Example 2

A girl runs upstairs and uses up 4000 J of energy from food she has eaten. If she gains 1000 J of gravitational potential energy, calculate the efficiency of her muscles.

$$\text{Efficiency (\%)} = \frac{\text{useful output energy}}{\text{input energy}} \times 100$$
$$= \frac{1000}{4000} \times 100$$
$$= 25\%$$

The other 75% would be waste energy, lost mainly as thermal energy as she climbs.

Try this 3.4

Calculating energy efficiency

Calculate the energy efficiency of each of the globes shown below. State which globe is no longer recommended for household use, and justify your choice.

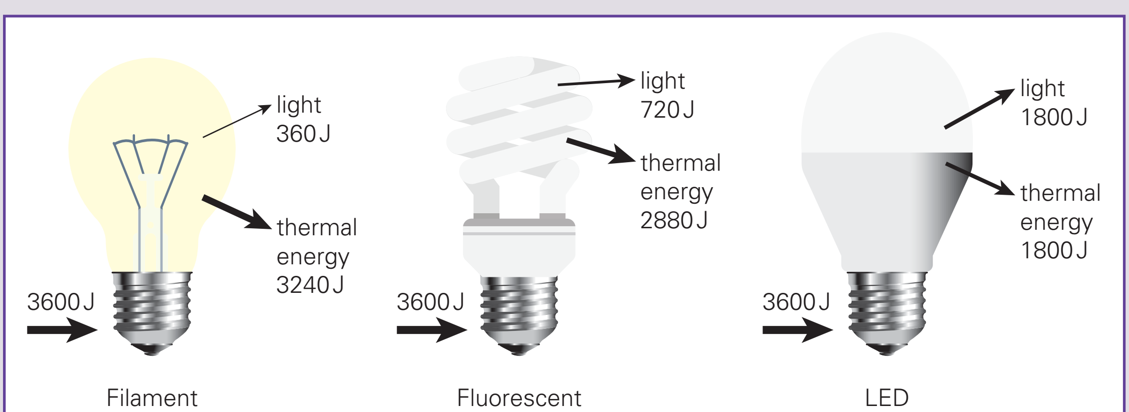

Figure 3.32 How efficient is each type of globe?

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Did you know? 3.3

Efficient light globes

Old-fashioned incandescent light bulbs work by passing electricity through a thin metal filament, which glows white hot. However, about 90% of that electrical energy is transformed into thermal energy. These days, compact fluorescent lights (CFLs) and light-emitting diodes (LEDs) are more efficient. About 50% of the electrical energy is wasted as thermal energy.

Quick check 3.8

1 Define the term 'energy efficiency'.
2 State an example of the useful energy and waste energy produced by each of the following devices.

Device	Useful energy output	Waste energy output
Light bulb		
Car		
Lawnmower		

3 A light bulb uses 3000 J of electrical energy. Of this, 600 J is transformed into light energy and 2400 J is transformed into thermal energy. Calculate the energy efficiency of this globe.

Practical 3.5

Energy efficiency of bouncy balls

Aim

To investigate which type of bouncy ball is most energy efficient.

Materials

- a range of bouncy balls (sizes, brands, etc.)
- metre rulers

Procedure

Design an experiment that will test the rebound height of a range of bouncy balls. In a group, discuss how you will carry out this experiment, and write out a step-by-step procedure.

Results

1 Draw a results table for your experiment.
2 Produce a suitable graph for your experiment.

Discussion

1 Calculate the efficiency of each type of ball using the drop height and the rebound height.
2 Identify sources of uncertainty in your experiment.
3 Suggest how your experiment may be improved.

Try this 3.5

Home electricity audit

Use the Australian Government's 'Energy rating calculator' website to audit the energy efficiency of appliances around your house. You may choose to investigate your TV, washing machine, dishwasher or fridge. Compare how much it costs to run each appliance for a year.

In your classroom, is one appliance consistently more efficient than others?

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Section 3.2 questions

QUIZ

Remembering

1 **Describe** the difference between an energy transfer and an energy transformation.
2 **Recall** the three ways in which heat can be transferred.
3 **Identify** the words that will complete the following sentences.
Heat naturally moves from a ____________ object to a ____________ object.
A liquid or gas is generally heated through the process of ____________. Heat moves through ____________ in a process called conduction.

Understanding

4 Using the law of conservation of energy, **explain** why thermal energy from a light bulb is considered as wasted energy.
5 **Explain** how the Sun's thermal energy reaches Earth, if space is a vacuum.
6 **Explain** why the process of convection is important in nature.
7 **Describe** the energy transformation that occurs in photosynthesis.

Applying

8 **Draw** or **describe** the energy flow diagram for each of the following situations.
  a A stone is dropped from the top of a building.
  b A car is slowing down as it moves up a hill.
  c A charcoal fire is burning in a barbeque.
  d A bungee jumper jumps from the top of the jump to the bottom.
  e An electric tram starts from rest and builds up to full speed.
  f A person rides on an escalator from the bottom to the top.
  g A sheepdog runs up a hill.
9 **Sketch** a diagram to show the three ways heat can be transferred.

Analysing

10 Think about all the different types of energy we encounter every day – driving a car is one example. Pick another example and **suggest** how you can make the process more energy efficient.
11 Look closely at Figure 3.33.
  a **Identify** the components of the playground that involve gravitational potential energy.
  b **Suggest** ways in which elastic potential energy could be incorporated into this playground setting.

Figure 3.33

Evaluating

12 Energy wastage occurs when energy is transferred from one type to another. For example, an incandescent light bulb takes in electrical energy and gives off light, but heat is also produced as a waste energy. **Propose** some ways that waste energy could be made useful.

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3.3 Electricity

Learning goals

1 To identify electric charges and their characteristics.

2 To understand the components of electric circuits.

Figure 3.35 Lightning over Parramatta Stadium. Lightning is a form of static electricity. How does it form?

Electric charges

WORKSHEET

As you know from your previous studies, atoms consist of a large nucleus containing protons and neutrons, and orbiting this nucleus are negatively charged particles called electrons. When looking at electricity it is these electrons we are interested in.

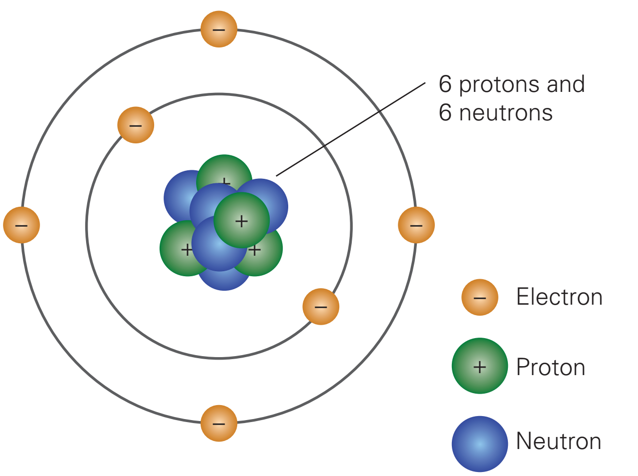

Figure 3.34 Model of an atom

Particle	Location	Electric charge
Proton	In the nucleus	Positive (+)
Neutron	In the nucleus	Neutral (0)
Electron	Orbiting the nucleus	Negative (–)

Table 3.3 The characteristics of subatomic particles

Electrons can be held loosely in their orbits around the nucleus, and therefore move easily in some materials. Most objects start off with a neutral or no electric charge but can be electrically charged by adding or removing electrons.

Static electricity

You may have experienced the movement of electric charges if you have been 'zapped' when getting out of a car, or sometimes you may notice crackling when removing a jumper or clothes. Electric charge can build up when objects rub against each other – electrons are collected together. This build-up of electric charge is called static electricity. The electric charges remain stationary or stored in the object until they are released by something or someone touching the charged object, allowing the charges to move.

Everyday static electricity uses

Static electricity may seem like an annoying thing but it does have its uses.

Cars and other metal surfaces are spray painted in a process that uses static electricity. The paint is given an electric charge as it enters the paint spray gun. A fine spray of paint is then directed towards the metal surface, which has been oppositely charged.

The paint is attracted to the metal surface and sticks to it. Once dried it gives a much smoother and even finish to the paint.

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This method of painting has a number of advantages – it is cleaner, there is less wastage of paint and less skill is needed by the painter.

Figure 3.36 Spray painting the hood of a car

Quick check 3.9

1 Name and describe the three parts of an atom.
2 Describe how static electricity can be useful.

Electric charge reactions

Objects that have the same electric charge repel each other, while objects with different electric charges attract.

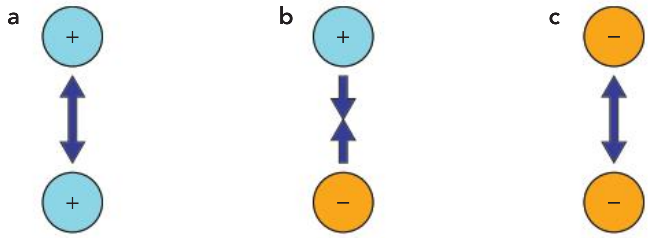


Figure 3.37 **(a)** similarly charged objects repel each other, **(b)** oppositely charged objects attract each other, **(c)** similarly charged objects repel each other

How do objects obtain electrostatic forces?

Most objects are neutral; that is, the positive charges in the object balance out the negative charges. So how do objects become charged? There are three ways objects can become charged.

1 Charging by friction

When two objects rub against each other, some negative charges (electrons) may be removed from one of the objects, giving it a positive charge, and attach to the second object giving it a negative charge.

Practical 3.6

Charging by friction I

Aim

To observe the effects of charging by friction.

Materials

- balloons
- balloon pump
- woollen jumper

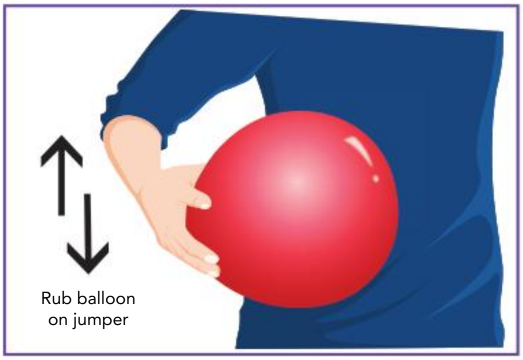
Procedure

Part A

1 Inflate the balloon with the balloon pump and tie it.
2 Rub the balloon on a woollen jumper.
3 Hold the balloon against the wall.
4 Describe what happens.

Part B

5 Inflate the balloon with the balloon pump and tie it.
6 Rub both balloons against a woollen jumper.
7 Holding the balloons by their openings, slowly move them towards each other.
8 Describe what happens.



Discussion

Use your knowledge of electric charges to explain these phenomena.

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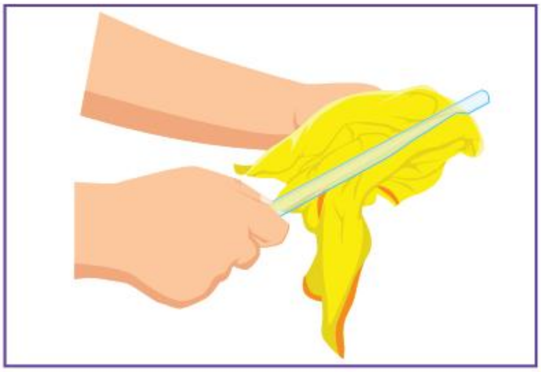
Practical 3.7

Charging by friction II



Materials

- perspex or plastic rod
- silk cloth
- confetti or small bits of paper
- water tap

Procedure

Part A

1 Rub the rod using the silk cloth.
2 Move the 'charged' rod near, but not touching, the confetti.
3 Observe what happens.

Part B

4 Charge the rod again.
5 Turn on the tap so there is a constant but very thin flow of water.
6 Move the charge rod near the water flow.
7 Observe what happens.

Discussion

1 What happens if the rod is rubbed more vigorously?
2 Explain how the rod is electrically charged.
3 Does the flowing water have an electric charge?
4 Why is the water flow bent by the charged rod?

2 Charging by contact

When a charged object comes into contact with a neutral second object some of the charge from the first object can be transferred or shared with the second object. This will result in both objects being charged (see Figure 3.38).

3 Charging by induction

A charged object can induce a charge in a neutral object. The second object remains neutral however charges move within the object causing sides of it to become charged (see Figure 3.39).

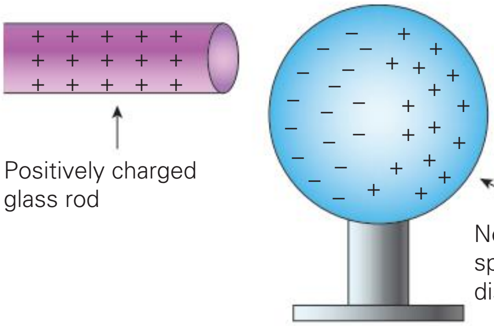


Figure 3.39 As the positively charged rod is moved near the sphere, the negative charges within the sphere are attracted to the positive charge rod giving the left side of the sphere a negative charge and the right side a positive charge. Overall, the sphere still is neutral.

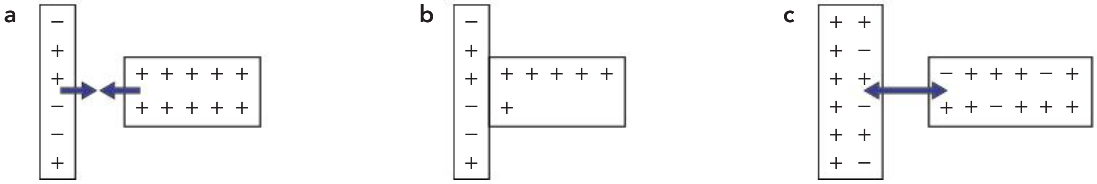


Figure 3.38 (a) One positively charged object and one neutral object are moving towards each other. **(b)** The two objects come into contact. Some of the negative charge from the first object is transferred to the second object. **(c)** The objects move away from each other. They now both have a positive charge.

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Quick check 3.10

1 State how electric charges react to each other.
2 Describe two ways an object can be electrically charged.

Practical 3.8

How to light a bulb

Materials

- small light globe
- 1.5 V battery (or similar)
- 2 pieces of copper wire (around 15 cm long)

Procedure

1 Use the battery, light globe and two connecting wires to make the light bulb light up.
2 Draw a sketch showing this set-up.
3 This time, light up the light globe using the battery and only one wire. Can this be done?
4 Draw a sketch showing this set-up.

Discussion

1 Which way was the easiest to get the light globe working? Why?
2 If you were to sell a device that lights up, which of the ones above would you sell and why?

Moving charge

Static electricity charge cannot be used to power our electrical devices. Why?

A consistent movement of electric charge is needed to power a device – this is called current flow. Current flow, which we will now call electricity, from a power point or a battery provides this consistent flow of electric charges.

Simple circuits

Moving charges need a path to move/flow along. This path is called an electric circuit. A simple electric circuit is a loop of conducting material that an electric charge can move along.

A circuit consists of four main components:

1 Conducting path – wires through which the electricity flows, starting and ending at the power source
2 Source – provides the electrical energy. This could be from a power point in your home or a battery
3 Load – the term used for the electric device that uses the electricity
4 Switch – the flow of electric charge must be able to be turned on and off. Therefore, a switch is needed.

Conductors and insulators

Materials that electricity easily flows through are called **conductors**. Conductors have electrons that can move easily. Materials that prohibit the flow of electricity are called **insulators**. Electrons in these materials are not free to move around. Both conductors and insulators are important when dealing with electricity. As electricity moves through a conductor, the conduction is surrounded by an insulating material to stop the electricity going where it is not wanted, e.g. electrocuting someone.

conductor material that allows electricity to easily flow through it

insulator material that prohibits electricity from flowing through it

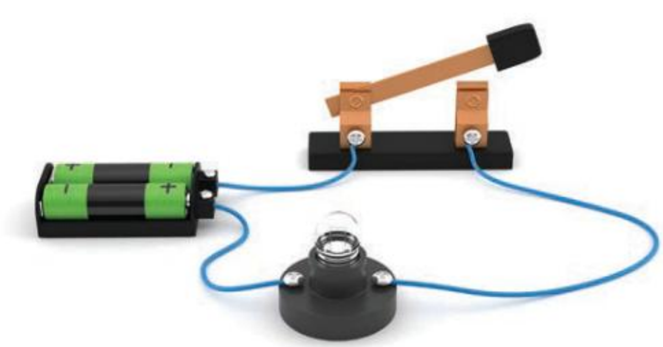

Figure 3.40 A light globe in a simple circuit. Can you identify the four components?

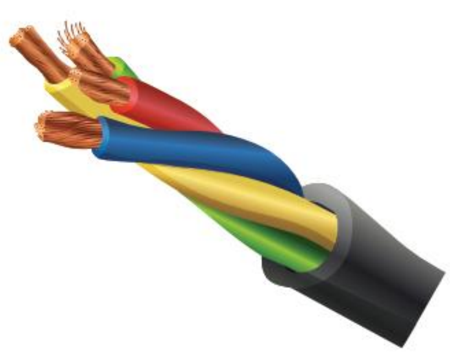

Figure 3.41 Electrical wiring (copper wire) with two layers of insulation. Why do you think there are two layers?

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Quick check 3.11

1 Name the four main components of a circuit.
2 Name some materials that are good conductors.

Circuit diagrams

Electric circuits can be quite complex to draw, so scientists use symbols (see Figure 3.42) and circuit diagrams to represent them. Circuit diagrams are drawn as boxes with the symbol for each component added in mirroring where they sit in the real circuit (see Figure 3.43). For a circuit to be complete, there must be a conducting path from the power source back to the power source – it must have a full loop to travel around.

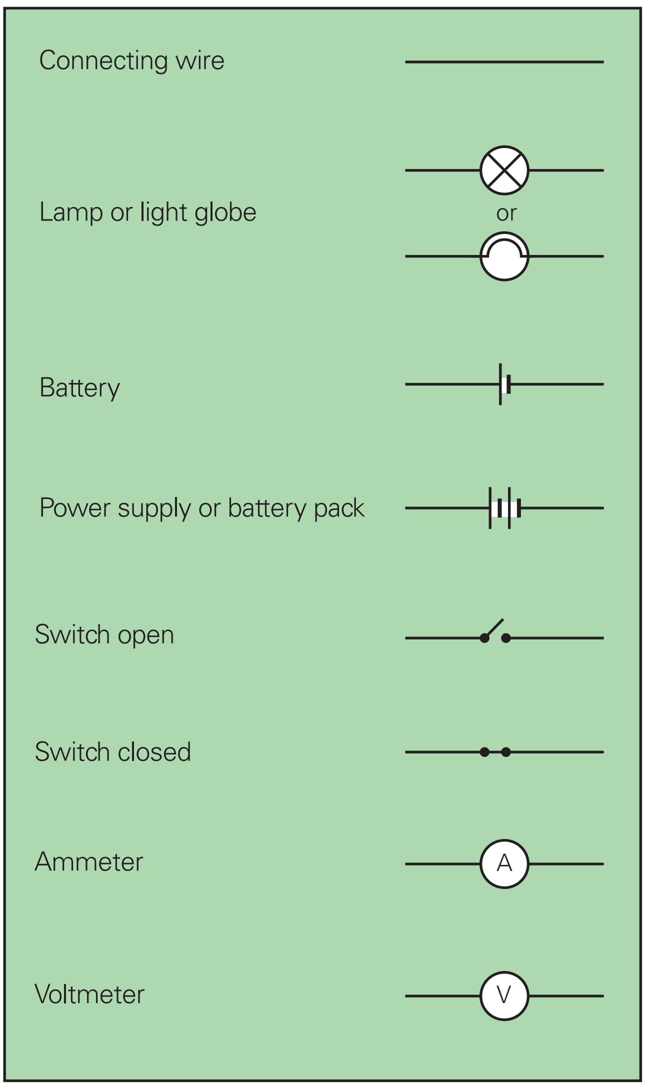

Figure 3.42 Simple electric circuit symbols

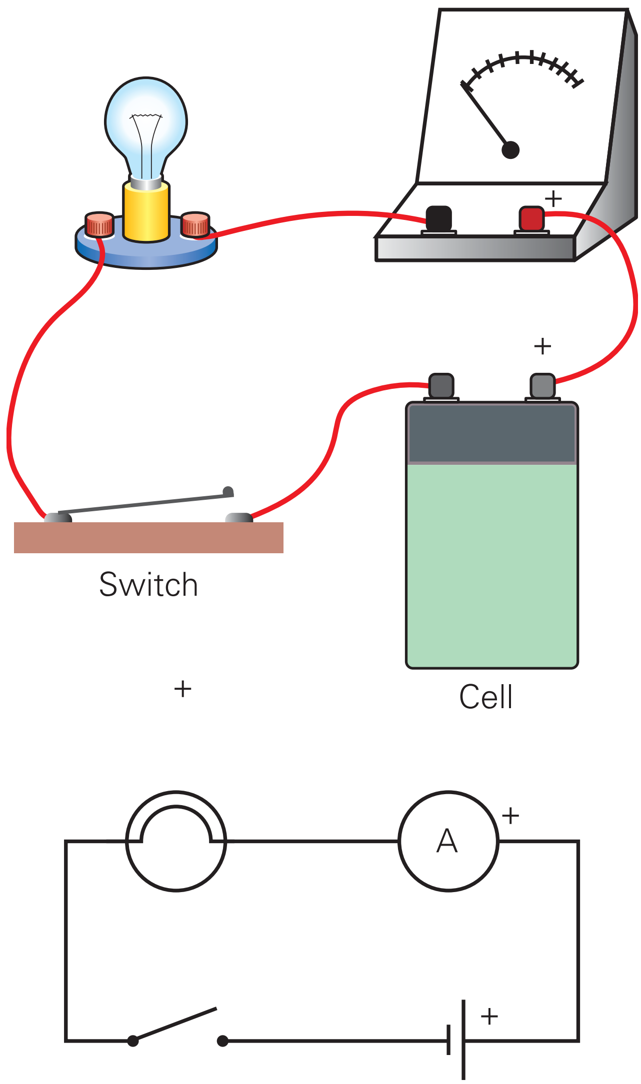

Figure 3.43 A simple circuit and its equivalent as a circuit diagram

Quick check 3.12

Draw the following as circuit diagrams.
1 A circuit with a battery, two light globes and an open switch
2 A circuit containing a power source, three light globes, a closed switch and an ammeter.

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Practical 3.9

Conductor or insulator

Be careful

Electrical shocks may occur.
Ensure the voltage output is not exceeded. Power supply is to be turned off when changing the circuit. Do not touch materials when the power pack is on.

Aim

To test various objects to see how well they conduct electricity.

Background

An ammeter is used to measure the amount of electric charge flowing through a circuit. It measures the electric current in units called amperes or amps (A).

Materials

- power pack
- connecting wires with alligator clips
- light globe
- ammeter
- connecting wires
- various objects – paperclip, pencil, coin, glass rod, nail, carbon rod, match stick, rubber band, copper wire, iron rod, aluminium foil, strip of paper, piece of string, pencil lead etc.

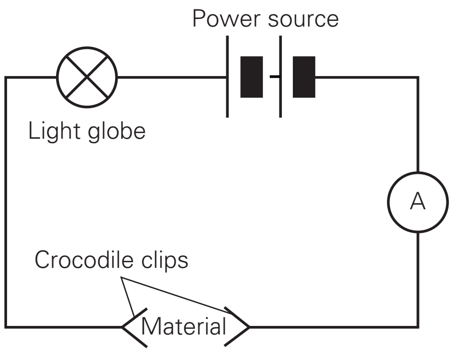

Figure 3.44 Set-up of the circuit

Procedure

1 Set up the circuit as shown. Get your teacher to check your circuit before switching it on.
2 Connect your first item to the alligator clips and switch on the circuit. Observe what happens to the light bulb.
3 Record the electric current reading on the ammeter in your results table.
4 Test each of the other objects.

Results

Object	Light globe lights up	Reading on ammeter (current), A	Conductor or insulator
Paperclip			
Pencil			
Coin			

Discussion

1 List the objects that are good conductors.
2 List the objects that are poor conductor (or best insulators).
3 Which object is the best conductor? Use the ammeter readings to decide this.
4 What do you notice about the objects that conduct electricity? Could you make a generalisation about objects that make good conductors?
5 How could you test if a liquid is a conductor or insulator?

Conclusion

1 What conclusions can be made from this activity regarding the material of an object and how well they conduct electricity?
2 What evidence did you gather to support the conclusions you have drawn? Begin your brief summary with 'We observed… Therefore…'

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Section 3.3 questions

QUIZ

Remembering

1 **List** the electric charges found on an electron, a proton and a neutron.
2 **Identify** where electrons are located in an atom.
3 **State** the three ways that an object could be given an electric charge. Give an example of each.

Understanding

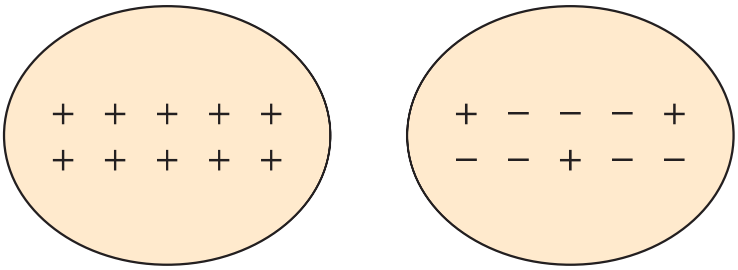
4 **Complete** the following sentence: Like electric charges ____________ each other, unlike electric charges ____________ each other.
5 **Explain** why a circuit consists of at least four components.
6 **Explain** why it is important to have good conductors as electrical wiring.

Applying

7 **Draw** a circuit diagram containing two light globes, a power source, connecting wires and a closed switch.
8 **Describe** some uses of electrical insulators.
9 Give an example of how an object can be charged by friction. **Explain** how the charging occurs.

Analysing

10 Sometimes when getting out of a car you get 'zapped'. **Explain** how the car becomes electrically charged.
11 **Explain** what you would expect to happen when the spheres touch each other.



Evaluating

12 **Propose** the effect on a circuit of the removal of a switch.
13 **Suggest** why electricity is the most common source of energy in the home used for heating.

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Chapter review

Chapter checklist

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

Success criteria		Check
3.1	**I can define energy.** e.g. Define energy.	
3.1	**I can describe the different types of energy.** e.g. Define potential energy.	
3.1	**I can distinguish between temperature, thermal energy and heat.** e.g. Contrast the following terms: temperature, thermal energy and heat.	
3.2	**I can recall the law of conservation of energy.** e.g. Recall the law of conservation of energy.	
3.2	**I can describe how energy is transferred and transformed.** e.g. Explain what occurs during an energy transformation.	
3.2	**I can calculate the efficiency of different machines.** e.g. A toaster uses 131 500 J of electrical energy: 80 650 J is used to produce heat to toast bread. Calculate the efficiency of the toaster.	
3.2	**I can describe the energy transformations that occur when producing electricity in different ways.** e.g. Draw a flow diagram to show the energy transformations that occur in a battery-powered torch.	
3.2	**I can describe how thermal energy is transferred.** e.g. Describe how heat is transferred in solid objects.	
3.3	**I can distinguish between static electricity and current electricity.** e.g. Explain why current electricity needs a conducting path.	
3.3	**I can identify the components of a circuit diagram and draw circuit diagrams.** e.g. Identify the parts of a circuit.	

SCORCHER

Reflections

1 What **connections** come to mind when you think about energy and your everyday life?
2 What new concepts have **extended** your thinking about energy?
3 What information did you find **challenging** or confusing?

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Data questions

Household use of electricity has been increasing rapidly over the last decade or so. In NSW, most of our electricity is still being supplied by the burning of fossil fuels, which is having adverse effects on our environment. Reducing our use of electricity at home is one way of helping the environment.
Figure 3.45 shows how Australians overall are using electricity in the home.

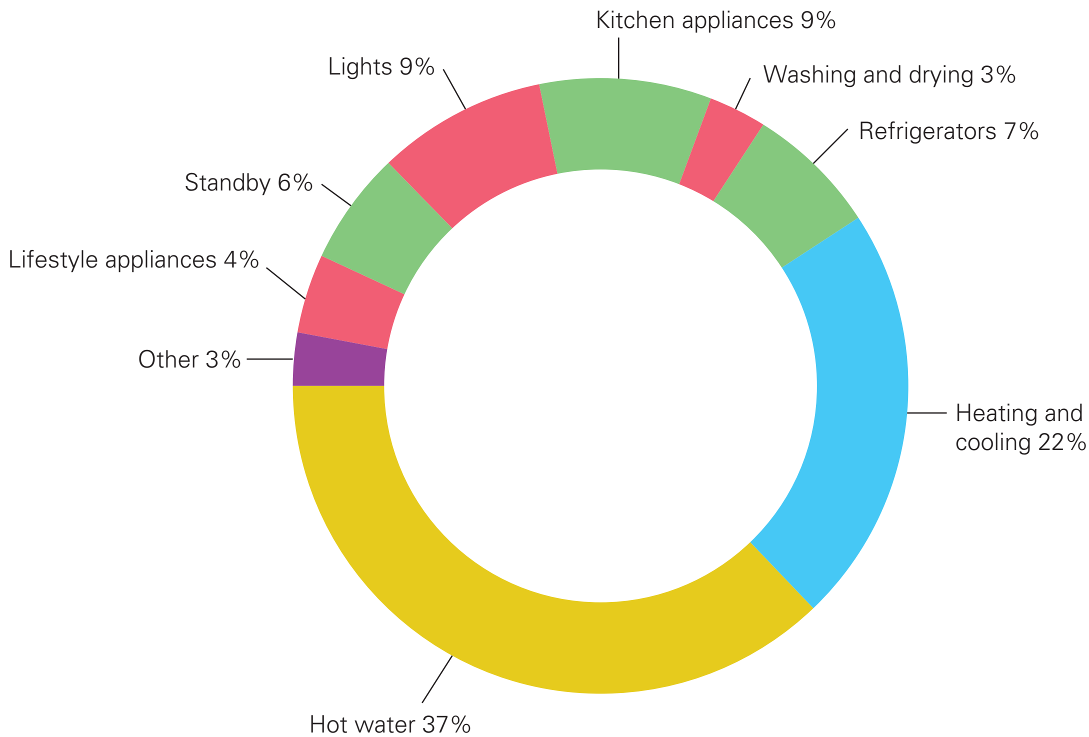

Figure 3.45 How electricity is used around the home

1 **Identify** which two features use the most electricity.
2 **Calculate** the percentage of electricity used in the kitchen.
3 On the the graph there is 'Other 3%'. **Suggest** items that could be included in this category.
4 **Propose** what is meant by 'Lifestyle appliances'.
5 Think about your household – does your home use electricity in the same ways shown on the graph? **Describe** how it is different.
6 There are nine different items on the graph. **Determine** when each item is mostly used: daytime, night time or both. You may **construct** a Venn diagram to show this.
7 Electricity used is measured in kilowatt hours (kWh). If a household uses 41 kWh of electricity per week, **calculate** how much energy is used for each item.
8 Sometimes households are empty. **Decide** which electricity in the household (from Figure 3.45) would still be used during this time.
9 Using the information from this graph, **propose** three realistic ways that you could reduce the amount of electricity used in your home.

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STEM activity: Energy transformations in roller-coasters

Background information

Energy can be transformed from one type to another type, depending on the intended use. Roller-coasters use this fact and require no additional input energy once the carriage has reached its maximum height. There are a number of energy transformations that take place when the carriage is travelling along the tracks.

Design brief: Create a roller-coaster for a marble so energy transformations can be observed.

Activity instructions

In groups, you will design and construct a simple roller-coaster for a marble. The track must include one vertical loop and two curves or bends. The marble must be able to travel the whole length of track without stopping.

Suggested materials

- pool noodles
- marble or ball bearing
- masking/packing tape
- toothpicks
- scissors
- box cutter knife
- string
- paper or cardboard

Research and feasibility

1 Research and discuss in your group how a roller-coaster operates using gravity.

2 Discuss the constraints of your building materials and testing area.

Design and sustainability

3 Sketch a number of roller-coaster designs for your group. Discuss the feasibility of your designs. For example, will this design allow the marble to reach the end of the track?

4 Identify and discuss the energy transformations that will affect your roller-coaster.

5 Discuss how sustainable your designs are. Are these realistic for a real-life roller-coaster?

6 Discuss the effectiveness of each design with respect to using gravitational potential energy as your initial energy source.

Create and modify

7 Construct your preferred roller-coaster model.

8 Test your model and make any modifications.

9 Mark on your model where gravitational potential energy (GPE) is increasing and where it is decreasing.

10 Mark on your model where kinetic energy (KE) is increasing and where it is decreasing.

Evaluate

11 Discuss and suggest three possible solutions to problems you encountered with your design and construction. (What modifications did you need to make and why?)

12 Predict what would happen if your model's starting point was raised higher, and then lower. Try this and describe what happens.

13 Did your group notice a relationship between GPE and KE? What is it?

14 Evaluate your model and present it to your class, describing the energy transformations that occur throughout the journey of the marble.

Figure 3.46 Different types of roller-coasters

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Chapter 4
Rocks

Inquiry questions

How are rocks formed?
Do rocks change over time?
How are rocks classified?

PRE-TEST

Chapter introduction

In this chapter, you will learn about Earth's crust and the rocks that make up its composition. You will learn about the three types of rock – igneous, metamorphic and sedimentary – and how rocks can change from one form to another, according to the rock cycle. You will also learn about the mining industry and how resources contained in the rocks are extracted to make useful materials, such as metals for technology, and glass and cement for building.

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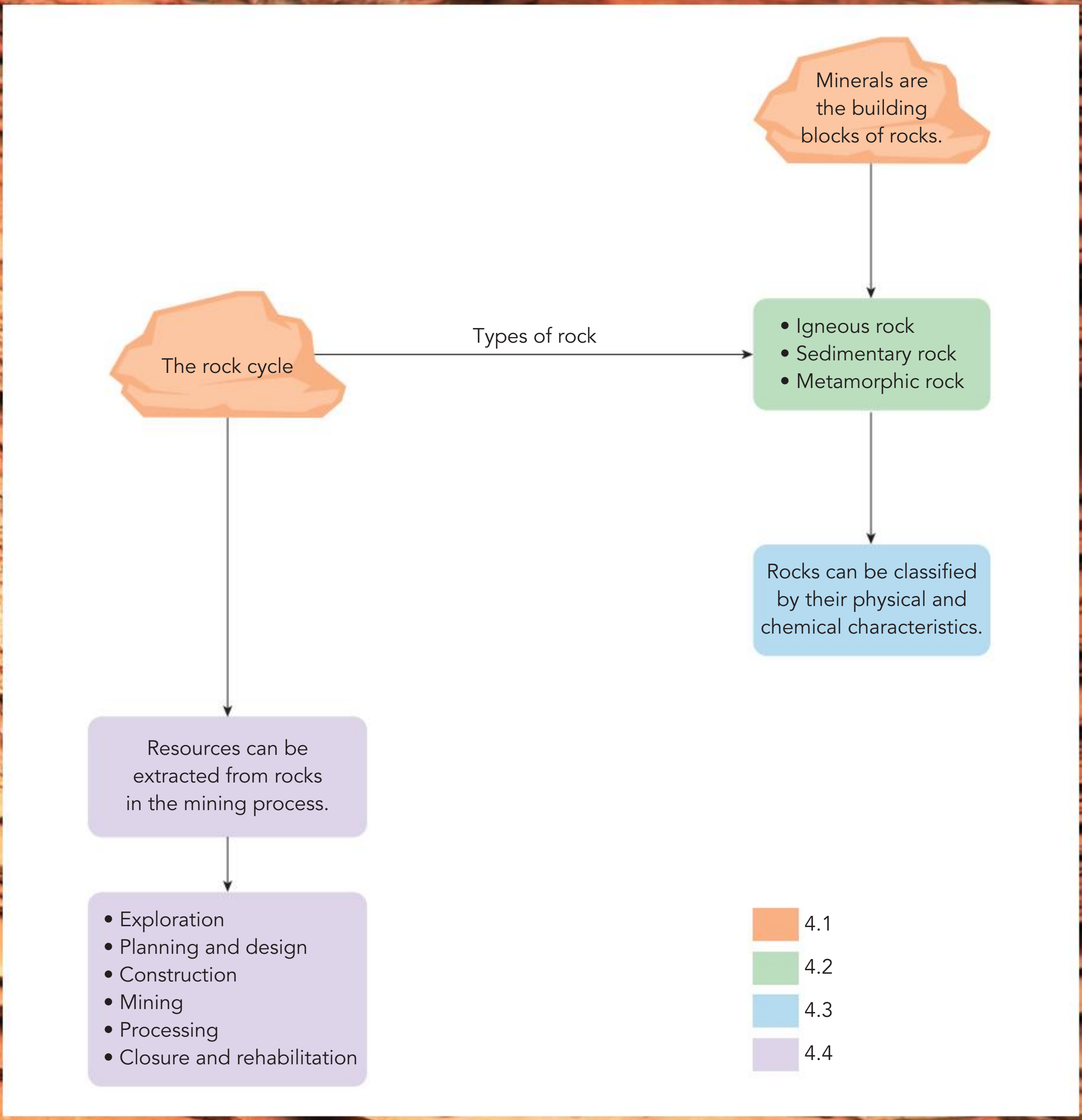
Chapter map



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4.1 Rock formation

Learning goals

1. To identify and describe Earth's layers.
2. To describe the rock cycle and the processes involved in the rock cycle.
3. To explain the eroding and weathering processes.

DOC WORKSHEET

Rocks and minerals

Rocks are a naturally occurring substance made up of one or more **minerals**. Minerals are considered to be the building blocks of rocks, and each mineral has a specific chemical structure. Rocks can be:

- **igneous** – formed from molten rock
- **sedimentary** – formed from the products of erosion
- **metamorphic** – altered by heat and pressure.

A mineralogist is a person who studies minerals. It can be an interesting job, because there are over 5000 minerals to study. Some minerals are found in the form of **crystals** and this can be an easy way to identify them.

rock
solid material forming Earth's crust; rocks are formed as part of the rock cycle

mineral
a chemical substance that is formed naturally in the ground

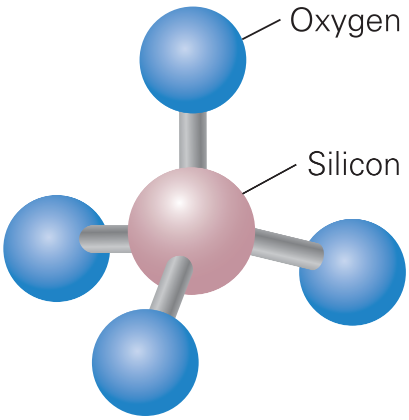
igneous
describes rocks made from lava on the surface or magma below the surface

sedimentary
describes rocks made from deposited materials that are the product of weathering and erosion

metamorphic
describes rocks that are changed by being exposed to high temperature, pressure or both

crystal
a mineral in which the atoms are arranged in an ordered way to form a geometric shape

Figure 4.1 Granite is an igneous rock. It is usually made up of four minerals. The large crystal size in the rock indicates that the rock cooled slowly, probably underground.



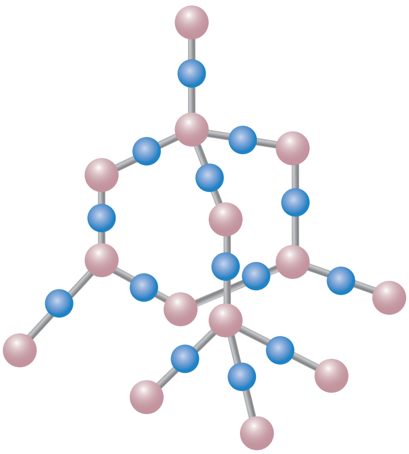


Figure 4.2 Quartz is a mineral made of silicon and oxygen atoms arranged in a continuous framework.

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Did you know? 4.1

Minerals include gemstones that are used in jewellery. Most gemstones are brightly coloured or transparent crystals. Diamond, for example, is a crystal made from carbon. Carbon is the same chemical element that is in graphite, which is used to make pencil leads.

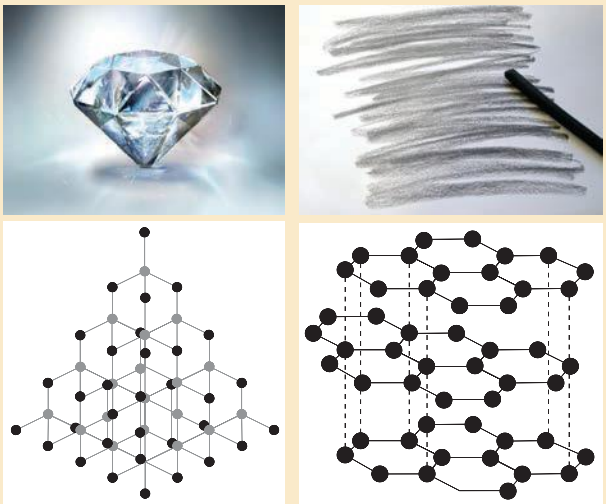

Figure 4.3 Diamond (shown at left) and graphite (shown at right) are both made of carbon atoms. However, the arrangement of the atoms makes a big difference to their properties.

Earth's layers

The **inner core** of Earth is currently thought to be mostly solid iron, while the **outer core** is made of liquid iron and nickel. Surrounding the outer core is the **mantle**, comprising mostly solid and semi-molten rock. Earth's outer layer is the solid **crust**. Rocks are formed and reformed in the **lithosphere**, which includes the crust and the uppermost mantle. The **asthenosphere** is found under the lithosphere. It is a thin layer of rock with the consistency of melted plastic.

inner core
the solid centre of Earth; probably made of iron

outer core
the liquid layer surrounding the inner core; probably made of liquid iron and nickel

mantle
the layer of solid and semi-molten rock that surrounds the outer core and extends up to Earth's crust

crust
the solid outer layer of Earth; continental crust is on average 35 km thick and the average thickness of oceanic crust is 10 km

lithosphere
the solid outer layer of Earth; includes the crust and uppermost mantle

asthenosphere
the almost liquid, layer under the lithosphere (hard rock)

Earth's mass is predominantly made up of iron, then oxygen, silicon and magnesium. Small amounts of all the other elements can also be found. This is what makes geology fascinating, as each type of rock contains different components and has different properties.

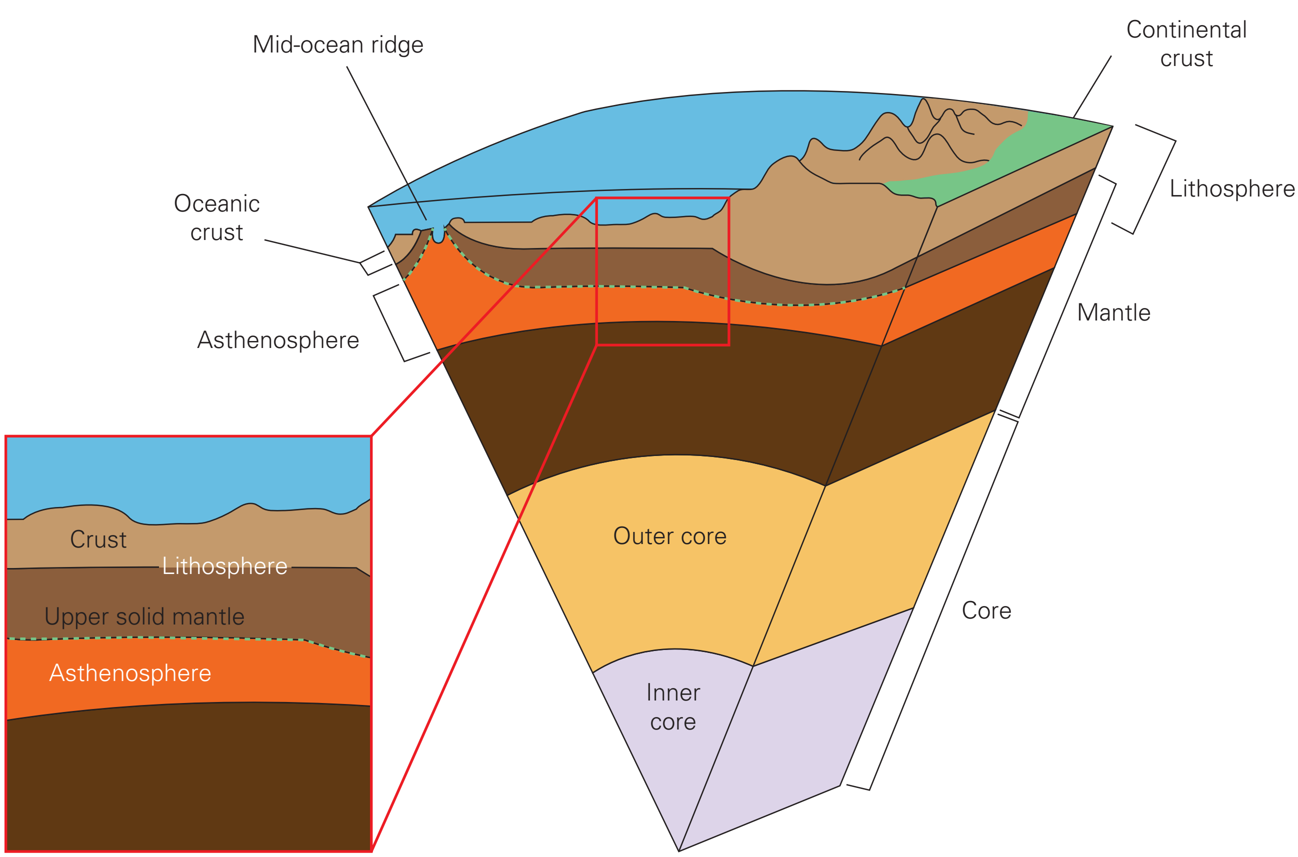

Figure 4.4 Earth is composed of several layers.

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Layer	Description and composition	Thickness	Temperature range
Crust	• The solid outer layer of Earth; rigid and brittle • Oceanic crust is made of denser basaltic rock, and lighter continental granite	8–70 km with the continental crust averaging 50 km and the oceanic crust averaging 20 km	The upper crust is around 20°C, while the lower crust can be up to 400°C
Lithosphere	• The solid outer layer of Earth; includes the crust and uppermost mantle • Behaves as a brittle, rigid solid	about 100 km thick	300°C to 500°C
Asthenosphere	• The layer in the upper mantle, composed of partially molten rock, a slushee-like material consisting of solid particles with liquid occupying spaces in between	about 180 km thick	300°C to 500°C
Mantle	• The layer of solid and semi-molten (like the consistency of honey) rock found beneath the crust • The mantle makes up 84% of Earth by volume	2900 km	1000°C near its boundary with the crust, to 3700°C
Outer core	• The liquid layer surrounding the inner core • Made almost entirely of metal such as iron and nickel	2200 km	4500°C to 5500°C
Inner core	• The solid centre of Earth, mostly composed of liquid iron and nickel	1230–1530 km	5200°C

Table 4.1 Properties of the layers of Earth

Element	% of Earth's mass
Iron	35
Oxygen	30
Silicon	15
Magnesium	13

Table 4.2 These four elements make up most of Earth's mass.

Quick check 4.1

1 Define and distinguish between rocks and minerals.
2 Where are rocks formed in Earth?
3 What elements make up most of Earth's mass?

The rock cycle

James Hutton, the founder of modern **geology**, tried to explain why Earth's surface is so complex. He came up with two conclusions.

- Earth is very old – Hutton called this **deep time**.
- Earth's surface has been constantly changing throughout its history. The rock component changes constantly due to some key processes, which together are called the **rock cycle**.

geology
the study of the rocks and similar substances that make up Earth and other planetary objects

deep time
the idea first suggested by James Hutton that Earth is very old

rock cycle
the constant process of change that rocks go through, between igneous, metamorphic and sedimentary forms

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Melting and cooling

As you can see in Figure 4.5, the melting of rock to form magma (molten rock), and then the cooling of that magma, results in the formation of igneous rock. The process of melting takes place beneath Earth's crust at temperatures that can be as low as 500°C and as high as 1600°C. The process of cooling can happen below or on Earth's surface. An interesting characteristic of igneous rocks is that the minerals in them may form crystals. This is because, when **magma** cools, crystallisation occurs. Below Earth's surface, magma takes a long time to cool, and the crystals formed in it are large. Magma that reaches Earth's surface is called **lava**. Because lava cools more quickly, the crystals formed are small and may even be microscopic.

magma
molten rock under Earth's surface

lava
molten rock from inside Earth (called magma) that has reached the surface

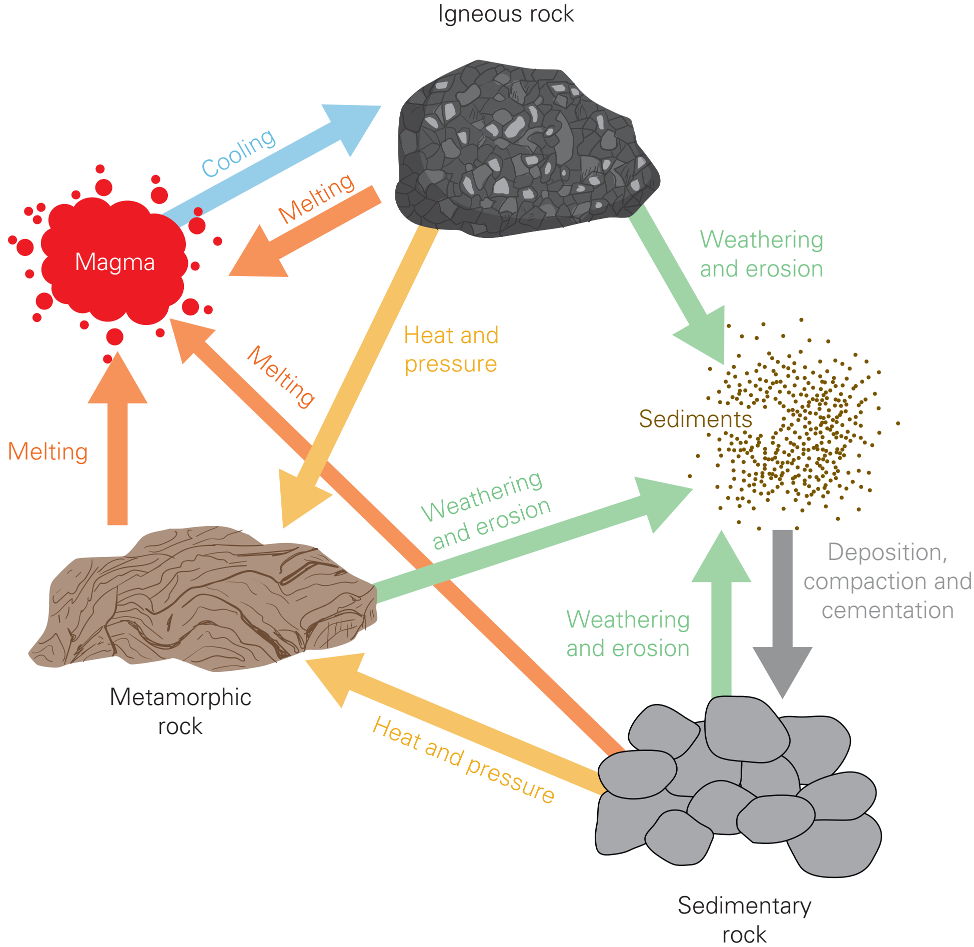

Figure 4.5 In the rock cycle, the three types of rock can change, through the action of weathering and erosion, deposition, compaction and cementation, melting and cooling, and heat and pressure.

Did you know? 4.2

'Igneous' and 'ignite' come from the same Latin word, *ignis*, which means 'fire'. This is an easy way to remember that igneous rocks are formed from hot magma.

Figure 4.6 *Igneous* comes from a Latin word meaning 'fire'.

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Quick check 4.2

1 What are the three types of rocks formed in the rock cycle?
2 What roles do melting and cooling play in the rock cycle?

Explore! 4.1

What is a meteorite?
From time to time, rocks arrive on Earth from space, in the form of **meteorites** that hit the ground. Use your preferred search engine to answer the following questions.

1 What is the composition of meteorites?
2 How does a meteorite end up on Earth?
3 Propose whether or not meteorites pose a threat to life on Earth. Justify your argument using examples of meteorites that have struck Earth, and the aftermath.

Figure 4.7 An iron meteorite from space that collided with Earth

Weathering

Weathering occurs when exposed rocks are broken down – for example, by ocean waves hitting a cliff face. Weathering breaks up large rocks into small particles called **sediments**. It includes physical weathering, chemical weathering and biological weathering.

meteorite
a rock from space (meteor) that has entered the atmosphere as a 'shooting star' and reached the ground

sediments
sand, stones, etc. that slowly form a layer of rock

physical weathering
the breaking down of rocks into smaller particles by contact with other rocks, wind, water or ice

Physical weathering is the breaking down of rocks into smaller particles by temperature, pressure or weather – for example, by extreme temperatures, high wind, snow, hail, rain and flooding. Ice is a very powerful agent in the weathering process, because of a process known as 'freeze–thaw action'. In this process, water enters a crack in a rock and freezes. As it freezes, it expands with great force and widens the crack. This can happen many times, widening the crack slowly until eventually the rock breaks apart.

Figure 4.8 A rock split in two by freeze–thaw action

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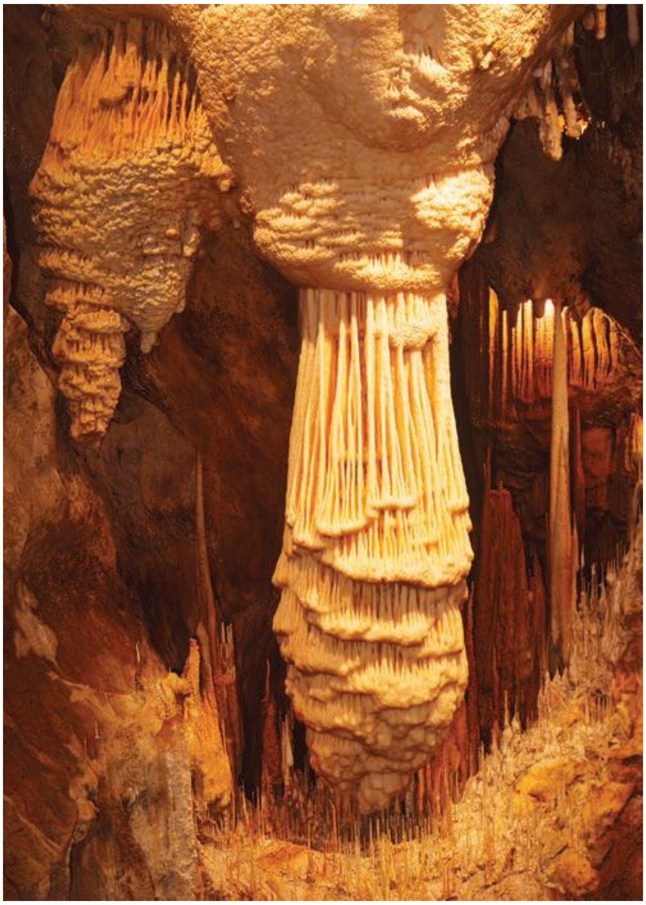


Figure 4.9 A pillar in the Jenolan Caves in New South Wales

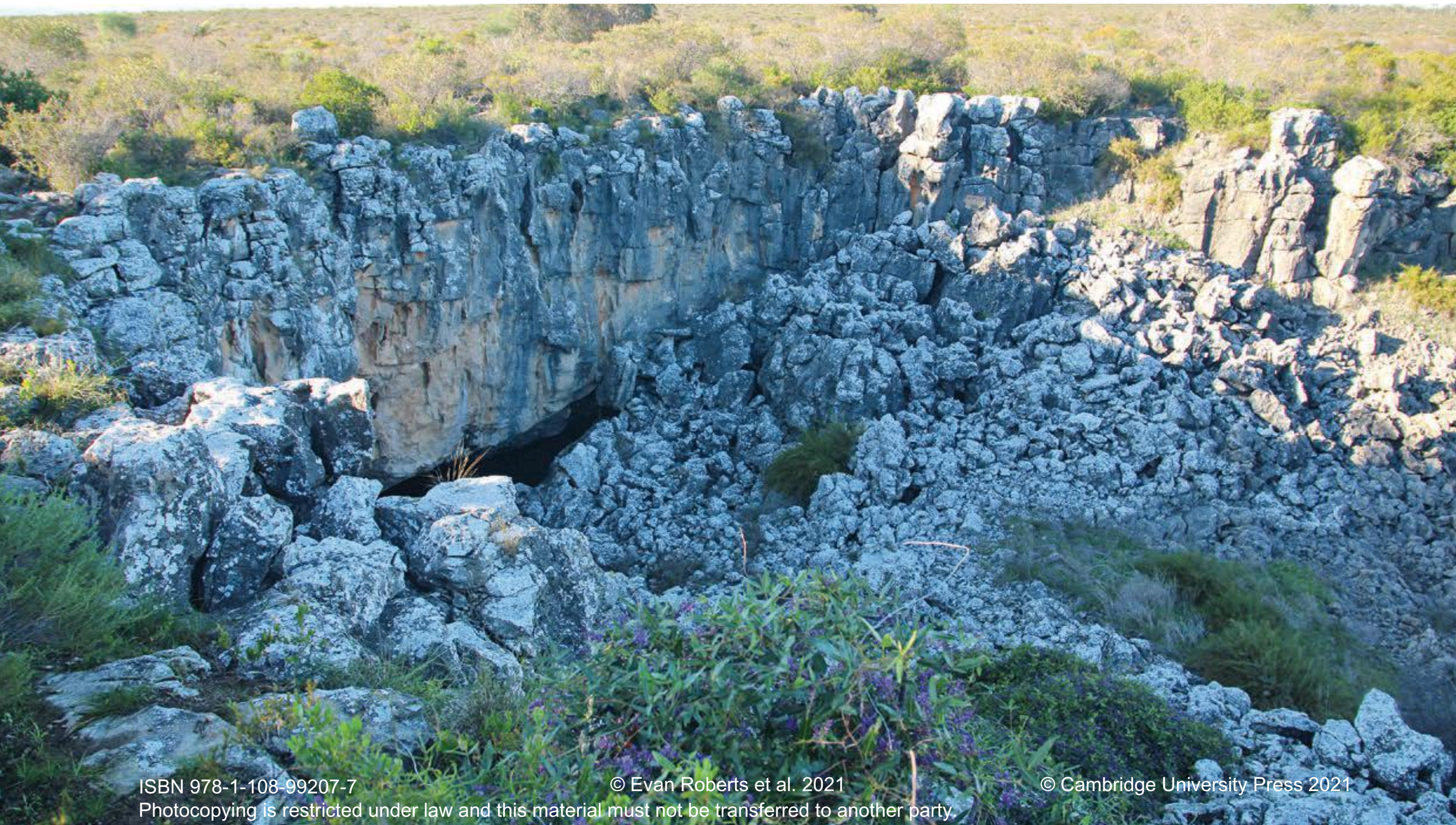
chemical weathering the disintegration of rocks caused by acidic rainwater

karst an area of land formed of rock such as limestone that is worn away by water to make caves and other formations

Chemical weathering occurs when rocks are slowly dissolved by substances in rainwater that make it slightly acidic. It is more effective on limestone and silicon compounds, as these will react with the acid in the water. Rainwater that seeps underground in a limestone area can slowly create vast underground caves over millions of years, as well as long underground rivers. Limestone caves often contain stalactites hanging from the roof and stalagmites on the ground; when these meet, they form columns or pillars. Limestone caves such as the Jenolan Caves (see Figure 4.9) are often developed as tourist attractions because of the beautiful limestone features they contain.

When limestone contains underground rivers, it can give a very characteristic landform called a **karst** landscape (see Figure 4.10), which has caves, sinkholes, limestone outcrops and dry valleys with no water because the river that formed them has gone underground. The Nullarbor Plain between South Australia and Western Australia is the world's largest karst landscape.

Figure 4.10 The entrance to a cave in a typical karst landscape. Rainwater enters the cave and can travel underground for many kilometres.



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Advances in science 4.1

Limestone mining in Kandos

Limestone was mined for around 100 years near the town of Kandos in NSW central west region before the mine closed in 2011. The limestone from here was used to make cement that was sent all around the world to be used in such structures as roads, bridges, reservoirs, pipes, posts, paths, fences and buildings. Kandos also supplied the cement for the construction of the Sydney Harbour Bridge as well as the Opera House. Kandos is known as 'the town that built Sydney'.

Figure 4.11 An old cement silo

Figure 4.12 The aerial ropeway used to carry limestone to the cement works. It has been dismantled.

biological weathering the disintegration of rocks that is caused by living things

Biological weathering occurs when rock is broken down into smaller particles by living things. For example, human feet can wear dips into the tops of stone steps (see Figure 4.13), plant roots grow into small cracks in rocks and make the cracks bigger, and people who do not stay on pathways in national parks damage the vegetation, which can eventually lead to erosion.

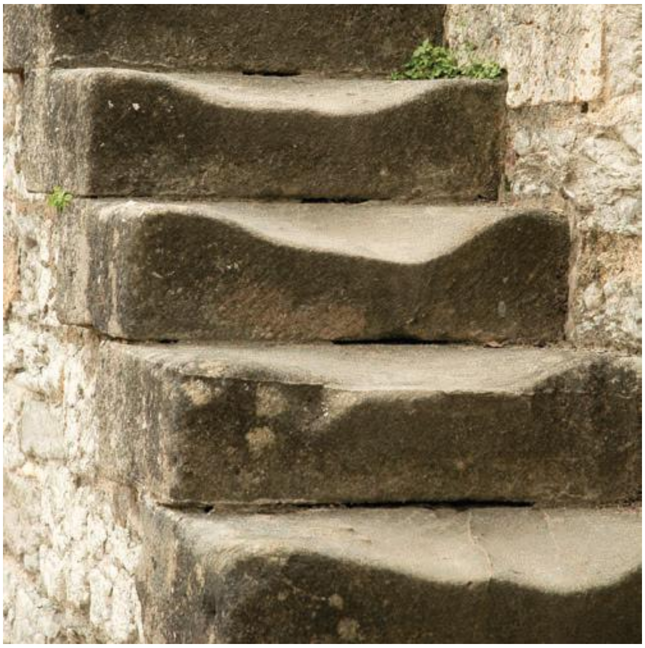

Figure 4.13 These steps have been 'weathered' by people walking on them. The particles of stone have been washed away or eroded by the rain.

Quick check 4.3

Distinguish between the three types of weathering: physical, chemical and biological.

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Erosion

Erosion occurs when rock that has been broken loose by weathering is transported or moved to a new location. It includes rocks or rock particles falling due to gravity, being carried away in the wind, or moved by waves, ocean currents, running water or even ice in a glacier.

The size of particles that can be carried is highly dependent on the way it is transported. Only small particles, such as sand, can be blown by the wind, but pebbles and even boulders can be transported in rivers and oceans. Glaciers can carry giant boulders trapped in the ice, for many kilometres. They are also powerful weathering agents, because the ice leaves a smooth surface as it passes over the bedrock.

Figure 4.15 Dove Lake on Cradle Mountain in Tasmania. The smooth appearance of the rocks is due to the action of glaciers 20 000 years ago.

During the ice age, large quantities of water were trapped in giant ice sheets. Because of this, the sea level was much lower and it was possible to walk on land from Victoria to Tasmania and from Queensland to Papua New Guinea. Although neither Australia nor Tasmania was covered in an ice sheet, glaciers formed on Cradle Mountain in Tasmania and the surrounding areas. The landscape was transformed by the ice moving over the rocks, leaving the characteristic smooth surface.

erosion
the transport of rocks from one place to another as a result of weathering

The profile of Wave Rock in Western Australia (see Figure 4.16) demonstrates the erosive power of wind. Sand grains carried by wind carried away the debris. Initially, it was chemical weathering (vegetation breaking down) that weakened the rock, and then the wind-borne sand started its work at the weakened lower levels of rock. Eventually a wave-like shape formed.

Figure 4.14 The Twelve Apostles, off the shore of the Port Campbell National Park in Victoria. These limestone stacks were formed on the seabed. Today, the seabed has been raised and the limestone is being weathered and eroded by the ocean waves.

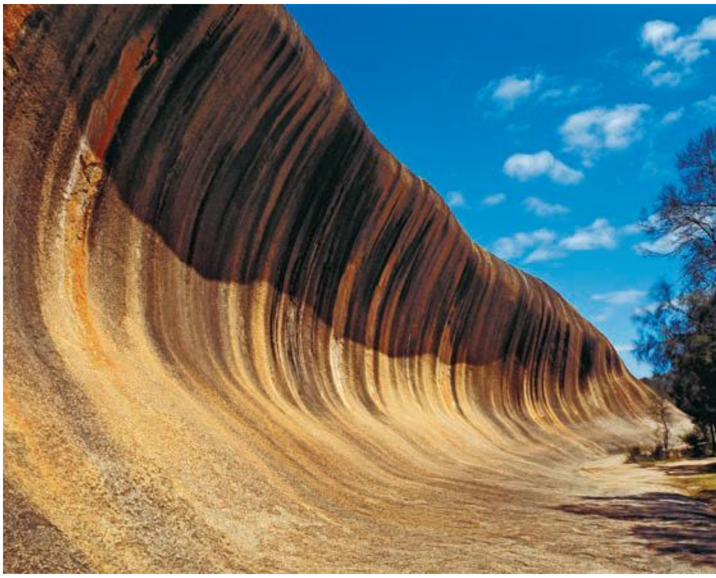

Figure 4.16 Wave Rock in Western Australia is made of granite that is more than two billion years old.

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Try this 4.1

Erosion by wind

You will need the following materials:

- Petri dish
- water
- dry sand
- pebbles of various sizes
- drinking straw
- newspaper.

Place the Petri dish on the edge of the newspaper. Moisten the bottom of the Petri dish with just a little bit of water, before filling it with sand. Place five pebbles on top of the sand and spread them out evenly. Gently blow through the straw, away from the edge of the newspaper, so the sand lands on the newspaper and does not make a mess.

What do you observe? Does the sand blow away more from under the pebbles or around the pebbles?

deposition
process that occurs when eroded particles stop moving and build up to form sedimentary rocks

compaction
the process of parts becoming closely positioned together, using very little space

cementation
the sticking together of sediment

fossil
the remains, shape or trace of a bone, shell, microbe, plant or animal that has been preserved in rock for a very long time

Deposition, compaction and cementation

Particles or sediments that are eroded come to rest when the wind or water moves more slowly or the ice melts. When the particles reach their destination, they are dropped, in a process called **deposition**. Often deposition occurs on ocean beds or lake beds. The particles are often deposited in visible layers, which become **compacted** or compressed by the weight of the layers above, and **cemented** together. These processes finally form sedimentary rocks. Sometimes animal and plant remains are mixed in with the sediments and preserved as **fossils**. On the seabed, this process can continue in the same place for millions of years and can create layers of sediment many metres high.

Quick check 4.4

1 Distinguish between weathering and erosion.
2 Explain the processes of deposition, compaction and cementation.

Figure 4.17 Sedimentary rocks are very common, covering more than 70% of Earth's surface. Some contain fossils that are billions of years old. Note the different layers of sediment, all cemented together.

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Practical 4.1

Deposits on a riverbed

Aim

To model and observe how sediments are deposited on a riverbed.

Materials

- soil
- sand
- gravel
- water
- jar with lid

Procedure

1. Add soil, sand and gravel to a jar, and mix them. Fill the jar to halfway.
2. Add water. Fill the jar ¾ full and put the lid on.
3. Make sure the lid is tight, and shake the jar for one minute. How do you predict the particles will settle?
4. Observe how the particles settle. Time how long it takes for each layer to form.

Results

Draw a diagram representing the different layers, and label them.

Discussion

1. Do the larger particles end up on the top layer or the bottom layer?
2. How long does each layer take to settle? Can you explain why this occurred?

Heat and pressure

Rocks that are deep underground may be exposed to extreme pressure, high temperature or both. This can change the nature of the rock, often making it harder and denser. These processes create metamorphic rocks.

Mudstone is a sedimentary rock made from mud. When it is exposed to high pressure and temperature it turns into slate, a metamorphic rock. If the temperature and pressure are increased again, it turns into schist, another type of metamorphic rock.

Figure 4.18 Slate is a metamorphic rock formed when mudstone is subjected to high pressure and temperature.

Figure 4.19 Pieces of schist, formed when slate is subjected to high temperature and pressure.

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Try this 4.2

Metamorphic pasta

You will need the following materials:

- 2 textbooks
- penne pasta (or any long type of pasta).

Scatter the pasta around in a random manner on a flat surface, between the two books, as shown in Figure 4.20. Keeping the book spines parallel to each other, slowly bring the spines together, with the pasta pieces in between. As the pasta pieces are compressed, they should align. How does this demonstrate the way in which metamorphic rock is formed?

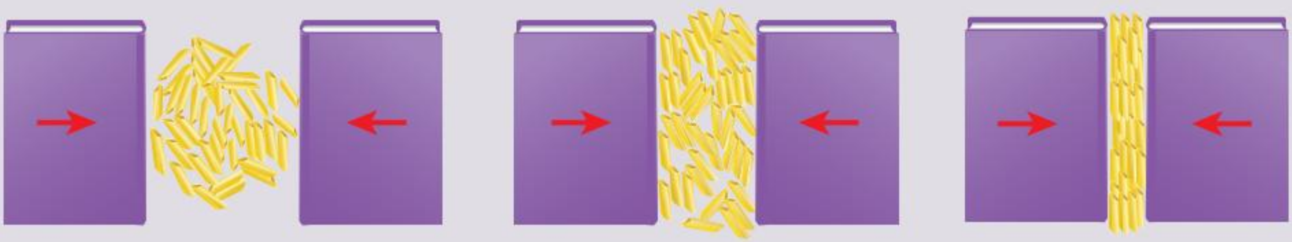

Figure 4.20 As you compress the pasta, the pieces align.

Quick check 4.5

1. List the three different types of rock.
2. Distinguish between the three kinds of rock in terms of how they are formed.

radioactivity
energy released from the nucleus of an atom when the atom decays; the age of rocks can be determined by measuring their radioactivity

Energy sources for the rock cycle

It takes a lot of energy to move rocks around, break them up, heat them until they melt or change them physically or chemically.

Type of rock	Source of energy	Details
Igneous Metamorphic	Earth's formation and elements that are **radioactive**	When planet Earth was formed, it contained radioactive atoms left over from a supernova. This radioactive energy has been released ever since and is what keeps the centre of Earth at a high temperature.
Sedimentary	Sun	The energy of the Sun causes weathering through rain, wind, waves and ice formation. It also causes rocks to heat up during the day and cool down at night.

Table 4.3 The energy required for the formation of the different rock types comes from different sources.

Try this 4.3

Rock cycle poster

Make a poster of the rock cycle and annotate it with details of the different processes you have learned about in this section. You are going to add to this poster in the next section, so make sure you leave space around the outside for extra information about the types of rocks.

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Section 4.1 questions

QUIZ

Remembering

1 **Recall** the name of the layer on Earth in which rocks are formed and reformed.

2 In Scotland, James Hutton saw igneous rock with millions of years' worth of sedimentary rock lying on top of it. **Outline** two observations that Hutton published after seeing this.

3 **Identify** the most common type of rock on Earth's surface.

Understanding

4 **Contrast** rocks, minerals and crystals.

5 Copy this image of the rock cycle in Figure 4.21 and label the missing processes. Then **explain** each of the processes.

6 **Outline** how the different types of rock from the previous question are formed.

Applying

7 Make use of what you have learned about weathering to **identify** one reason why weathering is important to the rock cycle, and one reason why we might want to stop weathering.

8 Imagine that Earth's core suddenly lost its thermal energy. Apart from the effect this would have on life on Earth, **identify** which type(s) of rock formation would be affected and **explain** why.

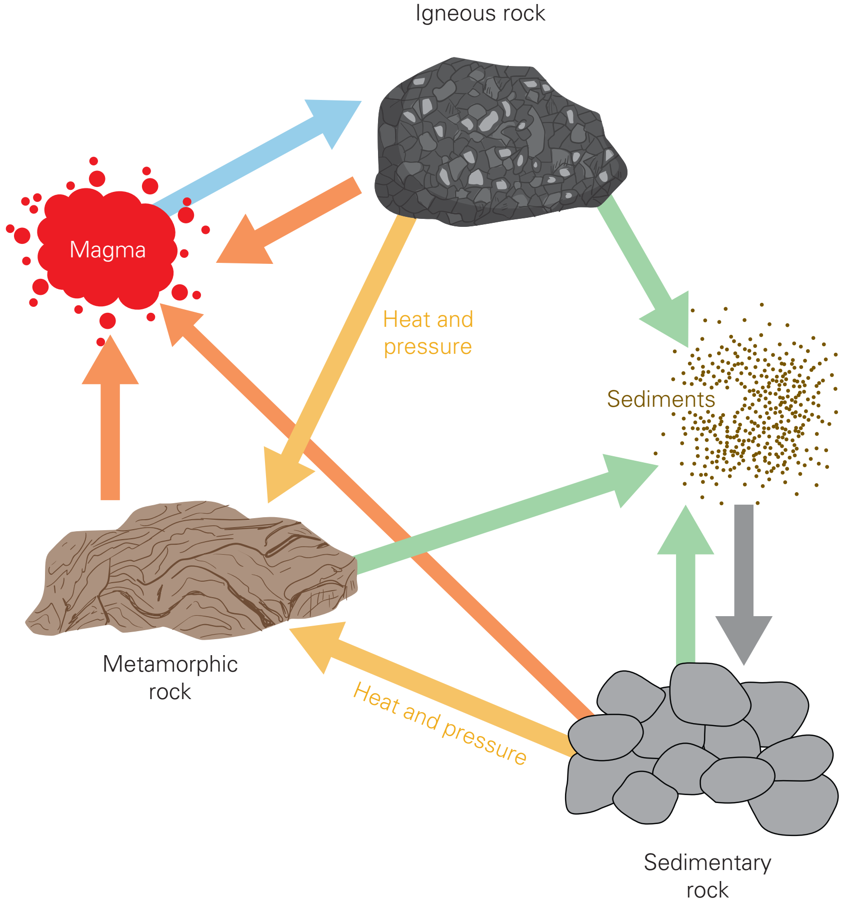

Figure 4.21 The rock cycle

Analysing

9 Examine Figure 4.22 and decide whether it is a mineral or a rock. **Justify** your answer.

Figure 4.22

Evaluating

10 'Once igneous rocks are formed, the only physical change they can experience is being broken down into smaller pieces until they are melted again.' **Assess** whether you agree with this statement and provide your reasoning.

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4.2 Types of rocks

Learning goals

1. To identify the three groups of rocks, how they form and their characteristics.
2. To identify the different types of fossils.

DOC WORKSHEET

Igneous rocks

Beneath Earth's thin outer crust is molten and semi-molten rock, called magma. When the surface crust becomes fractured, thin or weakened, molten magma can reach the surface and a volcano is formed. Igneous rocks are formed when lava cools quickly following a volcanic eruption, sometimes within minutes, or when magma cools and solidifies slowly underground in a magma chamber after it has been pushed close to the surface.

extrusive describes igneous rocks formed on Earth's surface; also called volcanic rocks

The crystals within igneous rocks can give information on how they were formed. The crystals may be anything from several centimetres long to visible only with a microscope. The size of the crystal gives a clue to how long the igneous rock took to cool and, hence, how close to the surface the rock was formed. When magma breaks through the crust and flows on the surface, it is called lava. The lava solidifies to form **extrusive** igneous rocks. Basalt, an igneous rock, has the interesting property of forming large hexagonal structures as it cools. Pumice, also an extrusive igneous rock, floats on water!

Figure 4.23 Igneous rock and lava in Hawaii

Figure 4.24 The columns or pillars of basalt found in Bombo Quarry near Kiama, NSW, are an example of magma flowing onto the surface, solidifying and forming igneous rock.

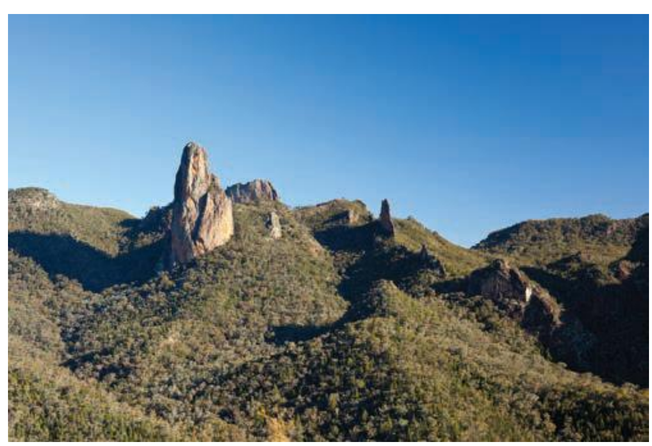

Figure 4.25 An example of intrusive igneous rock. This unusual landform in New South Wales contains the remains of an ancient volcano. Belougery Spire, on the left, was the magma chamber. The Breadknife, running along the right, was a crack in the volcano that filled with magma.

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Figure 4.26 Granite has a distinctive mosaic of crystals of different colours.

Another way for molten magma to form rocks is if it stops and cools before it gets to the surface, and solidifies underground. This rock will cool more slowly and so there is more time for crystals to grow, which means the individual crystals are bigger. Igneous rock formed in this way is called **intrusive** or plutonic. Although this rock is hidden when it is formed, it can be exposed later when the layers above have been eroded. Granite is an example of a plutonic igneous rock formed beneath the surface of a volcano.

intrusive
describes igneous rocks formed underground; also called plutonic rocks

Quick check 4.6

1 List some examples of igneous rocks.
2 Describe in your own words how intrusive and extrusive igneous rocks are formed.
3 Describe the relationship between crystal size and the time the crystal takes to form.

Practical 4.2

Crystals and cooling rate

Aim

To determine the effect that cooling rate has on crystal size formation.

Materials

- saturated potassium nitrate or magnesium sulfate
- beakers
- test tubes
- water
- ice
- hand lens

Planning

1 Write a rationale about crystal growth and the factors that can affect it.
2 Write a specific and relevant research question for your investigation.
3 Identify the independent, dependent and controlled variables.
4 Write a hypothesis for your investigation.
5 Write a risk assessment for your investigation.

Procedure

Using the materials, design an experiment to investigate how cooling rate affects the size of crystals of saturated potassium nitrate or magnesium sulfate.

Hint: To create crystals, you need to use a saturated solution of potassium nitrate or magnesium sulfate.

Results

Record your results. Consider different ways your results could be presented.

Discussion

1 Describe any patterns, trends or relationships in your results.
2 Explain any trends you have identified.
3 Identify any limitations in your investigation.
4 Suggest some improvements for this experiment.

Conclusion

Draw a conclusion from this experiment, using data to support your statement.

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Sedimentary rocks

Earth's surface is covered partly by water and partly by land. Weathering from waves, flowing water, wind, frost, rain, ice, chemicals and even living organisms, can break down the surface of exposed rocks. The particles of weathered rock are eroded: carried away by water, gravity, wind or ice. Eventually, the particles can no longer be carried, and sedimentary rocks are formed when these particles or sediments are deposited, compacted and cemented together. Sedimentary rocks take thousands to millions of years to form. Uluru in NT is 500 million years old (see Figure 4.27). The vertical ridges you can see were originally horizontal layers of sand and rock.

Figure 4.27 Uluru is an ancient sedimentary rock tilted by nearly 90° by the movement of Earth's crust.

Figure 4.28 shows how a lot of sedimentary rocks are laid down in layers. We can see that the oldest rock would be at the bottom, as these layers were laid down first, and therefore the youngest rock layers would be on top. Geologists use this method to help give sedimentary rocks relative ages.

By looking at the relative ages of sedimentary rocks and the fossils they contain, a geologist can estimate ages for these rocks.

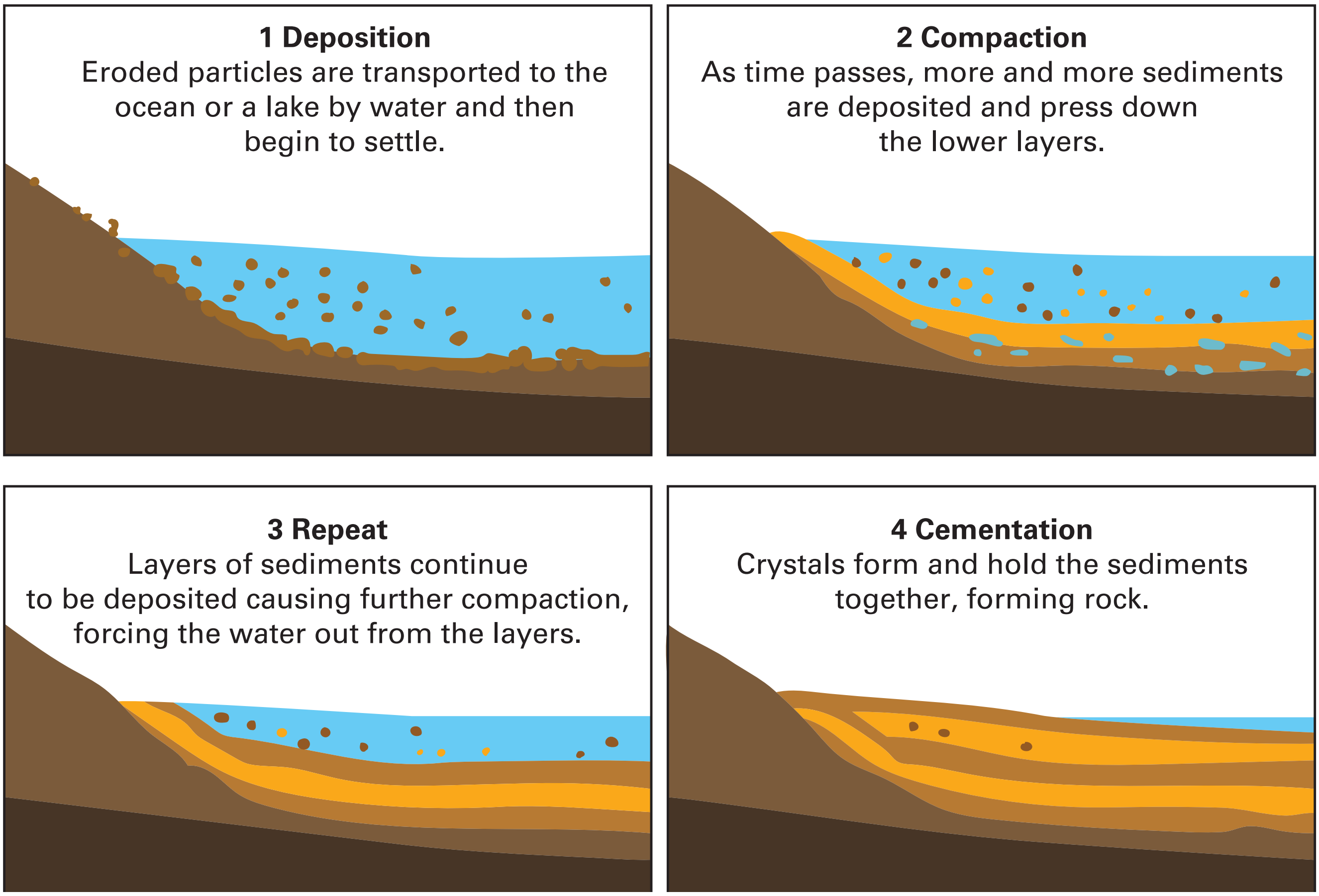

Figure 4.28 The formation of sedimentary rocks such as sandstone and mudstone

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The type of sedimentary rock formed depends on the particles that are deposited. Chalk is a common sedimentary rock and is formed from the remains of sea creatures whose bodies fell to the ocean floor. Chalk is made of calcium carbonate and can be identified by a simple test: when acid is placed on the surface, bubbles form. Chalk often contains fossils, and the age of the chalk can be determined from the fossils it contains.

Figure 4.29 A chert nodule, found in chalk. Chert is also a sedimentary rock.

Sea creatures that had tiny skeletons made of carbonates formed beds of chalk. Often gaps in the chalk filled with dissolved silica (also from sea creatures) formed flint nodules. Flint is a type of chert and was one of the first substances used to make tools.

Sand made of quartz is another familiar material that forms sedimentary rocks. Sand is commonly found all over the world on beaches, and at the bottom of rivers, lakes and the sea. The sedimentary rock formed from sand is called sandstone. It is a common building material because it is relatively easy to cut and is strong. Many of the early buildings in Sydney were built from sandstone mined locally from The Rocks area.

Figure 4.30 The outer wall of Parramatta Gaol is one of many building in Sydney made from local sandstone.

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Figure 4.31 Fossilised leaves in mudstone

Figure 4.32 Sedimentary rock made from rounded pebbles is called conglomerate.

conglomerate
sedimentary rock composed of rounded rock fragments larger than 2 millimetres

breccia
sedimentary rock composed of angular broken pieces of rock larger than 2 millimetres

Mud sediment forms mudstone (see Figure 4.31) and shale. It is not used extensively for building because it breaks easily. However, mudstone turns into slate at high temperature and pressure, and slate is used as a roofing material in some parts of the world. Half of the sedimentary rocks on Earth are made of mudstone or similar.

Sedimentary rock formed from small stones is called either **conglomerate** or **breccia**. Conglomerate is formed from rounded stones, whereas breccia consists of angular stones.

Explore! 4.2

How coal is made

Organic material from living creatures can also form sedimentary layers. Layers of plant material form coal, while oil was formed mostly from plankton. Although oil is a liquid, it is still sedimentary.

Use your preferred browser to research the following questions.

1. List three different uses for coal.
2. Coal is a non-renewable resource. Are there any alternatives to coal for the uses you listed in the previous question?

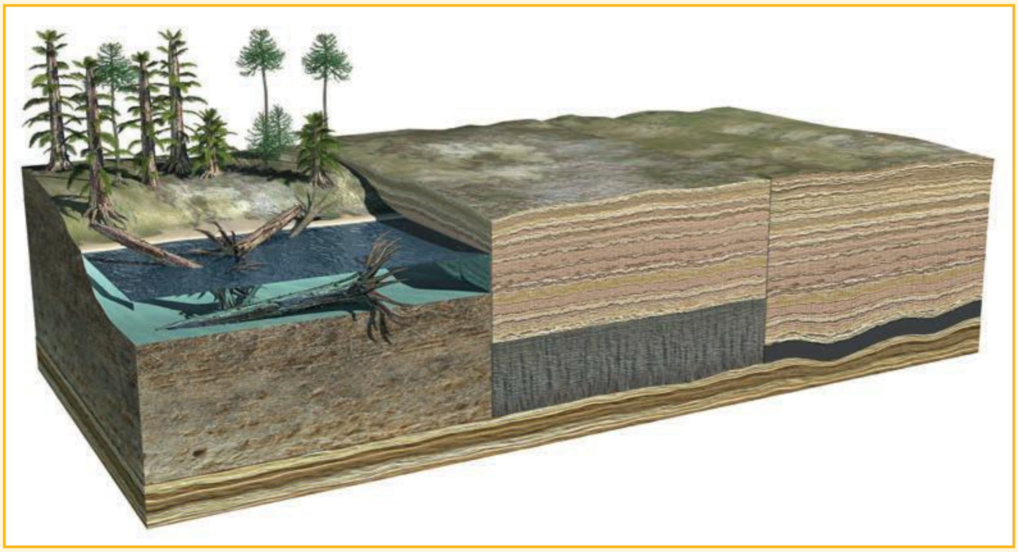

Figure 4.33 How coal is formed. Left: In the Carboniferous Period, trees died and formed a layer of wood. Middle: The wood was compressed by the layers of sediment above. Right: The compressed wood was transformed by heat and pressure into coal.

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Fossils

The bodies of different organisms may be deposited in sediment and form part of the sedimentary rock – this is how they become fossils. Fossils can include footprints of animals or faeces (coprolites). Generally, fossils are only formed in rocks that start as sedimentary rocks. But rocks are always changing, and if the rock is later subjected to intense temperature or pressure, it may become metamorphic without the fossil being destroyed.

Fossils can be used to trace the history of life on Earth. Because sedimentary rocks form slowly, the passage of time is traced in their layers, with the oldest rocks at the bottom. Fossils found in the same layer must have lived at the same time in the same location, and so were part of the same ecosystem. Fossils found in different layers must have lived at different times, with newer fossils being found above older fossils. Evidence of extinction events can be seen when a certain type of fossil suddenly disappears. For example, by studying sedimentary rocks, it is known that all the dinosaurs became extinct at the same time, about 60 million years ago.

Explore! 4.3

Fossil formation

Use your preferred search engine to find out about the process of fossilisation.

1 Not all living things become fossils. Describe the conditions necessary for fossils to form.
2 Evaluate some things that scientists have learned from fossils.

Types of fossils

There are various types of fossils, depending on how the impression was formed. Some common types are listed in Table 4.4.

Quick check 4.7

1 Recall how sedimentary rocks are formed.
2 List some examples of sedimentary rocks.
3 Distinguish between the five types of fossils discussed in this section.

Fossil type	Details
Mould	When a plant or animal decays in sediment, it may leave a hollow impression of itself.  **Figure 4.34** The mould of an ammonite
Cast	When an animal or plant dies, its body creates a space in the sediment. This gap fills with minerals, such as silica, over time and the shape of the animal is preserved as rock.  **Figure 4.35** A fossilised trilobite, extinct creatures that once dominated life on Earth
Imprint	These fossils leave behind a two-dimensional (flat) print. **Figure 4.36** Leaves are pressed flat by the pressure in the sedimentary layers and all that is left is a dark area, like a shadow. 
Whole body	This is the most common type of fossil. It consists of parts of the remains of living things, mainly the hard parts, e.g. teeth, shells, bones. **Figure 4.37** Whole body fossils are also found intact in a medium such as amber (tree resin that has become fossilised). 
Indirect or trace	These fossils do not consist of part of the organism. They are indirect records of biological activities, such as footprints, teeth marks or burrow marks.  **Figure 4.38** From a set of footprints, scientists can tell how fast the animal was moving, whether it was solitary or moved in groups, and how heavy it was.

Table 4.4 Five common types of fossils

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Advances in science 4.2

How did it become extinct?

The fossil record is the history of life as it is seen from fossils. It can tell us about groups of animals that are extinct, such as dinosaurs, and how animals and plants relate to each other. Unfortunately, the fossil record is incomplete because, as you investigated in *Explore! 4.3*, specific conditions are required for fossilisation to take place. Not all dead things become fossils.

Interpretation of the fossil record has always presented difficulties for paleontologists (scientists who study fossils). For example, for many years it was believed that the extinction of dinosaurs was gradual, but in 1980 evidence was found of a meteor impact that is now thought to have caused the mass extinction. Also, disappearance from the fossil record does not always mean that a species is extinct; there may be many other reasons for its absence from the record.

Paleontologists Steven Holland and Mark Patzkowsky designed computer models to aid the study of mass extinction, and are using the models to more accurately decipher the fossil record. Their work is still in progress; however, it provides an initial guideline for analysis and assessment of extinction events.

Figure 4.39 Dinosaur tracks fossilised on the ground on the edge overlooking Bull Canyon. 66 million years ago, a huge celestial object struck off the coast of what is now Mexico, triggering a catastrophic cooling period that eventually wiped out three-quarters of life on Earth, including the dinosaurs.

Metamorphic rocks

The third type of rock in the rock cycle is metamorphic rock. Metamorphic rocks are either igneous or sedimentary rocks that have been irreversibly changed by being subjected to high temperature or pressure. Earth's crust is very thin in proportion to its size, and rocks that lie beneath the surface can be subject to high pressure and temperature. The crystals inside these rocks may become deformed and the chemical nature of the rock may change. Rocks that have been changed into metamorphic rock tend to be denser and harder than before. Layers may become twisted when rocks are metamorphosed.

VIDEO Describe the three rock types

Over millions of years, buried metamorphic rocks can eventually make their way to the surface again. These rocks are found all over the world and they constitute about 10% of Earth's surface. Because of their toughness, they are often used for building materials. For example, if limestone (sedimentary) is subjected to high pressure and temperature, it turns into marble (metamorphic).

Figure 4.40 Folded layers are a feature of metamorphic rock.

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Marble is slightly denser and harder than limestone. Can you think of what marble is used for? Other common metamorphic rocks are slate, which is metamorphosed shale (sedimentary), and quartzite, which is metamorphosed sandstone (sedimentary).

Figure 4.41 Limestone (left) is a sedimentary rock. Marble (right) is a metamorphic form of limestone.

Explore! 4.4

Stone tools

Aboriginal and Torres Strait Islander peoples have developed techniques of crafting stone tools for various purposes. Stone tools are used in day-to-day life for activities such as hunting, harvesting and preparing food. The techniques involved in creating stone tools require knowledge from the various disciplines of science. Conduct research to investigate the following questions.

1. Explain how having a knowledge of the geological, biological, chemical and physical sciences helps to create stone tools that are fit for the intended purpose.
2. Determine the rock type for the following uses in Aboriginal and Torres Strait Islander cultures:
   a. The use of basalt as a stone tool
   b. The use of slate as a food grinding tool.
3. Examples of techniques and methods are knapping, lithic reduction, percussion flaking, pressure flaking and grinding. Describe what each of these processes involves and how they help create stone tools from the raw material.

Figure 4.42 A young girl from Bow River grinds stone to a powder that will be used for art works.

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Quick check 4.8

1 Describe how metamorphic rock is formed.
2 Recall some examples of a metamorphic rock and what components make up each one.

Try this 4.4

Summing up
Using the poster you began in *Try this 4.3*, annotate it with information about the three different rock types you have learned about, and their characteristics and examples.

Explore! 4.5

Stone pigments
Aboriginal and Torres Strait Islander peoples use paints, dyes and pigments originating from plant, animal and mineral sources.

1 Investigate one of these pigments and what rock (sedimentary/metamorphic/igneous) or mineral is used, as well as the chemical and/or physical processes involved:
   - red pigment
   - black pigment
   - white pigment
2 Fixatives can be applied to paints, enabling the pigment to bind to surfaces and increase the durability of the paintings. Name some fixatives historically used by Aboriginal and Torres Strait Islander peoples.

Figure 4.43 Ground natural paints

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Section 4.2 questions

QUIZ

Remembering

1 **Name** the type of rocks formed during a volcanic eruption.
2 **Name** the type of rocks formed when sedimentary rocks change due to high temperature and pressure.
3 **Recall** what sedimentary rocks formed from small rounded rocks are called.
4 **Name** five common fossil types.

Understanding

5 **Outline** how marble is formed and determine what type of rocks are involved.
6 **Explain** how the vertical layering of the rock forming Uluru indicates that Earth is ancient.

Applying

7 Figure 4.44 shows a basalt columns rock formation at Fingal Head in northern NSW. Use what you have learned about igneous rocks to **explain** how this formation came to be.

Figure 4.44 A set of basalt columns at Fingal Head in NSW

Analysing

8 Examine the igneous rocks shown in Figure 4.45. **Identify** which one is intrusive and which is extrusive. **Explain** your reasoning by first recalling the difference between intrusive and extrusive.

Figure 4.45 Which one is intrusive and which is extrusive?

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9 **Analyse** and **classify** the types of fossils shown in Figure 4.46.

Figure 4.46

Evaluating

10 **Evaluate** why the water in the Macleay River (near Kempsey, NSW) is brown. Use the following terms in your explanation: particles, sediment, weathering, erosion, deposit, rock.

Figure 4.47 Why is the water brown?

11 'A rock is clearly seen to be made of distinct and different layers. Therefore it must be a rock, not mineral.' **Evaluate** this statement and explain your reasoning.

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4.3 Classifying rocks

Learning goals

1. To classify rocks using their distinguishing characteristics.
2. To identify rocks based on their physical or chemical properties through a series of tests.

Classifying rocks is a skilled job, but it can be simplified by knowing some of the key characteristics of the different rock types, as well as the tests that can be done on rocks, and by using a dichotomous key.

Figure 4.48 Painite, the world's rarest gem

Are all rocks harmless?

Most rocks are harmless. However, some can pose a hazard and need to be handled with care. Beware of handling some metal **ores**, especially those containing mercury, lead or copper, and always wash your hands after handling rocks. Asbestos, which contains crystals in the form of fibres, is dangerous and should be avoided.

Figure 4.49 Asbestos is a dangerous mineral and SHOULD NOT be handled.

Characteristics of the different rock types

WORKSHEET

Recall that rocks are made of one or more minerals and can be classified into three groups according to how they have been formed.

1 Igneous rocks – formed from cooling magma, either intrusive or extrusive. They can differ in colour and texture. Some have holes because of gas that was trapped as the lava cooled. Some are characterised by visible crystals.

Figure 4.50 Examples of igneous rock are pumice (left) and diorite (right).

2 Sedimentary rocks – formed from layers of sediment being compacted and cemented together. They often appear grainy, and may contain fossils. They may be easy to crumble.

ore
a rock that can be mined and smelted to produce a metal

Figure 4.51 Examples of sedimentary rock are rock salt (left) and limestone (right).

3 Metamorphic rocks – igneous or sedimentary rocks that have been subjected to high pressure and/or temperature. They often appear layered, and may have crystals arranged in bands.

Figure 4.52 Examples of metamorphic rock are gneiss (left) and granulite (right).

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Explore! 4.6

Classifying rocks

You now know that rocks are made of minerals, there are three groups of rocks, and that rocks come in various shapes, sizes, colours and other characteristics. Conduct some research and find out how a rock's characteristics can be used to determine whether the rock is igneous, sedimentary or metamorphic.

1 What are the characteristics of igneous rock?
2 What are the characteristics of sedimentary rock?
3 What are the characteristics of metamorphic rock?

What tests can help us classify rocks?

Some common types of rocks are easy to identify, but others can be challenging. There are many different tests geologists use to help classify a rock. Each test allows you to identify the presence or absence of a chemical or the physical property of the rock, and this then allows you to classify the rock and name it.

Crystal size and shape

Does the rock contain crystals? Crystals are a feature of rocks, especially igneous rocks. Some rocks, such as quartz or diamond, are one giant crystal. These are known as crystalline rocks. Other rocks are made of tiny crystals or have crystals that can only be seen with a microscope. The shape and size of the crystals can help in identifying the rock. Earlier you learned that fast-cooling magma can produce small crystals in extrusive igneous rock, while slow-cooling magma can produce larger crystals in intrusive igneous rock.

Mohs scale
a scale from 1 to 10 that indicates the hardness of a rock

Hardness

A useful method to help identify rocks, which are made of minerals, is to determine how hard the surface is. In 1812, Friedrich Mohs classified all minerals according to their ability to scratch each other, on a scale from 1 to 10.

The softest mineral, with a 1 on the Mohs scale, is talc (metamorphic), and the hardest is diamond (metamorphic) with a 10. Any mineral with a high **Mohs scale** number can scratch any mineral with a lower number.

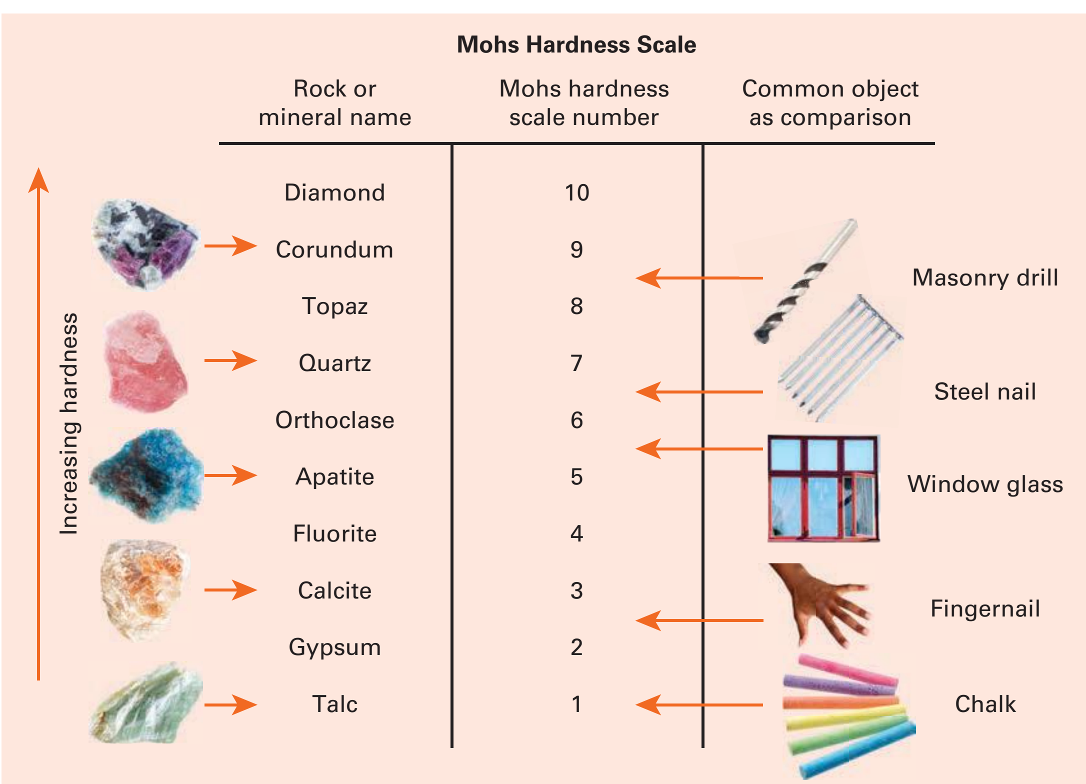

Figure 4.53 A table comparing objects of similar hardness on the Mohs hardness scale

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Behaviour in light

Most rocks are **opaque**, which means no light can pass through them. Some are **translucent**, which means light can pass through the rock but no clear image is visible through it. **Transparent** rock, such as diamond (metamorphic) and quartz (igneous), allow light to pass through and images are visible through them.

Figure 4.54 Amethyst (mineral) is a translucent crystal and can be found inside all three types of rocks, igneous, metamorphic and, less commonly, sedimentary.

Behaviour in acid

Weak hydrochloric acid can be used to test for carbonates. Bubbles form on the surface of marble (metamorphic), limestone (sedimentary) and chalk (sedimentary) when acid is dropped onto their surface. Rocks that do not contain carbonates will not fizz or bubble in acid.

opaque
blocking light completely

translucent
allowing some light through, but no clear image can be seen through the substance

transparent
allowing light to pass through, and a clear image can be seen through the substance

cleavage
the tendency of a mineral or rock to break in a particular way because of its structure

Behaviour when struck with a force

Some rocks break more easily in some directions than others. This feature is called **cleavage** and can help identify rock, such as slate (see Figure 4.55), which is a metamorphic rock containing mica.

WIDGET
A key to identify rocks

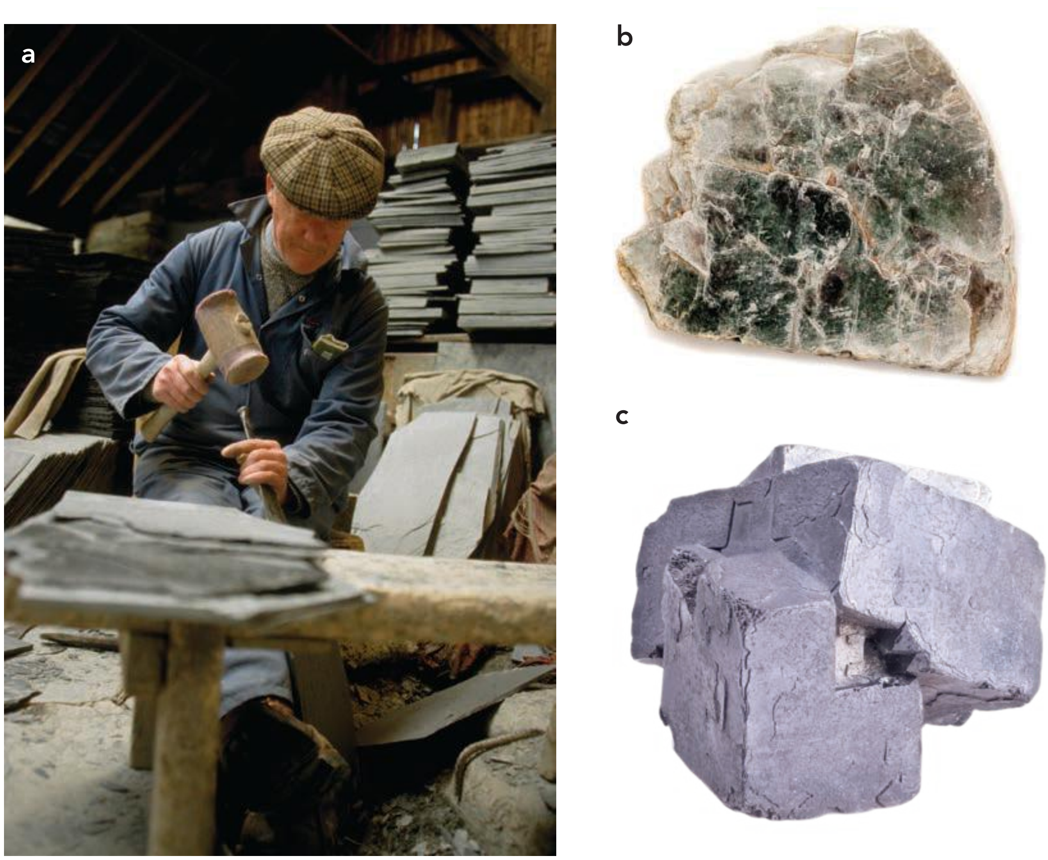

Figure 4.55 (a) Slate can be split into thin sheets for building. Slate is composed mostly of quartz and **(b)** mica. **(c)** Galena is another mineral which, like mica, has an identifiable cleavage plane.

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Behaviour in a magnetic field

Some iron-bearing rocks are attracted to a magnet, and others are naturally occurring magnets themselves. One of the most common magnetic minerals found in rocks is magnetite, named for its magnetic properties.

Figure 4.56 Magnetite is a mineral found in igneous, metamorphic and sedimentary rocks. It is also found in meteorites.

The streak test

When a rock is scratched onto a hard, ceramic surface, it can leave behind a coloured streak, which is a more reliable indicator of its colour than the colour of its surface. For example, gold and chalcopyrite have a similar surface colour, so a **streak test** is useful to distinguish between them.

streak test
a test used to help identify a mineral by scratching a rock on a hard ceramic tile

Figure 4.57 Examples of a streak test

Figure 4.58 The streak test for gold (left) shows up as gold, while the streak test for chalcopyrite (right) – also known as 'fool's gold' – shows up as dark green-grey.

Quick check 4.9

1. Describe ores and why some of them are harmful.
2. Explain the seven characteristics that can be used to help classify rocks.
3. Identify which of the characteristics from the previous question involves a chemical property.

Classifying and identifying rocks

In order to classify and identify types of sedimentary, igneous and metamorphic rocks, you need to use a magnifying glass and work your way through the different tests. A dichotomous key, such as the one in Figure 4.60 on page 160, will also help.

Table 4.5 gives the general characteristics of the three different rock types.

Igneous rock	Sedimentary rock	Metamorphic rock
• May contain holes • Crystals can be small or large • Usually hard	• Grains are cemented together • Can be soft	• Sometimes has a layered look • Can often be cleaved to a straight plane • Ranges from soft to hard

Table 4.5 Some characteristics of rocks

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Practical 4.3

Identifying 12 common rocks

Aim

To practise identifying and finding patterns, by classifying 12 of the most common rocks found in Earth's crust.

Materials

- hydrochloric acid 0.1 M
- 12 Petri dishes for the hydrochloric acid test
- dropper
- beaker of water
- hand lens
- disposable gloves
- two of each of the following rocks: basalt, chalk, gneiss, granite, limestone, mica, pumice, quartz, quartzite, sandstone, schist, slate

Figure 4.59 Twelve common rocks found in Earth's crust, in random order

Procedure

1 Use the following dichotomous chart to identify the rock and the rock type. You can work in 12 groups, each group being responsible for one rock (each group will hold two rocks: one for the general test, and one for the hydrochloric acid test).
Rocks are composed of one or more minerals. For this practical, if a rock is made up of only one type of mineral, identify the rock as a 'mineral'.

continued…

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...continued

1	Is the rock composed of crystals?	Yes	Go to 2
		No	Go to 5
2	Are the crystals flat and silvery?	Yes	Mica (igneous, metamorphic)
		No	Go to 3
3	Are the crystals large and transparent?	Yes	Quartz (igneous)
		No	Go to 4
4	Are the crystals small, easily removed by rubbing, and layered?	Yes	Sandstone (sedimentary)
		No	Granite (igneous)
5	Do bubbles appear when acid is placed on the rock? You will need to place the rock in the Petri dish and use the dropper to place 1–2 drops of hydrochloric acid on the rock. Do not handle the rock after hydrochloric acid has been added to it.	Yes	Go to 6
		No	Go to 7
6	Using a fresh rock, can the rock be scratched easily with a finger nail?	Yes	Chalk (sedimentary)
		No	Limestone (sedimentary)
7	Place the rock in a beaker of water. Does the rock float on the water?	Yes	Pumice (igneous)
		No	Go to 8
8	Is the rock translucent (allows some light to pass through)?	Yes	Quartzite (metamorphic)
		No	Go to 9
9	Does the rock have visible layers that may be curved or bent?	Yes	Gneiss (metamorphic)
		No	Go to 10
10	Does the surface of the rock appear to be made up of plates?	Yes	Schist (metamorphic)
		No	Go to 11
11	Does the rock break to form layers with a flat surface?	Yes	Slate (metamorphic)
		No	Basalt (igneous)

Figure 4.60 Dichotomous key for rock identification

2 Once you have identified your rock, label it. When all the rocks have been identified, sort them into the four groups: igneous rocks, metamorphic rocks, sedimentary rocks and rocks made up of only one type of mineral. Copy and complete the results table.

Results

Copy and complete this table to identify common characteristics of the different types of rocks.

	Rocks made up of only one type of mineral	Igneous rocks	Sedimentary rocks	Metamorphic rocks
Common characteristics				

Discussion

1 Recall what the hydrochloric acid test reveals about the rock material.
2 Discuss why you think pumice floats in water.
3 Design some rules and a different dichotomous key or chart to classify rocks as minerals, or igneous, sedimentary or metamorphic rocks. Identify any difficulties you encounter in doing this.

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Section 4.3 questions

QUIZ

Remembering

1 **Recall** seven characteristics that can be used to help classify rocks.

Understanding

2 Igneous rocks may contain holes. **Explain** why this is the case.

3 Sedimentary rocks often look like the grains are cemented together, and they are often soft. **Explain** why this is the case.

4 Metamorphic rocks sometimes have a layered look. **Explain** why this is the case.

Applying

5 **Identify** the following rocks, using the dichotomous key in *Practical 4.3*.

a The rock in Figure 4.61 does not bubble when acid is placed on it.

Figure 4.61

b The rock in Figure 4.62 does not bubble when acid is placed on it.

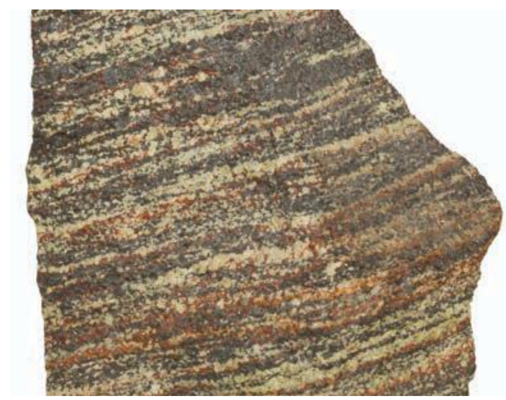

Figure 4.62

c The rock in Figure 4.63 bubbles when acid is placed on it. It cannot be scratched with a nail.

Figure 4.63

d The rock in Figure 4.64 does not bubble when acid is placed on it. The crystals are not easily removed.

Figure 4.64

Analysing

6 Using the rocks in Question **5** and the dichotomous key in *Practical 4.3*, **identify** each rock type, and **explain** how the appearance of each rock links to the rock type.

Evaluating

7 'All types of rock can be classified according to their physical characteristics only.' **Assess** whether or not you agree with this statement.

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4.4 The mining process

Learning goals

1. To describe the stages of the mining process.
2. To identify examples of metal resources mined in Australia.

WORKSHEET

VIDEO The mining process

Some minerals are useful to humans and can be mined. Mining is the process by which minerals and other useful materials are extracted from the ground. Salt, slate, gold, marble and coal can be used as they are found. Others need to be processed to make useful products such as metals, or building materials such as cement.

The mining process has several stages: exploration, planning and design, construction, mining, processing, and closure and rehabilitation.

Explore! 4.7

Australia, being such as a large country, is considered to be a 'resource-rich' country. Resource-rich usually refers to non-renewable resources such as metals, minerals and fossil fuel. In NSW, mining plays an important role in creating jobs and providing for the economy.

Find out about the Cadia mine located in central western NSW.

- What metal(s) do they mine here?
- How much metal is extracted?
- How is the metal mined?
- How many people work at this mine? Describe five different jobs.

Figure 4.65 The open cut pit at the Cadia mine

1 Exploration

Before any mining project begins, mining companies enlist the expertise of geologists to scout areas and search for mineral deposits. It is important that they find out the quality of the mineral and the size of the deposit. This is to determine whether it would be cost effective for the mineral to be mined, as a mining project is extremely expensive once it has started.

Mining companies should also communicate with the traditional owners of the land to ensure that any important cultural sites are protected. In 2020, Rio Tinto blasted a 46 000-year-old Aboriginal sacred site in the Pilbara region, Western Australia. This led to an unreserved apology to the Puutu Kunti Kurrama and Pinikura traditional owners, and a call for legislative change to protect Aboriginal and Torres Strait Islander heritage sites at risk of demolition.

Figure 4.66 Geologists sampling rocks during iron ore exploration in the outback (Pilbara, Western Australia)

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Advances in science 4.3

PMI guns

In modern mining, new technology is available to confirm a geologist's identification of a rock in just a few seconds. A positive material identification (PMI) gun uses high-energy radiation (X-rays) to excite the material in a rock, and records the response. Each different material has a unique response, like a fingerprint. By analysing the signal given out by the rock, the percentage of each element can be found.

Geologists and geophysicists use a technique called **reflection seismology** to determine the structure of the rocks that lie beneath the surface. An explosive charge, or other methods, is used to make a loud sound and, as the sound travels down, it is reflected from the layers beneath the surface. Once an area has been identified, a thin cylinder of rock, called a core sample, is extracted to positively identify any minerals found.

reflection seismology the use of shockwaves to investigate the structure of rocks underground

Figure 4.67 Miners can use a PMI gun to determine the composition of a rock.

Figure 4.68 Core samples taken from a diamond mine

2 Planning and design

If the results of the exploration strongly suggest that mining in a certain area would yield good results, then the project moves into the planning stage. Collaboration occurs among project managers, mining engineers, finance consultants and other experts to design safe, sound, economically viable and socially responsible plans.

Figure 4.69 Wollondilly Coal Mine. In late 2020, the company won approval to expand operations to extract an additional 3.7 million tonnes of metallurgical coal at its Russell Vale colliery.

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3 Construction

After research is carried out, planning is completed and permits are approved, the project moves to the construction stage. This may involve building roads, mining facilities and housing.

Figure 4.70 Constructing a mining site involves many people, such as construction workers, builders, landscape architects and engineers.

4 Mining

Mining is the process by which the minerals are recovered, using various tools and machines. When you think of mining, most people imagine an underground tunnel, which is a technique of mining that goes back to Roman times. **Underground mining** is highly skilled and can also be dangerous. The advantages of underground mining are that there is generally little impact on the environment, and minerals can be extracted from much deeper depths then surface mining.

underground mining traditional method of mining by digging tunnels underground to extract ore

surface mining method of mining that extracts a mineral from the surface, such as by digging an open pit

Figure 4.71 An underground coal mine

Another method of mining is called **surface mining,** such as strip mining and open-cut mining. Large quantities of a mineral can be extracted using this technique. Surface mining can only be used if the mineral is close to the surface. This method has become much more common in recent years, especially for the extraction of metal ores. It is relatively safe compared with underground mining, but there is a significant impact on the environment. Coal and iron ore are usually mined in this way in Australia.

There has been interest in mining deep sea deposits such as manganese–cobalt nodules in Pacific Ocean; however, there are strong environmental concerns associated with deep sea mining and to date, it is too difficult and expensive.

Figure 4.72 An open-cut coal mine in New South Wales. Australia supplies about 20% of the world's coal and about 40% of the world's iron ore.

Explore! 4.8

Mining extraction processes

There are different types of mining. Underground mining and surface mining are two of these; another two methods are *placer mining* and *in-situ leach* mining. Research these methods and answer the following questions.

1. What is involved in placer mining and in-situ leach mining?
2. List some advantages and disadvantages of the types of mining.
3. Which of the mining types are most environmentally friendly? Justify your answer.
4. Describe some of the ethical issues that need to be considered with regards to mining.

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Explore! 4.9

World's first fully automated mine

Use your preferred web browser to search for 'Syama automated mine'. Do some research with regards to advances in mining technology and automation, and answer the following questions.

1 Identify the advantages of fully automated mining technology.
2 Assess the concerns that have been raised for fully automated mining. Do you think these concerns are justified?

Quick check 4.10

Copy and complete the following table to summarise what you have learned about the mining process so far. Remember, there are still two stages to go, so leave space in your table for these stages.

Mining process	Details	Examples of people involved
1 Exploration		
2 Planning and designing		
3 Construction		
4 Mining		
5		
6		

5 Processing

Recall that ore is rock that contains the metal being mined. There are several ways to process the ore so that only the intended metal is extracted.

Grinding

The ore is usually first crushed so that the pieces are smaller and easier to process.

Smelting

The process of extracting the metal from its ore is called **smelting**. Basically, the metal ore consists of the metal combined with oxygen in the rock. The ore is heated in the presence of carbon (charcoal) and a chemical reaction takes place.

$$\text{metal oxide} + \text{carbon} \xrightarrow{\textit{yields}} \text{metal} + \text{carbon dioxide}$$

The extraction of metals, ores and other materials from the earth has a very long history. Archaeologists have named two periods of human history, the Bronze Age and the Iron Age, according to the metals that people were producing at that time.

Purifying

Electricity can be used to purify an impure sample of metal, in a process called **electrolysis**. The sample is connected to a positive terminal, and a pure piece of the metal is connected to the negative terminal.

smelting
the process of getting a metal from rock by heating it to a very high temperature

electrolysis
a method of extracting a metal from its ore or purifying it using electricity

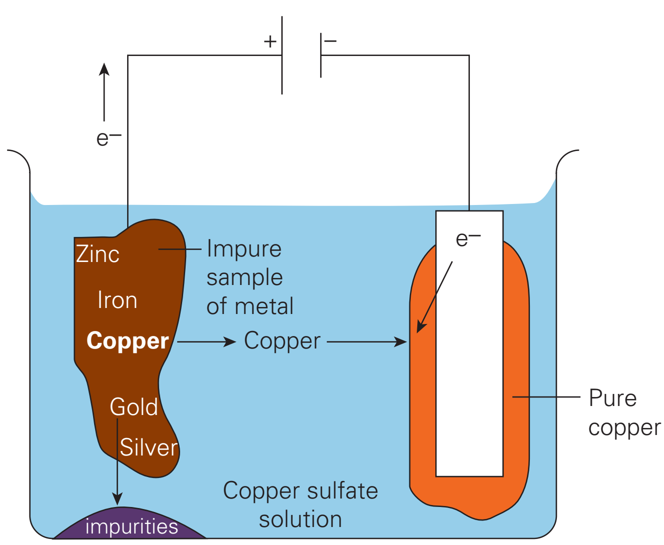

Figure 4.73 Use of electrolysis in purifying copper

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The terminals are placed in a solution containing the metal and, when the circuit is connected, the metal in the impure sample slowly moves through the solution from positive to negative. Any impurities are deposited near the positive terminal. When this is done with copper ore, the impurities may contain valuable metals such as gold.

Practical 4.4

Electrolysis of copper

Be careful

Ensure personal protective equipment is worn. All materials and solutions are to be collected. Electrical shocks may occur. Ensure the voltage output is not exceeded. Turn off the power supply when changing the circuit.

Aim

To see how metals can be purified using electricity, and to demonstrate electroplating.

Materials

- 0.5 M copper sulfate solution
- beaker
- 2 copper plates to act as electrodes
- 2 alligator leads
- an old metal fork or spoon
- 3 V DC power supply

Procedure

Part A

1 Place two copper electrodes in a beaker containing a solution of copper sulphate.
2 Connect the electrodes to a battery or low-power direct current supply (make sure it is switched off when you do this) using alligator leads.
3 Switch it on and leave it for a while (it may take 20–40 minutes). The cathode will slowly grow, and the anode will become smaller.
4 Switch the power supply off.

Part B

5 Replace the copper plate connected to the negative terminal with a fork.
6 Switch the power supply on. Copper will move from the other plate to the fork. When it reaches the fork, it will be deposited on the surface and a thin layer of copper will appear. This is called electroplating.

Results

Record your observations for each part of the experiment.

Discussion

1 Describe what you think happened when the power supply was switched on in Part A of the experiment.
2 Deduce some uses for electroplating, which you saw in Part B of the experiment.
3 Distinguish between electrolysis and electroplating.

6 Closure and rehabilitation

The final step in mining is closure and rehabilitation. When the resources in a mining site have been exhausted, the site closes down, all facilities are packed up and often removed, and a rehabilitation plan is developed. The purpose of this is to return the land to the state it was in before the mine was built. For example, if it was agricultural land, then the plan would involve trying to restore the land to its original level of productivity. Rehabilitation involves scientists, government personnel, bush regenerators and local wildlife experts, among others.

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Did you know? 4.3

Rehabilitation and biodiversity
Rehabilitation of the land also takes into consideration the native plants and animals that were in the site before it was mined. Disturbed areas are reshaped to reflect their original state as closely as possible, and care is taken to preserve plant species. An example of mining rehabilitation is the Woodcutters lead–zinc mine in the Northern Territory, which was closed in 1999. In 2002 it was acquired by Newmont, a mining corporation, which has rehabilitated and monitored the site as part of its commitment to sustainable business, in partnership with the Kungarakan and Warai people, who are the traditional owners of the land. The rehabilitation process has several stages, and the latest stage started in 2018, with the planting of wetland vegetation. The final goal is to hand back the land to the traditional owners.

Figure 4.74 Another example of rehabilitation is the Westside Mine, a coal mine near Lake Macquarie, NSW. The rehabilitation was completed in 2012, two months after operations stopped.

The mining industry in Australia

The mining industry is one of the most important industries in Australia. Table 4.6 shows a summary of some of the metal resources mined in this country.

It is not just metals that are mined or quarried. Stones are used to make roads. Coal (sedimentary) is mined as a source of energy; Australia is ranked fourth in the world in terms of coal supply. Limestone (sedimentary) is used to make cement; also, when sand is combined with small amounts of limestone and sodium carbonate, heated until it melts and allowed to cool, it becomes glass.

Resource	Details
Iron	Australia is the world's largest exporter of iron ore.
Uranium	The worldwide nuclear power industry needs uranium ore as fuel. There are no nuclear power stations in Australia, but about 10% of the world's uranium is mined here.
Gold	Australia's early history was highly influenced by gold, as many immigrants came during the gold rush days. Gold mining is still a large industry, and ore containing even a small amount of gold is mined, due to the high value of the gold. Gold mines in Australia account for 9% of the world's production and some of these mines are huge operations, occupying many hectares.

Table 4.6 Some important metals mined in Australia

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Gemstones, such as diamonds and opals, are mined in Australia, and gemstone mining is a major source of income for some Australian towns. Coober Pedy, for example, is the largest opal mining area in the world.

Figure 4.75 An Australian opal. Australia produces around 95% of the world's opals.

Explore! 4.10

Coal mining in New South Wales

Coal mining makes up a significant portion of NSW's mining industry, but coal mine sites often face community concerns over the environmental impact of mining and burning coal. Conduct some research and answer the following questions.

1. Name the type of rock that coal is sourced from in NSW.
2. Describe the cost and energy advantages of coal.
3. Describe the environmental impacts of mining and burning coal.

Quick check 4.11

1. Add the last two mining processes to your table from *Quick check 4.10*.

Mining process	Details	Examples of people involved
5 Processing		
6 Closure and rehabilitation		

2. List some of the metals, rocks and minerals mined in Australia.

Section 4.4 questions

QUIZ

Remembering

1. **Recall** the steps of the mining process, in chronological order.
2. **Recall** three processes that can be used in the processing stage of mining to obtain the intended metal.
3. **Identify** some metals and resources that are significant for the Australian mining industry.

Understanding

4. **Explain** the importance of performing the exploration stage before designing a mine.
5. **Outline** how geologists determine the content and structure of the rocks under the surface.

Applying

6. **Identify** an example of technological progress in the mining industry and **describe** how it helps the mining process.

Analysing

7. Give at least two advantages and disadvantages of open-cut or surface mining **compared** with underground mining.

Evaluating

8. **Evaluate** why electroplating with silver or gold is a very popular technique in jewellery making.

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Chapter review

Chapter checklist

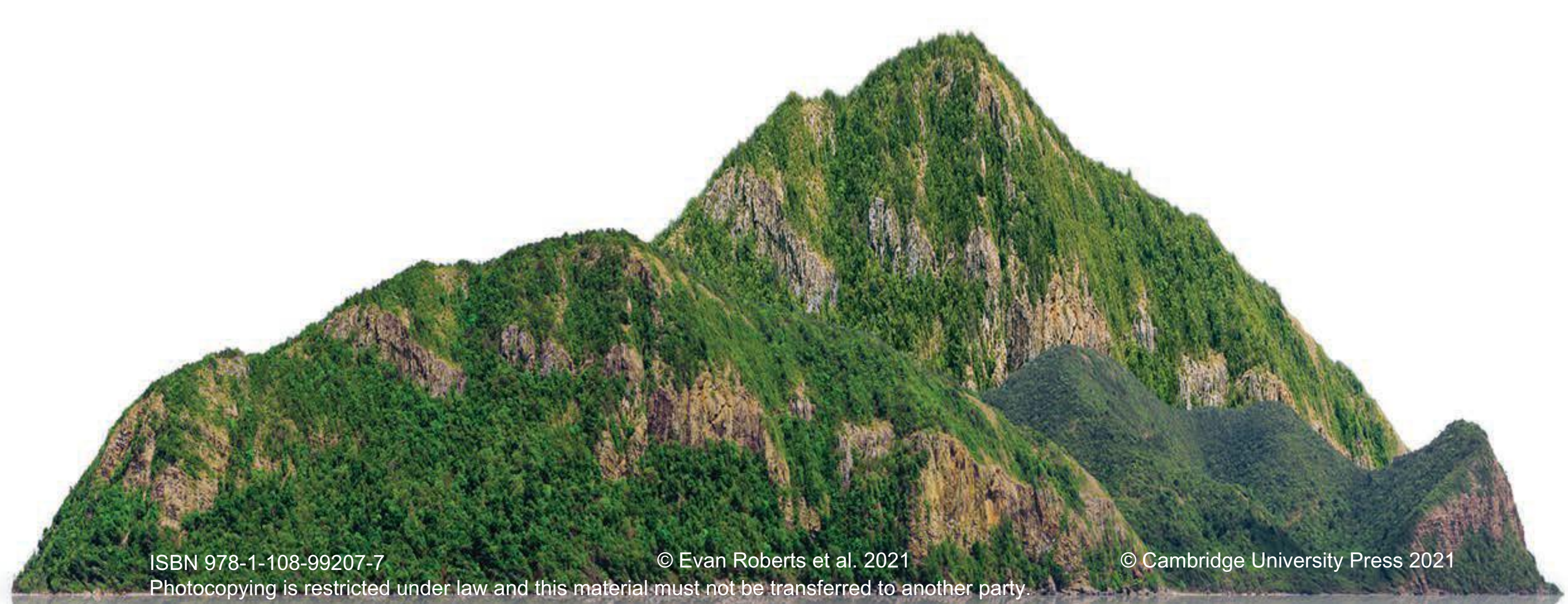
You can download this checklist from the Interactive Textbook to complete it.

Success criteria		Check
4.1	**I can recall the names of the three types of rock.** e.g. State the three types of rock found on Earth.	
4.1	**I can name the different geological layers of Earth.** e.g. Illustrate a diagram that shows the different geological layers of Earth.	
4.1	**I can describe the rock cycle.** e.g. Illustrate a diagram that shows the main processes of the rock cycle.	
4.1	**I can distinguish between physical, biological and chemical weathering.** e.g. Distinguish between the three types of weathering: physical, chemical and biological.	
4.2	**I can describe the following processes: weathering, erosion, deposition, cementation and compaction.** e.g. Define deposition.	
4.2	**I can discuss the formation of sedimentary, igneous and metamorphic rocks.** e.g. Discuss how metamorphic rocks are formed.	
4.3	**I can classify rocks by their different features.** e.g. Recall some of the characteristics of sedimentary rocks.	
4.4	**I can discuss the process of mining.** e.g. Summarise the following stages of mining: exploration, planning and design, construction, mining, processing, and closure and rehabilitation.	

SCORCHER

Reflections

1 What **connections** come to mind when you think about rocks and your everyday life?
2 What new concepts have **extended** your thinking about rocks?
3 What information did you find **challenging** or confusing?



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Data questions

Iron ore is a key Australian export, and an Australian iron ore deposit commonly contains the minerals hematite, magnetite and pyrite, among others. The iron content of these minerals is presented in Table 4.7, and an example of the percentage of mineral components at different depths of an iron ore deposit drill sample is shown in Figure 4.76.

Mineral	Formula	Iron content	Colour
Hematite	Fe_2O_3	70%	red
Magnetite	Fe_3O_4	72%	black
Pyrite	FeS_2	47%	yellow

Table 4.7 Examples of minerals found in Australian iron ores

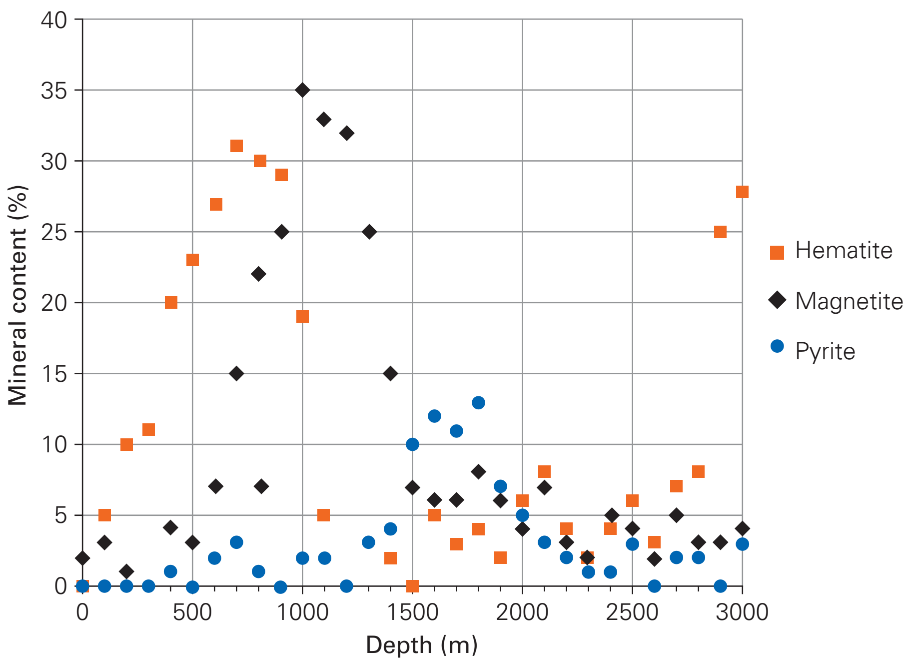

Figure 4.76 Mineral content of an iron ore exploration extract, depending on the depth of drilling

1 **Identify** which mineral described in Table 4.7 presents the highest iron content.
2 **Identify** the mineral with the highest content in the ore at 400, 1100 and 1800 m.
3 **Classify** the minerals hematite, magnetite and pyrite as 'oxides' or 'sulfides'.
4 **Contrast** the iron content in hematite, magnetite and pyrite and suggest which of these minerals is the least sought after.
5 **Deduce** which mineral has the lowest overall content in the ore at depths from 0–3000 m.
6 Given the response to Question **5**, **infer** a reason why the mining company has concerns about mining beyond 1500 m in depth.
7 Some miners had thought that they had found gold at a depth of 1800 m, but analysis revealed an iron-based mineral. **Justify** their observation with respect to the colours of iron-containing minerals.
8 At close to 3000 m depth, the content of hematite is raised again. **Predict** the percentage of hematite content at 3100 m in this drill sample.
9 **Predict** the colour of the rock sample taken 1200 m depth.

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STEM activity: Underground bunkers and asteroids

Background information

A bunker is a structure built underground for people to shelter or live in, protecting them from dangers above ground. For example, many homes in parts of the world that are prone to tornados have a bunker to protect the home owners. During World War Two, many major cities had huge bunkers built beneath them to protect residents from bombs.

Figure 4.77 A bunker provides protection from dangers above.

Design brief: Design an underground bunker to survive the imminent impact of an asteroid!

Activity instructions

BREAKING NEWS: AN ASTEROID IS HEADING FOR EARTH!

Scientists have calculated that the asteroid will collide with Earth in 20 days. The impact will be so destructive that all humans will need to stay in bunkers underground for at least three months. Your team of engineers has been tasked with building an underground bunker for 10 people in your local area.

Suggested materials/presentation formats

- large plastic container
- soil and crushed rock
- cardboard
- ice block sticks
- scissors
- sticky tape
- glue
- slotted masses/weights

Research and feasibility

1 Research the local rock formations in your area. Decide whether your bunker needs to be built underground or into local rock formations. You will need to research the common types of rock and the difficulty in excavating/drilling using the hardness scale for the rock type. You may need to consider other factors of the rock type that may be important when considering strength.

2 Also consider how you will access clean water, air and food in your underground bunker.

Design and sustainability

3 Decide as a group the volume of your bunker based on the number of people, and what your group believes are space requirements. Sketch proposed local area locations and a design for your bunker. Include annotations on your sketch for the bunker design, giving additional information on the thought processes behind it.

4 Discuss as a group how you can build a model of your proposed bunker for testing. Think about the type of local rock, your bunker shape, and how to make an effective model. Include in your discussion how you are planning to test your bunker to show its durability.

Create

5 Build the model of your bunker, and then test it using varying weights or methods.

Evaluate and modify

6 Describe some of the difficulties you encountered while calculating and estimating the amount of space people will need to live in.

7 Did you need to make compromises about quality of life for the people living in your bunker, to save space? Explain how you came to your decisions.

8 Describe some modifications you could make to your bunker to withstand more force.

9 Evaluate the feasibility of constructing a bunker located within the rock type you have chosen.

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Chapter 5
Planet Earth

Inquiry questions

Why does Earth have day/night and seasons?

How do we find out about the solar systems and space if we can't travel there?

How does the Sun and the Moon influence Earth?

PRE-TEST

Chapter introduction

In this chapter, you will find out more about the world you live in and investigate the motion of Earth, the Moon and the Sun through space. You will learn why a day is 24 hours long and why different countries have different time zones. You will also learn why there are 365.25 days in a year, why there are seasons, the phases of the Moon, and solar and lunar eclipses. You will investigate how technology has been used to improve the observations made of the night sky and how these observations have given us a clearer picture of the structure of our solar system, our galaxy and the large-scale structure of our universe.

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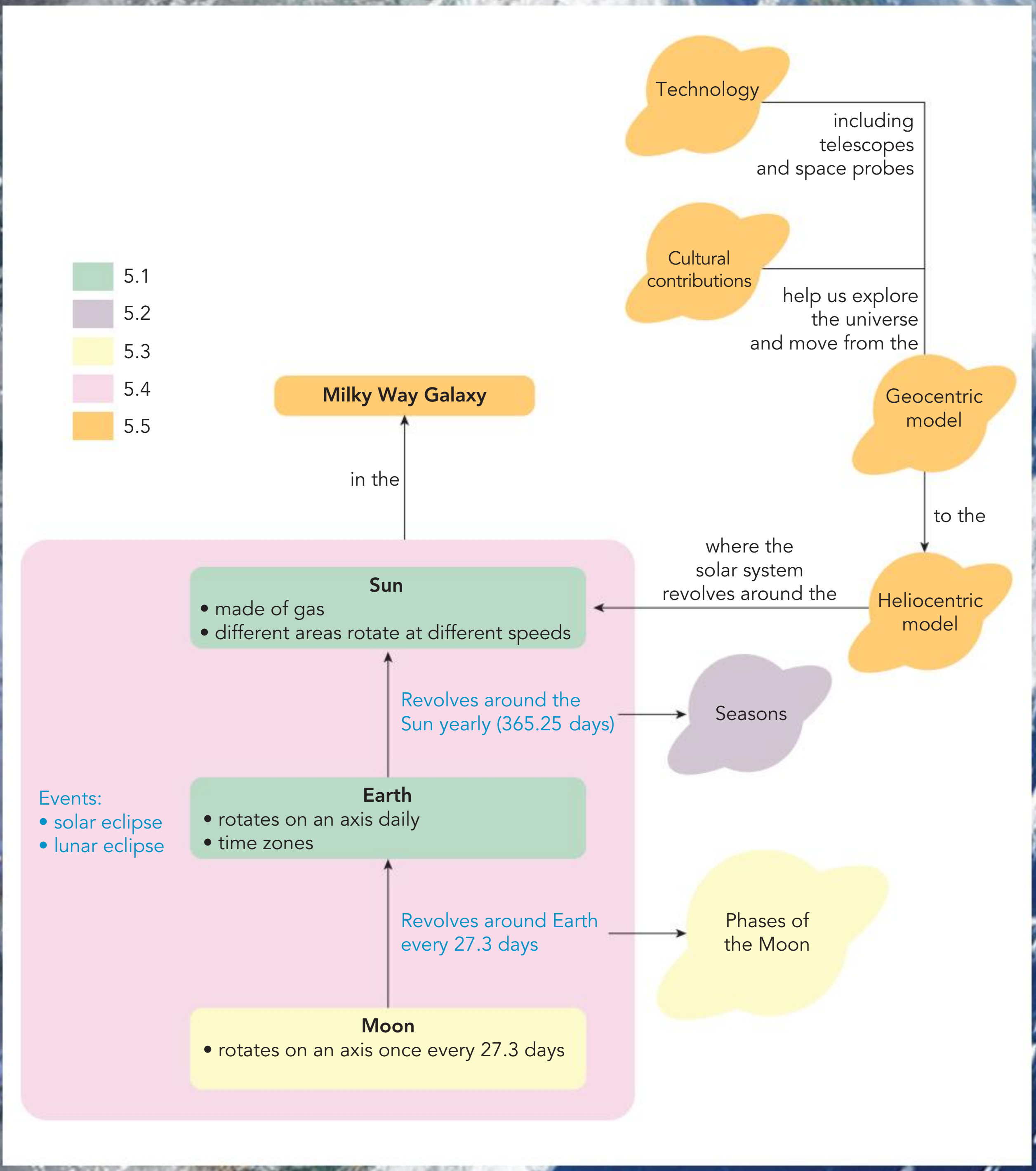
Chapter map



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5.1 Our rotating Earth

Learning goal

1 To explain that Earth's rotation causes daily cycles including day and night.

DOC WORKSHEET

The daily cycle

Have you ever thought about how much of your life is regulated by a daily routine? Much of this is determined by Earth, the Moon and the Sun.

Try this 5.1

The daily cycle

In small groups, think about and describe your observations of the Sun, Earth, Moon and stars during a typical day. For example, the day begins officially at midnight when the date changes. The new day starts in darkness. Most people are asleep as the dawn approaches. When the morning sun appears over the horizon, it is time for us to wake up. Birds announce the dawn, animals that hunt at night look for somewhere to hide and animals that are busy during the day get up to look for food. Now, keep going with the list, but remember to focus on the changes in the Sun, Earth and the Moon. List any other changes you have seen as the day or night progresses. Remember, you are only looking at what changes over a period of 24 hours, so do not include weather events because they do not repeat every day.

Figure 5.1 Newcastle at sunset. Temperatures increase during the day and decrease at night.

Our rotating Earth

Earth is a giant ball in space that is spinning counterclockwise (when viewed from the North Pole) slowly, one rotation per day. Sunlight shines on one side, while the other side is in darkness. The side of Earth facing towards the Sun experiences day and the side facing away experiences night. **Dawn** and **dusk** lie on the boundary between light and dark when the Sun is on the **horizon**. The Sun does not actually move across the sky. It appears to do so because Earth is rotating. If you are facing north, then Earth rotates from the west to east, which is why the Sun appears from the east and sets in the west.

dawn
the time of day when the Sun rises over the horizon or night turns into day

dusk
the time of day when the Sun drops below the horizon or day turns into night

horizon
the point where the sky appears to meet the land or the sea

Did you know? 5.1

Because Earth is rotating counterclockwise, the whole state of NSW is moving to the east at around 385 metres per second, which is faster than the speed of sound. You do not feel like you are moving because everything around you is moving as well. In addition to the motion caused by its rotation, Earth is also moving counterclockwise around the Sun at a speed of around 28 kilometres per second. If an aircraft could fly at that speed, it would get to London from Sydney in about 10 minutes!

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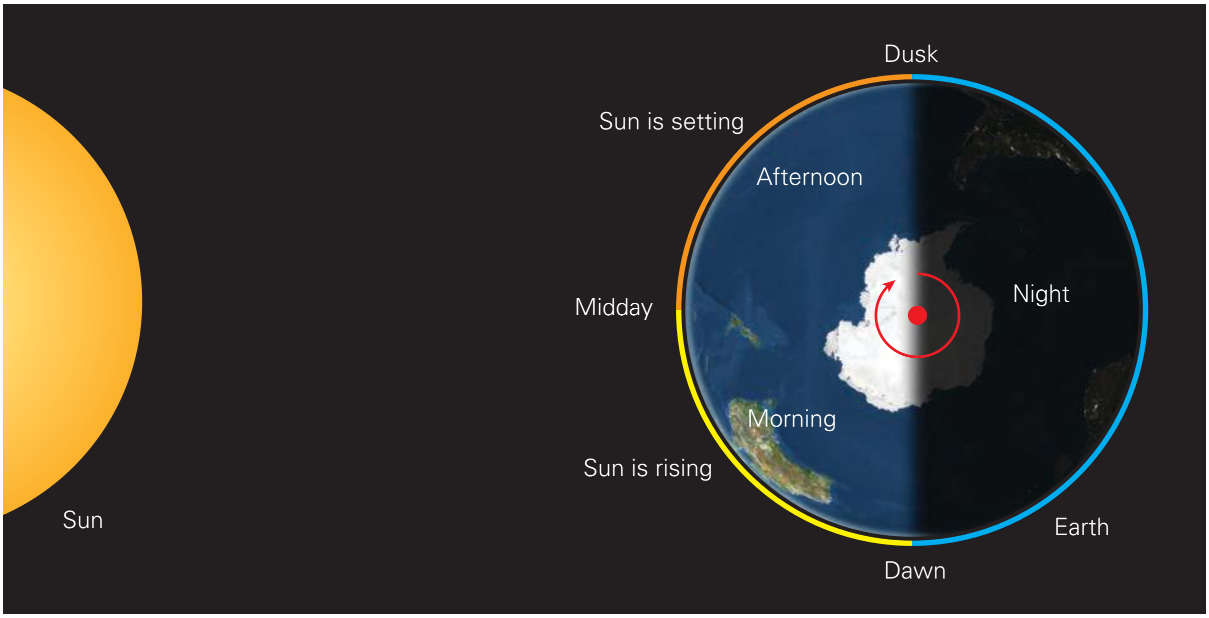

Figure 5.2 The view of Earth from above the South Pole. Earth is rotating clockwise from this pole. Different parts of the world experience morning (yellow), afternoon (orange) and night (blue). This image shows morning in Australia.

Temperature and shadow changes

The Sun is a star and the temperature changes during the day are due to the position of the Sun in the sky. If you track one location on our spherical Earth, it is turning towards the Sun in the morning and away from the Sun in the afternoon. This means the temperature increases in the morning as the Sun rises in the sky and continues to increase throughout the day as the Sun provides heat. At night, there is no heat from the Sun in that location and the temperature falls until the next day when the cycle repeats again.

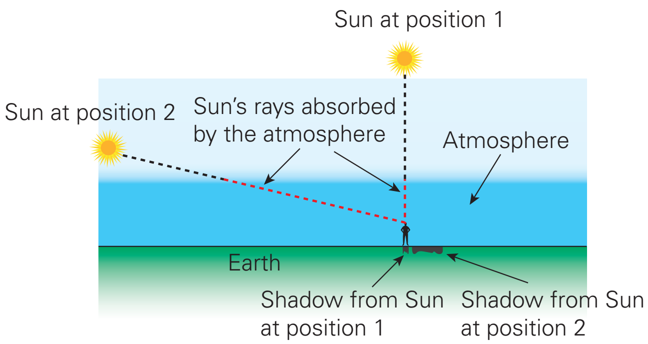

Figure 5.3 The Sun's rays pass through less atmosphere when it is close to being overhead due to their angle. For this reason, the midday sunlight is more intense and more likely to cause sunburn. The length of your shadow also changes.

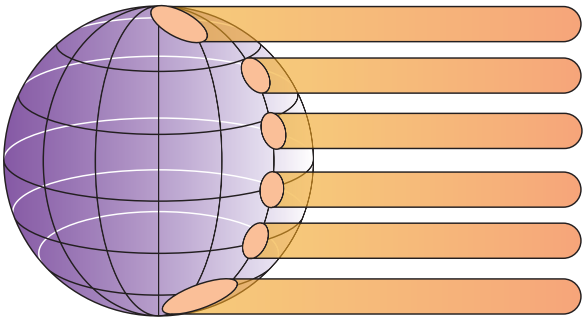

Figure 5.4 The angle of the Sun's rays also produce the different temperatures found on Earth. Equatorial regions are hotter than polar regions because they receive perpendicular rays (at a 90° angle).

Try this 5.2

Simulating the movement of the Sun

In a group, use a yellow balloon and a camera for this simulation. A simulation is a model of an event, or a way to see what happens without it actually happening.

1. Choose someone to be Earth and hold a camera.
2. Choose a second person to be the Sun by holding the balloon.
3. The person with the camera stands in front of the Sun and rotates slowly on the spot while recording a video.

What did you see? Did it appear as though the Sun is moving past the camera? What was the cause of the movement?

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Figure 5.5 The stars in the sky are not moving. It is Earth's rotation that makes them appear to move.

Quick check 5.1

1 Define the following terms in your own words: rotation, dawn, dusk.
2 Explain why the Sun and stars appear to move across the sky, when they are not really moving.
3 Explain why it is cooler at night and warmer during the day.
4 Explain the effect of the Sun on shadows when it is directly overhead, as opposed to at a low angle in the sky.

Did you know? 5.2

Antipodes

The place on the exact opposite side of the world to a region is called its antipode. The antipode of Sydney can be found in Lajes located in the Lajes das Flores, Azores Islands, off the coast of Portugal. If the Sun is setting in Sydney, it will be rising at its antipode. If it is winter in Sydney, it will be summer at the antipode.

Figure 5.6 The antipode of Sydney is Lajes das Flores in the Azores Islands.

Explore! 5.1

Daylight saving

Some states in Australia adopt daylight saving, which involves moving clocks forward at the beginning of summer.

Conduct some research to find out the answers to the following questions.

1 Name the Australian states that adopt daylight saving.
2 Describe the advantages and disadvantages of adopting daylight saving.
3 Name two other countries that observe daylight saving and two that do not.

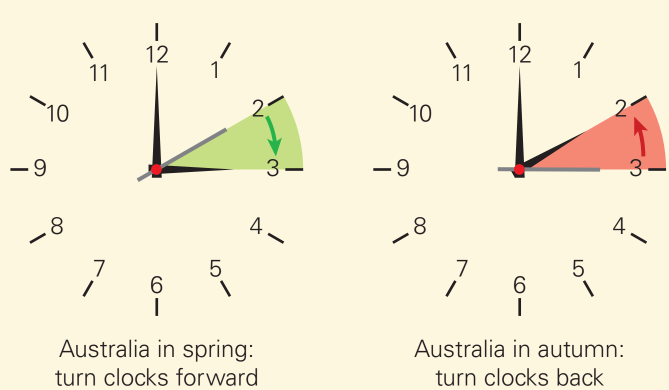

Figure 5.7 How daylight saving affects clock times

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Does the Sun rotate like Earth?

The Sun also rotates but at a very different speed to Earth. Unlike Earth and the Moon, the Sun is not solid – it is a hot gas – so different parts of the Sun rotate at different speeds. The equator of the Sun rotates about once every 25 days, while the poles (top and bottom) rotate at a much slower rate, about once every 38 days. Even though 25 days sounds like a long time, the Sun is so big that the surface at the equator is still travelling at around 2 kilometres per second!

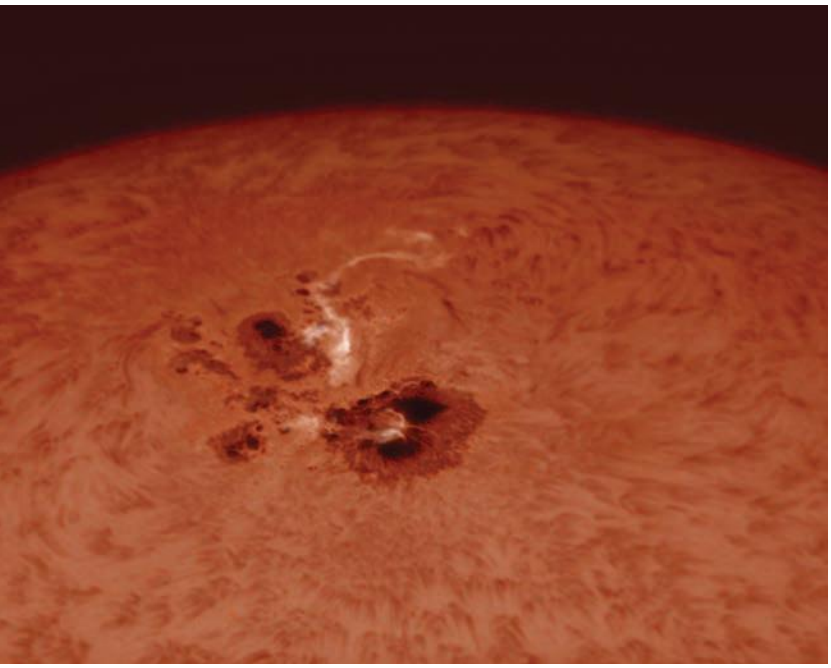

Figure 5.8 Sunspots, such as the one shown, stay visible for about 11 years as they cross the face of the Sun.

There are dark spots on the surface of the Sun called **sunspots**. These can be seen with special equipment and are seen to rotate with the surface, proving that the Sun rotates. You must *never* look at the Sun to see sunspots – you will not see them anyway and it is dangerous to look at the Sun, even with sunglasses.

VIDEO
Describe the Sun's surface and contrast it to Earth's

sunspot
feature on the Sun's surface that moves slowly across the surface

Be careful

Never use binoculars or telescopes to look anywhere near the Sun.

Quick check 5.2

1 State how long one rotation of the Sun takes.
2 Explain how it is known that the Sun rotates.

Section 5.1 questions

QUIZ

Remembering

1 **Recall** how long it takes Earth to complete one full rotation.
2 **State** what time of day the Sun reaches its highest point in the sky.

Understanding

3 **Explain** how Earth experiences day and night.
4 **Identify** why the Sun, Moon and stars rise in the east and set in the west.

Applying

5 At what time of the day is it most important to wear sunscreen and seek shade? **Explain** your answer.

Analysing

6 **Explain** the relationship between the time of day and how the length of your shadow changes.

Evaluating

7 'If Earth stopped rotating, one side of Earth would be in total darkness all the time.' Decide whether you think this statement is true. Give your opinion on how life would be different if Earth did not rotate and **justify** your answers.

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5.2 Earth's yearly cycle

Learning goals

1 To identify that yearly cycles on Earth are related to its revolution of the Sun including seasons.
2 To identify local Indigenous mappings of the seasons.

DOC WORKSHEET

Apart from rotating on its axis, which results in the day-night cycle that repeats every 24 hours, Earth also orbits around the Sun following an **elliptical** path. It takes 365.25 days for Earth to travel around the Sun; the path is called an **orbit**. One complete orbit around the Sun is called a **revolution**. The calendar is made simple by using 365 days and adding an extra day once every 4 years. We call that year a **leap year**.

elliptical
oval shaped

orbit
the curved path of a celestial object or spacecraft round a star, planet or moon

revolution
one complete orbit

leap year
a year that happens every four years and has an extra day on 29 February

mass
the amount of substance in an object that never changes, even in space

gravitational field
the region around a large object where another object can experience its gravity or pull

Southern Hemisphere
the half of Earth south of the equator

Northern Hemisphere
the half of Earth north of the equator

equator
an imaginary line drawn around the middle of Earth equidistant between the North and South poles

Why does Earth orbit the Sun?

An object with a large **mass** attracts an object with less mass and may cause it to go into orbit if it is in its **gravitational field**. The Sun is 333 000 times heavier than Earth and so the gravitational field of the Sun causes Earth to orbit the Sun.

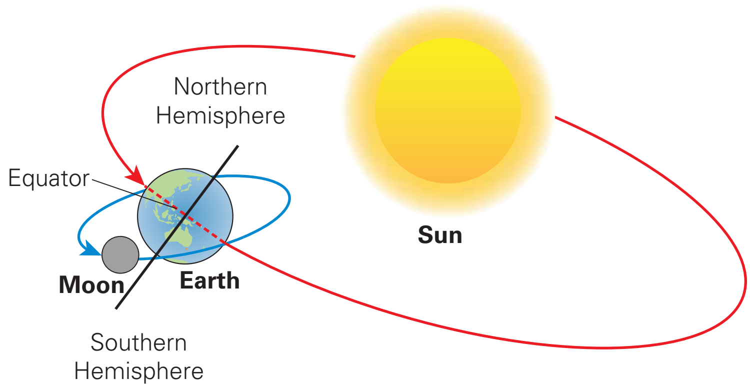

Figure 5.9 The Moon orbits around Earth, and Earth orbits around the Sun. Standing at the North Pole, the rotation appears anticlockwise.

Seasons

You may have observed that over the course of a year, each day is slightly different. In the **Southern Hemisphere** where Australia is located, the day length decreases from January to June and increases from July to December. The shortest day occurs around 21 June. The longest day occurs around 21 December. The opposite happens in the **Northern Hemisphere** where the longest day is in June and the shortest day is in December. Interestingly, for places on the **equator**, the day length is always 12 hours every day of the year.

Figure 5.10 Summer at Coffs Harbour, North Coast of NSW

Figure 5.11 Autumn in Mt Wilson, 100 km West of Sydney in NSW

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What changes during the year from season to season?

What things do you observe throughout the year that are explained by the seasons changing? Discuss with your group and see how many of the following you came up with.

- The number of hours of daylight. During the year, the time the Sun rises and sets changes. In spring, the days get longer and in autumn the days get shorter.
- The places on the horizon where the Sun rises and sets moves. The Sun always rises in the east and sets in the west, but the position varies, moving south in spring and north in autumn.
- The average daily temperature is colder in winter and hotter in summer. The difference between average summer and winter temperatures increases as you move away from the equator.
- The height of the Sun in the sky at midday increases in summer and decreases in winter.
- Some animals and plants change their behaviour and appearance at different times of the year. In winter, deciduous trees lose their leaves, some animals hibernate and others migrate. In the warmer months, birds nest and lay eggs, and plants produce flowers and then fruit though there are winter-flowering plants as well.
- Seasonal changes also affect people. For example, farmers are heavily reliant on seasons for their livelihood. They can only sow and harvest at certain times of the year.

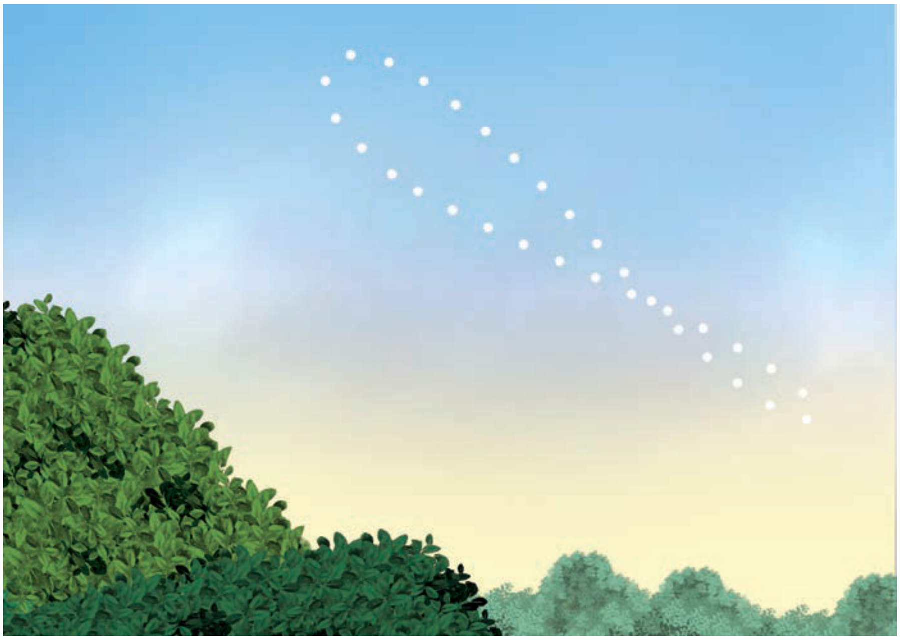

Figure 5.12 This illustrates the position of the Sun at the same time each week for a whole year.

Figure 5.13 The NSW snowfields in winter at Thredbo

Figure 5.14 Spring in Sydney

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Why do seasons occur?

Believe it or not, Earth's tilt can explain all of these observations! The axis of rotation of Earth passes through the North and South Poles. It is set at an angle of 23.5° from the vertical and the angle does not change as Earth goes around the Sun.

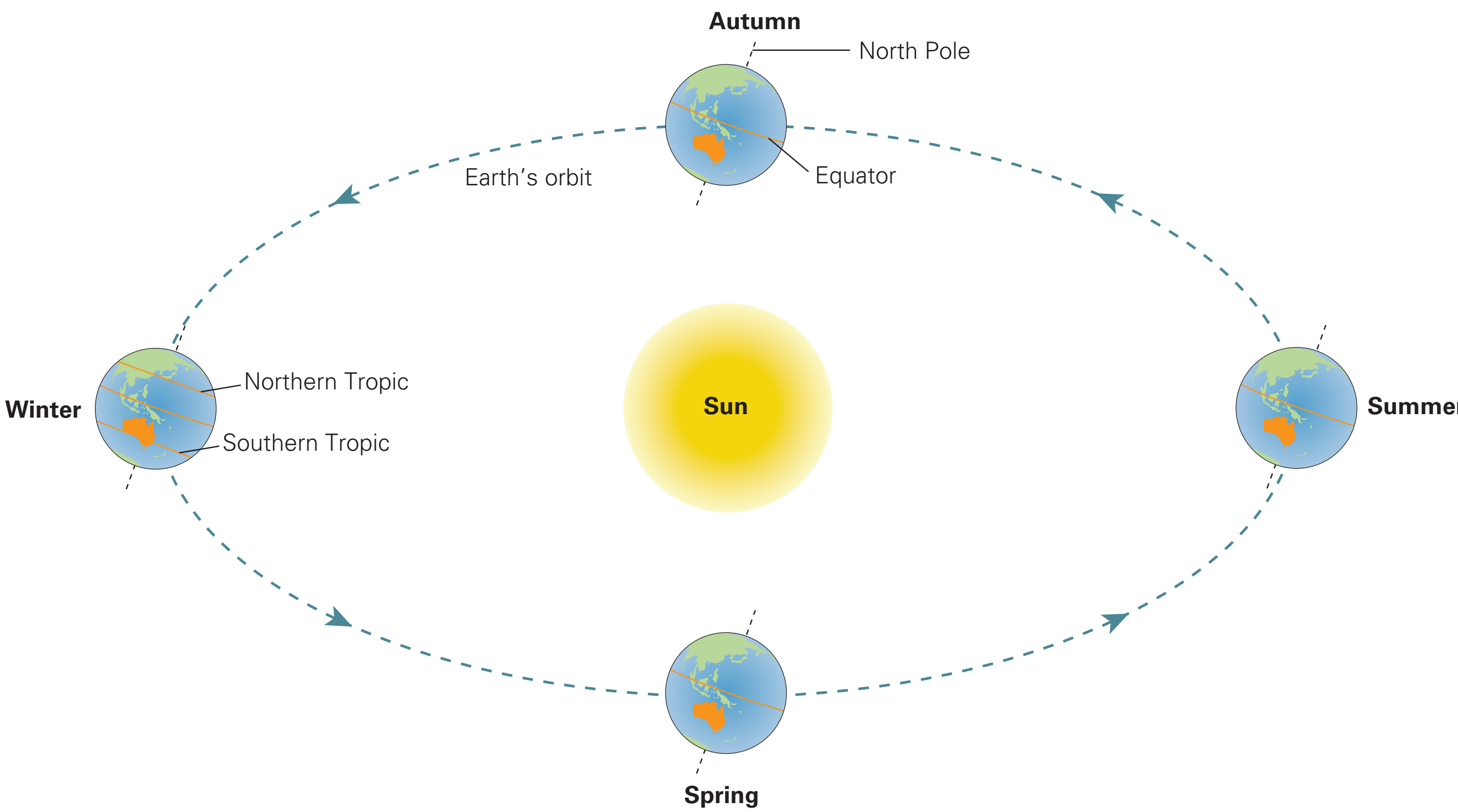

Figure 5.15 Seasonal arrangements of Earth and the Sun. Earth's tilt causes the different seasons during the year. Australia is shown in orange.

Quick check 5.3

1. Define the terms 'orbit', 'revolution' and 'elliptical' in your own words.
2. State how long it takes for Earth to orbit the Sun.
3. Describe things that change during the year due to the seasons.

Practical 5.1

Modelling the seasons

Aim

To investigate how the angle of Earth to the Sun affects the temperature of the area where the light hits.

Prior understanding

Light is energy from the Sun. Light rays can cause an area to heat up when they hit the surface of the area and are absorbed. When the Sun's rays hit Earth's surface close to the Equator, the energy is more direct (as it is closer to a 90° angle), so the area becomes warmer.

continued…

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…continued

Materials

- 1 opened aluminium can with small hole drilled in the side for the thermometer
- 1 thermometer
- putty adhesive
- lamp (a lamp used to heat reptile cages would be ideal)
- cylinder/rectangular shape to cover the lamp and direct light forward
- 1 m ruler or tape measure
- whiteboard with 1 cm graph paper or grid attached

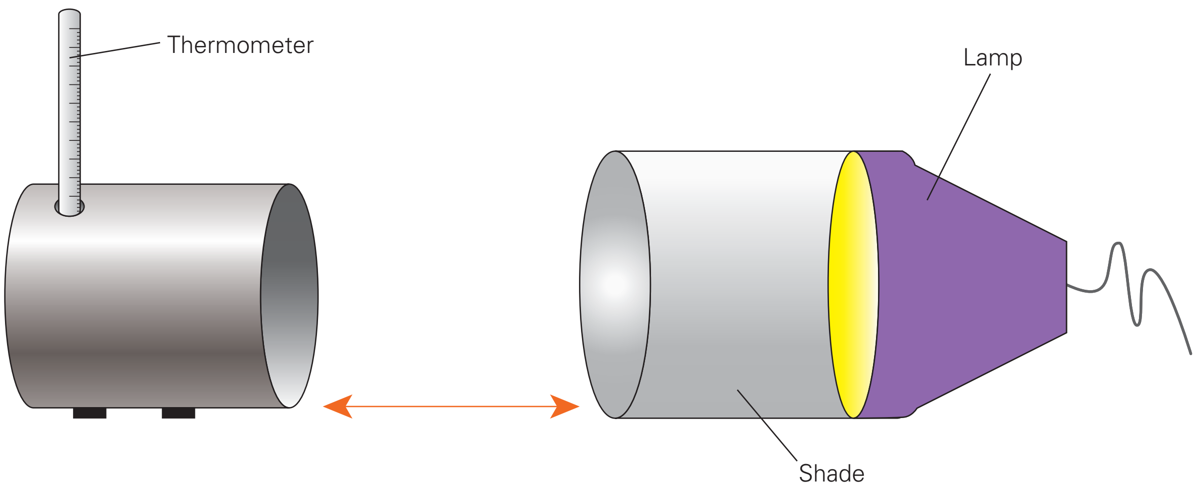
Be careful

Take care when handling light sources after extended use. They may be hot.

Take care when handling the opened can as it may have sharp edges.

Procedure

1. Attach a shade to the light to direct the light forward as much as possible.
2. Attach the thermometer through the hole in the can, making sure it is not touching the bottom. Secure in place with some of the putty adhesive.
3. Set up the equipment as shown. Keep the can upright, securing the bottom to the table with the adhesive putty.



4. Copy the results table into your science book.
5. Measure the *direct, or straight position*.
   a. Measure the temperature inside the can and record.
   b. Turn on the light for 15 minutes.
   c. Measure the temperature inside the can and record.
6. Repeat steps **5a–5c** for two more trials.
7. Place the whiteboard in front of the lamp and measure the diameter of the beam hitting the board, as shown in Figure **c** on page 182. Record the result.
8. Rotate the light until it is 30° to the tin as shown in Figure **b**.
9. Repeat steps **5–7** to measure the *angled position*.

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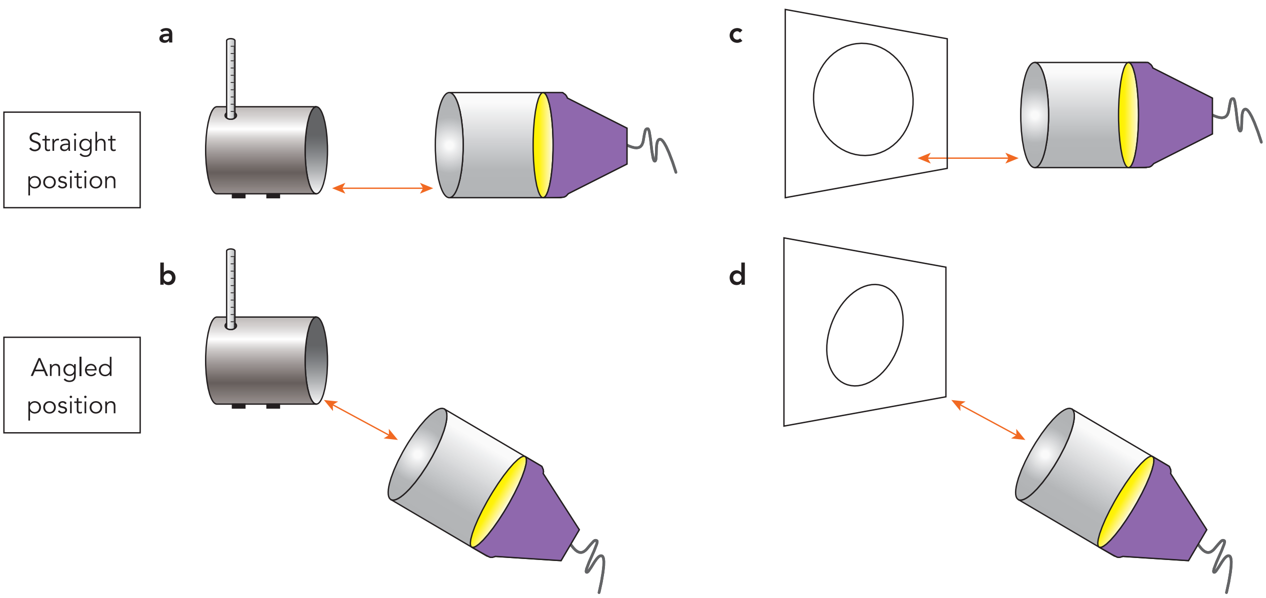

Results

Independent variable: Angle to the light		Dependent variables					
		Temperature (°C)			Light		
		Initial	Final	Change	Diameter of the beam (cm)	Radius of the beam (cm)	Area of the beam (cm^2)
Straight position	Trial 1						
	Trial 2						
	Trial 3						
	Mean						
Angled position	Trial 1						
	Trial 2						
	Trial 3						
	Mean						

Divide your diameter data by two to calculate the radius, and use this radius data to calculate the area, by using $A = \pi r^2$ (3.14 × radius^2).

Discussion

1 Describe the differences between the change in temperature when the lamp is in the straight position and when it is in the angled position.
2 Compare the area of the beam when it is in the straight position to when it is in the angled position.
3 Identify which group simulated the way the Sun hits the South Pole. Explain your reasoning.
4 Discuss how much variation was observed between the trials for each group.
5 Identify any other factors (controlled variables) that may have changed and affected the results.
6 Identify any changes that could be made to the method to improve the quality of the data in future experiments.
7 Discuss how the investigation could be extended in future experiments.

Conclusion

Develop a conclusion about the relationship between the area of the light beam and the temperature change.

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Explore! 5.2

How do animals adapt to the seasons?

Figure 5.16 Black bears hibernate.

Figure 5.17 Greylag geese migrate.

The cycles of animal and plant life follow the seasons.

Research bird migration and animal hibernation. Select one species from each category and summarise what you find out, including a picture and why it hibernates or migrates.

D'harawal peoples' seasons

Aboriginal and Torres Strait Islander peoples have different ways of mapping seasons depending on where they live in Australia. Peoples from far northern Australia only have two distinct calendar seasons – wet and dry. On the other hand, the D'harawal people recognise six seasons. Their area extends from the southern shores of Sydney Harbour to the Shoalhaven River in the south and the Wollondilly River in the west.

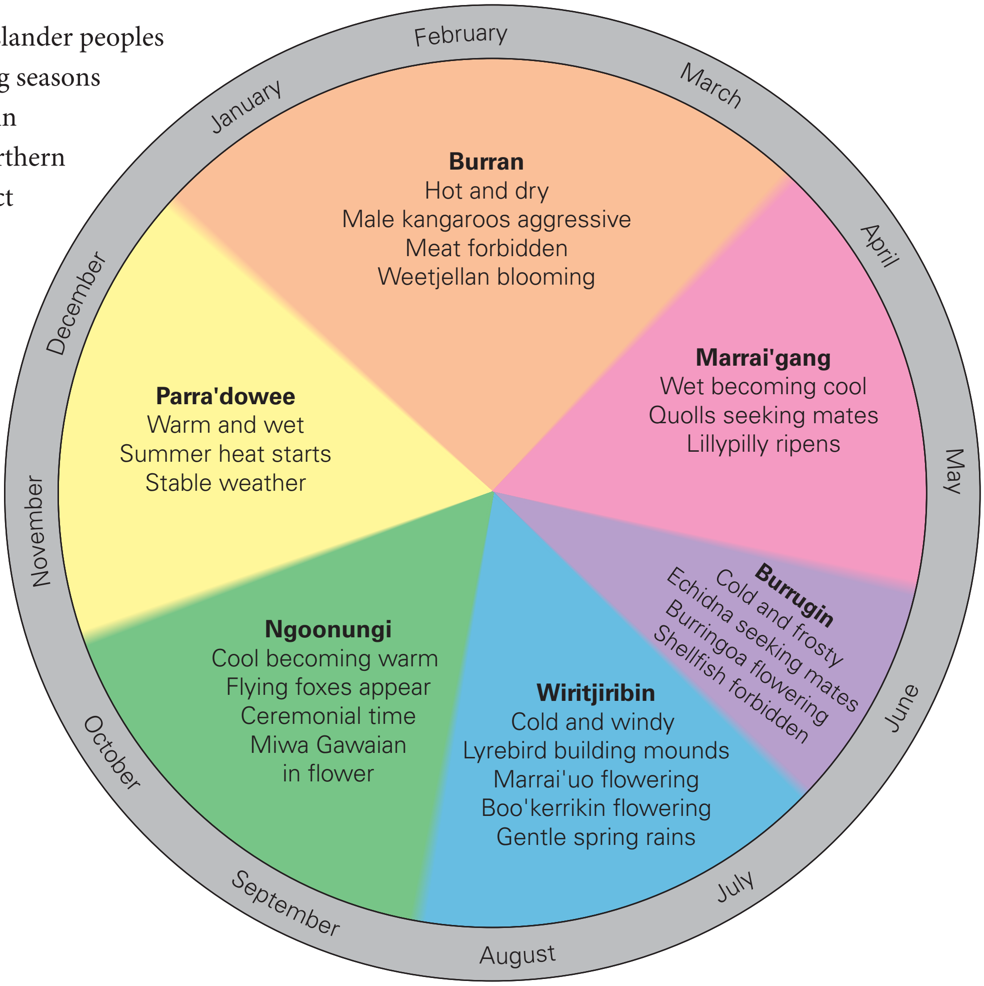

Figure 5.18 The D'harawal seasonal calendar

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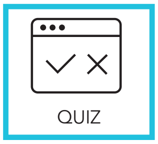
Section 5.2 questions



Remembering

1 **Identify** how long a complete cycle of all four seasons takes.

2 **Describe** how plants and animals act differently in summer than in winter.

Understanding

3 **State** the reason for the seasons on Earth.

4 **Describe** how the seasons are different in tropical north Australia.

Applying

5 Take a look at the seasons recognised by the D'harawal people (Figure 5.18 on page 183). How would you know which season it is if you observe increased lyrebird activity and occasional showers? **State** also the corresponding months this season occurs.

Analysing

6 **Describe** what the effect would be if the angle of tilt of Earth's axis of rotation was increased by 5°.

7 The table shows hours of daylight in Sydney on 30 April 2021.

Date	Sunrise	Sunset	Hours of daylight
30 April	6:28 a.m.	5:15 p.m.	10 h 47 min

State whether you expect the number of daylight hours to be more or less than 10 hours 47 minutes on 1 May.

8 At 3 p.m. in winter your shadow will be longer than at 3 p.m. in summer. **Explain** why this is the case.

Evaluating

9 Using the D'harawal seasonal calendar (Figure 5.18 on page 183), **propose** why Burran spans approximately 3 months, while Burrungin is only about 1 month.

10 The summer solstice is when the Sun reaches its highest point in the sky, and the winter solstice is when the Sun reaches the lowest point in the sky. These are marked by the longest and shortest days respectively. Deduce in which months these occur in the Southern Hemisphere. **Justify** your answer.

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5.3 Movement of the Moon

Learning goals

1 To identify phases of the Moon and the cause of these.
2 To identify the effects the Moon has on Earth.

Recall that Earth orbits around the Sun because the Sun has greater mass. The mass of Earth is 81 times the mass of the Moon and so, for the same reason, the Moon revolves around Earth.

The phases of the Moon

Although the Moon looks bright, it does not give out any light of its own. All the light that comes to us from the Moon is reflected from the Sun. Only the half of the Moon that faces the Sun is bright, the other half is in shadow. The area of the bright side you can see from Earth depends on which phase the Moon is in. Figure 5.19 shows the names of the phases of the Moon. Note that between a new moon and a full moon, the Moon is **waxing**. Between the full moon and a new moon, the Moon is **waning**.

Have you ever wondered how the Moon keeps the same face towards Earth? Observe the Moon over a period of two weeks. You will see that even though the phase changes, the craters and coloured areas on the Moon stay the same.

The reason the Moon always presents the same face to Earth is that the time taken for it to rotate once is the same as the time it takes to orbit Earth. The Moon takes about 27.3 days to orbit Earth – the same time it takes to rotate just once. This is known as **synchronous rotation**.

WORKSHEET

WIDGET Phases of the Moon

VIDEO Moon phases as seen from space

waxing
the period of about two weeks where the illuminated part of the Moon is increasing from a new moon to a full moon

waning
the period of about two weeks where the illuminated part of the Moon is decreasing from a full moon to a new moon

synchronous rotation
occurs when the rotation of an orbiting body is the same length of time as its revolution around a larger body

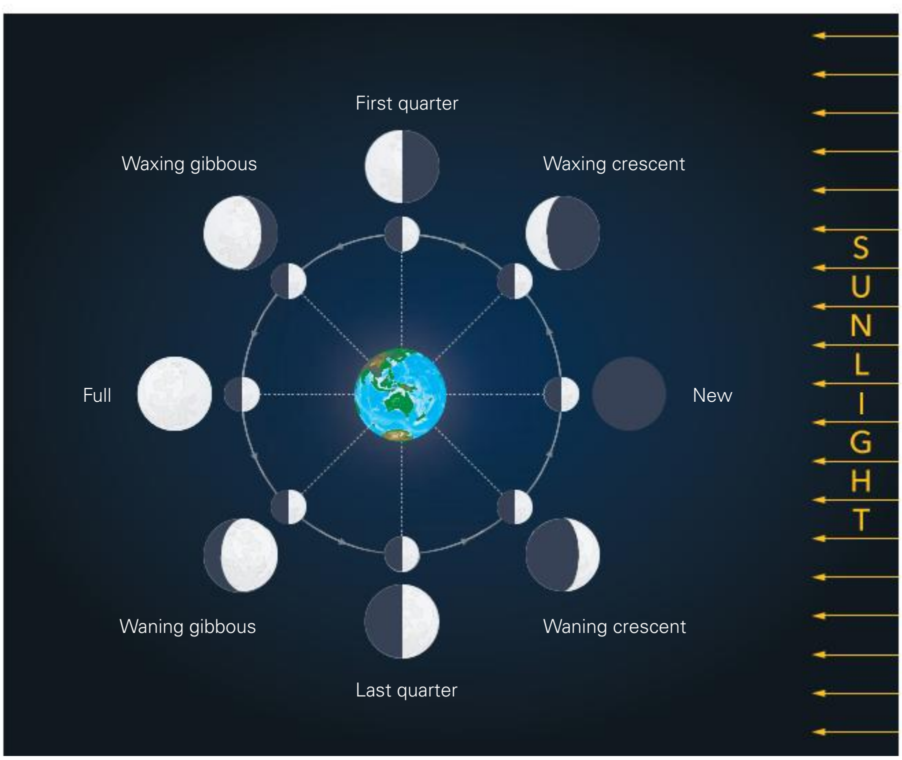

Figure 5.19 The phases of the Moon in the Southern Hemisphere

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Quick check 5.4

1 Explain how you can see the Moon if it does not give off any light of its own.
2 Explain why the Moon's surface always looks the same from Earth.

Moon orbit versus moon phase

One thing you might notice is that the time the Moon rises and sets changes every day. You might also notice that each day the Moon's phase changes slightly. It takes 29.5 days (hence a month is about 30 days) to complete a cycle of phases from new moon to full moon and back to new moon. Recall that it takes 27.3 days for the Moon to rotate and orbit once around Earth. Why are they different?

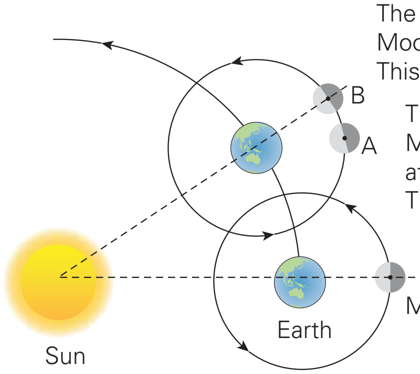

Figure 5.20 The time between full moons and the orbital period of the Moon is different by 2.2 days.

If Earth was not orbiting the Sun, both times would be the same. This means the reason must be related to Earth's movement. A full moon occurs when Earth, the Sun and the Moon form a straight line. After the Moon has completed an orbit 27.3 days later, Earth has moved and the Moon is no longer in line with Earth and the Sun. To form the next full moon and to line up with Earth and the Sun again, the Moon has to keep moving for another 2.2 days.

Advances in science 5.1

What does the far side of the Moon look like?

Because the Moon always turns the same face towards Earth, the **far side** was not seen until spacecraft started to visit the Moon. The first images were seen in 1959 when the Soviet probe Luna 3 sent back pictures to Earth. Over the past 60 years, NASA has sent out many probes to explore the solar system and have obtained clearer images of the far side of the Moon.

far side
the face of the Moon that is always turned away from Earth; also called the dark side

Figure 5.21 Image of the far side of the Moon taken in 1959. Detailed maps have now been made of the far side but until now, no crewed mission has landed on its surface.

Figure 5.22 (a) The far side of the Moon and **(b)** the near side (Northern Hemisphere view). The dark patches visible on the Moon's surface are called seas. They are not made of water but were once liquid in the form of molten rock or lava that flowed out into low-lying areas on the Moon's surface.

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Quick check 5.5

1 Define the terms 'waxing' and 'waning'.
2 Explain how you can tell the Moon is moving through the sky.
3 State how long it takes to complete a full cycle of the Moon's phases.
4 How do scientists know what the far side of the Moon looks like?

Try this 5.3

Modelling the phases of the Moon

Using an electric lamp, an 8 cm polystyrene ball and a pencil, follow the instructions to model the phases of the moon. Draw diagrams of your observations at each point in the cycle.

Be careful

Take care when handling light sources after extended use – they may be hot.

1 Stick the pencil into the foam ball so that the pencil can act as a handle. Place the lamp in the centre of a darkened room.
2 Extend your arm so you are holding the foam ball in front of you. The ball should be between your eyes and the lamp. The foam ball is modelling the Moon, the lamp is the Sun and your head is Earth. Note that the polystyrene ball does not generate light of its own, it reflects light from the lamp.
3 The Moon starts off in a 'new moon' position, as you can only see the unlit side.
4 Sweep your right arm in a clockwise direction to model the waxing moon phases. Move your head to the side to observe these phases. Record what you see in a results table.
5 Once the Moon is behind your head, it will be in the 'full moon' phase unless your head (Earth) is blocking the light and creating a lunar eclipse.
6 Switch the ball to your left hand and continue moving it clockwise back to the start to simulate waning phases of the Moon.

Describe where the ball was in relation to your head when it was at the following phases: new moon, full moon, waxing gibbous, waning gibbous, waxing crescent, waning crescent, first quarter, last quarter. Propose how you could improve this simulation.

Section 5.3 questions

QUIZ

Remembering

1 **State** how fast the Moon is moving.
2 **State** how long the Moon takes to orbit Earth.
3 **Describe** the surface of the Moon.
4 **Identify** the phases of the Moon.

Understanding

5 **Explain** why the time taken for the Moon to orbit Earth is different to the time between full moons.
6 **Explain** why a half-lit Moon is called a quarter moon.

Applying

7 **Explain** with the aid of a diagram why the Moon takes 27.3 days to orbit Earth and yet there are 29.5 days from one full moon to the next.

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8 Use the chart in Figure 5.23 showing the phases of the Moon for a particular year to answer the following questions.

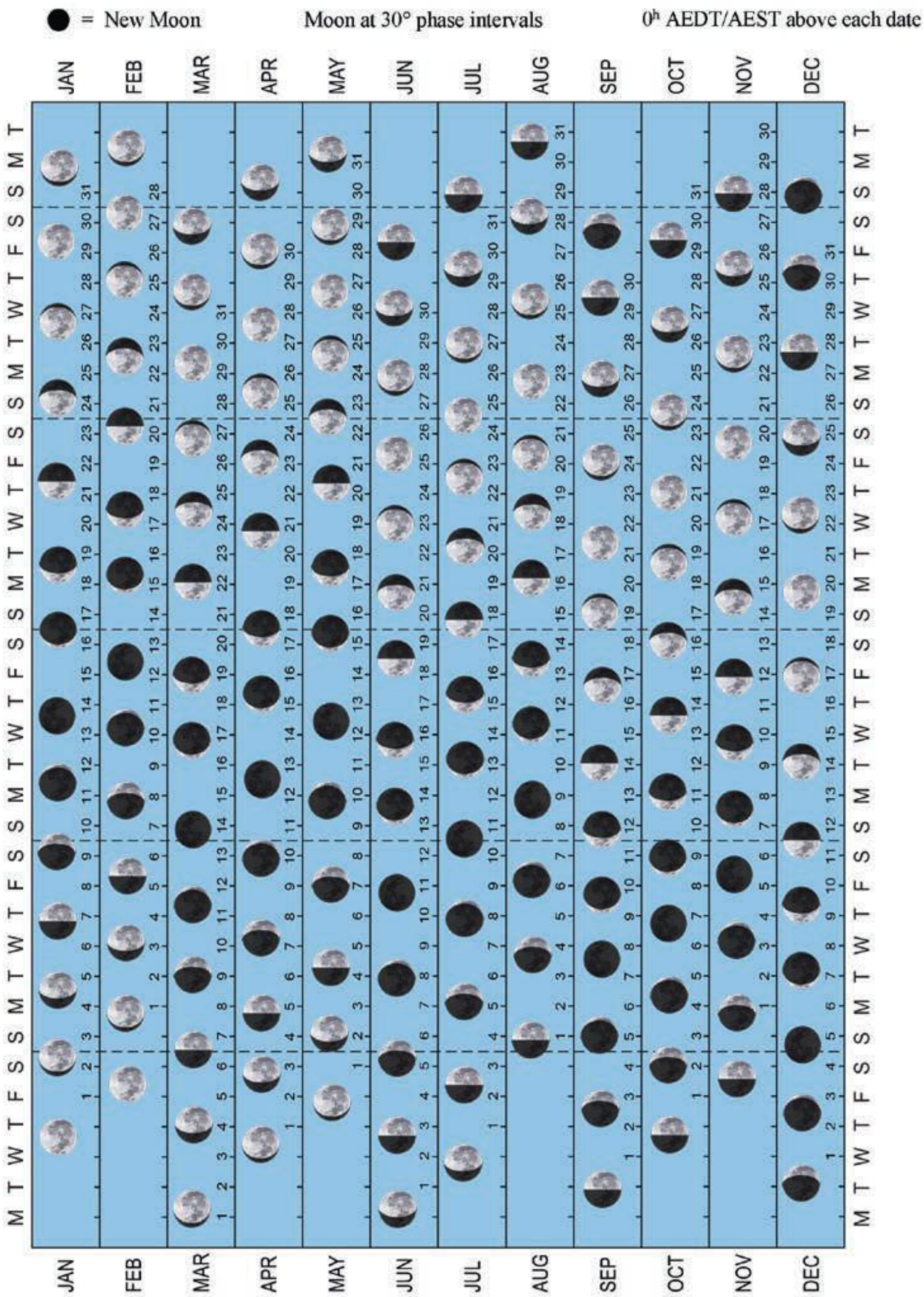

Figure 5.23 The chart from the Astronomical Society of Victoria shows the dates for each of the phases for 2021.

- a **Describe** the phase of the Moon on 4 August.
- b **Describe** the phase of the Moon on 27 October.
- c The saying 'Once in a blue moon' is used when discussing anything that happens rarely. A blue moon occurs if there are two full moons in a month. **Analyse** Figure 5.23 to see if there were any blue moons in that year.

Analysing

9 **Explain** how it is possible for the Sun's equator to rotate at a different rate to the Sun's polar regions.

Evaluating

10 **Discuss** how the Moon would look if it did have an atmosphere and experienced weather.

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5.4 Eclipses

Learning goals

1 To distinguish between solar and lunar eclipses.
2 To identify the causes and features of each type of eclipse.

The motions of Earth around the Sun and the Moon around Earth are complex and require mathematics to describe them precisely. However, they are completely predictable. By looking for patterns in observations made over many years, ancient astronomers could anticipate with reasonable accuracy some of the events you are going to learn about, such as:

- **solar eclipses**, where the Moon blocks the light from the Sun and casts a shadow on a small part of Earth
- **lunar eclipses**, which occur when Earth blocks the light from the Sun, throwing a shadow onto the Moon.

Solar eclipses

What happens when the Moon blocks the Sun?

Once a month, in its orbit around Earth, there is a chance that the Moon may come exactly between Earth and the Sun. If this happens and the Sun, Moon and Earth all line up, astronomers call it a **syzygy** and the result is a solar eclipse. Because the Moon is considerably smaller than Earth, a solar eclipse is only visible from a small region on Earth's surface.

DOC WORKSHEET

Total versus partial eclipse

During a solar eclipse, the Moon blocks the light from the Sun on a small part of Earth's surface. A **total eclipse** is visible from the dark coloured central part of the shadow called the **umbra**. A **partial eclipse** occurs when the light from the Sun is partially blocked, it is visible from the area that is lightly shaded on Earth called the **penumbra**. Both the umbra and penumbra are so small that even if there is a solar eclipse most people won't see it.

solar eclipse
an event when the Sun partly or completely disappears from view, while the Moon moves between it and Earth

lunar eclipse
a full moon becomes dark as it enters Earth's shadow

syzygy
the occurrence in astronomy of three or more objects moving into a straight line

total eclipse
an event when the Sun is completely blocked by the Moon

umbra
the region in a shadow where the light is completely blocked

partial eclipse
an event when the Sun is partially blocked by the Moon

penumbra
the region in a shadow where the light is partially blocked

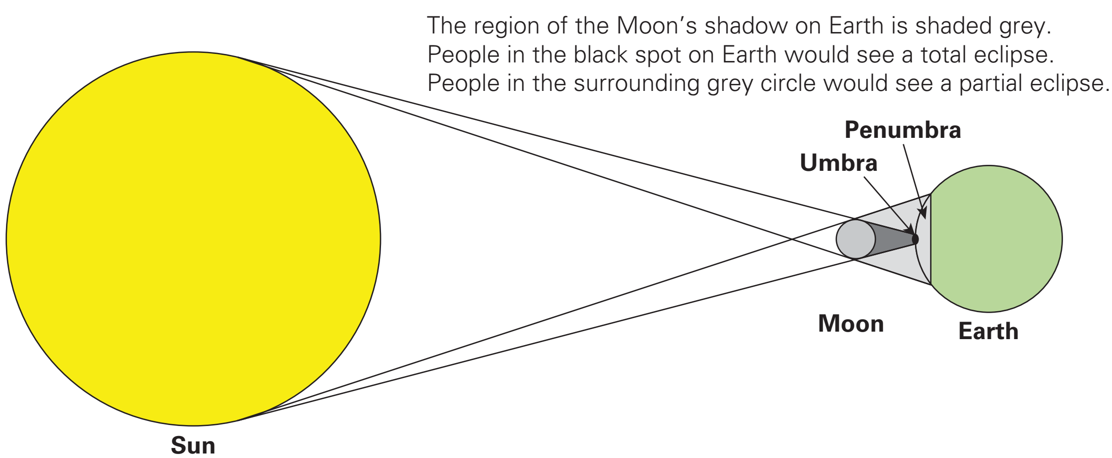

Figure 5.24 A solar eclipse occurs when the Moon comes between Earth and the Sun. This diagram is not to scale and the size of the shadow areas is greatly exaggerated.

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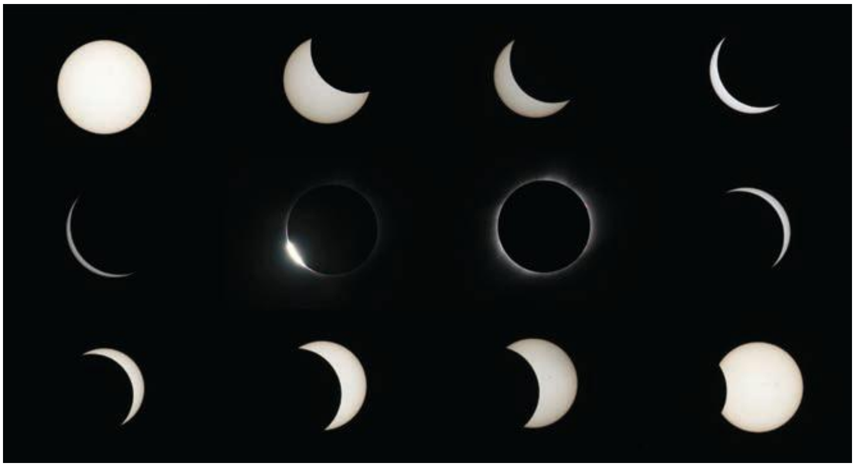

Figure 5.25 This series of images shows **(a)** the stages of a total solar eclipse, and **(b)** totality.

Figure 5.26 A solar eclipse photographed from the International Space Station. The Moon's shadow covers only a small fraction of Earth's surface.

Try this 5.4

How far is it to the Sun?

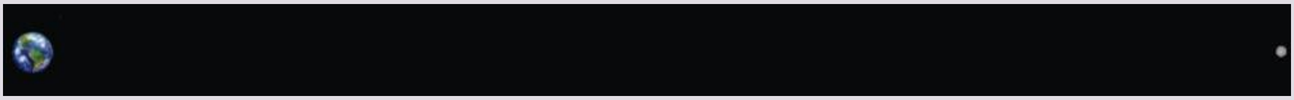

Figure 5.27 Earth and the Moon are drawn here to scale. The Sun is 400 times further away than the Moon.

Measure the distance from Earth to the Moon in Figure 5.27. Multiply the distance by 400 to work out how far away the Sun would be if it were also included in the picture. The distance between Earth and the Sun is known as 1 Astronomical Unit (1 AU). This prevents having to write huge numbers when we are measuring in kilometres.

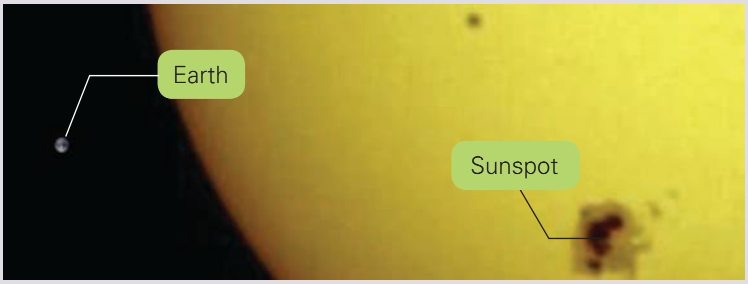

Figure 5.28 It might be tempting to think that the Sun is of a similar size to Earth because its light can be blocked by the Moon, but the Sun is much larger than Earth. In this image, Earth is placed next to a portion of the Sun to show their relative sizes.

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What is an annular eclipse?

The Sun is about 400 times bigger than the Moon but is also 400 times further away, so from Earth the Moon and Sun appear to be about the same size. This means that the Moon is just big enough to hide the Sun when it passes in front. However, the orbits of Earth and the Moon are not perfect circles and the Moon's apparent size can vary by up to 12% in its orbit around Earth. If the solar eclipse occurs when the Moon is closest to Earth, (**perigee**), the result is a total eclipse. If the Moon is at its furthest point, (**apogee**), the result is an **annular eclipse**. The mathematical word for the shape you get when you cut a small circle from the centre of a larger circle is an annulus, so this type of eclipse is called an annular eclipse.

perigee
the point in the Moon's orbit when the Moon is closest to Earth

apogee
the point in the Moon's orbit when it is furthest from Earth

annular eclipse
an event when the Moon blocks the Sun but the Moon is further away and the outer edge of the Sun is still visible

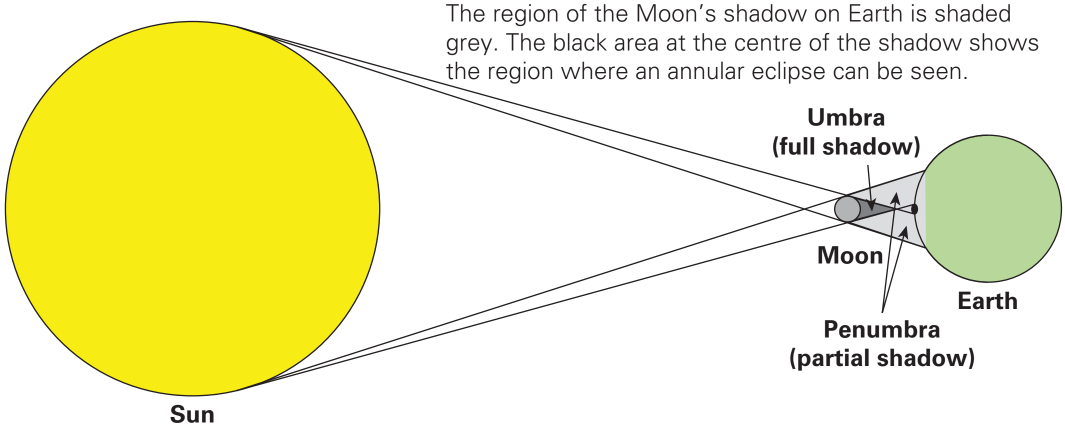

Figure 5.29 If the Moon is not at its closest to Earth at the time of the eclipse, the result is an annular eclipse. The dark area is where an annular eclipse can be seen, the lightly shaded region on Earth's surface experiences a partial solar eclipse (not to scale).

Figure 5.30 An annular solar eclipse seen through a cloud

Explore! 5.3

Aboriginal stories of the Sun and Moon

For some Aboriginal peoples, the Sun is female and the Moon is male. Many traditional stories involve one chasing the other across the sky, meeting whenever there was an eclipse.

1. Research the story that the Yolngu tell of Ngalindi (the moon).
2. Research the story that the Euahlayi tell of the sun woman, Yhi, who falls in love with the moon man, Bahloo.

Quick check 5.6

1. Define the term 'syzygy'.
2. Explain why a solar eclipse is visible from only a small part of Earth.

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Lunar eclipses

What happens when the Moon moves into Earth's shadow?

A lunar eclipse occurs when the Moon moves into Earth's shadow.

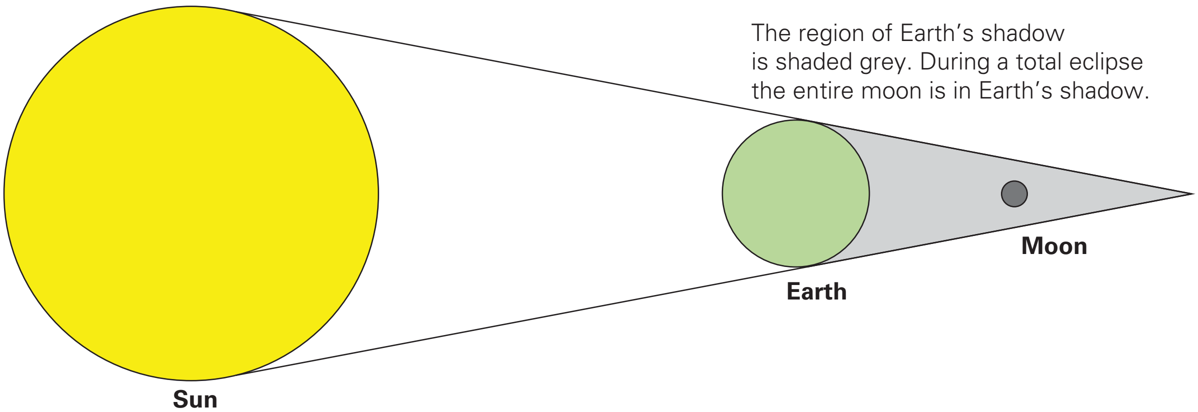

Figure 5.31 Earth is much bigger than the Moon, so Earth's shadow is big enough to cover the whole of the Moon.

Figure 5.32 A total lunar eclipse in progress. The round edge of Earth's shadow is visible.

When the Moon is completely in Earth's shadow during a total lunar eclipse, it is called a **blood moon**. The red colour is due to red light being refracted (bent) by the atmosphere around Earth. Hence, only red light reaches Earth during the total eclipse.

blood moon
a name given to the Moon during an eclipse while it is completely in Earth's shadow

Figure 5.33 A blood moon during a total eclipse is due to the red light being refracted by Earth's atmosphere.

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Comparison of solar and lunar eclipses

Although the Sun and Moon are involved in both kinds of eclipses, solar and lunar eclipses are very different. A solar eclipse is a rare event and results in the sky turning dark during the day, whereas a total lunar eclipse happens at night and results in the full moon moving into Earth's shadow.

	Total solar eclipse	Total lunar eclipse
Duration	A few minutes	A few hours
Who can see it	A small area only	Everyone on Earth on the side facing away from the Sun
Occurrence	Once every 18 months	1–2 per year
Safety	Special equipment required to view	Safe, anyone can watch, no special equipment required
Cause	Moon's shadow on Earth	Earth's shadow on Moon

Table 5.1 Differences between solar and lunar eclipses

Try this 5.5

Modelling solar and lunar eclipses

Use the materials listed to model a solar eclipse and a lunar eclipse.

- high wattage lamp
- globe
- tennis or golf ball
- string

Record your observations of the shadows created in this model. Explain how you modelled a solar eclipse in this activity. Explain how you modelled the lunar eclipse. Predict what would happen if you change the size of the ball. Discuss how this model could be improved.

Be careful

Take care when handling light sources after extended use – they may be hot.

Section 5.4 questions

QUIZ

Remembering

1 **Recall** how solar and lunar eclipses are created.

Understanding

2 **Explain** why a person is likely to see many more lunar eclipses in their lifetime than solar eclipses, even though both events occur with similar frequency.

3 **Outline** why the Sun and Moon appear the same size in the sky.

Applying

4 **Recall** the phases of the Moon. Utilise the information to **decide** in which phase of the Moon a lunar eclipse occurs.

5 **Recall** the phases of the Moon. Utilise the information to **decide** in which phase of the Moon a solar eclipse occurs.

Analysing

6 **Compare** and **contrast** a partial and a total solar eclipse.

Evaluating

7 **Clarify** why eclipses are so rare.

8 **Outline** the factors that need to be considered when viewing a solar eclipse versus a lunar eclipse.

9 **Describe** how our experiences on Earth would be different if the Moon was larger.

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5.5 Exploring the universe

Learning goals

1 To describe the two models of the solar system and evidence for each.
2 To identify the technologies that have allowed scientists to explore and study the solar system.

WORKSHEET

VIDEO Assess the shape of our solar system

The solar system

Earth is one of eight planets that orbit the Sun. All the planets except Mercury and Venus have moons. Jupiter, which is the biggest planet, has more than 70 moons. The solar system is the name given to the Sun and all its orbiting planets, including Earth, as well as dwarf planets such as Pluto.

The invention of the **telescope** gave us much more information about the solar system. With the introduction of the telescope, scientists discovered that Jupiter had moons and Saturn had rings. Scientists were able to look further into the solar system and the planets, Uranus (1781) and Neptune (1846) were discovered.

telescope
an optical instrument for making distant objects appear nearer and larger, or an instrument that detects electromagnetic radiation from space

Figure 5.34 The solar system includes Earth. All the planets except Uranus and Neptune can be seen without a telescope.

Explore! 5.4

Pluto, discovered in 1930, used to be considered a planet. Pluto, named after the Roman god of the underworld, was discovered in 1930. About a third of Pluto is covered in water in the form of water ice. At the time it was considered a planet.

In 2006, Pluto was reclassified as a dwarf planet. Conduct some research to investigate why this was the case. State the criteria which disqualified Pluto from being a planet.

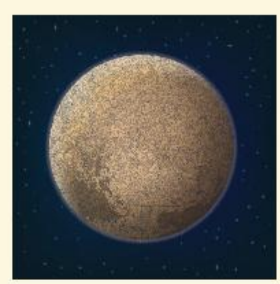

Figure 5.35 Dwarf planet Pluto

Figure 5.36 Jupiter and three of its moons: Ganymede, Europa and Callisto

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Advances in science 5.2

Different cultures and their contribution to current understanding of the solar system

Babylonian astronomy

The Babylonian were one of the first civilisations to record the movement of the Moon, Sun, planets and stars. These recording were taken on a daily basis and were used over the years to predict the positions of celestial bodies and help make predictions.

Greek astronomy

Over 2000 years ago, Greek scholar Eratosthenes calculated the circumference of Earth and the tilt on its axis of 23°. Compared to today's measurements, Eratosthenes calculations were comparatively accurate. Both great achievements considering the technology he had available. Pythagoras is another famous Greek scholar who, among other achievements, provided evidence that Earth was spherical in shape and that movement of the planets, Sun, Moon and stars could be predicted.

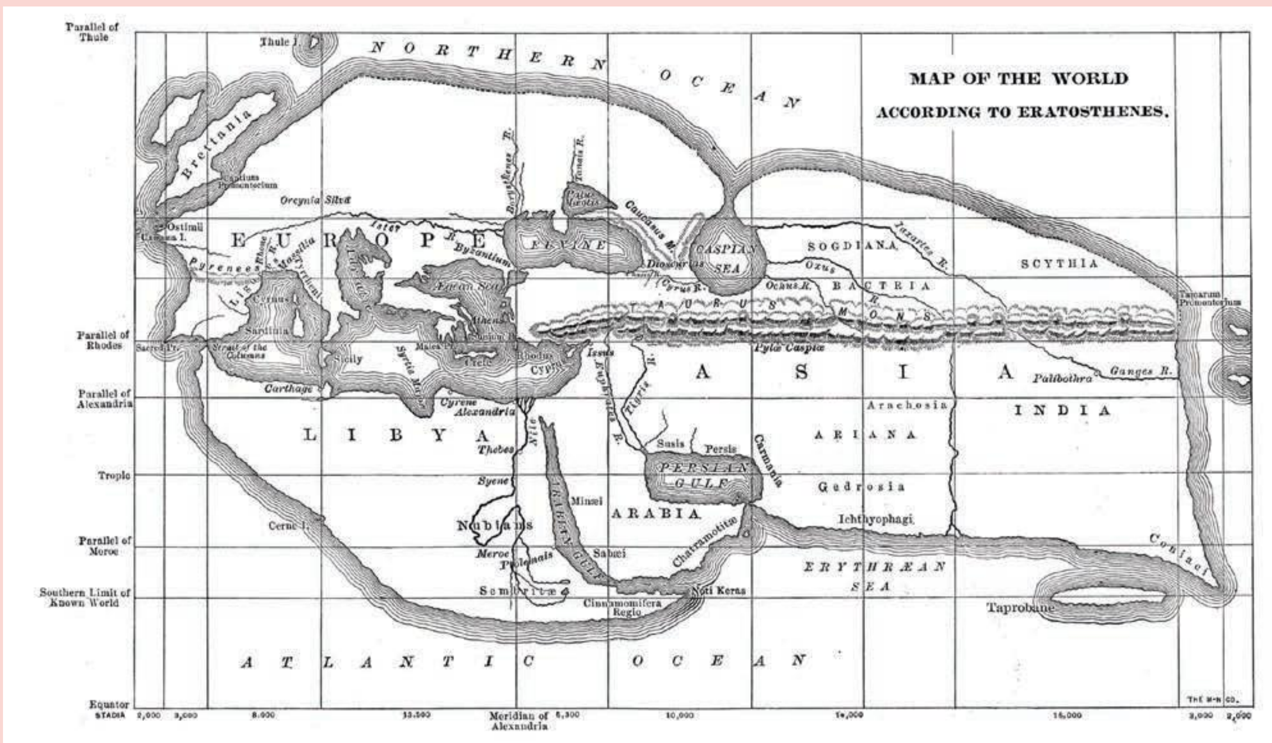

Figure 5.37 A map of the world according to Eratosthenes

Indian astronomy

Indian astronomer Aryabhatiya (476–550 CE) believed that the solar system was geocentric but he did summarise that that Earth rotates on its axis and that we can observe the Moon and other planets because they reflect light from the Sun.

Mayan astronomy

The Mayans studied the motion of the Moon, planets, Sun and stars by using shadow-casting devices they invented. They recorded their observations and used them to develop the Mayan calendar to track the passage of time.

Egyptian astronomy

Ancients Egyptians used their observations of celestial bodies such as the Sun, Moon and stars to predict seasons. This allowed them to prepare for the flooding of the Nile River (in the wet season). The Egyptians also used their study of the heavenly bodies to create a calendar. Their calendar was similar to ours in that it had 12 months, but one week consisted of 10 days, so there were only three weeks in a month.

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Advances in science 5.3

Geocentric versus heliocentric models of the solar system

Aristarchus of Samos who lived from around 310 BCE to 230 BCE developed the first known **heliocentric model** of the solar system; that is, all planets, including Earth, rotated around the Sun. His theory was rejected by many philosophers and astronomers at the time because they did not think such a thing could be physically possible.

heliocentric model
a model with the Sun as the centre of the solar system

geocentric model
a cosmological model where Earth was the centre of the universe

The most popular theory held by many astronomers in ancient times assumed that the Sun, planets, even the whole universe revolved around Earth. This model is called the **geocentric model** and was published in a book *The Mathematical Collection* by Ptolemy (Figure 5.38), an astronomer, geographer and mathematician who lived in 90–168 CE. All astronomers at that time used this model and it continued to be the preferred explanation of how the solar system works for more than a thousand years.

It was not until the year 1543, approximately 1400 years after Ptolemy (and 1800 years after Aristarchus!) that Nicolaus Copernicus published his heliocentric model, borrowing from the work of Aristarchus. The model stated that, in fact, it is Earth that revolves around the Sun (Figure 5.39).

In 1610, Galileo Galilei, an Italian astronomer, first looked at the heavens with a telescope and made observations confirming that the geocentric model was incorrect. About 150 years after Copernicus published his work, Isaac Newton (a physicist and mathematician) finally produced convincing proof that supported the heliocentric model.

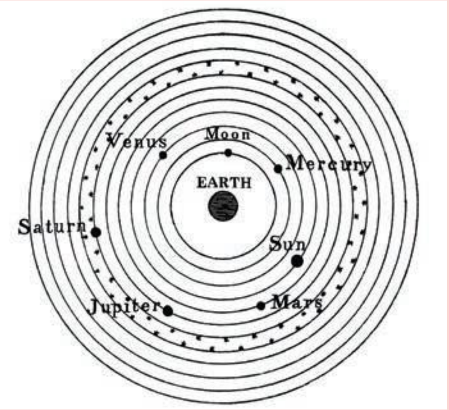

Figure 5.38 Historical artwork of the Earth-centred (geocentric) Ptolemaic cosmological model

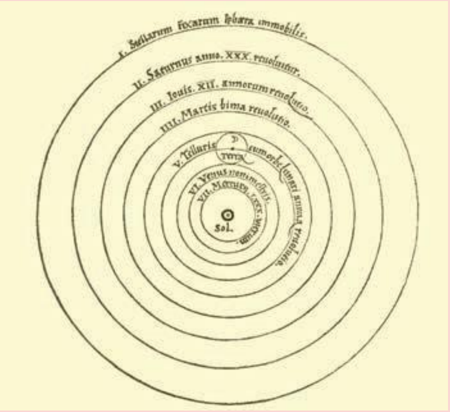

Figure 5.39 The diagram of Copernicus' heliocentric system, in Latin, as it appears in his book *De Revolutionibus orbium coelestium, On the revolutions of the heavenly bodies*, in 1543. 'Sol' is the Sun and 'Terra' is Earth.

Our galaxy

It was outside the solar system that the most exciting discoveries were made. The faint band of light that can be seen on dark moonless nights was found to be made up of countless individual stars and it was realised that our Sun is just one star in a galaxy of billions of stars called the Milky Way.

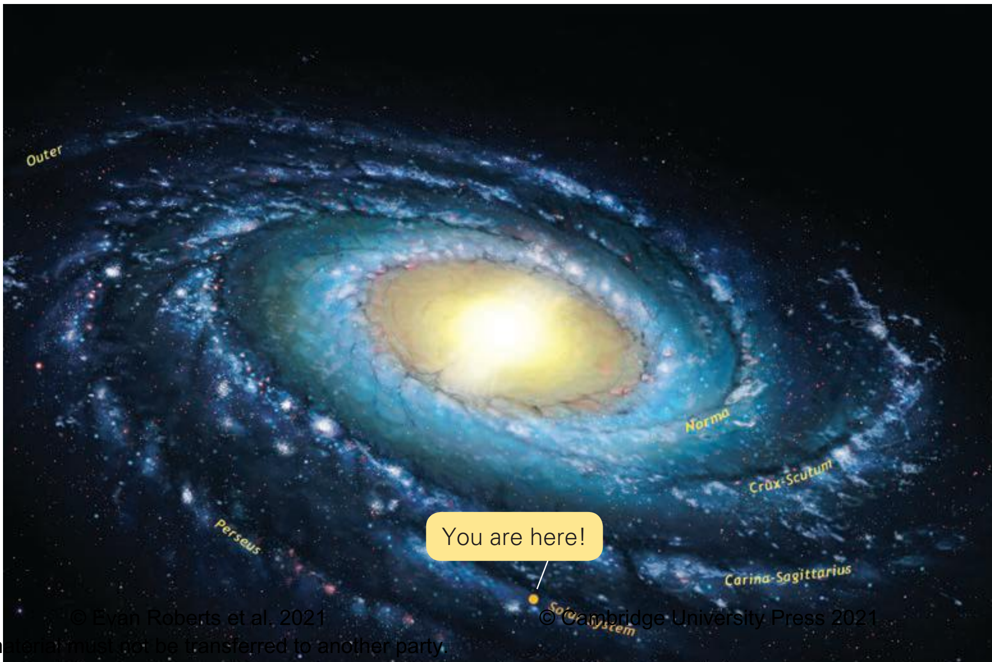

Figure 5.40 The Milky Way Galaxy showing the position of our solar system

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Try this 5.6

Making a telescope

Materials

- convex lens with 30 cm focal length
- convex lens with 5 cm focal length
- 2 cardboard tubes
- piece of card paper
- poster adhesive
- elastic bands

Be careful

WARNING: Do not look at the Sun or any bright lights with a telescope.

Instructions

1 Use poster adhesive or glue to fix the lenses to each of the cardboard tubes, as in Figure 5.41.
2 Wrap the piece of card around the tube with the lenses facing outwards. Secure with elastic bands.
3 Look at an object in the distance with your eye closer to the smaller lens. Focus the telescope by lengthening or shortening the tube. The length of the tube should be about 35 cm for viewing distant objects.

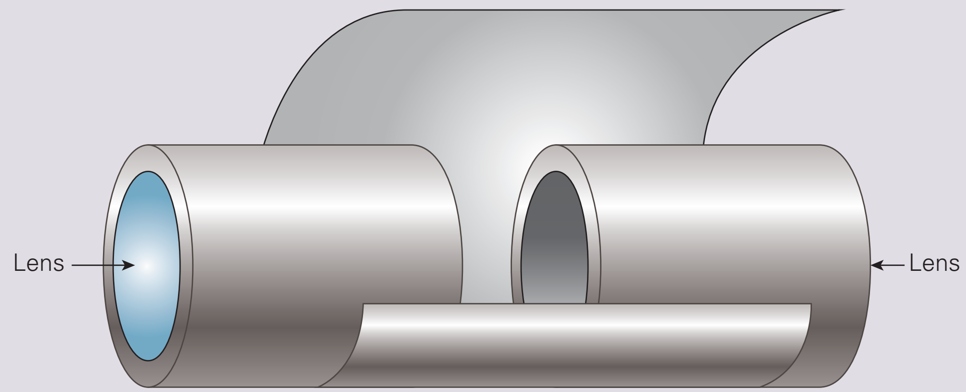

Figure 5.41 Make your own telescope

Describe how well your telescope worked. Explain how simple telescopes like this have helped scientists throughout history.

Technological advances: telescopes

The telescope has had a serious influence on our understanding of the universe and our place within it. There have been several technological advances in telescope design over the centuries. The first big advancement in telescope design was an invention by Newton who discovered a way to make powerful telescopes by replacing the lenses with mirrors. Over time, bigger telescopes were made that could see more detail. Observatories were built to house these giant telescopes on top of mountains to minimise the distorting effect of the atmosphere.

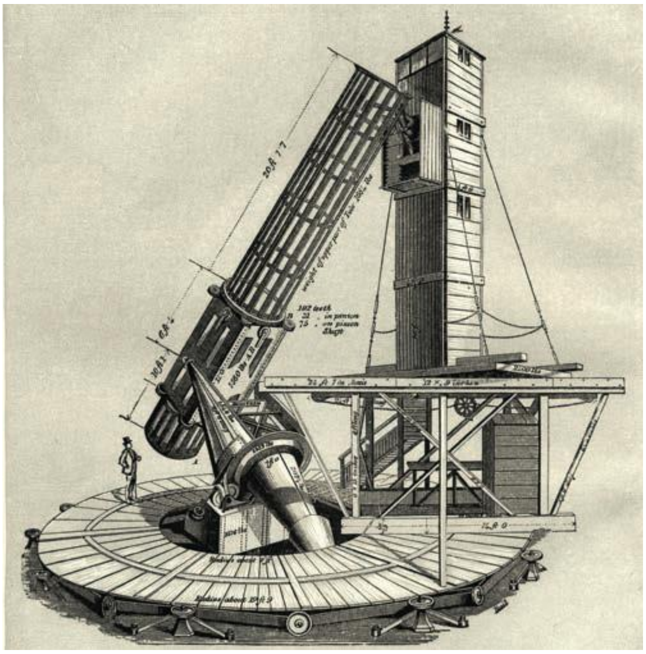

Figure 5.42 A sketch of a Newtonian telescope, 1870, a type of reflecting telescope that used two mirrors

While it is easy to measure the brightness of a star, more information can be obtained by attaching a spectrometer to a telescope. This allows astronomers to analyse the colours in the light from a star. The colour of a star indicates its temperature and by looking at

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the temperature and sizes of many stars, astronomers realised that stars do not stay the same but evolve over time. Using this information, astronomers estimate that our Sun is about 4.6 billion years old and is expected to continue shining for a further 4.6 billion years.

Galaxies outside our own?

Edwin Hubble was an American astronomer who made a significant contribution to astronomy in the 1920s. Not only was he the first to realise that our galaxy, the Milky Way, was just one of billions of galaxies in the universe but he also discovered that the galaxies were all moving apart from one another. Using this fact, he estimated that the universe formed 12–13 billion years ago in an event now called the Big Bang and that it has been expanding ever since.

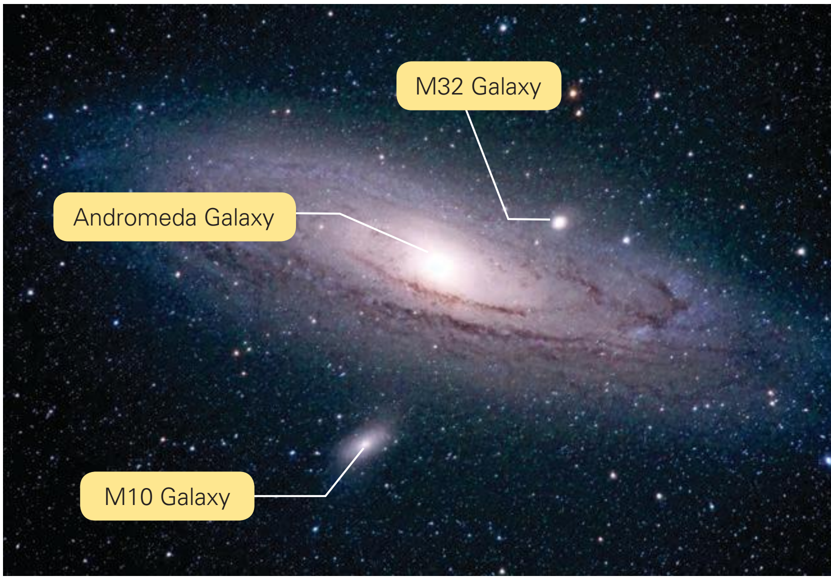

Figure 5.43 The Andromeda Galaxy. This nearby galaxy is similar in structure to our galaxy, the Milky Way. Two other galaxies (M10 and M32) are also visible.

Advances in science 5.4

The Hubble Space Telescope

Hubble's contribution was recognised when a telescope launched into space was named after him. The Hubble Space Telescope takes images that are free from any distortion from the atmosphere and, by using long exposure times, the images it takes are often both stunning and beautiful.

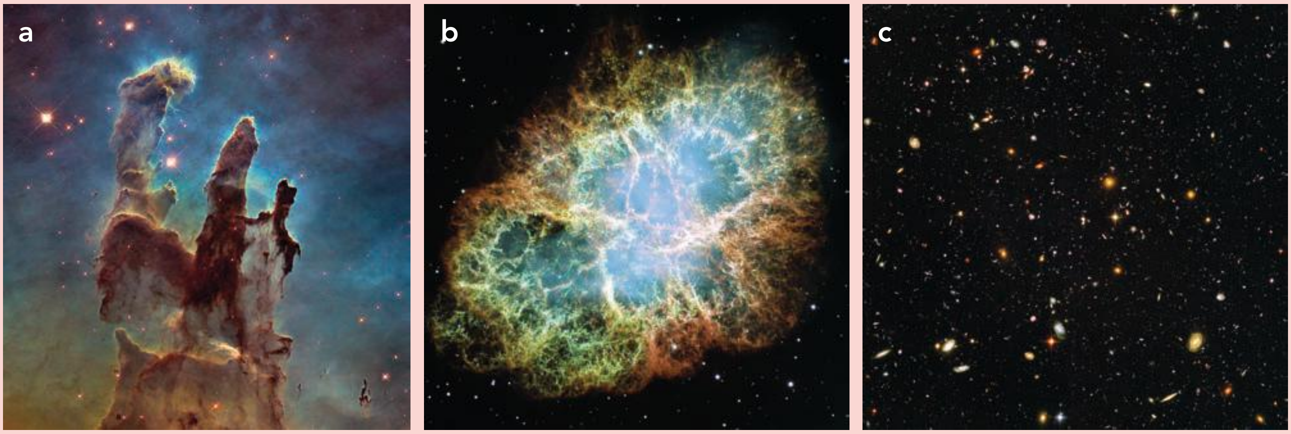

Figure 5.44 Images taken by the Hubble Space Telescope: **(a)** The Pillars of Creation, a star-forming region in our galaxy, **(b)** The Crab Nebula, the remains of a star that exploded in 1054 CE, **(c)** The Hubble Space Telescope shows that even the darkest patch of sky is found to be full of galaxies.

Technological advances: probes

A space probe is a device sent out from Earth into space to gather scientific data about planets, the Sun, other celestial bodies and space itself. Probes are unmanned but piloted remotely from Earth. Each probe contains a set of specifically designed scientific equipment that collects data for scientists to study and interpret. The data they collect is sent back to Earth via radio signals.

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The technology used by probes to collect information includes:

- imagery (photographs)
- infrared (to measure temperature)
- radar (to see through clouds)
- ultraviolet sensors (analyse atmospheric conditions)
- magnetometer (magnetic fields)
- soil analyser
- spectrometers (measure the properties of light)
- sensors to measure wind speed
- sensors to analyse the chemical composition
- drills and scoops for collecting rock samples.

There are different types of space probes ranging from satellite-like probes designed to orbit a planet, to probes that drift through the solar system collecting data, to planetary rovers that land on and explore the surface of a planet or moon. Recently, planetary rovers have been travelling on the surface of Mars gathering vital information about the planet.

Explore! 5.5

Mars rovers

Two missions to send rover probes to Mars were launched in 2020: NASA's *Perseverance* rover landed on Mars in February 2021 and the China National Space Administration rover is scheduled to land sometime in May or June 2021. Another joint mission by the European Space Agency and Russia's Roscosmos in scheduled for 2022. The USA has already sent four rovers to explore Mars and has received valuable data for scientists to study. Research the following Mars rovers: *Sojourner, Opportunity, Spirit* and *Curiosity*. Find out the aim of each rover's mission and answer the questions below.

1 What kind of data did the rover collect?
2 How long was it collecting data for?
3 Where on Mars was the data collected from? (Use a map of Mars.)
4 Where is the rover now?

Present the information you find in a table for comparison.

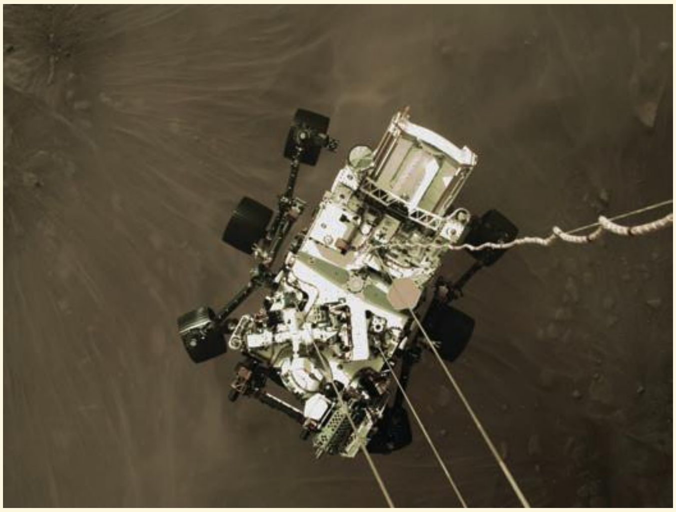

Figure 5.45 The Perseverance rover touching down in the Jazero crater area of Mars

Explore! 5.6

Australian Space Agency

On 1 July 2018, the Australian government opened the Australian Space Agency. According to its charter, the agency was set up 'to coordinate civil space matters' and to 'support the growth and transformation of Australia's space industry'.

Conduct research to find out what the purpose of this agency is and how it will help Australia participate in the space industry.

Create a poster or brochure with the information you find to promote the Australian Space Agency.

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Section 5.5 questions

QUIZ

Remembering

1 **Outline** what the solar system made up of.
2 **Identify** the galaxy Earth is in.

Understanding

3 **Explain** how telescopes can see in more detail.
4 **Explain** why telescopes are built on top of mountains.
5 **Describe** the sorts of discoveries that can be made with telescopes.
6 **Describe** ways that two different cultures have contributed to the understanding and exploration of our solar system.

Applying

7 **Explain** what the colour of a star can tell an astronomer.

Analysing

8 **Explain** why it is important to have telescopes that can gather data on light other than visible light.
9 **Compare** and **contrast** the geocentric and heliocentric models.

Evaluating

10 **Describe** how telescopes have changed our understanding of the universe. How might the understanding of the universe be different if the telescope had not been invented?
11 **Evaluate** how the use of technology in space probes over the last 50 years has improved our understanding of the universe.

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Chapter review

Chapter checklist

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

SCORCHER

Success criteria		Check
5.1	**I can explain what causes day and night.** e.g. Explain how the rotation of Earth causes day and night.	
5.2	**I can recall that gravity keeps planets in orbit around the Sun.** e.g. Explain why Earth orbits the Sun.	
5.2	**I am able to describe some differences between the seasonal calendars used by Aboriginal and Torres Strait Islander peoples and the typical twelve-month calendar.** e.g. Discuss why different peoples may have different calendars.	
5.1, 5.2, 5.3	**I can state the rotation times for Earth, the Moon and the Sun.** e.g. Define the term 'revolution'.	
5.2, 5.3	**I can compare the orbit times for Earth and the Moon.** e.g. Define the term 'orbit'.	
5.2	**I can describe the cause of seasons, including why different regions of Earth experience different seasonal conditions and how these seasonal changes affect people.** e.g. Describe how seasonal changes may affect a farmer located in the Riverina–Murray region, NSW.	
5.3	**I can describe how the phases of the Moon are caused.** e.g. Compare 'waxing' and 'waning'.	
5.4	**I can describe the cause of a lunar eclipse and a solar eclipse.** e.g. Illustrate a diagram to show the positions of Earth, the Sun and the Moon during a lunar eclipse.	
5.4	**I am able to recall some of the oral traditions of solar and lunar eclipses told by Aboriginal and Torres Strait Islander peoples.** e.g. Recall what gender the Moon and Sun are typically seen as in traditional Aboriginal stories.	
5.5	**I can discuss how technological advances have allowed for greater study of the solar system.** e.g. Describe how our knowledge of the solar system changed throughout history.	
5.5	**I can describe how models of the solar system have changed over time.** e.g. Compare the geocentric model with the heliocentric model.	

Reflections

1 What **connections** come to mind when you think about planet Earth and your everyday life?
2 What new concepts have **extended** your thinking about planet Earth?
3 What information did you find **challenging** or confusing?

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Data questions

Just like Earth's moon, the Moon, there are moons that orbit the planet Jupiter. In fact, Jupiter has 79 known moons! These vary in size and distance from the planet. The eight innermost moons and the periods of their orbits are shown in Figure 5.46.

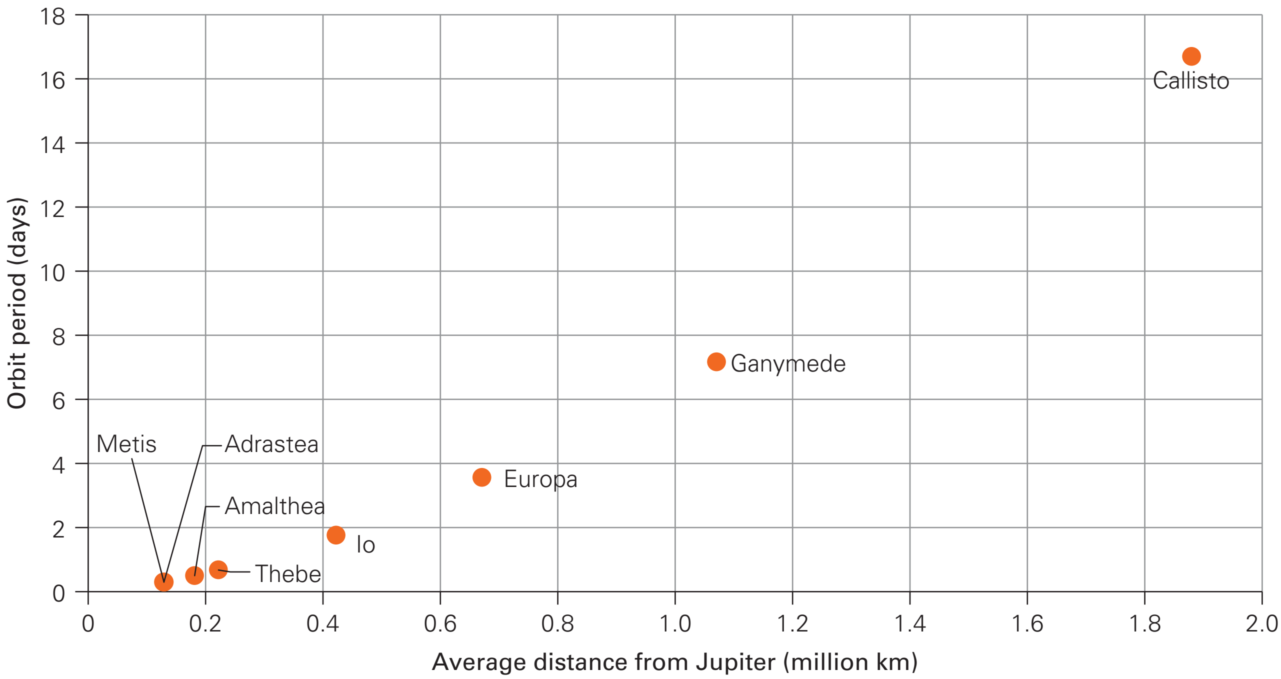

Figure 5.46 Orbital period of Jupiter's inner and Galilean moons

1 **Identify** which of the moons in Figure 5.46 orbits furthest in distance from Jupiter.
2 Use the data to **determine** which moon takes approximately 1.8 days to complete a full orbit of Jupiter.
3 Adrastea has an orbit time of 0.3 days, whereas Amalthea has an orbit time of 0.5 days. **Calculate** the difference in the number of hours it takes these moons to orbit Jupiter.
4 Galileo Galilei first discovered the four largest of Jupiter's moons in the 17th century, when he saw them through a telescope. They are those with an average orbit distance between 0.3 to 2 million km from Jupiter. **Categorise** the moons in Figure 5.46 as 'Galilean' or 'inner orbiting' (for those that orbit at distances other than 3 to 20 million km).
5 **Distinguish** the Galilean moons from the inner orbiting moons by referring to their possible size.
6 **Identify** the trend in the average distance of a moon from Jupiter and the time it takes for the moon to complete a full orbit of Jupiter.
7 Jupiter's ninth moon is called Thermisto, and its average distance from Jupiter is approximately 7.3 million km. A student has estimated, based on the trend in Figure 5.46, that the orbital period for Thermisto would be approximately 20 days. Use the data to **deduce** whether this would be an accurate estimate.
8 Earth's moon, the Moon, has an average distance from Earth of approximately 0.4 million km and has an orbit period of 27.32 days. **Compare** this data point to those provided in Figure 5.46 for the moons of Jupiter. Does Earth's lunar orbital period fit the trend identified in Question **6**?
9 **Justify** your response to Question **8** with an appropriate scientific explanation.

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STEM activity: Simulating the orbit of planets

Design brief: Create a simulation of the solar system planets orbiting the Sun.

Activity instructions

In this task, you will investigate how Kepler's laws of planetary motion explain why different planets orbit our Sun at different speeds. In a nutshell, Kepler's laws of planetary motion is straightforward, summarised as:

A planet's orbital speed changes, depending on how far it is from the Sun. The closer a planet is to the Sun, the stronger the Sun's gravitational pull on it, and the faster the planet moves.

We can observe the effects of Kepler's laws within our own solar system right now. Table 5.2 shows the relationship between distance and orbit of the planets Mercury, Venus, Earth and Mars.

Planet	Distance from the Sun (km)	Orbital period (days)
Mercury	55 000 000	88
Venus	105 000 000	225
Earth	150 000 000	365
Mars	228 000 000	687

Table 5.2 Distance and orbital period data for planets located in the inner solar system

Your task is to use Microsoft PowerPoint to create your very own simulation of the solar system (like the one shown in Figure 5.47), and to gain a visual understanding of how Kepler's laws of planetary motion apply to planets orbiting the Sun.

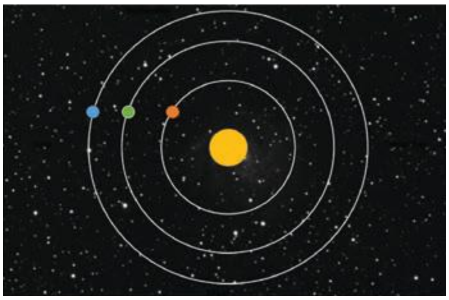

Figure 5.47 Model of the solar system

Suggested materials

- laptop
- Microsoft PowerPoint
- paper and pencil to perform simple calculations

Research and feasibility

1 Research our solar system, the names of the planets, their orbiting speed and distance from the Sun.

Design

2 Create a labelled model of the solar system. Include planet names, their orbital speeds and each planet's distance from the Sun.

Create

3 Use Microsoft PowerPoint to create your model.

4 PowerPoint has given all planets within the inner solar system the same orbital period (2 seconds). However, you know that planets closer to the Sun (e.g. Mercury) have shorter orbital periods compared to planets located further away (e.g. Saturn). Therefore, you should make changes to your simulation to make it behave as closely as possible to the real solar system.

5 Assuming that, on your model, Mercury orbits your Sun in 2 seconds (orbital period = 88 days), *estimate* the number of seconds required for Venus (orbital period = 225 days) and Earth (orbital period = 365 days). After you finish your estimation, you can change the values (seconds) to make your simulation more realistic.

Evaluate and modify

6 Discuss with your group the challenges you have encountered throughout this project. List the strategies or actions that allowed you to overcome it.

7 Reflection is an integral and vital aspect of any project in the real world. In your honest opinion, *list* what you would like to have included, removed or modified from this challenge as well as ways to improve the way we visualise our solar system.

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Chapter 6
Earth resources and management

Inquiry questions

Where do our resources come from?

Why is it important to use Earth's resources wisely?

Why is water such an important resource?

PRE-TEST

Chapter introduction

This chapter will help you understand the amazing resources that our Earth provides. Renewable and non-renewable resources will be investigated as well as how long they will last for. You will look at water in more detail as it is a very important example of a resource that cycles through the environment but is massively affected by the things we humans do to change our world.

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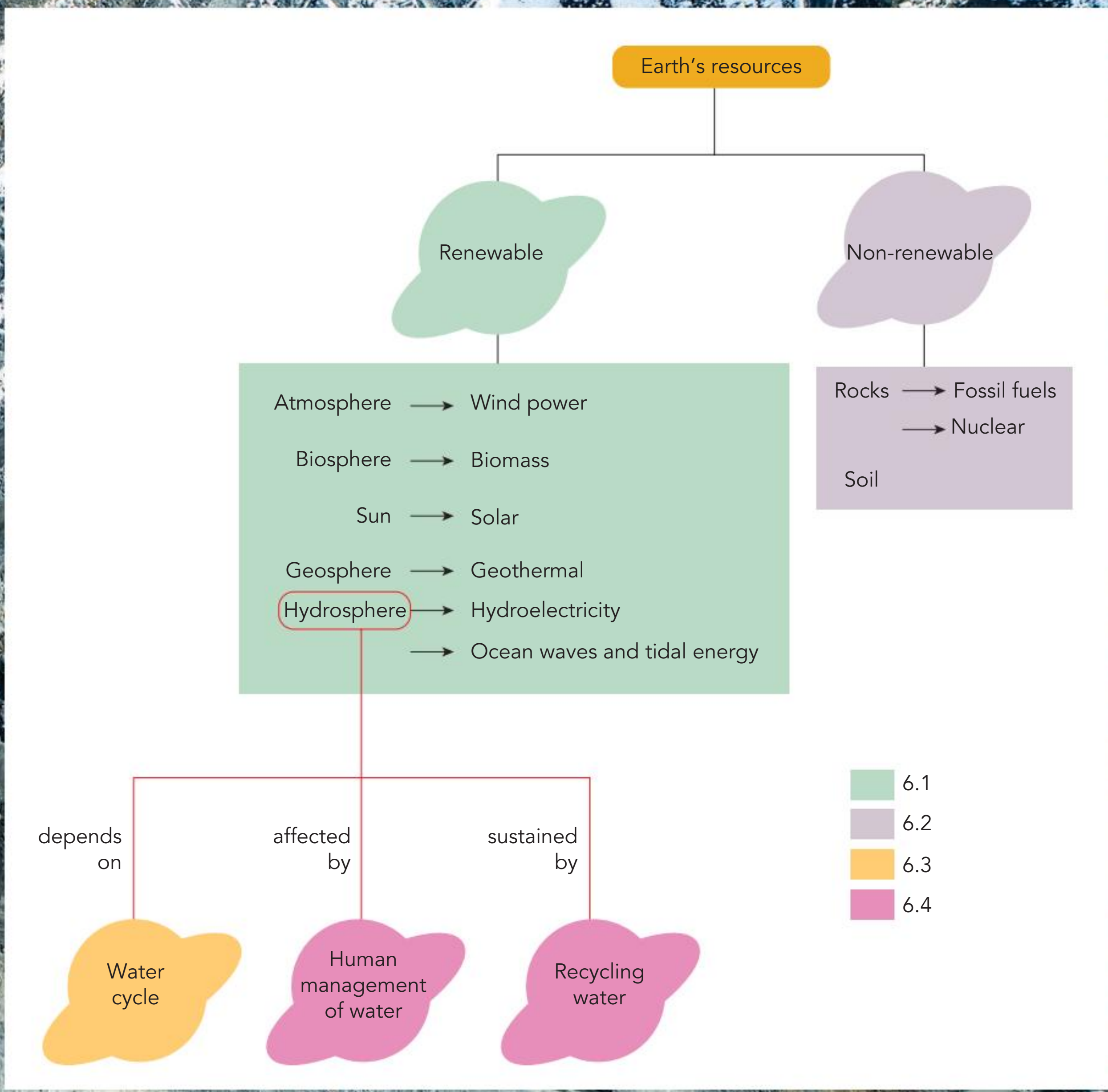
Chapter map



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6.1 Renewable resources

Learning goals

1. To identify Earth's renewable resources.
2. To describe different ways that energy can be produced using renewable resources.

WORKSHEET

Introduction to Earth's resources

Every year, you start school by bringing certain **resources** to your classes – for example, textbooks, laptop/iPad, sports gear and stationery – things that will support your learning. So, when the word 'resources' is used, it means something that is useful. Now consider the major resources of Earth. They are water, air, living things, rocks (containing **minerals** and **fossil fuels**), soil, heat from Earth and energy from the Sun. How are these things useful to us?

resource
natural commodity that is valuable in supporting life

mineral
substance formed naturally in the ground

fossil fuel
fuels, such as gas, coal and oil, that were formed underground from plant and animal remains millions of years ago

renewable
replenished by natural processes within a human lifetime

non-renewable
existing in limited quantities that cannot be replaced after they have all been used

Some of Earth's resources are **renewable**. This means that the resource is replenished (topped up) by natural processes within a human lifetime. There are variations in our planet's ability to replenish resources and the speed of their replenishment. Therefore, a close eye must be kept on how much and how quickly all resources are used. For example, wood is used for building, for heating and for cooking. Trees can be replaced by planting and can reach maturity within 30 to 40 years, and so are called renewable. A non-renewable resource is a resource that cannot be replaced or takes a very long time to be replaced, much longer than a human lifetime. For example, some of the minerals buried deep in the earth have taken millions of years to form and so are called **non-renewable**. Both renewable and non-renewable resources need close monitoring.

Figure 6.1 Guess the types of energy sources in the image. Are they renewable or non-renewable? You can discuss this with your classmates.

Left to right, top to bottom: biofuel from living things (renewable), hydropower from water (renewable), nuclear (non-renewable), wind (renewable), coal (non-renewable), solar or sun (renewable).

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Quick check 6.1

1 Name six of the major resources on Earth.
2 Define the terms 'renewable' and 'non-renewable'.
3 For each of the following, decide if the resource is renewable or non-renewable, and identify which of the major resources it fits into.

coal	wind energy	rice
solar energy	water	sand
timber	nuclear energy	oil
natural gas	minerals	

Renewable resources

Australia is lucky to have access to so many of Earth's renewable resources. Water, air, living things and energy from the Sun are all renewable resources. This means that these resources can also provide ongoing supplies of energy; for example, to power homes. Renewable forms of energy are **hydroelectricity** (water), **geothermal energy** (heat from the earth), energy from the ocean waves and tidal energy (water), wind energy (air), fuel from **biomass** (living things) and **solar energy** (energy from the Sun). These forms of energy are termed 'cleaner' than non-renewable forms, as they usually do not produce as much **greenhouse gas**.

Hydrosphere: Water

Water is a renewable resource as it cycles through the environment many times within a human lifetime. Fresh water is an extremely important resource that all living things need for their survival. However, only about 3% of all water on Earth is fresh water, and only one third of this is available for plants, animals, manufacturing, agricultural and the ecosystems in which we all live. The rest of the fresh water (2% of all water) has a massively important role in regulating the temperature of our planet and is locked away in ice caps and glaciers.

You probably know that Australia is one of the driest continents on Earth. Therefore, we often experience water restrictions because it is essential that our fresh water is conserved and, of course, contamination of our water supplies is minimised. So, how do we get fresh water? Where does it keep coming from? The answer is the **water cycle** and you will learn about this a little later in this chapter.

hydroelectricity producing electricity by the force of fast-moving water such as rivers or waterfalls

geothermal energy energy from the heat inside Earth

biomass plant and animal material suitable for using as fuel

solar energy using the energy from the Sun to produce electric power

greenhouse gas gases that prevent heat from Earth escaping into space

groundwater water that collects beneath Earth's surface

water cycle the way that water is taken up from the sea, rivers, lakes and soil, and then comes back down as rain, snow or hail

VIDEO
Renewable resources

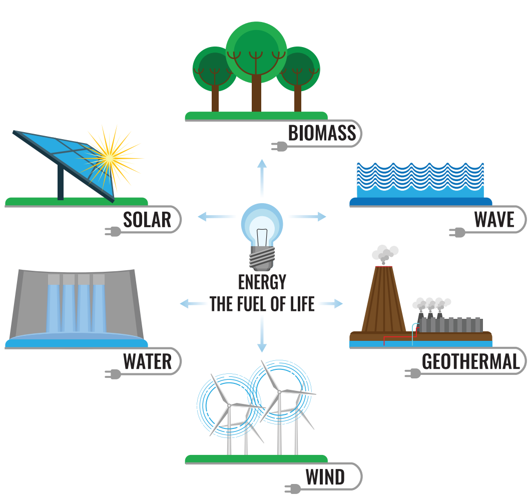

Figure 6.2 There are many different types of renewable energy sources.

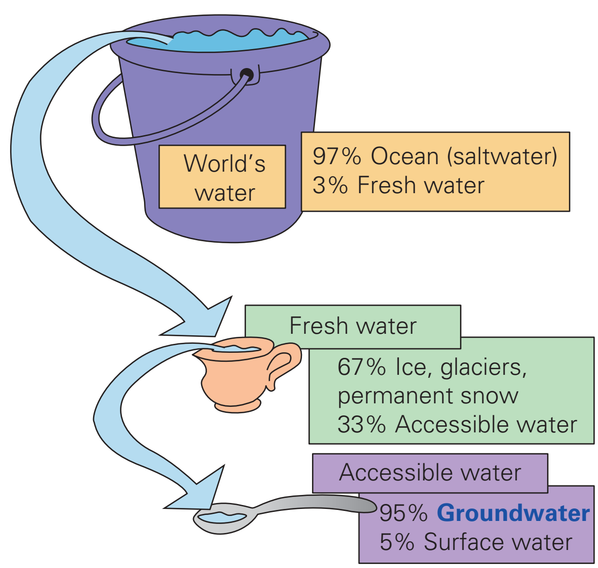

Figure 6.3 Only about 1% (33% of 3%) of the world's water is accessible fresh water. Groundwater can be accessed from bores, springs, wells, etc. Surface water is water that is in streams, rivers, lakes, etc.

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Energy from water: Hydroelectricity

Hydro (water) electricity is a clean source of energy, producing no greenhouse gases except in the construction of hydroelectric schemes. First, rivers are dammed to capture huge amounts of water. The dams hold water at a height, increasing the pressure of the water flowing to a lower level because of the pull of gravity. The water trapped in the dam is then allowed to run through pipes at great speed (and force) to a power station lower down. This is where the water turns turbines that drive the generators to produce hydroelectricity.

Unlike other renewable sources, the water can be stored, which means electricity can be produced whenever it is needed. However, producing electricity in this way is limited to areas with large river systems and land big enough for building dams to store water.

Figure 6.4 Cross-section of a hydroelectric dam

Energy from water: Ocean waves and tidal energy

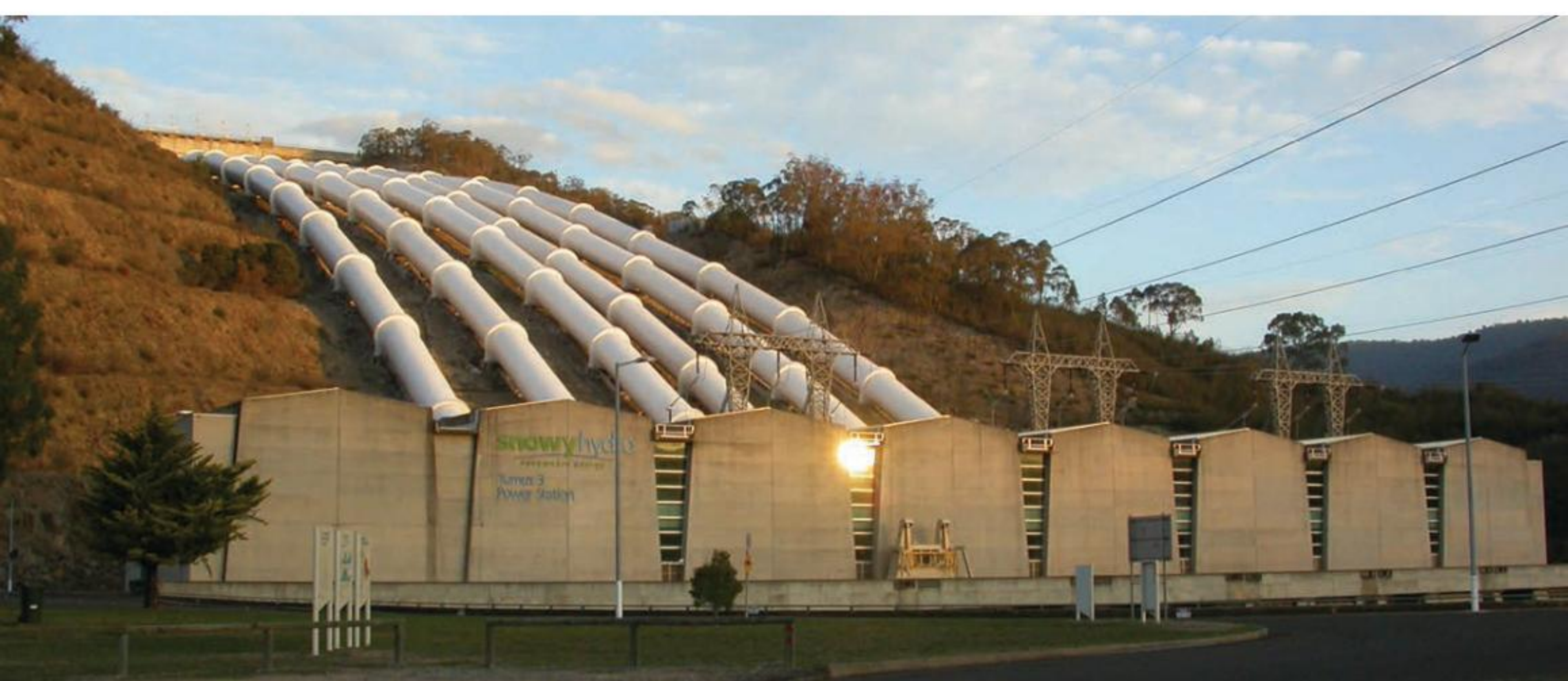
There is so much coastline around Australia, it makes sense to try to harness the energy provided by the marine environment. There are several different sources of **ocean energy**; the ones that current technologies enable us to use are:

- wave energy: energy from waves (swells) converted into electricity. Water flows into an enclosed chamber where the rise and fall of the waves causes the compression and decompression of air. This in turn spins turbines connected to a generator.
- tidal energy: movement of tides converted into electricity. Tides on Earth are caused by the gravitational pull of the Moon and the Sun. The Moon has a stronger pull than the Sun, due to its closeness to Earth. One method of doing so is through tidal **barrages** – water enters a basin next to the barrage and builds up. It is then released through gates (called sluice gates) to flow through turbines and these turn generators to produce electricity, as with hydroelectricity.

ocean energy
energy harnessed from the ocean such as waves and tides

barrage
a barrier to generate electricity from tidal power

Figure 6.5 Tumut 3 Power Station in NSW was the first major pumped-storage hydroelectric plant built in Australia. Talbingo Reservoir provides the water.



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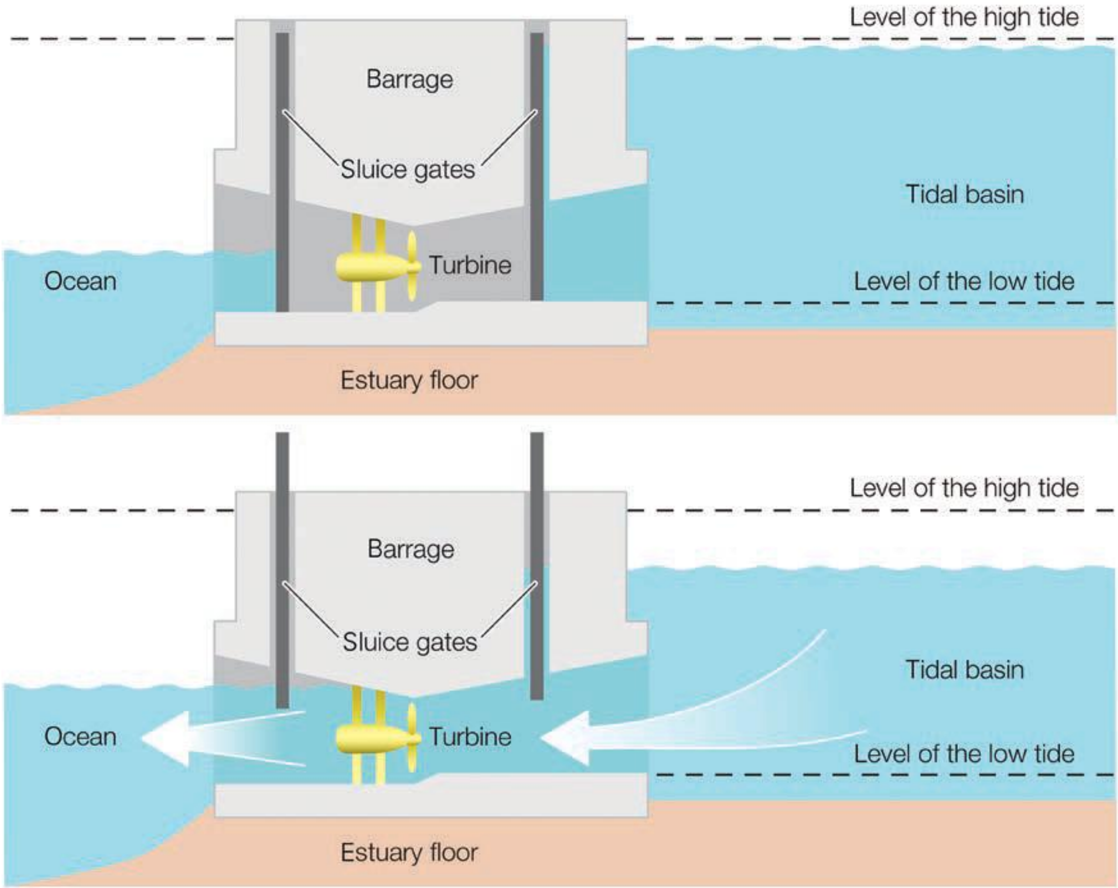

Figure 6.6 A tidal barrage, an artificial barrier, built across a river to generate electricity by tidal power

Geosphere: Heat from Earth

Energy from Earth: geothermal

Geothermal energy is naturally occurring heat from deep within Earth's interior. The deeper you go below the surface, the hotter it gets and so you can find geothermal energy in granite rocks (often called 'hot rocks') or trapped in liquids (hydrothermal process), 3 to 5 kilometres below the surface! The most common source of geothermal energy around the world is hot springs associated with volcanic activity.

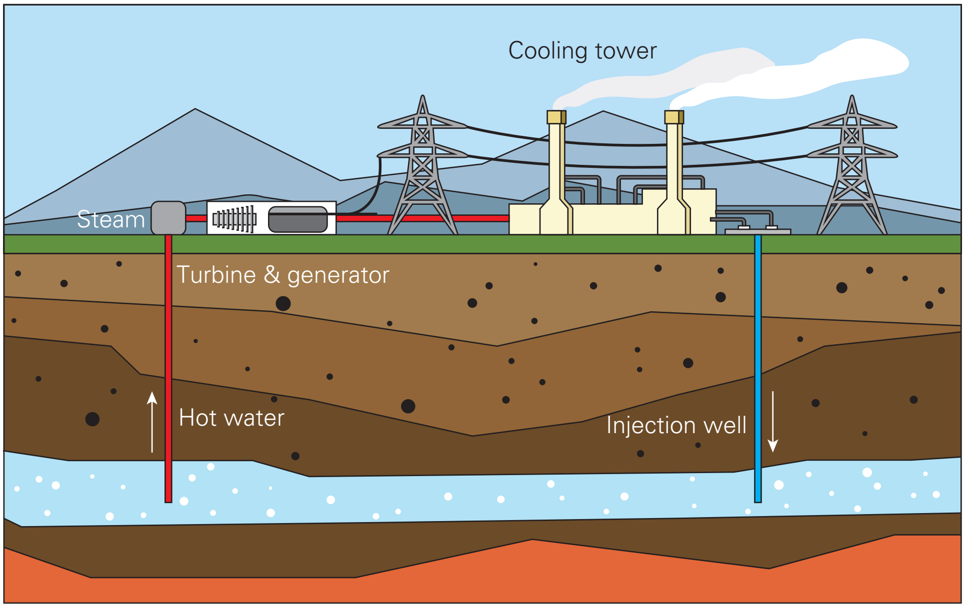

Figure 6.7 In geothermal power stations, heat from Earth's core is used to heat water and this is then used to turn a turbine. The water is cooled and returned to the heat source.

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Advances in science 6.1

Generating power from the ocean

In 1975, the CETO (Cylindrical Energy Transfer Oscillating) wave-energy system was conceived, designed and built by an Australian inventor, Alan Burns. His system was (and currently remains) the first wave-power converter to sit on the seabed. The buoys capture energy from the ocean waves as they pass by. It requires only a small pipe to carry high-pressure seawater ashore to a turbine to produce electricity with no dangerous emissions. For the last couple of years, the CETO 5 has been operating the world's first multi-machine wave-energy installation off the coast of Western Australia. In 2016, development of the CETO 6 (more efficient and will deliver increased power generation than the CETO 5) began.

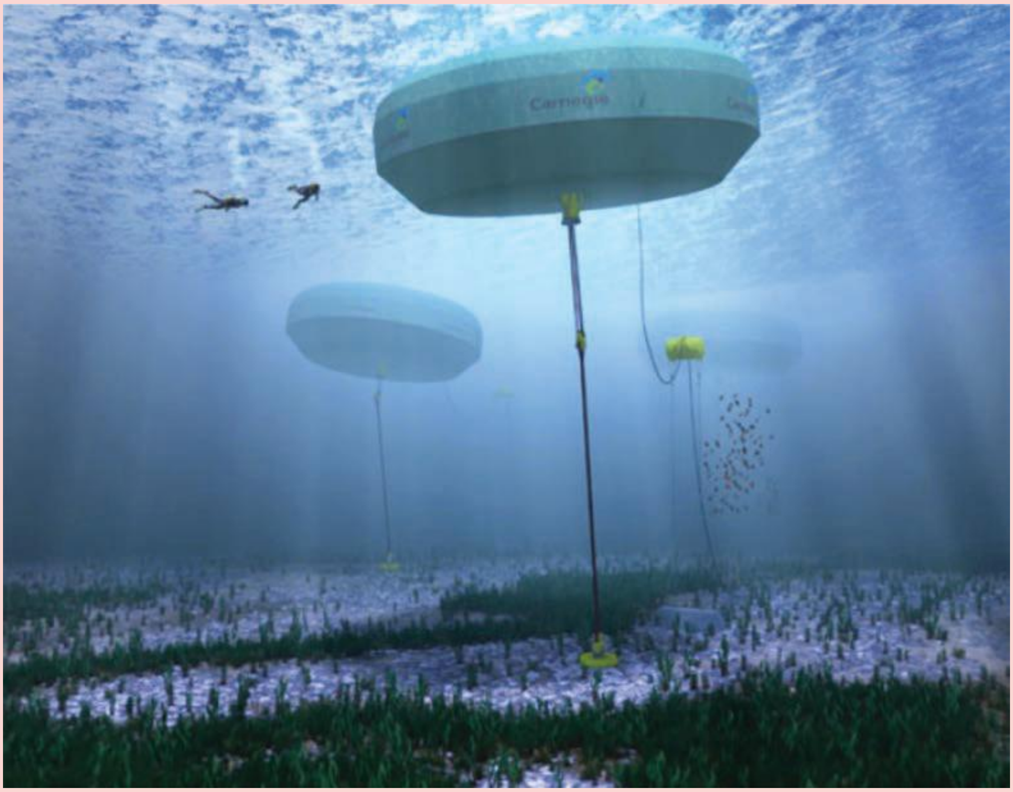

Figure 6.8 The CETO 5 is harnessing ocean energy off the coast of Western Australia.

Quick check 6.2

1 Recall why water is such an important resource for all living things.
2 Explain why water is considered to be renewable.
3 Draw a flow chart to illustrate the steps involved in making electricity from the flow of water.
4 Identify the energy types described below.
   a This form of energy is made by using the heat from the Sun.
   b This form of energy uses the energy made when burning plant and animal matter for heating our homes.
5 Read the following statements and decide whether each is true or false. If false, give a reason why.
   a Ocean wave energy uses waves to make electricity.
   b Ocean wave energy depends on the wind blowing across the sea.
   c Ocean wave energy depends on the gravitational pull of the Moon and the Sun, and Earth's rotation.

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Atmosphere: Air

The air is made up of mostly particles of nitrogen (78%) and oxygen (21%) with small amounts of other gases, including carbon dioxide. You may already know that animals (and also plants) need oxygen to produce energy, and carbon dioxide is used by plants in the special process of making sugars (called photosynthesis). Nitrogen is also needed for survival as it is an important component in proteins – living things need proteins to function and grow.

Energy from air: Wind

Winds are caused by the uneven heating of Earth and the atmosphere by the Sun. This means, that as long as there is a Sun, there will be wind. Like old-fashioned windmills, today's wind turbines harness the free energy of the wind to produce electrical energy. The wind pushes against the blades on top of the tower, making them spin. The blades are attached to a rotor and the rotor is connected to the main shaft, which spins a generator to produce electricity.

Large-scale wind farms are an amazing sight to see, and when connected to the electricity grid, can supplement the electricity supply of large towns and cities without producing any greenhouse gases.

Figure 6.9 A wind farm in Taralga NSW. What do you think may be the downside of wind farms?

Biosphere: Living things

Living things are considered a renewable resource because they can reproduce, meaning they are continually being replaced. For example, timber is considered a renewable resource as it takes about 25 years until a tree can be chopped down and used.

Energy from living things: Biomass

Biomass is the name given to any material derived from plant and animal matter, as well as their waste. The reason for this is that plants can convert the Sun's energy into another form that can be used later, and if animals eat the plants they essentially consume the stored energy. There are several ways in which the energy can be released.

- The breakdown of manure and food scraps produces methane gas that releases energy when burned.
- Burning biomass, such as wood, releases energy that can be used for heating and cooking.
- The processing of biomass produces biofuels such as biodiesel, biogas and alcohol, which can be used instead of traditional fossil fuels.

Figure 6.10 Wood pellets (top) and dry dung (bottom) are both examples of biomass – fuel developed from organic materials.

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Practical 6.1

Which plant produces more biomass?

Be careful

Wear a dust mask and gloves when using potting mix.

Aim

To determine which type of plant produces the most biomass in a set period of time.

Research question

Which type of plant produces the most biomass in 16 days?

Materials

Day 1

- 15 wheat or rye seeds
- 15 corn seeds
- 15 oat seeds
- potting mix
- 9 milk containers or small seedling pots (3 per independent variable group)
- well-lit area to place seedlings or a natural light source to set up inside
- Recommended: camera

Day 16

- 9 (new) milk containers or small seedling pots
- bucket or sink with water
- paper towel

Day 20

- electronic scales
- 9 takeaway containers

Planning

1 You need to provide some background information to the investigation. Complete some research and write a brief paragraph to explain the key concepts of biomass and factors that affect plant growth. Ensure you reference appropriately.
2 Identify the independent variable in this investigation.
3 Identify the dependent variable in this investigation.
4 Identify the controlled variables in this investigation.
5 Create a risk assessment for this investigation.

Procedure

Day 1

1 Prepare three containers to plant seeds. Label each container to identify the independent variable group number, description (the type of plant you will plant in it), date and student name.
2 Place moist soil in each container.
3 Carefully count out fifteen seeds of one species of plant. Spread five seeds evenly across the soil in each of the three containers.
4 Then plant them at the depth specified on the seed packet.
5 Repeat with fifteen seeds of the two other species of plant, each in their own container. (This brings the total number of containers used to nine.)
6 Spray the soil to moisten the soil thoroughly, at least to the depth of the seeds.
7 Place all nine containers under similar conditions in an undisturbed area to grow. Set it up so that all containers receive similar temperature and air flow and even amounts of light.

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

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8 Continue to spray the soil daily to keep it moist.
9 Monitor each group for 14–16 days. Taking photographs of each container including the label is recommended.
10 If any part of the set-up is changed, then note the reason for this.

Day 16

11 Label three new containers for drying each species of plant (nine in total).
12 Remove the plants from the first container and carefully wash the roots in a bucket of water to remove any soil.
13 Dry the plants with a paper towel.
14 Repeat steps **11–13** with the other containers.
15 Place the containers in the sun until the plants are completed dehydrated.

Day 20

16 Copy the results table for collecting the raw data.
17 Identify and label the different types of variables in the table.
18 Weigh an empty takeaway container to subtract from each set of dried plants + container.
19 Weigh each of the nine containers of dried plants.
20 Record the mass in the table.
21 Calculate the mean measurement for each *independent variable* group.
22 Calculate the range for each independent variable group on the table.
23 What type of graph would be best to represent the mean of each of the three groups to compare them? Make that type of graph and discuss your observations.

Results

Independent variable ____________	Dependent variable ____________			
	Trial 1	Trial 2	Trial 3	Mean
Group 1 ________				
Group 2 ________				
Group 3 ________				

Discussion

1 Decide which plant has the greatest rate of biomass production.
2 Describe how much variation was observed between the measurements within each group.
3 Describe how much the set-up or method was adjusted once the experiment was started.
4 Explain if the controlled variables were managed properly to ensure they did not change and affect the measurements.
5 Discuss any other changes that could be made to the method to improve the quality of the data in future experiments.

Figure 6.11 Which plant produces more biomass?

6 Evaluate the method and write out an improved version based on the answers to Questions **3–5**.

Conclusion

Answer the research question, using evidence to support your statement.

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Quick check 6.3

1 Recall what makes air a resource.
2 State some advantages and disadvantages of wind farms.
3 Explain why biomass is considered renewable.
4 Identify five examples of biomass that could be found at a garbage dump.

The Sun

The Sun is one of more than a billion stars in the Milky Way. Its energy is renewable as it has enough nuclear fuel to keep shining for another 4.6 billion years! This is certainly good news as plants need sunlight to make sugars by photosynthesis, which we (and other organisms) then need to eat to sustain our bodies. Our planet also needs the Sun's energy to keep warm.

photovoltaic
able to produce electricity from light

Energy from the Sun: Solar

You are probably very familiar with **photovoltaic** or solar cells, as there are so many solar-powered toys, calculators and outdoor lights on the market using solar cells to convert the Sun's energy into electricity. Solar cells are made up of silicon, and have no mechanical parts to wear out. Some considerations for building large photovoltaic power plants include their size, the upfront expense, and the fact that the Sun does not shine at night! New South Wales has several operational solar farms. Many of these farms are located in the south-west of the state. Why do you think they are located there?

Figure 6.12 The Sun's energy shines down on us and is essential for life on Earth.

Figure 6.13 These photovoltaic solar panels convert the Sun's energy into electricity directly.

Quick check 6.4

1 Explain why we call the Sun's energy a resource.
2 Evaluate if solar power is a reliable source of energy.
3 Explain how using solar energy impacts on the environment.

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Practical 6.2

Which solar collector is the best?

Aim

To carry out a fair test to investigate how different colours affect the absorption of light on a solar shower.

Prior understanding

Solar collectors absorb the light energy from the Sun and transfer or store the energy for use. In Australia, the use of solar collectors is increasing, now that better methods of storage are being developed.

One simple solar collector that has been used by campers for a long time is the solar shower. This is a plastic bag with a shower hose attached. The bag is filled in the morning and left in the sun to heat the water during the day. The hot water can be used to shower at night. The design of the solar shower needs to allow the bag to efficiently absorb the light energy with as little waste as possible and retain the heat once absorbed.

Materials

- 4 balloons of different colours, e.g. black, green, red and white, to act as solar collectors
- 4 straws
- 4 ice-cream containers
- aluminium foil
- approximately 1.5 L of sand, soil, or other packing material
- sticky tape
- a thermometer or data logging temperature sensor
- paper and pen or computer for the table entry

Planning

1 Identify the independent variable in this investigation.
2 Identify the dependent variable in this investigation.
3 Identify the controlled variables in this investigation.

Procedure

Follow these steps to make a solar collector.

1 Copy out and label the results table to record your data.
2 Line each ice-cream container with aluminium foil. Place it so that the shiny side is visible.
3 Fill the bottom of each container with packing material and make an indent in the middle to support the balloon.
4 Fill each balloon with about 200 mL of water. All four balloons must contain the same amount of water.
5 Place the balloons onto the sand in the ice-cream container.
6 Secure the opening of each balloon by taping the opening tightly around a straw, with the straw facing upwards.
7 Slide the thermometer into each full water balloon and record the *initial temperature*.
8 Place the solar collectors on the ground in sunlight for the same amount of time for each collector. Leave them for 15–20 minutes.
9 Record the *final temperature* inside the collector when the time is up.
10 Calculate the change in temperature.

Results

	Dependent variable ______________		
Independent variable __________	**Initial**	**Final**	**Change**
Group 1 ________			
Group 2 ________			
Group 3 ________			
Group 4 ________			

continued...

...continued

Discussion

1 Describe any trends or patterns in your results.
2 Organise the colours of the balloons from most effective to least effective in terms of absorbing light energy. Use data to justify your answer.
3 Critique your management of the controlled variables. Were they managed properly to ensure they did not change and affect the measurements?
4 Now that you know the best colour of solar collector, develop a new method that will allow you to investigate how the effectiveness of this colour can be improved further. Perhaps resting the balloon on a reflective surface, or changing the size or shape of the balloon, could increase the effectiveness.

Explore! 6.1

Engineering as a career

Engineering is a career that helps make people's lives easier and safer. Engineers are scientists, inventors, designers and builders, who can construct tools, create vehicles, run simulations, design chemical compounds and so much more.

1 Investigate and then summarise the role of a renewable energy engineer.
2 Make a list of some of the different skills a renewable energy engineer would have.

Figure 6.14 Some of the many roles of renewable energy engineers

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Section 6.1 questions

QUIZ

Remembering

1 Read each statement and **identify** which renewable energy source is being described.
  a Water wheels are the oldest machines used for capturing this type of renewable energy.
  b This energy source captures the energy from moving air.
  c By digging deep wells and pumping the heated underground water or steam to the surface, this energy can heat homes.
  d This type of energy depends on the gravitational pull of the Moon and the Sun.
  e This energy source can use wood, straw and manure.
  f This energy source involves building a dam to raise the level of water in the reservoir.
  g This energy source involves water rising and falling, which compresses and decompresses air.

Understanding

2 **Summarise** the different renewable energy sources: hydroelectric, solar, wind and geothermal. Include the following information:
  - How it works
  - Advantages
  - Disadvantages

Applying

3 **Discuss** what prevents hydroelectricity from being used everywhere in Australia.
4 **Explain** why hydroelectricity would not be possible if it was not for solar energy.
5 **Compare** a hydroelectric power station and a nuclear power station.
6 **Deduce** why solar energy is sometimes called 'green' energy.
7 **Outline** the disadvantages of using solar energy.

Analysing

8 **Summarise** the advantages and disadvantages of a hydroelectric power scheme. You may construct a table for the information.
9 We are often encouraged to recycle, reduce and reuse rather than buy new items. **Explain** why this is the case.
10 **Compare** hydroelectricity with a giant battery.

Evaluating

11 Turbines usually spin in one direction, but the turbines used to capture tidal energy move in two directions. **Deduce** why this would need to be the case.
12 **Justify** why some people think forests can be classified as a renewable resource and others consider it to be a non-renewable resource.

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6.2 Non-renewable resources

Learning goals

1 To identify Earth's non-renewable resources.
2 To describe ways to minimise society's dependence on non-renewable resources.

DOC WORKSHEET

VIDEO Non-renewable resources

Remember that non-renewable resources cannot be replaced easily and not within a human lifetime. Of Earth's resources, rocks, minerals and soil are all non-renewable resources. These resources also provide non-renewable energy sources like fossil fuels and **nuclear energy**.

nuclear energy
the energy obtained from changes within the atomic nucleus from nuclear fission or fusion

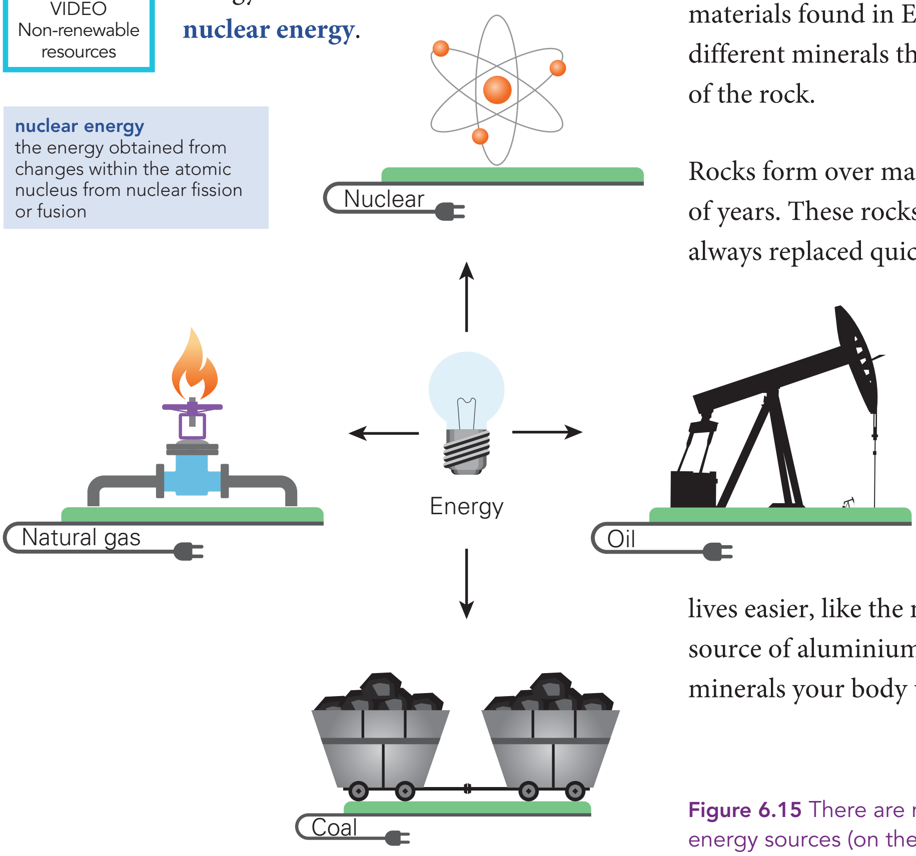

Figure 6.15 There are many different types of non-renewable energy sources (on the left).

Rocks and minerals

Rocks and minerals are all around us – we have them in our homes, in our gardens, at our schools and in our cities. Minerals are the building blocks of rocks and have a specific chemical structure that is the same throughout the entire mineral. Rocks, on the other hand, are solid materials found in Earth's crust and are composed of different minerals that vary throughout the structure of the rock.

Rocks form over many thousands or even millions of years. These rocks and their minerals are not always replaced quickly once they have been mined and used, and consequently they are considered a non-renewable resource.

The minerals contained in rocks can be important for us when properly processed. There are lots of minerals used to make our lives easier, like the mineral bauxite, which is the main source of aluminium. Table 6.1 summarises some of the minerals your body uses.

Mineral	Calcium	Zinc	Potassium	Iron
Use in the body	Helps make your bones strong	Supports your immune system in fighting illness and infection	Keeps your nervous system and muscles working properly	Carries oxygen around your body in your blood
Mineral source				

Table 6.1 Some of the different minerals that our bodies need

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Energy: Fossil fuels

Rock layers also contain resources that are not made from rock, such as coal, oil and natural gas. These are collectively known as fossil fuels and are a major source of energy. Unfortunately, they are non-renewable because the process of forming fossil fuels takes millions of years, and we are using them faster than they can be renewed.

Why do you think fossil fuels are called fossil fuels? The energy in fossil fuels originally came from the Sun. Plants use the Sun's energy to make sugars (by photosynthesis), and this energy in plants passes to the animals that eat them. Once the living things have died, the effects of pressure and temperature due to burial can change the plant and animal remains into fossil fuels. So, we can say that fossil fuels are made from the remains of fossilised prehistoric living things. To be specific, coal is formed from dead plant material, while oil and gas are formed from dead marine life. The burning of the fossil fuels releases the energy for humans to use.

Figure 6.16 Mt Piper coal-fired power station near Lithgow NSW. The short wide towers are the cooling or condensing towers; they allow the recycling of steam and release water vapour. The tall chimney releases carbon dioxide as it is connected to the furnace. Coal-fired power stations are usually located next to a coal mine. Why is this?

In the case of coal, once it is removed from the ground, it is transported to a coal-fired power plant. Here the coal is crushed and burnt in a furnace. The heat energy released is used to heat water into hot steam used to turn turbines. The turbines drive generators, which produce electricity. The steam is then condensed and recycled.

As with all energy sources, whether renewable or non-renewable, there are advantages and disadvantages to the use of coal. Advantages that people see with the use of coal are that it is abundant, relatively inexpensive to start up with, and provides a steady amount of heat. The disadvantage is that burning fossil fuels releases carbon dioxide, a greenhouse gas that scientists believe is the chief man-made cause of global warning. Additionally, mines could make a mess of the landscape.

The other fossil fuels, oil and gas, are among the most important raw materials we have. Every day, we use many things that are made from oil or gas. Look at Figure 6.17 and think about all the things you may have used today that rely on oil or gas.

Figure 6.17 We use oil and gas every day in so many ways. Can you list all the different items you use regularly that are made from oil or gas?

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Quick check 6.5

1 Define the terms 'rocks' and 'minerals'.
2 Explain why rocks and minerals are considered to be non-renewable.
3 Name the three resources that collectively are called fossil fuels.
4 Summarise the steps involved in turning coal into electricity.

Practical 6.3: Teacher demonstration

Foul smelling gas

Be careful
Dispose of all materials in a well-ventilated area.

Aim
To model the production of natural gas from organic material.

Materials
- 1 tablespoon of fresh or tinned fish
- 1 cup of chopped green leaves (for example, lettuce or spinach)
- 1.5 L of pond water or water that has been sitting under pot plants
- sand and soil
- 2 L clear plastic bottle
- 1 large balloon
- gaffer/duct tape
- funnel
- stirring rod

Procedure
1 Use a funnel to pour about 2 cm of sand into the bottom of the plastic bottle.
2 Then alternate layers of fish, green leaves and sand, ending with sand on the top about three-quarters of the way up the bottle.
3 Gently pour the pond water down the stirring rod so as not to disturb the sand 'sandwich'.
4 Pre-stretch a balloon by blowing it up several times, then fit the uninflated balloon over the top of the neck of the bottle and tape it down so there are no gaps.
5 Label the bottle with a safety warning, as the bottle should not be opened under any circumstances during this activity.
6 Put the bottle beside a sunny window so that it will warm up. Watch the changes over several days, up to a week.

Figure 6.18 Experimental set-up

7 Write a prediction: what do you think you will observe in the bottle and what will you observe in the balloon?

Results
Record your observations of the changes in the bottle, and the changes in the balloon.

Discussion
1 Explain what caused the balloon to inflate.
2 Propose how the results of this experiment can be used to suggest alternative uses of garbage dumps. Identify somewhere in the world where this is already happening.
3 Considering the time you let this experiment run, explain why the content of the bottle did not create oil or fossil fuels.
4 Describe how you could improve this activity to better model the production of natural gas from organic material.

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Energy: Nuclear

Nuclear power stations use energy released from some radioactive metals, like uranium, to boil water. This produces steam that drives turbines to produce electricity.

The origin of the energy released in a nuclear power station is the energy from the centre of the particles. There are two types of nuclear energy: fusion and fission. These are summarised in Table 6.2.

Nuclear power is not renewable, but it is potentially unlimited. Its main advantage is that it does not produce greenhouse gases, but its disadvantages are serious. Nuclear power stations are very expensive to build, and there are safety concerns about radioactivity, toxic waste, security and the risk of explosions.

Type	Description	Example
Nuclear fusion energy	Where particles are fused together to form new particles. This fusion causes a large amount of energy to be released.	The Sun
Nuclear fission energy	This type of energy comes from splitting particles, which releases a large amount of energy as a result.	Nuclear power plants heat water and produce high-pressure steam. This high-pressure steam is used to run turbines which generate electricity.

Table 6.2 There are two types of nuclear energy.

Figure 6.19 Australia's only nuclear reactor is located in Lucas Heights in southern Sydney. It is used in research and medical developments, not for producing electricity.

Quick check 6.6

1 Describe the two different types of nuclear energy.
2 State the advantages and disadvantages of nuclear energy.

Explore! 6.2

Going nuclear

Australia has more than one third of the world's known uranium resources. New uranium mines are being constructed in Western Australia and South Australia, but all the uranium is exported to other countries.

1 Research the environmental impact of both the extraction and disposal of nuclear waste.
2 Explain the arguments for and against building a nuclear power station in Australia.

Soil

Soil is made primarily from rocks. Rocks break down and form rock particles, clay, **silt**, sand or gravel. These combine to form soil. Soil production occurs over very long periods of time, sometimes only a centimetre of depth every thousand or so years. Soil also contains air, water, and often material from decaying plants and animals, and living things (such as worms, bacteria and fungi). These components of soil are renewable within a human lifetime, even if the soil as a whole is not.

silt
sand or soil that is carried along by flowing water and then dropped usually at a river's opening or bend

Figure 6.20 Rocks are worn back and broken down by the action of elements like wind and rain (weathering). This forms small particles, which are carried away from the source rock in a process called erosion. Here you can see the evidence of erosion in the Warrumbungles, the remains of a volcano near Coonabarabran NSW.

Quick check 6.7

1 Recall what soil is made of.
2 Explain why soil is considered to be a non-renewable resource.

Section 6.2 questions

QUIZ

Remembering

1 Match up the following words with their definitions in the second column.

Term	Definition
1 Mineral	**A** Made from broken down rocks and from clay, silt, sand or gravel, which combine in different proportions
2 Soil	**B** Solid materials found at Earth's crust
3 Rock	**C** Building blocks that have a specific chemical structure, which is the same throughout the entire substance

2 **Outline** why minerals are non-renewable.
3 **Identify** a non-renewable energy source that is not a fossil fuel.
4 For each resource, **indicate** whether it is renewable or non-renewable.

Resource	Non-renewable	Renewable
Water		
Oil		
Gum trees		
Sheep		
Gas		

Understanding

5 If oil and gas resources run out, **outline** three of our uses for oil and gas that will be affected.

Applying

6 **Outline** two reasons why soil is such a precious resource.
7 **Explain** why coal, oil and gas are fossil fuels.
8 **Describe** why the term 'fossil fuel' is used for coal, oil and natural gas.
9 **Identify** the reasons why it is so important for us to reduce our dependence on fossil fuels.
10 **Describe** two advantages of using nuclear energy as an energy source.

Analysing

11 **Distinguish** between a nuclear power station and a coal-fired power station and the way they work.
12 **Explain** why are nuclear power stations considered as alternatives to coal-fired power stations in attempts to reduce greenhouse gases.
13 Most of the methods of generating electricity involve using turbines. **Discuss** some examples of how turbines are used in different situations to produce electricity.

Evaluating

14 In 2017, Australian researchers developed printable solar technology. They made an electronic ink product from non-toxic materials, and when this ink was printed onto plastic sheets, they had flexible solar panels. **Predict** some of the uses of this new solar panel in the future.
15 **Justify** why there is a shift in farming practices to return to the ways of the Aboriginal and Torres Strait Islander peoples in terms of land management.

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6.3 The water cycle

Learning goals

1 To explain the water cycle in terms of the physical processes involved.
2 To describe the natural factors that affect the water cycle.

Good management of water is essential to the future of life on the planet. The water cycle is a way of showing how this resource moves through the environment. Before you look at it in more detail, remember that water has three states – solid, liquid and gas.

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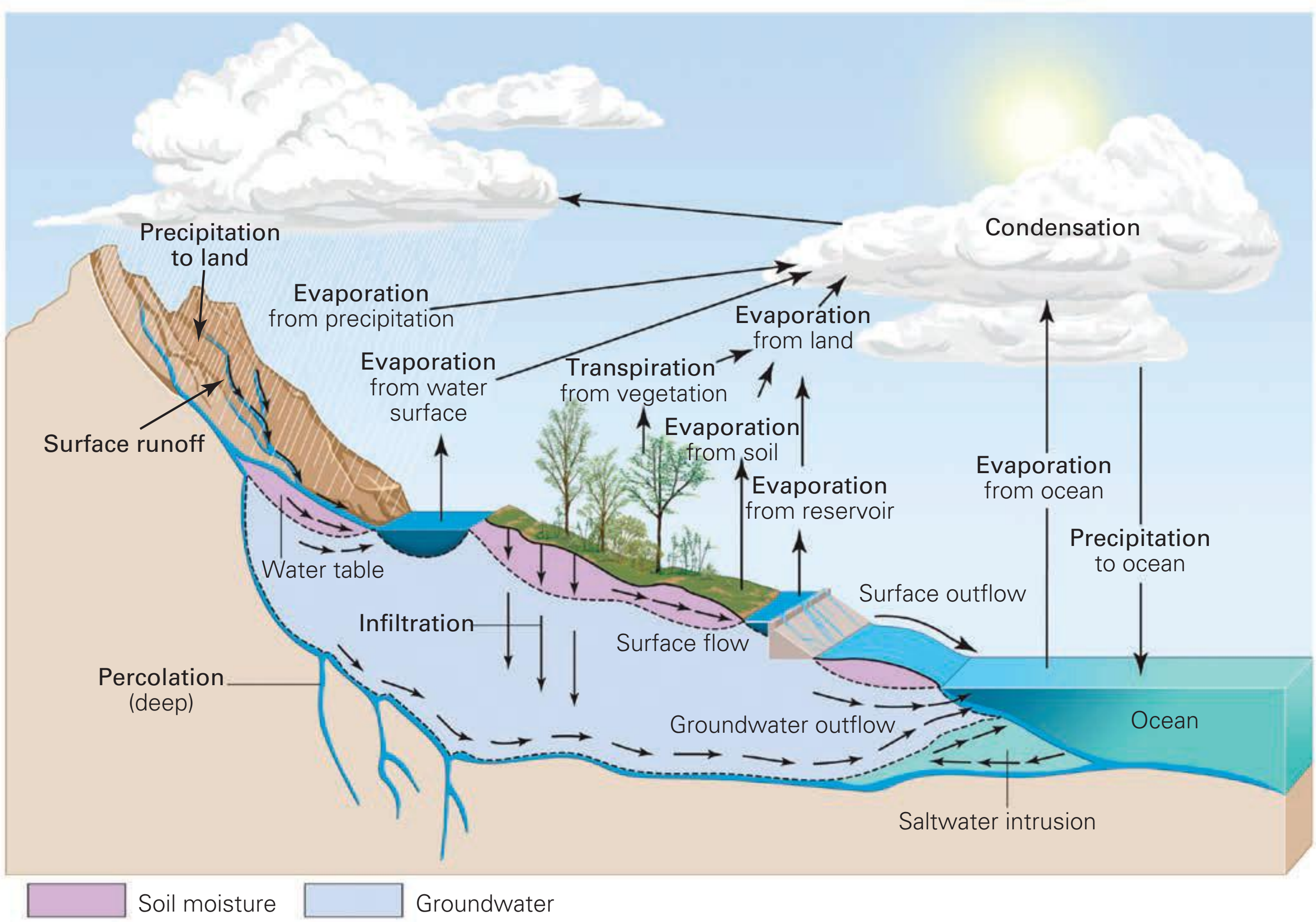

Figure 6.21 A representation of the water cycle demonstrating the processes involved

The water cycle

Uptake from roots

Plants take up soil water through their roots, absorbing water and nutrients to grow. Some trees have specialised root structures that allow them to obtain water from sources deep underground. Such trees can extract huge amounts of water, and in this way, trees can affect the rate at which water moves from the soil to the atmosphere.

transpiration the movement of water upwards through a plant to its leaves, from where the water evaporates

Transpiration

Plants draw water from their roots up through their stems and trunks to their leaves. This water is then released to the atmosphere in the form of water vapour through tiny pores in the leaves called stomata. This process is called **transpiration**. When the temperature is high, these stomata may close to reduce water loss.

WIDGET The water cycle

VIDEO The water cycle

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Practical 6.4

Transpiration

Aim

To investigate the movement of water through a plant.

Materials

- 2 test tubes
- oil
- 2 cuttings from the same plant (each about the same size and with the same number of leaves)
- water
- petroleum jelly (Vaseline or similar)
- test tube rack
- permanent marker

Procedure

1. Set up the test tubes in the rack.
2. Smear petroleum jelly over both sides of all the leaves on one of the cuttings.
3. Place the cutting with petroleum jelly in one test tube.
4. Place the other cutting in the other test tube.
5. Add water to fill two-thirds of each test tube.
6. Add a layer of oil on top of the water in both test tubes to prevent evaporation.
7. Mark the water line with the marker.
8. Place the test tube rack in a sunny spot.
9. Monitor the test tubes (about once a day) until your teacher tells you to stop. Each time you check the test tubes, mark the side of the test tube, write the date, and measure how far the water level has fallen in each test tube.

Results

1. Design a results table for this experiment. Record your results.
2. Graph your results. Put both sets of data on one set of axes.

Discussion

1. Describe any trends, patterns or relationships in your results.
2. Explain why petroleum jelly was smeared on the leaves of one plant.
3. Explain why there were two test tubes in the experiment.
4. Identify any sources of error in this experiment and how they could be minimised in future experiments.

Conclusion

What can you conclude about the action of water in plants, from this activity? Explain the evidence of the action you describe.

Quick check 6.8

1. Name the three states of water.
2. Explain how water taken up into the roots of plants is linked to transpiration.
3. Describe what changes in state occur during transpiration.

Evaporation

Evaporation is when water changes from a liquid to a gas (i.e. into water vapour).

evaporation
when heat causes liquid to become gas

Heat from the Sun provides enough energy to evaporate liquid water from the sea, lakes and wet land surfaces and turn it into water vapour. Remember, hot air rises and so the water vapour gets carried upward.

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Did you know? 6.1

Rain shadows

The Great Dividing Range (GDR) is located along the coastline of Queensland and New South Wales. It affects the overall climate on the East Coast because air cools as it travels over the ranges, creating rain. In the GDR, winds blowing across the ranges from the ocean fall as rain on the eastern side of the divide, meaning the western side is far drier. This is known as the rain shadow effect.

Figure 6.22 The Great Dividing Range

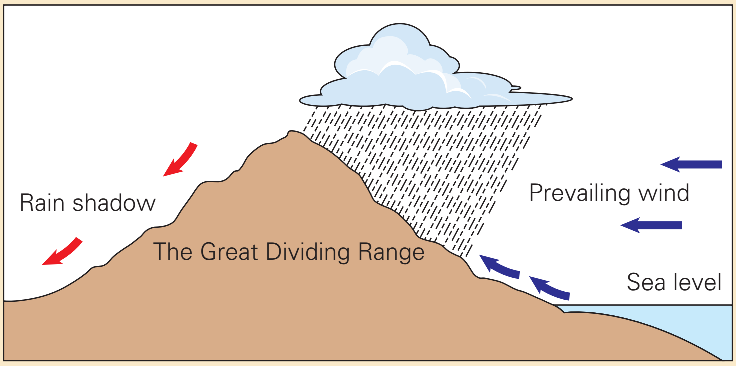

Figure 6.23 A rain shadow and its effects

Condensation

Water vapour rises up into the atmosphere: as it gets higher, the temperature becomes lower. When the temperature drops below a certain point, which we call the dew-point temperature, **condensation** causes clouds to form. This changes the state of water vapour to liquid water droplets. A cloud always has parts that are evaporating and condensing at the same time, causing certain areas to shrink or grow.

Quick check 6.9

1. Link the processes 'evaporation' and 'condensation' to the formation of clouds. State whether they are heating or cooling processes.
2. Name the state change that occurs in order for water to form clouds.
3. State if the water in clouds is fresh water or salt water. Explain why that is the case.

Precipitation

Precipitation is condensed water vapour, i.e. droplets of liquid water or crystals of solid water, that falls as rain, snow or hail because it has become too heavy and overcomes gravity. Because there is still water vapour rising due to evaporation, not all of the condensed water in the clouds falls. When there is not enough precipitation for a long period of time, it may cause a **drought**, especially if there are ususually high temperatures.

Infiltration and percolation

Infiltration is the movement of water into the soil after precipitation has occurred.

Percolation is the movement of water within the soil. This is affected by the characteristics of the soil like grain size, geological features, gravity and how fast infiltration is happening in the surrounding soil.

Remember, for something to be a cycle, it must complete a loop, so the water that was evaporated from the sea, condensed as rain and fell on the land must percolate through the land to rejoin the sea. Moving water and the sediment it carries changes the surface of our planet. Erosion also contributes by changing the shape of mountains and taking sediments into the sea.

condensation
where heat is lost causing a gas to become a liquid

precipitation
water that falls from the clouds towards the ground as rain or snow

drought
a prolonged period of unusually low rainfall that leads to a shortage of water

infiltration
to move slowly into a substance

percolation
the process of a liquid moving slowly through a substance that has very small holes in it

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impermeable
not allowing liquid or gas to go through

runoff
water that flows away from high areas to low areas

permeable
allows liquids or gases to go through it

pervious
a substance that allows water to pass through via cracks or defects in the rock

But what happens if the precipitation lands on rock, not soil, so infiltration and percolation cannot occur? If rain falls on an **impermeable** surface (a surface that water cannot move through, such as granite, clay or concrete) the water may evaporate directly back into the atmosphere, run into rivers or may be directed to a dam or reservoir. This is called surface **runoff.**

Figure 6.24 Uluru in the rain. Uluru is composed of arkose rock, which is a coarse-grained sandstone, rich in the mineral feldspar (an abundant rock-forming mineral).

To replenish our underground reservoirs, water must be able to seep through soils and rocks that are **permeable**. Sand is an example of a permeable surface as it will allow water through, while clay will not allow water through and so is called impermeable. Soils and rocks with high permeability allow water to penetrate not only through to plant roots, but all the way down to join the underground layer of water-bearing permeable rock (called **pervious** rock).

Quick check 6.10

1. Define these terms: precipitation, infiltration, percolation, runoff.
2. Identify the stage of the water cycle that follows the process of condensation in the atmosphere.
3. State the term that is used to describe the movement of water into Earth's surface.
4. Explain how the permeability of rocks plays a role in the water cycle.

Natural factors affecting the water cycle

In this section, you have worked through the natural processes involved in the water cycle. You may have noticed that you have also been learning about how factors in the environment affect these processes. Table 6.3 summarises the factors affecting the water cycle.

Factor in the environment	What process is affected?	Description of how it affects the water cycle
Temperature	Evaporation Transpiration	The higher the temperature (e.g. from hot sun), the more evaporation occurs from oceans, rivers and the soil. The higher the temperature, the faster transpiration occurs. Plants can manage this water loss by closing the stomata (tiny openings) in their leaves so the water escapes more slowly.
Humidity	Evaporation Transpiration	When the air is humid (contains lots of water vapour), evaporation and transpiration slow down. It is as though the air is already too full of water, so it cannot take on any more.
Wind	Evaporation Transpiration	When there is wind or moving air, evaporation increases as the air carries away the water vapour, allowing for more of these processes to occur.
Landscape features	Runoff Percolation	When the precipitation lands on a permeable surface, there is a high amount of percolation and very little runoff.
Vegetation	Transpiration	Plants in rainforests have access to lots of water, so can carry out transpiration as much as they like, while desert plants must minimise their water loss from their leaves, and so have a low rate of transpiration.

Table 6.3 Summary of the natural factors that affect the water cycle

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Practical 6.5

Modelling the water cycle

Aim

To model the water cycle.

Materials

- 250 mL beaker
- large watch glass
- water
- ice cubes
- Bunsen burner
- heatproof mat
- tripod
- gauze mat
- matches
- safety glasses

Be careful

Be careful when using a Bunsen burner. Be careful of hot equipment and hot water.

Wear your safety glasses.

Procedure

1 Half fill the beaker with water.
2 Use the Bunsen burner to heat the water to boiling.

3 Stop heating and carefully cover the beaker with the watch glass. It needs to act as a lid on the beaker. Observe what happens to the bottom of the watch glass. Record your observations.
4 Remove the watch glass and heat the water again until it boils.
5 Stop heating and turn the burner and gas supply off.
6 Quickly cover the beaker with the watch glass and place ice cubes on its top.
7 Observe what happens to the space between the water and the watch glass.

Risk assessment

Safety is important when carrying out experiments. Look at the illustration and consider what you already know about safety in the laboratory to list the safety precautions you need to follow when using a Bunsen burner.

Results

Record your observations at each stage.

Discussion

1 In detail, describe what happened to the bottom of the watch glass the first time you covered the boiling water with it. What was the change of state?
2 In detail, describe what happened to the space between the water and the watch glass the second time the beaker was covered, but with ice cubes on its top. What change of state has taken place this time?
3 Explain how clouds are formed in nature. Describe in detail how the experiment represents the formation of clouds.
4 Explain which components of the water cycle are represented in this model. Explain each component and which part of the experiment represents them.
5 Describe how the model could be improved to better model the water cycle.

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Section 6.3 questions

QUIZ

Remembering

1 **State** the everyday terms for the states of water.
2 **Identify** the changes of state involved when water changes from gas to liquid to solid.
3 **Outline** how rain forms.

Understanding

4 **Identify** whether the following statements are true or false and then **justify** your answer.
   a The water cycle has no start and no end.
   b Clouds are made of water in gas form.
   c When clouds become full of water droplets, they fall as rain, snow or hail.

Applying

5 Study Figure 6.25 and work out what process each number represents. **Identify** and **describe** each of the processes.
6 Evaporation and transpiration appear similar. **Distinguish** between these two processes.

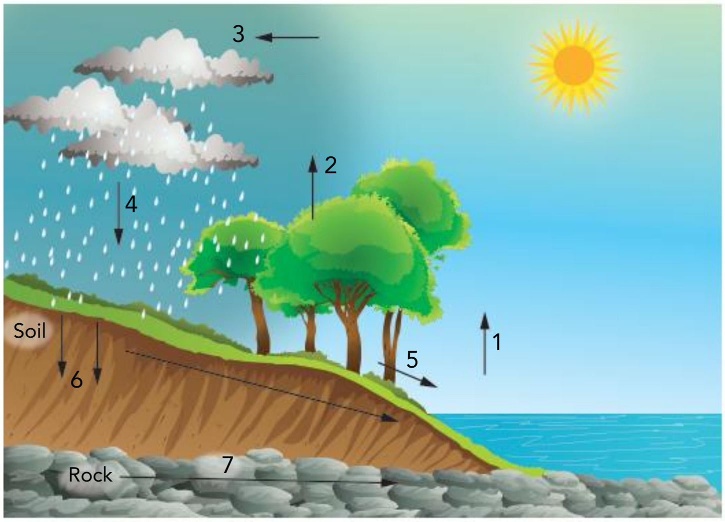

Figure 6.25 The water cycle

Analysing

7 **Summarise** the changes (if any) in state that water goes through in each process below. You may do so in a table format as shown.

Process	State of water – start	State of water – end	Where this process happens
Evaporation			
Transpiration			
Condensation			
Precipitation			
Runoff			
Infiltration			
Percolation			

8 Gardeners with pot plants or gardens that are sandy are likely to have experienced water-repellent soils if the soil has been dry for long periods of time. Thankfully, wetting agents can be used. **Identify** which process in the water cycle the soil wetting agents help with.
9 Sometimes clouds are full of water vapour and yet never produce precipitation. **Explain** why this may be the case.
10 **Summarise**, with explanations, the natural factors in the environment that can affect the process of transpiration.

Evaluating

11 'If we are not careful, one day Earth will run out of water.' Decide if this statement is true or false. Using the terms you have learned in this section, give reasons to **justify** your opinion.
12 What would happen to Earth if the process of precipitation was not part of the water cycle? **Justify** your answer.

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6.4 Human management of water

Learning goals

1. To compare the urban waster cycle with the natural water cycle.
2. To identify ways waste water can be processed.

The natural water cycle is free of any objects made by humans, and is mostly composed of permeable surfaces like soil. Remember, these permeable surfaces encourage the water to move through by infiltration, resulting in higher levels of groundwater. However, humans have changed the landscape and developed ways to store water, move water and treat water.

The urban water cycle

The way we humans have urbanised our world has affected the natural water cycle, consequently it often gets referred to as the **urban water cycle**. As our population grows, the management of this urban water cycle becomes increasingly important.

Water catchments to tap

Most of Sydney's domestic water comes from the Blue Mountains west of Sydney. This area is called a catchment as it is like a giant bucket, waiting to catch rain. The water then flows down the mountains along creeks and into rivers and oceans. When it rains, the runoff eventually flows into the reservoirs and water mains that make up our water supply system (that is, the clean water that we can use in our homes). Is this a natural process?

WORKSHEET

urban water cycle a water cycle that includes the consequences of increased development

No, humans have interfered with the water cycle so that we can store water for when we need it, tap into bores for use on agricultural land, and use pumps and pipes to transport the water to our homes and gardens.

Figure 6.26 Warragamba Dam provides Sydney with 75% of its domestic water.

Figure 6.27 Lake Burragorang is created by the Warragamba dam wall.

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Practical 6.6

Gravity and water pumps

Aim

To investigate the effect of gravity on water and to build a working pump.

Materials

- measuring cylinder
- 2 plastic cups
- 2 basins for holding water
- soap dispenser pump
- plastic tub that both cups can sit in
- a straw
- sticky tape
- 1.5 m of clear vinyl tubing (1/4 inch inner diameter)
- 0.5 m of PVC pipe

Procedure

Part A

1 Place the two cups in the plastic tub. Fill one cup with 100 mL tap water.
2 Now try to pour water from one cup into the other through the straw. Record your observations and measure how much water is lost into the plastic tub.
3 How could you transfer the water through the straw more efficiently? Try some ideas and again record your observations and how much water is lost to the plastic tub.
4 Next, you will try the soap dispenser pump. First, write down how you think the results will change if we use a pump like the soap dispenser pump.
5 Repeat the experiment and this time use the pump to transfer water from one cup to the other. Record your results.

Part B

6 Archimedes was a Greek inventor who lived in the 3rd century BCE. His water pump invention is still used today! Find out about the Archimedes water pump called a screw. You can see a sketch of this pump in Figure 6.28.
7 Collect your materials and carefully wrap the tubing around the pipe leaving a couple of centimetres hanging from each end of the pipe.
8 Place one basin on top of a short stool. Leave the other on your bench and fill with water.
9 Place the wrapped pipe into the lower basin and lean the pipe so that the tube at the top will empty into the top basin.
10 Gently turn the pipe, watching the water move up the tubing and exit into the empty basin on the bench. This is like moving water up a hill.
11 Play around with how tightly the tube is wrapped around the pipe and the incline, to see if you can determine the fastest way of moving water up the hill.

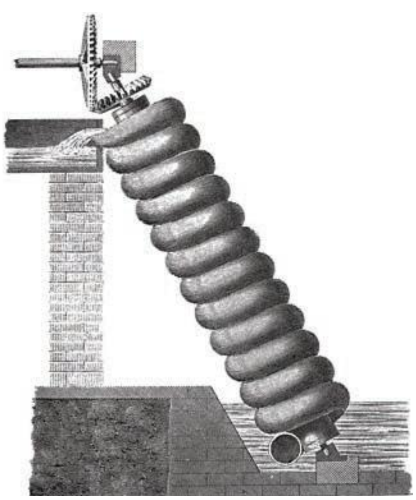

Figure 6.28 19th century engraving of Archimedes' pump, called a screw, used to raise water

Results

1 Record your observations from the different steps of the experiment including how much water is lost to the plastic tub that the cups are sitting in each time you try something new.
2 Record your findings on the fastest way to move water up an incline.

continued…

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...continued

Discussion

1. Summarise your findings from Part **A** by comparing the results of the different techniques you tried.
2. Summarise your findings from Part **B** by describing the conditions that were needed for the most efficient transport of water up the incline.
3. Recall where we use pumps in our everyday lives.
4. Water is pumped to the top of water towers by many kinds of pumps. Water tanks are elevated because height affects the pressure. Predict whether it would take more pressure to pump water to a house that is at the top of a hill or to one at the bottom of the same hill. Fully explain your answer.

Sewage – toilets to treatment plants

The water that leaves our homes is typically classified as wastewater and enters into a sewer system. Sewer systems travel under the urban environment, transporting our wastewater to wastewater treatment plants. These treatment plants remove toxic substances, so the sewage can be safely pumped out to sea and back into the natural water cycle, or recycled and used for irrigation on farms, parks and golf courses.

Stormwater – drains to our bays

Sadly, the natural water cycle cannot function normally in urban areas because buildings, concrete and other sealed surfaces prevent water from soaking into the ground. As a result, natural water flows are altered and stormwater is created. When stormwater collects on impermeable surfaces, it is called stormwater runoff and is guided along parking lots, curbs and streets to gutters and then into the stormwater system. This is different from the sewer system. Eventually, the stormwater collects in nearby rivers and creeks, then travels out into our rivers, where it re-enters the natural water cycle.

It is important to keep in mind there are problems with stormwater, which are summarised in Table 6.4.

Problem	Consequence
Picks up rubbish/toxic substances	• Pollutants are carried directly into our waterways, bays and oceans
High volumes	• More pollution • Stream banks will erode more quickly • Habitat of aquatic animals may be damaged • Breeding cycles of those aquatic animals may be disrupted
Low soil moisture	• Trees develop shallow root systems • Trees become unstable

Table 6.4 Summary of the issues with stormwater

Figure 6.29 Stormwater drains and pipes return water to rivers and the oceans but not always in the condition it should be in.

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Explore! 6.3

The Great Artesian Basin

The Great Artesian Basin is the largest and deepest underground basin in the world. Underlying more than 22% of the country, it stretches for 1 700 000 km^2 over four states. Artesian water is pressurised water that is trapped underground. This water can be tapped by a bore, allowing it to flow naturally to the surface. The basin provides fresh water for much of inland Australia. It is so important that the federal government has set up a special authority to manage it.

1 Use your preferred search engine to research and read about the Great Artesian Basin Coordinating Committee (GABCC). Why was it important for such a committee to be set up?
2 What is the cause of the long-term decline in water pressure across the basin? How is this being managed?

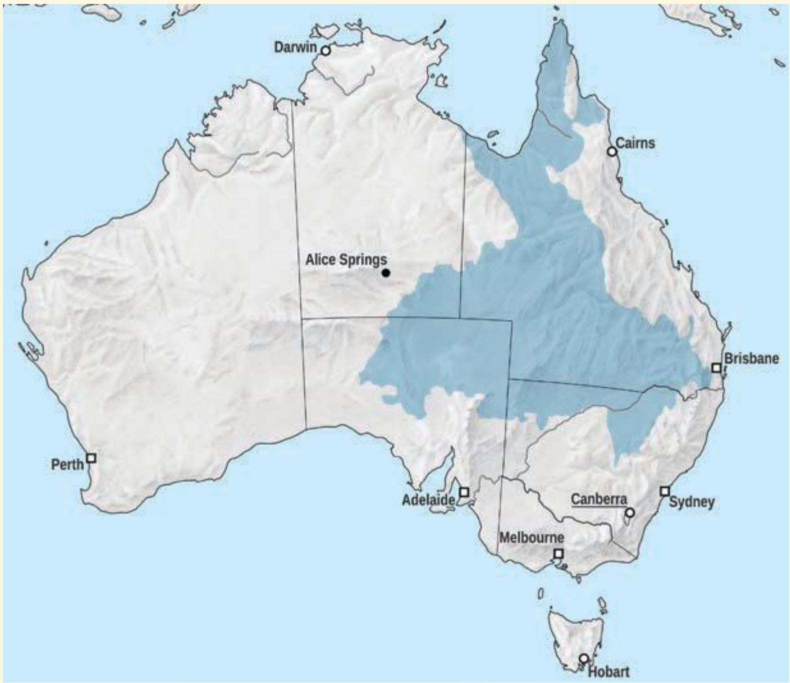

Figure 6.30 The Great Artesian Basin lies under the arid and semi-arid land of Queensland, New South Wales, South Australia and the Northern Territory.

greywater
water that has been used before; for example, from washing, which can be stored and used again for other uses such as toilets

blackwater
waste water from toilets

Recycling water

Two types of wastewater are created in your home: **greywater** and **blackwater**.

Greywater

Greywater is wastewater from non-toilet plumbing in your house, such as showers, basins and taps. The exact contents of greywater depends on the household producing it. So, if you keep your chemical use to a minimum by using environmentally friendly, biodegradable soaps and detergents whenever possible, you could recycle the water by using it to water your plants. Greywater can also be treated and then reused indoors for things like toilet flushing and clothes washing, both significant water consumers.

Figure 6.31 The use of greywater has become popular.

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Try this 6.1

Create a table that compares what happens in the case of the natural water cycle and what happens in our urban water cycle for the following processes. You may need to do some research online.

evaporation	precipitation	infiltration	condensation
transpiration	runoff	percolation	

How do we recycle greywater?

If you want to recycle your greywater at home, you will need to use some sort of treatment process. This may be biological, chemical, mechanical or a combination of these. Some of the key steps are outlined below and may be quite familiar if you have completed Chapter 13 Mixtures:

- Coarse filtration: removes large particles, including hair, and prevents clogging
- Fine filtration and biological treatment: microbes in a sand filter breakdown plant/animal matter in the water
- Disinfection: UV or ozone disinfection.

Blackwater

Blackwater is water that has been mixed with waste from the toilet. In addition, water from kitchens and dishwashers is excluded from greywater (and called blackwater) because of the potential for contamination by germs and grease. This waste does not break down and decompose in water fast enough for use in domestic watering systems. It requires biological or chemical treatment and disinfection before re-use.

Quick check 6.11

1. Explain the difference between greywater and blackwater.
2. If you want to recycle your greywater, list the places where it comes from and what you could do to improve its quality before recycling.
3. Summarise the advantages and disadvantages of reusing your household greywater.

Water treatment

In the state of Victoria, Werribee has one of Melbourne's two water treatment plants. It is a historic plant that treats half of Melbourne's sewage, and also is an internationally recognised bird habitat! Can you believe it produces 40 billion litres of recycled water a year and is totally energy self-sufficient? It uses sewage gas to create all the electricity it needs!

Figure 6.32 The lagoons of the Western Treatment Plant in Werribee

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Explore! 6.4

Aboriginal and Torres Strait Islander resource management

Australian Aboriginal and Torres Strait Islander peoples have traditionally taken care of the land and its resources, living as one with the environment. This close relationship with the land has allowed Aboriginal and Torres Strait Islander peoples to develop sustainable practices in using natural resources carefully to ensure their continual existence.

This knowledge and culture associated with Aboriginal and Torres Strait Islander resource management plays an important role in how we as a nation move forward in managing all of our natural resources.

Using your preferred search engine, research how Aboriginal and Torres Strait Islander peoples care for and use the natural resources in the communities. Include details about water resource and land management.

Figure 6.33 Caring for land may include conducting site assessments and long-term studies of specific areas.

Section 6.4 questions

QUIZ

Remembering

1 **Outline** what recycling greywater might involve.
2 **Define** the terms ‘urban water cycle’ and ‘stormwater’.

Understanding

3 **Explain** why water tanks that supply water are built high up in towers or on the top of hills.
4 **Outline** how blackwater is different to greywater.
5 **Outline** the advantages of recycling greywater at home.

Applying

6 **Identify** some ways water in nature can be kept unpolluted.
7 **Identify** one method you could use at home to recycle water, and **explain** why it is important that water is recycled in nature.
8 You want to recycle your greywater and use it to water your vegetable garden. **Summarise** what should you do to ensure your greywater is safe to use on plants.

Analysing

9 **Select** the processes in the water cycle that are affected when land is cleared of vegetation to create urban areas (cities and housing).
10 **Compare** pervious rock and impermeable surfaces.
11 **Draw** a simple sketch of the urban water cycle.
12 **Compare** natural water flow to stormwater flow in terms of impact on the environment.

Evaluating

13 **Propose** reasons, based on what you have learned in the last two sections of this chapter, why water should be considered an important renewable resource and how we are threatening its quality as a resource.
14 **Justify** your decision to drink or not drink recycled water.
15 Do you think humans have altered the water cycle? **Justify** your reasons.
16 **Deduce** the relationship between the temperature of the atmosphere increasing due to global warming, and rain.

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Chapter review

Chapter checklist

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

SCORCHER

Success criteria		Check
6.1, 6.2	**I can state the definitions of 'renewable' and 'non-renewable'.** e.g. Define 'renewable'.	
6.1, 6.2	**I recognise that different resources have different regeneration timescales.** e.g. Discuss why some biomass sources may not be considered to be renewable.	
6.3	**I can describe the water cycle, including the changes in the states of water and the factors that affect each part of the cycle.** e.g. Illustrate your own labelled diagram of the water cycle.	
6.4	**I can describe how human management of water can impact the water cycle.** e.g. State some advantages of having a greywater recycling system in every household.	

Reflections

1 What **connections** come to mind when you think about Earth's resources and management and your everyday life?
2 What new concepts have **extended** your thinking about Earth's resources and management?
3 What information did you find **challenging** or confusing?

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Data questions

Renewable energy generated 24% of Australia's electricity in 2019. This is an increase of 2.7% over the previous year. In NSW, only 17% of our electricity was from renewable sources.

Wind, at 35%, became Australia's dominant source of clean energy in 2019, replacing hydro as the greatest source. The large growth and investment in wind and solar energy, as well as drought conditions across much of Australia, have led to the lower generation of electricity from hydro sources.

1 **Identify** which of the renewable energy sources contributed the most to electricity production in 2014 and in 2019.
2 **Determine** which energy source decreased between 2014 and 2019.
3 **Determine** which renewable energy source grew the most between 2014 and 2019.
4 **Calculate** the total percentage of solar energy generated in 2019 (including small-, medium- and large-scale).
5 **Contrast** the growth of hydro-energy to wind-energy over the five-year period.
6 **Identify** the trend in the total renewable energy generated over the five years.
7 Using the two sets of data, **predict** the year that Australia could reach 50% renewable energy use.
8 Using the trend in the data, **predict** the renewable energy source will be the most common in the year 2030. **Justify** your answer.
9 In 2019, NSW generated about 17% of its electricity needs from renewable energy sources. Which of these sources do you think will generate the most energy for NSW into the future? **Justify** your answer (think about the geography, population centres and size of NSW).

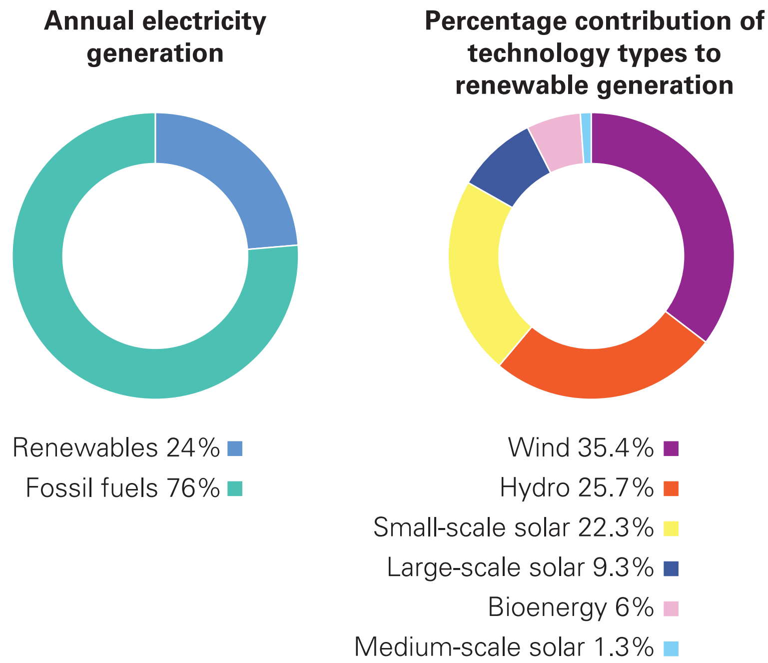

Figure 6.34 Sources of Energy Production 2019 in Australia

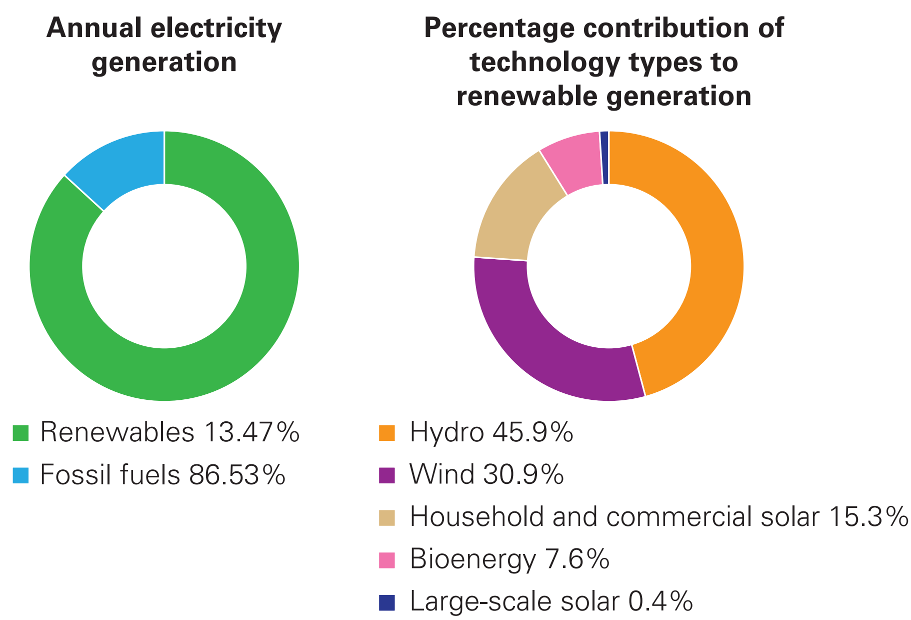

Figure 6.35 Sources of Energy Production 2014 in Australia

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STEM activity: Diseases in water

Background information

Waterborne diseases (diseases that spread through water) are caused by a variety of microorganisms that can lead to devastating illnesses. Outbreaks of waterborne diseases often occur after severe weather events like droughts, floods and tsunamis. The drinking of polluted water, poor sanitation and overcrowding in temporary settlements are all contributing factors to the spread of the disease.

The purification of water is not a straightforward and easy process, with so many different possible pollutants and diseases. Therefore, full water treatment generally includes multiple steps to cover as many situations as possible. These steps include sedimentation (a process in which small pieces of a solid material fall to the bottom of a liquid and form a layer), filtration and disinfection.

Design brief: Build a water filtration device using commonly available materials.

Activity instructions

In this activity, you will design and build a water filtration device using commonly available materials. To meet this challenge, you will take on the role as an engineer from the 'Super Dooper Clean Water Company' and work through the engineering design model, which includes designing, building, testing and evaluating the performance of the filtration device. You will then use this information to work towards an improved water filtration design.

Research and feasibility

1 Research and identify different common materials that can be used to filter polluted water.

2 List the constraints you will need to consider before you design and build your prototype for the polluted water you will need to filter (size of the particles in the polluted water, sterilisation of microorganisms, testing the cleanliness of the water etc.).

Figure 6.36 Bacteria can reproduce very quickly and so require immediate removal from water sources to prevent their spread.

Design

3 Design your prototype filtration system, including labels for all key components.

Create

4 Construct your prototype filtration system.

5 Use your filtration system to filter the polluted water.

6 Measure the volume of polluted water poured into your filtration system and the volume of cleaned water produced. What was the change?

Evaluate and modify

7 Explain the possible causes of any differences between the volume of water before and after filtration.

8 Evaluate the effectiveness of your prototype filtration system. Did the different materials remove what you thought they would? Explain why or why not.

9 Consider the quality of your water. Do you think the filtered water is clean enough to drink? Or clean enough to put into a river? Explain why or why not.

10 Reflect upon your design. What improvements would you make to your prototype filtration system? List some ideas for ways you might get the 'polluted' water even cleaner. Are there other materials you would like to use that could improve your design?

11 What design constraints or limitations might be different for engineers developing real water filtration systems?

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Chapter 7
Classification

Inquiry questions

Why do we group things together?
How do scientists share knowledge?
What classifies as a living thing?

PRE-TEST

Chapter introduction

Whether you are answering questions about what food you would like to eat, what music you like to listen to or what movies you like to watch, you are unknowingly grouping many things together based on similarities. This process is called classification. In this chapter, you will explore the way scientists use classification systems to share their knowledge and group all of the living organisms on Earth.

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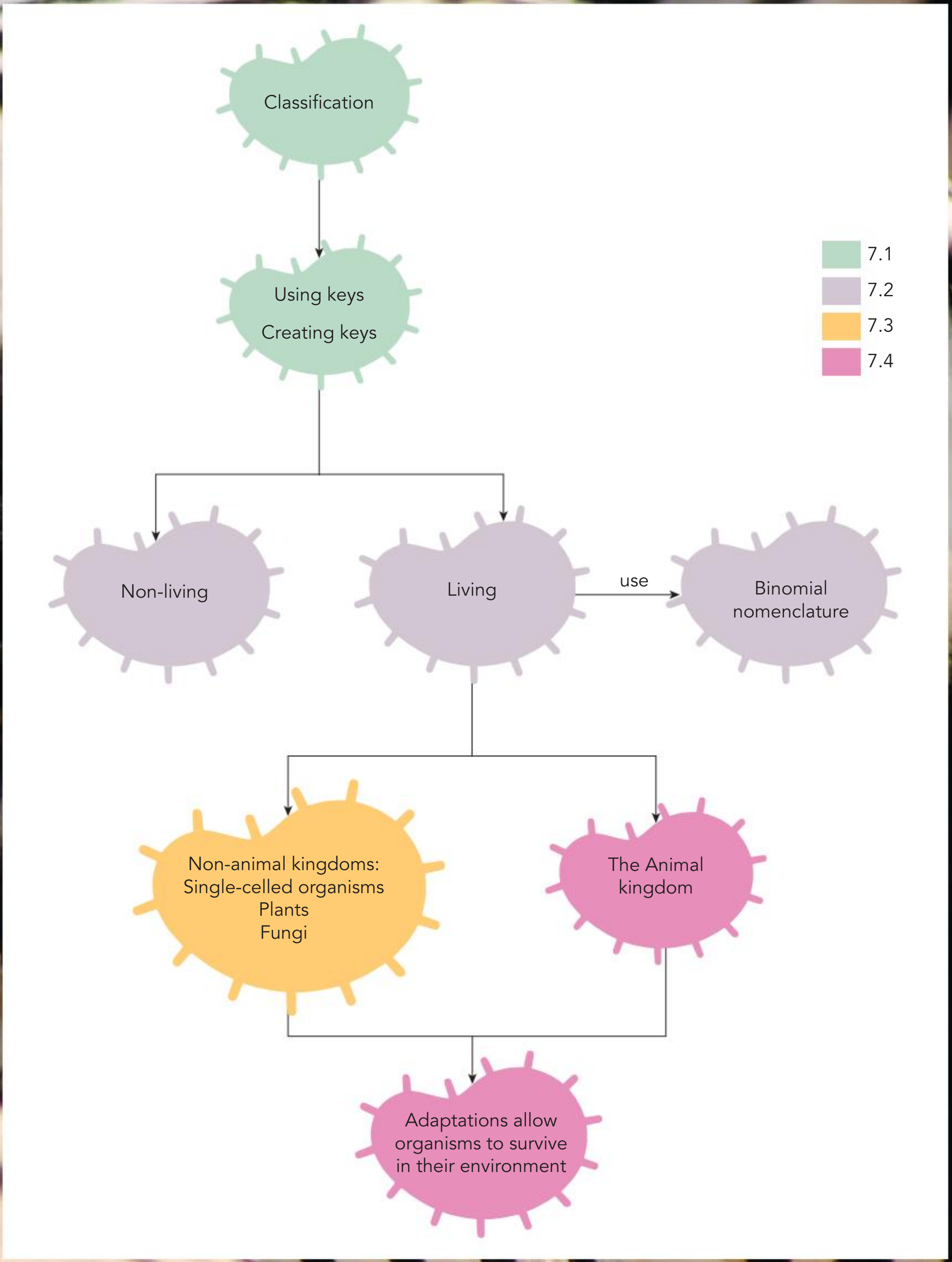
Chapter map



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7.1 Classification and keys

Learning goals
1 To understand how classification is useful to identify living organisms.
2 To be able to interpret and construct a dichotomous key.
3 To explore the totemic classification used by Aboriginal and Torres Strait Islander peoples.

DOC WORKSHEET

You do it all the time!

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

classification
the grouping of similar objects or organisms together

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

characteristic
a feature or quality of something

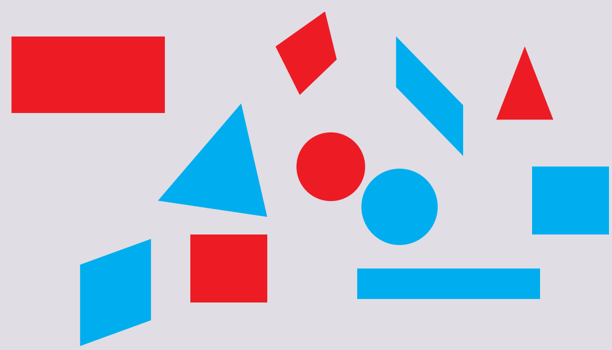
When you are looking for a show on a streaming platform, you automatically scroll through different **genres** such as comedy, drama, family or sci-fi to find what you want. Just imagine if all the shows that are available to you were just placed online in no particular order. It would be next to impossible to find what you were looking for. This is why classification is necessary.

People are also classified in many different ways. How many times have you been asked your year level, school name or date of birth? These are all ways that people can gather information about you and place you into a group.

Figure 7.1 Supermarkets are a place where classification is really important; otherwise, how would you be able to run in and out in five minutes to get your microwave popcorn for movie night?

Try this 7.1

Classification
Take a look at the image below.



1 Decide how many groups are in the picture.
2 Justify your answer.
3 Compare your answer with other people in your class.
4 Discuss why different people may have different answers.

Communication is key

In science, it is important to be able to share and develop ideas with people all over the world. To do this, scientists across different fields need to create a universal language that everyone understands and agrees on. If universal classification systems were not put into place, biologists, for example, would not know if an organism they had discovered was new and one chemist wouldn't know if another chemist was talking about the same substance as them.

To be able to classify, you must first make detailed observations about the **characteristics** of the things being classified, then you can group the things with the most similarities together.

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Try this 7.2

Let's practise observing the different characteristics or features of living things. Describe the features you see in each animal. Compare your observations with your classmates. Did you observe the same features?




Quick check 7.1

1 Define the term 'classification' in your own words.
2 Name three examples of classification systems that you named in *Try this 7.2* and explain how they demonstrate classification.
3 Explain why it is important that scientists all use the same language of classification.

Unlocking classification

Before you explore some different types of classification systems, it is important that you understand how to use **keys**. You usually think of a key as something that unlocks a door, but in science, the term is also used when you are 'unlocking' or sorting out a group of items into an order that makes sense. Keys allow you to follow a series of steps and identify objects that have already been classified. In Figure 7.3 on page 242, there are six different species of frog or toad that are found in Australia. You can use the key to determine their names.

key
a tool used to identify organisms

Explore! 7.1

Aboriginal and Torres Strait Islander peoples have developed complex and unique classification systems that are completely different from those used in western science. These systems involve linking plants, animals and geographical features to families or groups. One of the simplest forms of Indigenous classification relates to the use of plants and animals. Instead of classifying them by how they look, they may instead be classified as edible or inedible.

Aboriginal peoples also have a totem classification system. Totems can refer to any plant, animal or geological features like hills or rivers. This system groups moieties (groups of people or families) with specific totems. Individuals are also allocated a totem from an Elder in the family. This individual totem represents their identity and is very special to the person.

The moieties are experts in their totems, and it is their responsibility to protect and maintain their totems and their environment. This usually means that they cannot eat or hunt their totem. Moieties perform ceremonies associated with their totems which are extremely important to each group. Knowledge about the totems is passed from the Elders to the children through stories and art.

Research the significance of totems to Aboriginal and Torres Strait Islander peoples.

Figure 7.2 Aboriginal art showing an emu, the totem of the Karingbal people

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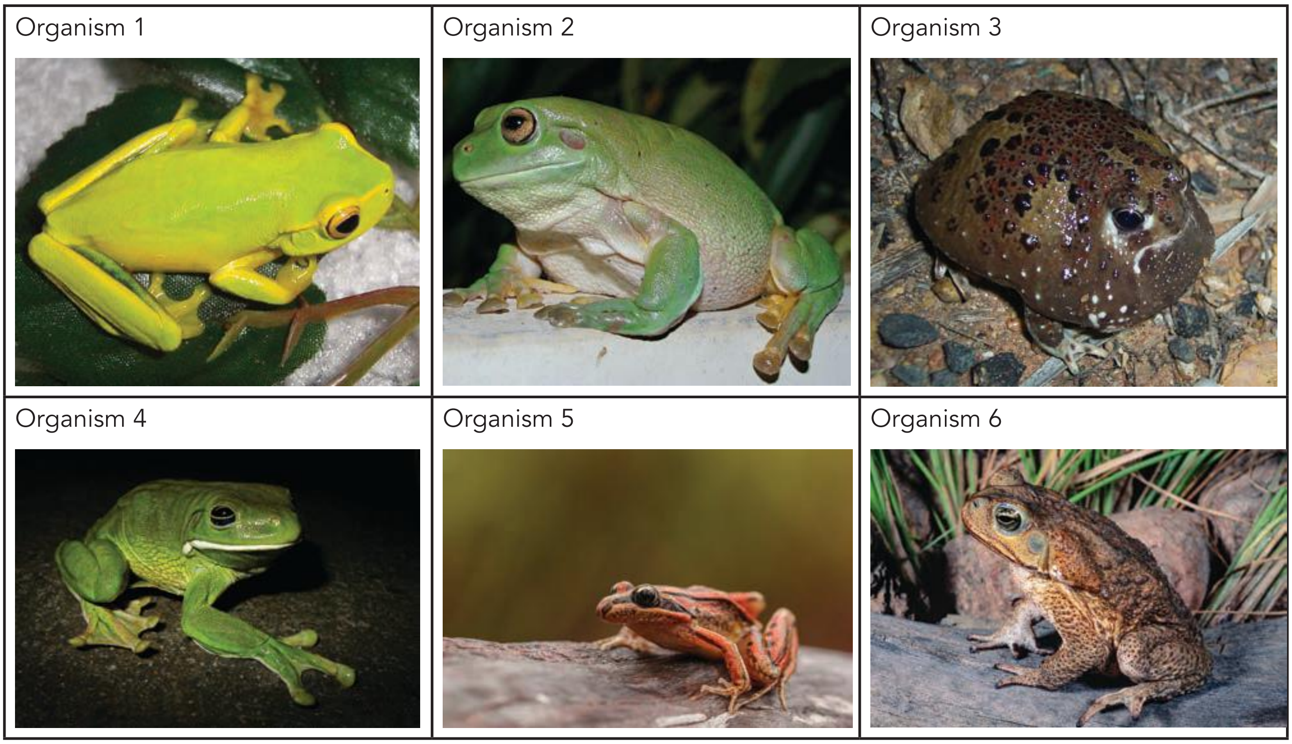

Figure 7.3 Some frog and toad species. Use the key in the Figure 7.4 to identify them.

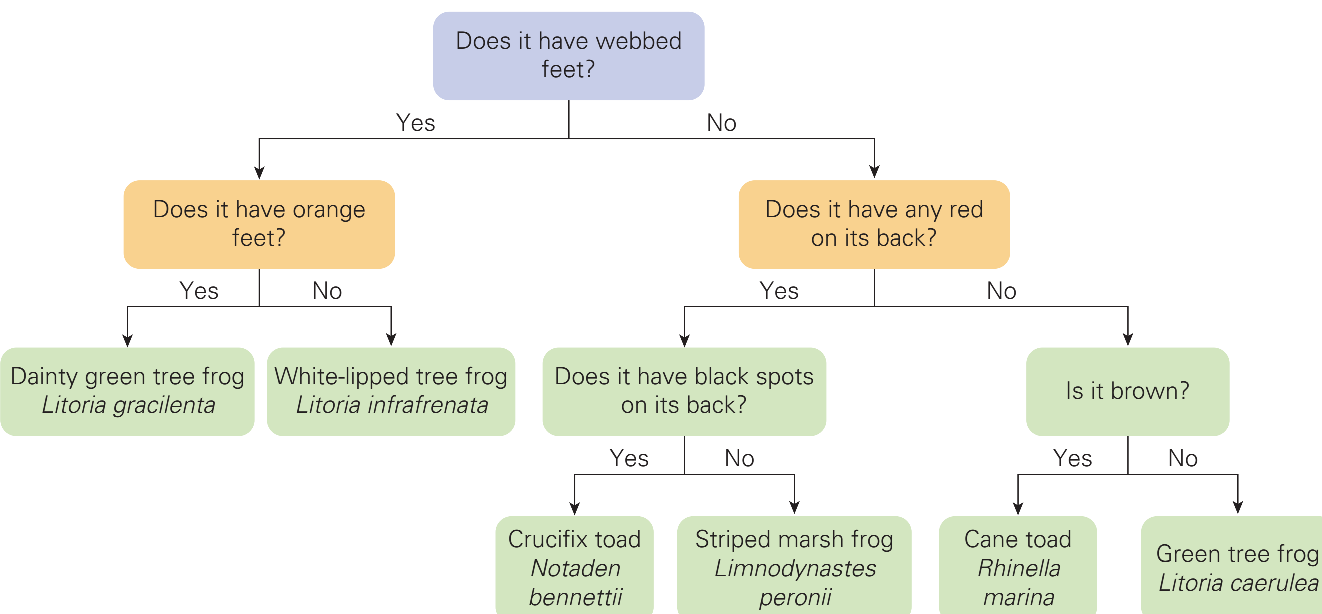

Figure 7.4 A branching dichotomous key for classifying the frog and toad species in Figure 7.3

Using keys

Imagine you are a scientist wanting to focus your research on the green tree frog. You have been sent a photo of organism 2 as shown in Figure 7.3 but are not sure if it is the green tree frog. To determine if you have the correct organism, you must use the key in Figure 7.4.

dichotomous key
a tool for scientists to identify an organism from a series of choices between two characteristics

Can you work out whether the name of organism 2 is the green tree frog? Start at the top and at each step in the process, make a yes/no decision.

The key that you just used is known as a **dichotomous key**. A dichotomous key is an organised set of couplets of mutually exclusive characteristics of biological organisms (in other words, an organism will always be

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one or the other, but not both items in each level of the key). The word *dichotomous* literally means 'to cut in two'. At each stage, it gives you just two options based on the organisms you are looking at, allowing you to narrow down the possible choices. If the organism falls into one category, you go to the next indicated couplet. There is no right or wrong way to start a key, as long as it has two options and is specific. A key can also be drawn as a table. Test whether you get the same answer using this key in Table 7.1 as you do when using the branching key in Figure 7.4.

1a	Webbed feet	Go to Question 2
1b	No webbed feet	Go to Question 3
2a	Orange feet	Dainty green tree frog
2b	No orange feet	White-lipped tree frog
3a	Red on back	Go to Question 4
3b	No red on back	Go to Question 5
4a	Black spots on back	Crucifix toad
4b	No black spots on back	Striped marsh frog
5a	Brown colouring	Cane toad
5b	No brown colouring	Green tree frog

Table 7.1 A dichotomous key in table format to identify the amphibians (also known as a 'go to' key)

Quick check 7.2

1. Explain the purpose of a key.
2. Define the term 'dichotomous key' and describe how it works in your own words.
3. Use the dichotomous key of amphibians in Table 7.1 and Figure 7.4.
   a. List the characteristics of the cane toad.
   b. Identify amphibians 1 to 6 in Figure 7.3.

WIDGET
Classifying Australian animals

Try this 7.3

Making a branching dichotomous key

As a class, discuss some ways that a deck of cards can be grouped by listing the different characteristics. Create groups of similar cards based on these characteristics. Are there different ways you could classify or group the cards? Challenge a classmate to find a certain card using one of the grouping methods you come up with. Perhaps they could race your teacher who is trying to find the same card but in a shuffled and ungrouped deck of cards. What can you conclude?

Now try to make a branching dichotomous key based on one of the ways you chose to group your cards. Test it on a classmate to see if it works.

Creating a key

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

Will the characteristics change over time?

Grouping organisms based on what they look like considers a creature's **morphology**. However, some characteristics, like colour, size and shape, are not so useful for making a key as these characteristics can change over time, or with the seasons. For example, think about your hair colour – was it the same colour when you were born? Will it change as you get older? Another example from the animal world is the stoat (Figure 7.5 on page 244). It has a white winter coat that offers it camouflage when there is snow on the ground, while in summer it completely changes colour to brown!

VIDEO
How quickly do these animals change appearances?

Are the characteristics specific?

You might have noticed that the amphibian key in Table 7.1 and Figure 7.4 focused on specific observable characteristics of each creature at each stage of the key.

morphology
the study of the size, shape and structure of organisms

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Figure 7.5 This is an image of a stoat with its winter coat (white) and summer coat (brown). It seems like it could be two different animals!

This is very important to remember when constructing a key, as otherwise scientists will get muddled and get different answers when they use the same key. If you were to design a key based on the three adult females shown in Figure 7.6, you might be tempted to describe their height as short, medium and tall. This would not be a dichotomous classification as it is very subjective – what someone else calls short may be different from what you call short! The term **qualitative** is used when a characteristic is described in this way. Starting your key with 'Is the adult female taller or shorter than 160 cm?' would be better as there are only two options to choose from in this case, and the answer is clear.

qualitative
a form of data that is a descriptive measurement

quantitative
a form of data that is a numerical measurement

The term **quantitative** is used when a characteristic is measured or described using numbers.

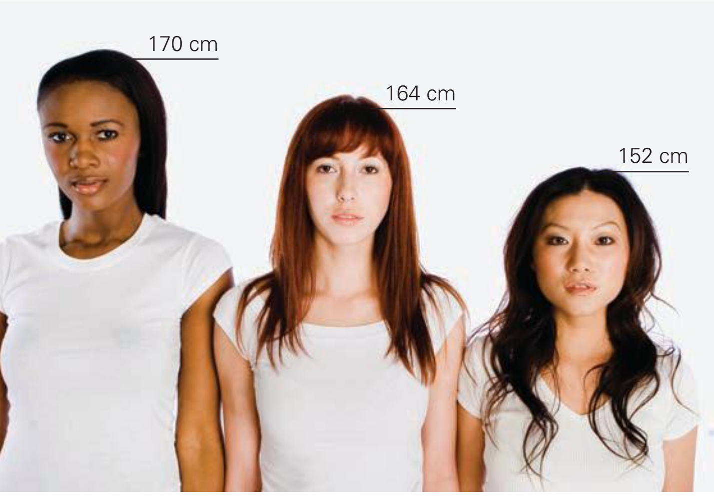
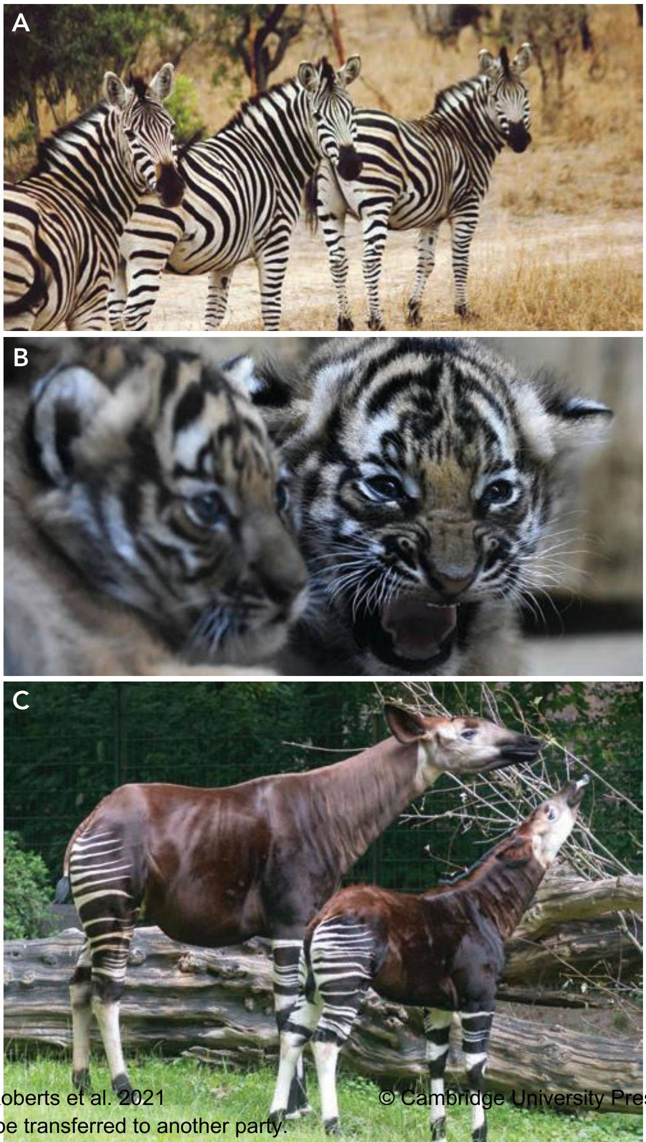


Figure 7.6 Height can be described (qualitative) or measured (quantitative), but to classify, you need to make sure the characteristic is clear and measurable (i.e. quantitative) where possible.

Narrowing down the choices

You need to make sure that the features of the object you are choosing are unique to that object or at least different from a few of the other options. If you were to classify the animals shown in Figure 7.7, you could not use 'striped' as a defining feature.

Figure 7.7 Can you name these striped animals?



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Quick check 7.3

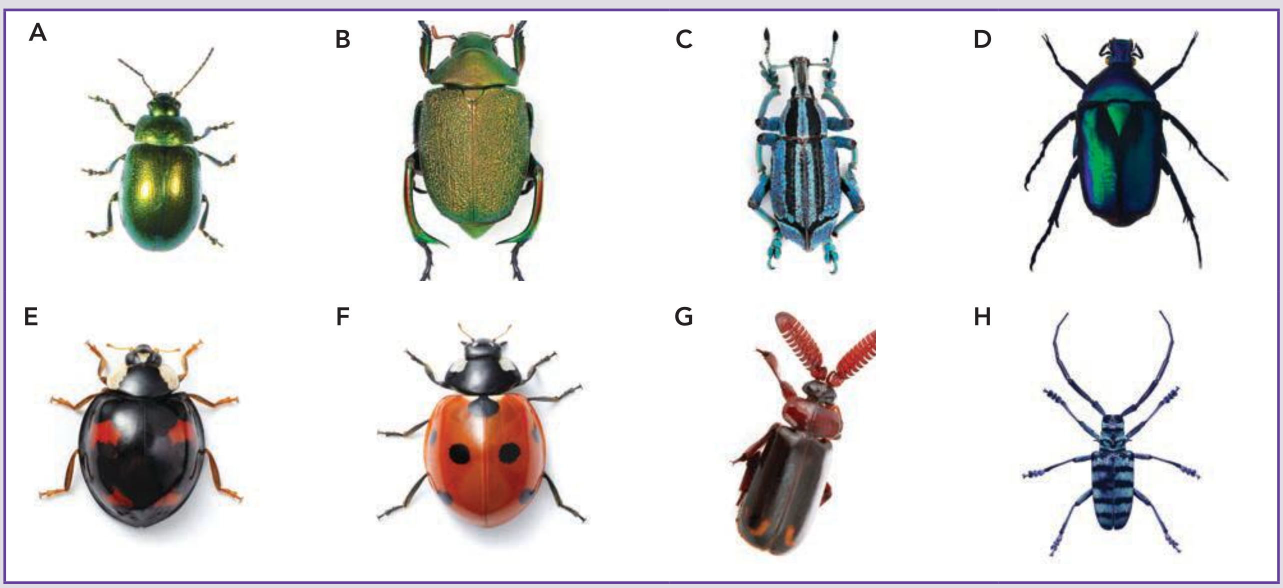
1 Summarise the key points to remember when selecting characteristics to create a key.
2 Define the terms 'qualitative' and 'quantitative' in your own words.
3 When making a key, discuss whether the characteristics need to be qualitative or quantitative.
4 In the table below, give an example of a quantitative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

Characteristic	Qualitative	Quantitative
Height	Tall	
Legs	Many	
Fur length	Short	
Wing size	Big	

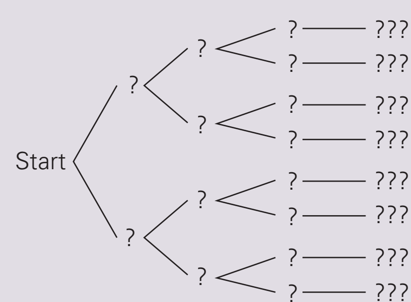
Try this 7.4

Creating a key for some insects

The diagram below shows eight different beetles (**A–H**).



1 Observe the different insects and describe their main differences.
2 Use the main difference between the insects to separate them into two groups. Create and label a tree diagram, shaped like the example on the right on a piece of paper to show these divisions.
3 Separate each group into two further groups, and then continue until there are eight individual insects on the final level of the tree diagram.
4 Use the differences you have identified to construct a dichotomous key for the insects.



5 Pass the key to a classmate and get them to use it on your insects to make sure it is easy to follow. In other words, your classmate should arrive with the eight insects in the same categories at the bottom of the diagram, as you intended.
6 After you have tested the key, make any alterations that you need to in order for it to work.
7 Explain the main difficulties you faced when you constructed your key.
8 Discuss the reason for any changes you made after testing the key with a classmate.

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Section 7.1 questions

QUIZ

Remembering

1 **Define** the term 'classify'.
2 **Outline** why scientists need to classify things.
3 **Recall** the term given to a key that has two possible options at each stage.

Understanding

4 **Select** the characteristic which would be best to use when making a classification key for birds.
   A Where the bird was last observed
   B What food the bird likes to eat
   C The number of birds in your suburb
   D Colour markings on the bird's wings

5 **Explain** why the shape of an animal may not be the best defining feature to focus on when creating a key. Suggest some features that would be useful.

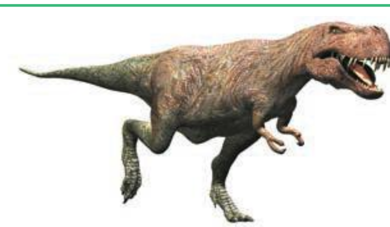
Applying

6 **Identify** which of the following features would be useful when creating a key to identify types of plants. (There may be more than one correct answer.)
   A Short leaves vs. long leaves
   B Smooth leaves vs. spiny leaves
   C Tall vs. short
   D 1 m average height vs. 0.2 m average height
   E Pink spots on leaf vs. no pink spots
   F Dark green colour vs. light green colour

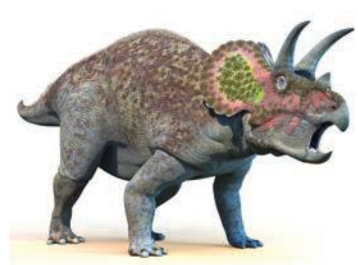
7 Copy and **complete** the results table on page 247 using the images and dichotomous key below.

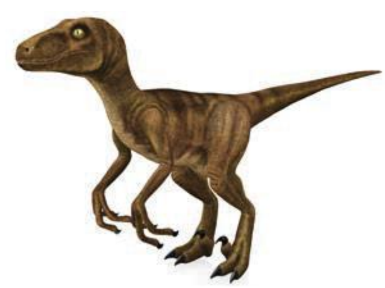

A


B


C


D


E


F

Dinosaur dichotomous key:

1	Has four legs	Go to #2
	Has two or fewer legs	Go to #3
2	Has horns or plates	Go to #4
	Has no horns or plates	*Diplodocus*
3	Has wings	*Archaeopteryx*
	Has no wings	Go to #5
4	Has horns	*Triceratops*
	Has plates on back	*Stegosaurus*
5	Arms less than half the length of the legs	*Tyrannosaurus rex*
	Arms longer than half the length of the legs.	*Velociraptor*

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Results

Dinosaur	Species
A	
B	
C	
D	
E	
F	

Analysing

8 Aboriginal and Torres Strait Islander peoples use many endemic plants for medicinal purposes. Some of these are shown below.

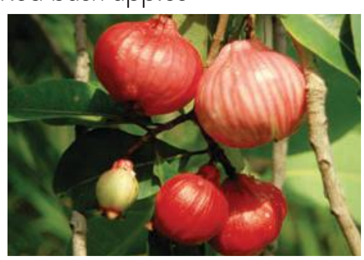
Finger lime

Quandong

Kutjera

Riberry

Red bush apples



Small leaf tamarind

- a **Classify** the native fruits into two groups based on a specific characteristic. Outline the features of each fruit that led you to your classification.
- b Now use the images again to **classify** these native fruits but this time into three groups. Outline the features of each native fruit that led you to your classification.
- c Ask to see the groups your classmates listed and **compare** with yours.

9 **Distinguish** between qualitative characteristics and quantitative characteristics.

10 When you are older, you may be interested in buying a second-hand car. Most likely, you will jump online to a car sales website and begin your search. The state you live in might be one of the first things you enter to narrow down your search. **Suggest** other features or characteristics you may need to use to refine your search. **Justify** your choices, stating if you think everyone would follow the same pathway as you.

Evaluating

11 **Copy** and **construct** the following table. Decide whether the features are good or weak descriptors to use in a dichotomous key for humans. **Justify** your choices.

Feature	Good or bad descriptor	Justification
Blue or brown eyes		
Long hair		
150–160 cm tall		
Likes cats		
Size 6 shoe		

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7.2 Classifying living things

Learning goals

1 To be able to classify a living organism.
2 To be able to use conventions to name organisms.

WORKSHEET

VIDEO
The seven criteria of living things

Is it alive?

One of the most basic classification groupings that can be used is 'living' or 'non-living'. The characteristics of living things are often summarised using the acronym MRS GREN. Can you work out what these characteristics are, based on this acronym? The flow chart in Figure 7.8 will give you some clues. It is important to keep in mind, that when a thing is described as non-living, it doesn't mean the same thing as dead. Something that is dead used to exhibit all the characteristics of living things, while something that is non-living never exhibited them.

The first characteristic, movement, needs some explanation. Movement from one location to another – locomotion – is easy to see, but the characteristic also refers to movement while staying in the same place, which may be difficult to observe, partly because it could be so slow. Examples are a change in orientation (e.g. plants moving leaves to catch sunlight); moving parts of the organism in relation to the whole (e.g. flowers opening and closing, or spores being released); or internal movement, such as movement of sap; or movement seen inside cells with a microscope.

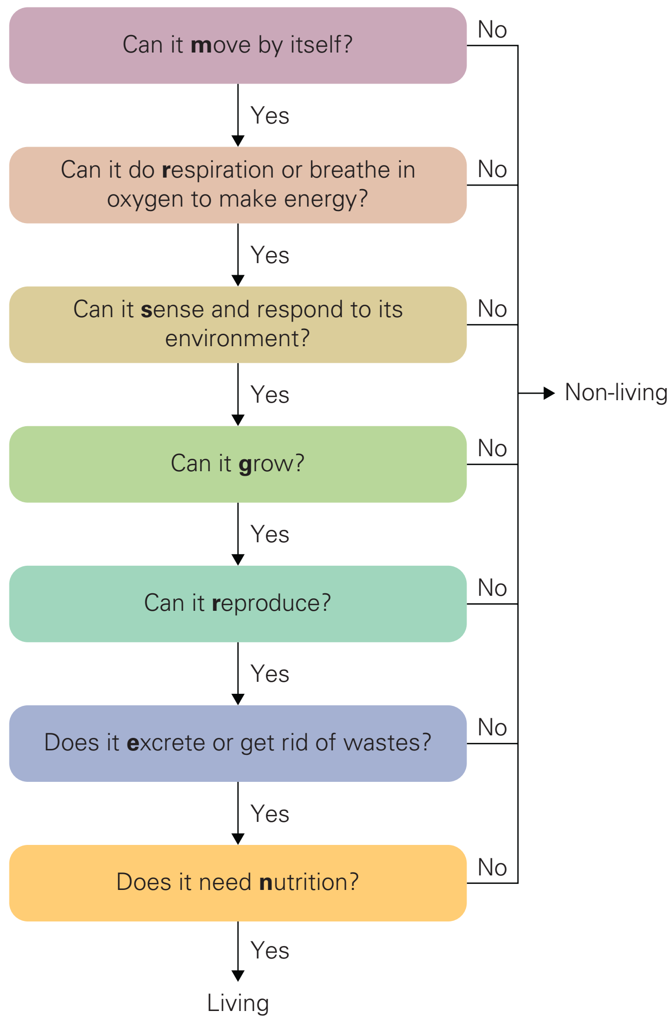

Figure 7.8 Unless all seven criteria are met, a thing cannot be classified as 'living'.

Explore! 7.2

Search online for information on how crystals grow. Would you classify crystals as living things? What about an aeroplane? The Sun? Justify your answers by listing which criteria they meet and which criteria they do not meet.

Quick check 7.4

1 State the characteristics that all living things share and describe an example for each (plant/animal/insect).
2 Explain what non-living means.
3 Distinguish between non-living and dead.

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Figure 7.9 Taxonomists maintain collections of living things to study their features and DNA for classification.

Taxonomy

organism
a living creature

taxonomy
a branch of science that groups organisms

So far, you have learned why it is important to classify things and about the tools that help do that. Now you are going to look at how biologists use these systems to classify all living things or **organisms**. The branch of science that classifies organisms is known as **taxonomy**. Taxonomy is just like a magical filing system for the 8.7 million different living things that exist in our world!

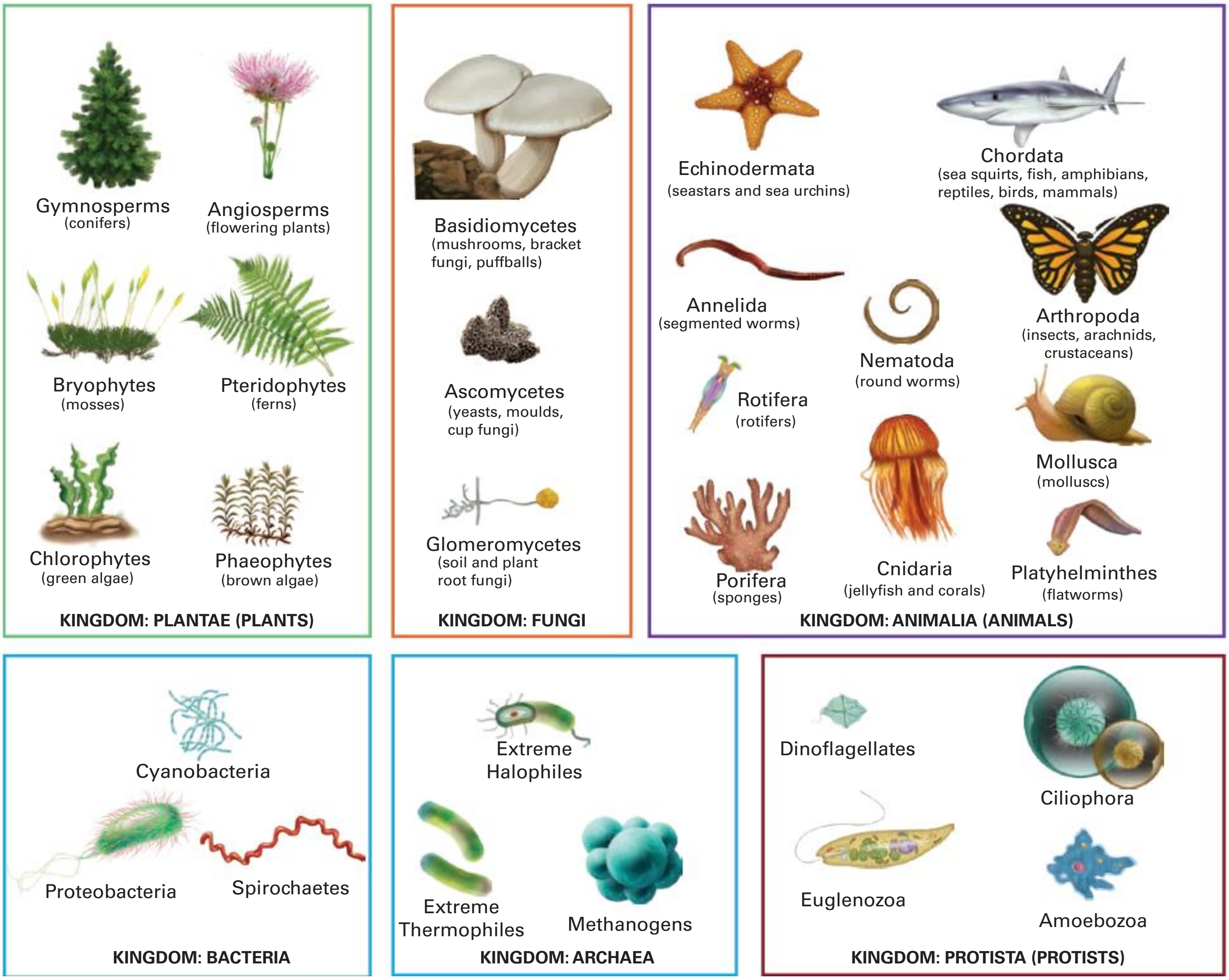

Figure 7.10 The six-kingdom classification of living organisms, with some representative groups within each. Note that there are many more groups than the ones shown, especially in the kingdoms Bacteria, Archaea, Protista and Fungi.

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Figure 7.11 Linnaeus on a scientific expedition

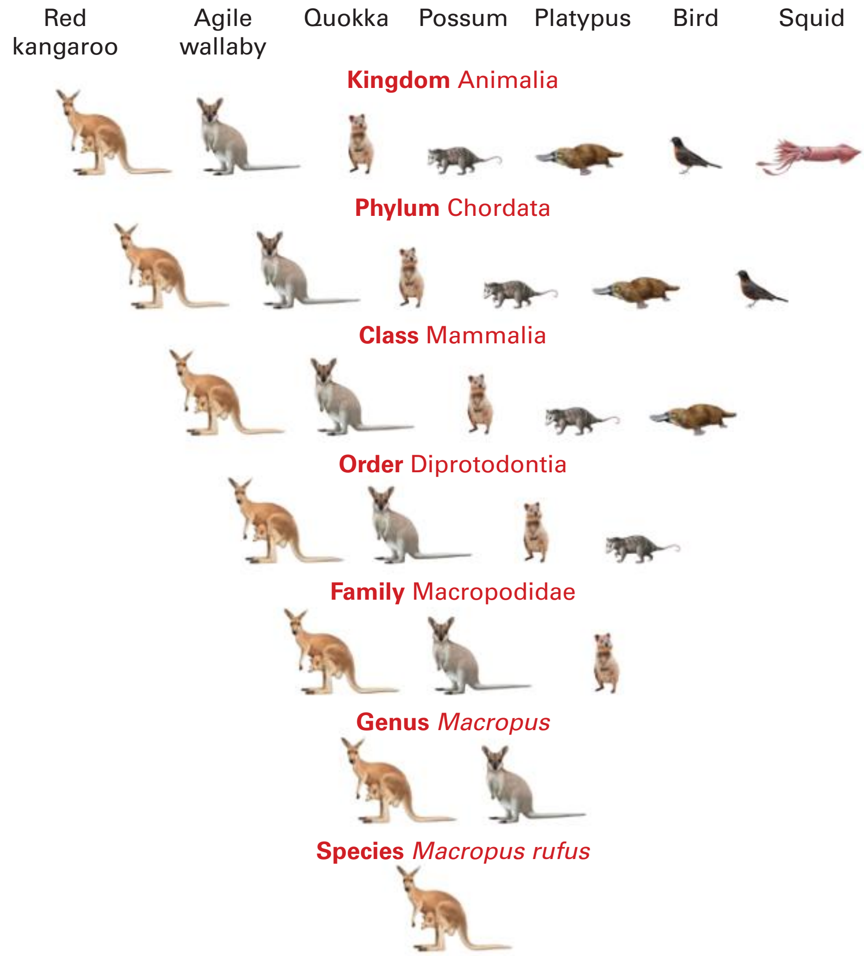

Figure 7.12 Linnaeus' classification hierarchy: at each level as you go down the organisms share more characteristics and are more similar.

botanist
a scientist who studies plants

kingdom
the highest classification on the Linnaean taxonomic rankings and the most broad

phylum
the taxonomic ranking below kingdom and above class

class
the taxonomic ranking below phylum and above order

order
the taxonomic ranking below class and above family

family
the taxonomic ranking below order and above genus

genus
the taxonomic ranking below family and above species

species
the most specific taxonomic ranking below genus

Carl Linnaeus

Carl Linnaeus was a Swedish **botanist** born in 1707. He realised quite early on in his career that the classification system used at the time was not working. For example, the scientific name for a tomato plant during his time was: *Solanum caule inerme herbaceo foliis pinnatis incises racemis simplicibus* – what a mouthful! Linnaeus noticed that as new organisms were discovered, the names for each got longer and longer, so the current naming system was going to have to change.

Linnaeus was responsible for sorting living things or organisms into groups based on their physical similarities. He called the largest group 'kingdom' and the smallest group 'species'. The levels of classification that he developed were **Kingdom**, **Phylum**, **Class**, **Order**, **Family**, **Genus** and **Species**. He managed to classify more than 10 000 organisms during the course of his life and his work forms the basis of the current classification system.

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Try this 7.5

The order and names of Linnaeus' different levels of classification can be remembered by using a mnemonic device such as **K**eep **P**ond **C**lean **O**r **F**roggy **G**ets **S**ick, or **K**ids **P**refer **C**heese **O**ver **F**ried **G**reen **S**pinach. Try to make up your own mnemonic to remember each level.

Carl Woese

In addition to the original levels that Linnaeus suggested, a higher, broader level was proposed by Carl Woese (a **microbiologist**) in 1990. This level is called **domain** and it consists of Bacteria, Archaea and Eukarya. The domain Eukarya includes the kingdoms you are most likely familiar with, such as animals, plants and fungi.

microbiologist
a scientist who studies very small living things like bacteria

domain
the highest taxonomic rank above kingdom and even more broad

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

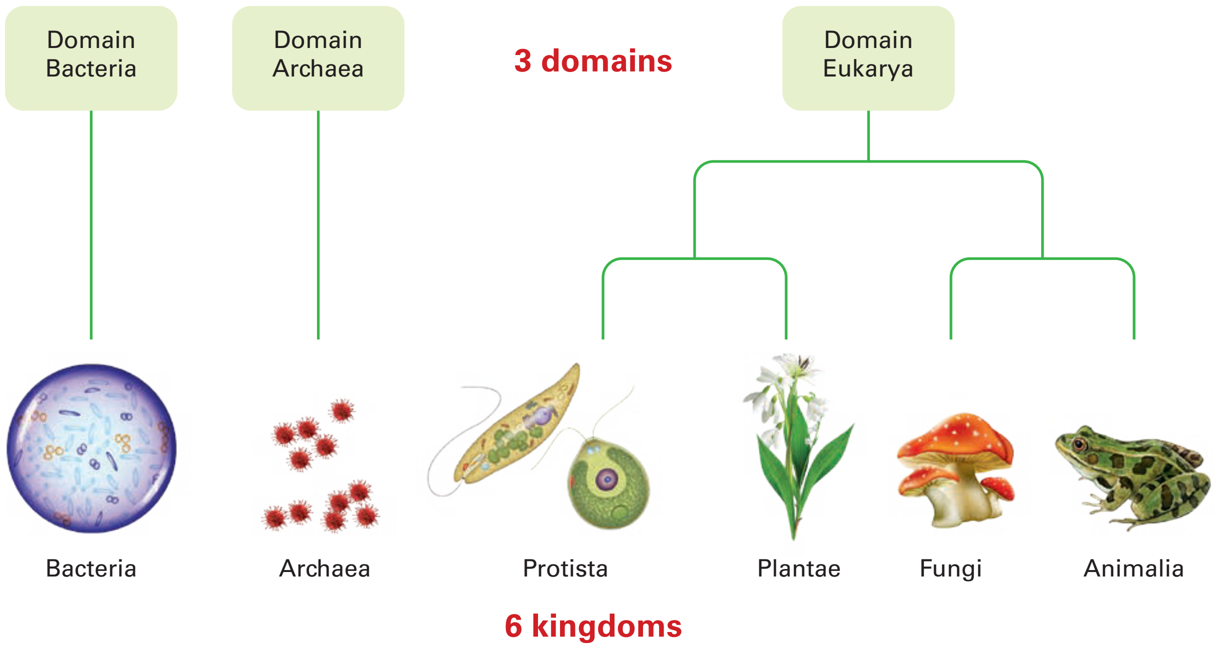

Figure 7.13 The links between Woese's domains and kingdoms

Explore! 7.3

Changes in classification

New advances in technology has allowed us to learn that certain organisms are more closely grouped than we thought. By analysing **DNA**, we can see that even things which don't look alike can be classified together! Research online the link between the whale and hippo; the elephant, manatee and hyrax; and the horse and rhino.

Quick check 7.5

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

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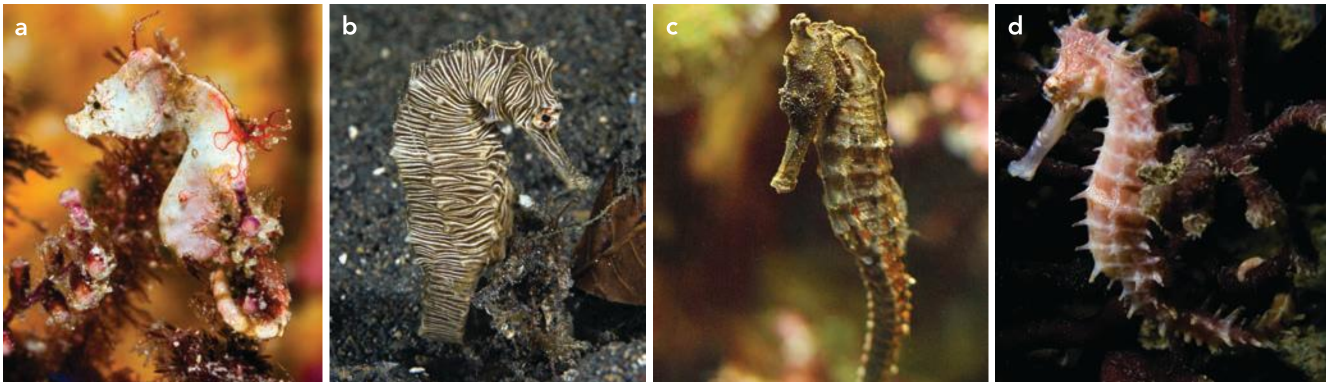

Figure 7.14 (a) *Hippocampus colemani*, **(b)** *Hippocampus zebra*, **(c)** *Hippocampus kelloggi*, **(d)** *Hippocampus histrix*

How to write the names

You might have noticed that when writing an organism's scientific name, there are a few rules that need to be followed.

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

For example, *Hippocampus colemani*, *Hippocampus zebra*, *Hippocampus kelloggi* and *Hippocampus histrix* are all different types of seahorse found around Australia. The genus name (first part of the name) for all these species, Hippocampus, is from the words *hippos* meaning 'horse' and *campe* meaning 'sea monster'. As you can see from Figure 7.14, they share many similarities but are all unique. That is why the species (the second part of the name) is also used to identify specific organisms.

Binomial naming

Linnaeus is also responsible for the two-part naming system described above, which is known as **binomial nomenclature**. This replaced much longer names such as the one for the tomato plant given on page 250. Linnaeus renamed it *Solanum lycopersicum*. Earlier in this chapter, you learned about the importance of a universal language in science. Scientists usually use a form of Latin or Ancient Greek to name an organism, which is why it sometimes can sound like a spell from the *Harry Potter* books – '*Macropus giganteus!*' – (that's an eastern grey kangaroo!).

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

Common name	Eastern grey kangaroo
Kingdom	Animal
Phylum	Chordate
Class	Mammal
Order	Diprotodon
Family	Macropod
Genus	*Macropus*
Species	*giganteus*
Scientific name	*Macropus giganteus*

Table 7.2 *Macropus giganteus* taking a nap, and its classification

Try this 7.6

Classifying Australian animals

Find three similar Australian organisms, for example three snakes or three parrots, and draw up a table like Table 7.2. Find out their classifications and scientific names. How similar are the three organisms? List some characteristics they share. How different are they? List some characteristics that are unique. At what level do you notice they are different? What does this mean about how closely related they are?

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Did you know? 7.1

In recent years, instead of using names derived from meaningful Latin or Greek words, scientists have started using made-up Latin-sounding names as more species are discovered every day. Some scientists are using the world of *Harry Potter* for inspiration! They have named a new species of crab, *Harryplax severus*, after both Harry Potter and his potions teacher Severus Snape. They also named a species of wasp, *Ampulex dementor*, after the spooky prison guards.

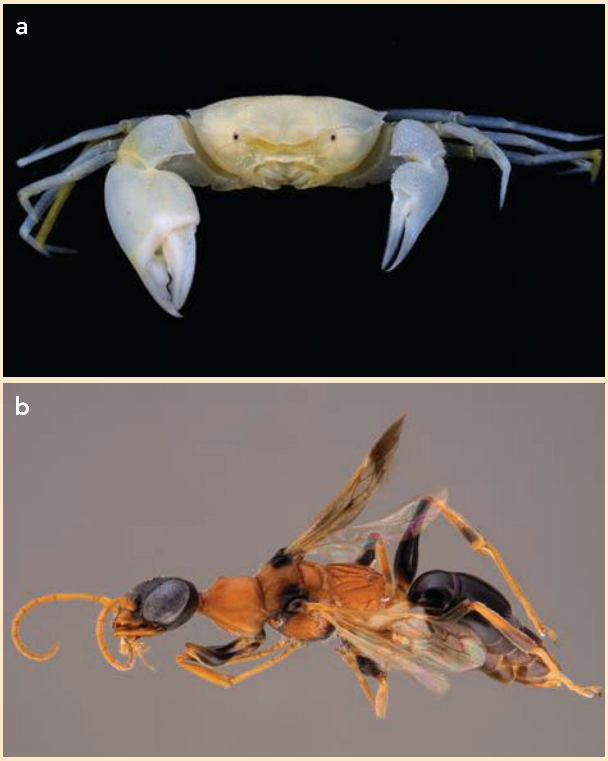

Figure 7.15 (a) *Harryplax severus*, **(b)** *Ampulex dementor*

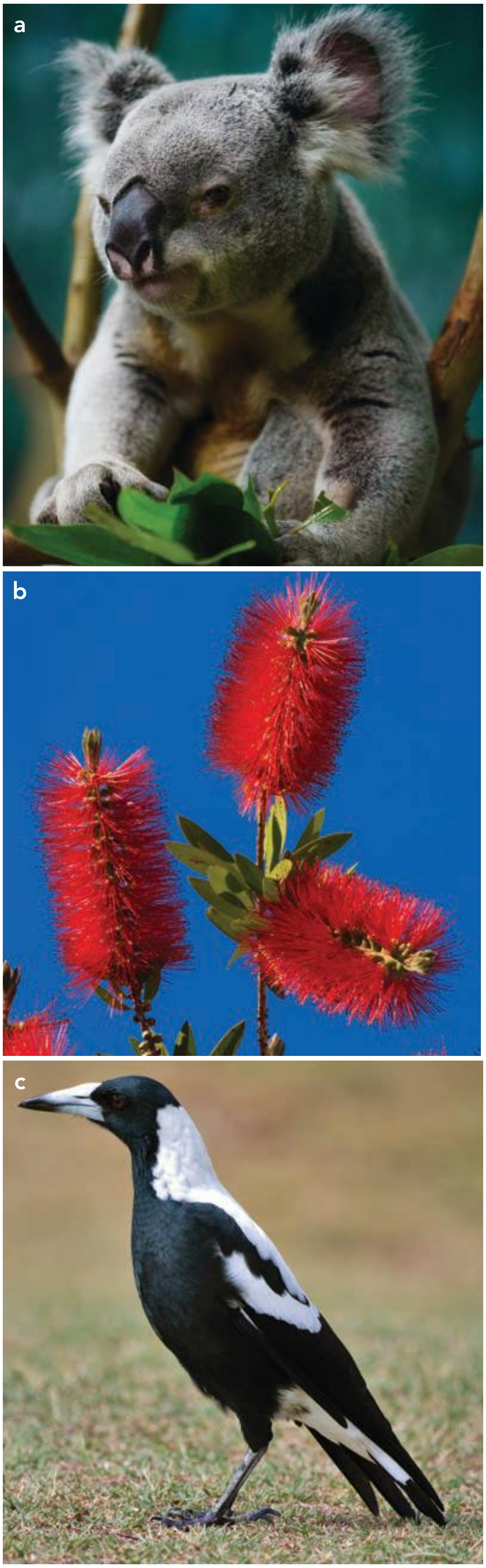

Figure 7.16 (a) koala (*Phascolarctos cinereus*), **(b)** crimson bottlebrush (*Callistemon citrinus*), **(c)** Australian magpie (*Cracticus tibicen*)

Why are scientific names important?

In everyday life, it is quite rare to use the Latin names of plants and animals because the words are often hard to pronounce and remember. If you were asked to identify the organisms in Figure 7.16 as *Phascolarctos cinereus, Callistemon citrinus* or *Cracticus tibicen*, you probably would not be able to. However, if you were to use their common names – koala, bottlebrush and magpie – it would be easy.

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You may ask, why can't you just use the common name? Well, some common names for animals are repeated all over the world, but they are not the same species. For example, the Australian magpie is a completely different species from the British magpie (Figure 7.17). In fact, they are not even in the same family! It is likely that the name originated from European colonial settlers, who saw a black and white Australian bird and named it after the most common black and white bird from their country of origin.

Figure 7.17 British magpie (*Corvus pica*)

Quick check 7.6

1 Define the term 'binomial nomenclature' in your own words.
2 When looking at a list of scientific names, state how you would know which organisms were most similar.
3 Discuss some of the difficulties scientists would experience if they only used the common names of organisms.

Try this 7.7

Creating an animal

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

1 Obtain sketch paper and pencils or search for 'make new animals' on the internet.
2 Draw your animals or use an online animal building tool to create a new animal with features of many different types of animals (e.g. Switchzoo).
3 Take a screenshot of your creation and then create a description of the animal.
   Your description should include:
   - name of animal
   - habitat: aquatic, terrestrial, both
   - behaviours
   - diet
   - how it uses the features you have chosen
   - warm blooded or cold blooded
   - how its offspring are born
   - how long it lives
4 Classify your animal into a group (insects, birds, mammals, reptiles etc).
5 Using your description, justify why you classified your new animal as you did.

Section 7.2 questions

QUIZ

Remembering

1 **Name** the person who is called the 'father' of modern taxonomy.
2 **List** the six kingdoms.
3 **List** the seven characteristics of living things.
4 **List** the eight levels of classification, from general to specific.

Understanding

5 The scientific name for the Australian common bluetail damselfly is *Ischnura heterosticta*. **Name** the country or countries for which this name applies.

Figure 7.18 Male common bluetail damselfly

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

Applying

8 The pangolin is one of the world's most illegally traded animals. Its body is covered in hard scales, it is nocturnal, and it gives birth to live young that feed on milk from their mother. As an adult, it eats mainly ants and termites, which it captures with a tongue that is as long as its bodies. Use this information to **decide** what class the pangolin belongs to. **Give reasons** for your answer.
9 **Explain** how Aboriginal and Torres Strait Islander classification systems are different from Linnaean classification systems.

Analysing

10 **Examine** the illustration of the platypus in Figure 7.19. The platypus is a monotreme which is a type of mammal. **Explain** why some of the features of the platypus might confuse early explorers with their classification.

Figure 7.19 A female platypus (*Ornithorhynchus anatinus*)

Evaluating

11 **Predict** how closely related the fish in Figure 7.20 are to the clownfish on the bottom left based on physical characteristics. Justify your prediction.

Figure 7.20 Tropical fish

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7.3 Non-animal kingdoms

Learning goal

1 To be able to distinguish the six kingdoms of living organisms based on common characteristics and features.

WORKSHEET

VIDEO Can you identify one useful bacteria?

Single-celled organisms

Most of life on Earth is **unicellular**, meaning it only is made up of one cell. You might not instantly get excited about single-celled life, but some of these organisms can thrive in places that no other living creature could survive, like in a 300°C hot pool or freezing Antarctica!

unicellular
consisting of one cell

Figure 7.21 Unicellular organisms have only one cell, which performs all the cellular functions.

Archaea

- Oldest form of life on Earth
- Date back to 3.5 billion years ago
- Found in the most inhospitable and extreme environments on Earth
- Common in oceans
- Used in treatment of sewage
- Found in the gut, especially of ruminants and termites.

Figure 7.22 Archaea can be found in inhospitable (harsh) environments like these geothermal hot springs or even toxic oil wells.

Did you know? 7.2

We have one kind of archaea in our bodies. It is called a methanogen because it produces methane gas. So, you can blame the archaea next time you expel methane from your body!

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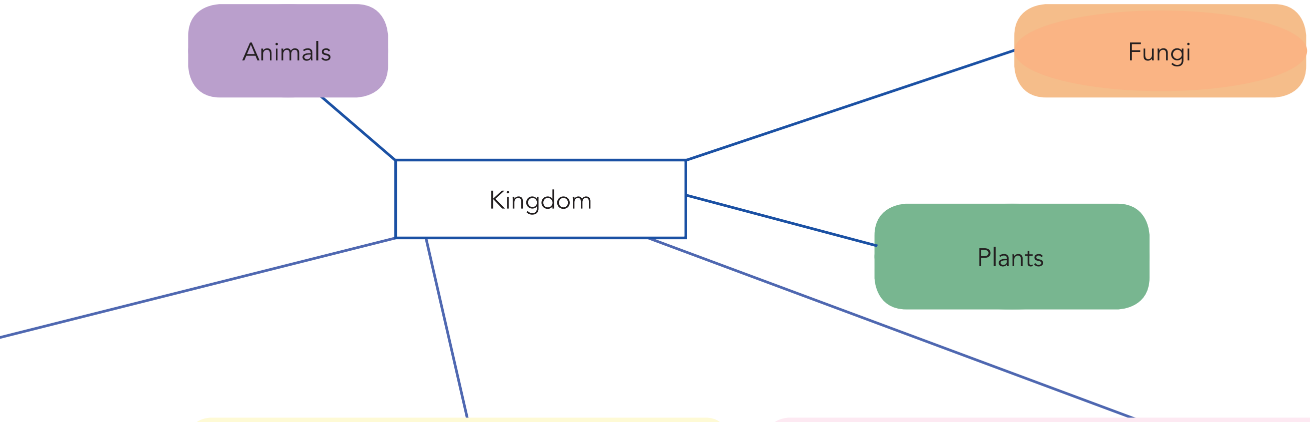

Bacteria

- Nearly as ancient as Archaea, appeared about 2.5–3 billion years ago
- Vital for digestion in animals, including humans
- Decompose wastes
- Create fertile soil, vital for agriculture
- Used to produce food (cheese, yoghurt) and industrial materials
- Some are harmful, causing infectious diseases.

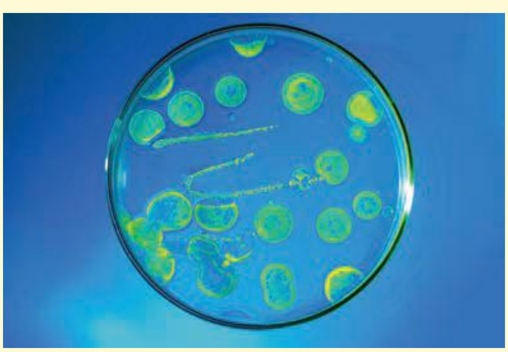

Figure 7.23 Bacteria adapt quickly to threats, which is a problem doctors are facing as some harmful bacteria become antibiotic resistant.

Protista

- Single cells like bacteria and archaea but complex in comparison
- Do not always have a cell wall and can be varied in size
- Organisms that do not fit into the other kingdoms get placed in the Protista kingdom
- Appeared in the fossil record about 1.7 billion years ago
- Most live independently but some form small colonies
- Some can cause disease but most are harmless to humans
- Most phytoplankton and many algae are protists, responsible for a huge proportion of photosynthesis
- Digest cellulose in the guts of ruminants and termites
- They also break down wastes and help make fertile soil.

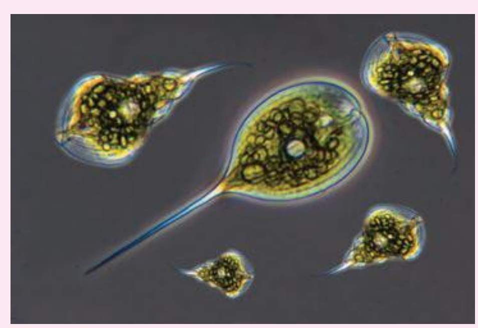

Figure 7.24 These *Phacus* euglenoids can swim and make sugars by a process called photosynthesis, just like plants can.

Quick check 7.7

1. Name the kingdoms that contain single-celled organisms.
2. Define the term ‘microscopic’ in your own words.
3. Summarise the key characteristics of bacteria.
4. Name an organism in the Protista kingdom.
5. Decide whether all single-celled organisms are harmful.

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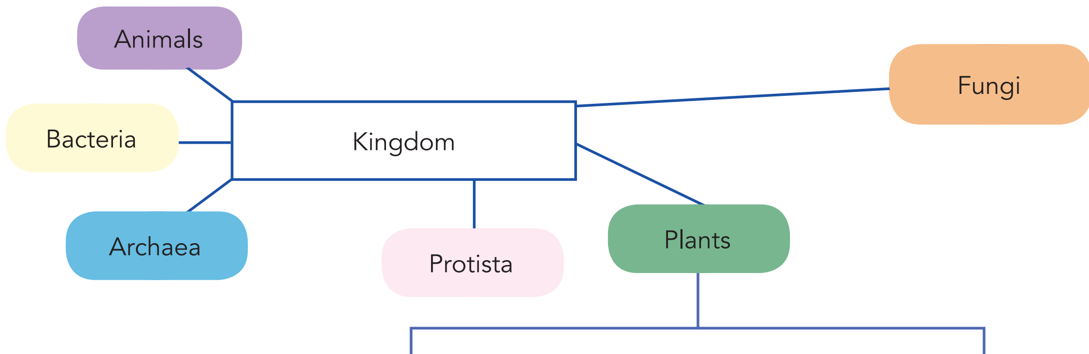
Plants

Plants do incredible things for us! They turn the toxic greenhouse gas carbon dioxide into the very useful gas oxygen that allows us to stay alive. Plants have been on Earth for millions of years longer than animals and spent that time transforming the atmosphere into one that contains oxygen and can support life. Plants are producers because they produce the primary food source for all life on land. This happens because they are **autotrophs** capable of converting the energy from the Sun into useful sugars that can be digested.

autotroph
an organism that produces its own food from light, carbon dioxide, water or other chemicals

Figures 7.25 to 7.29 show how the Plant kingdom is divided, based on whether they have vascular tissue and if they produce seeds.



non-vascular
not containing veins or specialised fluid vessels

vascular
containing veins or specialised fluid vessels

Non-vascular

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

- cannot grow very large or tall
- often found spread across rocks or the ground in cool, moist, shaded areas
- reproduce using spores (a single-celled reproductive unit)
- include mosses, liverworts and hornworts, and some algae.

Figure 7.25 Mosses can take in water and nutrients through their leaves. They do not need to have roots, therefore they can grow on hard surfaces. They also reproduce using spores, which are single-celled and hence smaller than seeds.

Vascular

Vascular plants have a specialised vascular system; that is, roots and stems for transporting water and nutrients around the plant. The veins that you normally see on leaves are special pathways for water and nutrients to flow called xylem (for water transport) and phloem (for sugars and nutrients). Ferns, non-flowering plants and flowering plants all have these transport systems.

Figure 7.26 Veins that you see on leaves are special pathways for water and nutrients to flow.

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Flowering plants

- Use brightly coloured flowers and sweet nectar to lure insects, birds and other animals to the flower
- Help spread the flowers' pollen to produce seeds
- Develop seeds inside the 'fruit', which in botany includes pods, capsules and all 'fruiting bodies'
- Can have fruit that is edible and attractive, so when animals eat the fruit, they spread the seeds over large distances.

Figure 7.27 Flowering plants are the most advanced form of life in the Plant kingdom.

Ferns

- Have been on Earth for about 360 million years
- Are vascularised
- Can grow to large sizes
- Reproduce through spores
- Like moist, humid, shaded areas
- Do not have seeds.

Figure 7.28 Ferns mainly grow in moist, humid areas.

Non-flowering plants

- Include cycads and conifers
- Reproduce using seeds, which are a complex way of reproducing as seeds contain multiple cells, not just one These cells are protected by a waterproof layer much like the hard shells of reptiles and birds, which prevents the seed from drying out
- Include conifers that produce cones that are male (they contain pollen) or female (they contain seeds)
- Rely on wind to move the pollen from the male cone to the female cone.

Figure 7.29 The Wollemi Pine is an ancient non-flowering, seed-producing plant that is only found in Australia.

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Quick check 7.8

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

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

Practical 7.1

Observing *Euglena*

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

Be careful
Ensure proper microscope handling and use is observed.

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

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

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

Fungi

Fungi have traits that are similar to both plants and animals, but they are different enough to form their own kingdom. Fungi, like animals, cannot produce their own food as plants do. They absorb their nutrients from organic matter including dead organisms in their environment, or as parasites growing on or in living organisms. Unlike animals, most are **sessile**, meaning that they cannot move around too much. The Fungi kingdom ranges from microscopic single-celled organisms, such as yeast, to multicellular organisms, such as mushrooms.

sessile
an organism that does not independently move its location but may move body parts

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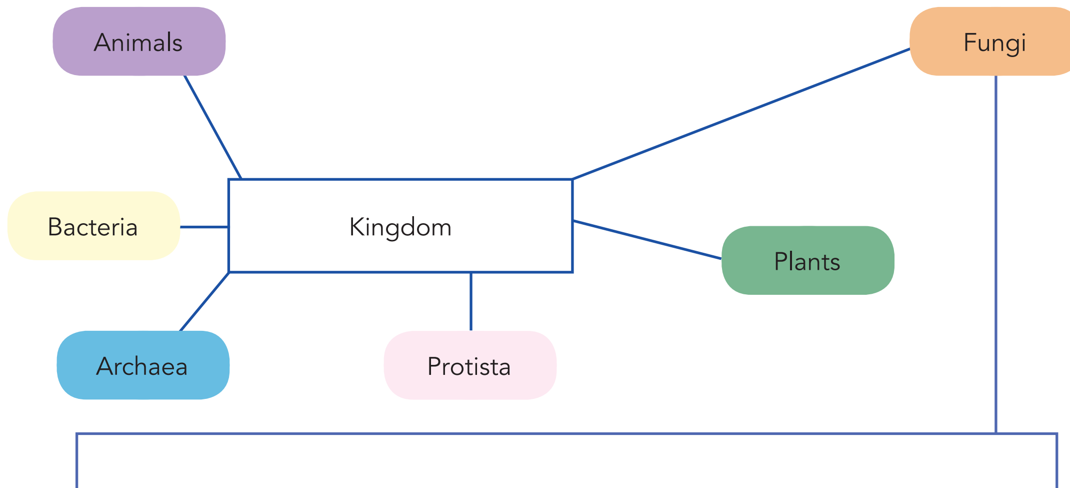

Single-celled fungi

Yeast is a single-celled fungus used to make bread rise and in the manufacture of beer.

Figure 7.30 Yeast cells seen under a microscope

Multicellular fungi

Fungi are the source of some medicines. For example, the antibiotic penicillin, which is used to fight bacterial diseases, is prepared from the mould *Penicillium chrysogenum*.

Figure 7.31 *Penicillium chrysogenum* growing in a Petri dish

Fungi (as well as some bacteria, archaea and protists) have one of the most important roles on Earth. They feast on the deceased – they eat and break down all dead organisms, allowing nutrients to be recycled in the circle of life. Nutrient recycling is important. If there were no decomposers, life on Earth simply could not exist, as the nutrients that organisms take from soil or water would never return.

However, some fungi are **deadly**. *Batrachochytrium dendrobatidis* is a fungus that causes the deadly disease chytridiomycosis in frogs. When the disease enters a frog population, it kills all of them! This disease was first discovered in Australia in 1993 but it is thought to have been in Australia since the 1970s. Currently, it is found in all states and territories except the Northern Territory. The disease is believed to have been the cause of at least four recent frog extinctions and ten rapidly declining frog species in Australia. Currently, there is no cure or method of controlling this disease in the wild.

Figure 7.32 Fungi recycling a fallen tree

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Figure 7.33 Dead Lesueur's frog, *Litoria lesueurii*, in a river

Some fungi are just plain weird! *Ophiocordyceps unilateralis* is sometimes referred to as the zombie fungus. This fungus can infect ants, take control of their bodies and force them to leave their nests and climb a nearby plant. The fungus then bursts out of the ant's head and spreads its spores to other ants in the colony.

Figure 7.34 Fungi sprouting out of the brain of an ant!

Quick check 7.9

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

Practical 7.2

Spores are all around us

Be careful

Make sure you do not open or puncture the bag once growth has begun.

Ensure that growing conditions remain under 30°C for safety considerations.

Aim

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

Time period

Approximately 1 week

Prior understanding

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

Materials

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

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Planning

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

Procedure

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

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

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

Results

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

Discussion

1 Describe any trends, patterns or relationships in your results table.
2 Identify any outlier results that you found.
3 Analyse how much variation was observed between the measurements within each group.
4 Describe how the set-up or method was adjusted, if at all, once the experiment was started.
5 Critique your management of the controlled variables. Were they managed properly to ensure they did not change and affect the measurements?
6 Were there any obvious sources of error or parts of the procedure that caused the data to be less accurate than it could have been? Describe any changes that could be made to the method to improve the quality of the data in future experiments.

Conclusion

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

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Try this 7.8

Classification super-challenge!

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

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

Section 7.3 questions

QUIZ

Remembering

1 **State** three examples of fungi.

2 **Define** 'vascular plant'.

3 **State** the kingdom that Penicillium mould belongs to.

Understanding

4 **Explain** the benefits of a seed compared to a spore.

5 **Describe** two ways in which seeds can spread.

Applying

6 **Distinguish** between unicellular and multicellular.

7 **Identify** why animals depend on bacteria and fungi.

Analysing

8 **Place** each one of these species into the correct kingdom.

a *Streptococcus pneumoniae* is an organism that can make you very sick. It belongs to the second oldest kingdom and is made up of single cells.

b *Trypanosoma evansi* is a single-celled organism that needs to eat other organisms to survive. Its cells have specialised structures inside of them.

c *Osmunda regalis* is an organism that uses sunlight to make sugars and reproduces using spores. This organism has specialised vascular tissue.

d *Tremella fuciformis* is an organism that reproduces using spores and is a parasite of other organisms to gain food.

e *Haloferax volcanii* is a single-celled organism that can survive in extreme environments that no other organism could survive in.

9 In the past, fungi were part of the Plant kingdom. **Suggest** reasons why this might have been the case.

Evaluating

10 Suzi discovered that a piece of bread left in a zip-lock bag had developed a black fuzzy mould-like substance. She decided to investigate the factors affecting mould growth. She used the same brand of bread and zip-lock bags. She placed the sealed bags in different temperatures.

a **Identify** the variable she was changing or testing (independent variable).

b **Identify** the variable she was measuring (dependent variable).

c **Propose** some examples of variables she kept the same or controlled.

d **Suggest** two other variables she could test with a similar experiment assessing the growth of mould.

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7.4 The Animal kingdom and adaptations

Learning goals

1 To describe the difference between invertebrates and vertebrates.
2 To recall the seven classes of chordates.
3 To describe the three types of adaptations.
4 To explain how Australian plants and animals are adapted to their environment.

DOC WORKSHEET

When you think of an animal, your first thought is most likely of a large and probably charming creature such as a sloth or penguin. What you probably do not think of is a sponge or coral. It might surprise you to know that most of the animals on our planet are microscopic and look nothing like the animals you first thought of. All organisms that are placed in the Animal kingdom share some defining features that set this kingdom apart from the others.

Figure 7.35 A tardigrade is an example of a microscopic animal.

All animals:

- are multicellular (made up of more than one cell working together)
- have cells that contain special structures inside of them
- are **heterotrophs**, meaning they eat other organisms or their secretions, excretions or remains to gain energy
- can independently move their location (they are motile) or their body parts if they stay in one location (if they are sessile)
- can digest food inside their body (the majority) or in some cases outside their body.

Animal phyla

heterotroph
an organism that cannot make its own food, instead relying on other organisms for energy

vertebrate
has a backbone

invertebrate
does not have a backbone

There are more than 35 phyla in the Animal kingdom, but you are going to just focus on the nine key ones, as shown in Table 7.3. Often, scientists will talk about **vertebrates** or **invertebrates**. A vertebrate is an animal with an internal backbone or endoskeleton, while an invertebrate is an animal with no internal backbone. Instead, invertebrates may have a a hard outer casing called an exoskeleton. However, despite vertebrate and invertebrate being important terms to know and understand, they are not used as an official level in the classification system.

ANIMAL KINGDOM		
Phyla (scientific name in brackets)	**Examples**	**Invertebrate or vertebrate**
Poriferans (Porifera)	Sponges	Invertebrates (they have no backbone)
Cnidarians (Cnidaria)	Jellyfish, sea anemones, coral	
Platyhelminths (Platyhelminthes)	Flatworms	
Nematodes (Nematoda)	Roundworms	
Annelids (Annelida)	Earthworms	
Molluscs (Mollusca)	Shelled animals	
Arthropods (Arthropoda)	Insects, spiders, crustaceans	
Echinoderms (Echinodermata)	Seastars, sea urchins	
Chordates (Chordata) (not all chordates have backbones)	Fish, amphibians, reptiles, birds, mammals	Mainly vertebrates, but some invertebrates

Table 7.3 Summary of the nine key phyla in the Animal kingdom. Note that eight of the nine phyla contain animals with no backbone.

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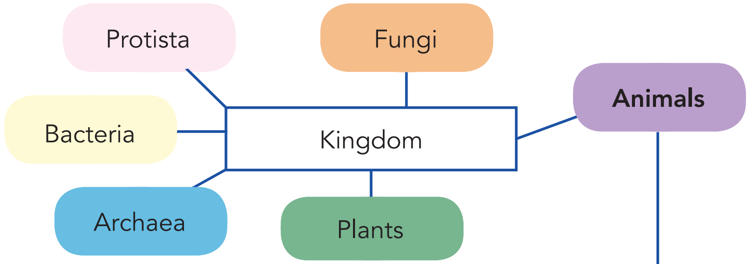

The Animal kingdom is divided into many phyla; Figures 7.36 to 7.44 on pages 266 and 267 show the nine key ones. Animals are also divided informally into two large groups: invertebrates and vertebrates.

Invertebrates

Poriferans

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

- 'Pore-bearers', have holes
- Use filters to obtain food
- No organs
- Sessile (do not move)
- Simple animal, no specialised organs
- Include sponges.

Figure 7.36 This sponge has a simple tube form for filtering water.

Cnidarians

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

- 'Stinging nettle'
- Soft, hollow body
- Fires stinging spine at target like a harpoon
- One opening for food and waste
- Include anemones, coral and jellyfish.

Figure 7.37 The bluebottle *(Physalia physalis)* is often found washed up onto Sydney beaches, and the tentacles of dead specimens can still sting.

Platyhelminthes

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

- 'Flat worms'
- No segmentation, unlike Annelids
- Have a simple brain and eyes
- Can be cut in half and they will continue to live
- Many are decomposers – they recycle waste, or are parasites living in other organisms
- Include all flatworms.

Figure 7.38 Flatworms display many vibrant colour combinations.

Nematodes

(pron. *nee-ma-toads*)

- An unsegmented worm found in soil, water and the bodies of other organisms as **parasites** and pests
- Also known as roundworms
- Most are very small or microscopic
- Widespread and very numerous.

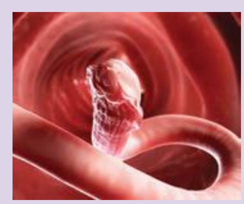

Figure 7.39 Many nematodes are parasites.

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

Annelids

(pron. *an-e-lids*)

- 'Ringed worms', meaning have ringed body segments
- Soft bodies
- One hole for food, one for waste
- Need a moist environment, can survive on land
- Include earthworms.

Figure 7.40 The tiger worm is named so because of its stripes.

Molluscs

(pron. *mol-usks*)

- Second largest of all of the phyla, second only to Arthropods
- Have a muscular foot and soft body
- Have a mantle (a cover or outer layer like a cloak), and for some it forms a shell
- Have a radula, a scaping device for eating
- Include squid, snails, slugs, octopuses and oysters.

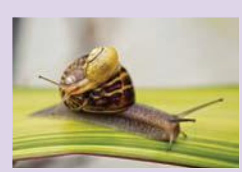

Figure 7.41 This small snail is taking a ride on another snail!

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Arthropods

(pron. *arr-throw-pods*)

- 'Jointed foot', means their limbs are made of jointed segments
- Exoskeleton
- Contain 80% of all animal species
- Found in every habitat, in the air, in fresh and salt water, and underground
- Have complex sensory organs such as compound eyes and antennae for hunting and detecting threats
- Include insects, spiders, scorpions, millipedes, crustaceans (crabs, lobsters, prawns) and many more.

Figure 7.42 Spider wasps paralyse spiders and drag them to their nests where they lay an egg on the spider. When the young hatches, it will eat the spider.

Echinoderms

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

- 'Spiny skin'
- Found in the ocean, not freshwater
- Have specialised organs, but no brain and no blood
- Most have radial symmetry
- Include sea urchins, sea cucumbers, brittle stars.

Figure 7.43 When a starfish loses a limb, it can grow back.

Vertebrates

Chordates

(pron. *core-dates*)

The Chordate phylum contains the most complex group of animals – they all have a spinal cord. The spinal cord is a long nerve that connects the brain of the animal to the rest of the body. This nerve is usually, but not always, protected by bones that are called vertebrae. Run your fingers down your back to feel your vertebrae that are protecting your spinal cord. You may remember that animals with such bones are called vertebrates. Humans, all other mammals, fish, reptiles, amphibians and birds all belong to the Chordate phylum but are further grouped into classes based on their similar characteristics.

Figure 7.44 Elephant seals and penguins are both examples of chordates.

Explore! 7.4

Some scientists believe they have found an immortal jellyfish (*Turritopsis dohrnii*). Research how the scientists explain this immortality and propose whether the same biological trick could ever be used by humans.

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radial symmetry
organism is symmetrical around a line drawn through the centre in more than one position

bilateral symmetry
organism can be divided into two symmetrical halves

Symmetry

When classifying animals into their correct phyla, their symmetry is also used as a structural feature to help classify it. **Radial symmetry** means you can draw an imaginary line in several directions through the centre of the animal and you will get identical halves. **Bilateral symmetry** means you can only draw an imaginary line in one position to get identical halves. As seen in Figures 7.45 and 7.46, some animals are not entirely symmetrical.

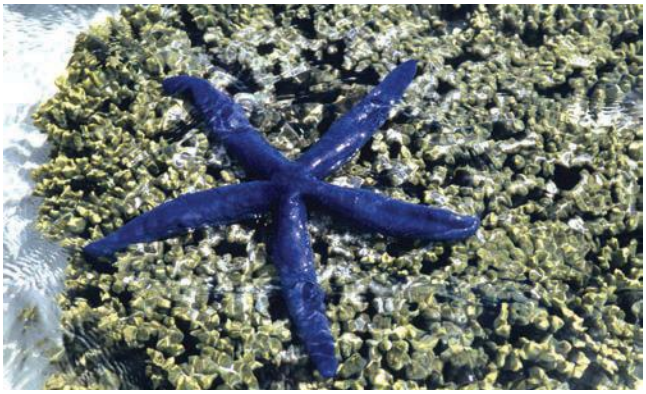

Figure 7.45 The blue seastar shows radial symmetry.

Figure 7.46 Australia's brown falcon shows bilateral symmetry.

Try this 7.9

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





Quick check 7.10

Which phylum?

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

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

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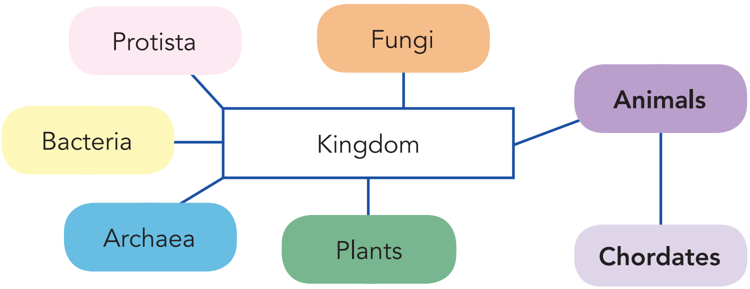
Animal classes

Kingdoms are divided into phyla and the next grouping down after phylum is Class. You will now take a closer look at the seven classes of Chordates: Agnatha, Chondrichthyes, Osteichthyes, Amphibia, Reptilia, Aves and Mammalia (Figures 7.47 to 7.56).



Agnatha (jawless fish)

(pron. *ag-na-tha*)

- Flexible
- Often parasites or scavengers
- Oldest chordates
- Include all jawless fish.

Figure 7.47 The hagfish is extremely flexible.

Chondrichthyes (cartilaginous fish)

(pron. *con-drik-thees*)

- Have cartilage (softer and more flexible than bone)
- Have fins on the sides of their bodies (lateral fins) and on their backs (dorsal fins)
- Very manouevrable and fast swimmers
- Efficient hunters
- Include sharks, skates and rays.

Figure 7.49 The great white shark is a fearsome hunter.

Osteichthyes (bony fish)

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

- Bony fish with a skeleton of ridged bone (not as flexible as cartilage but offers more protection of organs)
- Include salmon, tuna, eels, trout and clownfish
- **Ectothermic** (cold-blooded) – the temperature inside their bodies is controlled by the temperature of their environment.

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

Figure 7.48 A salmon swimming upstream to spawn

Amphibia (amphibians)

(pron. *am-fib-ee-a*)

- Can live in and out of water
- Always need a water source nearby to lay their eggs
- Their eggs do not have a waterproof shell
- Develop from an egg and then into a tadpole or larvae
- Undergo **metamorphosis** (a change in form, in this case from a tadpole with gills and a tail to having lungs, legs and no tail)
- Use their moist skin and lungs to take in oxygen from the air
- Include toads, frogs, newts and salamanders.

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

Figure 7.50 The White's tree frog is found in Australia.

Explore! 7.5

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

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Reptilia (reptiles)

(pron. *rep-til-ee-a*)

- Have waterproof scales as covering
- Most lay eggs, but have a leatherier shell than amphibian eggs and do not dry out
- Ectothermic
- Have lungs for breathing
- Include snakes, lizards, turtles and crocodiles.

Figure 7.51 Frilled lizards use their frill to catch more heat from the sun to warm up.

Aves (birds)

(pron. *ah-vays*)

- Have feathers covering their body
- Lay eggs with hard shells
- Beak for feeding
- Winged, but not all birds can fly
- **Endothermic** – they can control the internal temperature of their bodies and do not have to rely on their environment to remain warm
- Control of internal temperature – allows birds like penguins to live in freezing cold places such as Antarctica where reptiles would never be able to survive
- Include all living birds.

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

Figure 7.52 Birds such as emus and cassowaries have grown too large to fly and have adapted to a life on the ground.

Mammalia (mammals)

(pron. *mam-ay-lee-a*)

- Feed their offspring on milk produced by the mother
- Have a covering of hair or fur
- Endothermic
- Have three subclasses based on how they produce offspring: placentals, monotremes and marsupials.

Figure 7.53 Dogs are not only very good friends, they are also placental mammals like us!

Figure 7.54 Quokkas are very friendly marsupials found on Rottnest Island in Western Australia.

The class Mammalia is divided into three subclasses based on how they produce offspring.

Placentals nourish their young inside the mother's body until the offspring is fully developed. The young is attached by a cord to the mother's placenta, which supplies their food. Most mammals are placental mammals and include mice, horses, dingoes, whales and humans, among others.

Monotremes lay eggs just like reptiles, in leathery shelled eggs. They include echidnas and platypuses; in fact these are the only monotremes that exist now.

Figure 7.55 A mother giraffe cleans her newborn offspring.

Figure 7.56 Echidnas use their long nose to hunt for termites.

Marsupials have offspring that live in a pouch from a very early stage in development. The offspring latch onto their mother's nipple inside the protective pouch and remain there until they are fully developed. They include kangaroos, wombats, possums and koalas. Marsupials are only found in Australasia, South America and, in smaller numbers, in Central America and North America.

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Practical 7.3

Dissecting a squid

Be careful

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

Aim

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

Materials

- 1 squid
- dissecting tray (plastic chopping board)
- dissecting scissors
- probe
- newspaper
- 11 toothpicks
- 11 sticky labels
- gloves
- lab coat
- Optional: dissecting microscope
- Recommended: laminated copies of squid internal and external anatomy diagrams (Figures 7.57 & 7.58) for reference during dissection.

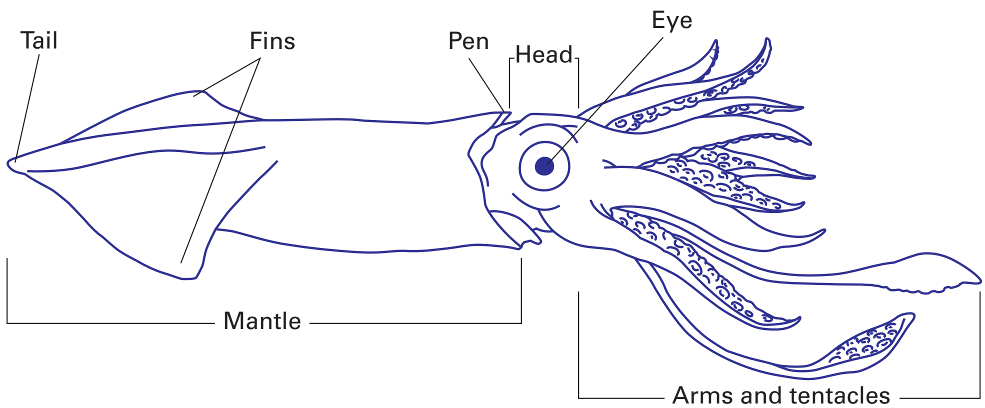

Figure 7.57 External anatomy of the squid

Procedure

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

Part A: External anatomy

2 Place the squid on the dissecting tray and lay it out flat.

3 Study the external anatomy diagram in Figure 7.57. Place your toothpick labels to identify all the external parts of your squid.

4 Count the number of arms the squid has. Arms are different from the tentacles, as they are shorter and have suction pads all the way along them.

5 Count the number of tentacles the squid has. Tentacles are longer than the arms and only have suction pads at the end.

6 Pick up the squid and hold the mantle like an ice-cream cone. Allow the arms to spread backwards over your hand. This will expose the mouth of the squid.

7 Locate the beak of the squid. It will be hard and brown.

Part B: Internal anatomy

8 Place the squid back on the dissecting tray and use the scissors to cut the mantle upwards from the tentacles to the top.
Be careful to cut away from the centre of the squid so you don't damage its organs.

continued…

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...continued

9 Open up the mantle of the squid, like opening a book.

10 Locate the gills, ink sac, heart and gonads (see Figure 7.58) and label them using your toothpicks. *Be careful not to puncture the ink sac at this point, as it will spill all over the squid.*

11 Once you have labelled all the internal parts of the squid, try to remove each organ very carefully and place around the dissecting tray.

Part C: Optional

12 Locate and remove the pen. The pen is a hard, transparent part of the squid's internal anatomy. It is the remains of a shell and offers support for the squid when moving. It is located in the centre of the mantle. Once you locate the pen, you should be able to peel it away from the surrounding tissue using your fingers.

13 Remove the ink sac from the squid. Place it on a dish to catch any mess, and try popping it with a toothpick. Use the pen of the squid or the toothpick to write your name on a piece of paper.

14 If you have successfully located and removed the beak and radula, observe these structures under a dissecting microscope.

Results

Develop a table to record the following:

- Main features identified (see Procedure)
- Number (how many times was this feature observed).

Discussion

1 Squids are classified in the class of Cephalopoda, which comes from the Greek words for 'head-foot'. Discuss how this name relates to the squid's anatomy.

2 Squids are classified in the phylum of Mollusca, which includes all shellfish. Discuss a probable reason for why the squid is classified this way when it does not have a shell.

3 Propose a reason why it would be beneficial for a squid to be able to produce ink.

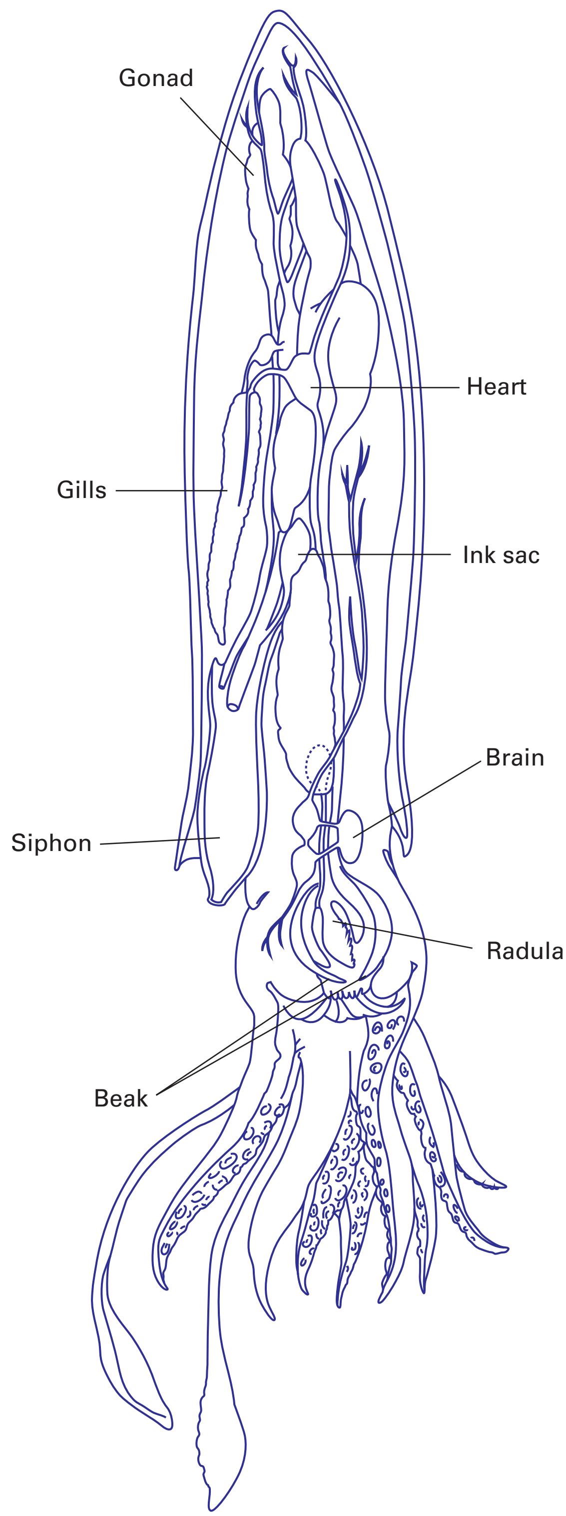

Figure 7.58 Internal anatomy of the squid

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Did you know? 7.3

Reptile roadkill

When you drive through the countryside, you often see reptiles killed by vehicles. This is because the bitumen that the road is made from holds the day's heat better than the sandy soil around it. At night, reptiles seek out warm rocks to keep themselves warm but, unfortunately, vehicles drive on that warm tarmac as well.

Figure 7.59 Reptiles looking for warmth may often be run over.

Quick check 7.11

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

Try this 7.10

Exploring the Animal kingdom

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

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

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

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

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

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Adaptations

Adaptations are special features that allow organisms to survive in their environment. These features develop randomly but give the organism an advantage over others of the same species and increase their chances of surviving and reproducing. This might mean that they can get more food, conserve more water or hide better from predators.

transpiration
the process by which plants lose water from their leaves

Figure 7.60 shows some adaptations of the kangaroo rat that allow it to survive the dry Australian outback.

Australian plants also have many brilliant adaptations that allow them to save water in the dry climate (see Figure 7.61 on page 275). Plants lose a lot of water from their leaves when water evaporates, this is known as **transpiration**.

Adaptation	Description
Behavioural	This is an action that the organism does in order to survive in its environment. For example, seeking shade from the hot sun.
Structural	This is the general shape or size of the organism or an external feature like big ears or webbed feet.
Physiological	This is an internal feature of the organism. It could be a chemical process like photosynthesis or a bodily function like sweating.

Table 7.4 Three types of adaptations

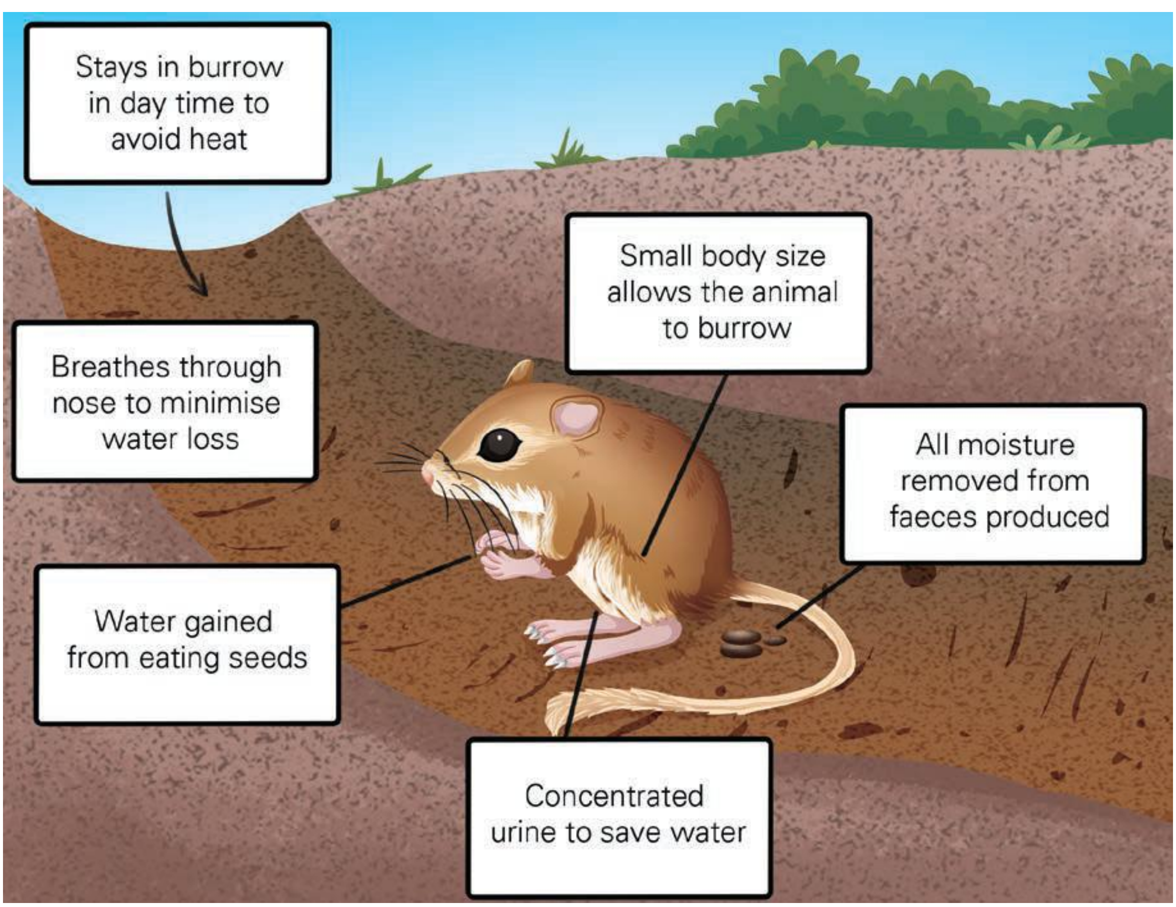

Figure 7.60 Adaptations of the kangaroo rat (genus: *Dipodomys*)

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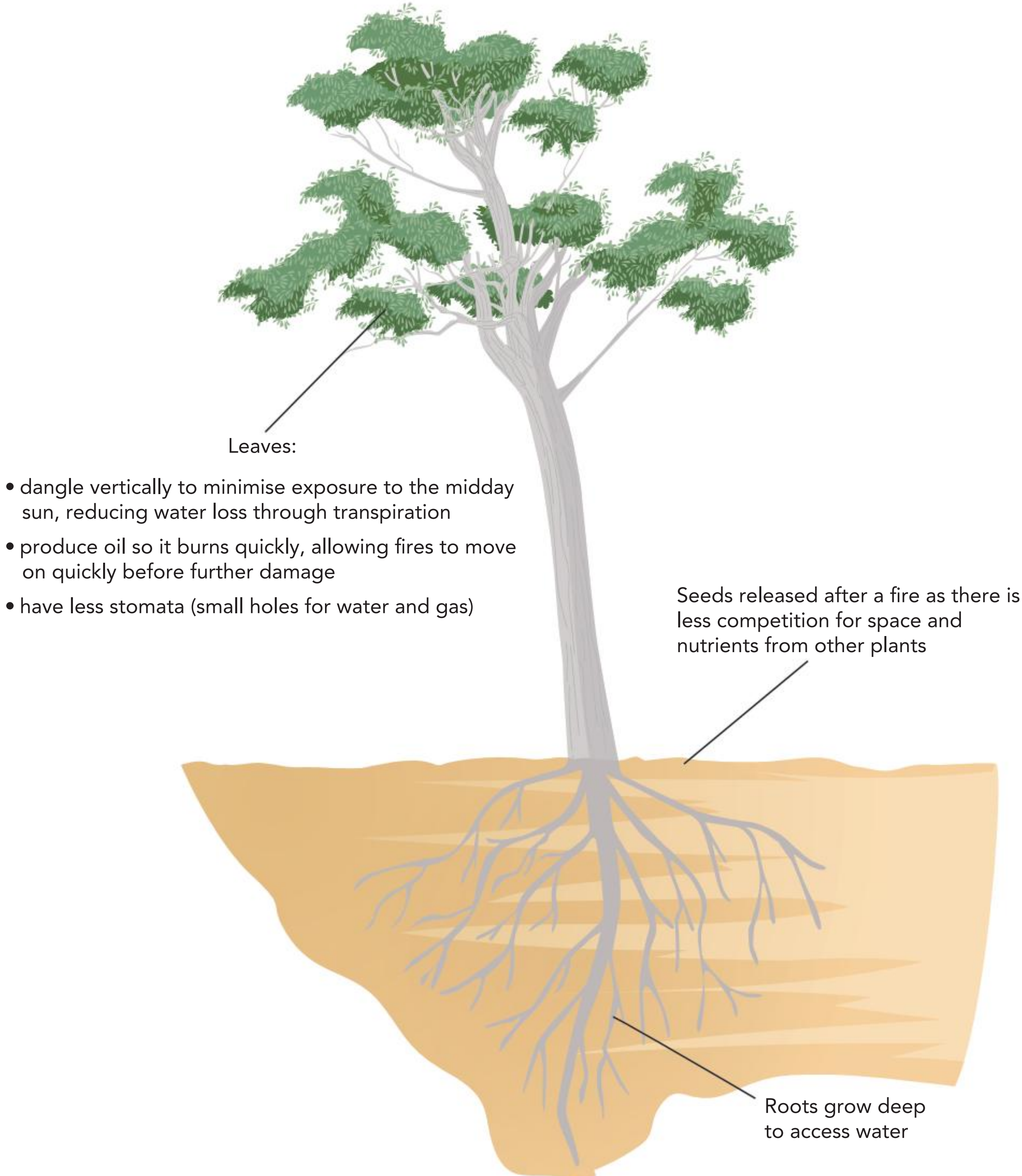

Figure 7.61 Adaptations of the *Eucalyptus rossii* tree

Quick check 7.12

1 Describe why adaptations are important.
2 Classify the adaptations of the eucalyptus tree as behavioural, structural or physiological (see Figure 7.61).

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Section 7.4 questions

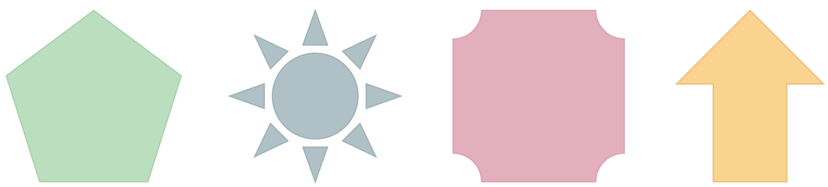
QUIZ

Remembering

1 **Recall** where you would find living sponges.
2 **Name** three examples of an arthropod.

Understanding

3 **Describe** how two of the adaptations of a *Eucalyptus rossii* tree allow it to conserve water.
4 **Identify** the characteristics you would use to differentiate between the following animals:
  a jellyfish and earthworm
  b kookaburra and koala
  c frog and tuna.
5 **Identify** whether each of the following shapes has bilateral or radial symmetry.



a b c d

Applying

6 **Describe** the difference between a vertebrate and an invertebrate.
7 **Explain** why reptiles can live in deserts whereas amphibians need a moist environment.
8 **Classify** the adaptations of the kangaroo rat as behavioural, structural, physiological (see Figure 7.60).

Analysing

9 The sea pig (*Elpidiidae scotoplanes*) is an unusual animal that lives on the bottom of the ocean. It can only survive in salty water. It has feeding tentacles and five to seven pairs of feet. Its body has bilateral symmetry and is soft.
  a **Outline** which animal phylum the sea pig shares features with.
  b **Outline** which phylum you believe the sea pig belongs to and why.
10 **Select** an Australian animal and produce an annotated diagram **proposing** how its adaptations allow it to survive in its environment.

Evaluating

11 **Explain** the reason why many animals that live in water are ectotherms rather than endotherms.
12 **Compare** and **contrast** animals found in the Amphibia and Aves classes.

Figure 7.62 A sea pig

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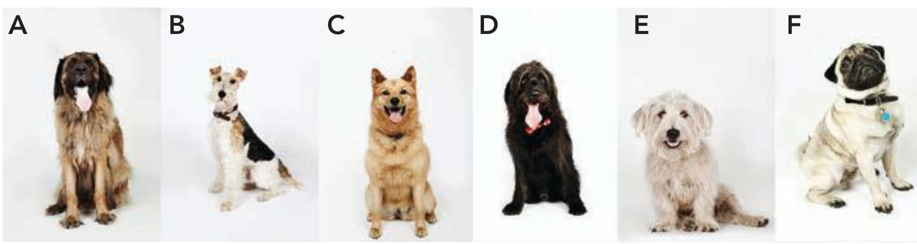
Chapter review

Chapter checklist

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

SCORCHER

Success criteria		Check
7.1	**I can explain the reasons for classifying living organisms.** e.g. Explain why organisms need to be grouped.	
7.1	**I can group organisms on the basis on their similarities and differences.** e.g. Recall some of the issues of classifying based on physical characteristics.	
7.1	**I can use keys to identify organisms** e.g. Construct a dichotomous key to identify the dogs **A–F** below. 	
7.2	**I can explain how biological classification has changed over time.** e.g. State who developed the binomial system of classifying living organisms.	
7.2	**I am able to classify using a hierarchical system.** e.g. Identify the missing words: Kingdom, ______, Class, Order, ______, Genus, Species.	
7.2	**I can use scientific convention when naming species.** e.g. Explain the term 'binomial nomenclature'.	
7.3	**I can distinguish the six kingdoms of living organisms.** e.g. Name the kingdoms of living organisms.	
7.4	**I can identify adaptations of Australian plants and animals.** e.g. Name some adaptations of the kangaroo rat that enable it to survive the Australian outback.	
7.4	**I can distinguish between behavioural, structural and physiological adaptations.** e.g. Decide what type of adaptation the ability to sweat is.	

Reflections

1 What **connections** come to mind when you think about classification and your everyday life?
2 What new concepts have **extended** your thinking about classification?
3 What information did you find **challenging** or confusing?

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Data questions

Use the following figures to answer the questions below.

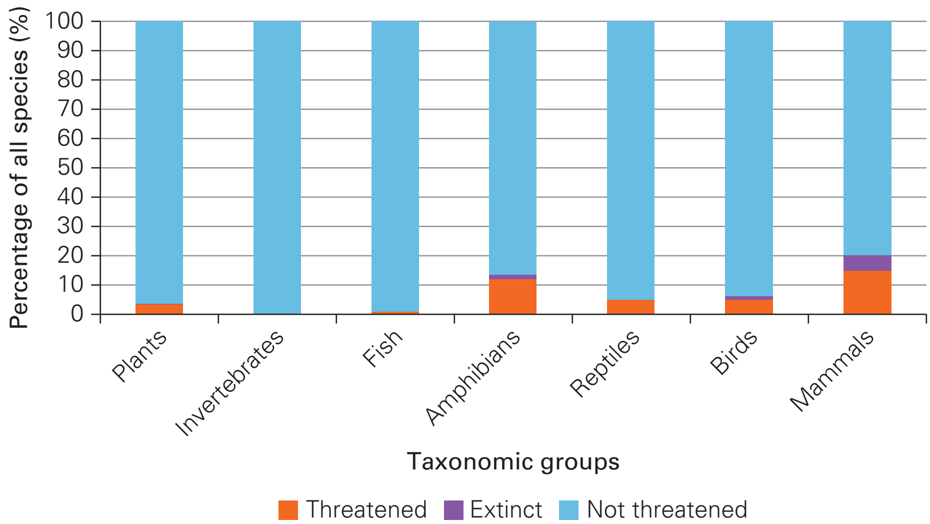

Figure 7.63 The conservation status of different taxonomic groups in Australia

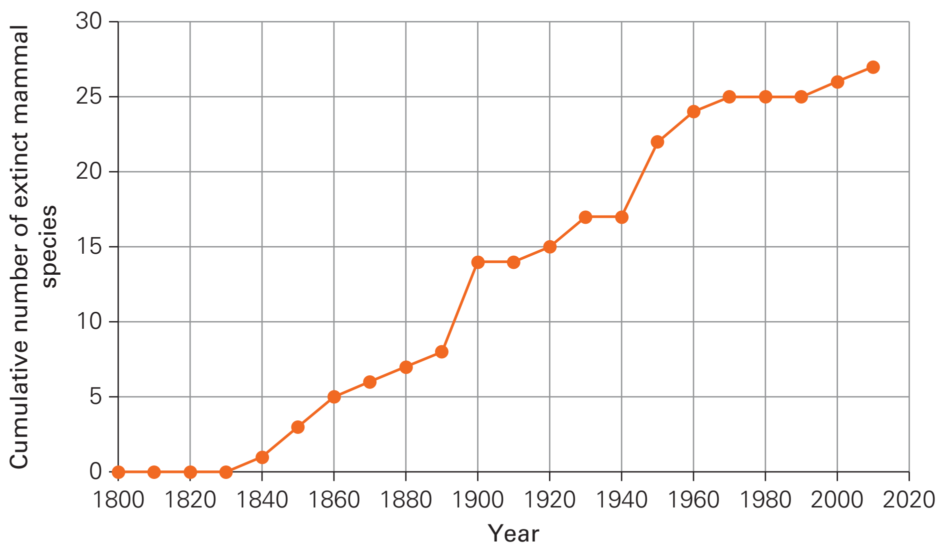

Figure 7.64 The cumulative number of extinctions of mammal species in Australia since 1800

1. **Identify** the taxonomic group that is under the least threat, using Figure 7.63.
2. There are 828 bird species in Australia. Six per cent of these species are considered as threatened. **Calculate** the number of species of birds that are considered as threatened.
3. **Calculate** the average rate of mammal extinctions per year from 1800–1920, using Figure 7.64.
4. **Organise** the taxonomic groups in the graph from most threatened to least threatened, using Figure 7.63.
5. **Contrast** the number of extinct and threatened species in mammals with the number of extinct and threatened species in amphibians in Figure 7.63.
6. **Predict** the number of extinct Australian mammal species in the year 2020, using Figure 7.64.
7. **Infer** the two worst decades for Australian mammal extinctions, using Figure 7.64.
8. **Justify** your answer to Question **7**.

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STEM activity: Biomimicry

Background information

Engineers often work with designers and architects to use the natural world as inspiration for solving engineering problems and to develop new products that improve our lives. Some examples of biologically inspired designs include Velcro® (based on those pesky prickly seeds that stick to your socks on a bush walk), adhesives that mimic the sticky feet of geckos, and sonar navigation technology (inspired by the echolocation abilities of bats).

This new area of science is called 'biomimicry', which means to imitate life or to learn from nature.

Figure 7.65 Bobsled outfits were designed to mimic shark skin. They are made from a woven ribbing fabric that reduces drag while still allowing movement.

Design brief: Apply biomimicry to solve a human problem.

Activity instructions

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

Suggested materials

- A3 and A4 paper
- pens, pencils
- ruler

Research and feasibility

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

Major causes of traffic	Effects	What would animals do here?
Blockages on the roads	Traffic comes to a complete stop	If there is anything blocking an ant's path, an ant will remove it, which allows the other ants to move past without interference.

2 Explain the problem and the cost on society (including environmental, social, and psychological costs).

Design

3 Identify your plant, insect or other animal and its scientific name, and briefly describe why mimicking the organism could help with a prospective solution to the human problem.

4 Describe the unique features of your organism. Are these characteristics linked to its classification?

5 Describe how you mimic the material, colour and structure of the organism to design something new.

6 List the materials their physical properties, as well as what purpose it was used for. You may wish to create a table.

Create

7 Create a scale drawing of your invention, including a front and side view of your invention.

8 Describe your design by listing the special features of the design and which aspect of your organism inspired those features.

Evaluate and modify

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

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Chapter 8
Cells

Inquiry questions

What do all living things have in common?
Why do cells look different?
How do cells work?

PRE-TEST

Chapter introduction

Everything can be broken down into its smallest components. A house is made of timber, pipes and wires; cakes are made of flour, eggs and sugar; and all living organisms are made of cells. Cells are the basic building blocks of life, meaning that they are the smallest unit that can, potentially at least, carry out the processes that all living things do, such as moving, producing energy, sensing their environment, growing, repairing, excreting and absorbing nutrients. In this chapter, you will explore the basic components of cells and the many types of cells that can be found in the natural world.

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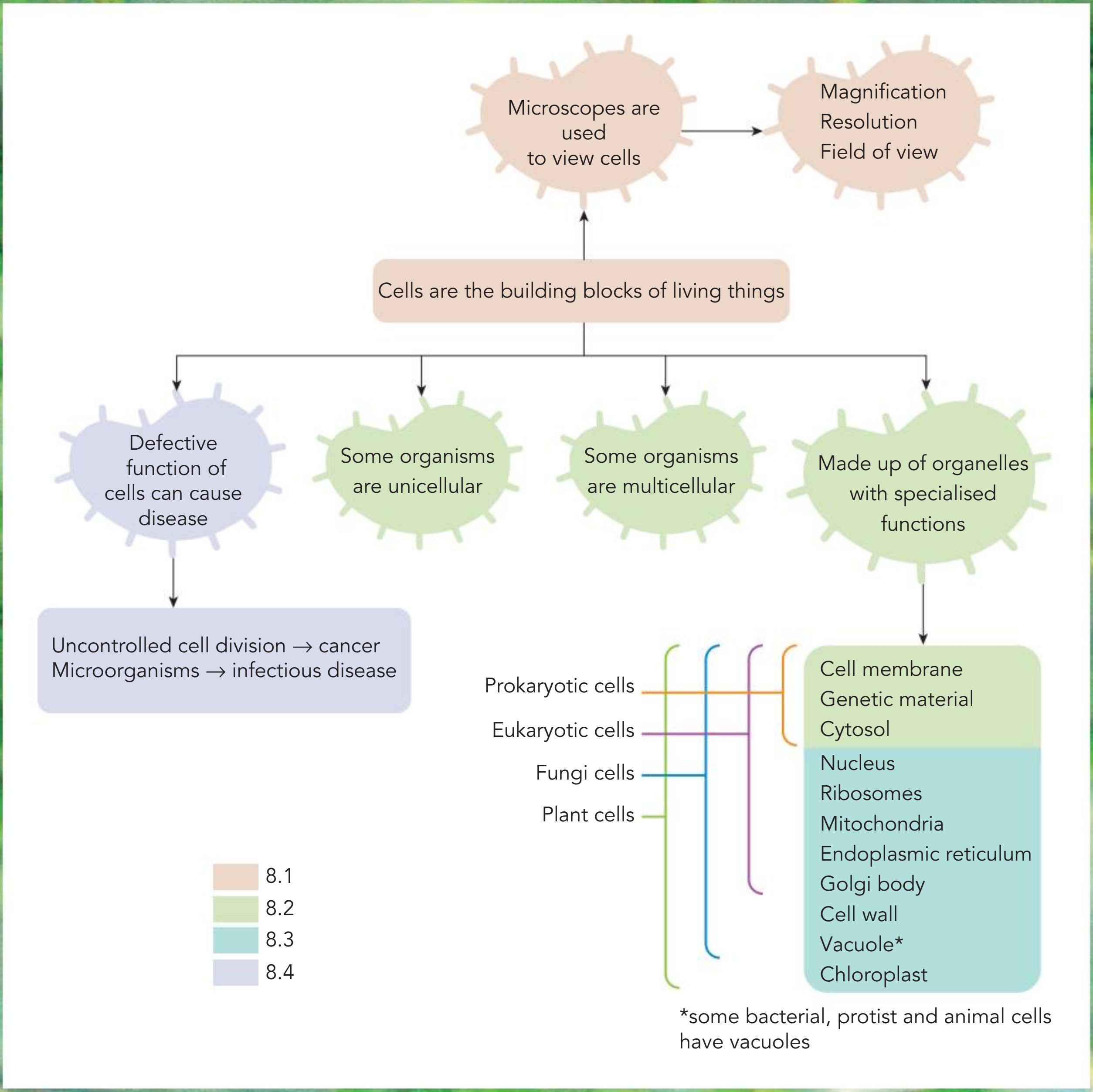
Chapter map



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8.1 Microscopes and cells

Learning goals

1. To explain how microscopes allow us to observe cells.
2. To describe cell theory.
3. To describe the size of cells.

DOC WORKSHEET

The microscope

Throughout this chapter, you will explore the structure and function of cells. However, you would not have been able to learn this information without the invention of the microscope. It all began about 500 years ago, when scientists used hand-held magnifying glasses to view small **macroscopic** specimens – these were large enough to be visible to the naked eye. Scientists wished to view smaller and smaller specimens, and they soon found that using two lenses together enabled them to do so. This discovery led to the invention of the first light microscope. The light microscope that you use today in school is not very different from those used by scientists hundreds of years ago, but the technology used to produce today's lenses is more advanced and enables us to see things at higher magnifications. Anything that can only be seen clearly with the use of a microscope is described as **microscopic**.

macroscopic
visible to the naked eye

microscopic
anything that can only be seen clearly with the use of a microscope is described as microscopic

Did you know? 8.1

The scientist who first discovered single-celled organisms was Antonie van Leeuwenhoek. He called these organisms 'animalcules', meaning 'little animals'. We now call these animalcules 'microorganisms'.

Figure 8.1 Animalcules

Explore! 8.1

The history of the microscope

In 1665, Robert Hooke published a book based on his observations of the microscopic world. He was able to do this because he had built a compound microscope with a twist-operated focusing mechanism – this had never been seen before. He further improved the microscope by placing a water flask beside the microscope to focus light from an oil-lamp onto his specimens to illuminate them brightly.

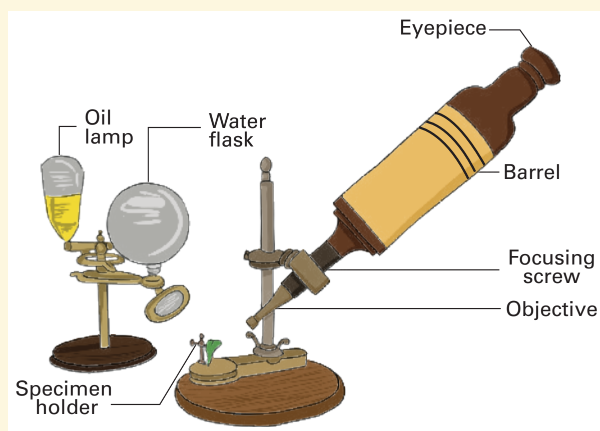

Figure 8.2 The Hooke microscope (circa 1660)

1. Find out about the role of the following scientists in the development of the microscope: Professor Pratibha Gai-Boyes, Professor Ed Boyes and Ian Wright; Robert Hooke and Antonie van Leeuwenhoek; Frits Zernike; Marvin Minsky; Ernst Ruska; and Gerd Binnig and Heinrich Rohrer.
2. Using A3 paper, draw an annotated timeline showing who developed what and when.

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Parts of a microscope

Although some microscopes are more advanced than others, most of those you use at school are light microscopes that have the same basic components. The microscopes you use have at least two lenses: the eyepiece (ocular) lens and the objective lens. They also have a light source, a stage on which to place specimens, and knobs to adjust the focus. The monocular microscope shown here is for use with one eye. Binocular microscopes can be used with both eyes.

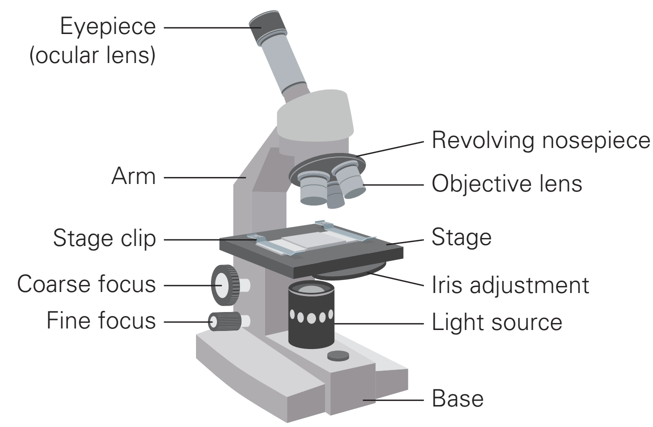


Figure 8.3 The parts of a monocular microscope

Try this 8.1

Parts of the microscope

Draw up a table with the parts of a microscope in the left column. Find out the function of each part, and put this information in the right column.

Microscope terms

When you use a microscope, you will often encounter special terms. Table 8.1 summarises some key terms.

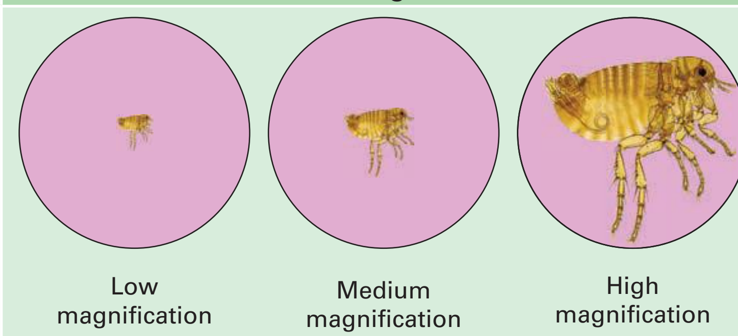
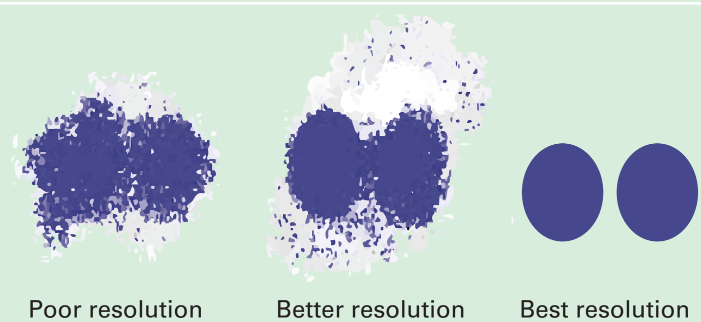
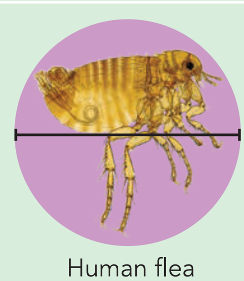
Term	Definition	Image
Magnification	How much the image of the specimen or object is increased in size (i.e. how much you are zooming in)	
Resolution	How detailed and clear the image is (i.e. how easy it is to tell two separate objects apart)	
Field of view (FOV)	How much of the object you can see when you look through the eyepiece	

Table 8.1 Some key terms used in microscopy

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Advances in technology

Binocular microscopes have an eyepiece for each eye. There are two types: simple binocular and stereoscopic. Simple binocular microscopes have one light path from the specimen, which is split and led to both eyepieces, so each eye has the same view. Therefore, the image looks flat (2D). Stereoscopic ('stereo') microscopes, which are much more expensive, lead two separate light paths from the specimen to each eye, so they have different views. The image has depth (3D). This is useful for manipulating or dissecting specimens, and the magnification does not have to be very large.

Light microscopes are limited in their usefulness. They can magnify a specimen up to 1500×, which is enough to make **bacteria** visible. However, the resolution at this magnification is not very high, and so light microscopes do not enable you to view anything smaller than bacteria in any great detail.

bacteria
very small prokaryotic organisms that have cell walls, but lack membrane-bound organelles and a nucleus

In order to see things that are smaller than bacteria, scientists invented a different type of microscope, called an *electron microscope*. This microscope uses tiny particles called electrons, instead of light, to view an object. Electron microscopes have a magnification of around 10 million times and very high resolution. Since the invention of the electron microscope in 1933, we have been able to observe the structure of extremely small objects in high detail. There are now two types of electron microscope:

- transmission electron microscope (TEM) – the specimen to be viewed is sliced very finely and the internal structure can be seen
- scanning electron microscope (SEM) – the specimen to be viewed is not sliced, and the external surface can be viewed.

Unfortunately, electron microscopes are extremely expensive, and all specimens that are observed have to be prepared in a way that requires them to be killed first.

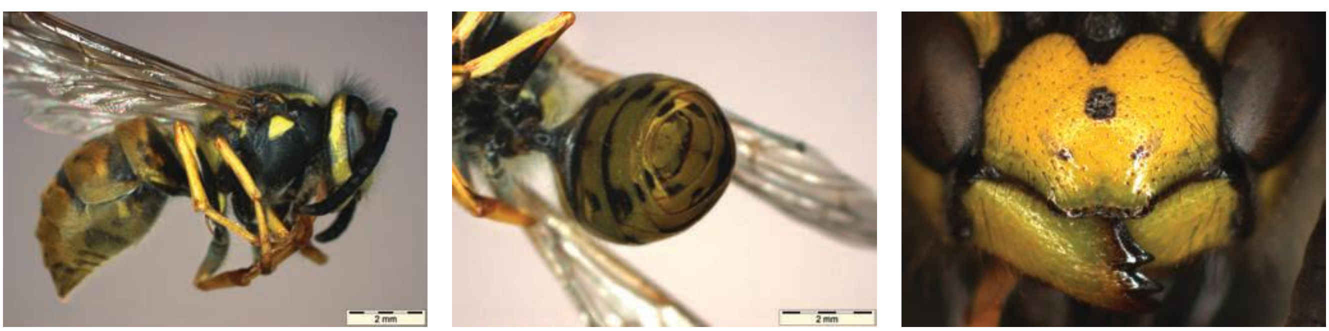

Figure 8.4 Stereo microscope images taken of a European wasp show its full body, its abdomen and its mandible.

Figure 8.5 Examples of specimens as seen through a TEM (left: Wolbachia bacteria within an insect cell) and a SEM (right: a larva)

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Explore! 8.2

Types of microscopes

1 Do some research into the different types of microscopes that are used today: monocular microscope, stereo microscope and electron microscope.
2 Copy and complete the following table.

Type of microscope	Magnification	Resolution	Advantages	Disadvantages	Example of what can be seen
Monocular light microscope					
Stereoscopic light microscope					
Electron microscope					

Quick check 8.1

1 State the maximum magnification of the monocular microscope, the stereo microscope and the electron microscope.
2 State what microorganisms were originally called.
3 Define the following key terms, in your own words: magnification, resolution, field of view.
4 Organise the different types of microscopes, in order from most powerful to least powerful.

Practical 8.1

Using a microscope

Aim

To become proficient in using a microscope.

Materials

- glass microscope slide
- light microscope
- newspaper
- scissors
- sticky tape

Be careful

Ensure that the microscope is carried appropriately. Carry it with one hand holding the arm and one hand under the base. Do not use the coarse focus knob to cause the objective lens to touch the glass slide and damage it.

Procedure

1 Cut one word out of a newspaper.
2 Attach the word to the centre of a glass slide, using sticky tape.
3 Set the lowest magnification or smallest objective lens in place. Turn the coarse focus knob until it is as close to the stage as it will go.
4 Place the slide on the stage of the microscope and secure it in place with the clips.
5 Using the coarse focus knob, focus on the word.

continued…

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…*continued*

6 Draw what you can see in the field of view at this lowest magnification. Record the magnification next to your drawing. In order to calculate the magnification, you will need to multiply the magnification of the eyepiece (ocular) lens by the magnification of the objective lens. For example, if the eyepiece is 10× magnification and the objective lens is 4× magnification, then the overall magnification is 10 × 4 = 40×.
7 Try moving the stage left and right, forwards and backwards, and note what you observe about the movement of the image.
8 Repeat steps **3–6** for each of the optical lenses. You no longer use the coarse focus knob to focus now; use only the fine focus knob to focus your specimen.

Results

Your results will consist of:

- your drawings of the field of view using the different objective lenses. Include the magnification of each drawing.
- your notes about what happens when you move the stage left and right, forwards and backwards.

Discussion

1 Explain what happened to the word when viewed under the microscope at low magnification.
2 Describe what happened when you increased the magnification using the different objective lenses.
3 Describe what you observed as you moved the slide – did the word go in the same direction as the direction in which you moved the slide?
4 What did you notice about the orientation of the letters in the word? Were they the right way up? Back to front? Explain.
5 As the magnification of an image increases, the resolution decreases. State the magnification at which you would have had the lowest resolution.
6 Explain what happened to the field of view as you increased the magnification of the objective lens.
7 Outline a safety precaution you would use when observing a specimen using the highest magnification objective lens.
8 Summarise the advantages and disadvantages of using a light microscope.

Cell theory

Robert Hooke built a compound microscope that lit up the specimen he was viewing. Because of this invention, he was able to observe that a dead cork plant appeared to be made of small blocks. He named these blocks ‘cells’ because they looked like the small identical ‘cells’ that monks lived in at the time.

Nearly 200 years later, after many other scientists had observed and catalogued many more types of cells, a *cell theory* was proposed.

This first cell theory made the following statements.

- Cells make up all living things.
- Cells are the basic building blocks of all living things.
- All cells form spontaneously from their environment, in a similar way to crystals forming.

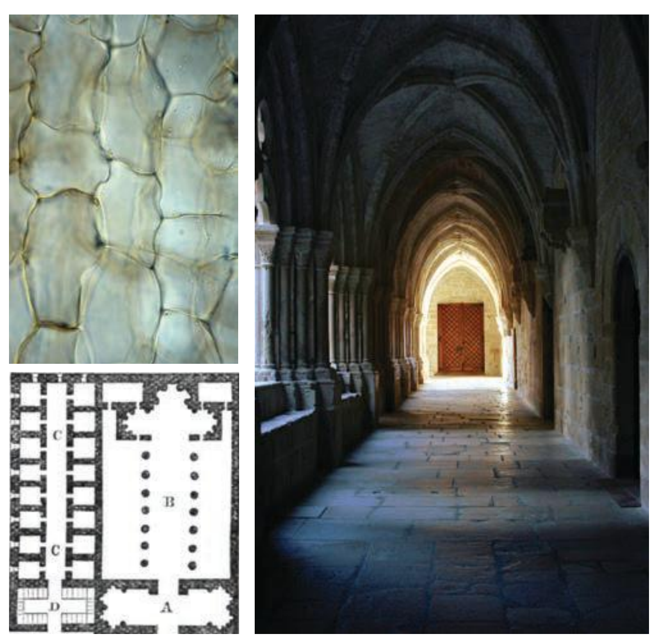

Figure 8.6 The cork cells (top left) Hooke observed looked like the monks' cells in the building plans (bottom left) of monasteries (right).

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We now know that the third part of this theory is incorrect, as cells do not just pop into existence. Modern cell theory has expanded on earlier theories.

- Cells make up all living things.
- Cells are the basic building blocks of all living things.
- All new cells are produced from existing cells.
- All cells contain genetic information, which is passed from cell to cell during cell division.

Size of a cell

Cells are extremely small and most cells cannot be seen with the naked eye. That is why it was not until the invention of the microscope, around 350 years ago, that we even knew cells existed. If you take a look at your arm you can see skin and hair, but it is impossible to see the individual skin cells. They are described as being microscopic.

You may wonder why cells come in many sizes. The main reason is simple: their size and structure depends on their function. Red blood cells are biconcave, small and carry oxygen in your blood to different parts of your body. When mature, they don't have a **nucleus**, and so there is more space to carry haemoglobin, a red pigment that holds oxygen. Being **biconcave** increases surface area, and their small size allows the red blood cells to squeeze through tiny blood vessels to deliver oxygen throughout your body.

nucleus
part of a cell that contains the genetic material

biconcave
concave on both sides

Figure 8.7 Red blood cells

Did you know? 8.2

Egg cells

Cells come in many shapes and sizes. The largest cells are eggs – an unfertilised egg is a single cell. Each egg holds the genetic information for the female of the species, and if fertilised, will eventually grow into a new individual. Egg cells are 'macro' cells. Macro means 'large-scale', and so they can be seen with the naked eye – that is, without a microscope.

Figure 8.8 The largest cells are eggs, and the largest of all is the ostrich egg.

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Quick check 8.2

1 Name the largest cell in the world.
2 Contrast the terms 'micro' and 'macro'.
3 Explain why cells come in many shapes and sizes.

Try this 8.2

Cell size

In science, it is important to use appropriate units when measuring different objects. You would not measure the size of a bedroom in kilometres, or the size of an ant in metres. Therefore, when you measure cells, it is important to use a very small unit. This is usually a micrometre (μm). A micrometre is 1000 times smaller than a millimetre (mm).

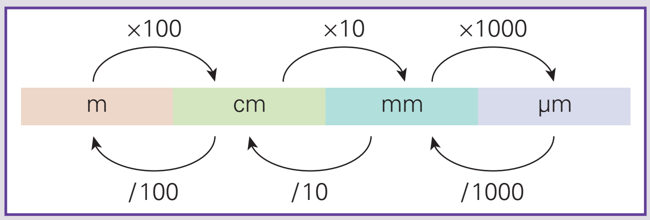
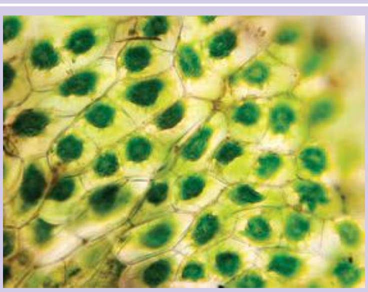
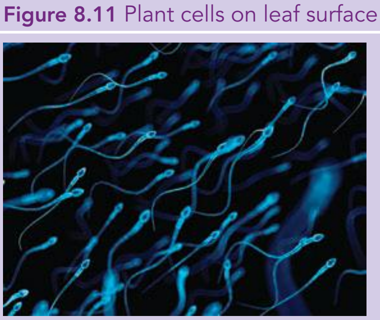


Figure 8.9 Conversions needed for different measurements

Using Figure 8.9, convert the cell sizes below into millimetres (mm) or micrometres (μm).

Cell type	Size (mm)	Size (μm)
 **Figure 8.10** Red blood cells	0.0065	
 **Figure 8.11** Plant cells on leaf surface		100
 **Figure 8.12** Sperm cells	0.05	

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Section 8.1 questions

QUIZ

Remembering

1 **Define** the term 'microscopic'.
2 **State** the modern cell theory.
3 **State** the function of each of the following parts of a microscope.
- Stage
- Eyepiece
- Objective lens
- Coarse focus knob
- Fine focus knob

Understanding

4 **Outline** the structure and function of a red blood cell.
5 **Summarise** the advantages of using:
  a a monocular light microscope
  b a stereo microscope.
6 **Outline** the contribution of Robert Hooke to our understanding of the cell.
7 Fill in the magnification of the microscope when using the following objective lenses:

Eyepiece	Objective lens	Magnification of specimen
×10	×10	
×10	×5	
×10	×80	

Applying

8 **Suggest** the reason that different units are used to measure different-sized objects.
9 A nanometre (nm) is 1000 times smaller than a micrometre (μm). Generally, a virus is around 0.0225 μm in size. **Calculate** this size in nanometres.
10 **Summarise** why it is important to turn the coarse focus knob until it is as close to the stage as it will go, before putting the slide on the stage. (Think about the safety notes.)
11 Copy and complete the following table.

Specimen	Size		
	Nanometres (nm)	Micrometres (μm)	Millimetres (mm)
Atom	0.1		
Bacterium		1	
Virus	35		
Animal cell		10	
Chicken egg			50

Analysing

12 **Distinguish** between a TEM and an SEM.
13 **Demonstrate** how you would determine the size of a cell.
14 **Classify** the following specimens into three groups: those that can be seen easily with the naked eye; those that can be seen with a light microscope; and those that can be seen only with an electron microscope. (Some might belong in more than one group.)
- Plant cell (100 μm)
- Frog egg (1 mm)
- Red blood cell (7 μm)
- Phytoplankton (2 μm)
- Chicken egg (50 mm)
- Virus (35 nm)
- Bacterium (1 μm)

Evaluating

15 **Create** a detailed set of step-by-step instructions for a Year 6 student, on how to use a microscope safely.
16 **Justify** the statement 'the development of microscopes has changed our understanding of cells'.

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8.2 Organelles

Learning goals

1. To name the features common to all cells.
2. To describe the structure and function of the main organelles found in eukaryotic cells.

DOC WORKSHEET

All cells

Everything that we classify as living is made up of one or more cells. People, trees, fish and mushrooms are made up of many different cells working together, and are known as **multicellular**. These cells depend on each other and cannot survive alone. Organisms in the kingdoms Bacteria, Protista and Archaea are made of single cells, and are referred to as **unicellular**. Each of these single cells carries out all the processes needed to stay alive, by itself. Generally, unicellular organisms are quite simple and are similar to some of the oldest forms of life found on Earth, whereas multicellular cells are specialised and much more complex.

All cells, no matter how simple, contain the same three components:

- a **cell membrane**
- **genetic material**
- **cytosol**.

multicellular
made of many cells

unicellular
made of just one cell

cell membrane
the barrier that separates the inside of the cell from the external environment

genetic material
the material containing the code that allows the cell to produce copies of itself and to regulate the functions within the cell

cytosol
the water-based mixture that fills the cell, containing different molecules, large and small; many chemical processes that happen within a cell occur in the cytosol

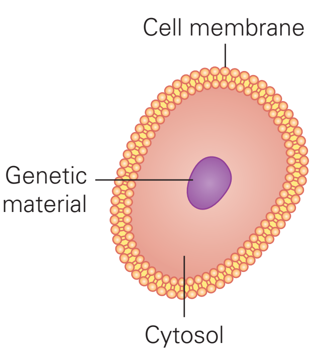

Figure 8.13 All cells, no matter how simple or complex, contain these three components.

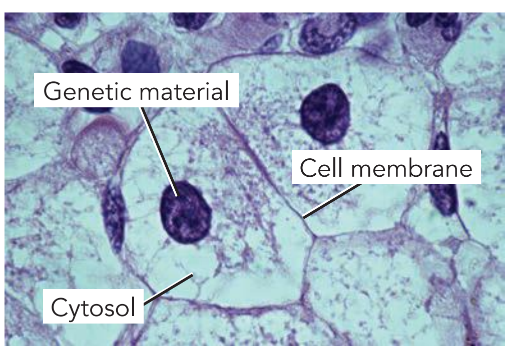

Figure 8.14 Shown here are human liver cells.

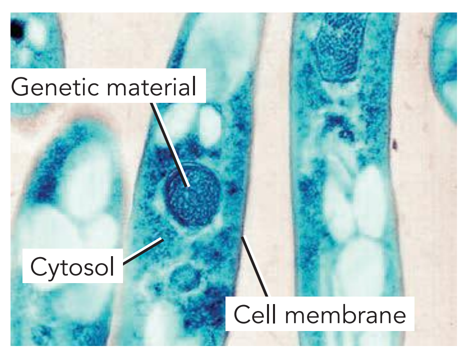

Figure 8.15 Shown here are *Bacillus anthracis* bacteria, which are unicellular organisms.

VIDEO
What three components do all cells have in common?

Quick check 8.3

1. Define these terms and include examples of each: unicellular, multicellular.
2. Recall the three components of all cells.

Organelles

Simple and complex cells

prokaryote
unicellular organisms that lack membrane-bound organelles and a nucleus

eukaryote
any cell or organism that possesses membrane-bound organelles and a nucleus

All cells can be grouped into two main categories: **prokaryote** (simple) and **eukaryote** (complex). Prokaryotes are unicellular organisms such as bacteria, while eukaryotes can be unicellular or multicellular. Examples of prokaryotes are animals, plants, fungi and protists. The two categories of cell type are based on the structures found inside each cell. All cells have a membrane, cytosol and genetic material, but eukaryotic cells are more complex and also have many membrane-bound structures, including a nucleus, that carry out specific functions.

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Prokaryotic cells do not have a nucleus or any membrane-bound structures.

The term 'prokaryote' means 'before (*pro*) nut, kernel (*karyon*)', meaning they were present before eukaryotic cells. The specialised structures inside cells are known as **organelles**, because they are like 'mini' organs with specific jobs.

organelle
a specialised structure in a cell, which has a specific function or job

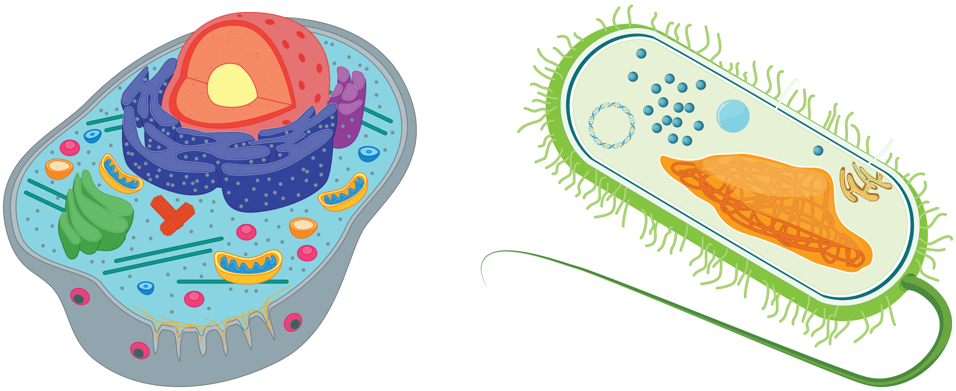

Figure 8.16 Eukaryotic cell (left) vs. prokaryotic cell (right). Can you identify the cell membrane, genetic material and cytosol in each cell type?

Try this 8.3

Prokaryotes vs. eukaryotes

For the following list of organisms, identify which are examples of prokaryotic cells and which are examples of eukaryotic cells.

Mushrooms	Archaea	Cyanobacteria	Tapeworms
Grass	Potatoes	Fruit flies	*Escherichia coli*

The cell city

Although all cells contain the structures described previously, only complex eukaryotic cells contain the specialised membrane-bound organelles that you are going to read about in this section. It is helpful to think of the cell as a city. A city has many needs, and each organelle caters for those needs. This idea is developed further in the STEM activity for this chapter.

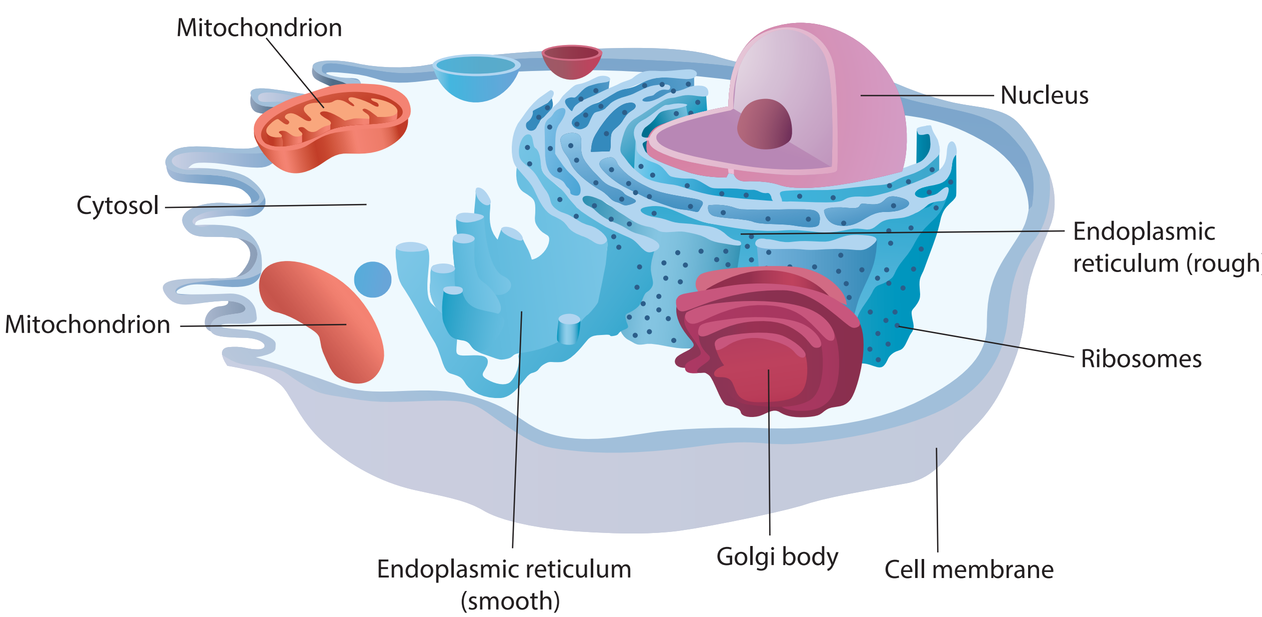

Figure 8.17 A eukaryotic cell with labelled organelles

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Nucleus

The nucleus is a large structure that holds the genetic material of a cell. It is like the brain of the cell and controls all of its functions. In a city, the nucleus would be the top level of government, which keeps all the plans and blueprints and makes all the important decisions.

double helix
a description of the structure of DNA where two strands wind around each other like a twisted ladder

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

Genetic material

The genetic material, or deoxyribonucleic acid (**DNA**), is found in every cell. DNA is the coded information that makes you who you are and tells every cell what to do. The code has all the instructions that a living organism needs to grow, reproduce and function. A DNA molecule is shaped like a twisted ladder, and this shape is called a **double helix**. In the cell city, DNA would be the plans and blueprints which the top level of government uses to keep everything running smoothly.

Figure 8.18 Top left: Graphic representation of a nucleus. Top right: an electron microscope image of a nucleus within a plant cell. Bottom: Parliament House, Canberra. The nucleus makes all the major decisions for the cell city.

Figure 8.19 Graphic representation of a DNA molecule

Did you know? 8.3

The Moon and back!

We have trillions of cells in our body and each one contains DNA. If you stretched the DNA in one cell all the way out, it would be over two metres long! This means if you lined up the DNA from all your cells, it would reach to the Moon and back approximately 1500 times!

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Cell membrane

The cell membrane is a thin double layer of molecules that separates the inside of the cell from its external environment, and controls what enters and leaves the cell. The cell membrane is like a protective border around the cell city, controlling who enters and leaves.

Cytosol

Cytosol is a water-based mixture of organelles and small and large molecules that fills the cell. In eukaryotic cells, it refers to the liquid outside the organelles. Although it appears mostly transparent in a light microscope, it has a very complex structure, with regions that vary greatly in concentration and viscosity, so parts of it may resemble jelly. Many of the chemical reactions that cells require to function take place between molecules dissolved in the water of the cytosol, controlled by enzymes. Many nutrients and other materials may be stored in the cytosol.

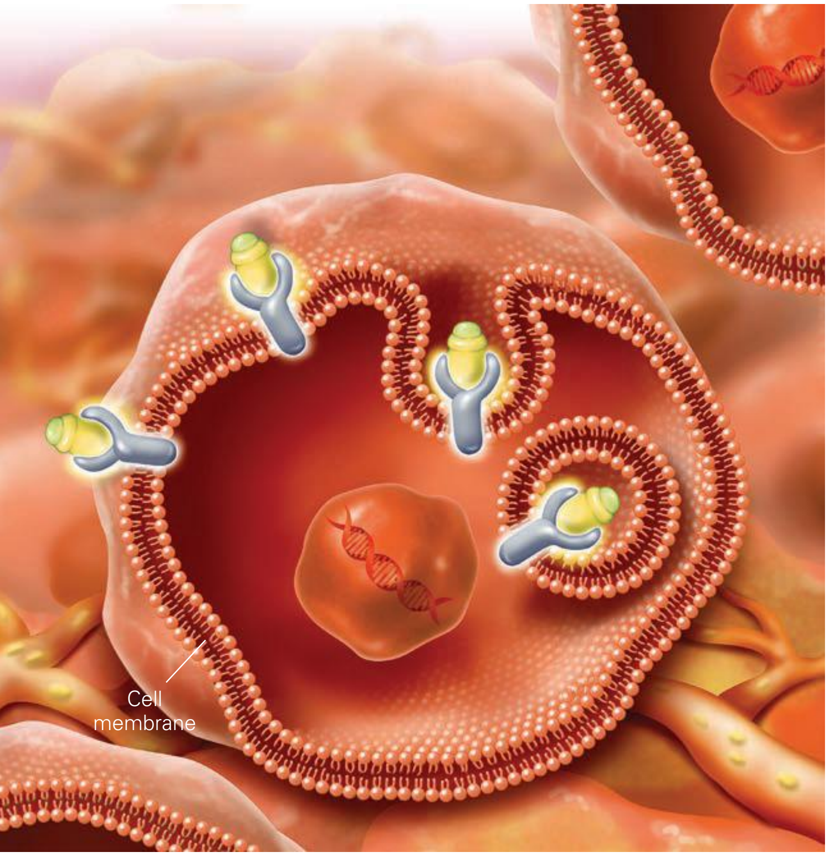

Figure 8.20 The cell membrane provides 'border security' for the cell.

Using the city analogy, we would say the cytosol makes the city to be like Atlantis, or a coral reef – it is an underwater city. The water fulfills the same functions for the cell city that the air does for us.

Ribosomes

Ribosomes are very small structures that 'read' the codes sent to them in the genetic material and use these to produce proteins that the cell needs to create structures and carry out different functions. Ribosomes would be the factories of the cell city, producing bricks, cars and different tools for the city to use.

Mitochondria

Mitochondria (singular: mitochondrion) are where sugars from food are turned into energy, in a process called **cellular respiration**. The output is a substance called ATP, the cell's source of energy. Cells use this energy for many tasks, such as moving things into and out of the cell, and cell growth, repair and reproduction. The mitochondria can therefore be thought of as the power station of the cell.

Endoplasmic reticulum

The **endoplasmic reticulum** (ER) is a large folded membrane attached to the nucleus. The name 'endoplasmic reticulum' might sound complicated but it is just a description of what it does: *endo* (inside), *plasmic* (cytoplasm), *reticulum* (network). There are two types of ER in the cell. When ribosomes are attached, the ER is rough, and it is involved in the synthesis and transport of proteins. If no ribosomes are attached, then it is smooth and is involved in the making of lipids and **steroids**. The ER is basically a highway that produces, then connects and delivers substances to different parts of the cell.

ribosome
a structure in a cell that reads genetic information to produce protein from amino acids

mitochondrion
a structure in a cell that converts the energy from food into the form needed by the cell during cellular respiration

cellular respiration
a process that occurs inside the mitochondria, where oxygen and glucose react to form carbon dioxide and water, producing useable energy

endoplasmic reticulum
a network of tubes within a cell that are involved in protein and lipid synthesis

steroids
compounds made by cells that are used in cell membrane stability and for cell signalling

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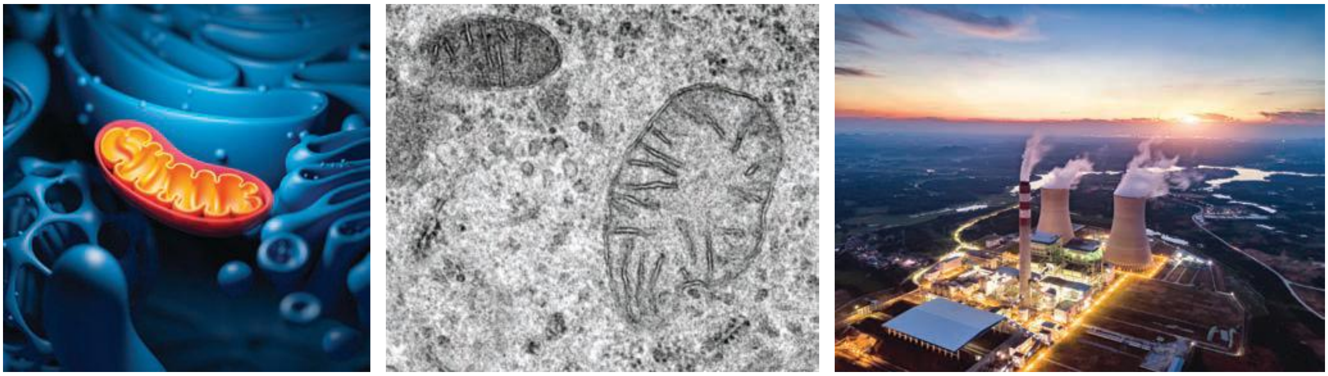


Figure 8.21 Left: Graphical representation of a mitochondrion. Middle: An electron microscope image of mitochondria. Right: The mitchondria produce energy from glucose, much like power stations can produce electricity from coal.

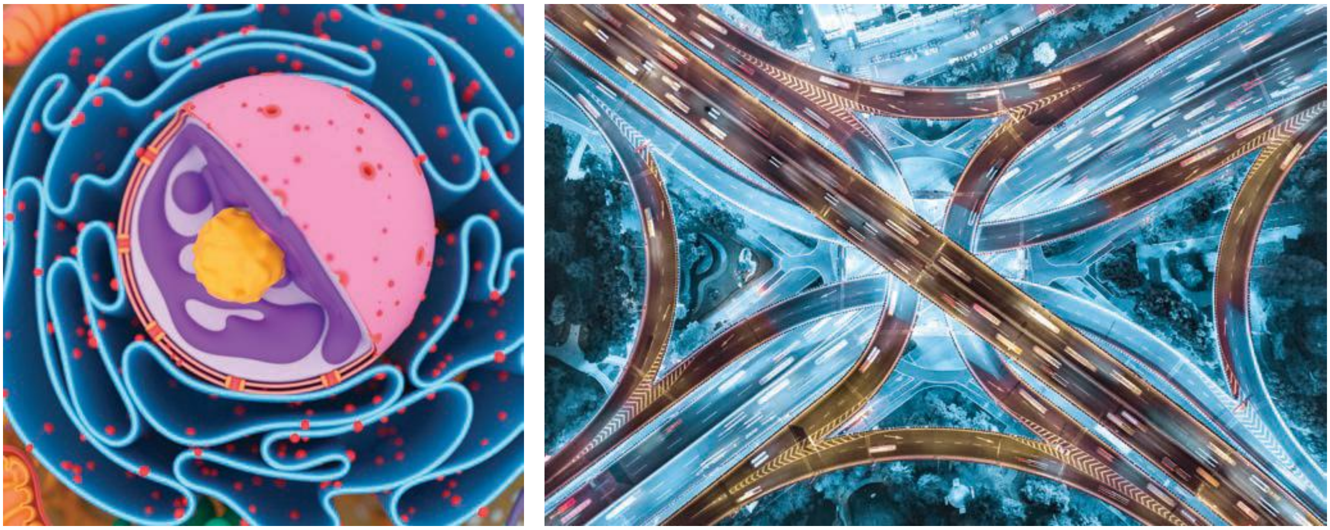


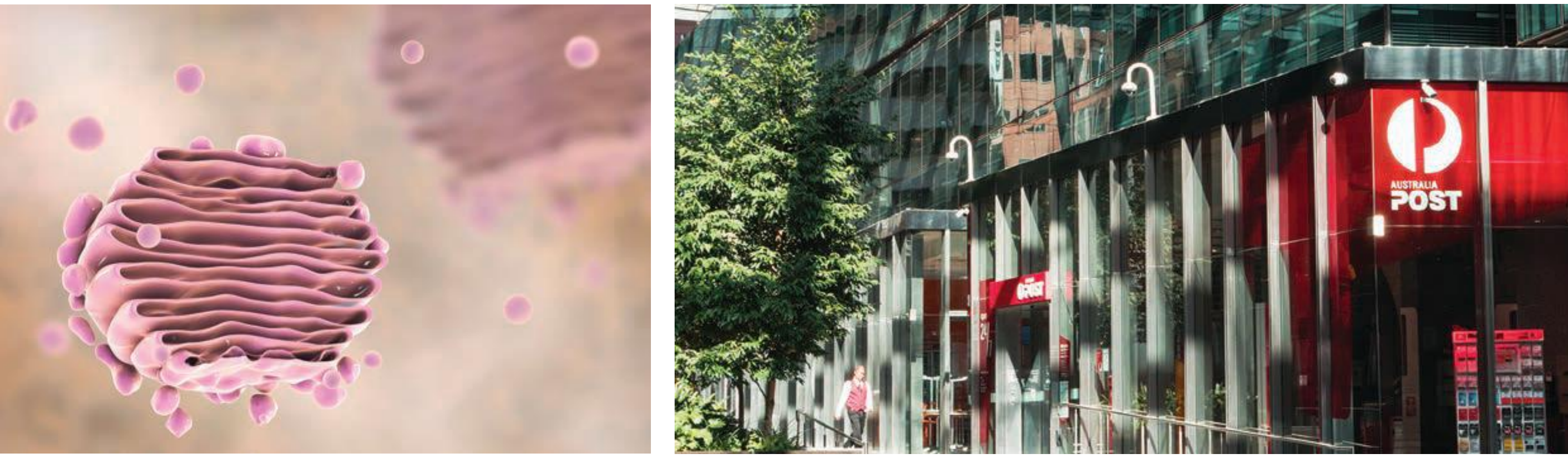
Figure 8.22 Left: Graphical representation of the endoplasmic reticulum around the outside of the nucleus. Right: The endoplasmic reticulum is the highway network of the cell city.

Golgi body

Golgi body
a structure in a cell involved in the modification, packaging and transport of proteins and lipids

The role of the **Golgi body** (also known as the Golgi apparatus) is to modify and package the proteins and lipids made by the endoplasmic reticulum, then export them to their destination. Golgi bodies are like the post office of the cell. They place proteins and lipids into small sacks of membrane, called vesicles (postal vans), and send them to where they are required.

Figure 8.23 Left: Graphic representation of a Golgi body. Right: Golgi bodies act as the postal system of the cell city.



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Try this 8.4

Organelles

Draw up a table with three columns. List all the organelles covered in this section in the left column. Give a description of their role in a cell in the middle column, and provide a simple picture or diagram in the right column.

Quick check 8.4

1 State the terms used for simple and complex cells.
2 Define the term 'organelle'.
3 Copy Figure 8.24 and label the following organelles: cell membrane, cytosol, nucleus (includes genetic material), ribosomes, smooth and rough endoplasmic reticulum, Golgi bodies, mitochondria.

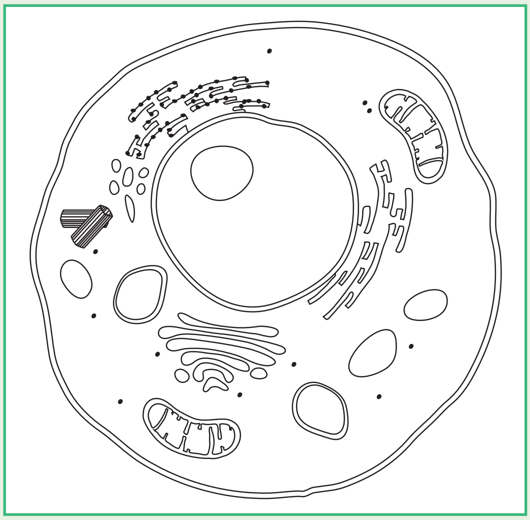

Figure 8.24 Diagram of a eukaryotic cell, ready for you to label it

VIDEO What organelles do all eukaryotic cells contain?

Section 8.2 questions

QUIZ

Remembering

1 **List** three organelles found in all cells.
2 **List** three organelles found in all eukaryotic cells (not including the three from Question **1**).

Understanding

3 **Explain** the function of the nucleus.
4 **Outline** why the Golgi body can be thought of as the post office of the cell.
5 **Identify** the following components of the cell.
   a I produce energy in the form of ATP for cells.
   b I am a barrier between the inside and the outside of cells, and I control who enters and leaves.
   c I am a water-based mixture that fills the cell, and many chemical processes happen within me.
   d I make proteins using the code in the genetic material of the cell.

Applying

6 **Compare** the function of the cell membrane with that of the nucleus.
7 **Summarise** the role of the ER and the Golgi body.

Analysing

8 **Distinguish** between unicellular and multicellular, using examples.

Evaluating

9 Different cells have different numbers of mitochondria. **Suggest** a reason why muscle cells contain more mitochondria than skin cells do.
10 **Propose** why cells would contain many ribosomes.

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8.3 Eukaryotic cells

Learning goal

1 To be able to distinguish between plant and animal cells.

DOC WORKSHEET

All eukaryotic organisms have many of the same organelles as each other. Eukaryotes can be found in the kingdoms Animalia, Plantae, Fungi and Protista. In this section, you will look at the differences between the cells of animals, plants, fungi and protists.

Figure 8.25 Plants and fungi living together

Animal cells

Animal cells contain all the organelles you learned about in the previous section. However, the numbers of organelles in a cell may vary, depending on what type of animal cell it is. Multicellular organisms like yourself are made up of many different types of specialised cells. Each of these different cell types has a specific job that allows your body to function properly. All the cells in your body start off as one cell, the **zygote** (fertilised egg). This cell divides into similar cells, which eventually differentiate into all the specialised cells around your body. A fertilised egg cell in the early stages of growth and differentiation is known as an **embryo**.

zygote
a fertilised egg cell

embryo
a fertilised egg cell in the early stages of growth and differentiation

stem cell
a cell that is able to develop into many different types of cells

Cells that have the potential to turn into any other type of cell are called **stem cells**.

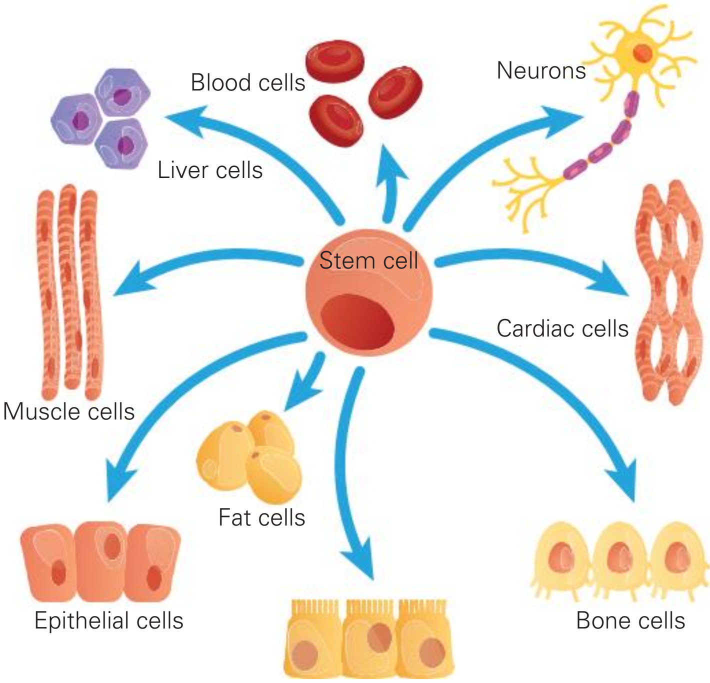

Figure 8.26 Embryonic stem cells can become many types of cells, in a process known as cell differentiation

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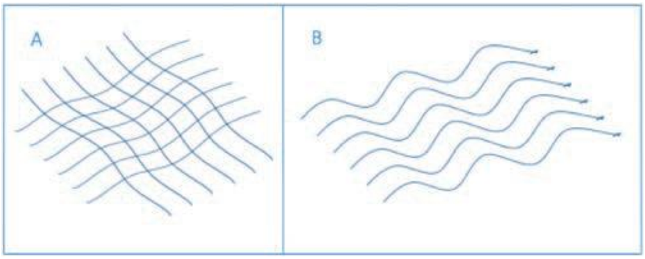
The process by which stem cells become specialised is called **differentiation**. Once a stem cell has differentiated into a specialised cell, such as a nerve cell, it can only ever replicate into another cell of the same type.

Stem cells don't only exist in embryos. You still have some stem cells in your body today that are ready to turn into any type of cell you need. They can be found in different tissues around your body and are activated by certain triggers, such as an injury. For example, if you cut yourself, stem cells below the layers of your skin turn into skin cells to help replace the damaged cells. This replacement is not always perfect and, if the damage is too extreme, it can leave a scar.



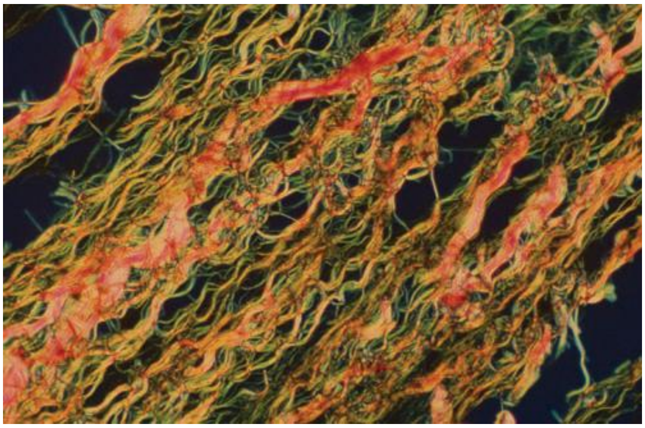


Figure 8.27 Top: Collagen fibre structure in normal tissue (A) and scar tissue (B). Bottom: Scar tissue.

The tissue that makes up a scar is made of the same material as normal skin, a protein called collagen. In normal tissue, collagen has a cross-weave structure where the fibres are oriented randomly. However, in scar tissue, it has a parallel alignment where all fibres run in the same direction. There is a simple reason for this: open wounds are dangerous and need to be healed as soon as possible. Parallel alignment is the faster way of repairing this tissue.

differentiation
the process by which stem cells become specialised

Explore! 8.3

Stem cell therapy

Because stem cells are able to turn into any type of cell, they have the potential to be used in treating and curing many types of diseases and conditions. These treatments are known as stem cell therapy or regenerative medicine.

1 Find out about the blood cancer called leukaemia.
2 Investigate how stem cell therapy is used to treat leukaemia, and summarise your findings.

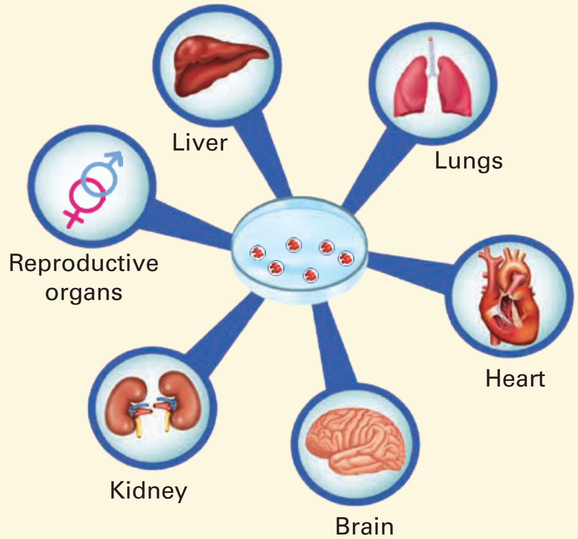


Figure 8.28 A stem cell can replicate and become any one of the 200+ types of cells in the body.

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Advances in science 8.1

Exciting uses of stem cells

Late in 2018, the results of two exciting research projects were published by scientists in Europe. First, in Germany, scientists succeeded in generating beating heart muscle cells from stem cells. Their work may provide a new approach for the treatment of heart attacks. Second, in Sweden, scientists developed a faster method of generating functioning brain cells from embryonic stem cells. The new method reduces the time required to produce the cells from months to two weeks, and may help in the treatment of degenerative diseases of the nervous system, such as dementia.

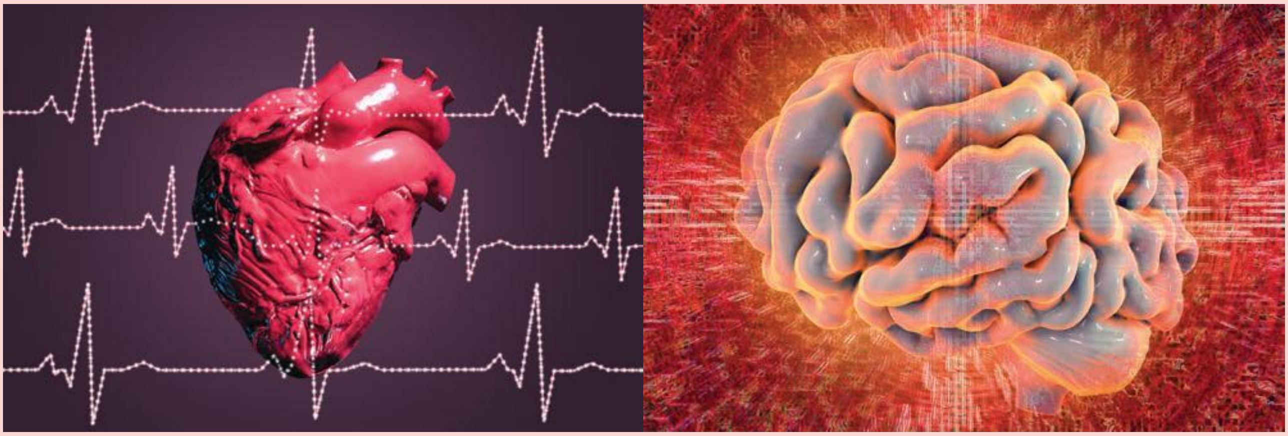
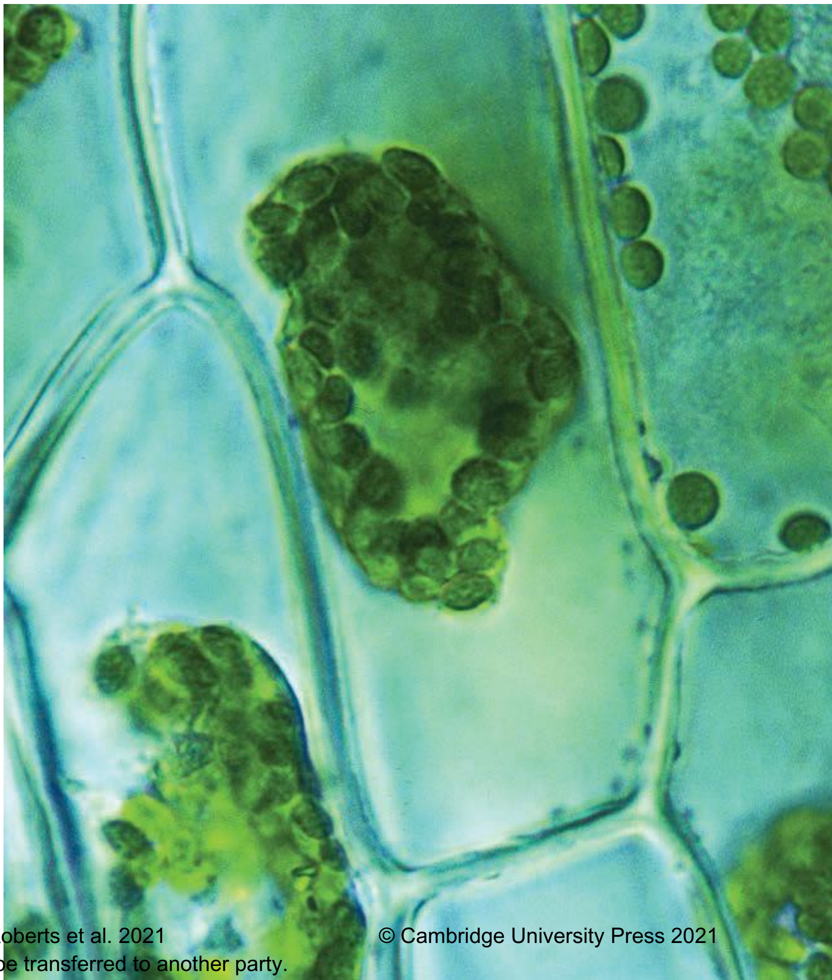


Figure 8.29 Stem cells may help in the treatment of heart and degenerative diseases of the nervous system.

Quick check 8.5

1 State the organelles that are found in animal cells.
2 Multicellular organisms are often made up of specialised cells. Describe what the term 'specialised cells' means.
3 Use the term 'differentiation' to explain how specialised cells form.
4 Describe what stem cells are and their use in medicine.

Figure 8.30 Plant cells: the green blobs are chloroplasts. Also note the thick cell wall that surrounds each cell.



chloroplast
a structure in a plant cell that contains chlorophyll and conducts photosynthesis

Plant cells

Plants are different from all other eukaryotic organisms in many ways. Most noticeably, they do not need to move in order to search for food, because they can make their own food in the process called *photosynthesis*. This difference means that plants have some organelles that animals and fungi lack. The special organelle in plants that carries out photosynthesis is called a **chloroplast**.

Chloroplasts contain a green pigment called *chlorophyll*, which captures the Sun's light and makes plants green. Chloroplasts are found in plant cells that are exposed to light (e.g. leaf cells) but not in cells of the roots.

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Because plants do not need to move, they lack a skeleton and muscles, but they still need to be able to support their weight so they can grow tall, towards the light from the Sun. This is why plant cells have a **cell wall**. The cell wall is a rigid structure that surrounds each cell (sitting outside the cell membrane) and provides shape and support for the plant. The cell wall is made of a substance called *cellulose*.

Plant cells also contain an organelle called a **vacuole**. This organelle stores water and other nutrients for the plant. It also works with the cell wall to help support the plant and give it shape. If you have ever forgotten to water your plants at home, you might have noticed that they droop and wilt, becoming floppy, and if not watered will start to die. This is because the vacuoles in each cell are losing water, the cells become flaccid, and so the plant cannot hold its shape. Animal cells also contain vacuoles, but they are much smaller and are mainly used for storage of nutrients. The cells of some fungi, protists and bacteria may also have vacuoles.

Figure 8.31 A thirsty plant: the vacuoles are no longer full of water and so they cannot help to support the plant in standing upright.

Distinguishing animal cells from plant cells

You have seen that animal cells and plant cells have many organelles in common, as they are both eukaryotic cells that have many processes in common. However, you have also learned about the additional organelles that plant cells have due to their different structures and functions.

WIDGET
Eukaryotic organelles

In addition, it is generally easy to identify plant cells under the microscope, because the cell wall usually gives them a shape with rigid straight lines and a thick outline, whereas animal cells have a less uniform shape and a much thinner outline.

cell wall
a rigid structure that surrounds each cell, shaping and supporting the cell

vacuole
a structure in a cell that stores water and nutrients

Quick check 8.6

1 Name the organelles in a plant cell that an animal cell does not have.
2 Explain why plant cells have each of these 'extra' organelles.

Figure 8.32 Animal cell (top) and plant cell (bottom) showing the major structures and organelles

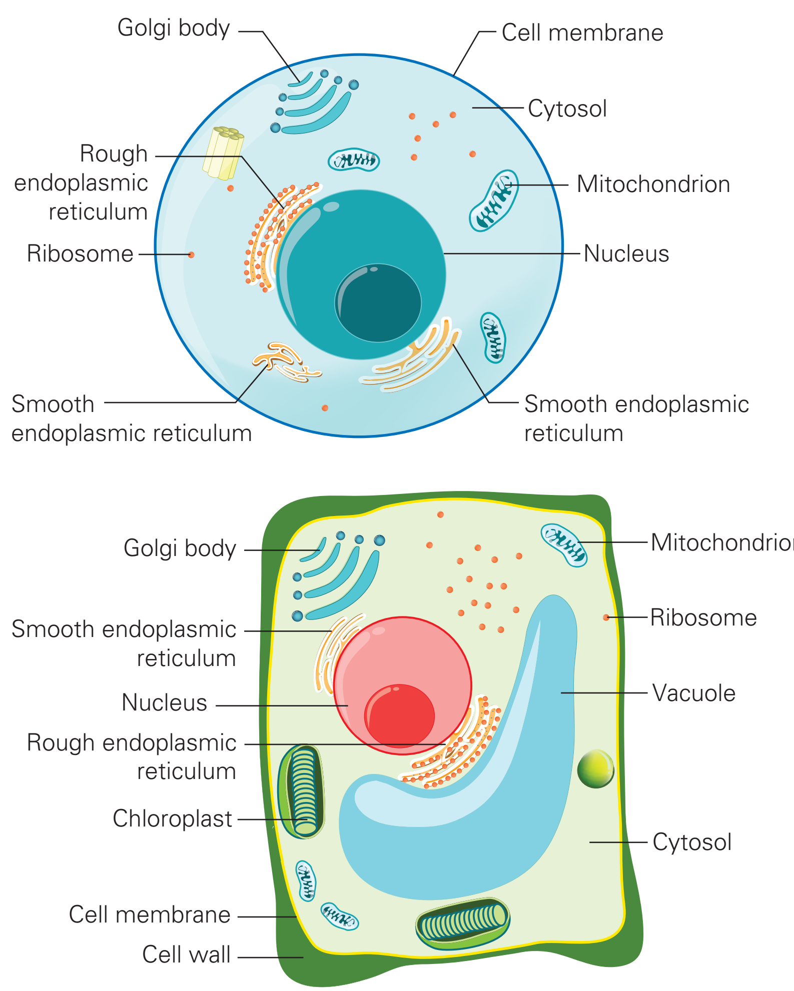

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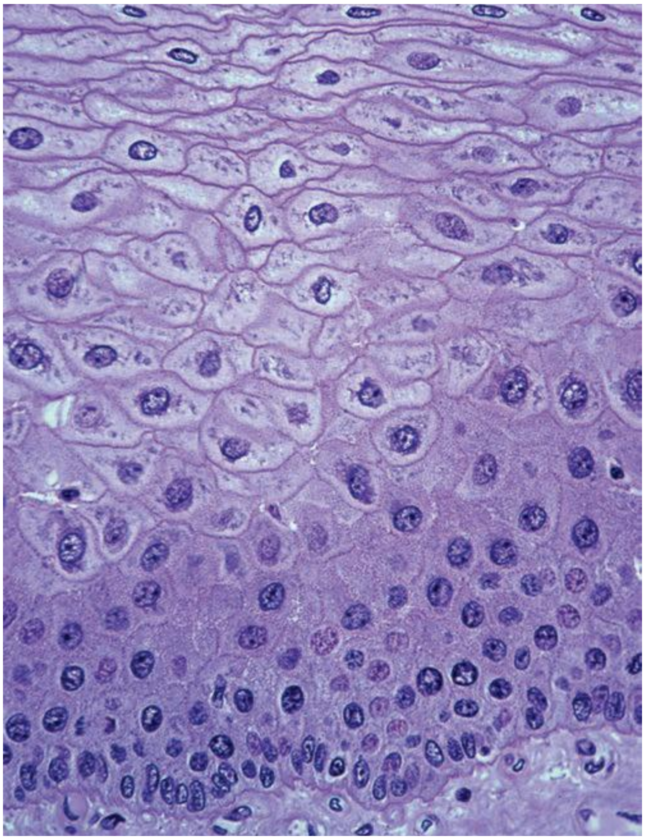
Figure 8.33 Left: Animal (oesophagus) cells at 100× magnification. Right: Plant cells at 100× magnification



Try this 8.5

Making a wet mount

When you want to observe cells under a microscope, you need to prepare what is called a *wet mount*. Let's practise using pond water.

Use a pipette to place a drop of pond water in the centre of a glass slide. Then gently lower a cover slip onto the water, as shown in Figure 8.34. If the cover slip drops too quickly, it can trap air bubbles and then you won't be able to see your specimen as easily. Use a tissue or blotting paper on the edge of the cover slip to soak up any extra liquid.

Note: Some specimens may be dry and so you would need to add a drop of water. Some may be transparent, so you would need to add a stain instead of (or in addition to) water.

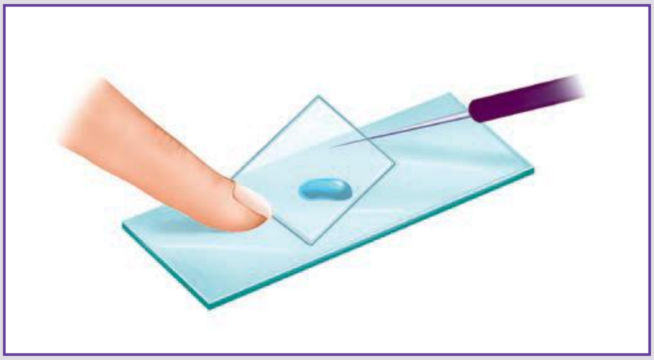


Figure 8.34 Lowering the cover slip slowly is very important when preparing a wet mount.

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Practical 8.2

Observing cells under a microscope

Aim

To observe the characteristics of plant and animal cells.

Materials

- iodine solution
- glass slides and cover slips
- prepared animal slides
- onion and celery
- ripe and unripe bananas
- light microscope
- toothpick

Be careful

Ensure that the microscope is carried appropriately. Carry it with one hand holding the arm and one hand under the base. Do not use the coarse focus knob to cause the objective lens to touch the glass slide and damage it. No food items are to be consumed.

Procedure

1 Follow these steps to prepare a wet mount.
   a Peel a translucent (see-through) piece of tissue from the onion.
   b Place the piece of onion tissue on a glass slide and add a drop of iodine solution.
   c Cover the slide with a cover slip, using your wet mount technique.
   d Repeat steps **a–c** for the celery.
   e Use the toothpick to collect some ripe banana cells and smear them as thinly as you can across a glass slide.
   f Add a drop of iodine solution and then cover with a cover slip.
   g Repeat steps **e–f** for the unripe banana.
2 Observe the cells: starting with the microscope on the lowest magnification, turn the coarse focus knob until it is as close to the stage as it can go. Place on your first slide and focus using the coarse focus knob. Once focused, turn to the next objective lens. Use only the fine focus knob to focus now. Once focused, move to the highest magnification and again focus using the fine focus knob.
3 Draw a diagram: using a pencil, draw diagrams of an onion cell, a celery cell, a ripe banana cell, an unripe banana cell, and four animal cells from the prepared slides. Label all the organelles you can see, using a ruler and labels at the side of the diagram. Record the name of the specimen, the magnification the drawing was drawn at, and determine the cell size.

Results

Your results will be in the form of four plant cell diagrams and four animal cell diagrams.

Discussion

1 Explain why stains are needed.
2 Compare the onion and celery cells: what similarities and differences did you observe?
3 Compare the ripe and unripe banana cells: what similarities and differences did you observe? Can you explain the differences?
4 What characteristics did you observe in the plant cells? In the animal cells? What did they have in common? Explain why there are differences.
5 Were the plant and animal cells all the same size? If there are differences, can you explain why?

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Practical 8.3

Making a model: 3D cell

Aim

To create a 3D model of a plant cell and an animal cell using the materials provided.

Materials

- black beans
- white beans
- ping pong balls
- zip lock bags
- red food colouring
- green food colouring
- takeaway food container
- poppy seeds
- balloons
- glue and tape

Procedure

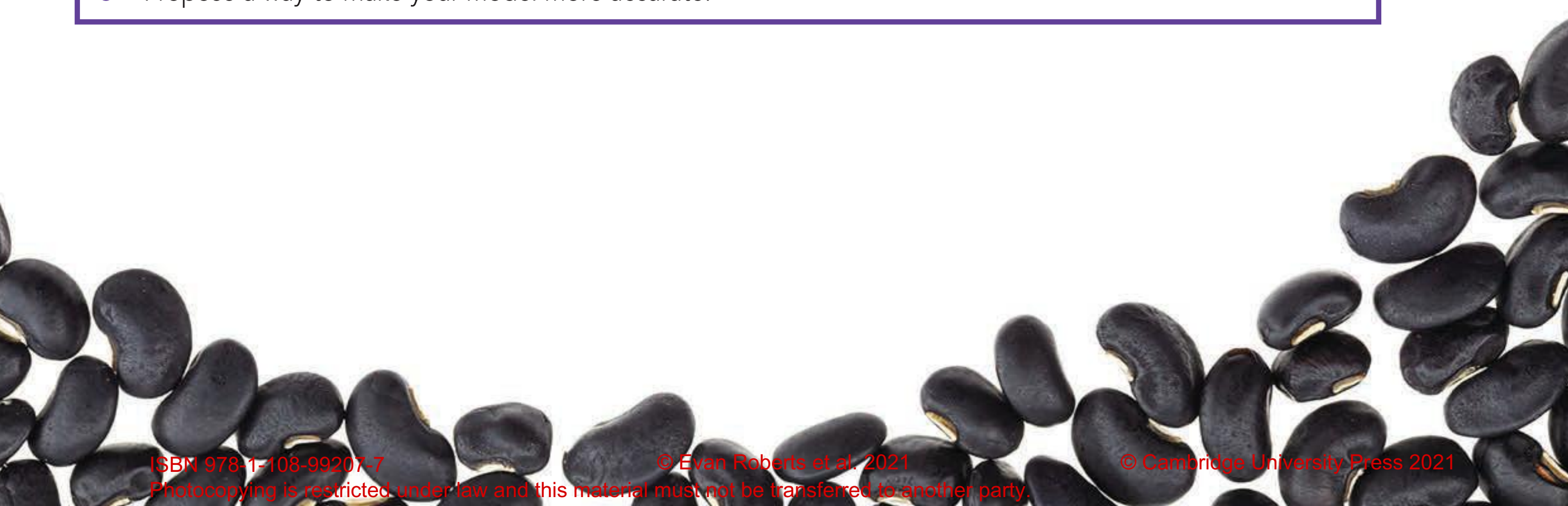
1 Look at the materials your teacher has provided for you and decide what you are going to use to represent each part of the plant cell and the animal cell.
2 Copy and complete the table below to indicate how each organelle is going to be represented in your model.
3 Construct your 3D model of the cell.
4 Explain to the class and your teacher how your model represents all the parts of a cell.

Results

Plants		Animals	
Cell	Material used	Cell	Materials used
Nucleus		Nucleus	
Cell membrane		Cell membrane	
Mitochondria		Mitochondria	
Ribosomes		Ribosomes	
Golgi body		Golgi body	
Endoplasmic reticulum (rough)		Endoplasmic reticulum (rough)	
Cytosol		Cytosol	
Large vacuole		Small vacuoles	
Chloroplast			
Cell wall			

Discussion

1 Explain why models are used in science.
2 Assess two strengths and two limitations of your model.
3 Propose a way to make your model more accurate.



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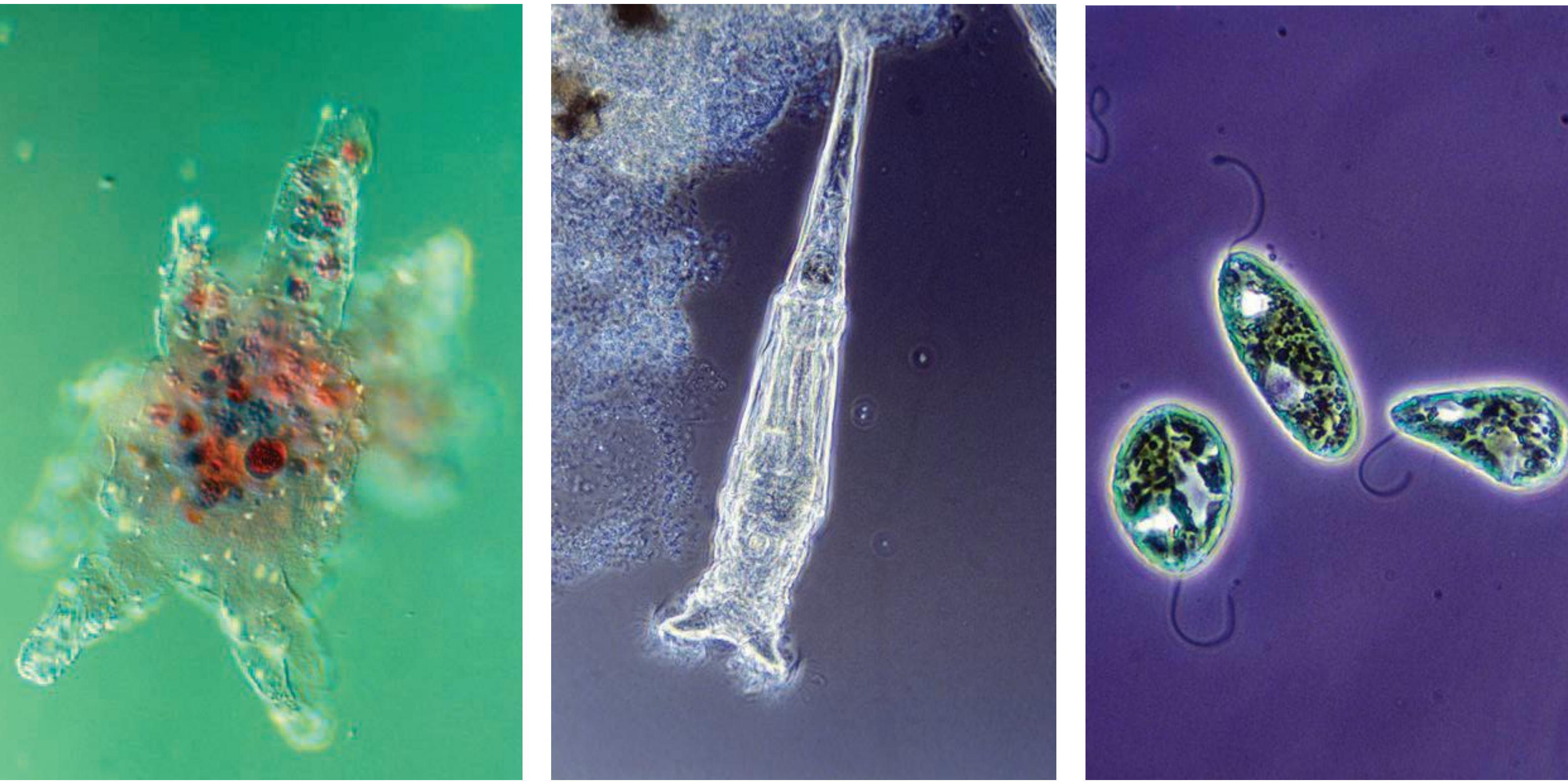

Figure 8.35 Protists: (left) amoeba; (middle) rotifer; (right) *Euglena*

Protists

protist
a eukaryotic organism that is part of the kingdom Protista

Protista is a kingdom that consists mostly of unicellular organisms; however, there are a few multicellular examples, such as kelp. They are eukaryotic, so they contain the organelles that you learned about in the previous section. However, scientists have changed the classification of many of these organisms several times, because they display characteristics of both plants and animals. All **protists** need to live in a moist environment and so are very common in most aquatic environments. If you look at a sample of pond water under the microscope in the warmer months of the year, you will likely see many types of protists, such as *Euglena*, rotifers, amoebas and *Paramecia*. Each of these types of protists is slightly different in structure, depending on its function.

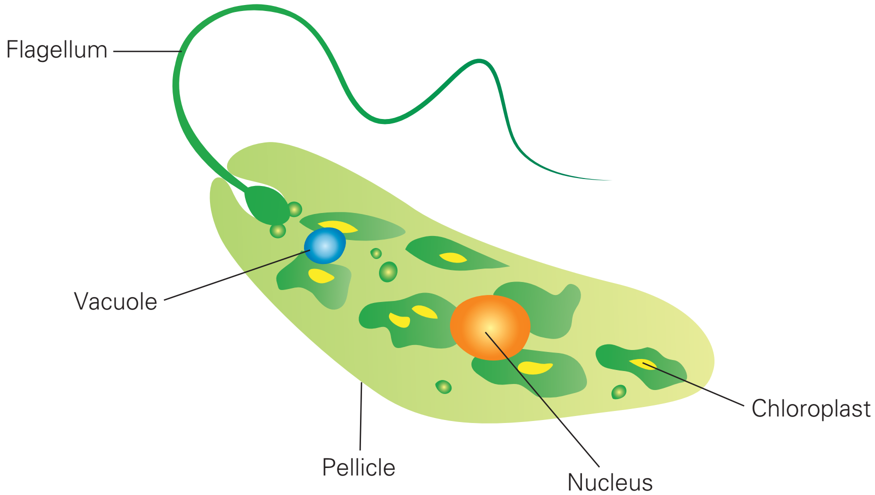

Figure 8.36 Euglena have chloroplasts which are typically considered a plant cell organelle, but they also have a flagellum which is more typical of an animal cell.

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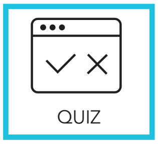
Section 8.3 questions



Remembering

1 **State** the organelle involved in photosynthesis.
2 **Name** the three key differences between plant cells and animal cells in terms of their organelles.
3 **List** three examples of protists.
4 **Define** the term 'specialised cells' and provide examples.

Understanding

5 **Outline** the two parts of a plant cell that provide support and explain how they work together.
6 **Explain** why fungi are known as heterotrophs.
7 **Summarise** the steps you need to take when preparing a wet mount.

Applying

8 a **Name** the organelles labelled A to E in the eukaryotic cell shown in Figure 8.37.

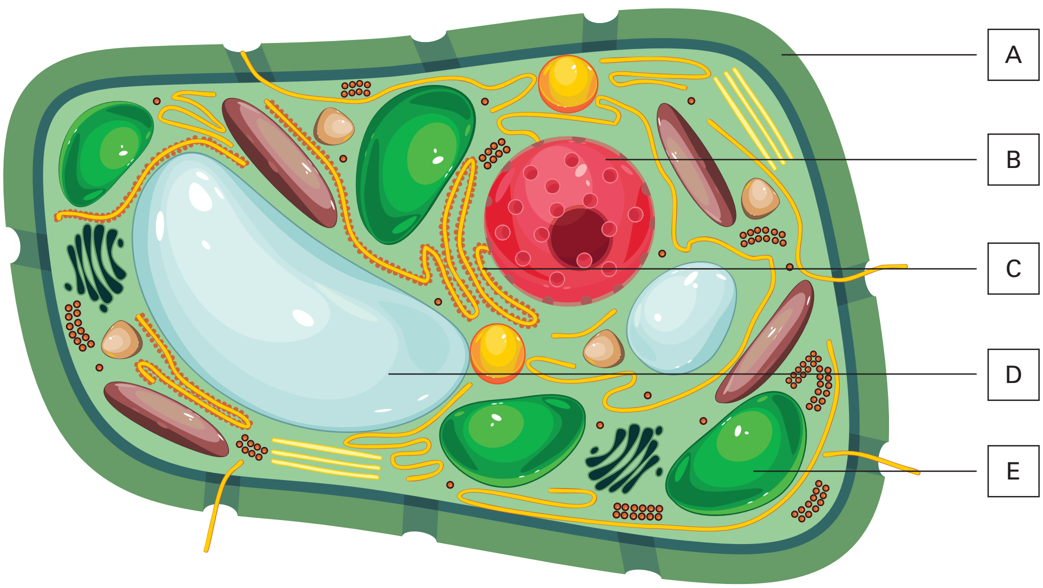


Figure 8.37 Eukaryotic cell

b What type of cell is shown in Figure 8.37? **Explain** your answer.
9 **Identify** where you are most likely to find protists.
10 **Explain** how the shapes of various cells help them to carry out their function within the body. You may like to refer to red blood cells, sperm cells and muscle cells.

Analysing

11 a **Compare** an animal cell to a fungal cell in terms of the cell's structure and organelles. You may choose to present the information in a Venn diagram.
b **Compare** a plant cell to a fungal cell in terms of the cell's structure and organelles. You may choose to present the information in a Venn diagram.
12 Yeast are unicellular eukaryotic cells, and belong to the Fungi kingdom. A student conducted an experiment to test the effect of temperature on the activity of yeast, which will produce a gas when added to a solution of sugar in water. The student placed 2 g of yeast and 10 g of sugar into a glass apparatus full of water, designed to trap any gas produced in a narrow closed vertical tube at the top. The amount of gas can be measured by the height of the column of gas that collects in the tube. They did the experiment three times with the apparatus containing water at three different temperatures, and measured the height of the column of gas produced after 1 minute.

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Temperature (°C)	Height of column of gas produced in the tube (mm)			
	Trial 1	Trial 2	Trial 3	Average
10	60	64	62	62
30	102	98	100	100
60	20	14	17	17

a Using the student's results, **assess** the effect of temperature on yeast function.
b **Identify** the optimum temperature for yeast activity.
c **Suggest** the effect that an even higher temperature, such as 100°C, would have on the yeast being tested.

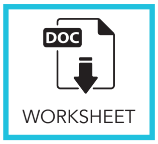
Evaluating

13 **Propose** reasons why humans need muscles and a skeleton, whereas plants do not.

8.4 Function and malfunction

Learning goals

1 To describe how cells reproduce.
2 To explain why cells reproduce.



Cell division

At the start of this chapter you learned about cell theory. The development of cell theory was made possible by the invention of the microscope, which allowed scientists to observe and prove certain characteristics that all cells display. One of the most easily observable parts of cell theory is that 'all cells come from pre-existing cells'. This is referring to cell division, when one cell splits to form two new identical cells, called *daughter cells*. The scientific term for this process in eukaryotes is **mitosis**. In prokaryotes, it is known as **binary fission**.

Why do cells divide?

Mitosis happens for a number of reasons: repair, growth and reproduction.

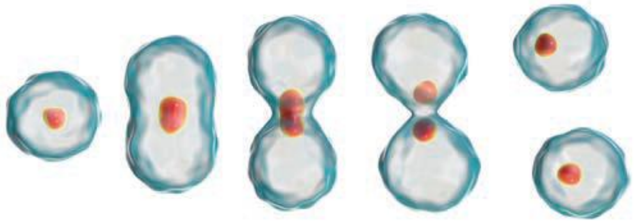


Figure 8.38 A simplified representation of mitosis: one cell forms two new identical daughter cells

Repair

If you cut your skin or break a bone, your body can close the wound or set the bone over time. This happens because millions of new cells are produced to replace the damaged cells. Some cells in your body, such as your red blood cells and skin cells, need to be replaced regularly.

mitosis
the type of cell division in which one cell divides into two cells that are exactly the same

binary fission
a mode of asexual reproduction by bacteria, where genetic information is copied and the cell splits in half

Figure 8.39 A cut heals because mitosis occurs, creating new cells to replace the damaged ones.

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Growth

In order to grow, your body needs to make more cells. You first started out as a single cell, which was a fertilised egg. By the time you become an adult, you will be made of around 37.2 trillion cells. A massive amount of cell growth occurs before you are born and in your first few years of life, but you will still be growing until your late teens. This means your bone cells need to reproduce in order for you to get taller, your muscle cells need to keep up with your bone cells, and your nerve cells need to grow in order to extend throughout your body.

Did you know? 8.4

Skin

You lose about 40 000 skin cells every minute of every day. This means that, over a lifetime, you will lose at least half of your body weight in skin cells. Have you ever wondered where dust comes from? Most of the dust in your house is made up of your dead skin cells. No wonder mitosis happens a lot!

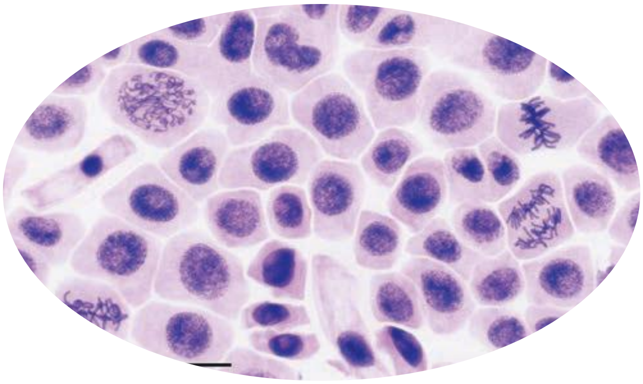

Figure 8.40 The ability to view cells under a microscope, such as the onion cells undergoing mitosis shown above, has helped us understand cell function and division.

Reproduction

Unicellular organisms such as bacteria remain as one cell their entire life. They don't undergo cell division for growth and repair, because their whole body is just one cell. The only reason bacteria divide is for reproduction. This form of reproduction is known as *binary fission* and involves the bacterium splitting in half to produce an identical copy of itself. Because this process does not require a mate and is fairly simple, bacteria can reproduce around every 30 minutes. This means that, in one day, a single bacterial cell could become 140 737 488 355 328 cells.

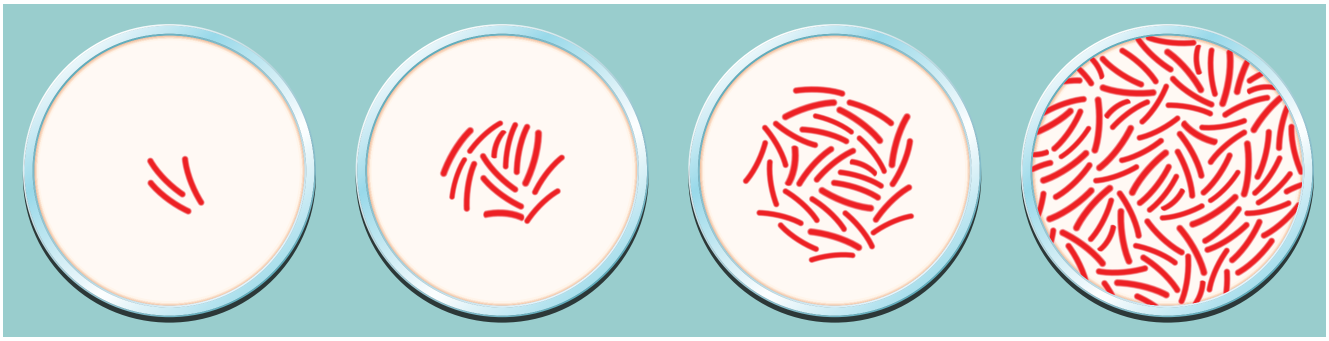

Figure 8.41 Bacteria, under the right conditions, can reproduce very quickly by binary fission.

Explore! 8.4

Cancer

Cancer is a disease of the body's cells. Cells normally grow and multiply in a controlled way, but if there is a change in someone's genetic code, this control can be lost. Cancer is the term used to describe uncontrolled cell division. Because cancerous cells can arise from almost any type of cell, there are about 100 different types of cancers.

1 Research and define the terms 'benign' and 'malignant'.
2 Select a type of cancer to investigate – for example, prostate, breast, bowel, skin, lung. Summarise the cause, prevention and treatment of the chosen cancer.

Figure 8.42 Doctor checking a mole for signs of skin cancer

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Quick check 8.7

1 Cell division is a normal process that occurs in your body. Recall the three reasons it occurs.
2 Explain why skin cells need to divide regularly.
3 State the name of the process that bacteria undergo to reproduce.
4 Describe a disease that results from a malfunction of the normal process of cell division.

Microorganisms

Microorganisms are organisms that are so small they can only be viewed using a microscope. Bacteria, some fungi and some protists are examples of such small organisms. As you know, most bacteria (such as those in your intestines) and fungi (such as the yeast used to make bread) are harmless and can actually benefit us in some way. However, some are dangerous. 'Germ' or '**pathogen**' is the general term used to refer to a microorganism that can cause a disease or infection. When you go to the toilet, you probably wash your hands straight away. This is because you were taught from an early age that washing your hands kills germs. This might seem like common sense, but until about 150 years ago, people didn't know that diseases came from microorganisms and that the air is full of microorganisms. Before this time, people believed that mould on bread appeared spontaneously – this theory is known as *spontaneous generation*.

pathogen
an organism that causes disease

A scientist known as Louis Pasteur was a microbiologist who used microscopes to study the microscopic world. He conducted a series of experiments proving that food went off because it was contaminated by microorganisms in the air. His experiments in the 1860s led him to invent *pasteurisation*, which is the process of heating food or drink to a high enough temperature to kill any harmful microorganisms, before sealing it. This greatly increases the shelf life of foods and prevents the spread of disease.

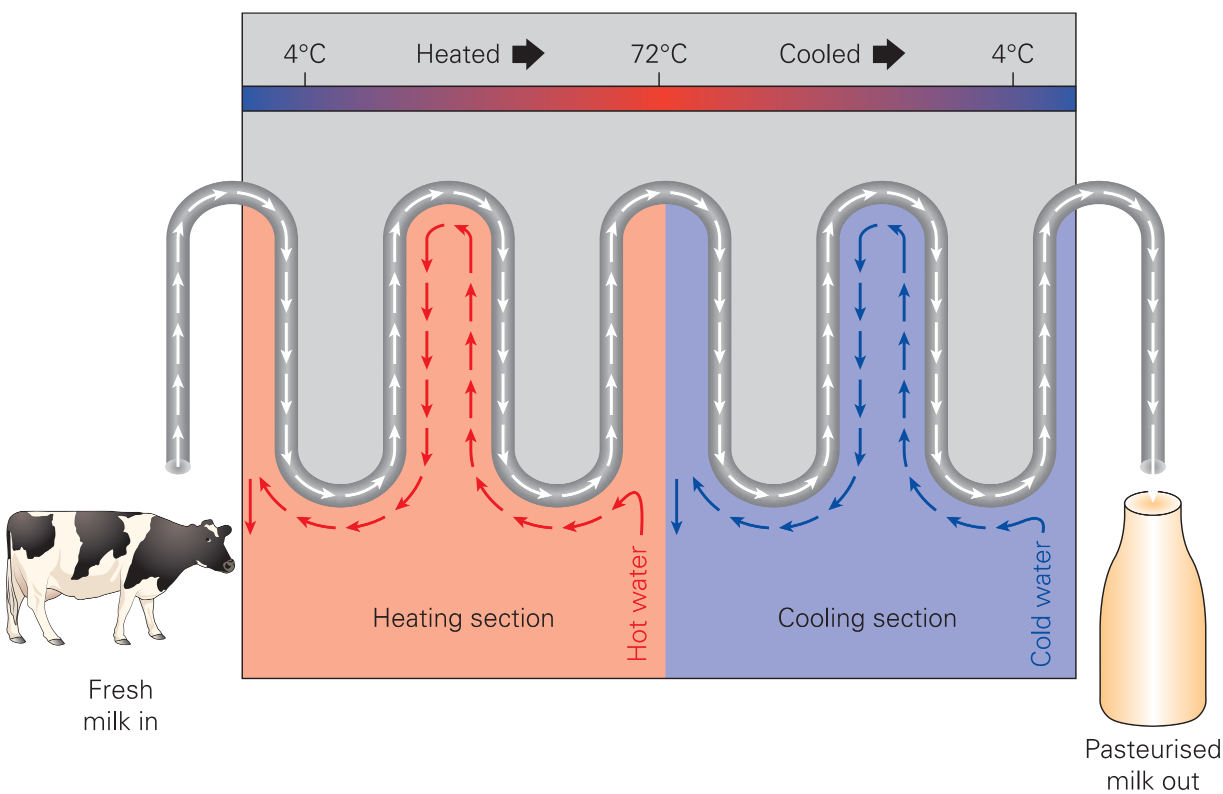

Figure 8.43 The process of pasteurisation has been used for a long time.

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Try this 8.6

Observing 'friendly' bacteria under the microscope

Using your microscope and wet mount preparation skills, look at some bacteria under the microscope. You will need the stain called methylene blue, and a sample of yoghurt or probiotic drink containing live bacteria strains. Look at the size and structure of the bacterial cells, and consider how similar/different they are to eukaryotic cells like plant and animal cells.

Practical 8.4

Modelling pasteurisation

Aim

To test the effect of temperature on the growth of bacteria.

Planning

1 Write a rationale about the factors that affect the growth of bacteria and methods that prevent this growth.
2 Write a specific and relevant research question for your investigation.
3 Identify the independent, dependent and controlled variables.
4 Write a hypothesis for your investigation.

Be careful

Ensure benches are cleaned and hands are washed before leaving the laboratory.

Do not open the agar plates after sealing.

Materials

- 4 agar plates
- evaporation dish
- probiotic drink
- sterile swabs
- Bunsen burner
- tripod, heatproof mat, pipe clay triangle
- sticky tape
- disposable gloves

Procedure

Part A: Boiled (100°C) probiotic

1 Place 10 mL of probiotic drink into the evaporation dish.
2 Heat to boiling point using a Bunsen burner.
3 When the mixture starts to boil, turn off the heat.
4 Dip the sterile swab into the heated mixture and spread the mixture over the agar sheet, as shown in Figure 8.44 and explained below.

   Swabbing technique

   When you use the sterile swab, gently rub the swab over the agar in tight lines to start with, and then slowly spread the lines apart as you move down the agar plate.
5 Place the lid on the plate and, with 2 to 4 pieces of sticky tape, tape down opposite edges of the plate.
6 Label the agar plate. Write your group name, date and the independent variable. Keep your writing small, and write around the outside edge of the agar plate.
7 Place the agar plate in the incubator with the agar side up at 30°C for two days.

Figure 8.44 How to rub the swab over the agar

continued…

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...continued

Part B: 30°C probiotic

8 Dip a new sterile swab into the original probiotic mixture (unboiled).
9 Swab an agar plate as you did previously.
10 Place the lid on the plate and, with 2 to 4 pieces of sticky tape, tape down opposite edges of the plate. Label the agar plate.
11 Place the agar plate in the incubator with the agar side up at 30°C for two days.

Part C: Refrigerated (4°C) probiotic

12 Repeat steps **8–10** and place the agar plate in the refrigerator at 4°C for two days.
13 After two days, remove the agar plates from the incubator and refrigerator, and count the number of colonies that you can see on the agar plates. A colony should look like a slightly raised round dot on the agar plate.

Results

1 Draw a results table for your experiment.
2 Produce a suitable graph for your experiment.

Discussion

1 Describe any patterns, trends or relationships in your results.
2 Suggest a reason for any relationships you have identified in Question **1**.
3 Suggest two ways that your results could be useful for controlling bacterial growth.
4 Identify any limitations in your investigation.
5 Propose another independent variable that could have been tested, to expand on your results.
6 Suggest some improvements for this experiment.

Conclusion

Draw a conclusion from this experiment regarding the effect of temperature on bacterial growth, using data to support your statement.

Following on from Pasteur's experiments, other scientists used microscopes to help them link microorganisms to disease. This led to the realisation that washing our hands, cleaning our homes and cooking food properly can limit the spread of disease.

Figure 8.45 Washing hands can prevent the spread of microorganisms.

By following simple hygiene practices, humans are living much longer and healthier lives. Below are some ways in which you can prevent the spread of microorganisms and prevent diseases from passing from one person to another.

1 Cover your mouth and nose with a tissue or your elbow pit when you sneeze.
2 Wash your hands regularly, especially if you cough or sneeze into your hands.
3 Avoid touching your eyes, nose or mouth after touching contaminated surfaces such as hand rails or door handles.
4 Do not share drink bottles or cutlery with other people.
5 Quarantine – this is when a sick person is kept away from the healthy population, to prevent the illness from spreading. If your doctor has ever told you to stay home from school, that is a form of quarantine.

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Section 8.4 questions

QUIZ

Remembering

1 **Define** the term ‘mitosis’.
2 **State** the three reasons that cells divide.

Understanding

3 **Explain** how bacteria reproduce.
4 Sometimes cells are described as clones. **Explain** what this means.

Applying

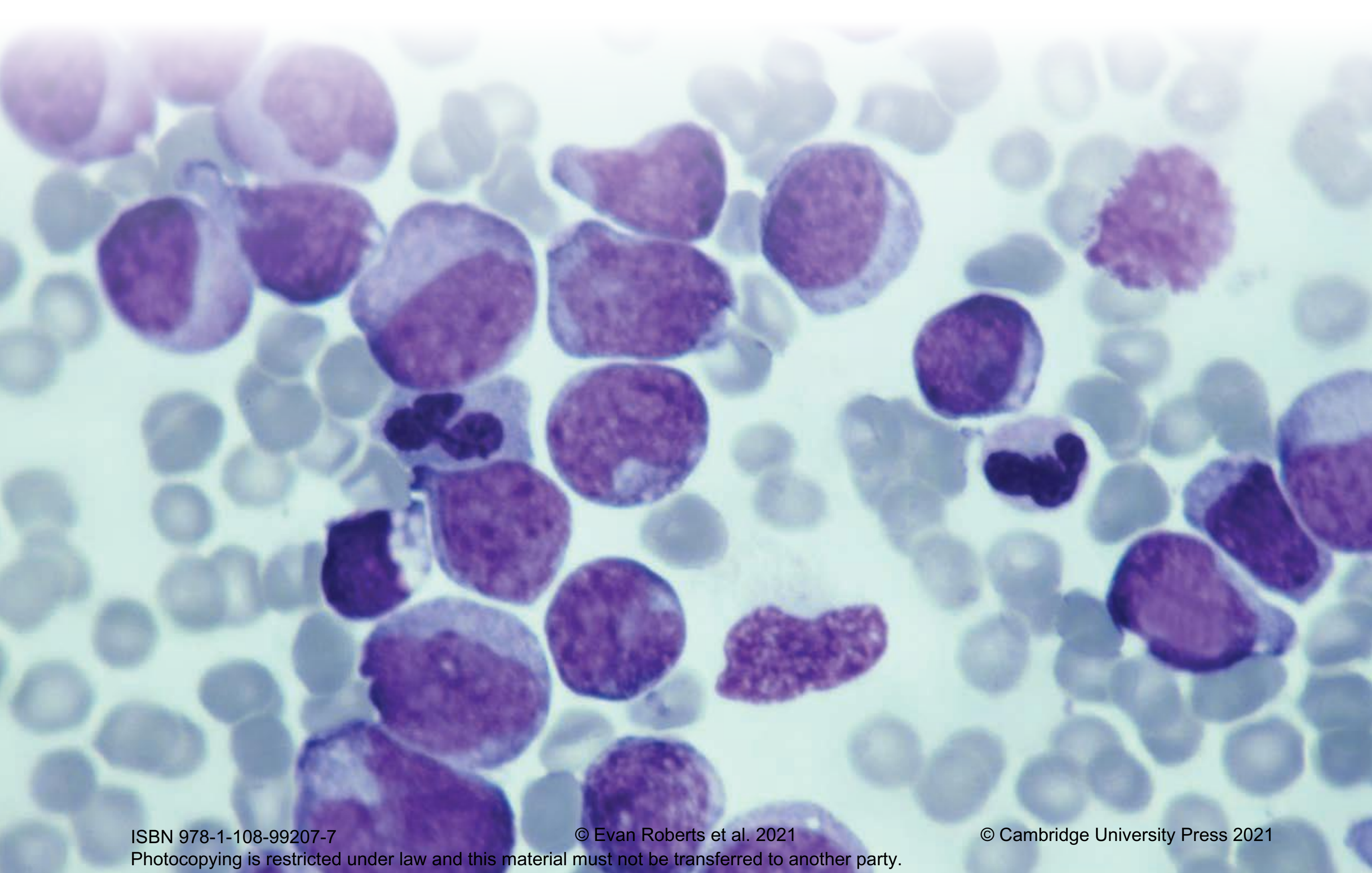
5 **Summarise** the process of pasteurisation, illustrating how it is beneficial to humans.
6 **Explain** in what way cancer relates to the control of cell division.

Analysing

7 **Distinguish** between malignant and benign cancer.

Evaluating

8 ‘Pasteurisation has led to improved human health.’ **Assess** the truth of this statement.
9 **Design** an experiment that investigates hand washing. Your aim is to determine the effectiveness of washing hands on preventing bacterial growth. You may like to begin by identifying your independent and dependent variables, and consider using agar plates for this task.



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Chapter review

Chapter checklist

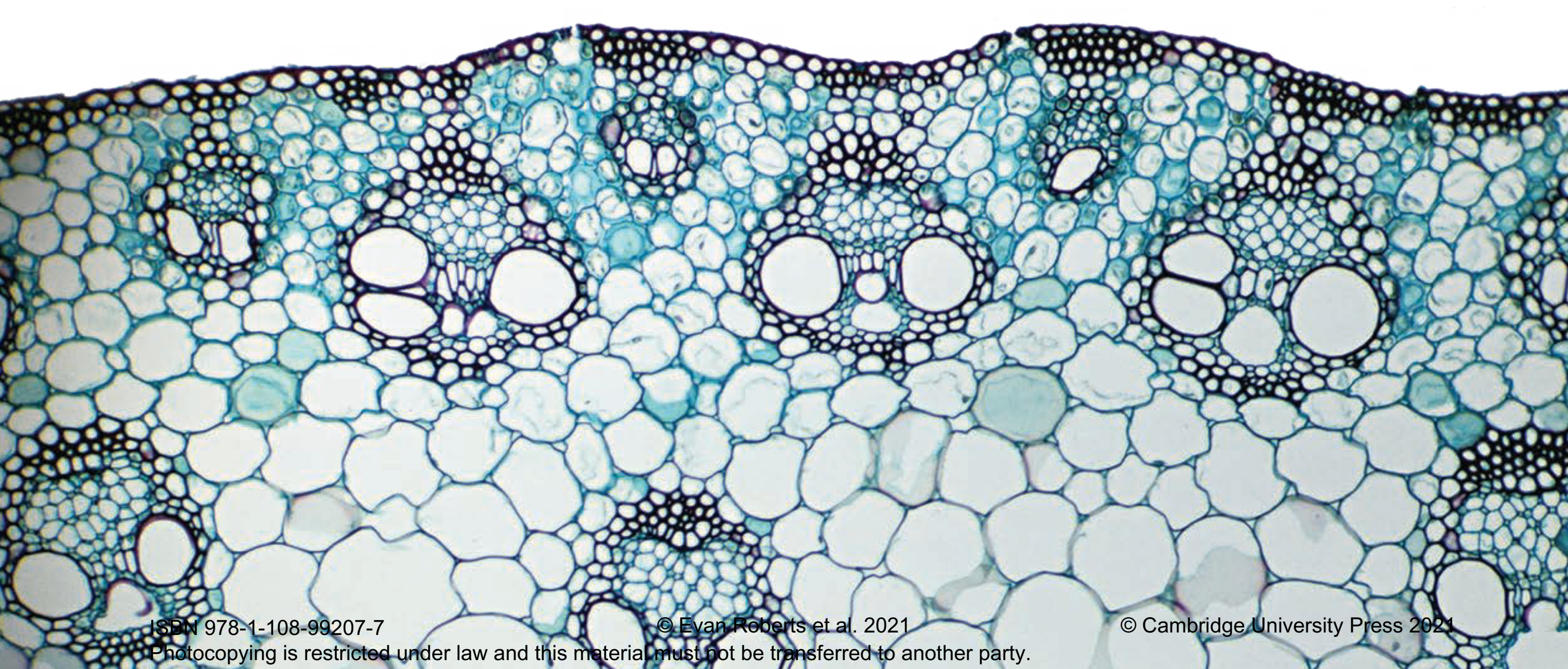
You can download this checklist from the Interactive Textbook to complete it.

Success criteria		Check
8.1	**I can explain why microscopes are needed to observe cells.** e.g. How does a microscope enable you to see cells?	
8.1	**I can distinguish between different types of microscopes.** e.g. Discuss the advantages of using electron microscopes.	
8.1	**I can recall modern cell theory.** e.g. Recall the main statements that describe modern cell theory.	
8.2	**I can compare prokaryotic and eukaryotic cells.** e.g. Describe how you would identify prokaryotic and eukaryotic cells.	
8.2	**I can describe the structure and function of different cell organelles.** e.g. Describe the structure and function of the Golgi body.	
8.3	**I can compare animal, plant and fungi cells.** e.g. Use a Venn diagram to compare animal, plant and fungi cells.	
8.4	**I can recall the purpose of mitosis.** e.g. State the three reasons why cells divide.	
8.4	**I can describe the effect of microorganisms on human health.** e.g. Define pasteurisation.	

SCORCHER

Reflections

1 What **connections** come to mind when you think about cells and your everyday life?
2 What new concepts have **extended** your thinking about cells?
3 What information did you find **challenging** or confusing?



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Data questions

Eukaryotic organisms can achieve cell growth and repair through the process known as mitosis. The relative time required for each of the stages of cell duplication in a eukaryotic cell is shown in the pie chart in Figure 8.46. The time taken for the mitosis phase (M) of cell division for different types of cells is given in the table.

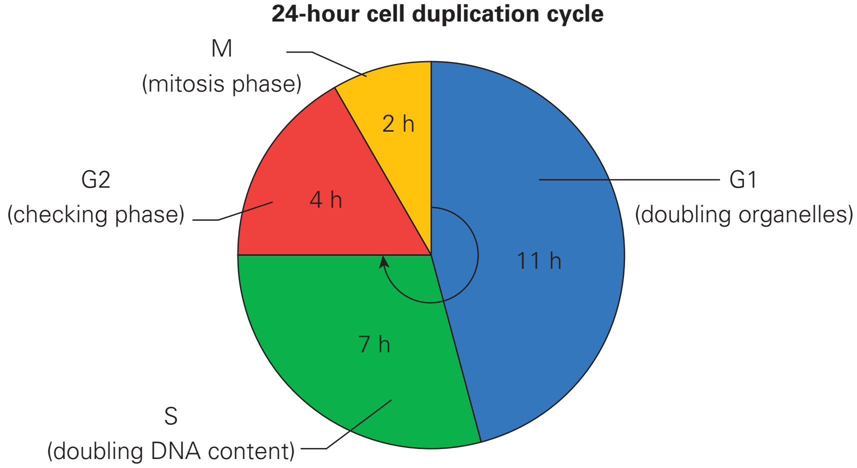

Figure 8.46 Relative duration of each of the four phases of a typical 24-hour cell division cycle in a eukaryotic cell.

Cell type		Temperature (°C)	M phase duration (min)
Plants	Grass	20	110
	Sunflower	20	85
	Pea	3	18000
		10	4200
		20	110
		25	80
Animals	Rat	37	43
	Chicken	37	80
	Cockroach	35	140

Table 8.2 Duration of the mitosis phase (M phase) at different temperatures for different cell types

1. **Identify** which stage in the eukaryotic cell division cycle takes the longest time.
2. **Identify** which animal in Table 8.2 has the longest mitosis phase duration.
3. **Calculate** the percentage of time in the cell duplication cycle used for doubling organelles.
4. **Identify** the relationship between the duration of the M phase in a pea cell and the temperature.
5. **Identify** how long a cell will take to duplicate all of its content if it follows the typical 24-hour cycle.
6. **Infer** why the M phase duration is given at different temperatures for plants and animals in Table 8.2.
7. **Predict** in what phase of cell duplication the content of DNA in the cell is the highest.
8. Refer to Table 8.2 and **deduce** whether or not it is possible to affirm that animals have longer mitosis phases than plants.
9. Based on the data provided, **predict** whether the mitosis phase of cell replication would be faster or slower for a grass cell at a temperature lower than 20°C.

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STEM activity: Designing a city

Background information

Although cells are small, they are complex and contain even smaller components, called organelles. These organelles all have different functions and work together to keep the cell alive. The way in which organelles in a cell function together can be compared with the way in which the components of a city work together to make the city function well. Cities all need to have structures and processes in place, to manage functions such as transport, sanitation, utilities, housing, construction and food production. There also needs to be a governing body that oversees everything.

Design brief: Design a city using cells as a model.

Activity instructions

In a group, you will use your knowledge of the functions of cells and make comparisons with the functions of a city to create a modern city design that addresses some of the challenges we face in modern cities (e.g. transportation, overcrowding). You can present your work to the class through a poster, PowerPoint or vlog/video.

Suggested materials/ presentation format

- Poster
- PowerPoint
- Video

Figure 8.47 A cell can be compared to a city.

Research and feasibility

1 List all the major organelles and their functions. Research the issues/resources that face a city and then match the issues/resources required with the organelle.

Organelle	Function	City issue/ resource	How the organelle provides the solution
Mitochondria	Provide energy for the cell	Cities need energy from a power plant.	They are like a power plant that gives energy to the whole city.

Design and sustainability

2 Discuss which type of cell you are going to model your city on and sketch a diagram of this type of cell. Then, as a group, label the organelles with the name and corresponding city resource.

3 Discuss the sustainability of the city you have designed. How could the city be self-sufficient for ALL its resources?

Create

4 Reflect on your basic design and start building a larger drawing that uses all your ideas. Keep thinking about all the issues faced by a city and how they are managed.

Evaluate and modify

5 Analyse the solutions you have come up with and comment on how achievable they would be in the real world today.

6 Explain any problems that might be encountered when implementing your solutions in the real world today. What types of technologies could be incorporated into your solutions (e.g. artificial intelligence, renewable energy)?

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Chapter 9
Organ systems

Inquiry questions

How do body systems work together?
What things does your body need to survive?
How do plants survive and grow?

PRE-TEST

Chapter introduction

You are a large and complex multicellular organism. You eat, move, sleep, think, breathe and fight disease every day, and you can only do this because of all the different types of cells and tissues in your body. Throughout this chapter, you will learn about how the cells, tissues and organs in your body work together to allow you to function effectively. You will also explore how scientific advances have allowed humans to repair and replace parts of the body.

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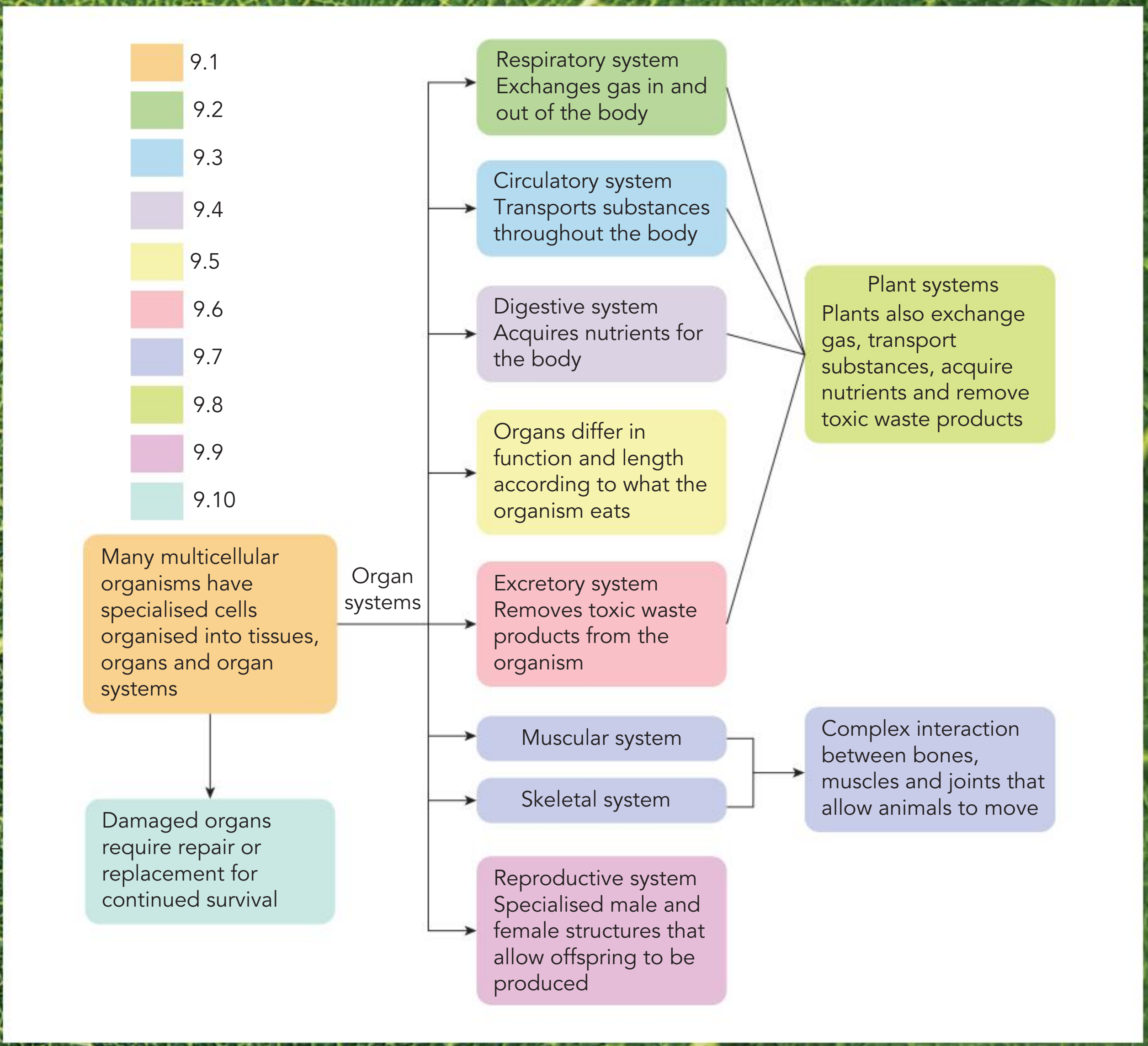
Chapter map



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9.1 Cells to systems

Learning goals

1 To name several specialised cells.
2 To state the levels of organisation in a multicellular organism.

DOC WORKSHEET

Specialised cells

structure a physical part of an object

function the job that an object does

differentiation the process by which cells become specialised

neuron a nerve cell

biconcave concave on both sides

Humans are animals, and our cells contain a nucleus, cell membrane, cytosol, mitochondria and all the other organelles discussed in the previous chapter. Even though most of our cells contain the same basic components, the different types of specialised cells within our bodies all have certain features or **structures** that allow them to perform a specific **function**. A structure is any physical part of an object, and a function is an activity that the structure helps the object to complete.

All the cell types in your body begin as unspecialised stem cells. As the cells grow and develop, they **differentiate**, forming over 200 different types of cells that are you. These cells then replicate to produce more copies of each type of specific cell.

Neurons

Nerve cells or **neurons** allow all the parts of your body to work together, by transferring signals to and from your brain to each part of your body via the nervous system. Nerves are important because they allow us to interact with the world around us via our senses. Neurons are long, thin cells that connect to each other via their highly branched ends. They have long axons, which are specialised to carry electrical signals over long distances, at very fast speeds. The longest nerve cell in your body is your sciatic nerve, which stretches from the bottom of your spine to your big toe.

Figure 9.1 Neurons are shown on the left, and on the right is the main organ of the nervous system, the brain.

Red blood cells

Red blood cells transport oxygen to all the cells in your body. These blood cells have to pass along tiny blood vessels and so they are flat and have a **biconcave** shape.

When they reach maturity, they do not have a nucleus, which gives them extra room to carry oxygen around the body.

As they do not have a nucleus, they cannot undergo cell division, and so all red blood cells are produced in the bone marrow. Your red blood cells are replaced every 120 days.

Figure 9.2 Red blood cells travelling through a blood vessel. Note their biconcave shape.

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Sperm cells

Sperm cells carry half the genetic information of a normal human body cell. Their purpose is to combine with an egg cell in a process known as fertilisation, which is the first step of reproduction. This means that the sperm cells have to be able to move. That is why they have a specialised tail, called a flagellum, which beats in a corkscrew motion and allows the sperm cell to swim. Sperm cells have many mitochondria in their midpiece, to provide energy for fast movement. Their head also contains an acrosome, a sac of digestive enzymes which digest through the membrane of the egg cell, allowing the sperm nucleus to enter.

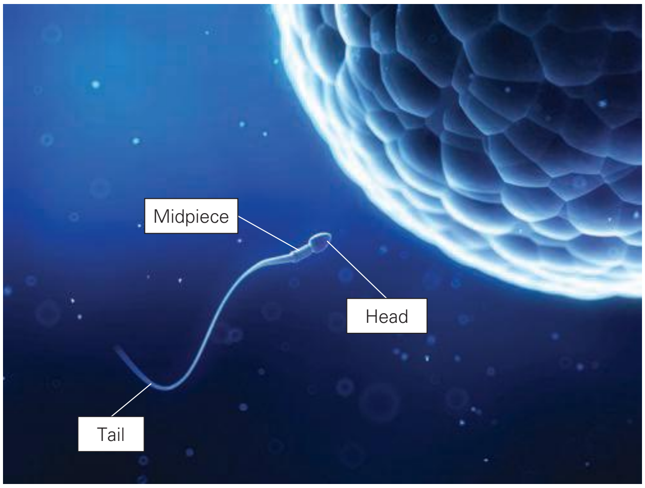

Figure 9.3 A sperm swimming towards an egg. Note its long whip-like tail.

Quick check 9.1

1 Recall the number of different types of cells in the human body.
2 Recall what unspecialised cells are called.
3 Identify one structural feature of each of the following cell types:
   a Neuron
   b Red blood cell
   c Sperm.

Practical 9.1

Specialised cells

Aim

To observe specialised cells under the microscope

Materials

- prepared slides of blood
- prepared slides of neurons
- prepared slides of blood vessels
- compound microscope
- transparent ruler

Be careful

Ensure that you carry the microscope appropriately. Carry it with one hand holding the arm and one hand under the base. Do not make big changes in magnification, so the glass slide does not get damaged.

Procedure

Part A: *Estimating the field of view*

1 Place the transparent ruler on the stage of the microscope.
2 Starting on the lowest magnification, focus on the ruler.
3 Measure the diameter of the area you can see under the microscope (field of view) using the ruler.
4 Record this measurement (in mm) in the field of view (FOV) table.
5 Calculate the FOV diameter in micrometres (μm) by multiplying the FOV in millimetres by 1000.
6 Calculate the FOV for each of the higher magnifications by repeating steps **2–5**.

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***Part B:** Estimating the size of the object*

7 Place your first prepared slide on the stage of the microscope.

8 Focus on the object using the lowest-power lens.

9 Estimate how many of the cells will fit in a straight line across the middle of the FOV.

10 Divide the total FOV diameter that you have already calculated by the estimated number of cells that will fit across the FOV.

11 Record your estimated diameter for the object in the results table.

12 Draw a scientific drawing of the cell you are observing.

13 Repeat steps **8–12** for each slide.

Results

Copy the following tables and use them to record your observations and measurements.

Magnification (ocular lens × objective lens)	FOV diameter (mm)	FOV diameter (μm) (mm × 1000)

Cell	Scientific drawing and magnification	Number of times cell would fit across the FOV	FOV diameter	Estimated diameter of object (FOV/ number of times object fits across)
Blood				
Neuron				
Blood vessel				

Discussion

1 Describe how the size and shape of each of the cells you observed benefits its function.

2 Assess the accuracy of your estimated sizes.

3 Suggest a way of improving your size estimates.

Levels of organisation

Cells are organised into tissues, tissues into organs, and organs into organ systems. An example is shown in Figure 9.4.

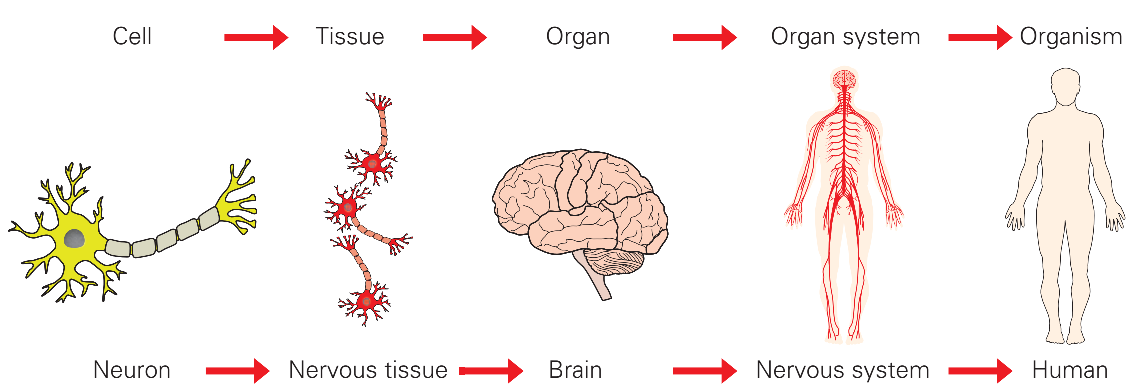

Figure 9.4 The nervous system is an example of cells being organised into an organ system.

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Cells

A cell is the basic unit of life. Every living organism is made up of at least one cell. Unicellular organisms are made up of only one cell and this cell interacts directly with its environment. This means that the cell can absorb nutrients from the substance it is on or in, and excrete waste directly into its surroundings. Humans are multicellular, and are composed of many specialised types of individual cells that carry out specific functions. Because of this, the cells inside your body cannot gain nutrients and get rid of wastes without the help of other cells. This is where tissues, organs and organ systems come into play.

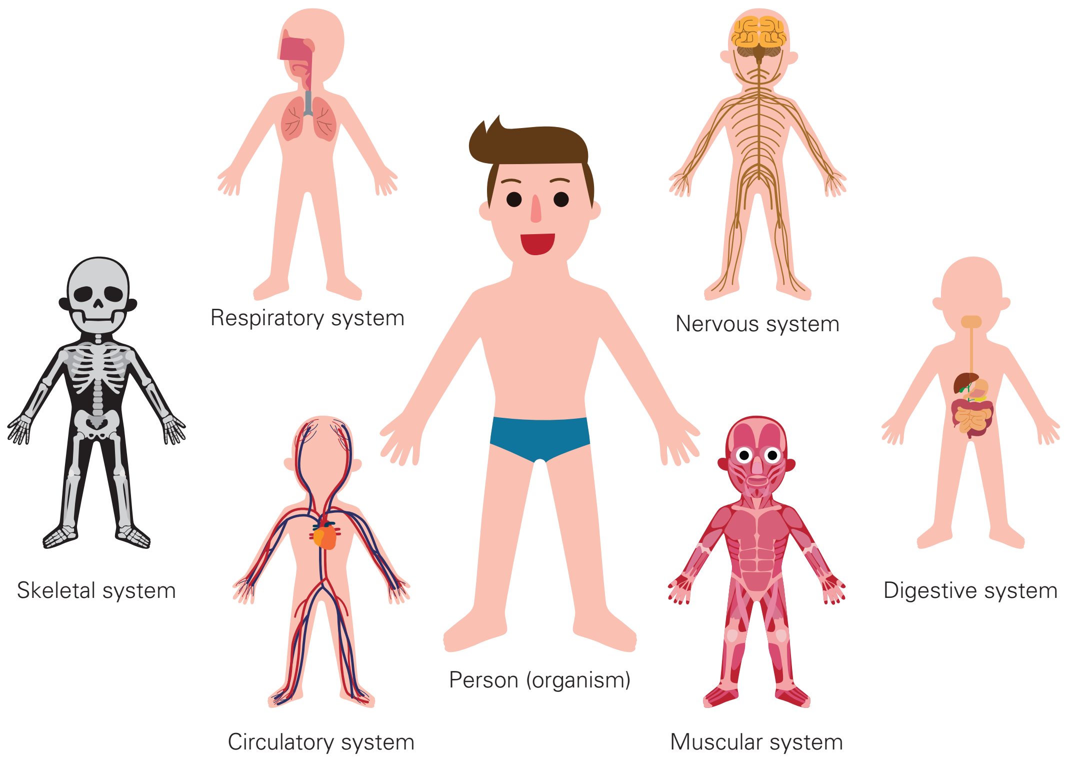

Figure 9.5 A multicellular organism, such as a human, is composed of many specialised cells, which are organised into tissues, organs and organ systems.

Tissues

When a group of cells of the same type work together in a body, we call them a **tissue**. One of the most obvious tissues in animals is muscle tissue. These groups of cells contract and relax in order to generate movement by the animal. Muscle tissues require lots of energy, and so each cell has many mitochondria to carry out **cellular respiration** and provide that energy. Muscle cells also have a good supply of blood to deliver oxygen and glucose for cellular respiration and to remove waste products such as **carbon dioxide**. Other types of tissue include lung tissue, liver tissue, and connective tissues such as tendons and ligaments. Even blood is considered a tissue.

tissue
a group of cells performing the same function

cellular respiration
a process that occurs inside the mitochondria, where oxygen and glucose react to form carbon dioxide and water, producing useable energy

carbon dioxide
a waste product produced in respiration

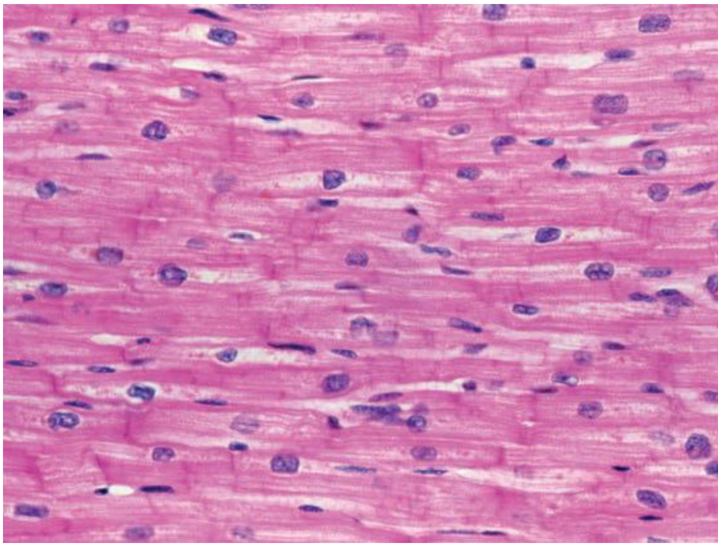

Figure 9.6 A high-magnification photograph of human cardiac (heart) muscle, seen through a light microscope. Each of the long, thin muscle cells has a purple nucleus. Note that a stain has been added to the tissue to make it more visible.

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Organs

A group of different tissues working together to perform a specific function is called an **organ**. The brain is one of the most important organs in the body and is made up of different nerve tissues that make up the grey and white matter. There are also many blood vessels that flow through the brain.

organ
a group of tissues working together to perform a function

Figure 9.7 The human brain is a complex organ composed of neurons, blood vessels and other cells.

Did you know? 9.1

The largest organ in the human body is actually our skin. On average, skin weighs around 2.7 kg and, if stretched out, would cover over 1.5 square metres. If you look closely at a small area of skin – say, the top of your hand – you will see tiny holes, called pores. What you can't see is that there are over six metres of blood vessels, thousands of nerve endings and hundreds of tiny glands secreting oil onto your skin. The skin cells themselves are replaced every 10–30 days, which means that, on average, we each get through around 900 complete skins in a lifetime.

Organ systems

A group of different organs working together is called an organ system (or body system). The structures of the system each perform distinct processes or functions. Your digestive system is one of the most diverse organ systems in your body, with around twelve main organs, such as the mouth, stomach, liver, pancreas and intestines, along with many other smaller organs and glands that help to break down food and absorb nutrients into your bloodstream.

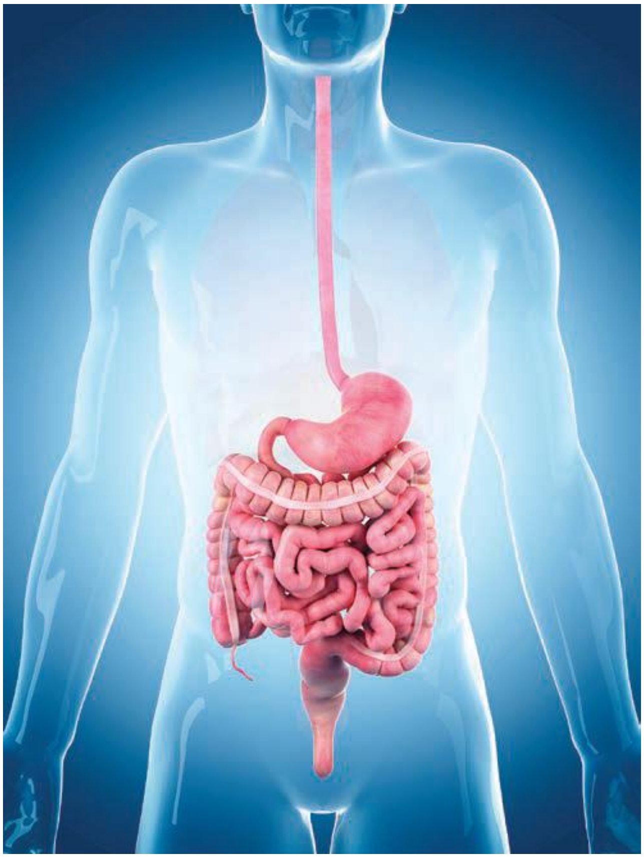

Figure 9.8 The human digestive system is essentially a long tube from the mouth to the anus. Many accessory glands assist in the digestive process.

Advances in science 9.1

Practice makes perfect

In late 2017, a research team from the University of Minnesota used 3D printers to produce lifelike artificial organs for training surgeons to practise on. While the use of models and computer simulations in surgical training is not new, these fake organs are much more realistic, as they perfectly mimic the anatomical structure, look and feel of a patient's organ. It is even possible to embed soft sensors in them, to give the surgeons feedback about their technique, with the aim of minimising surgical errors and improving patient outcomes.

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Try this 9.1

How many human organ systems can you name? Brainstorm with a partner and make a list. A helpful starting point might be to think of organs in the body and then classify them according to what organ system they belong to.

Organisms

A group of organ systems working together supports a living being, called an **organism**. Each day, we eat food, breathe air and excrete waste products from our bodies. The many organ systems in our bodies work together in integrated ways to detect and respond to changes and complete the processes required to keep us alive.

organism
a living creature, such as a plant or an animal

Explore! 9.1

Plants are complex

They are eukaryotic organisms, just like us. This means their cells have complex membrane-bound organelles, such as the nucleus. We tend to think that because plants are usually sessile (stationary), they are less complicated than animals, but plants also have specialised cells that are organised into tissues, organs and organ systems.

Research one plant of your choice and list one example of each of the levels of organisation:

- Cell:
- Tissue:
- Organ:
- Organ system:
- Organism:

Figure 9.9 A couple show an ultrasound image of their unborn baby. It is amazing to think that inside this tiny organism (within another organism!), all the body's essential organ systems are developing.

Quick check 9.2

1 Sequence the following structures into the correct level of organisation, from largest to smallest: cell, organ system, organism, organ, tissue.
2 Propose why unicellular organisms don't have organs.
3 Name five components of the human digestive system.

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Try this 9.2

Levels of organisation study mate

Step 1 Hold a piece of A4 paper in 'portrait' (upright) orientation.

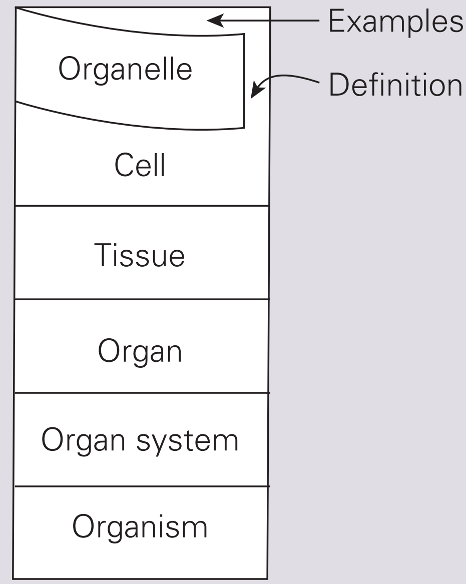
Step 2 Fold it in half vertically – from left to right. You have formed a brochure with four sides or pages.

Step 3 Cut the front page only into six horizontal sections, and label the front of these six flaps 'organelle, cell, tissue, organ, organ system, organism' from the top down.

Step 4 On the back of each flap, add the definition of each of the six levels of organisation.

Step 5 On the third page of the brochure, add some examples of each of the six levels of organisation.

When you look at the front of the brochure, you should see the names of the levels of organisation. As you open each flap, you should see the definition and examples.



Section 9.1 questions

Remembering

1 **State** the function of red blood cells.

2 **State** one structure of a nerve cell that allows it to complete its function.

3 **Define** the term 'tissue'.

Understanding

4 **Explain** how the sperm cell's tail relates to its function.

5 **Explain** why multicellular organisms need multiple specialised cell types working together to function properly.

Applying

6 **Sketch** some simple diagrams that model the difference between a cell, a tissue, an organ and an organ system.

7 **Choose** which of the following statements are correct.

A An organ is composed of different types of tissue.

B A tissue is composed of only one type of cell.

C If you look at a tissue under the microscope, you will see many different organs.

Analysing

8 **Compare** and contrast a sperm cell and a red blood cell.

9 **Categorise** the following terms as either cells, tissues, organs, organ systems or organisms: liver, neuron, sperm, dog, digestive, human, eucalyptus, brain, muscle, blood.

Evaluating

10 A new organism is discovered, and a study of its internal anatomy reveals that nutrients enter via a hole and are transported through a long tube into a storage area, before being excreted through a **sphincter**. **Justify** whether this is evidence of a tissue, an organ or an organ system.

sphincter
a muscle that surrounds an opening in the body and can tighten to close it, e.g. at the bottom of the oesophagus, leading into the stomach

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9.2 The human respiratory system

Learning goals

1 To contrast breathing and respiration.

2 To describe the organs found in the respiratory system and their function.

DOC WORKSHEET

Breathing vs. respiration

You can probably hold your breath for about a minute, maybe two, but after that your body forces you to take a huge gulp of air. This is because the cells in our bodies need a constant supply of fresh oxygen to produce energy and function efficiently. Cellular respiration is the process that happens inside the mitochondria in our cells, which turns glucose and oxygen into useable energy called ATP. The process also produces the waste products of carbon dioxide and water. If you stop breathing, you are preventing oxygen entering your body and therefore depriving your cells of oxygen, meaning ATP cannot be made.

Key idea

To summarise: breathing is a physical process, respiration is a chemical process.

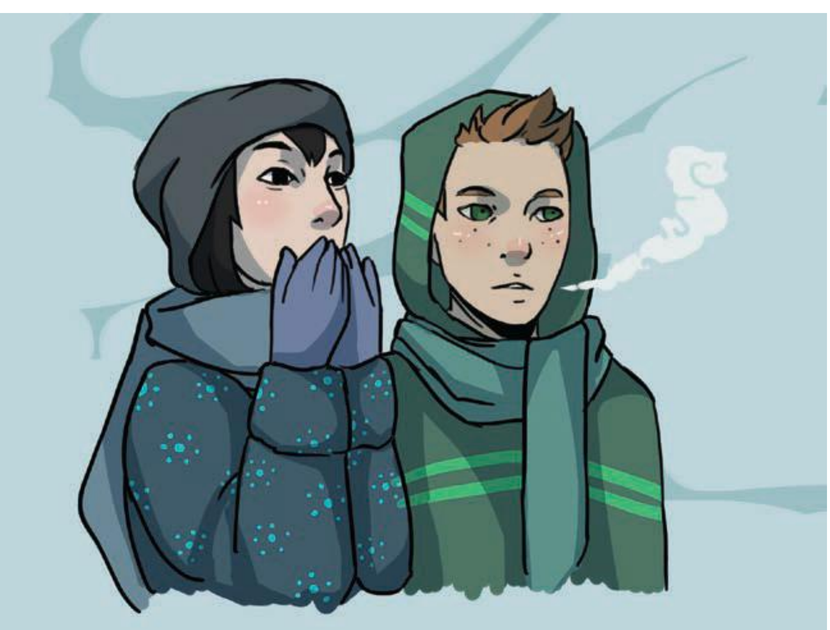

Figure 9.10 When you breathe out on a cold day, you can see your warm breath start to condense in the cold air.

Did you know? 9.2

Freedivers

While you or I might be able to hold our breath under water for about 30 seconds, people who practise freediving can hold their breath for more than 20 minutes! Freedivers do not use equipment like scuba gear. Instead, they have developed techniques such as hyperventilation, which allows them to reduce the concentration of carbon dioxide in their blood. Special breathing exercises aim to increase their lung capacity, and their bodies are adapted to dealing with prolonged periods of low oxygen. In 2018, Croatian freediver Budimir Šobat held his breath under water for 24 minutes and 11 seconds, breaking the Guinness World Record by 8 seconds.

Figure 9.11 Freediving in the ocean

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The respiratory system

The main function of the organs in the respiratory system is to get oxygen into your body cells and release the waste product carbon dioxide into the air. The respiratory system works very closely with the circulatory system, which transports the oxygen you breathe in and removes the carbon dioxide you breathe out.

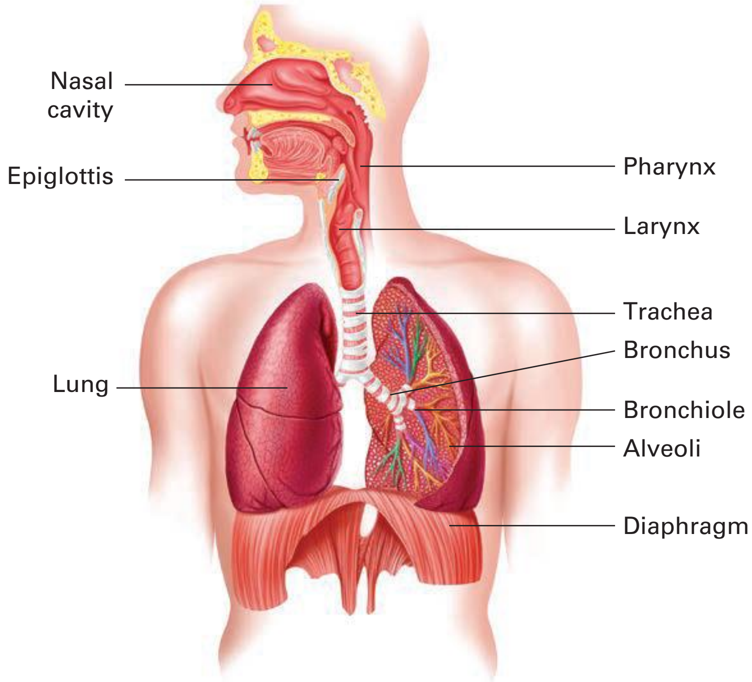

Figure 9.12 Structure of the human respiratory system

Big breath in!

When you breathe in (inhale), a large muscle at the base of your ribs, called the **diaphragm,** contracts and pulls down. At the same time, the **intercostal muscles** between your ribs contract, moving the ribs upwards and outwards. This increases the volume in your chest, drawing air in through your mouth and nose, decreasing the pressure in your lungs compared with the outside. As you breathe out (exhale), the diaphragm relaxes and air is passively released through your nose and mouth because the pressure has increased in the lungs.

diaphragm
a dome-shaped muscle that separates the chest and abdominal cavities; it contracts to cause us to inhale

intercostal muscles
many different groups of muscles that run between the ribs, which help form and move the chest wall

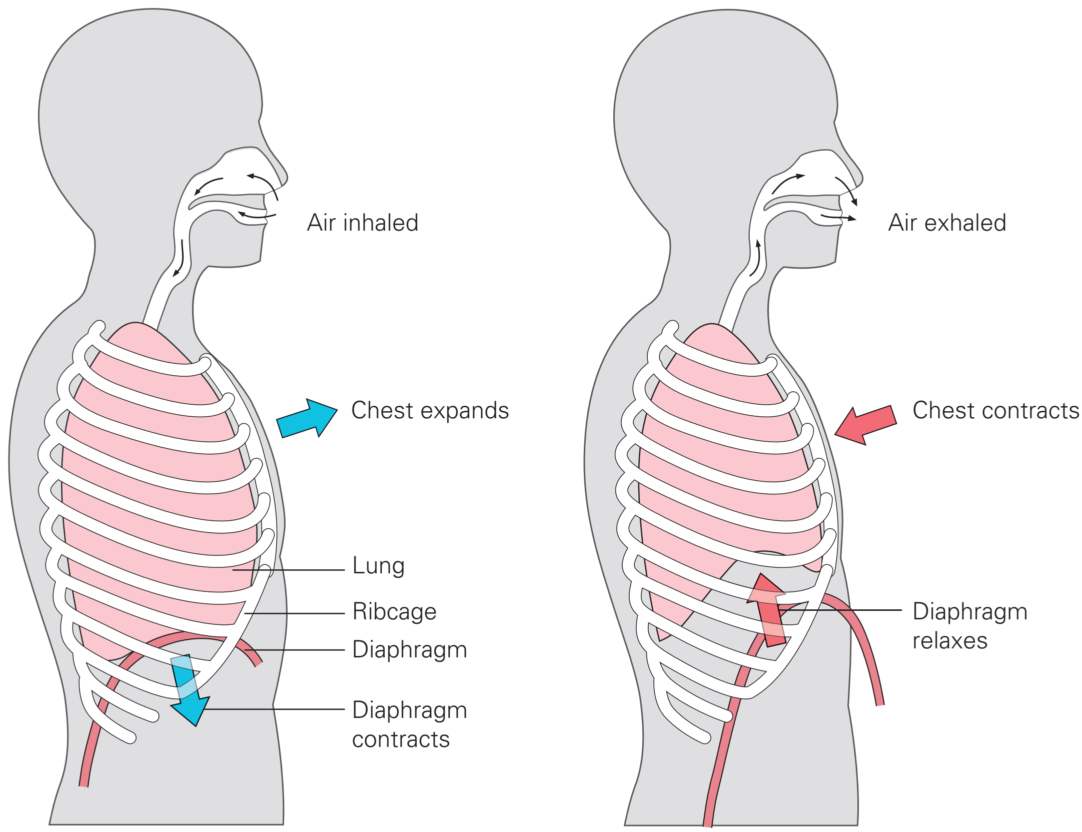

Figure 9.13 The movements of the chest during inhalation and exhalation

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Mouth and nose

The two main openings to your respiratory system are your mouth and your nose. It is best to breathe through your nose, as the function of your nose is to warm up and moisten the air coming into your body, filter out any particles via the hairs in your nasal cavity and also stimulate your sense of smell. If you close your mouth and exhale, the air will be directed out through your nose. This is because the nose and the mouth are connected in a region called the **pharynx**, which leads to the **trachea** or windpipe.

Trachea and bronchi

The trachea is a wide tube with thick protective rings of cartilage that keep it open. You can feel the rings if you feel your throat. Warm, moist air from the nose and mouth enters the lungs by travelling down the trachea. The structure of your lungs is very similar to a tree. The trunk of the tree is the trachea, and this large tube splits into two smaller tubes called **bronchi**, which are similar to branches and lead into the left and right lungs. The bronchi then branch into smaller and smaller tubes called **bronchioles**, which are similar to small twigs.

Alveoli

When the air gets to the end of the smallest bronchiole, it enters small sac-like structures called **alveoli**. The alveoli are only one cell thick and are surrounded by a net of very small blood vessels, called **capillaries**. This is where gas exchange occurs: inhaled oxygen diffuses out of the alveoli and into the capillaries (into the bloodstream) for transport around the body. Carbon dioxide moves in the opposite direction, from the capillary into the alveoli. As the diaphragm and intercostal muscles relax, the carbon dioxide-rich air is exhaled out through your nose and mouth.

pharynx
the throat region where the nasal cavity and oral cavity meet, leading into the trachea

trachea
the tube that carries air down to the lungs; also known as the windpipe

bronchi
the two branches of the airways that split off the trachea, one main left bronchus to the left lung and one main right bronchus to the right lung

bronchioles
smaller branching tubes that branch off the two large bronchi and lead to the alveoli

alveoli
the tiny sacs at the end of bronchioles in the lungs; the site of gas exchange with the capillaries

capillaries
the smallest blood vessels, one cell thick, and the site of gas exchange with cells

VIDEO
Describe what happens in an alveolus

Figure 9.14 This drawing of the lungs shows the blue central trachea dividing into the left and right bronchi. The orange bronchi then branch into bronchioles.

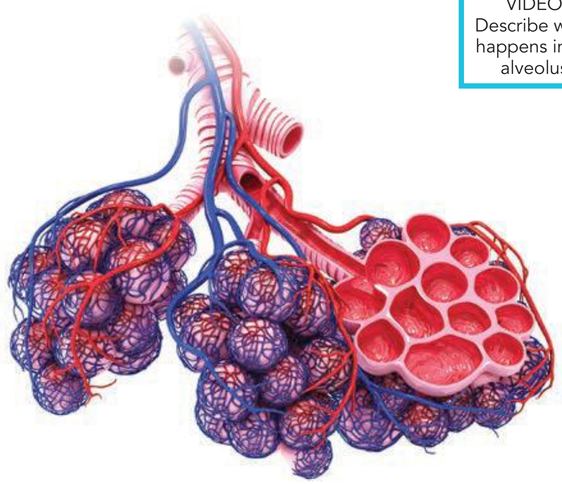

Figure 9.15 Gas exchange occurs between the alveoli and the capillaries. The oxygenated blood is returned to the heart, and the carbon dioxide-rich air is exhaled.

Explore! 9.2

Snoring

Snoring can be an annoying habit and can prevent people from getting a good night's rest. You snore because parts of your throat relax and vibrate as you breathe once you're asleep. However snoring can also be a symptom of bigger medical problems. Do some research into why snoring occurs and what can be done to stop it. Your research should answer the following questions.

1. What are some risk factors for snoring (things that increase your likelihood of snoring)?
2. Which structures in the respiratory system are involved in snoring?
3. Snoring can be a warning sign of a medical condition called sleep apnoea. Describe this condition.
4. What treatments are available to reduce snoring?

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Practical 9.2

Modelling the pressure changes in the lungs

Aim

Model how contraction of the diaphragm creates negative pressure inside the lungs. Use the following materials:

Materials

- plastic bottle, 500 mL or 1 L
- straw
- 2 rubber bands
- 2 balloons
- putty
- scissors
- sticky tape

Procedure

1 Tie a knot in one of the balloons and then cut off about a quarter of the other end.
2 Cut the bottle in half and only use the top half.
3 Put sticky tape around the cut edge of the bottle.
4 Stretch the cut balloon over the cut bottle opening, and secure in place with an elastic band and sticky tape.
5 Put a straw into the second balloon and use an elastic band to hold them together.
6 Place the straw with balloon attached through the neck of the bottle and seal the hole with putty.
7 Pull down on the bottom balloon covering to mimic the diaphragm contracting and describe what you observe.

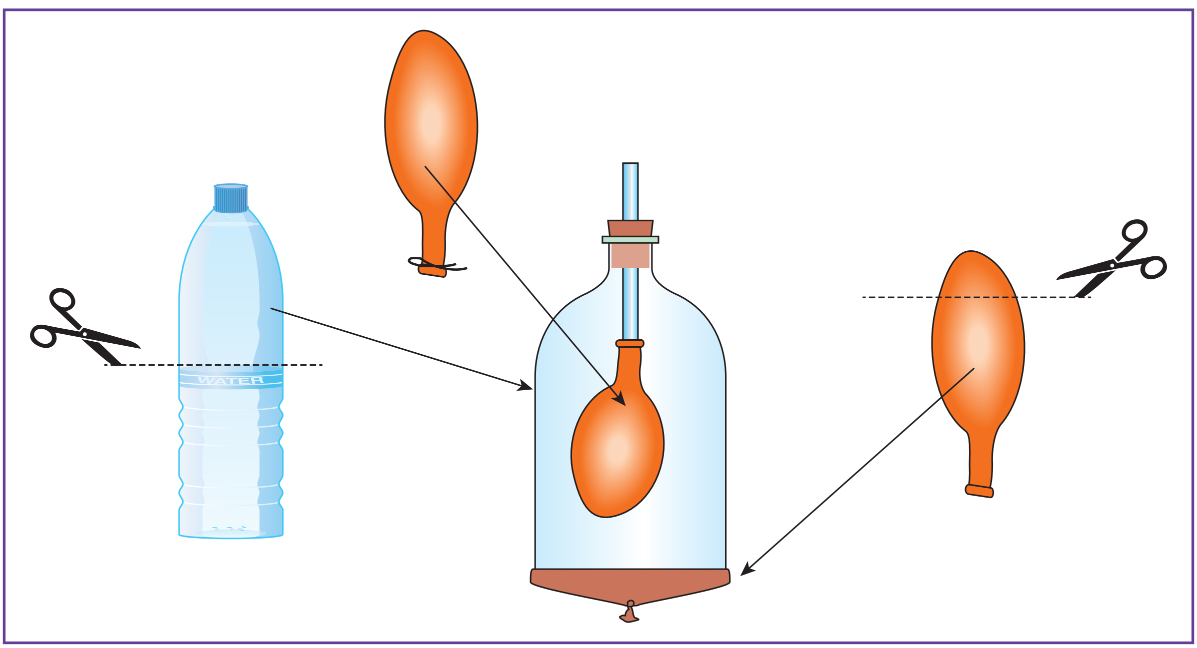

Figure 9.16 Experimental set-up. Breathing in: pressure in the lungs is lower than the atmosphere, so air flows in. Breathing out: pressure in the lungs is greater than the atmosphere, so air flows out.

Results

Draw your model of the lung in your book and label each of the parts that represent the following structures: lungs, ribs, diaphragm, trachea, mouth.

Discussion

1 What similarities can you draw between your model and the actual human respiratory system?
2 Describe the flow of air when you pull down on the balloon at the bottom of your model.
3 Explain what happens to the balloon lung when you push the balloon at the bottom of your model upwards.

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Advances in science 9.2

Asthma

Asthma is a chronic lung condition that involves inflammation of the airways, tightening of the bronchioles in response to certain triggers, and hypersecretion of mucus in the airways. People who suffer from mild asthma might feel slightly tight in the chest when they exercise or breathe in cold air, but some people with severe reactions must take medication such as steroids every day to treat the inflammation.

A recent development has seen asthma patients benefitting from using an antibody that has previously been used to treat eczema (an inflammatory skin condition that causes dry, itchy rashes). The antibody appears to block a protein that causes some of the inflammation in the airways, and results in improved lung function in the participants and less reliance on steroid medications.

Figure 9.17 An asthma sufferer uses a reliever medication (an inhaler or puffer) to reduce the inflammation and open up their airways.

Quick check 9.3

1 Define the main function of the respiratory system.
2 Describe what happens to air as it passes through the nose.
3 Sequence these terms in order so that they represent the direction of airflow during inhalation: alveoli, pharynx, nose/mouth, bronchus, trachea, bronchiole.
4 Explain how the diaphragm is involved in breathing in and out.

Did you know? 9.3

Your lungs float!

Each of your lungs contains around 300 million alveoli, which you can imagine as tiny balloons. When ‘inflated’, the lungs are the only organ in the human body that can float on water.

Gas exchange in animals

Deep in the lungs, the alveoli are the site of gas exchange in humans and other species that have lungs. But some members of the animal kingdom have developed very different specialised structures for gas exchange, such as gills in fish, skin in frogs and tracheoles in insects. All these structures share common features to allow for efficient function. These features are:

- a very large surface area. This is usually achieved by a folded surface, which increases the amount of gas that comes into contact with the animal’s blood.

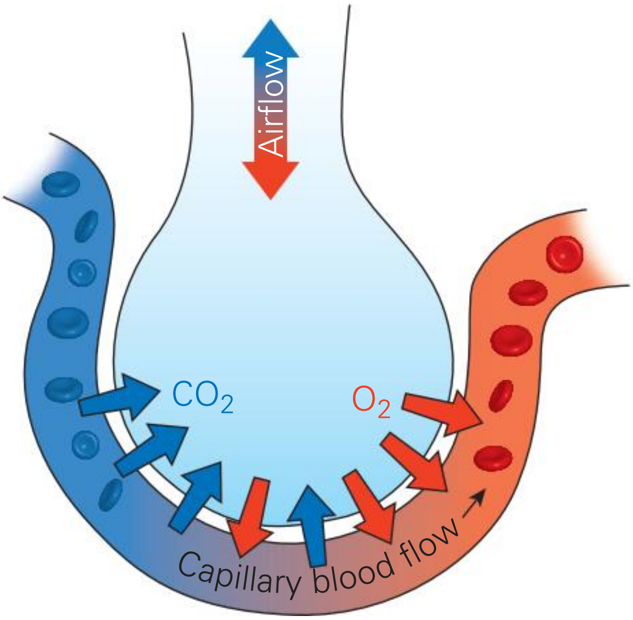

Figure 9.18 Gas exchange between the alveolus and the capillary. Note the direction of diffusion as oxygen enters the bloodstream and carbon dioxide leaves the bloodstream.

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- a moist surface that gases dissolve into before they enter or leave the body. This makes the process of diffusion much easier for gases.
- a thin surface and small barrier between the inside and the outside of the body. This means that the gas has to travel a smaller distance.
- a transport system near these structures, such as blood vessels, to transport the gases to all parts of the body.

The alveoli in our lungs have all the features listed previously, which makes them an extremely efficient gas exchange surface. Their surface area is so large that if you were to pop your alveoli open and spread them out flat, they would cover 18 table tennis tables. That is a lot of surface area for gas exchange, squeezed into your chest.

Quick check 9.4

1 Recall the site of gas exchange in the lungs.
2 State three other gas exchange structures found in the animal kingdom.
3 Recall the advantage of having a moist surface for gas exchange.

Explore! 9.3

Frog business

Life began in the oceans, and gills were the first form of respiratory organ. As animals began to move onto land, a new gas exchange surface was needed. Evidence of this gradual change from aquatic life to terrestrial (land) life is present in amphibians today. In amphibians such as frogs, newts and salamanders, there are several ways in which gas can be exchanged. Unlike mammals and birds, amphibians are cold blooded. This means that their level of respiration can be lower, compared with warm-blooded animals, and so their cells need less oxygen to function properly.

1 Tadpoles spend all their time in water. Find out how they get oxygen, and explain how the features of gas exchange (thin, moist surface etc.) relate to this process.
2 As tadpoles transition into adults, the process they use to gain oxygen changes. Explain how it changes.
3 Find out what 'cutaneous respiration' is and how it relates to a frog getting oxygen. Link this information to the features that gas exchange surfaces exhibit.

Figure 9.19 A frog keeping its nostrils above water to breathe

Figure 9.20 A frog with an extended buccal cavity

Try this 9.3

Modelling an animal respiratory system

Using whatever materials you can find (suggestions: plastic bags, string, bucket, rubber tubing), construct a model of an animal's respiratory system.

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Section 9.2 questions

QUIZ

Remembering

1 **Name** the gas that is absorbed into the body by the respiratory system.
2 **Name** the gas that is removed from the body by the respiratory system.
3 **State** the scientific name for the 'windpipe'.

Understanding

4 **Describe** the features necessary for effective gas exchange.
5 **Explain** how the parts of the respiratory system are similar to a tree.
6 **Outline** the functions of each of the following parts of the respiratory system:

Structure	Function
Alveolus	
Trachea	
Nose	
Bronchiole	

Applying

7 **Summarise** the movement of the diaphragm during inhalation and exhalation.
8 **Identify** how the structure of the alveoli facilitates gas exchange.
9 A person suffers a spinal cord injury at a level that paralyses their diaphragm. **Describe** the effect this would have on their ability to breathe.
10 **Construct** a flow chart showing the route taken by an oxygen molecule, starting from the air in your classroom and finishing in a body cell.

Analysing

11 **Contrast** the term 'breathing' with the term 'respiration'.
12 The graph in Figure 9.21 shows a person's respiration rate when resting and when exercising.
  a **Identify** the person's respiration rate at rest.
  b **Identify** their respiration rate at the maximum treadmill speed.
  c **Infer** why their respiration rate increased during exercise.

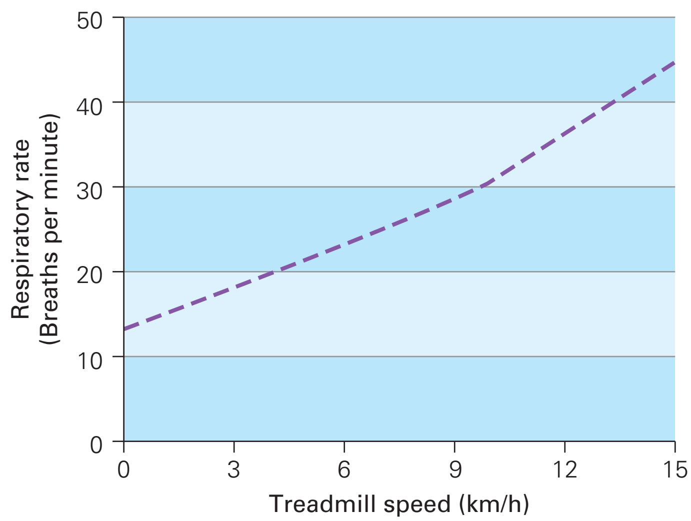

Figure 9.21

Evaluating

13 **Suggest** why it is better to breathe through your nose than through your mouth.
14 Cystic fibrosis is a disease that causes over-production of mucus in the airways and can be life-threatening if the person catches a cold or the flu, resulting in a chest infection. **Suggest** a reason why a build-up of fluid in the lungs can be harmful, and why the person may experience shortness of breath.

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9.3 The human circulatory system

WORKSHEET

Learning goals

1 To describe the structure and function of organs found in the circulatory system.
2 To describe the purpose of the circulatory system.

The partner of most of the organ systems in the body is the circulatory system. This is a transport system that moves oxygen, nutrients, **hormones**, immune cells, waste and heat throughout the body, in one continuous loop, for your entire life. Without the circulatory system, none of the other organ systems would be able to function.

hormone
a chemical produced by cells that controls and regulates different processes in the body

Heart

The heart is a powerful muscular pump. It has one job: to maintain pressure in your circulatory system, which moves the blood around your body. It generates high pressure, which pushes blood out of your heart into the arteries. Blood is pushed towards the heart because valves in the veins prevent back-flow, and it continues moving because of muscles around the veins applying pressure.

Advances in science 9.3

Printed heart

In 2019, scientists in Israel announced that they had 3D-printed an entire heart, using a bio-ink gel made from cells. The thumb-sized heart was printed in just three hours and contained the atria and ventricles of a normal heart. The scientists are now working on how to make it beat and circulate blood, but this development could potentially be used in the future to 3D-print organ replacements for humans.

Figure 9.22 3D printing of a human heart

Try this 9.4

Testing your heart rate

Your heart rate responds to the oxygen requirements of your body. For each of the following test conditions, follow the procedure below and record your heart rate (in beats per minute) in the table. You will need a stopwatch.

Find your pulse by gently pressing two fingers over your radial artery (on the soft side of your wrist, slightly off centre towards the thumb). Count the number of beats you feel in 15 seconds, using the stopwatch, and then multiply by 4 to find your heart rate in beats per minute (bpm).

Test your pulse under the following conditions, then copy and complete the table.

Test condition	Heart rate (bpm)
Lying down	
Sitting	
After jogging for 3 minutes	

Figure 9.23 Feeling for the radial pulse

Graph your data as a bar chart, and answer the following questions.

1 During which test condition was your heart rate:
  a at its highest
  b at its lowest?
2 For each answer you gave to Question **1**, propose a reason why this was the case.

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Once in your heart, blood is ready for recirculation. Your heart does this by contracting and relaxing about 60–90 times per minute.

Your heart is located near the centre of your chest, and it is about the same size as when you form a fist with your hand. It is made up of four main sections: the right **atrium** and left atrium (top parts of the heart), and the right and left **ventricles** (v-shaped bottom part of the heart).

Unlike other muscles in your body, the heart is myogenic, meaning it contracts (beats) without having to receive instructions from the brain. The heart has its own natural pacemakers, called the **sinoatrial node**, located in the wall of the right atrium, and the **atrioventricular node**, located between the atria and the ventricles. The nodes send an electrical signal throughout the heart, causing it to contract.

The human circulatory system is like a double pump: the left side sends blood out to the body, and the right side sends blood to the lungs. Let's follow the path of a red blood cell through the circulatory system, using Figure 9.25 on page 332.

atrium
one of the two upper chambers of the heart, the left atrium and right atrium

ventricle
one of the lower two chambers of the heart, the left and right ventricles

sinoatrial node
a natural pacemaker that controls the heartbeat and is located in the wall of the right atrium

atrioventricular node
a natural pacemaker that controls the heartbeat and is located in between the atria and the ventricles

VIDEO
Describe how the heart chambers contract

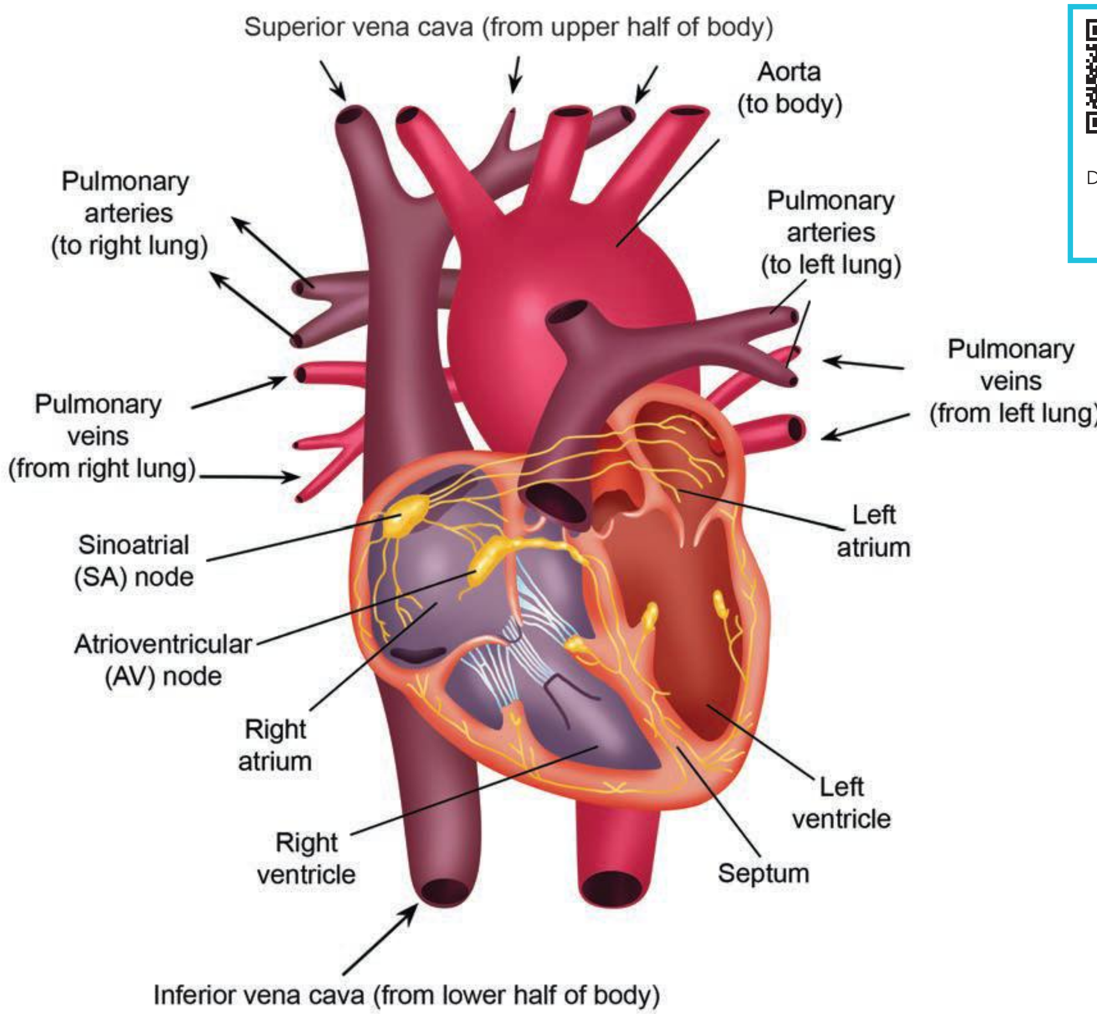

Figure 9.24 The human heart and its major vessels, chambers and valves. The heart is labelled as it sits in your chest, but it is drawn as if it were visible to someone facing you. This is why the left ventricle is located on the right-hand side of the diagram.

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Did you know? 9.4

Red or blue?

When you look at your wrist, you might be tempted to think that your veins are blue. The light passing through our skin makes our veins look blue, but this is just an illusion! Veins look blue because blue and red light have different wavelengths and penetrate your skin with different levels of success. Red light travels easily through your skin and is absorbed by the red pigment (haemoglobin) in your red blood cells. However, blue light is largely scattered when it hits your skin and is reflected back to your eye as blue light.

Blue veins are particularly noticeable on very pale skin, and may have caused the expression 'blue blood' when talking about royals. In the 18th century, nobility were untanned as they did no manual labour outside, and so their veins would have appeared very blue.

Your veins contain deoxygenated blood (lower levels of oxygen), which is actually still red, just a darker shade. Some diagrams use blue to indicate areas of the circulatory system containing deoxygenated blood, but this is just a colour choice. Your blood is always red.

vena cava
the large vessel that returns deoxygenated blood to the heart, emptying into the right atrium

aorta
the largest vessel leaving the heart, from the left ventricle, carrying oxygenated blood to the body

Blood returning to the heart from the body enters the heart though the **vena cava** and goes into the right atrium. This blood has low levels of oxygen and high levels of carbon dioxide, and so in the diagram it is coloured dark red.

The blood then passes into the right ventricle, and is prevented from travelling backwards by a valve between the atrium and the ventricle. Once in the ventricle, the blood is then pumped out of the heart and travels via the pulmonary artery to the lungs.

As the blood passes through the lungs, it releases the carbon dioxide it has stored within it and gains oxygen from the alveoli of the lungs. Notice that, in Figure 9.25, the blood coming from the lungs is now coloured bright red.

The oxygenated blood then returns from the lungs through the pulmonary veins into the left atrium, where it passes into the left ventricle and is then pumped out via the **aorta** to all the different parts of the body, delivering oxygen to the cells and picking up the waste carbon dioxide.

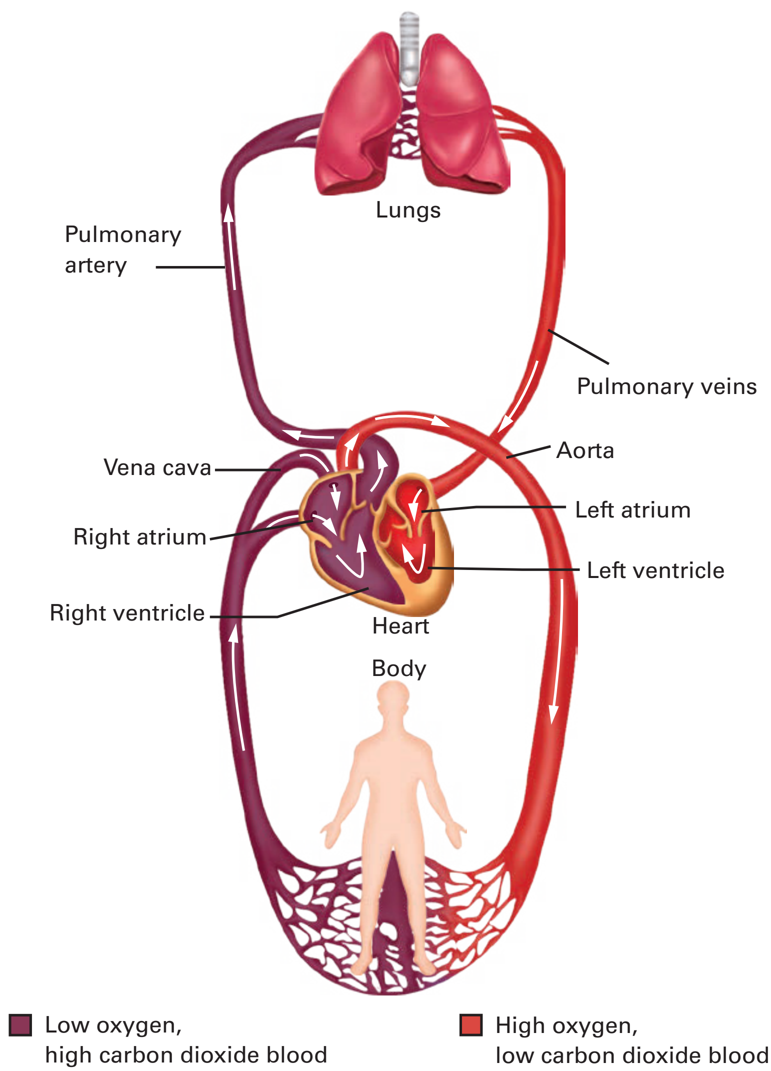

Figure 9.25 Blood flows in the following loop: right atrium ➔ right ventricle ➔ pulmonary artery ➔ lungs ➔ pulmonary vein ➔ left atrium ➔ left ventricle ➔ aorta ➔ body tissues ➔ vena cava ➔ right atrium … and the loop starts again.

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Quick check 9.5

1 Name the four chambers of the heart.
2 Name the two structures that make up the heart's natural pacemaker.
3 For each of the vessels listed below, state whether it carries oxygenated or deoxygenated blood.
   a Vena cava
   b Pulmonary artery
   c Pulmonary vein
   d Aorta

Practical 9.3

Sheep heart dissection

Aim

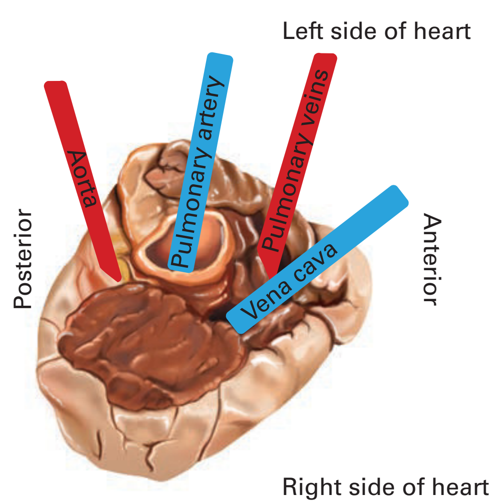
To identify the path of blood flow through the heart and become familiar with the structures.

Materials

- lamb heart, preferably with aorta and vena cava attached
- dissecting scissors
- disposable gloves
- two blue and two red pipe cleaners (or straws)
- wash bottle
- dissecting tray

Procedure

1 Place the heart on the dissecting tray, and identify the front (anterior) and back (posterior).
2 Before cutting into the heart, identify:
   - the vena cava – place a blue pipe cleaner into the vena cava (representing deoxygenated blood)
   - aorta – place a red pipe cleaner into the aorta (representing oxygenated blood)
   - pulmonary artery – place a blue pipe cleaner here (representing deoxygenated blood, note that this connects to the same chamber as the vena cava)
   - pulmonary vein – place a red pipe cleaner here (representing oxygenated blood, note that this connects to the same chamber as the aorta)
   - right/left side (remember, these will be opposite your left and right).



3 Place your finger into the vena cava and then into the aorta. Notice the difference in strength and thickness of the walls of the blood vessels.

continued…

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...continued

Right atrium

4 To open the right side of the heart, place the dissecting scissors into the vena cava and cut down the wall of the heart, stopping about a quarter of the way down the heart.
5 Open the atrium chamber and locate the valve joining the right atrium to the right ventricle.
6 Using water from a wash bottle, fill the right ventricle through the valve.
7 Gently squeeze the heart and observe as the water moves up and tries to re-enter the atrium.

Right ventricle

8 Continue to cut down the same line you made earlier, to expose the right atrium.
9 Locate the 'heart strings' within the ventricle.

Left side of the heart

10 Repeat the process above to expose the left side of the heart.
11 Compare the thickness of the walls of the heart on the left and right sides.

Discussion

1 Identify which chambers of the heart receive the blood and which pump the blood.
2 Describe the action of the valves in the heart.
3 Compare the wall thickness of the right and left sides of the heart. Suggest a reason why they differ.
4 Describe how the vena cava and aorta felt on your finger.

Advances in science 9.4

Mapping the heart

The electrical signals generated in your heart usually keep it beating in a way that allows the atria to fill, then the ventricles to fill, and then the blood to exit via the major vessels. But occasionally, the electrical signals go haywire. In some cases, the heart can go into a rapid, dangerous arrhythmia. In a recent study, scientists created 3D simulations of a patient's heart, to allow them to tailor medical treatment. A 3D simulation can allow cardiac surgeons to identify the exact location of the electrical problem, and destroy the tiny areas of heart muscle that are causing the problem, to prevent the heart from going into a fatal arrhythmia.

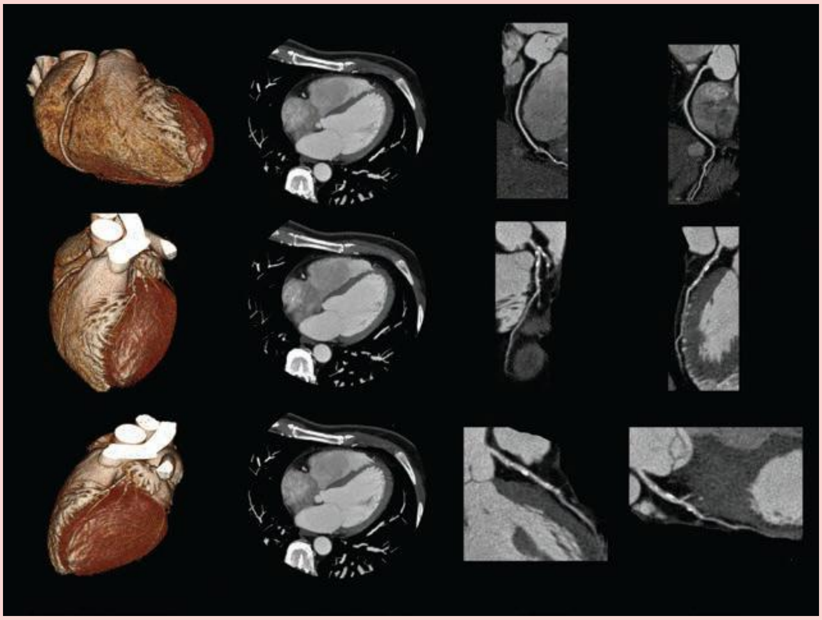

Figure 9.26 A CT scan of a patient's heart

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Vessels of the circulatory system

There are three main types of blood vessels in the body: arteries, veins and capillaries.

Arteries

Arteries take blood away from the heart. They usually carry oxygenated blood to all the cells of the body, with one exception: the pulmonary artery, which carries deoxygenated blood to the lungs. The blood in arteries is pumped out of the heart with a lot of force and this means that the artery walls have to be thick, muscular and strong to withstand the great pressure being pushed upon them.

artery
a thick, muscular elastic vessel that carries blood away from the heart

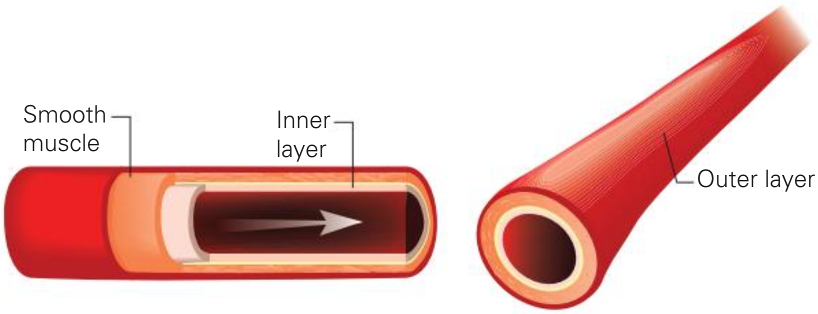

Figure 9.27 The structure of an artery

Capillaries

As the blood travels away from the heart, it enters smaller and smaller blood vessels, eventually leading to the capillaries. Just like the alveoli in the lungs, all other tissues in the body are surrounded by a network of tiny capillaries that allow nutrients and gases to be delivered to cells while removing waste. The walls of capillaries are extremely thin, only one cell thick, to allow nutrients and gases to pass into the tissues.

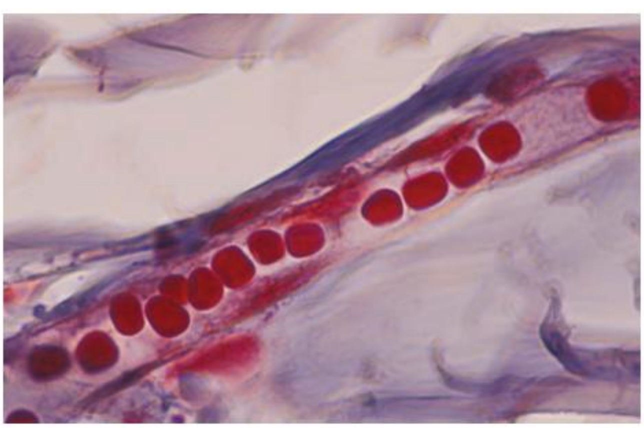

Figure 9.28 A capillary is only slightly wider in diameter than a red blood cell.

Veins

As the blood travels away from the body tissues and back towards the heart, it moves from the capillaries into the **veins**. At this point in the cycle, the blood is under much less pressure and so the vein walls do not need to be as thick and muscular as artery walls. However, the veins need to prevent blood from flowing backwards, and so they have special valves that prevent this from happening.

vein
a thin-walled vessel with valves that carries blood back to the heart

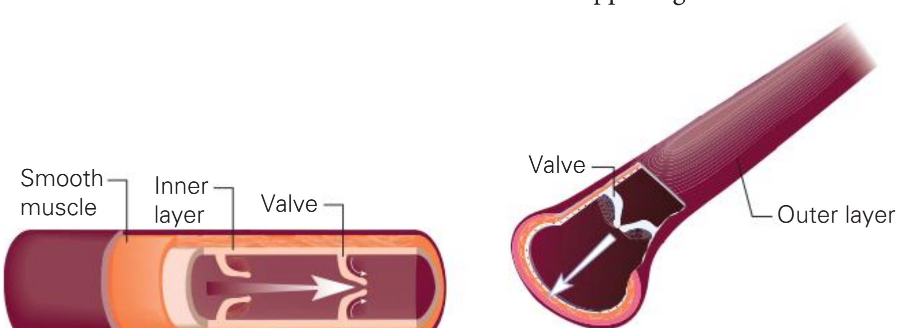

Figure 9.29 The structure of a vein

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Quick check 9.6

1 State the vessel type that matches each feature listed below.
  a Thick, muscular walls
  b Diameter one cell wide
  c Valves to prevent backflow of blood
  d Carry oxygenated blood (except for the pulmonary vessel)
2 Explain why arteries carry blood at high pressure.

Explore! 9.4

Circulatory system technologies

There are a number of surgical procedures and devices that can assist people who have malfunctioning hearts. Choose one or more of the following to research, and answer the questions below.

- Coronary artery stents
- Automatic external defibrillators
- Implanted pacemakers
- Mitral valve replacements

1 How does this device or technique work?
2 What problems of the heart does it assist with?

Did you know? 9.5

Bruises

Bruises occur when an impact breaks the capillaries under the skin. As the trapped haemoglobin in the red blood cells breaks down, it changes colour, leading to the colour changes you see in bruises over a couple of weeks.

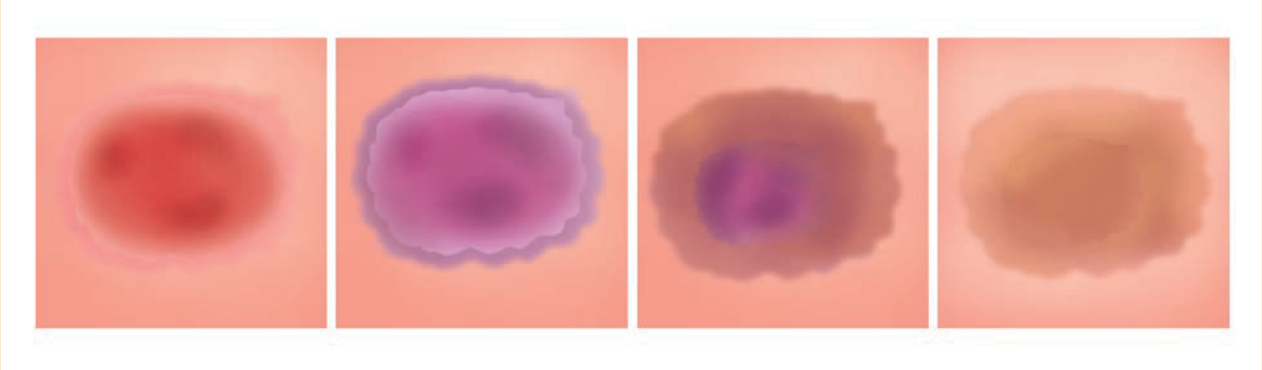

Figure 9.30 from left to right, a stage 1 bruise is red; a stage 2 bruise is purple. At stage 3 it becomes blue, and at stage 4 it becomes more yellow.

Try this 9.5

Examining vessel types

Your teacher can provide some prepared slides showing cross-sections of arteries, veins and capillaries. Observe these vessel types under the microscope, and try to identify all the features discussed in this section.

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Blood

The human circulatory system is structured around a pumping heart and connected vessels, but the third part is the tissue that is actually circulated: blood.

You have around five litres of blood circulating around your body all the time. This blood contains dissolved nutrients, gases and several types of cells.

Most of your blood is made up of a liquid called **plasma**. Plasma is a yellowish liquid, made up mainly of water, that contains all the dissolved nutrients and hormones that are travelling to the tissues around your body.

The second-largest component of blood is the red blood cells. These cells contain a molecule called **haemoglobin**, which gives blood its red colour. Haemoglobin molecules contain iron and can bind with oxygen molecules. Red blood cells are unusual, as they do not have a nucleus. This gives them more space for haemoglobin that can carry oxygen molecules. The biconcave shape provides a greater surface area for gas exchange and also allows the cells to be extremely flexible so that they can fit through small capillaries easily.

Figure 9.32 Red blood cells

plasma
the yellow liquid component that makes up 55% of blood; carries water, dissolved gases and hormones

haemoglobin
the red pigment in blood that binds to oxygen, allowing red blood cells to carry oxygen

White blood cells make up about one per cent of the overall volume of blood. This varies depending on whether you are sick, because white blood cells are part of the immune system. White blood cells are generally much bigger than red blood cells. They help the body fight infection by foreign organisms, by engulfing these organisms and breaking them down or by using special chemicals known as antibodies to destroy the invaders.

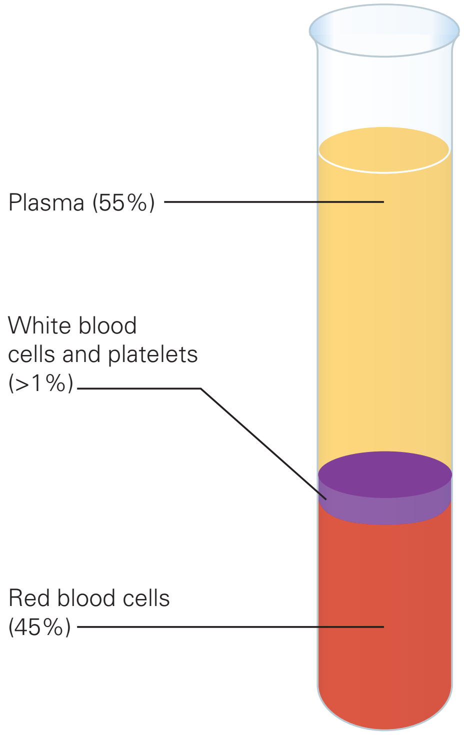

Figure 9.31 The components of blood, separated into layers using a centrifuge

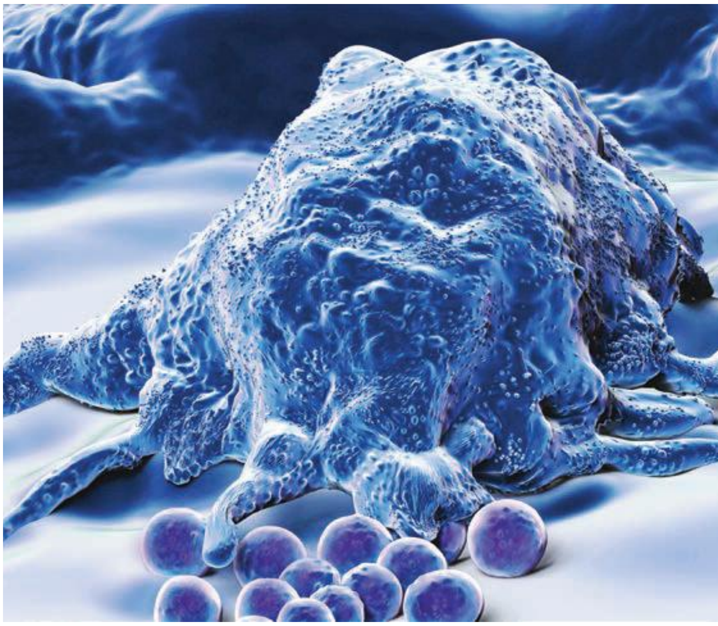

Figure 9.33 A large white blood cell (called a macrophage) engulfing and destroying bacteria

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Another component of your blood is the **platelets**. These tiny cells help blood to clot and help scabs form. Platelets are much smaller than red blood cells. If platelets come into contact with any punctures along the blood vessels, they become activated and change shape. This allows them to seal the puncture. If your body has too few platelets, then you won't be able to stop bleeding if you have an injury. On the other hand, if you have too many platelets, clots can form inside the blood vessels and stop the blood from flowing properly. These internal clots can lead to heart attacks or strokes.

platelets
tiny cells that assist with blood clotting

Figure 9.34 Platelets help a scab to form over a wound

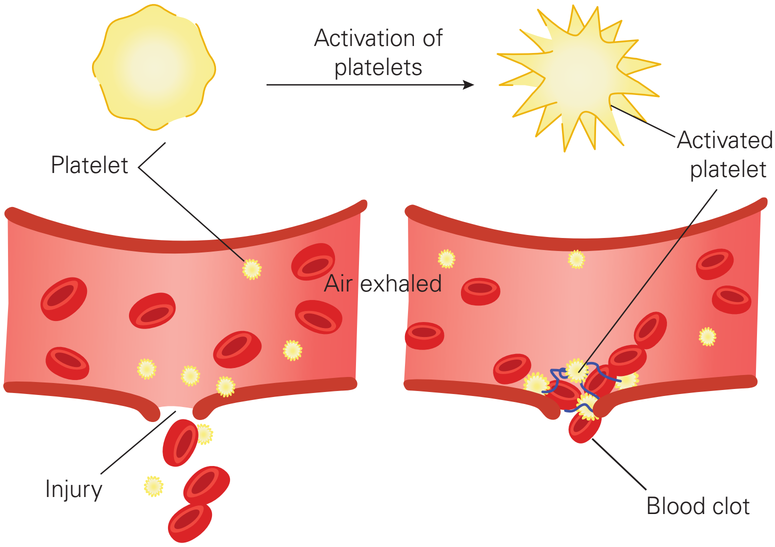

Figure 9.35 Platelets in the blood, sealing a hole in a blood vessel

Did you know? 9.6

Changing blood composition

The composition of your blood can change, depending on many environmental factors. At higher altitudes there is less air, and so there is less available oxygen. People who live at higher altitudes have more red blood cells to cope with this. If you were to go and live on the top of a mountain, after about a week your blood would have adjusted too.

Quick check 9.7

1. On average, recall how much blood is in your body.
2. Name the three components of the human circulatory system.
3. Name three types of cells found in the blood, and state their approximate percentage composition in the blood.
4. Recall what is contained in the plasma.

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Section 9.3 questions

Remembering

1 **State** the function of the heart.
2 **Recall** how many times a healthy human heart beats per minute.
3 **State** the components of blood.
4 **Name** the smallest type of blood vessel.

Understanding

5 **Explain** how heart muscle is different from a muscle in your arm.
6 **Explain** the function of a platelet.
7 **Explain** how the structure of a capillary allows it to exchange nutrients and gases with cells.

Applying

8 **Determine** the point in your circulatory system where your blood pressure would be highest.
9 **Determine** the point in your circulatory system where your blood pressure would be lowest.
10 The image below is an ECG readout of a person's heartbeat. The ECG machine captures the electrical signals of the heart. The section between the arrows represents one full cardiac cycle (heart beat + refilling stage). If the person's heart rate is 120 beats per minute, **calculate** how much time a full cycle takes.

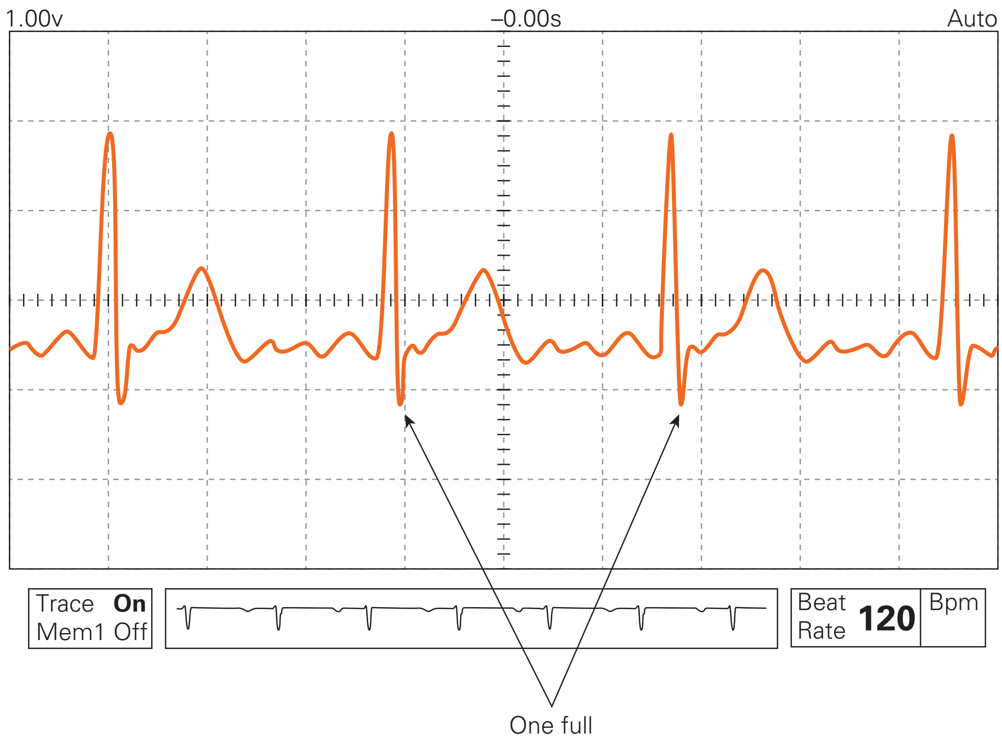

Figure 9.36 ECG printout of a person's heartbeat

Analysing

11 A baby is diagnosed with 'patent foramen ovale', a condition distinguished by a hole in the wall of the heart, between the left and right atria. **Identify** what effect this hole would have on the blood that is being pumped out the aorta.
12 **Construct** a flow chart showing the path of an oxygen molecule, from when it diffuses from the alveoli into the capillary, until it reaches a muscle cell in your leg.

Evaluating

13 **Suggest** a problem that would be faced by someone who has too few platelets in their blood.

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9.4 The human digestive system

Learning goals

1. To describe the structure and function of organs found in the digestive system.
2. To describe the purpose of the digestive system.

DOC WORKSHEET

The nutrients we need

Humans are **heterotrophs** and we cannot produce our own food as plants can. We need to obtain nutrients from the environment around us by eating other living organisms.

heterotroph
any organism that obtains its nutrients by consuming other organisms

The main types of nutrients that humans need can be grouped into four main categories:

- carbohydrates – the main source of energy in the human diet. Bread, pasta, rice and oats are all great sources of carbohydrates. The simplest carbohydrate is glucose.
- proteins – the building blocks of life and the main structural component of most of the living parts of your body. Needed for growth and repair. Meat, cheese, eggs, seeds, nuts and legumes are great sources of protein.
- lipids – also called fats and oils. Fats transport some vitamins around our bodies, are a good energy source, and also help protect the delicate organs inside our bodies from shock or impact.
- vitamins and minerals – essential for the efficient functioning of our body. There are many vitamins and minerals that we can't make ourselves, so we have to consume them in the food we eat.

Quick check 9.8

1. Recall the simplest carbohydrate.
2. Recall what you might also know lipids as.
3. Name some sources of protein.

Did you know? 9.7

Where does vitamin C come from?

Vitamin C helps the body to absorb more iron, which is required for oxygen-carrying haemoglobin in the blood. It also aids in the production of collagen, which helps heal cuts in your skin.

You would get most of your vitamin C from red, yellow and orange fruits and vegetables. But where do carnivores get their vitamin C from? Dogs and many other animals can actually make their own vitamin C inside their bodies.

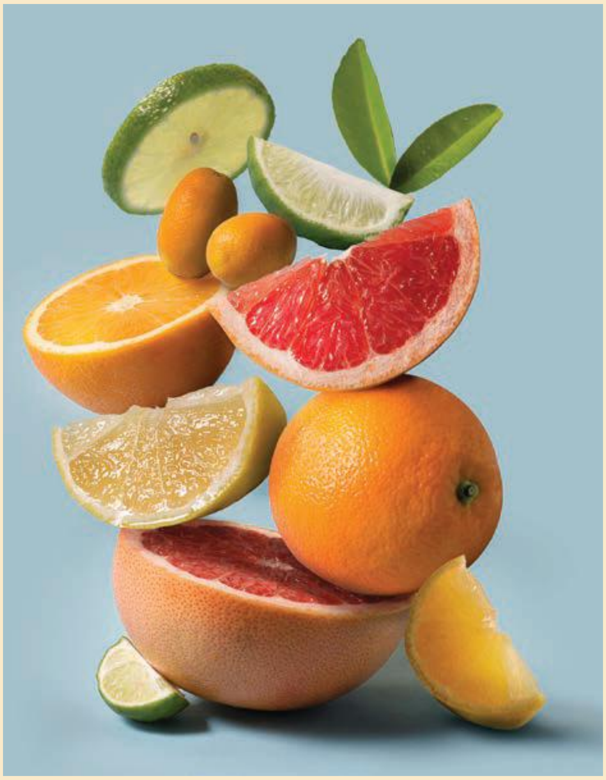

Figure 9.37 All citrus fruits have a high level of vitamin C.

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Parts of the human digestive system

The role of the digestive system is to acquire all the nutrients the body needs. Food is broken down into its smallest components by chemical and mechanical digestion, and the nutrients are absorbed into your bloodstream and transported to the cells that need them.

Mechanical digestion involves physical changes – that is, physically breaking food into smaller components but not changing the chemical structure of the food. Examples include breaking food apart with your teeth and tongue, and bile acting to emulsify (break up) fats.

Chemical digestion involves chemical changes that occur when enzymes break the food down into its most basic chemical components.

mechanical digestion
a series of mechanical processes that breaks food down, such as chewing with teeth, mixing in the stomach and emulsification with bile

chemical digestion
a series of chemical reactions in which enzymes break food into simpler chemical substances that can be used by the body

The human digestive system is essentially a long tube from your mouth to your anus! Let us take a closer look at the structure and function of this vital organ system.

Mouth and tongue

The mouth has many specialised structures that start the digestive process. First, your teeth snip, tear, chomp

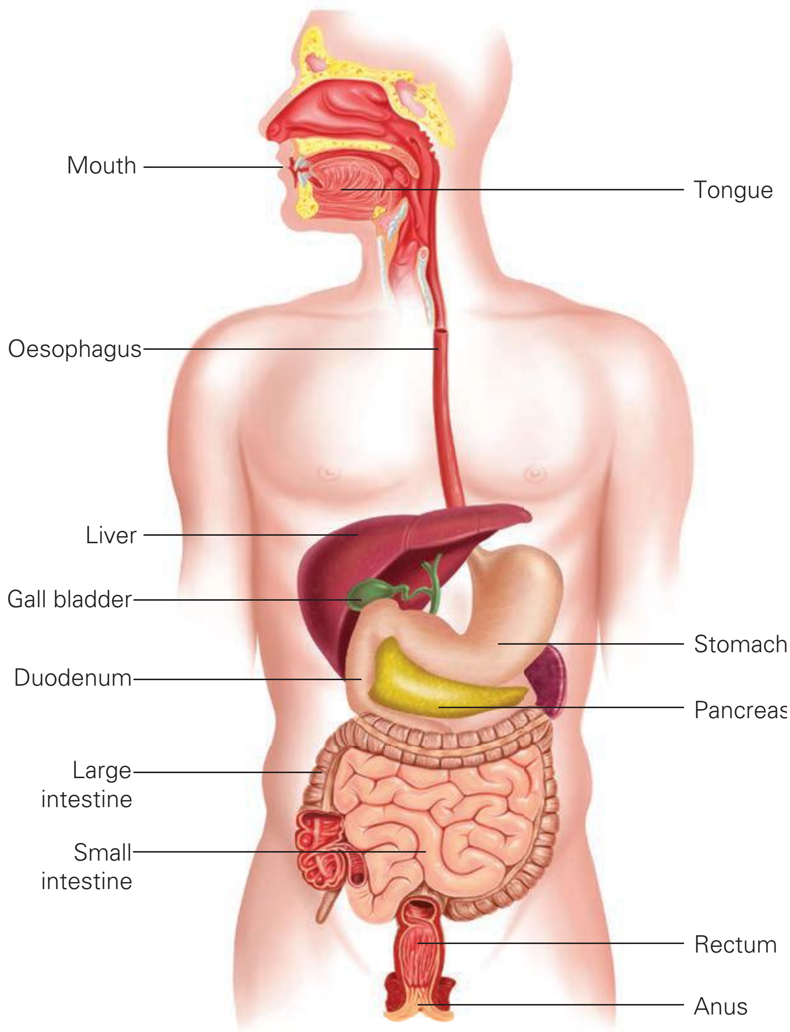

Figure 9.38 The human digestive system

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bolus
a lump of partially digested food

saliva
liquid secreted by the digestive system to lubricate a bolus of food; also contains enzymes to assist chemical digestion

enzyme
a protein that can help speed up chemical reactions

and grind the food, breaking it down into smaller pieces. This increases the surface area of the food, which helps with chemical digestion later. The tongue moves the chewed food around the mouth and coats it in saliva. It forms a lump of partially broken-down food, called a **bolus**.

Saliva lubricates the food to make its movement through your body smoother. It also contains special chemicals, called **enzymes**, that begin to break down the food at a molecular level.

The main enzyme found in your saliva is called *amylase* and it begins to break down carbohydrates, such as starch, into maltose in your mouth. Many more enzymes are found along the digestive tract, and each is designed to break down a particular food type.

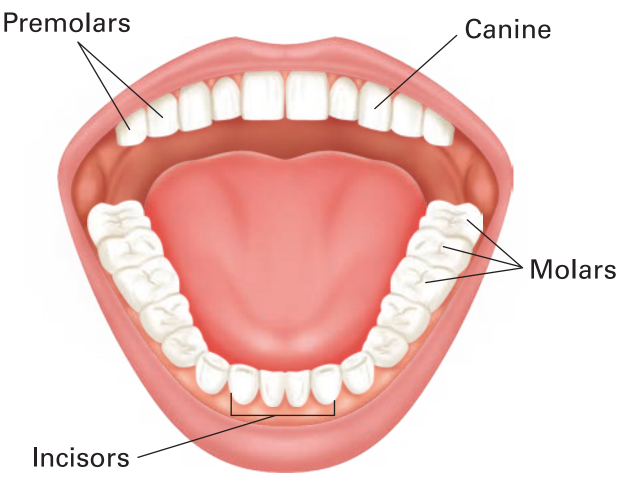

Figure 9.39 The different kinds of adult teeth: incisors for cutting, canines for tearing, and molars for grinding

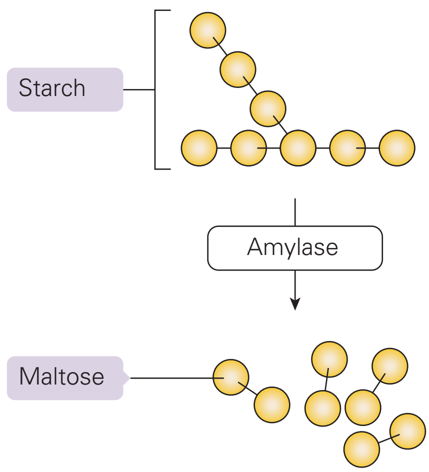

Figure 9.40 Amylase breaks the bonds in starch to form smaller maltose molecules.

Did you know? 9.8

The average person's tongue is around 8.5 cm long and has 2000–4000 taste buds on it. A quarter of the population have 4000 taste buds and have a superior sense of taste. Your taste for certain foods can change throughout your life, because as you age you lose some taste buds and your sense of smell decreases, meaning that you become less sensitive to food. As a teenager, your sense of smell and taste are much stronger than an adult's.

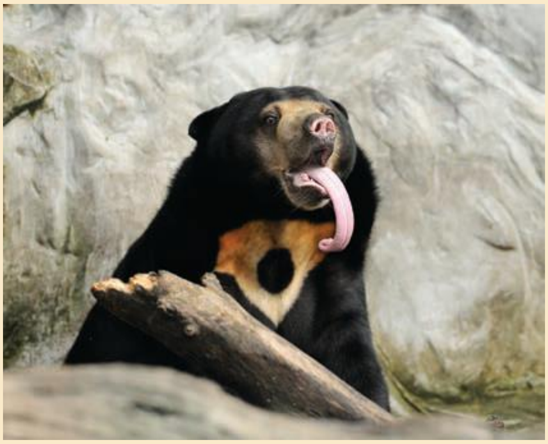

Figure 9.41 An average human tongue (left); an average sun bear tongue (right)

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Try this 9.6

Thanks, enzymes!

Ask your parent/guardian if you can try this at home. Place a small piece of bread or a dry savoury cracker on your tongue and leave it to sit there for a while. As the amylase in your saliva begins to break down the carbohydrates, you should be able to taste the sweeter maltose sub-units.

Oesophagus

When you swallow food, a wave-like contraction of your oesophagus pushes the food down towards your stomach. This movement is known as **peristalsis**, and it continues all the way along your digestive tract to constantly keep the food moving along. Peristalsis is so effective that you could actually eat upside down and the food would still be pushed against gravity, up your oesophagus!

peristalsis
a wave-like contraction of the muscles of the digestive tract that pushes the food along

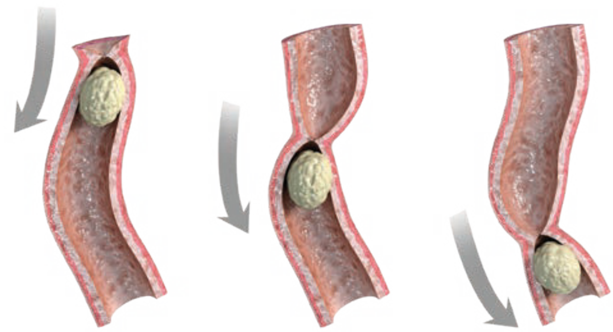

Figure 9.42 Peristalsis moves food down the oesophagus.

Try this 9.7

Modelling peristalsis

Find a nylon stocking and cut off the toe end of the leg. Place a tennis ball at the toe end and gently squeeze behind the tennis ball, to move it along the length of the stocking. This is how the muscles of the oesophagus push a bolus of food along.

VIDEO
Describe peristalsis

Quick check 9.9

1 Describe the function of saliva.
2 Name the enzyme found in saliva.
3 Recall the number of taste buds that an average person has.
4 State if chewing food is an example of mechanical or chemical digestion.
5 Define 'peristalsis'.

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Stomach

sphincter
a muscle that surrounds an opening in the body and can tighten to close it, e.g. at the bottom of the oesophagus, leading into the stomach

At the bottom of your oesophagus is a **sphincter** that opens to allow food to enter your stomach. The stomach contains many types of enzymes, along with very strong hydrochloric acid – these are known as the gastric juices. The sphincter at the opening of the stomach is very important, as it prevents these enzymes and acids from entering the oesophagus and burning the tube, causing a symptom called indigestion or 'heartburn'.

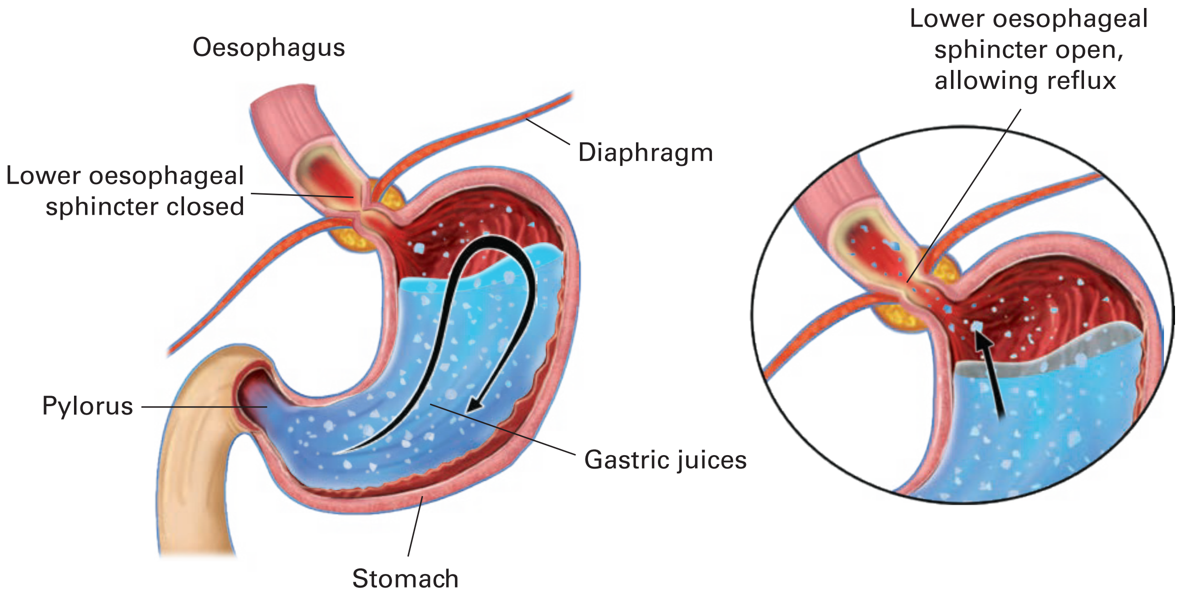

Figure 9.43 When the oesophageal sphincter fails to close, gastric juices can irritate the bottom of the oesophagus.

Try this 9.8

How do antacids work?

Antacid tablets are taken during episodes of heartburn, to try to neutralise some of the acid in the stomach. Let's observe how they work.

You will need the following: pH data logger and probe, 1 M hydrochloric acid, antacid tablets (such as Rennie®), 200 mL beaker, 3 mL pipette, mortar and pestle, distilled water.

Be careful
Ensure appropriate personal protective equipment is worn.

Step 1 Crush one antacid tablet using the mortar and pestle. Place in the beaker with 50 mL of distilled water and mix well.

Step 2 Measure the pH using the probe.

Step 3 After a minute, add around 1 mL of 1 M hydrochloric acid and monitor the change in pH. Stir the beaker regularly.

Food stays in your stomach for 2–6 hours, depending on the size, amount and type of food. During this time, the stomach contracts and churns the food (mechanical digestion), helping to further break up the large particles, while mixing the bolus with the gastric juices (chemical digestion). The acid in your stomach also performs some important functions: it kills many of the harmful bacteria that might be found on the food you eat and provides an optimum pH for protein enzymes to work at. The stomach wall is a mucosal membrane, which produces mucus to protect the stomach tissue from the strong acid.

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Enzymes act to *catalyse* (speed up) chemical reactions. The main enzyme in your gastric juices is called *pepsin* and its role is to begin the digestion of protein. Each enzyme has a specific shape that fits only one type of molecule, and therefore each food type has a special enzyme dedicated to breaking it down in the body. For example, pepsin can only break down protein.

The stomach absorbs some substances into the bloodstream, such as water, medicines and alcohol. The digested bolus is now called **chyme** and it leaves the stomach by passing through the pyloric sphincter into the small intestine.

chyme
a partially digested mass of food after it leaves the stomach

Figure 9.44 Each enzyme fits a specific type of molecule, like a key fitting a lock. An enzyme attaches itself to a food particle and speeds up the chemical reaction that breaks down the food particle, and then it releases the broken-down food particle.

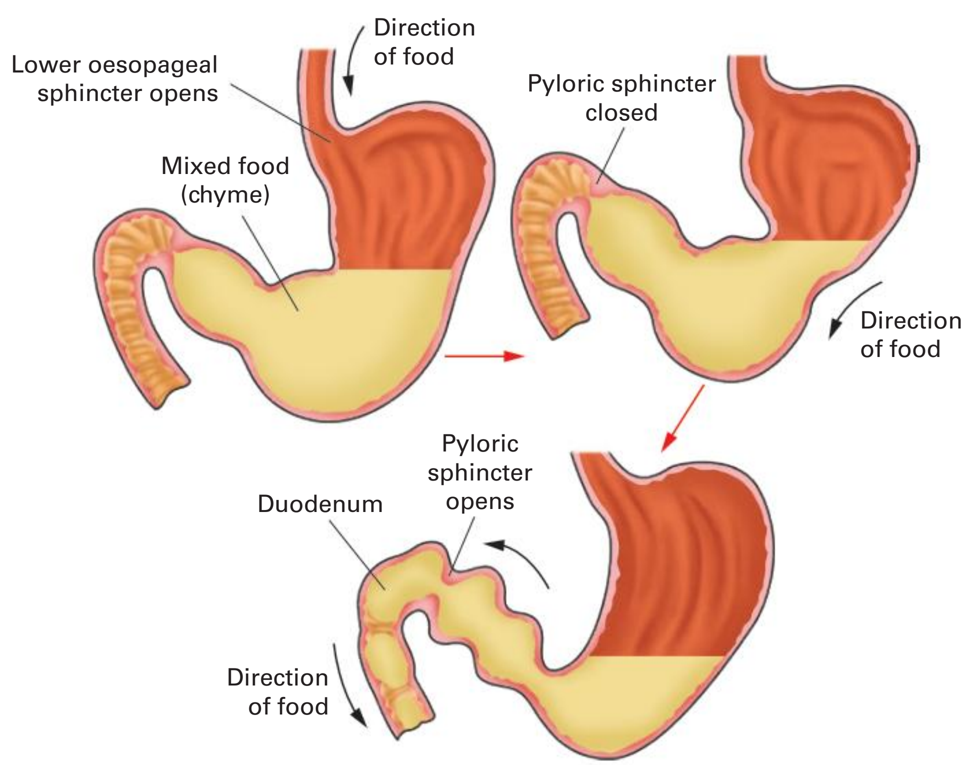

Figure 9.45 The pyloric sphincter controls the flow of chyme out of the stomach and into a region of the small intestine called the duodenum.

Quick check 9.10

1 State two sites of mechanical digestion.
2 Define 'chyme'.
3 Name the enzyme that catalyses the digestion of protein.
4 Explain why the stomach wall is lined with mucus.

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duodenum
the first section of the small intestine

jejunum
the second section of the small intestine, where food breakdown and nutrient absorption occur

ileum
the third section of the small intestine, where further food breakdown and nutrient absorption occur

liver
an excretory system organ that detoxifies poisonous substances in the body

bile
a substance produced in the liver and stored in the gall bladder, which helps emulsify fats

gall bladder
a small gland near the liver that stores bile and secretes it into the duodenum

pancreas
an organ that secretes pancreatic juices containing enzymes into the duodenum to assist with the digestion of food

villi
finger-like structures in the digestive system that have a high surface area and rich blood supply for absorption of nutrients

Small intestine, liver, gall bladder and pancreas

The small intestine is only called 'small' because it is narrower in diameter than the large intestine. It is actually very long, measuring an average of nearly six metres. Because it is so long, the small intestine is divided into three main parts: **duodenum**, **jejunum** and **ileum**.

The duodenum is the first part of the small intestine. Many digestive enzymes are secreted into it, which help to continue digestion of the chyme. Peristalsis is still propelling the chyme forwards and continues all the way along the digestive tract.

The **liver** produces **bile**, which helps to break down fats or lipids mechanically. The bile is stored in the **gall bladder** and is excreted into the duodenum if you eat a fatty meal. Bile acts like a detergent – it emulsifies or breaks big globs of fats and oils into little globs that can be easily moved and broken down further. Bile has the second job of neutralising the harmful acids from the stomach and preventing damage to the intestines. The **pancreas** secretes pancreatic juices, which also help to neutralise the acids from the stomach and contain more enzymes to keep chemically digesting the different food types.

Most of the nutrient absorption takes place in the middle section of the small intestine, the jejunum. This section is lined with millions of finger-like structures, called **villi**. These structures have a large surface area and a high flow of blood, which increases the efficiency of nutrient absorption into the bloodstream.

The end section of the small intestine is the ileum. The main function of this portion of the intestines is to finish off any absorption of nutrients, and to compact the remaining digested food and pass it through into the large intestine.

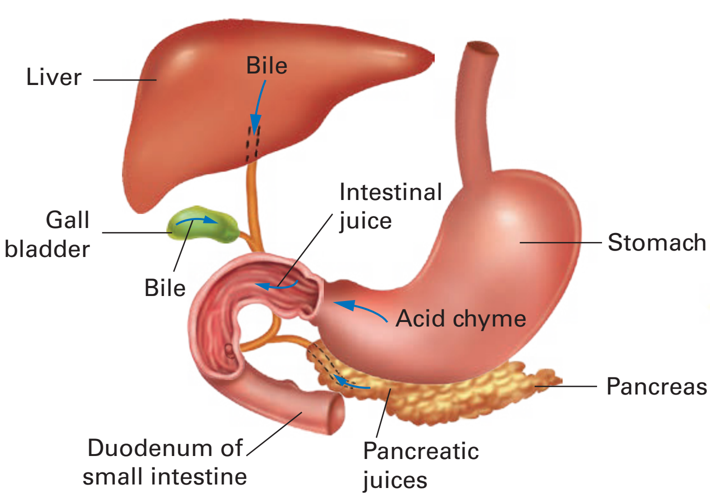

Figure 9.46 The liver, gall bladder and pancreas all contribute to the digestion of food and are connected to the duodenum.

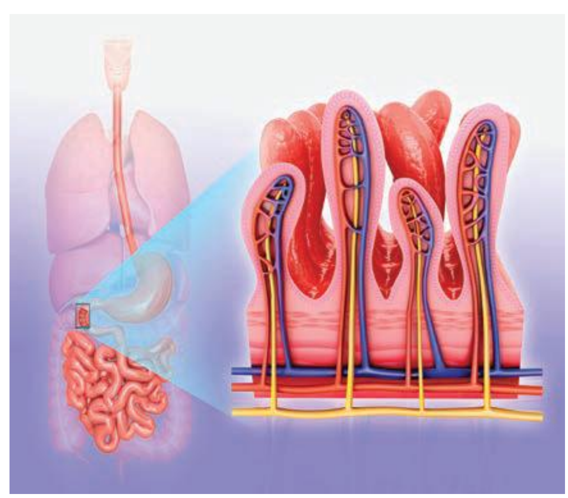

Figure 9.47 Finger-like villi in the intestines are specialised for absorption of nutrients.

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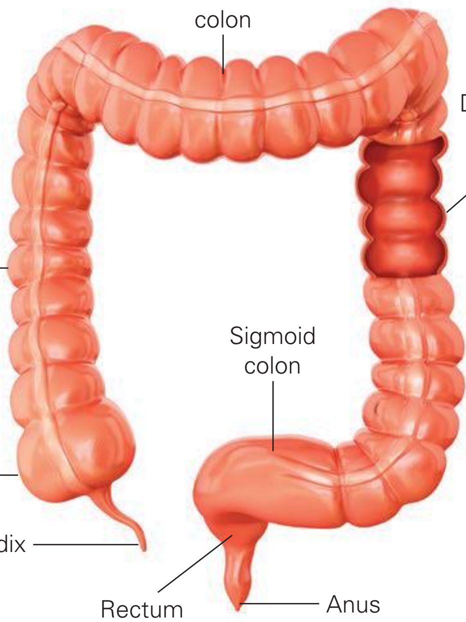

Figure 9.48 The five sections of the large intestine

Large intestine

The **large intestine** is 1–2 metres long and has five parts: caecum, appendix, colon, rectum and anus. Its function is to absorb most of the water from the material left over from digestion. The large intestine also has large numbers of friendly bacteria that can produce vitamin K and vitamin B for your body to use. In humans, the **caecum** is a pouch at the start of the large intestine, where it joins the small intestine. The appendix has long been considered a useless organ that is a remnant of evolution, but there is ongoing debate about what its actual role is (see *Did you know? 9.9*). As waste enters the large intestine and passes through the colon, water leaves the waste, resulting in a solid mass called faeces. Faeces are stored in the **rectum** and when the rectum is full, it sends a signal to your brain to tell you to go to the toilet. The faeces then pass out through a sphincter called the **anus**.

large intestine
the organ that is connected to the small intestine at one end and the anus at the other

caecum
a pouch that forms the first part of the large intestine

rectum
the second-last section of the large intestine; stores faeces

anus
the opening at the end of the digestive tract, through which solid waste leaves the body

Did you know? 9.9

A lot of you is not you!

The average person's body has around the same number of bacterial cells as human cells.

Until recently, it was thought that the number of bacteria in our bodies outnumbered our own cells 10:1. However, recent research in Canada suggests that the average person is more likely to have a 1:1 ratio of bacteria and human cells. Most of these bacterial cells are 'friendly bacteria' found in our digestive system that help our body break down and digest nutrients from the food we eat. It is thought that the appendix could be a safe haven for good bacteria that can repopulate the gut after sickness and diarrhoea. So next time you eat a meal, think about all the bacteria hard at work in your digestive system, helping you break it down.

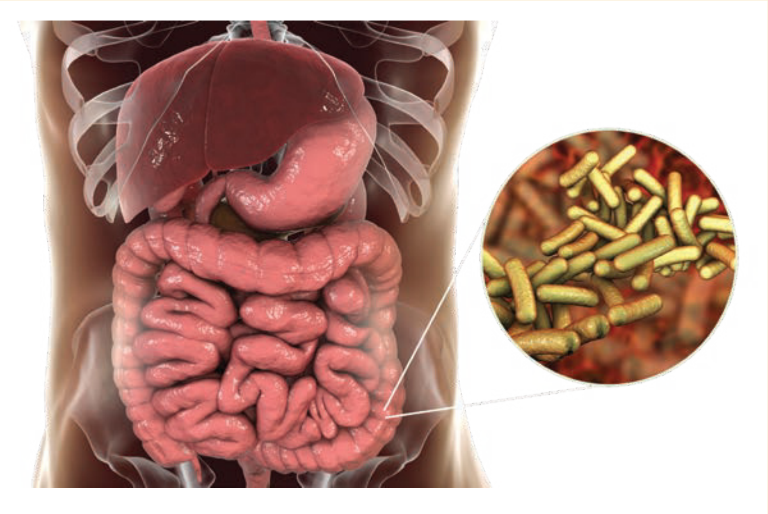

Figure 9.49 Most bacteria in your body are in the intestine.

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Quick check 9.11

1. State the three sections of the small intestine.
2. The liver produces bile, which is stored in the gall bladder. Recall the type of food that bile helps to mechanically digest.
3. Explain how villi improve absorption of nutrients.
4. Organise the following sections of the large intestine in the correct order that faeces pass through: rectum, colon, anus, caecum, appendix.

Did you know? 9.10

Is your stomach rumbling?

Ever heard those gurgling stomach noises when you are hungry? Well, they are actually the sounds of hyperactive peristalsis in the intestines, and are named *borborygmi*. When the muscles in your stomach and small intestines are pushing everything along, all the food packed inside muffles the sound. But if it's been a while since you've eaten, most of that food is gone (hence why you equate it with being hungry!) and all those gurgling gases are easier to hear.

Digestion gone wrong

Food poisoning

Your body is very smart – it can detect hazardous substances in the food you eat. Sometimes food can be contaminated with toxins or microorganisms that could do harm to your body. If your body senses the presence of these harmful substances, it signals your digestive system to empty fast. This causes the stomach to contract violently, causing vomiting, and it also causes the intestines to contract, causing diarrhoea. Even though getting sick is never fun, it is your body's way of protecting you from a much worse fate.

Digestive disorders

Many people cannot eat certain foods, because of intolerance or allergy. An **intolerance** is when a food cannot be properly broken down by the body and results in an adverse reaction.

intolerance
an inability to eat a food without undergoing adverse effects

One of the most common intolerances in humans is lactose intolerance. Lactose-intolerant people are unable to digest the sugar in milk and dairy products, called lactose. Normally when somebody eats food containing lactose, the enzyme lactase is released in the small intestine to break down the carbohydrate into simple sugars. People who are lactose intolerant do not have lactase, and this means that the sugars do not get digested and absorbed. Instead, the bacteria in the intestines break down these sugars, leading to bloating, lots of gas and diarrhoea.

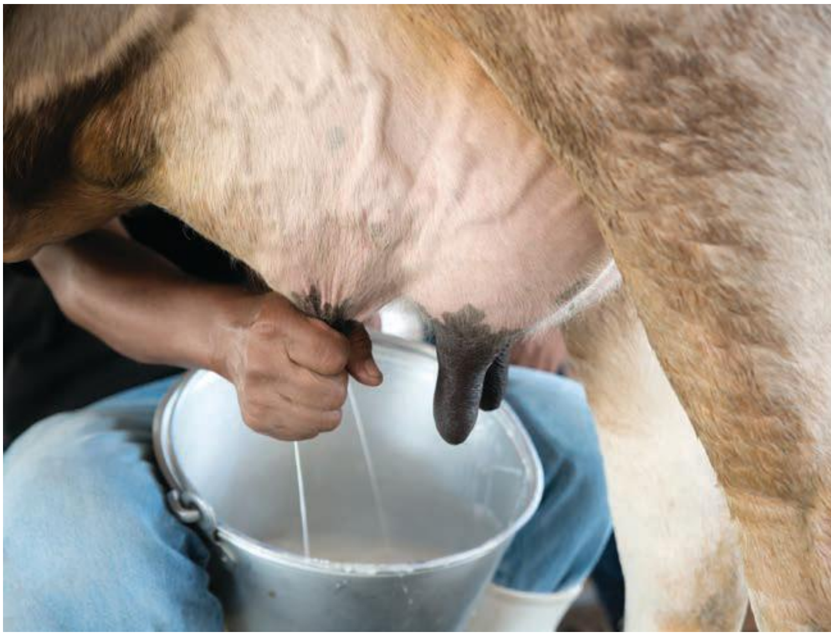

Figure 9.50 All mammals produce milk, but not all adult humans can digest it.

Because humans are mammals, we can all drink milk as babies. This means that the enzyme called lactase, which breaks down lactose, is found in everybody when we are young. Anyone can become lactose intolerant at any stage in their life, although there are certain groups of people who are more likely to become lactose intolerant.

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Some examples:

- People of Asian, African, Indigenous and South American backgrounds are more likely to develop lactose intolerance at a young age.
- People who already have problems with their digestive system caused by disorders such as coeliac disease or Crohn's disease are more likely to develop lactose intolerance.
- Certain antibiotics can trigger temporary lactose intolerance, by interfering with the intestine's ability to produce the lactase enzyme.
- As people get older, their bodies can stop producing lactase.
- If you go for a long period of time without eating dairy, your body may stop producing lactase.

Explore! 9.5

Coeliac disease

People are becoming more aware of foods that contain gluten, and many people have started to follow gluten-free diets. Gluten is a protein in wheat, rye and barley-based products such as bread, pasta, pastry, cakes and biscuits. Bread has been a stable part of the human diet for thousands of years, and so many people view gluten intolerance and coeliac disease as new phenomena, but humans have been affected by these conditions throughout history. However, it was not until about 100 years ago that doctors began to diagnose and treat coeliac disease.

1 Find out how many people suffer from coeliac disease and how many people have gluten intolerance. You may like to find out the statistics for the world or investigate different countries.
2 Outline the symptoms of coeliac disease.
3 Research and then summarise what it is about gluten that makes people sick. Include an explanation of how a coeliac sufferer's body responds to gluten.

Advances in science 9.5

Seeing you from the inside

Imagine swallowing a pill-sized camera that captures images over the next 24 hours as it makes its way through your digestive system. Well, this technology is not new, and it gives doctors a unique view of what is going on inside your oesophagus, stomach and intestines. But there is a lot that a camera can't do: it can't deliver drugs, it can't grab a foreign object and remove it, and it can't perform a biopsy (slice off a tiny piece of tissue for analysis). This is why medical researchers are working with engineers to design tiny robots that can be put to work in your digestive tract. These robots need motors, sensors and smooth outer surfaces so that they can pass through your digestive organs without damaging them, before finally being excreted just like any other waste product.

Figure 9.51 An artist's impression of a tiny robotic device crawling through an intestine

Figure 9.52 An illustration showing the scale of a robot frozen inside some ice, which the patient swallows. Once warmed up in the digestive tract, the robot unfolds into the shape on the left.

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Section 9.4 questions

QUIZ

Remembering

1 **State** the food group that glucose belongs to.

2 **Recall** the route that food waste/faeces takes after it leaves the stomach. List the three sections of the small intestine and the five sections of the large intestine it passes through.

3 **State** the function of the tongue in digestion.

4 **Name** the type of acid that is found in the human stomach.

Understanding

5 **Describe** the role of the stomach in food digestion.

6 **Explain** how the structure of villi assists in the absorption of nutrients.

7 **Explain** how food is transported along the digestive tract.

Applying

8 Certain nutritional deficiencies in the body can be linked to damaged digestive organs. **Suggest** what deficiencies could be linked to a damaged large intestine.

9 **Develop** a hypothesis about what might happen if the large intestine was removed from the digestive tract.

10 A friend who is coming to your house for dinner suffers from coeliac disease and lactose intolerance. **Suggest** a meal you could cook that would be suitable for this friend.

Analysing

11 **Compare** the duodenum to the jejunum.

12 **Classify** the processes listed below as mechanical or chemical digestion.

- Stomach churning and contracting
- Chewing food
- Bile released from gall bladder into the duodenum to emulsify fats

Evaluating

13 Crohn's disease is a bowel condition that causes flare-ups of inflammation in the ileum, which leads to impaired nutrient absorption. It also causes inflammation of the large intestine. **Propose** what effect this might have on the faeces.

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9.5 Comparing digestive systems

Learning goals

1 To compare the digestive system of other animals to humans.
2 To relate differences in digestive systems to diet.

Have you ever had food poisoning? If so, it was probably from that time when you ate undercooked chicken or you finished the slightly questionable leftovers from several nights ago and ended up spending the following day on the toilet. Well, that was because the food that you ingested had too many bacteria on it for your body to deal with. But why does that happen to you, when some scavenger animals can eat half-rotten corpses and not get sick?

How is it that some animals eat only leaves and still manage to get all the protein, fats and iron they need to be healthy?

The answers to both these questions can be found in their specialised digestive systems.

Carnivores

The human digestive system is designed to process and break down both animal and plant products. However, unlike other animals, we have learned to cook our food, which vastly reduces the amount of harmful bacteria our digestive system has to contend with. **Carnivore** and scavenger species such as vultures have several traits that have evolved which allow them to eat food containing large amounts of bacteria that could kill a human.

DOC WORKSHEET

carnivore
a consumer (heterotroph) that feeds on animal matter

omnivore
an organism that eats a variety of plant and animal matter

Figure 9.53 Vulture eating a rotting corpse

Digestive system length

The digestive system is shorter in a carnivore than in a herbivore or an **omnivore**. Because animal cells do not have a cell wall (cell walls contain cellulose which is hard to digest), they are easier to digest and so it takes less time for them to pass through the consumer's digestive system. Because the food spends less time in the body of the carnivore, any harmful bacteria on the food have less chance to grow and cause illness.

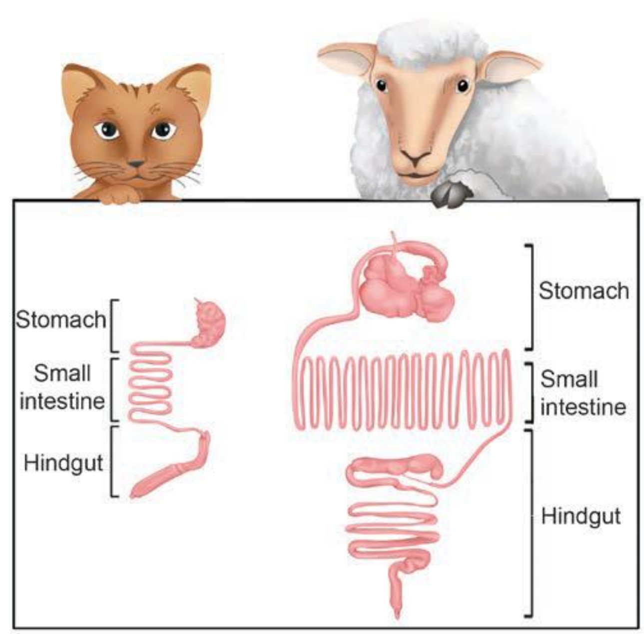

Figure 9.54 Cat (carnivore) and sheep (herbivore) digestive systems

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Stomach acid

The stomach acid in humans is around 1.5 to 3.5 on the pH scale. This is quite strong and allows our bodies to kill many harmful microorganisms, but not all of them. In comparison, a vulture's digestive acid is 0–1 on the pH scale, which is strong enough to dissolve certain metals and so is more than a match for any bacteria.

Figure 9.55 Make sure you check the use-by date of meat. Bacteria on the meat will multiply and eventually reach levels unfit for human consumption, spoiling the meat.

Did you know? 9.11

Bird vomit

As a defence mechanism when threatened, vultures and other birds, such as some seagulls, can projectile vomit onto predators. As you know, vomit smells bad at the best of times but just imagine how it would smell if you had been eating rotting flesh! If you add to that the corrosive levels of acid in the stomach, vomit makes a very effective warning system.

Figure 9.57 Vultures and many gulls use vomiting as a defence technique.

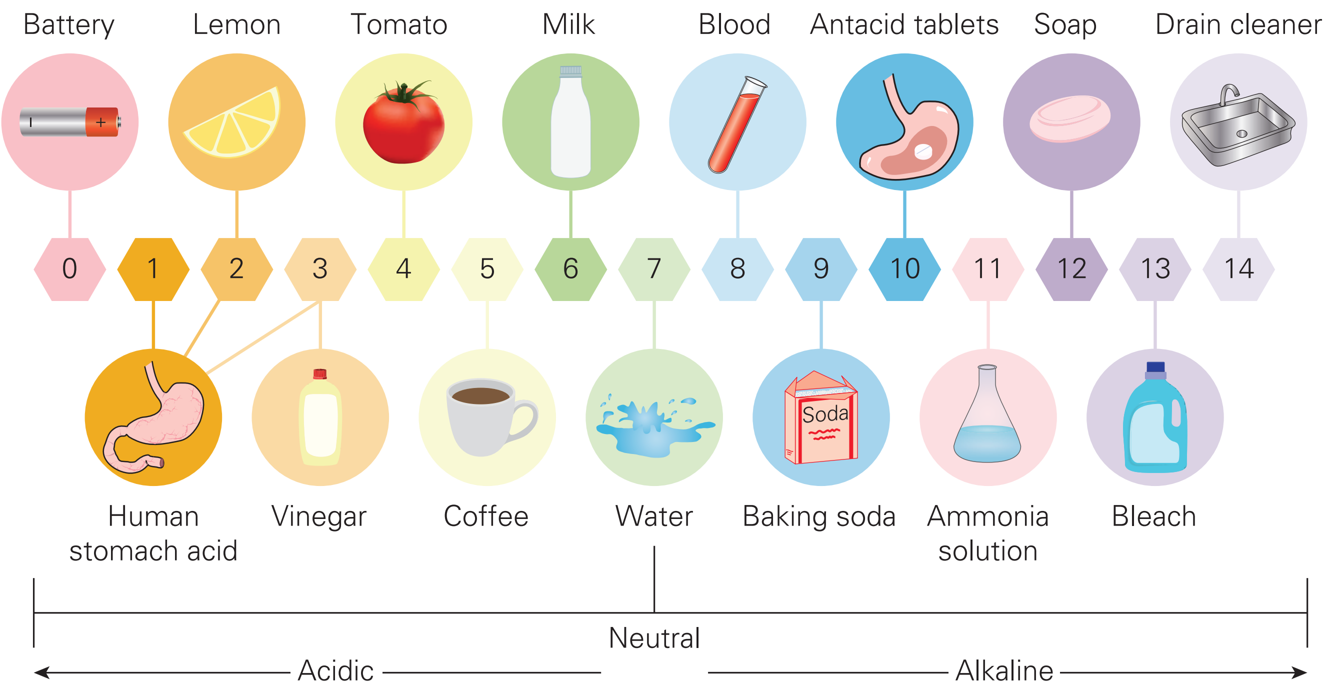

Figure 9.56 The pH scale

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Quick check 9.12

1 Explain how vultures defend themselves from predators.
2 Contrast a vulture's stomach acid with a human's.
3 State who has a shorter digestive tract: carnivores or herbivores.

Explore! 9.6

Carnivorous plants

Not all plants rely solely on sunlight and water for their food. Some add meat to their diet to give them a nutrient boost. Most carnivorous plants live in swamps and marshes, where the soil doesn't have many nutrients, especially nitrogen, and so they rely on breaking down insects to absorb nutrients.

Find out about each of the following carnivorous plants and summarise how they catch their prey, the structures they have that allow them to catch their prey, and how they digest their prey.

1 Venus flytrap
2 Sundew
3 Pitcher plant

Figure 9.58 A Venus fly trap and an unsuspecting fly

Figure 9.59 A sundew wrapping around an insect

Figure 9.60 A pitcher plant, and its possible prey

Herbivores

Eucalyptus leaves are toxic for humans. In fact, if you ever tried to eat some you could find yourself struggling to breathe, losing your balance and feeling very dizzy. Leaves are also made of cellulose, which is not easy for humans (or carnivores) to digest and obtain any nutrients from. So it is surprising that eucalyptus leaves are the koala's primary source of nutrition.

Koalas are **herbivores**, and so they have many adaptations that allow them to obtain the nutrients that they need from eucalyptus leaves. They have a long digestive tract and a very large caecum, around 200 cm long and 10 cm wide, where cell walls can be digested. In herbivores, the caecum contains millions of friendly bacteria that are specialised to break down certain plant materials (such as eucalyptus leaves). Koalas get most of their water from the leaves they eat, and so they do not often need to climb down from the tree they are living in.

herbivore
a consumer (heterotroph) that feeds on plant matter

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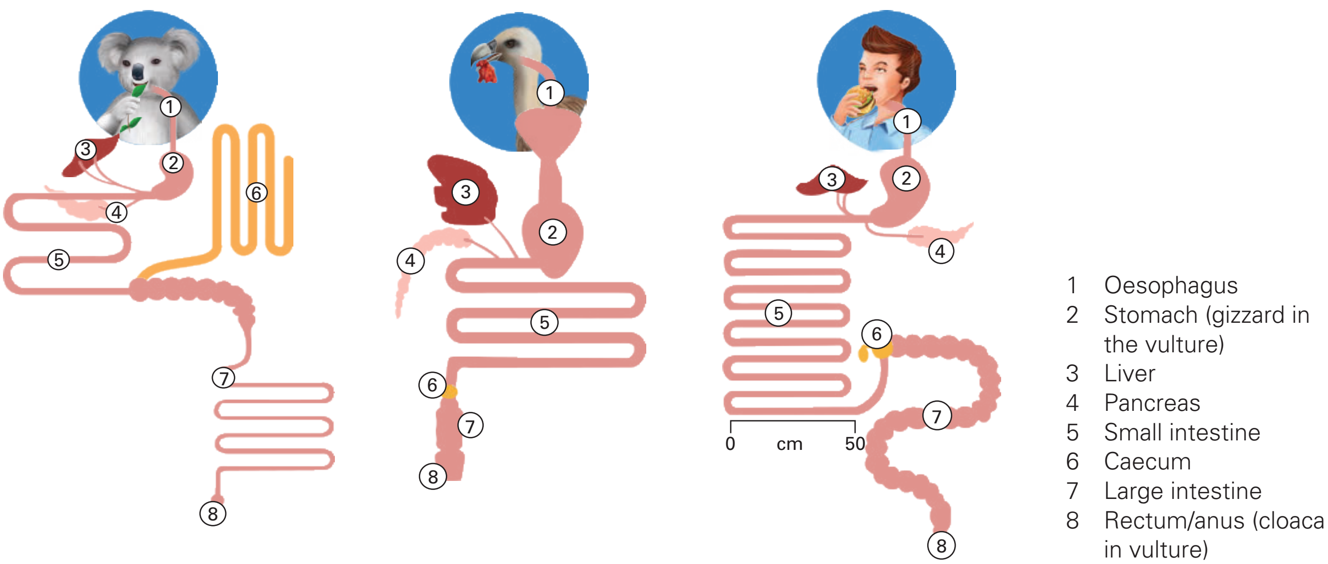

Figure 9.61 Digestive systems and food transit times for koalas, vultures and humans

Eucalyptus leaves are very low in nutrients and so, even with a caecum, koalas need to eat for five hours a day to get enough food to sustain them. They spend most of the rest of their day sleeping, to conserve energy and to allow their bodies to digest their food.

In total, it can take around four whole days for a leaf to pass through a koala's digestive system. This maximises the amount of nutrients and water that are absorbed from the food.

Did you know? 9.12

Eating Mum's faeces

Baby koalas are not born with the special friendly bacteria they need to digest eucalyptus leaves. They need to eat their mothers' faeces (called pap) in order to start their own colony of bacteria in their caecum.

Figure 9.62 A mother and baby koala

Advances in science 9.6

Cows and the climate

Cows burp a lot of methane gas, which is a naturally occurring product of fermentation in their rumen. The microorganisms that colonise their digestive tract assist in breaking down the plant matter, producing methane as a waste product. Unfortunately, methane is also a potent greenhouse gas – cows account for about 25% of the methane produced in the USA.

A recent study has experimented with supplementing the diets of dairy cows with a chemical compound that inhibits microorganisms from producing methane. It showed a 30% reduction in methane, and the cows actually gained more weight without eating any extra feed, meaning they were extracting more energy. The feed supplement is in the early stages of development, but could be a helpful tool in the fight against climate change.

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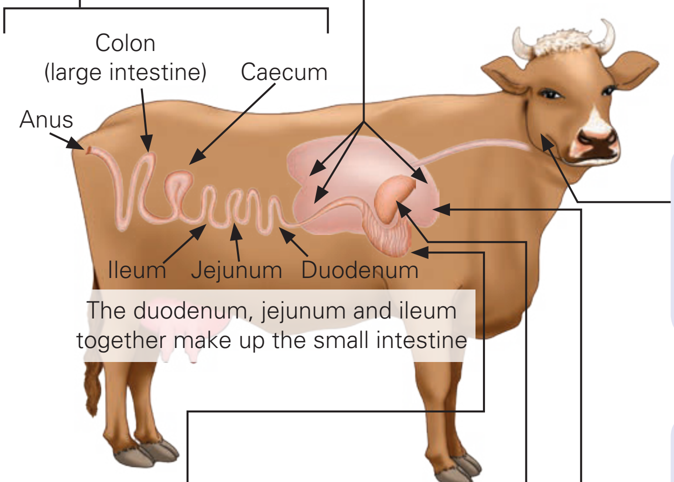
Ruminants

WIDGET
The mammalian digestive system

If you've ever seen a cow, it was probably chewing. Cows are herbivores, just like koalas, so they need to eat for most of the day to gain as much nutrition from their food as possible. Cows are in a special category of herbivores, called *ruminants*. Ruminants, including antelope, sheep, buffalo and goats, deal with being a herbivore in a unique way. Figure 9.63 shows the path of food through a ruminant.

2 Stomach round 1
The grass passes into the largest part of the four-part stomach, called the rumen (this is where the term 'ruminant' comes from). The rumen, like the caecum, contains bacteria that digest cell walls.

6
The food passes through the small intestine, caecum and large intestine in much the same way as it does in other herbivores. The only difference is that the extended amount of time the food has already spent in the cow's stomach allows maximum nutrient absorption by the intestines.



1 First chewing
Cows graze on plants using their incisor teeth to snip leaves and then grind and chew their food using their molar teeth briefly before swallowing it for the first time.

3 Second, third and fourth chewing
Food from the rumen is regurgitated back up into the mouth, with the help of the second chamber of the stomach, called the reticulum. This process assists the bacteria in breaking the grass down ready to be digested. The regurgitated food is called 'cud'. Cows 'chew the cud' for around 6–8 hours during times of the day when they are not grazing.

5 Stomach round 4
Finally, the food passes into the abomasum, or 'proper stomach', where enzymes and digestive juices start to properly digest and absorb the nutrients.

4 Stomach rounds 2 and 3
When the cud is sufficiently broken down, it passes into the third chamber of the stomach, called the omasum, where most of the excess water and saliva are absorbed.

Figure 9.63 The passage of food through a cow's stomach

Quick check 9.13

1. Summarise the role of the caecum.
2. Define the term 'friendly bacteria'.
3. Distinguish between the length of a carnivore and a herbivore digestive tract.
4. Describe the way a ruminant digests plant matter.

Try this 9.9

Digestive flow charts

Construct three flow charts on a poster showing the digestive tracts of a carnivore (not a human), a herbivore and a ruminant. Annotate the structures of the digestive tract, showing their specialised functions so that the key differences between these organisms are obvious.

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Section 9.5 questions

QUIZ

Remembering

1 **Recall** the four parts of a herbivore's digestive system.
2 **State** how many chambers there are in the stomach of a cow.
3 **Name** the substance that leaves are composed of, which is difficult for humans to digest and gain nutrients from.
4 **Fill** in the gaps: Acids have a ______________ pH and bases have a ______________ pH.

Understanding

5 **Identify** the product in the stomach that kills bacteria.
6 **Outline** one way that the vulture uses its stomach acid other than for digestion.
7 **Explain** how the vulture's digestive system is adapted to eat rotting meat.
8 **Describe** how baby koalas gain their friendly bacteria.

Applying

9 **Identify** two ways in which a vulture's digestive system is different from a human's digestive system.
10 **Compare** the digestive system of a koala with that of a human. You may choose to lay the information out in a table.

Analysing

11 Use the images in Figure 9.64 to answer the following questions.

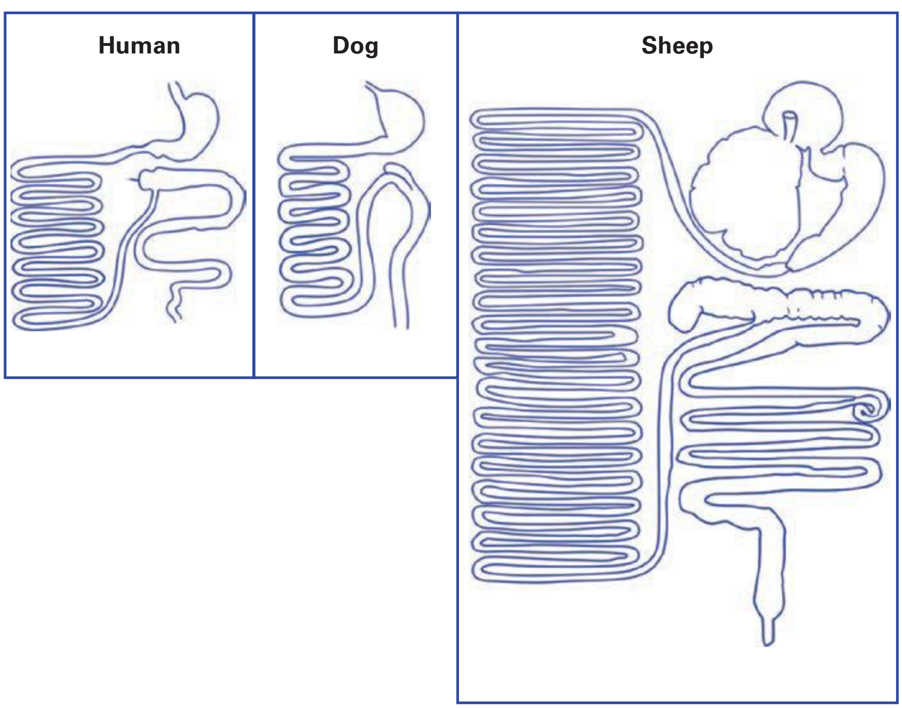

Figure 9.64 Digestive systems of a human, a dog and a sheep

a **Contrast** the digestive system of a dog and a sheep.
b **Suggest** which two of the animals in Figure 9.64 probably have a similar diet.

Evaluating

12 Carnivorous plants tend to prey on small insects or amphibians. **Give reasons** why attracting larger mammals rather than insects might be a problem for carnivorous plants.

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9.6 The human excretory systems

Learning goals
1 To describe the structure and function of organs found in the excretory systems.
2 To describe the purpose of the excretory systems.

WORKSHEET

Each cell in our body that keeps us alive is like a little factory. Just like factories, they produce useful things like energy and proteins for our bodies but they also produce waste products such as ammonia and carbon dioxide. It is important for our bodies to remove these waste products from our bodies because otherwise they build up and can cause harm. The system of organs that deals with waste is called the **excretory system**. There are four main organs involved with excretion: the liver, kidneys, lungs and skin.

Excretion is the removal of waste products from inside the body, whereas **defecation** is the term we use to describe the undigested food that passes through the digestive system.

The liver is an important organ in the excretory system as it can break down complex molecules we eat into simpler molecules that can be used in the body. When protein is broken down, it produces a toxic substance called **ammonia**. Liver cells have the ability to convert ammonia into **urea** which is much less harmful to the body. Urea is not the only harmful substance the liver breaks down, it can also detoxify the body from poisonous substances such as alcohol and medicines.

Excretion through the urinary system

Urea passes from the liver into the blood. It eventually reaches the **kidneys**, which are a pair of organs that filter the blood for waste through millions of tiny tubes called **nephrons**. Urea, along with other waste products in the blood is pushed down collecting ducts and forms **urine**. The urine travels down a tube called the **ureter** and gets stored in the **bladder** until you eventually go to the toilet.

excretory system
the body system that is responsible for filtering the blood and removing cellular waste products

excretion
the process of removing metabolic waste from the blood via the lungs, kidneys and skin

ammonia
a poisonous substance that is produced when protein is broken down

urea
a substance that is produced by the liver by breaking down ammonia

kidneys
a pair of organs that filter waste products from the blood and excrete them as urine

nephron
small filter structures that are found in the kidney

urine
waste product from the body made of water, urea and other excreted wastes

ureter
the tube that leads from the kidneys to the bladder

bladder
the organ that stores urine

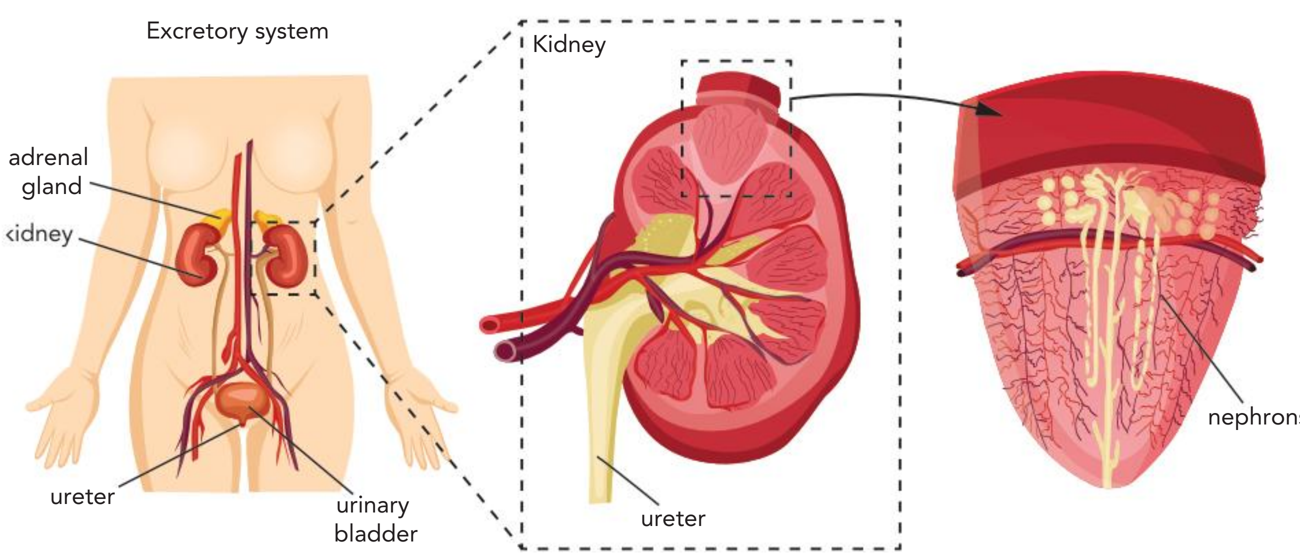

Figure 9.65 The human excretory system

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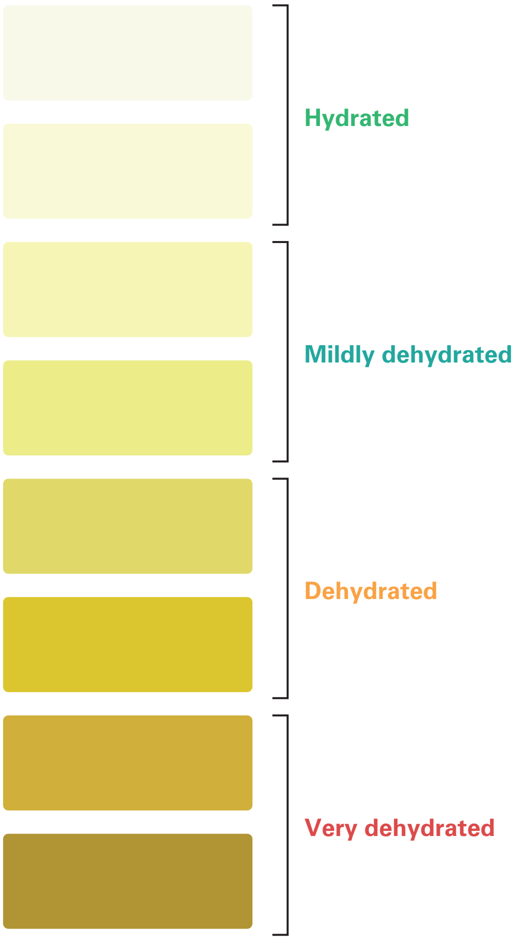

Figure 9.66 The colour of urine can indicate how hydrated a person is.

Urine usually ranges in color from transparent to yellow and sometimes nearly brown. The colour of urine can tell us a few things about our health. Firstly, the darker the urine the more dehydrated a person is. This means that you need to drink more water if you have dark urine. Sometimes urine can be other colours, such as red or green. When this happens it means that something is seriously wrong with your body and you need to see a doctor.

Excretion through respiratory system

A major waste product our bodies constantly produce is **carbon dioxide**. You will recall that carbon dioxide is a product of respiration reactions that produce energy for our cells. If carbon dioxide builds up in our bodies it can create an acidic environment that can cause harm. We excrete carbon dioxide when we exhale air from the lungs.

Figure 9.67 Carbon dioxide is excreted from the body when we breathe.

Excretion through the skin

The **skin** is the largest organ in our bodies and it plays a vital role in keeping the internal conditions constant.

The skin is made of three main layers:

- **Epidermis**: The very outer layer of the skin. It is waterproof and sheds dead cells constantly.
- **Dermis**: This is where hair is made and sweat glands are.
- **Hypodermis**: This is a fat layer that helps to insulate our bodies. Blood vessels are found in this layer.

carbon dioxide
a waste product produced in respiration

skin
the biggest organ in the body, which forms a protective outer layer on a person

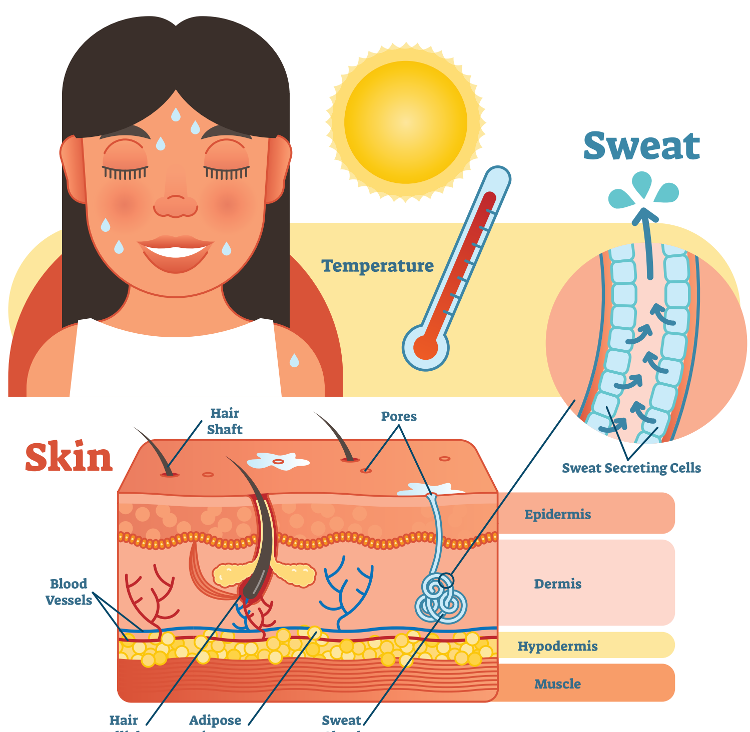

Figure 9.68 How perspiration occurs

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The skin can keep us warm by reducing the blood flow to the outer parts of the body and it can cool us down by **sweating**. Sweat is a form of excretion and it contains water, salts and urea. Sweat cools us down by using our excess body heat to evaporate off the skin. The urea and salts are left behind on the surface of our skin and either get cleaned away when we wash or drop away when our skin cells shed.

Figure 9.69 In humans, sweat glands can be found all over the body, but are particularly widespread on the forehead, underarms, the palms of the hands and the soles of the feet.

Practical 9.4

The products of breathing

Aim

To demonstrate the products found in exhaled air.

Materials

- bromothymol blue
- conical flask
- glass Petri dish
- water
- air pump
- straw

Procedure

Part A: *Bromothymol solution*

1. Add 50 mL of water to a conical flask.
2. Add a few drops of bromothymol blue and record the colour in the 'Observations before' column of your results table.
3. Using a pump and a straw, blow air slowly through the solution for 30 seconds.
4. Record your observations in the 'Observations after' column.
5. Using your breath and the same straw, blow air slowly through the bromothymol solution for 30 seconds, being careful not to suck up any of the solution.
6. Record your results in the 'Observations after' column.

Part B: *Petri dish*

7. Using a pump, blow air directly over the Petri dish.
8. Record any changes in the results table.
9. Using your breath, exhale directly over the Petri dish.
10. Record any changes in the results table.

Results

Air source	Bromothymol solution		Petri dish	
	Observations before	Observations after	Observations before	Observations after
Pump				
Exhaled				

continued…

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...continued

Discussion

When carbon dioxide is dissolved in water, it becomes acidic. Bromothymol blue turns from blue to green/yellow when it is exposed to acid.

1 Using the information and the results you collected, explain your bromothymol blue before and after results.
2 Discuss your observations of the Petri dish portion of the practical, and relate your findings to the products of respiration.

Section 9.6 questions

QUIZ

Remembering

1 **Name** two waste products produced by the body.
2 **State** the organ that converts ammonia to urea.
3 **State** the components of sweat.

Understanding

4 **Explain** why ammonia is changed into urea.
5 **Explain** why your breathing rate increases when you exercise.

Applying

6 **Compare** the terms 'defecation' and 'excretion'.

Analysing

7 **Create** a flow diagram to describe the processes that occur between the production of ammonia and the excretion of urine.

Evaluating

8 People can survive if they have a kidney removed but they may have health problems if they are not careful about their lifestyle choices. **Explain** why this is true.

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9.7 The human muscular and skeletal systems

Learning goals

1 To describe how the muscular and skeletal systems allow movement to occur.
2 To name types of muscles.
3 To identify types of joints.

Muscles

We have over 600 muscles in our bodies that allow us to perform many tasks ranging from climbing a mountain to focusing our eyes. Each action requires the interaction between several muscles, joints, tendons and bones to help us achieve our goal.

DOC WORKSHEET

The three main types of muscle found in the body are skeletal, cardiac and smooth muscle.

Muscle type		
Skeletal	**Cardiac**	**Smooth**
		
Skeletal muscles attach to the bone or skeleton via tendons and are involved in voluntary movement. Voluntary movement is the type of movement you think about like walking or typing.	Cardiac muscle is only found in the heart and pumps blood around the body every second you're alive.	Smooth muscle lines many of our organs such as the intestines and the uterus. Smooth muscle is involved in involuntary movement inside our bodies.

Types of muscle movement

There are three main types of muscle contraction that allows skeletal muscles to move the body. The first two types of muscle contraction are shortening of the muscle (contraction) and lengthening of the muscle (relax). This usually happens in pairs in our bodies to generate a controlled movement of different parts of the body.

A great example of this are the biceps and triceps on our upper arm.

If you wish to lift a glass, the bicep is shortened (contracted) and the tricep is lengthened (relaxed). By using the elbow joint as a flex point the forearm and the hand rise.

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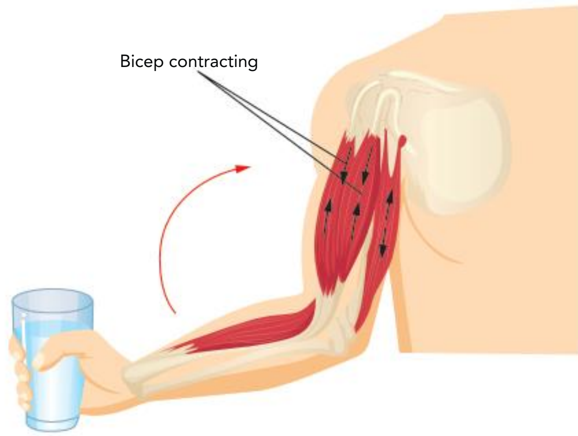

Figure 9.70 The black arrows show how the muscle contracts or relaxes. In this case, the red arrow indicates the movement of the arm as the biceps contract and the triceps relax.

If you wish to lower your hand the opposite action takes place where the bicep relaxes and the tricep contracts.

The third type of muscle contraction is to remain contracted or rigid. This allows us to grip onto objects or to remain standing still.

Figure 9.71 Can you guess which areas may have muscles that are contracted and which are relaxed?

Control of muscles

Voluntary	Involuntary	Semi-automatic
		
Most of the skeletal muscles can be controlled by your thoughts. We call this voluntary control which means that you have to think about it, just like when you type a message or throw a ball.	Actions involving our soft muscles, such as moving food through our digestive system, are controlled by the autonomic nervous system, which means that it happens automatically and we do not have to think about it (involuntary).	Breathing and blinking are both actions controlled by skeletal muscles and they are classed as semi-automatic because they occur without us directly thinking about them, but we can take control of them for a short amount of time.

Quick check 9.14

1. Identify the three types of muscle tissue.
2. Describe how two of the muscles in the arm interact to raise a hand.
3. Explain why blinking is classed as a semi-automatic action.

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Bones

Bones are extremely important for any organism that lives on land. Bones give us shape and allow our muscles to move our bodies by expanding and contracting against a rigid surface. Have you ever seen a jellyfish washed up on the beach? It looks like a blob of flesh and it cannot move. This is because jellyfish use the water to support their bodies and to push against to move. If we didn't have bones we would look a lot like one of those washed-up jellyfish.

Figure 9.72 Out of water, a jellyfish's body has little structure because it has no bones.

Cartilage

Bones start out as soft cartilage as they grow and take shape. Cartilage is a soft and flexible material unlike true bone which is hard and stiff. When you are born many of your bones are still growing, infant babies have around 300 bones which eventually fuse together to form the 206 bones you have as an adult. During this early stage in your life many of the bones are made of cartilage and there is even a hole at the top of the head called a fontanel where the skull is still growing.

ossification
the process of bone formation from cartilage

Over time the cartilage undergoes a process called **ossification**. During this process cartilage takes on a lot of calcium, gets harder, less flexible and turns into bone.

Figure 9.73 Babies have more bones than adults.

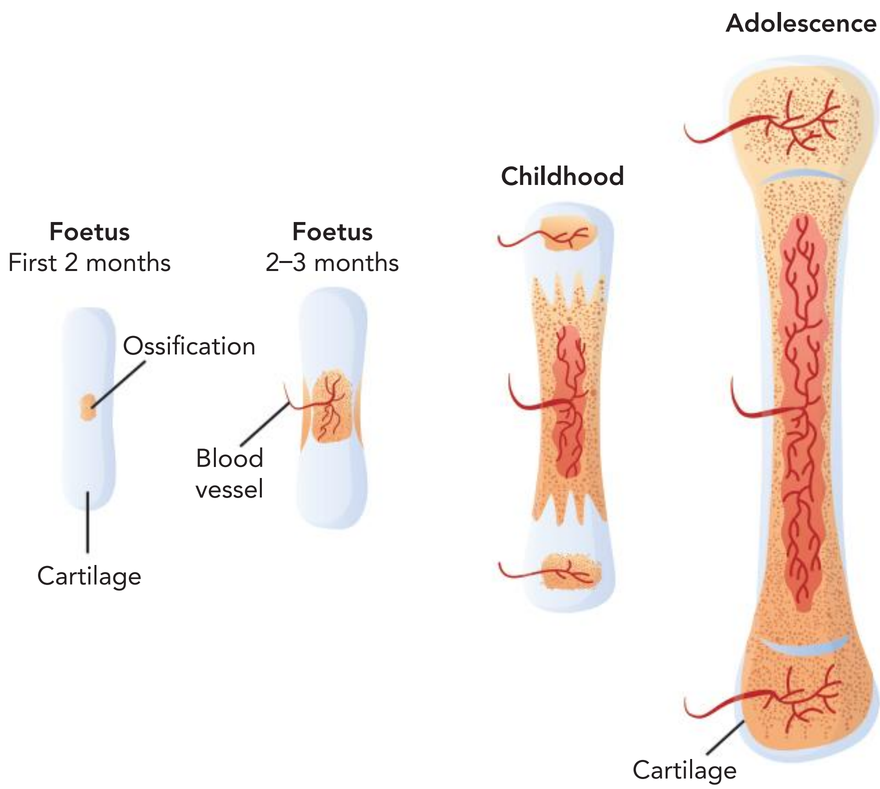

Figure 9.74 How bones grow in a baby to adolescence

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Bones are living parts of our bodies that have several layers each with a specific job.

- The first layer is a thin membrane that surrounds hard bone called the periosteum. This thin layer contains nerve cells and brings blood and nutrients to the bone.
- The next layer is compact bone. This is very hard and the most familiar to look at. This is what you see when you look at a skeleton.
- Underneath the compact bone layer is a region that looks like a sponge called cancellous tissue. Although this region looks like a sponge it is still very hard and strong.
- In the centre of many bones is the bone marrow. This is a thick jelly-like substance where blood cells are made.

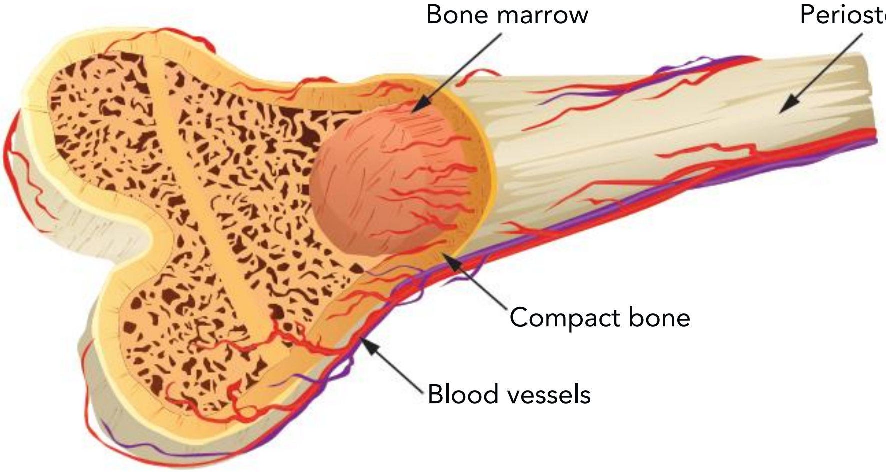
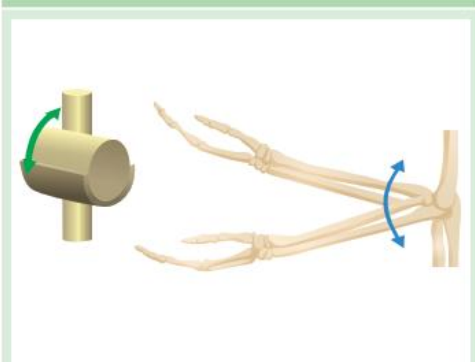
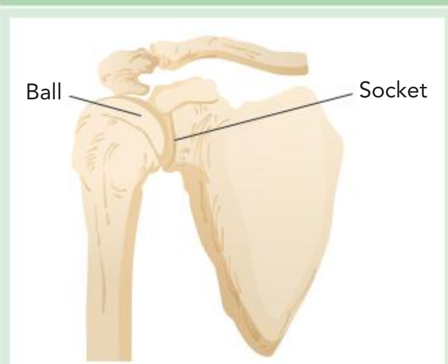


Figure 9.75 Parts of a bone

Joints

Joins are the points between bones. They allow the muscles to move the body by moving individual bones. Not every joint works in the same way and many only allow specific types of movement.

The main joints involved in movement can be split into three categories.

Hinge joint	Pivot joint	Ball and socket joint
		
This is just like the hinge of a door that allows movement in one direction, e.g. open and close or up and down.	These joints give more movement options and allow rotating and twisting.	These joints are the most flexible joints. Movement can go in many directions.
Examples: elbow, wrist	Example: shaking your head	Example: the shoulder

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Practical 9.5

Chicken wing dissection

Aim

To dissect and identify the bones and muscles in a chicken wing.

Be careful

Always ensure you are cutting away from you and other people.

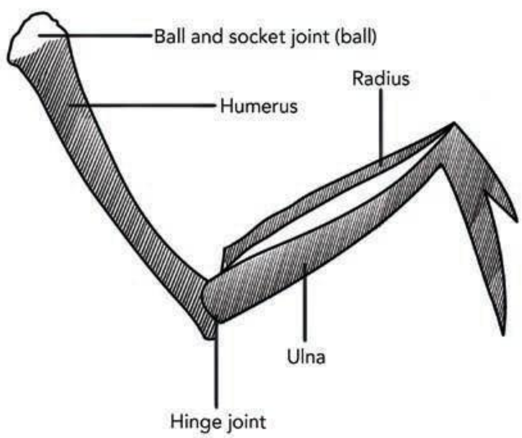
Materials

- raw chicken wing
- dissecting scissors
- dissecting board
- disposable gloves

Procedure

1 Hold the chicken wing and feel the skin, muscle and bone by squeezing and pinching the wing at different parts.
2 Pinch the skin and pull it upwards away from the muscles underneath.
3 Using the dissecting scissors cut the skin just below the pinch, being careful not to cut the muscle underneath.
4 Slide your fingers into the cut in the skin and start to pull the skin layer away from the muscle. You may notice white or yellow patches under the skin, this is fat.
5 As you loosen the skin use the scissors to cut it away.
6 Continue this process until all of the skin has been removed.
7 Sketch the wing muscles in your science book.
8 Using Figure 9.76, label the sketch you have drawn.
9 Notice the tendons that attach the muscle to the bone.
10 Begin to remove the muscles by cutting the tendons until you are left with the bones.
11 Sketch the bones in your science book and label them using the diagram below.

Results



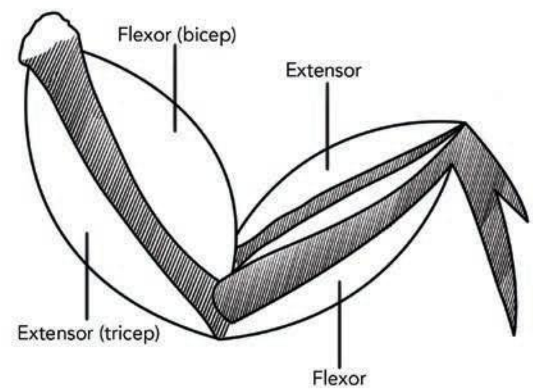


Figure 9.76 One sketch should show the bones and joints, while the other should show the muscles.

Discussion

1 Research and compare the bones and muscles found in a chicken wing to those found in a human arm.
2 Explain using your observations how the bicep and triceps help to move the wing.
3 Identify one risk you faced during this practical activity and describe how you minimised it.

Conclusion

1 What conclusions can be made from this activity regarding the relationship between bones and muscles and their function? Begin your sentence with 'This activity suggests that ...'
2 What evidence did you gather to support the conclusions you have drawn? Begin your brief summary with 'We observed … therefore …'

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Section 9.7 questions

QUIZ

Remembering

1 **Identify** the type of muscle that is involved in voluntary movement.
2 **Name** the type of muscle only found in one organ.

Understanding

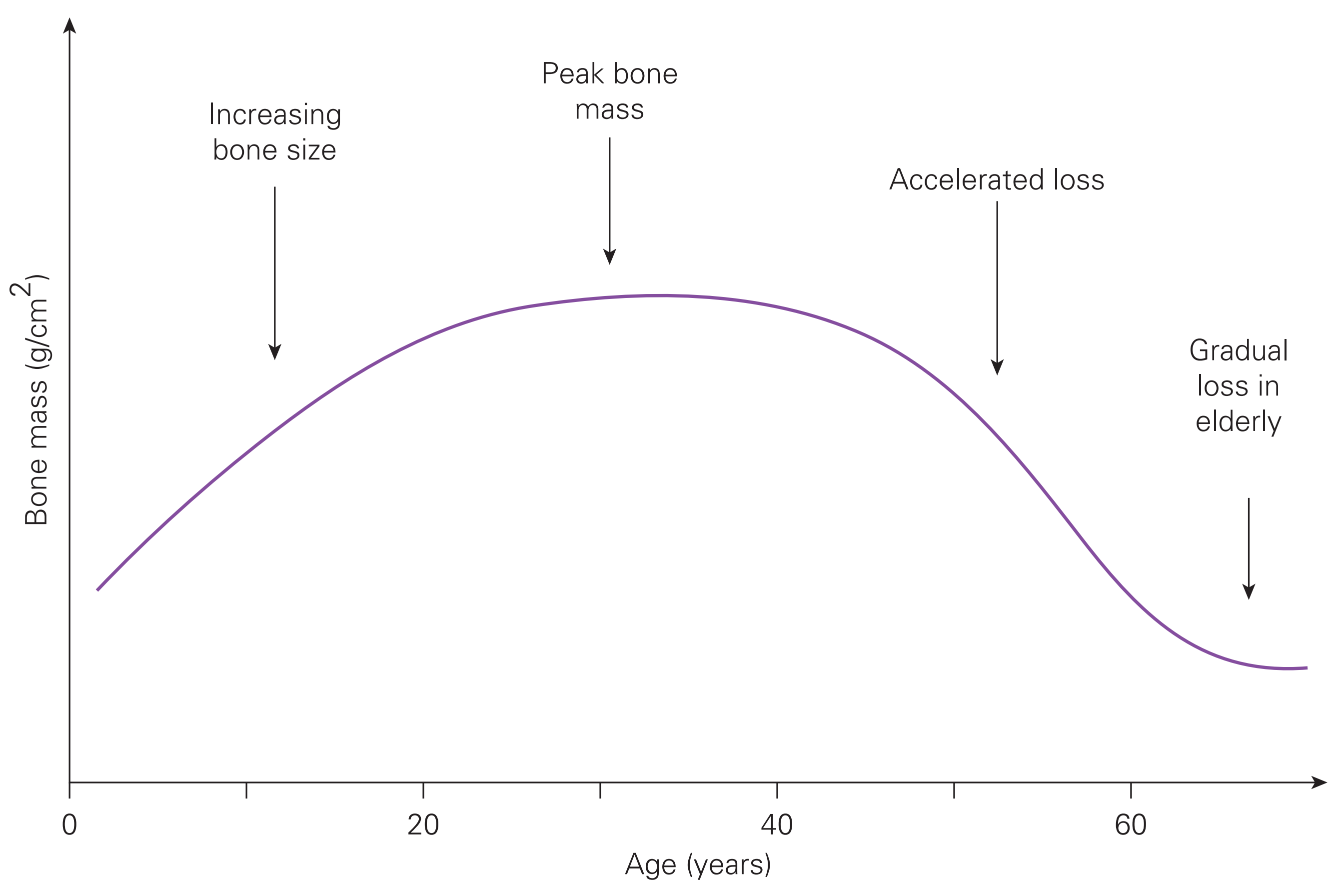
3 **Explain** how skeletal muscle interacts with the skeleton.
4 **Explain** why a jellyfish cannot move on land.

Applying

5 **Sketch** a labelled diagram of a human bone including the blood vessels, compact bone and bone marrow.

Analysing

6 Use the graph below to answer the following questions.
   a **Describe** the trend shown in the graph.
   b **Suggest** a reason for the increase in bone mass from 0–20 years of age.
   c Older people are at a greater risk of breaking bones when they fall over. **Explain** a reason for this, using information from the graph.



Evaluating

7 Early ocean organisms that first evolved containing bones and muscles became extremely efficient hunters and easily caught prey. **Account** for this.

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9.8 Plant systems

Learning goals

1 To identify the organ structures in plants such as the roots, shoots and leaves.
2 To explain the role of the roots, shoots, leaves and flowers in plants.

Roots

The part of the plant that is underground is called the root system. The root system has two primary functions.

1 To support the plant and hold it in place. This allows the above ground part of the plant to grow tall and compete with other plants for light.
2 To absorb water and nutrients from the soil. This provides the plant with the nutrients needed for photosynthesis and growth.

Roots need to cover as much of an area as possible and are often covered in small fine structures called root hairs. These structures are only a few cells thick, creating a short diffusion distance. Root hairs also increase surface area, maximising the intake of water and nutrients.

Shoots

DOC WORKSHEET

The shoot system is the part of the plant that is above the ground. This part of the plant is everything you can see including the leaves, flowers and stem.

The stem of the plant contains tubes called the xylem and phloem that transport water and nutrients through the plant.

- **Xylem** moves water from the roots to the leaves travelling in one direction.
- **Phloem** move sugars from the leaves where they are created to other parts of the plant where they are needed.

xylem
vascular tubes that transport water in one direction through the plant

phloem
vascular tubes that transport sugars and nutrients throughout the plant

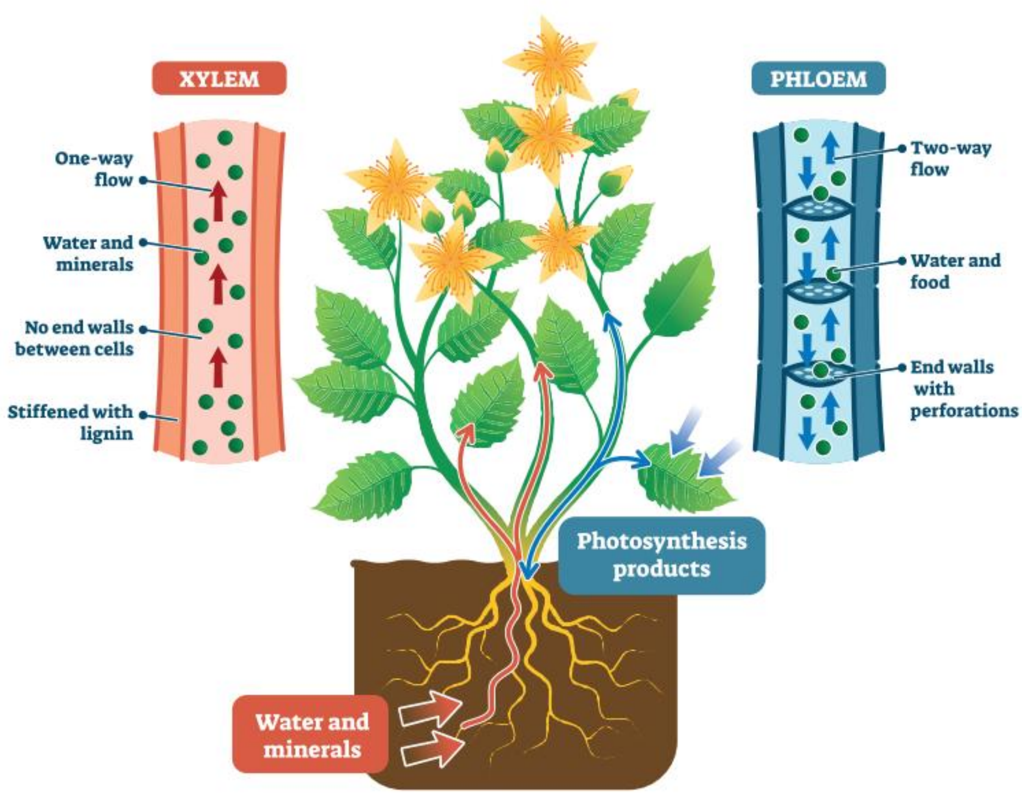

Figure 9.77 Xylem and phloem transport water, minerals and nutrients through the shoots of plants.

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Figure 9.78 Leaves are like lungs for a plant.

Leaves

Gas exchange is important for all living organisms, including plants. Plants carry out cellular respiration as well as photosynthesis, and so they need organs that allow their internal structures to exchange gases with the environment. The main gas exchange organ in plants is the leaf. Most photosynthesis takes place in a layer of cells near the top of the leaf called palisade cells. As photosynthesis takes place in the leaf it needs to be able to take up carbon dioxide (one of the reactants in photosynthesis) and release oxygen (a waste product of photosynthesis).

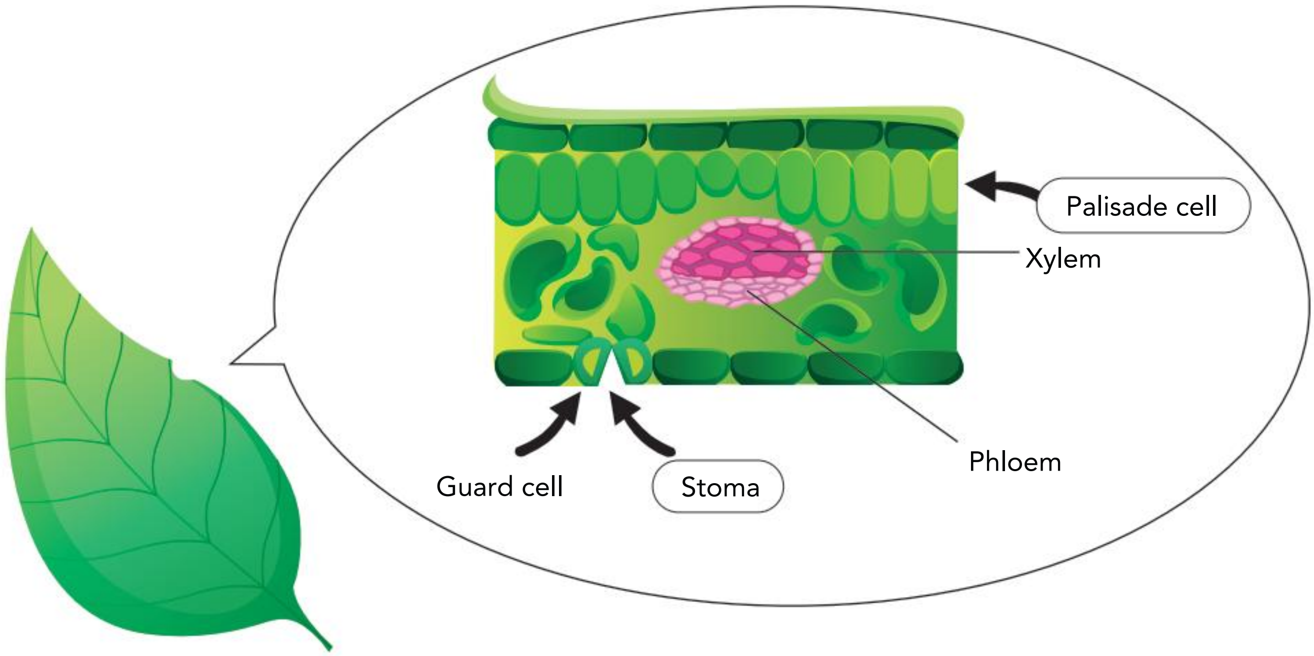

Figure 9.79 Gas exchange occurs in the leaves of plants.

stomata
tiny pores (holes) in leaves that allow entry/exit of gases such as oxygen and carbon dioxide

guard cells
cells on either side of a plant stoma that control gas exchange by opening and closing the stoma

Each plant has many leaves, in the same way that your lungs have many alveoli. Leaves are usually flat, which increases the surface area not just for light absorption but also for gas exchange. Each leaf has tiny pores called **stomata** (singular: stoma). The stomata are mainly on the underside of the leaf, and they control the entry and exit of gases from the plant. **Guard cells** in the stomata enable them to open and close.

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The guard cells of stomata contain large vacuoles that, when filled with water, hold the stomata pores open. The vacuoles fill with water when plants are in strong sunlight or high carbon dioxide concentration. However, when the plant begins to dry out in periods without rain, or in high temperatures or low humidity, the vacuoles inside the guard cells empty out and the cells become floppy or flaccid. This closes the stomata pores and reduces the amount of water vapour lost through the leaf. The stomata also close at night, when the light levels required for photosynthesis are low. Plants need to allow gases to move in and out, but they also need to minimise the loss of water vapour through the stomata. It is a balancing act, and plants do an amazing job (especially those that live in the desert).

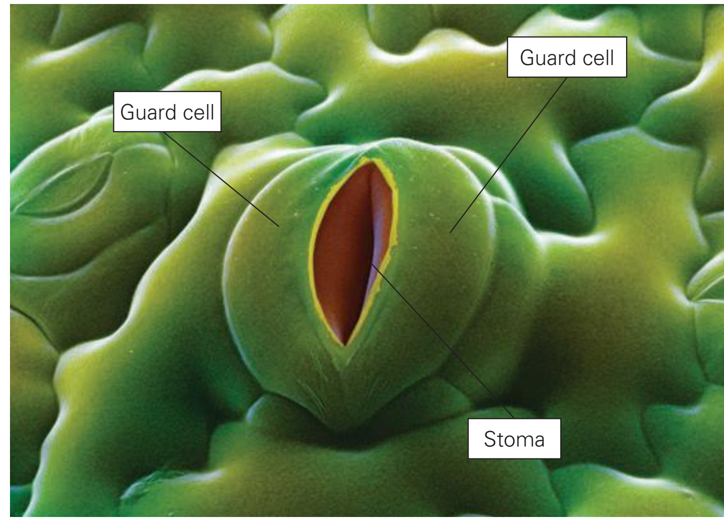

Figure 9.80 Swollen guard cells have forced open this stoma, allowing gases to enter and exit the leaf.

Practical 9.6

Stomata lab

Be careful

Carry the microscope appropriately, with one hand holding the arm and one hand under the base. Do not make big changes in magnification, so that the glass slide is not damaged.

Aim

To observe plant stomata using a compound microscope, and estimate their size.

Materials

- leaves
- compound microscope
- transparent ruler
- sticky tape
- glass slide
- transparent nail polish

Procedure

Part A: *Calculating FOV and estimating the size of the object*

Refer to Practical 9.1 for the methods of calculating the size of the field of view and estimating the size of the object.

Part B: *Creating a stomata slide*

1. Either pick three leaves from a walk around your school grounds or choose from leaves provided by your teacher.
2. Identify the top and bottom of the leaf.
3. Use the nail polish to paint a thin layer of varnish on a small section of the bottom side of the leaf.
4. Allow the polish to dry completely.
5. Place the sticky tape over the dry polish and pull it off.
6. Place the sticky tape with the polish impression onto a microscope slide, and use the compound microscope to focus on the stomata impression.
7. Focus on the highest possible magnification and sketch an image of the stomata. Use the FOV calculations to estimate the diameter of the stomata.
8. Repeat for each leaf.

continued…

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…continued

Results

Magnification (ocular lens × objective lens)	FOV diameter (mm)	FOV diameter (μm) (mm × 1000)

Plant	Sketch, magnification and diameter estimate

Discussion

1 State the estimated size of a stoma.
2 Explain why different plants are likely to have a different number of stomata.
3 Suggest a reason why some stomata are open while others are closed.

Try this 9.10

Modelling stomata with a balloon

1 Using a twist balloon, blow it up and fold it in half but do not tie a knot in the end.
2 Keeping the balloon folded, allow some air to escape slowly from the balloon.
3 Notice how the two sides of the balloon begin to come together.

This is similar to what happens in the stomata as it loses water. By closing the stomata, the plant is able to limit water evaporation and save water.

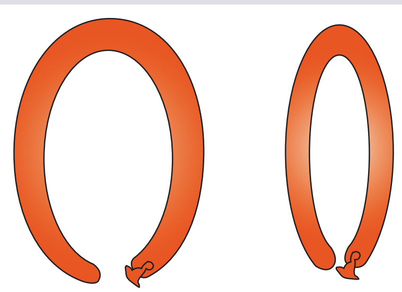

Figure 9.81

Advances in science 9.7

Thirsty plants

At present, agriculture consumes 90% of the world's fresh water to irrigate (water) crops. Scientists have found a way to genetically alter crops so that they are only able to partially open their stomata. This means the plants lose less water vapour when they open their stomata to gain the carbon dioxide they need to carry out photosynthesis. In a study conducted on tobacco plants, the modification improved crop water use by 25% but did not affect the yield of the crops – that is, the same amount of tobacco was produced. Tobacco plants are easier to genetically modify, but now the research team hope to apply their discoveries to food crops.

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Figure 9.82 The small horizontal slits in this tree trunk are lenticels. You may have seen these on trees but not known what they are.

Although the stomata on leaves do a great job of providing gases for the leaves, other parts of the plant need to respire, using oxygen. The thick woody parts of trees, such as the branches, stems and trunks, have structures called **lenticels**. You can often see these in the bark – they look like small dots or stripes. Lenticels allow the thick woody parts of the plant to exchange gases with the air.

lenticels
small slits on trunks or branches of trees that allow gas exchange

Quick check 9.15

1 Name the structures that allow gas exchange to occur in leaves.
2 Recall three environmental factors that could cause stomata to close.
3 Describe the need for lenticels on a tree.
4 Compare xylem and phloem.
5 Name the structure that can be found in the shoot system.

Section 9.8 questions

QUIZ

Remembering

1 **Define** the term 'gas exchange'.
2 **State** the location of stomata.
3 **Define** 'lenticels'.

Understanding

4 **Explain** how stomata open and close.
5 **Explain** why the stomata also closed at night.

Applying

6 **Describe** the two primary functions of the root system.
7 **Compare** the structure of the lungs to the structure of a tree.

Analysing

8 **Distinguish** between the two types of tubes for water transport in plants: xylem and phloem.

Evaluating

9 Plants need to allow gases to move in and out, but they also need to minimise the loss of water vapour through the stomata. **Discuss** why the authors of this text book think that plants do an amazing job (especially those that live in the desert).

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9.9 Reproductive systems

Learning goals

1. To describe the structure and function of organs found in the reproductive system.
2. To describe the purpose of the reproductive system.

DOC WORKSHEET

asexual reproduction a method of reproduction in which there is one parent organism and all offspring are genetically identical

sexual reproduction a method of reproduction in which there are two parent organisms and genetic variation in the offspring

gametes the sex cells (eggs and sperm), each of which contains half the genetic material required to make an organism

gonads the reproductive organs, where gametes are produced; testes for males and ovaries for females

zygote a fertilised egg cell

embryo a fertilised egg cell in the early stages of growth and differentiation; in humans, this would be from between two and eight weeks after fertilisation

Every living thing on the planet will eventually die. Therefore, in order for life to continue, organisms need to produce more of their own kind through the process of reproduction.

There are two main types of reproduction: asexual and sexual.

Asexual reproduction occurs when organisms make an exact copy of themselves. There is no need for a second parent.

Sexual reproduction involves the genetic input of two parents, and tends to result in offspring with lots of variation. Humans reproduce via sexual reproduction. This means that, while siblings might look similar, they are rarely identical.

VIDEO Contrast asexual and sexual reproduction

Sexual reproduction

Sexual reproduction requires two organisms of the same species to each contribute a special cell that combines with the other to produce a new, unique offspring.

Sexual reproduction requires a sperm cell from the male and an egg cell from the female to combine. These cells each contain half the genetic information needed to form a new organism of the same species. We call these cells **gametes** and they form in the **gonads** of males and females. The male gonads are the testes and the female gonads are the ovaries.

When an egg cell and a sperm cell meet, they combine to form a fertilised egg, called a **zygote**. This cell has the correct amount of genetic material and it can begin to replicate by mitosis, which you may remember from Chapter 8, in which eukaryotic cells make copies of themselves. As this new cell replicates and becomes many cells, it grows and the cells take on special functions. The zygote will eventually develop into the **embryo** of the organism.

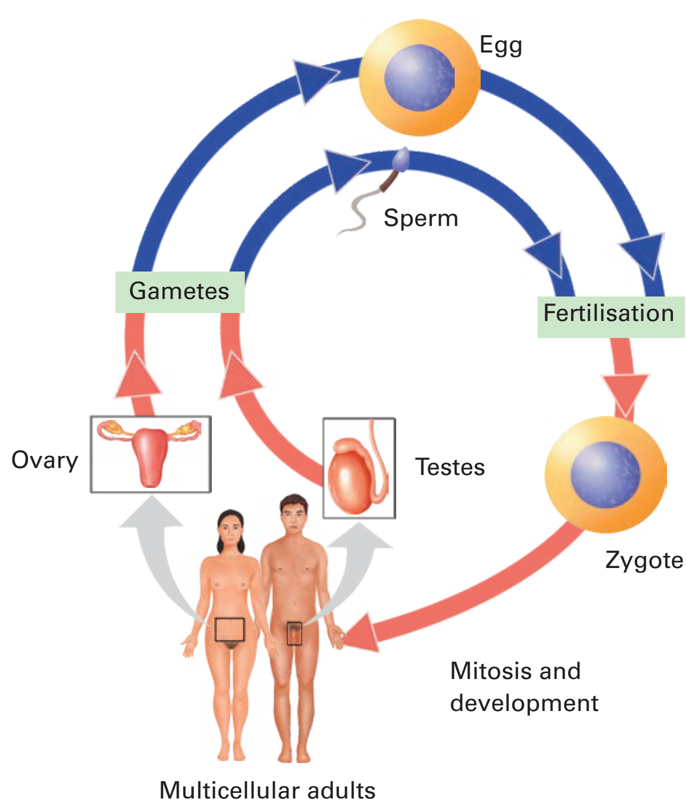

Figure 9.83 The human reproductive cycle

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Quick check 9.16

1 Define the following key terms: asexual reproduction, sexual reproduction, gametes, gonads, zygote, embryo.
2 Recall the number of parents involved in asexual and sexual reproduction.
3 Name the female and male gonads, and name the female and male gametes.

Sexual reproduction in humans

The female reproductive system

When a female is born, she has between 1 and 2 million eggs in her ovaries, in tiny sacs called follicles. Most of these eggs will be lost by the time she reaches puberty. Once she reaches puberty, one egg (**ovum**) is released into the Fallopian tube each month, through a process called **ovulation**. If this egg is not fertilised, then the uterine lining is shed (along with the egg) and the woman experiences **menstruation** (a menstrual period).

ovum
egg, or female gamete

ovulation
the release of an ovum (egg) from the ovary into the Fallopian tube

menstruation
the cyclical shedding of the unfertilised egg and the uterine lining; also known as the menstrual period

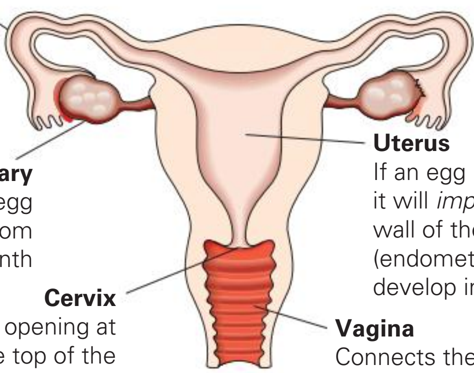

Figure 9.84 The female reproductive system

Did you know? 9.13

More than one uterus

Animals such as rabbits have a branched uterus, which allows for the development of multiple foetuses at the same time, even up to 14! However, this is not the only factor in the rabbit's rapid rate of reproduction. They also have a gestation period of 28–31 days, which means a single female could give birth to 168 live young per year! Due to their quick rate of reproduction, rabbits are considered a risk to agriculture and native flora and fauna. This is why it is illegal to possess a pet rabbit in Queensland without proper authorisation. You may, however, keep a domesticated rabbit as a pet in NSW.

Figure 9.85 Rabbits are excellent breeders.

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The male reproductive system

Gamete production in males is a little different: once a male reaches **puberty**, he starts to produce **sperm** in his **testes**. The testes are suspended from the body in a sac called the **scrotum**, which is around three degrees cooler than core body temperature as sperm production is best at this temperature.

puberty
the time of transition from juvenile form to adult form

sperm
the male reproductive cell, or gamete

testes
the male reproductive gland that produces sperm

scrotum
a sac that encloses the testes

Sperm are around 0.05 mm long and are well adapted for swimming through the mucus of the vagina and the uterus to reach the egg. Each sperm has a long whiplike tail that beats in a corkscrew motion to propel the sperm forwards. They also have many mitochondria in their midpiece to provide energy for swimming, and a sac of enzymes in their head to digest through the egg membrane. Unlike eggs, sperm are produced in huge quantities throughout a male's life.

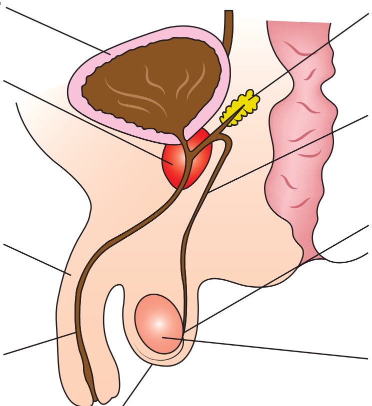

Figure 9.86 The male reproductive system

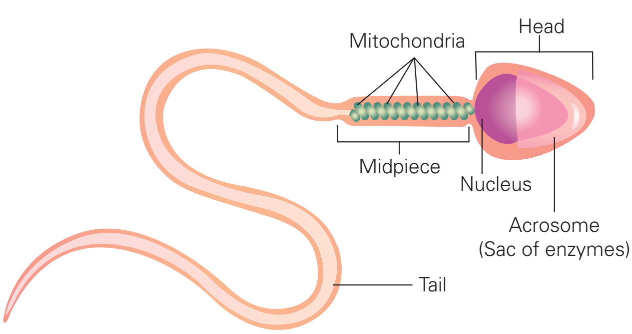

Figure 9.87 Sperm with its adaptations

Quick check 9.17

1. From where are eggs released and into what structure?
2. Describe what happens when an egg is released but not fertilised.
3. Recall what the vas deferens is.
4. Summarise the parts of the female and male reproductive systems and their function. You may choose to do it in table format.

Try this 9.11

Model/diagram

Construct a model or a diagram showing the structures of the female reproductive system and the process of fertilisation (from ovulation until the zygote implants in the uterine wall).

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Did you know? 9.14

Cloaca – one hole does it all!

Humans have an anus to defecate out of, a urethra to urinate out of and, if you are a female, a vagina that babies come out of. But not all animals are like that. In fact, it is much more common to have one hole that does all of the above. This organ is called the **cloaca** and it is found in amphibians, reptiles, birds, some fish and even monotremes. This is why it can sometimes be tricky to distinguish between the sexes of certain animals. For example, birds mate by pressing their cloacas together in a process known as a 'cloacal kiss', where muscular undulations move the sperm from the male to the female.

cloaca
a hole used for defecating, urinating and giving birth that is present in some amphibians, reptiles, birds, fish and monotremes

Figure 9.88 Turtles and tortoises lay eggs through their cloaca.

Figure 9.89 Echidnas also have a cloaca.

Sexual reproduction in flowering plants

pollen
the male gamete in flowering plants

ovule
a structure in a flowering plant where the female gamete is produced and where seeds develop; also used to mean the female gamete

pollination
the process by which pollen sticks to the female structures of a plant and fertilises the ovule

nectar
a sweet liquid produced by flowers to attract pollinators

If you sit near a patch of flowers on a summer day, you may see a bee or a butterfly paying them a visit. Many flowers rely on these insects to help them reproduce by sexual reproduction. The flower is the sexual organ of the plant. The **pollen** it produces is the male gamete (similar to sperm) and the female gamete is inside the **ovule**. The parts of a flower are shown in Figure 9.95 on page 378.

Pollination is the fertilisation process in which the pollen from one flower reaches the ovule of another flower. Bees and other insects are attracted to brightly coloured and scented flowers, in addition to the sweet **nectar** they produce, and pick up pollen while they are feeding. When the bee moves to the next flower, some of the pollen on the bee sticks to the stigma of the new flower, and the pollen grain then grows down the style to the ovule. This is where fertilisation occurs and seeds develop.

WIDGET
Sexual and asexual reproduction

Figure 9.90 A bee with large yellow pollen sacs on its legs

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Explore! 9.7

Pollination

Pollination is an important process. It allows plants to reproduce. After fertilisation, the ovary swells and grows into a fruit. There are different methods by which pollen can be transported from one flower to another and allow pollination to occur – examples are wind, insects, birds and animals.

When male gametes (pollen) fertilise female gametes (ovule) on the same plant, this is called **self-pollination**. When pollen from one plant fertilises the ovule of another plant, it is called **cross-pollination**. Cross-pollination results in genetically diverse offspring that increase variation in the species, making it more likely to be able to survive changes in the environment.

self-pollination
pollination that occurs by pollen from the same flower or from another flower on the same plant

cross-pollination
pollination that occurs by pollen from another flower or plant

1 Draw up a table with two columns. In the first column, list the four methods of moving pollen from one flower to another. Then research the types of flowers that use each method of pollination. In the second column, summarise what you have found out about the characteristics (shape/colour/size) of the flowers, their stamens and pistils.
2 What are the advantages and disadvantages of self-pollination? Do some research to find out how plants prevent self-pollination occurring.

Figure 9.91 These flowers are pollinated by different methods. Can you identify what those methods are?

Did you know? 9.15

Palynology

Pollen grains come in many shapes and sizes, depending on the plant that produces them. This is why pollen from certain plants can trigger an allergic reaction in some people, while other pollen has no effect. Palynology is the name for the study of pollen grains. Palynologists study pollen samples found in places such as archaeological digs or at crime scenes. Palynology suggests that Australia's oldest flowering plants are approximately 126 million years old, and they resembled modern magnolias, buttercups and laurels.

Figure 9.92 There are many types of pollen in the air.

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Humans are attracted to flowers because of their beautiful and varied colours and scents, but the colourings that we see are just the tip of the iceberg. Many insects can see further into the electromagnetic spectrum than we can. If you view flowers under ultraviolet light, you will see that many have patterns that resemble a bullseye target or a landing strip. These patterns are designed to tell the insects exactly where they need to go to get the nectar.

Figure 9.93 Flowers with (left) a bullseye pattern and (right) a landing strip pattern

Figure 9.94 Conifers, such as pine trees, have separate male (left) and female (right) cones on the same tree, they do not have flowers. They are wind-pollinated, male cones release pollen to the wind. When ready the female cones open and the pollen is blown inside to fertilise the female gametes, which develop into seeds. To reduce self-pollination, female cones are on the higher branches and male cones on the lower branches.

Quick check 9.18

1. Name the male gamete and the female gamete of plants.
2. Bees and insects can transfer pollen from one flower to another flower. Name some other ways that pollen can be transferred.
3. Summarise the parts of the flower and their role in sexual reproduction. You may choose to do it in table format.

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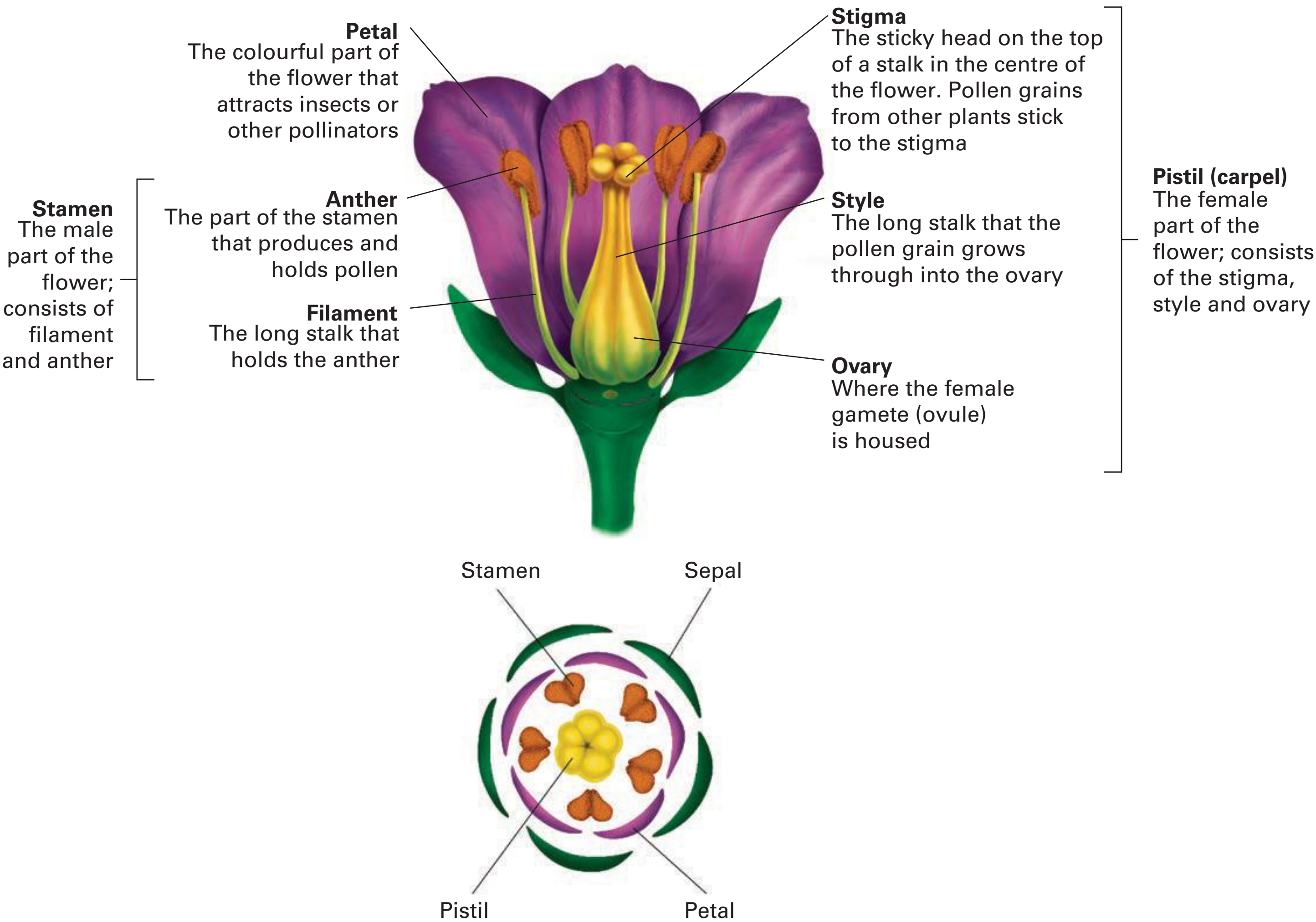

Figure 9.95 Top: A vertical section showing the reproductive parts of a flower. Bottom, left: a cross-section of the reproductive parts. Bottom, right: a lily showing stamens, style and and stigma.

Practical 9.7

Flower dissection

Be careful

Take extreme care when handling the razor blade.

Aim

To identify the parts of a flower, and link their structure to their role in reproduction.

Materials

- a variety of flowers for dissection
- hand lens
- stereomicroscope
- tweezers
- single-sided razor blade
- chopping board

continued…

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…continued

Procedure

1 Refer to Figure 9.95 to help you to identify the parts of your flower. Draw a diagram of your first flower. Note the number of petals and sepals, and label these on your diagram.
2 Holding the flower carefully with tweezers on the chopping board, cut the flower in half vertically. This means you should now be looking at a vertical section of the flower, similar to the top picture in Figure 9.95.
3 Draw a diagram of the flower, and label all the parts of the flower you can recognise. Add 'M' next to the male parts of the flower and 'F' next to the female parts of the flower.
4 Gently remove the sepals and petals, by pulling them down towards the stem. Use a microscope to look at the tip of the petal at low magnification. Record your observations of the petal's texture in your results.
5 Remove the flower's stamens, by breaking or gently cutting them off the stem. Examine the pollen with your microscope. Record your observations of the pollen's shape and texture in your results.
6 Gently remove all parts except the pistil, so that it remains alone on the stem. Carefully cut the pistil in half lengthwise, and use your hand lens to look at the inside of it. Record your observations of the style, ovary and ovules in your results.
7 Repeat steps **1–6** with the other flowers.

Results

Your results should consist of:

- labelled diagrams of the whole flower and vertical section of the flower
- observations made during the dissection.

Discussion

1 Consider the different flowers you looked at. List the similarities and differences between them.
2 Explain why these differences between flowers might exist.
3 Use a flow chart to summarise the process of sexual reproduction in plants. Use the names of the parts of flowers that are involved and their role in reproduction.

Advances in science 9.8

Healthy bees need diversity

Bees pollinate most of our crops, but bee numbers are decreasing rapidly. Bees can fly between flowers at about 25 km per hour and visit up to 5000 flowers in one day. In fact, bees are so important that artificial hives are moved all around the country to help pollinate new crops.

Figure 9.96 The blue-banded bee

Imagine that you were only allowed to eat one type of food. That would become boring and you probably would not be very healthy. Australian and German researchers have discovered that a diversified plant environment helps bees maintain stable populations. The bees' quality of life is highest in gardens and biodiverse forests, and lowest in mono-crop areas. As plant biodiversity declines, bees produce less offspring, and eventually bee colonies shrink in size. This means we need to protect our biodiverse environments in order to help prevent the extinction of bees.

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VIDEO
Australian plants and seed dispersal

Seed dispersal

In conifers and flowering plants, after fertilisation the embryo develops inside a seed or nut. **Seeds** may be in a fleshy structure that developed from the ovary after flowering. You know this as fruit!

seed
a plant embryo enclosed in a protective coating

seed dispersal
the spread of seeds away from the parent plant

In every day language, when you use the word 'fruit', you will probably be thinking of something edible that is sweet or sour, such as apples, lemons, grapes or nectarines. However, in plant science, 'fruit' means the seed-containing structure which in flowering plants develops from the ovary, and this includes bean pods, wheat grains or corn kernels.

In pine trees and other conifers, the woody female cones protect their seeds. When the seeds are fully developed, the cones open and release the seeds.

Figure 9.97 Peaches produce a large seed surrounded by tasty flesh.

Figure 9.98 Pine cone ready to drop its seeds

Plants produce many seeds, to increase the chances of survival. Many seeds will be eaten by animals, or land on areas where they cannot grow, or be destroyed. Adult plants often take up a lot of space and resources, and so, in order for their offspring to thrive, the seeds need to spread to new places. This is known as **seed dispersal**, and plants have many clever ways of doing this.

Exploding!

The seed pods of a group of plants known as *Impatiens* are ticking time bombs. When the fruit is ripe, the slightest touch can trigger the pod to explode suddenly, flinging the seeds it contains in many directions, although the seeds often do not travel far.

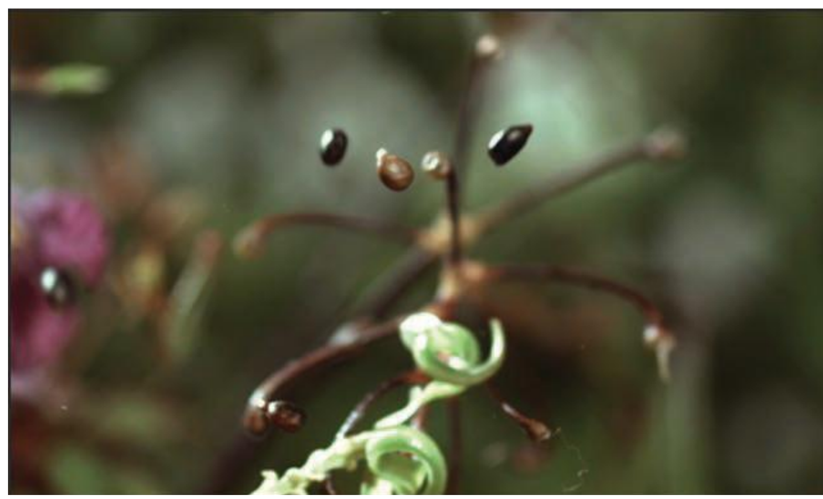

Figure 9.99 Exploding seed pod

Hitching a ride on the outside

Certain plants, including grasses, use spiky pods (burrs) that latch onto an animal's fur or a human's clothing to disperse. The spiky pod stays on the animal's fur until the animal gets itchy and scratches it off, and then the pod falls to the ground in a new location.

Figure 9.100 Burrs caught on a dog's fur

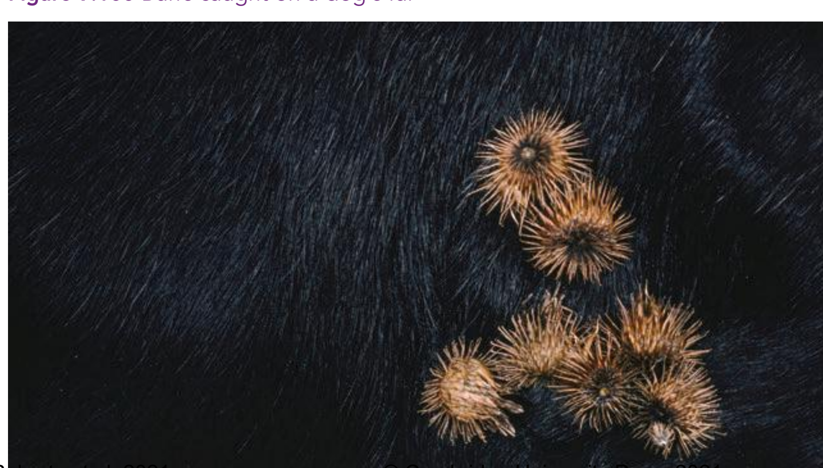

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Figure 9.101 Animals ingest seeds in fruit and then defecate the seeds in a new location.

Figure 9.102 Dandelion seeds leaving a dandelion clock after getting caught in the breeze

Hitching a ride on the inside

As you know, fruit not only protects the seeds, but also can be very tasty. Some plants make their fruit extra sweet to encourage animals to eat the seeds. The seeds have a tough coat so that they won't be digested. When they eventually pass intact through the animal, they are in a brand new spot, where they may begin to grow.

Shooting the breeze

Dandelion seeds are so light that they are blown extremely long distances by just a gust of wind. A fluffy tuft called a pappus acts as a parachute to carry each seed away. A dandelion head is not just one flower but is made up of many florets that each produce an individual seed. One dandelion head can make around 500 seeds. This is why dandelions are such an effective weed.

Floating away

A coconut is one giant seed. It is hollow and so it can float. This is how coconuts are able to move between islands and across oceans.

Figure 9.103 A floating coconut

Quick check 9.19

Summarise the different ways in which seeds can disperse. Include examples where appropriate. You may choose to do it in table format.

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Practical 9.8

Seed germination

Aim

To design a valid, reliable and accurate experiment to test the conditions necessary for a seed to germinate, using the materials provided. You may investigate other factors that contribute to the plant's germination (light levels, water, nutrients, heat etc.)

Materials

- Petri dish or glass jar
- paper towel
- water
- seeds
- fertiliser
- sugar
- salt
- water
- black paper
- heat lamp
- cotton wool

Planning

1 Write a rationale about the factors that affect seed germination.
2 Write a specific and relevant research question for your investigation.
3 Choose a suitable independent variable to test.
4 Identify the dependent and controlled variables.
5 Write a hypothesis for your investigation.
6 Write a risk assessment for your investigation.
7 Construct a detailed method to explain the procedure you will follow in your experiment. Include all the instruments and exact measurements you will use. Set it out in step-by-step form. Include the number of repeats you expect to conduct. Do not forget to mention how the data is recorded. Remember, another scientist should be able to read this procedure and replicate your experiment exactly, so be detailed in your instructions.
8 After confirming with your teacher that your method is satisfactory, carry out your investigation.

Results

1 Draw a results table for your experiment.
2 Produce a suitable graph for your experiment.

Discussion

1 Describe any patterns, trends or relationships in your results.
2 Explain any trends you have identified.
3 Identify any limitations in your investigation.
4 Propose another independent variable that could have been tested, to expand on your results.
5 Suggest some improvements for this experiment.

Conclusion

Draw a conclusion from this experiment, using data to support your statement.

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Advances in science 9.9

Technology and farming

There is continuous development in modern farming techniques. Technologies are applied in order to improve crop yields and sustainability. Two such examples are hybrid seeds and cloning.

Hybrid seeds are produced by companies through selective breeding. Two plants with favourable characteristics are bred together. For example, a strawberry plant that is drought tolerant may be cross-pollinated with a strawberry plant that produces a large amount of fruit. Hybrid seeds are common in commercial farming, especially to increase crop yields.

Figure 9.104 In 2014, several prefectures in Japan developed a new hybrid of strawberry capable of year-round production; they named the hybrid 'Yotsuboshi'.

Cloning technology is also used in farming. All over the world, wine growers are reporting that their grapes are ripening earlier due to hotter temperatures. Growers are having to respond by:

- irrigating their vines
- more effectively managing the grape canopies for shading
- moving their vine plantings to cooler parts of their properties.

However, as temperatures continue to increase, growers may have to consider growing grape varieties that are more drought and heat tolerant. One way of doing this is by cloning grape varieties that are well known for their tolerance to hot conditions and planting them in areas that are predicted to get hotter.

Figure 9.105 Grapes are cloned by taking a cutting from an existing grape vine and then grafting it onto another vine or encouraging the cutting to grow roots.

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Section 9.9 questions

QUIZ

Remembering

1 **State** the function of the following structures in the human reproductive system:
   a ovary
   b scrotum
   c Fallopian tube
   d prostate
   e uterus
2 **State** the purpose of the petals of a flower.
3 **Define** the term 'pistil'.
4 **Identify** what mode of asexual reproduction is used by:
   a a yeast cell
   b a bacterial cell
   c a strawberry plant

Understanding

5 **Explain** the purpose of fruit.
6 **Explain** how seed dispersal by the wind is effective.

Applying

7 **Construct** a comic strip or series of diagrams to model how sexual reproduction occurs in a flowering plant. Ensure the reproductive organs are labelled appropriately.
8 **Compare** sexual and asexual reproduction to show the advantages and disadvantages of each method.

Analysing

9 **Distinguish** between sexual and asexual reproduction.
10 **Compare** a peach with a pine cone.
11 **Distinguish** between self-pollination and cross-pollination.

Evaluating

12 A biologist is investigating a species of frog that lives in an environment that is changing rapidly. **Propose** a reason why sexual reproduction would be better for this species of frog.
13 Ezra lived in England for 15 years and never experienced hay fever. Hay fever is caused by pollen irritating the nasal passageways. Since moving to Australia, Ezra has had hay fever every summer. **Suggest** a reason for this.
14 A new volcanic island has formed in the middle of the Pacific Ocean. **Suggest** the first type of plants that will grow on the island, and justify your answer, based on its method of seed dispersal.

Figure 9.106

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9.10 Technologies

Learning goals

1 To explain how organ transplants work.
2 To describe different people's opinions of organ transplants and the different laws from around the world.

Each of the organ systems in your body rely on the specialised function of many different organs working together to keep you healthy. But what happens when one of these organs is damaged, infected or cannot do its job properly? If one organ in a system cannot function at full capacity, it results in a chain reaction that can cause people to become very ill and have to go to hospital.

Figure 9.107 Most of us have two healthy kidneys. If they are damaged, one option is a kidney transplant.

Organ transplants

Damaged organs can sometimes be given the chance to repair through certain medications, diet and lifestyle changes. However, if an organ becomes so damaged that it can no longer work at all, the only option may be to completely replace it. This is done through a medical procedure known as **organ transplantation**, in which a healthy organ from one body is used to replace the damaged organ in another.

One organ that is commonly transplanted is the kidney. The kidney is located near your lower back. It filters waste products out of your blood and produces urine.

DOC WORKSHEET

Diseases and environmental factors that can damage your kidneys include medications, alcohol and diabetes. We have two kidneys in our body, but we can manage with only one. Therefore, some people volunteer to donate one of their healthy kidneys to a friend or family member who needs a replacement one.

In order for an organ transplant to be successful, the donor (person giving the organ) and the recipient (person receiving the organ) must have similar matching markers on their cells. If these markers are not matched, the body will recognise the new organ as a foreign invader and attack the organ using the immune system. This is known as **organ rejection**. Unfortunately, the chances of two people being a match is low, even within families. This means that there is a high demand for organs but a very low supply available.

organ transplantation the process of removing a donor organ and then surgically implanting it into a recipient, to improve their organ function or replace a diseased organ

organ rejection when an organ transplant recipient's immune system recognises the organ as foreign and attacks it

Figure 9.108 A surgeon performing a kidney transplant

Organ donation is sometimes possible when a person dies, and has previously indicated that they would like to donate their organs. This amazing gift can save multiple lives, as organs such as the heart, lungs, kidneys, liver, large intestine, pancreas and some tissues, such as skin and corneas from the eye, can all be donated. In 2019, 1683 Australian lives were transformed by 548 deceased and 239 living organ donors and their families.

Not many deaths occur in a way that allows organ donation. For example, the person must pass away in a hospital, and very strict procedures must be followed to ensure the health of the organs being donated. Sometimes the families of registered organ donors refuse to give consent. This is why it is very important that people discuss their wishes with their families and consider registering their intentions on the Organ Donor Register.

xenotransplantation transplanting organs from one species into another

Quick check 9.20

1 If an organ is damaged, recall the first treatment options before a transplant is considered.
2 Name some of the organs and tissues that can be donated in Australia.
3 Describe what would happen if a transplanted organ came from a donor who was not a good match for the recipient.

Explore! 9.8

Kidney transplants

A kidney transplant is a life-prolonging surgery but it does not provide a cure for end-stage kidney disease. The recipient must be medically suitable, and an available matching organ needs to be found. Conduct some research into kidney transplants in Australia and answer the questions below. The 'Kidney Health Australia' website is a great resource.

1 What are the steps involved in transplanting a kidney?
2 Where is the donor kidney positioned in the recipient's body?
3 What influences the success of the organ transplant? Give some statistics in your answer and discuss the anti-rejection drugs the person will need to take.

Organ replacement

Because of the high demand but low supply of organs available for transplantation, scientists are developing new ways to overcome this problem. One new technique is **xenotransplantation**. This is the process of transplanting organs from a different species than the recipient.

Doctors have been transplanting porcine (pig) heart valves into humans since 1965. Now scientists are trying to find a way to transplant entire pig organs. Pig organs are a similar size and shape to human organs. There are two main biological challenges that scientists face with this procedure.

- The biological markers on pigs' cells and organs do not match those in humans, and so the human recipient's body would reject the organ.
- There are viruses in pigs' genetic material that could infect and harm humans who receive a pig organ.

The first challenge that scientists are focusing on is to remove the viruses from the genetic material of pigs. This can be done using technology known as CRISPR, where an enzyme is used to cut out the parts of the genetic material of pigs that contain the viruses. CRISPR acts like a cut-and-paste tool, where the harmful parts of the genetic material are cut out and then a non-harmful section of genetic material is pasted in its place.

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Scientists have used the CRISPR process to produce several healthy genetically modified pigs that do not contain the harmful viruses. Scientists now have to overcome the problem of the markers on pig organs that cause human bodies to identify the organs as foreign.

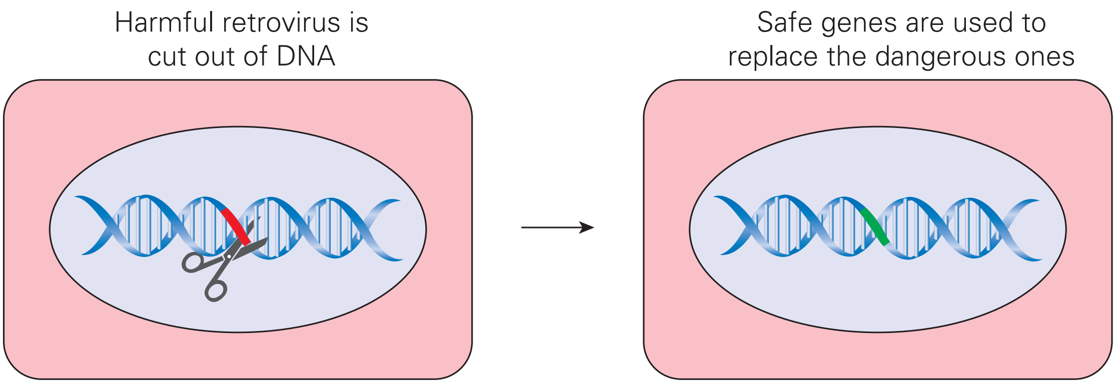

Figure 9.109 In the CRISPR process, the virus is cut out, and harmless genetic material is pasted in.

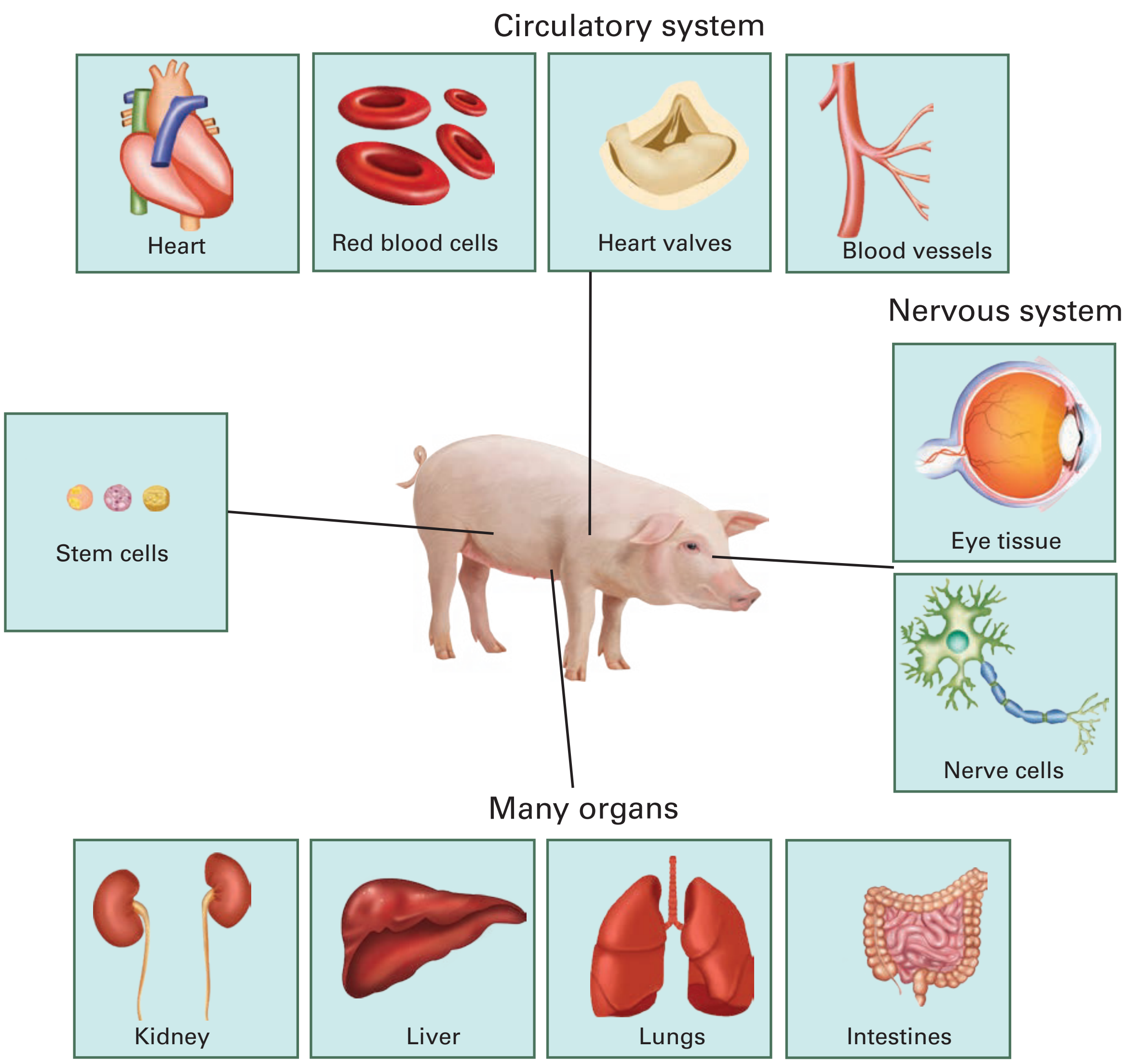

Figure 9.110 All the possible transplanted tissues and organs we could get from pigs

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Advances in science 9.10

Robots making organs?

Organoids are tiny clusters of cells that organise themselves into miniature and rudimentary versions of our organs. They present biomedical researchers with an opportunity to study organ development and experiment with drug technologies. Organoids develop from stem cells that have been grown in tiny 'wells' and induced to differentiate into specialised cells, such as neurons. These neurons then make connections and begin to behave in a similar way to how they do in a patient's actual brain.

In 2018, researchers at the University of Washington successfully put robots to work in making trays of kidney organoids in the lab. The automated system completes a researcher's daily work in around 20 minutes and makes fewer mistakes. The robotic system has also been programmed to analyse the genetic material in the organoids, and has led to new discoveries about the kidneys' blood supply and kidney disease.

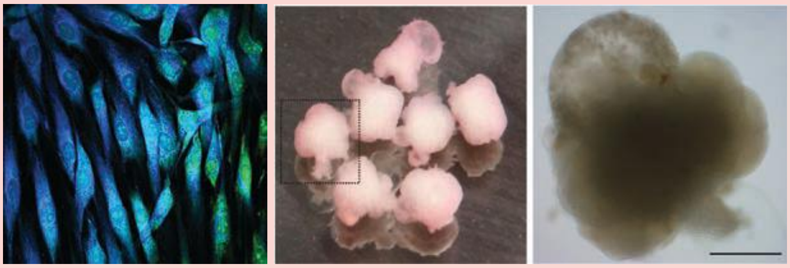

Figure 9.111 Mini brain organoids grown from stem cells. Left: Fibroblast cells (shown here) are used to produce stem cells. Middle and right: The stem cells are grown in culture and induced to form brain tissue, or 'mini brains'.

Organ regeneration

The liver is the largest internal organ in your body. It is located just below your ribs, on the right side of your body. The liver is involved in many important processes, such as producing enzymes for digestion, storing vitamins and removing toxins from your blood. If the liver is exposed to too many toxins over a long period of time, it can become damaged and not perform its job properly.

Alcohol is a toxin that the liver filters out of the blood. People who regularly drink too much alcohol can permanently damage their liver. Another toxin that your body naturally produces is hydrogen peroxide – the same chemical that people use to bleach their hair. Obviously, having too much of this substance dissolved in the blood could cause major damage throughout the body.

The liver usually does a great job of turning hydrogen peroxide into the harmless substances water and oxygen. However, too much salt in the blood can reduce the liver's ability to break down hydrogen peroxide. Salt comes directly from our diet, and people who eat fast food or processed foods regularly consume high levels of salt and so are at risk of reducing their liver's ability to function. If caught early enough, a change in lifestyle habits can reverse or limit the damage done to the liver. In severe cases, however, liver transplantation surgery may be necessary.

Figure 9.112 Hot chips are delicious, but you need to be careful how much salt you eat.

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As you learned earlier in this chapter, organ transplants come with many risks, and matching donors are hard to find. That is why scientists are working on the ability to regenerate or grow organs from living healthy tissue found in the patient. This process is called **tissue engineering** and it is a fast-growing area of research. The liver is the only human organ that can not only repair itself but can regrow dead or damaged areas. This means that healthy living organ donors can donate part of their liver and their liver can grow back to nearly the same size over time. Because of the regenerative properties of the liver, scientists can grow whole new organs from as little as a quarter of an original liver.

If scientists could grow and regenerate organs using the patient's own tissue, then the body would not reject the transplanted organ.

tissue engineering the combined use of cells and engineering to improve or replace biological tissues

Quick check 9.21

1. Contrast organ replacement and organ regeneration.
2. Define 'xenotransplantation'.
3. Summarise two potential problems with xenotransplantation.
4. Name two toxins filtered out by the liver.
5. Recall the size of liver that the organ can regrow from.

Practical 9.9

Investigating the impact of salt on liver function

Be careful
Safety glasses and gloves must be worn.

Introduction
During this experiment you will add hydrogen peroxide to blended cow's liver. If the hydrogen peroxide is broken down, then oxygen bubbles will be produced.

Aim
To test the effect of salt on liver function.

Materials
- 3% hydrogen peroxide
- 0%, 10%, 20%, 30%, 40% salt solutions
- 4 large boiling tubes
- 10 mL measuring cylinder
- liver solution (100 g of cow liver blended with 100 mL water)
- test tube rack
- disposable gloves
- marker
- stopwatch
- detergent (this is to trap the gas produced and form the bubbles to be measured)

Planning
1. Write a rationale about the role of the liver and factors that can affect liver function.
2. Write a specific and relevant research question for your investigation.
3. Identify the following variables in your experiment: independent, dependent and three controlled variables.
4. Construct a hypothesis for your experiment: predict what effect the different concentrations of salt solution will have on the number of oxygen bubbles being created.
5. Write a risk assessment for your investigation.

Procedure
1. Place the boiling tubes in a rack and label them 0%, 10%, 20%, 30%, 40%.
2. Add 3 mL of liver solution and 3 mL of the first salt solution and allow them to combine for 3 minutes.

continued…

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...continued

3 Add two drops of detergent to each boiling tube and mark the level of the solution with a marker.
4 Add 2 mL of hydrogen peroxide to the boiling tube and time the bubbles until they stop being produced.
5 When the bubbles stop being produced, record the time and the maximum height of the bubbles in the results table.
6 Repeat steps **4–5** after combining liver solution and a different salt solution in each of the remaining tubes.

Results

1 Draw a results table for your experiment.
2 Produce a suitable graph for your experiment.

Discussion

1 Describe any patterns, trends or relationships in your results.
2 Explain any trends you have identified.
3 Identify any limitations in your investigation.
4 Using your results, suggest a range in the salt percentage that you would test in a follow-up investigation.
5 Explain the reason that a test tube containing no salt was included in the experiment.

Conclusion

Draw a conclusion from this experiment regarding the effect of salt on liver function, using data to support your statement.

Ethics

When we discuss organ transplants, we often have to think about the **ethical** implications of taking an organ from one person and using it in another. 'Ethics' is the term we use to discuss what is right and wrong in society. As there are many different beliefs, cultures and people around the world, ethics can vary from country to country or from person to person. When something is considered right, we say it is ethical, and if it is considered wrong, we say it is unethical.

ethical
relating to ethics, the field of considering what is right and wrong

Our laws are linked to the ethical beliefs of a nation and can change over time as people's perception of ethics evolves. However, just because something is considered unethical does not necessarily mean that it is illegal.

Figure 9.113 Judges make decisions based on law, but ethics may also be a consideration in the decision-making process.

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Ethics of organ transplants

Some donated organs, such as kidneys and partial livers, come from living donors. This creates an ethical dilemma for the doctor who is performing the surgery. Should they risk the life of a healthy person to save or improve the life of a patient? Some questions they have to consider are:

- Does the living donor know and understand all the risks?
- What if something goes wrong during surgery and puts the donor's life at risk?
- What if the transplant is rejected by the patient and the organ goes to waste?
- What happens if the donor is left with long-term pain, infection or impaired health after the surgery?

The donor may be under a lot of pressure from friends or family, which can make them feel forced into donating.

At any one time, there are around 1600 people on the Australian organ transplant waiting list. There are many rules in place to ensure that organs are allocated to patients in a fair process that is not affected by race, religion, gender, disability, social status or age, unless an adult organ is too large for a child (or a child's organ is too small for an adult).

There are a very limited number of organs available at any one time, and so the wait for an organ could be anywhere from six months to more than four years. As a result of this, several factors are used to decide who gets an organ, such as:

- how long the person has been waiting for a transplant
- how well the organ matches the patient
- how urgent the transplant is for the patient's health
- whether the organ can be brought to the person in time.

Try this 9.12

The pros and cons of organ donation

Create a two-way table showing the possible advantages and disadvantages (risks) for both an organ donor and a recipient.

Explore! 9.9

Opt in or opt out?

In some countries, such as Wales and Spain, all adults are automatically registered as organ donors. These adults can 'opt out' of the registration if they do not wish to be an organ donor. Many do not opt out. Spain consequently has one of the shortest waiting times for organ transplants in the world.

Research the current percentage of Australians who are registered organ donors and our average waiting list times, and compare these with Spain's.

Answer the following questions and justify your opinion with evidence.

1. Do you think Australia would benefit from an 'opt out' organ donation system?
2. What are some of the advantages and disadvantages of an 'opt out' system?

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Section 9.10 questions

QUIZ

Remembering

1 **State** the function of the kidneys.
2 **Name** two factors that can damage the kidneys.
3 **List** the two main challenges that scientists face with xenotransplantation.
4 **Name** the largest organ inside a human.

Understanding

5 **Define** 'organ donor'.
6 **Define** 'organ transplant'.
7 **Explain** why organs are rejected.

Applying

8 **Summarise** how too much salt can be harmful to a person.
9 **Identify** one organ that can regenerate.
10 **Identify** how Australian rules keep organ donation fair.

Analysing

11 **Compare** ethics to laws.
12 Patients who are waiting for a kidney transplant might undergo daily or weekly dialysis treatment. Dialysis involves attending a hospital and being connected to a machine that filters your blood, and then returns it to your circulation. The graph in Figure 9.114 shows percentage survival rates for patients on dialysis versus patients who receive a kidney transplant. Use the graph to answer the following questions.

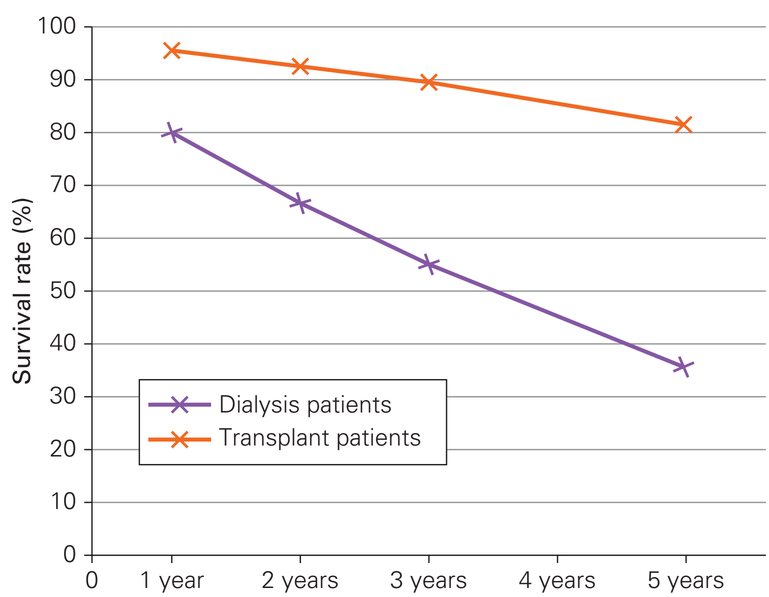

Figure 9.114 Survival rate of patients on dialysis vs. patients who have received a kidney transplant

a **Determine** the difference in survival rates at the 1-year mark for dialysis patients versus transplant recipients.
b **Determine** the difference in survival rates at the 5-year mark for dialysis patients versus transplant recipients.
c Using your knowledge of organ transplantation, **account** for the difference in survival rates for these two patient populations. (What advantages does transplantation offer?)

Evaluating

13 **Justify** why liver regeneration would be more beneficial than a liver transplant.

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Chapter review

Chapter checklist

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

SCORCHER

Success criteria		Check
9.1	**I can describe how a specialised cell's structure is related to its function.** e.g. Describe the role of nerve cells.	
9.1	**I can recall the levels of organisation in an organism.** e.g. Cell, __________, organ, organ system, organism	
9.2	**I can describe the process of cellular respiration.** e.g. Describe the products of cellular respiration.	
9.2	**I can identify the different parts of the respiratory system.** e.g. Describe the role of alveoli.	
9.3	**I can identify the different parts of the circulatory system.** e.g. Contrast veins and arteries.	
9.4, 9.5	**I can identify the different parts of the digestive system.** e.g. Describe the role of the intestines.	
9.6	**I can identify the different parts of the excretory system.** e.g. List the organs involved in the excretory system.	
9.7	**I can describe how the muscular and skeletal systems works.** e.g. Describe how muscles work with bones to produce movement.	
9.8	**I can describe the role and function of organs found in plants.** e.g. Identify the part of the plant involved in photosynthesis.	
9.9	**I can describe the human reproductive system.** e.g. Identify the different parts of the reproductive system.	
9.10	**I can describe different methods of organ repair and replacement.** e.g. Describe xenotransplantation.	

Reflections

1. What **connections** come to mind when you think about organ systems and your everyday life?
2. What new concepts have **extended** your thinking about organ systems?
3. What information did you find **challenging** or confusing?

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Data questions

Biathlon is a winter sport whereby an athlete competes by completing three legs of cross-country skiing and two legs of shooting at a target. In each phase of the race, the biathlon athlete's heart rate will change as the athlete uses energy to ski and then calms themselves for a shooting phase. The heart rate of a biathlon competitor is plotted over the various phases of the race in Figure 9.115. The relationship between maximum heart rate (HR_{max}) and age of the athlete is shown in Figure 9.116.

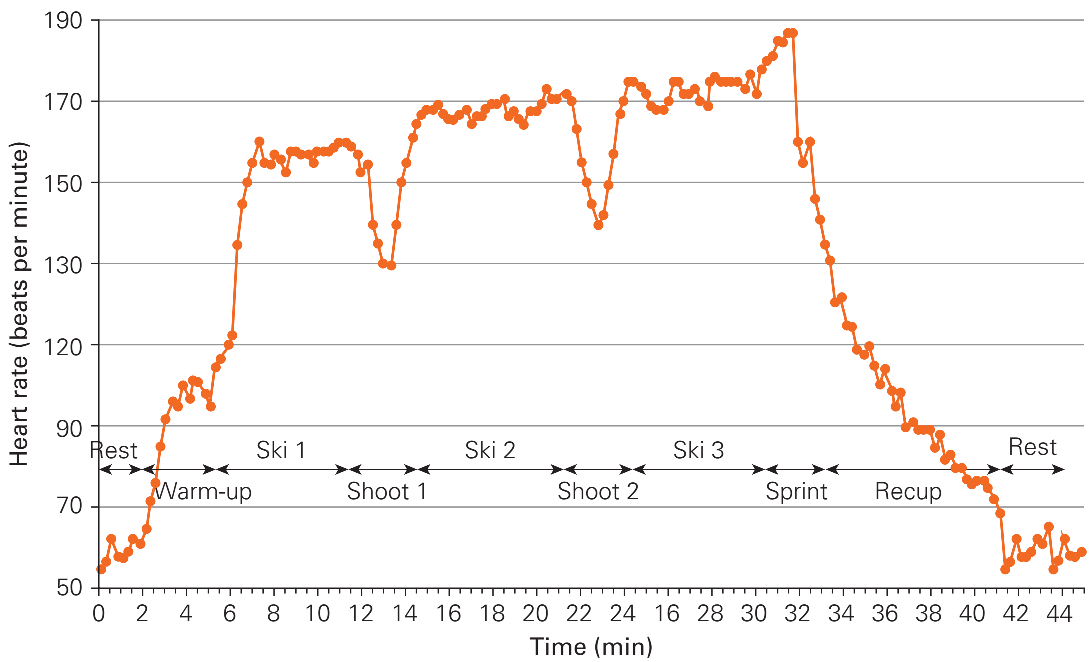

Figure 9.115 Heart rate of an athlete during a biathlon race including warm-up, three ski phases, two shootings, a final sprint and a recuperation phase.

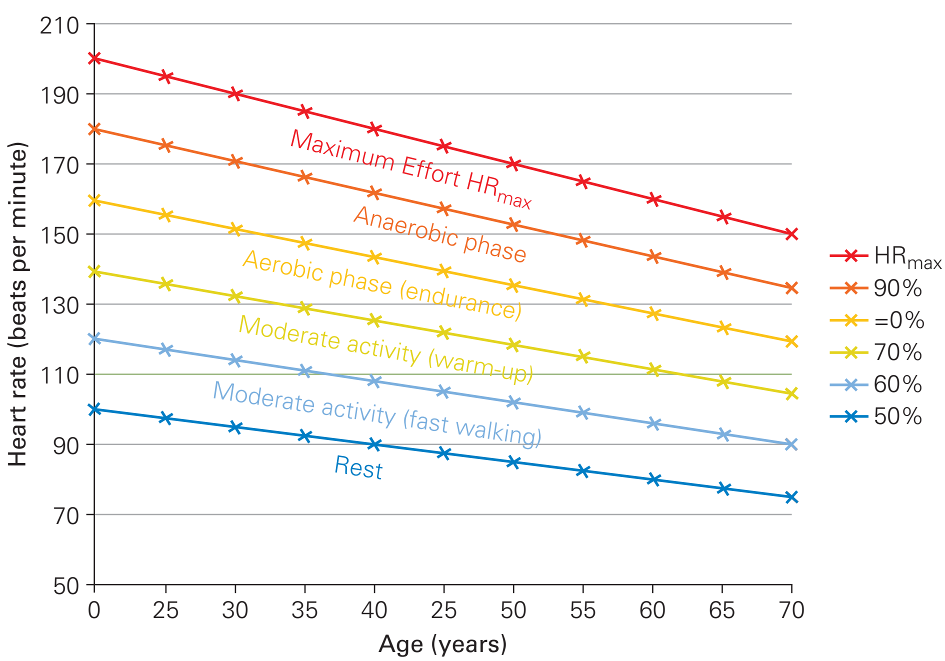

Figure 9.116 Activity intensity linked to the average human heart rate as a function of its age. (Following the commonly accepted relation HR_{max} *= 220 – age)*

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1 With knowledge that the heart rate is higher during the ski periods and lower for the shooting periods, **identify** the time range for each of the three ski periods and the two shooting periods.
2 **Identify** when the athlete's heart is beating at its lowest rate.
3 **Calculate** the duration of the athlete's recuperation phase, when the heart rate goes from its highest, back to the resting pace.
4 Using the graph in Figure 9.116, **identify** the potential age of the athlete knowing his HR_{max} is 190, and that HR_{max} = 220 – age.
5 **Identify** the relationship between the heart rate during the successive ski periods and the fatigue of the athlete across the race.
6 **Contrast** the heart rate between 24 and 30 minutes (third ski phase), and between 30 and 32 minutes (final sprint).
7 Another athlete in the race was 40 years old and had a heart rate of 150 beats per minute during the second shooting phase. **Deduce** the activity intensity for this athlete during this phase.
8 **Infer** whether or not the heart rate of the athlete during the ski phase would be identical on a longer race with five ski periods and four shootings.
9 **Predict** the maximum heart rate of a 70-year-old athlete running a marathon if the athlete was using the maximum effort.

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STEM activity: Clearing a blocked artery

Background information

Many people around the world experience heart conditions that are life threatening. An example is coronary artery disease (CAD), a major cause of death in Australia. Many heart conditions can be treated with medication, and some require surgery. Other conditions, such as dilated cardiomyopathy, CAD and heart-related birth defects, can only be treated with a heart transplant. However, sadly, the number of people on waiting lists for heart transplants is far greater than the number of donor hearts available. When a person has CAD, substances including cholesterol, calcium, and fat deposit on the walls of their coronary arteries. These deposits make the coronary arteries narrower, reducing the blood supply to the heart, and therefore reducing the supply of oxygen to the heart muscle.

Two ways of using surgery to overcome this problem of blocked coronary arteries are shown in Figures 9.117 and 9.118.

It is important to note that neither of these methods actually cleans the plaque away. This is because blood vessels are fragile, and cleaning the plaque would cause it to dislodge, which is dangerous because it might then completely block a narrower blood vessel, causing a heart attack.

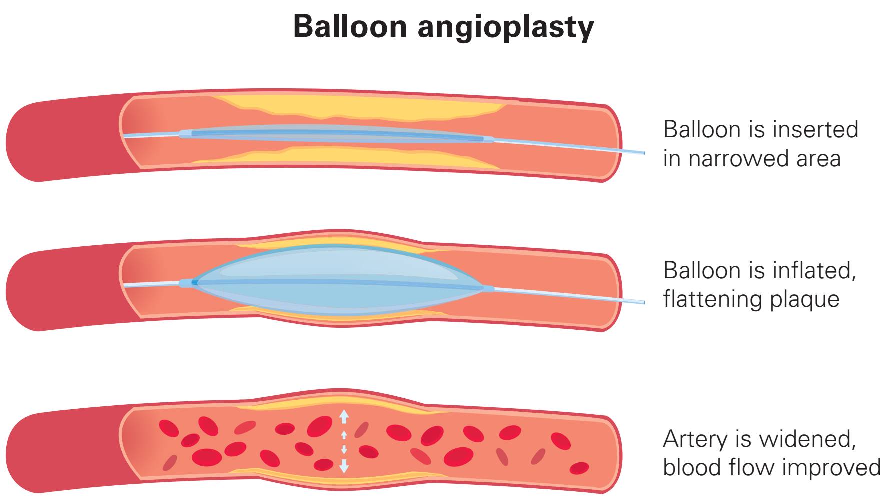

Figure 9.117 In angioplasty, a small 'balloon' is inflated inside the artery, which pushes the plaque aside and widens the vessel.

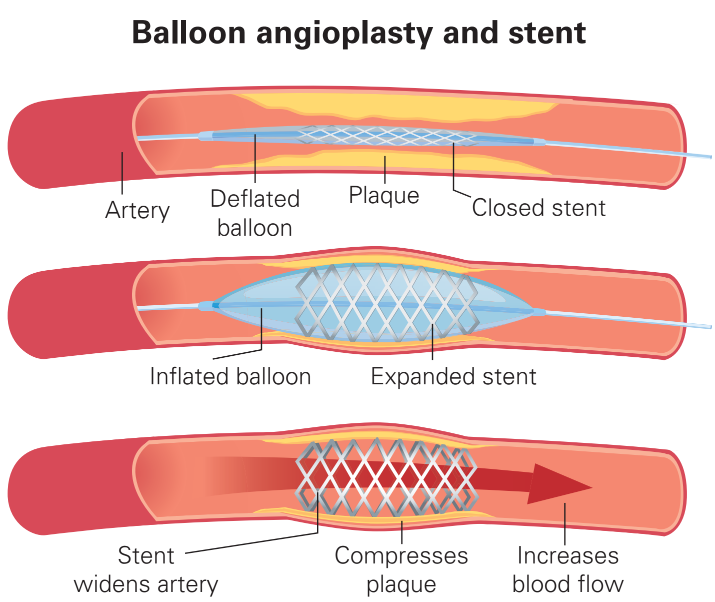

Figure 9.118 Many people also have a stent inserted inside the artery after the artery has been widened by angioplasty. A stent is a small tube made of plastic or metal that is inserted into the artery to prevent it narrowing again.

Design brief: Design a device and a procedure to clear blocked arteries while trapping the dislodged plaque.

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Activity instructions

In groups of three or four, you will design a device along with the procedure to unblock an artery. As part of the design brief, your device and procedure will also need to trap any of the plaque that is cleared out.

You can only insert any devices from the top end of the 'artery' tube (see Figure 9.119).

Figure 9.119 A model of an artery

Suggested materials

- model of a blocked artery, created using a tube or a toilet roll tube and Play-Doh
- paperclips
- string
- ice block sticks
- cloth
- glue
- tape
- cardboard
- paper

Research and feasibility

1 Together as a group, discuss your understanding of the problem. Discuss the materials you have available and any constraints you may have in your design.

2 As a group, research methods of filtration, and reflect on their suitability for trapping dislodged plaque.

Design and sustainability

3 Research materials used in surgery, and as a group, think about the sustainability of these materials. Use this information when considering your design.

4 As individuals, sketch your own solution/solutions to the design brief and then share as a group. Annotate each group member's sketches and together sketch your preferred model, making note of annotations for your design.

Create

5 As a group, build the model first agreed by the group and then test for effectiveness. You may wish to create a table such as the one below.

	Prototype 1	Prototype 2
Time taken for cleaning plaque		
Difficulty of procedure		
Percentage estimate of dislodged plaque caught in trap		

6 Modify your model and test again, you can test as many prototypes as you have time.

Evaluation and modify

7 For each model that you created, discuss how effectively the model performed. Consider how long the procedure was and how difficult it was to carry out. Evaluate how effective the 'trap' was at catching the dislodged pieces – how much of the plaque did it catch?

8 Imagine you had to do this procedure on a real patient. Discuss the limitations of your model of a blocked artery, and how your device and procedure might need to be modified to better reflect real life.

Method of filtration	How it works?	Usability of filtration method for trapping plaque
E.g. Mesh/sieve	The mesh stops things that are larger than the hole to pass through.	Mesh would stop plaque of a certain size, the mesh size and material would need to be thought of.

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Chapter 10
Interactions in ecosystems

Inquiry questions

What are the components of ecosystems?
Why are ecosystems important?
How can we maintain biodiversity?

PRE-TEST

Chapter introduction

Congratulations! You are at the top of your food chain. In fact, you are at the top of many food chains. Whether you are eating a pancake or a steak, the last organism that will use the energy stored in that food is you. But what would happen if all the pancakes disappeared? Would you go hungry or would you find another food source? In this chapter, you will look at how the interaction of organisms and their environment are linked together. You will also explore the long-reaching effects that just a few small changes to an environment can cause.

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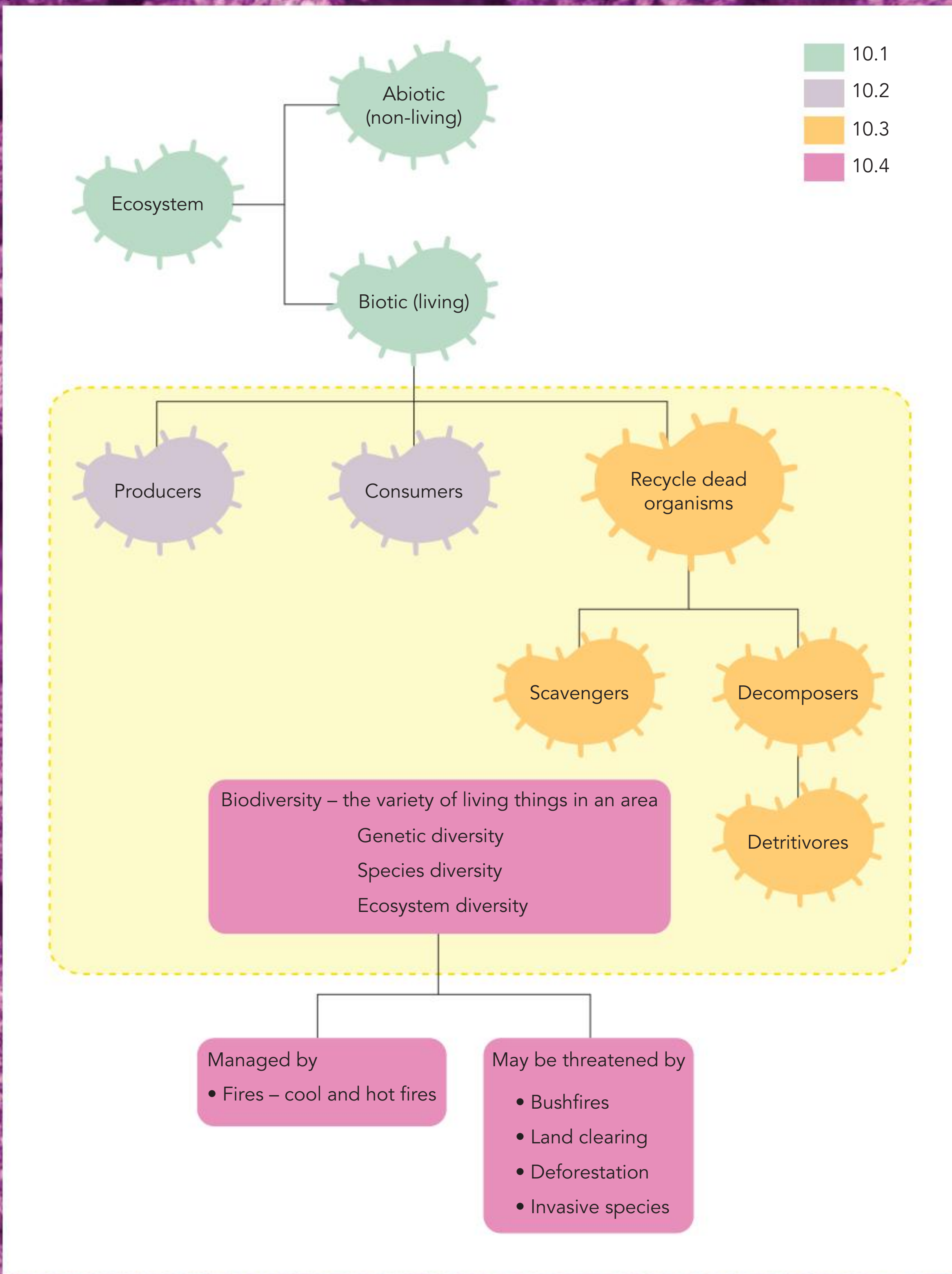
Chapter map



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10.1 Ecosystems

WORKSHEET

Learning goals

1 To describe the levels of organisation through an ecosystem from individual to biome.
2 To identify biotic and abiotic factors of an ecosystem.

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

biotic
relating to the living things in an ecosystem

abiotic
relating to the non-living things in an ecosystem

environment
the air, water and land conditions in which an organism lives

Ecosystems are all the living and non-living parts of a particular area. All parts of an ecosystem are linked and therefore even the smallest of changes can produce massive results. Deserts, forests, coral reefs and grasslands are among the many ecosystems found on Earth.

Describing ecosystems

When scientists discuss ecosystems, they refer to all the living (**biotic**) and non-living (**abiotic**) features within an area and how they interact. The **environment** of an ecosystem includes the abiotic conditions that affect an organism in its habitat. For example, the temperature, amount of light, amount of rain and type of soil.

Some examples of the biotic and abiotic features of an environment are listed in Table 10.1.

Biotic	Abiotic
Animals	Water
Trees	Rocks
Fungi	Weather
Food	Temperature
Diseases	Light

Table 10.1 Some examples of biotic and abiotic features of ecosystems

If you are trying to decide if a feature of an environment is biotic (living) or abiotic (non-living), you may like to remind yourself of the life processes displayed by all living things that you learned about in Chapter 7.

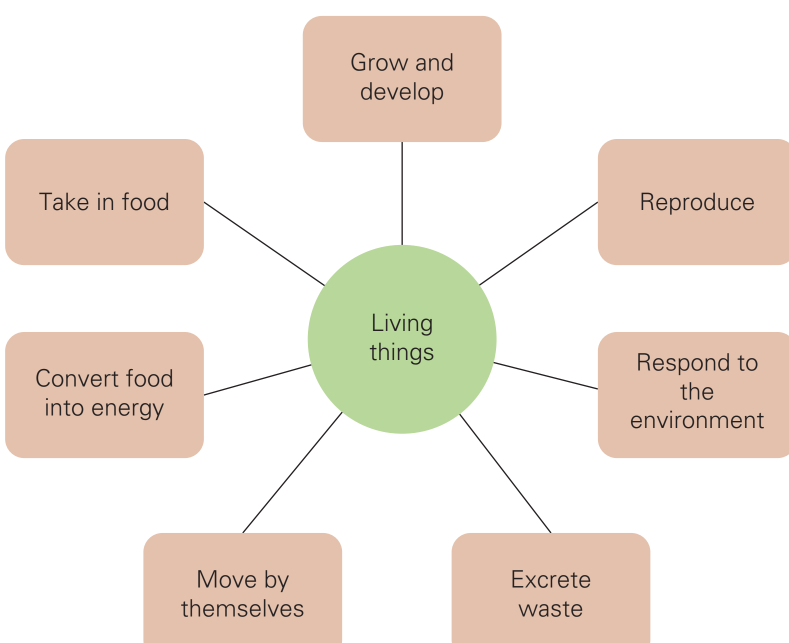

Figure 10.1 All living things demonstrate these processes.

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Try this 10.1

Coral reefs

A coral reef is an example of an ecosystem. List as many biotic (living) and abiotic (non-living) features of this type of ecosystem as you can. The images in Figure 10.2 may help to inspire you. After you have tried on your own, chat with your classmates to see what other ideas they had that you can add to your two lists.

Figure 10.2 Three images of the beautiful ecosystem that is our Great Barrier Reef

Habitats

Imagine an emperor penguin in a desert. He is surrounded by sand as far as the eye can see, there is no water, and it is extremely hot. This penguin is not very happy because he is not in his natural **habitat**. He does not have any of the things near him that he needs to survive like water, fish and other penguins. The same could be said for a desert snake in Antarctica. All organisms have a specific set of needs that will allow them to thrive, and the area in which they live that provides these needs for them is called their habitat.

Some examples of these needs that make up an organism's ideal habitat include:

- food
- water
- shelter
- space to live
- environmental conditions, like temperature and light intensity
- other similar organisms for reproduction.

A habitat has specific living and non-living conditions within it. For example, the Daintree River ringtail possum lives high up in the canopy of rainforest trees, where it can keep cooler than organisms living lower down. Their habitat suits their needs perfectly. Each ecosystem is made up of many individual habitats that are the perfect places for specific organisms to survive.

habitat the natural home of an organism

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

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

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

Levels in an ecosystem

When scientists discuss an ecosystem, they can also describe the biotic (living) organisation at different levels from large to small: **community**, **population** and individual. Table 10.2 summarises each level.

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

Table 10.2 The levels of organisation in an ecosystem

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Explore! 10.1

Look at Figure 10.3. It illustrates how the different levels of organisation of an ecosystem are related and can be demonstrated. But there are two levels you have not looked at yet. Use your preferred browser to research the following questions.

1 Define what a biome is. What does it include?
2 Define what a biosphere is. What does it include?

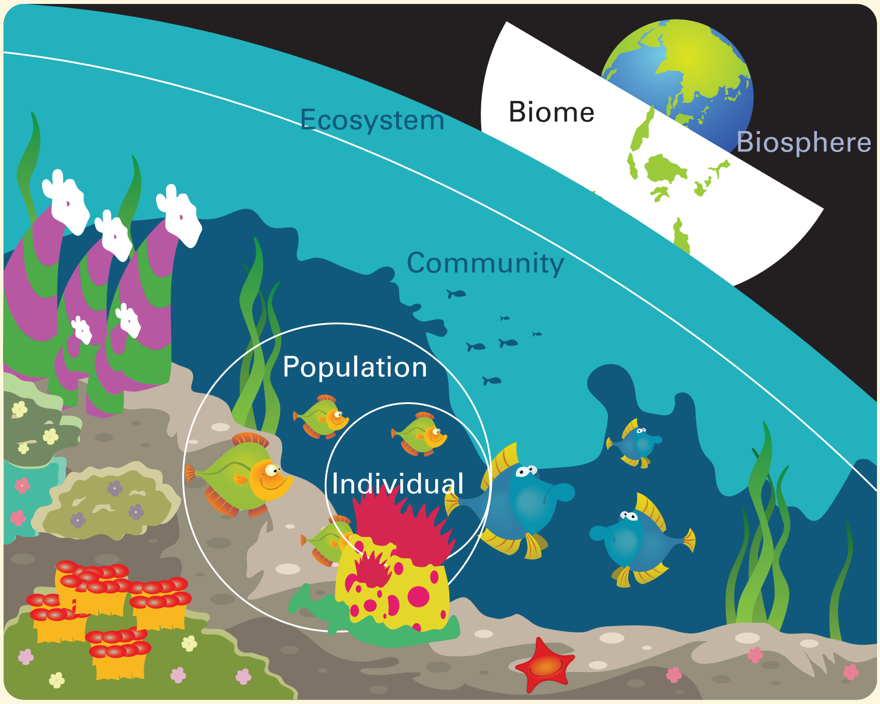
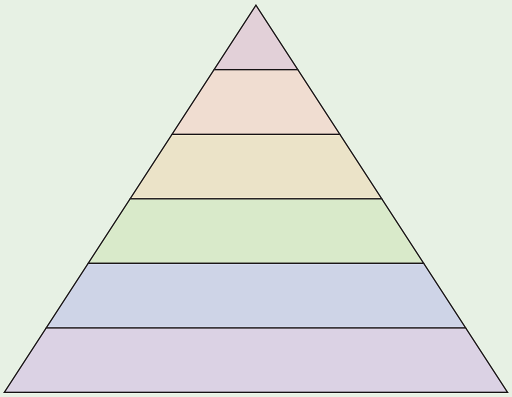


Figure 10.3 Levels of organisation

Quick check 10.1

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



If you study a community, you might observe how a bird eats the fruit from a specific plant. However, a scientist studying an ecosystem would also study the effects of a bushfire on an entire habitat, which would include many living and non-living features.

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Section 10.1 questions

QUIZ

Remembering

1 **List** the components of an ecosystem, from largest to smallest.
2 **List** two environmental features found at the Great Barrier Reef.
3 **List** three biotic features of the Great Barrier Reef.

Understanding

4 **Name** a population in the reef and state its abundance.
5 **Define** the term 'habitat'.

Applying

6 Imagine you are dropped into the middle of the wilderness. **Construct** a detailed list of all of the features you would require in your ideal habitat to survive. Remember to be very specific.
7 Make a **judgement** about the following statement and **explain** your reasoning: 'The changes in the abiotic components of an ecosystem will affect the biotic components of an ecosystem.'
8 Look at Figure 10.4 and **identify** parts of the ecosystem such as communities, abiotic and biotic factors, populations and habitats.

Figure 10.4 A rich ecosystem

Analysing

9 **Compare** the terms 'ecosystem' and 'environment'.
10 **Compare** and **contrast** abiotic and biotic factors in an ecosystem. You may use a Venn diagram.

Evaluating

11 Environmental conditions are changing in ecosystems every day. **Propose** the changes in abiotic factors that occur in a desert ecosystem over the course of a day and how these changes would affect the biotic parts of the ecosystem.

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10.2 Food chains and food webs

Learning goals

1. To describe the role of a producer and consumer in an ecosystem.
2. To identify the source of energy for a food chain.
3. To create a food web.
4. To predict the consequences of removing an individual from a food web.

DOC WORKSHEET

energy
the ability to do work by producing heat or motion

glucose
a simple sugar that can be converted into energy inside cells

cellular respiration
the chemical process by which cells release energy from food

Energy

We have a lot in common with all the living creatures around us, such as dogs and fish and even a slug, but the main similarity is that we all eat. We all need to gain **energy** from eating other organisms to live. In humans, we use this energy to grow, move, reproduce, repair and stay warm. Even plants need energy, but because they do not have mouths to eat, they do it differently, they make their own food. They then use this energy to grow, move, reproduce and repair, just like humans.

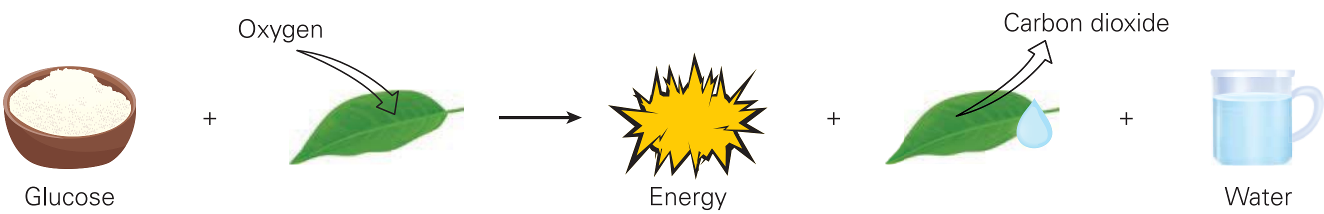
Plants make their own food while animals eat ready-made food that they find. Once an organism has acquired the food, it then needs to turn this food into energy. It does this at a cellular level by using the **glucose** produced in the digestion of food, in a process called **cellular respiration**.

This is the cellular respiration word equation:

glucose + oxygen → energy + carbon dioxide + water

The energy produced in cellular respiration is used for all the processes in each living organism. A common mistake is to think that plants do not perform cellular respiration because they make their own food. In fact, they must do cellular respiration, otherwise the food they produce would never get turned into energy, so they would never be able to grow.

Figure 10.5 The process of cellular respiration



Quick check 10.2

1. Define the term 'energy' in your own words.
2. Explain what energy is needed for.
3. Explain why cellular respiration is a necessary process carried out by all living things including plants and animals.
4. Name the inputs and outputs of the process of cellular respiration.

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Producers

Think about your garden at home or at school. How are the plants kept alive? You would probably say that someone has to make sure the plants have access to sunlight and water them every so often. You are right, plants use the water in soil along with the light energy from the Sun and carbon dioxide in the air to form sugars called glucose in their leaves. This process is known as **photosynthesis** and it is how plants make their own food. This is the reason that plants are also called **producers** – they produce or make their own food.

This is the word equation for photosynthesis:

$$\text{carbon dioxide} + \text{water} \xrightarrow{\text{light}} \text{glucose} + \text{oxygen}$$

Figure 10.6 Green leaves absorb light energy from the Sun to make food.

Plants then break down these sugars in their bodies just like you do and use these sugars for energy. This energy is used to grow, reproduce and repair themselves.

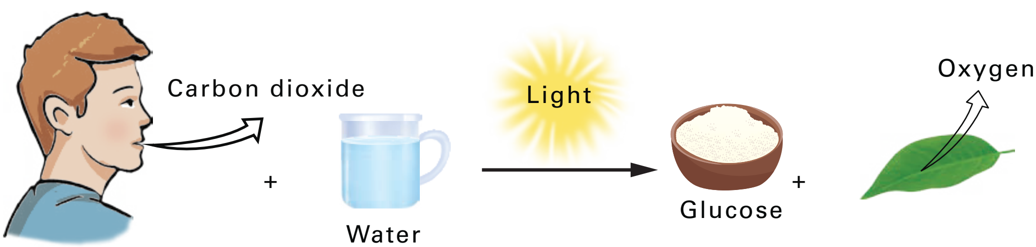

Figure 10.7 Photosynthesis

photosynthesis the process by which a plant uses the energy from the light of the Sun to produce its own food

producer an organism capable of producing food from photosynthesis

Practical 10.1

Observing photosynthesis

Aim

To investigate the effect of changing light intensity on photosynthesis.

Time period

Approximately 2–3 days

Prior understanding

Photosynthesis uses carbon dioxide (CO_2), water and light energy to make glucose and oxygen. Aquatic plants extract dissolved carbon dioxide from the water to photosynthesise. A way to measure the amount of dissolved carbon dioxide in the water is to add the indicator bromothymol blue. Water will appear yellow when a high concentration of carbon dioxide is present and turn to blue as the concentration of dissolved carbon dioxide is reduced.

Be careful

Bromothymol blue can be harmful when inhaled. Blow into the balloon, and then use the balloon to bubble carbon dioxide into the water. Do not blow directly into the solution. Ensure the room is well ventilated and wear appropriate personal protective equipment.

continued...

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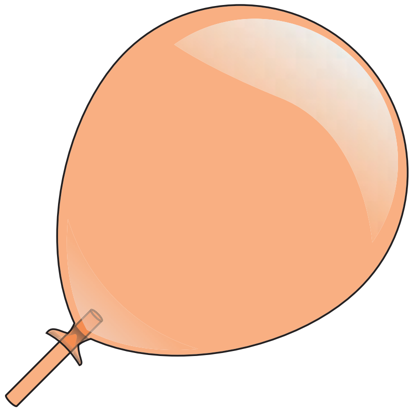
Materials

- bromothymol blue solution (acts as an indicator to show if photosynthesis is occurring)
- 4 small conical flasks
- 500 mL beakers
- large measuring cylinder
- aquatic plant
- straws
- balloons
- aluminium foil or stopper



Procedure

1 Pour 320 mL of water into a 500 mL beaker.
2 Add enough drops of bromothymol blue solution to turn the water a pale blue colour.
3 Blow up a balloon and insert a straw into the end of it as shown, pinching it shut to hold in the air.
4 Dissolve carbon dioxide into the water by inserting the straw into the beaker and *gently* releasing the air into the solution causing it to bubble through for approximately one minute until the water turns pale yellow.
5 Label each conical flask with the following information.

Group 1: Control Description: No plant in light Date: Student/s name:	Group 2: Light Description: Plant in light Date: Student/s name:	Group 3: Control Description: No plant in dark Date: Student/s name:	Group 4: Dark Description: Plant in dark Date: Student/s name:

6 Measure out 80 mL of bromothymol blue + water solution from step **4** and pour it into one of the four conical flasks. Repeat this for each of the three remaining flasks.
7 Add a 7 cm piece of the aquatic plant to the Group 2 and Group 4 flasks. Use the straw to gently push the plants into the water to make sure they are submerged.
8 Cover each flask with aluminium foil or a stopper.
9 Copy the table shown in the results section into your science book.
   - Label the independent variable and its groups in the table.
   - Label the dependent variable in the table.
10 Record the initial colour of the water in each flask.
11 Position the flasks as described on the label.
   - Group 1 and Group 2 flasks next to a window.
   - Group 3 and Group 4 flasks in a cupboard away from any light.
12 Observe the flasks after 2–3 days. Has the colour changed?

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Results

	Dependent variable ________		
Independent variable ________	**Initial water colour**	**Final water colour**	**Change in dissolved carbon dioxide?** • None • Some reduction • Substantial reduction
Group 1 ________			
Group 2 ________			
Group 3 ________			
Group 4 ________			

Discussion

1 Identify any trends, patterns or relationships in your results.
2 Explain what a change of colour means in terms of whether photosynthesis is occurring in the plant. What does it mean when the solution is yellow? What does it mean when the solution is blue?
3 Discuss if there was any change in the control flasks. Explain why you think that is.
4 Explain the importance of having flasks with no aquatic plants.
5 Did you have any errors during this experiment that you could have minimised? Propose any changes that could be made to the method to improve the quality of the data in future experiments.

Conclusion

State a conclusion about the relationship between light and photosynthesis in plants.

Quick check 10.3

1 Discuss why plants are called producers.
2 Explain why photosynthesis is a process carried out by plants.
3 Name the reactants and products of the process of photosynthesis.

Consumers

Humans do not have the ability to photosynthesise, so we, and other animals, need to eat plants or other organisms to gain their sugars (glucose) to turn it into energy. You might think, 'how come we don't have the ability to photosynthesise?' The fact is, we need a lot more energy in our everyday lives compared to plants. If we could photosynthesise, we would need massive sails of skin and to spend every minute outside to produce even a fraction of the energy we would need. This would not give us much time to do anything else!

consumer
an organism that obtains food from consuming other organic material

The fact that animals eat food that is ready-made, means that we are all considered to be **consumers**.

Figure 10.8 A koala and a giraffe are consuming producers.

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Try this 10.2

Producers and consumers

Look at the pictures of Australian organisms in Figure 10.9 and organise them into producers and consumers.


Wattle


Quokka


Fruit bat


Eucalyptus


Koala


Bottlebrush


Kangaroo paw


Kangaroo

Figure 10.9 Australian organisms

Did you know? 10.1

Life deep under the sea


Figure 10.10 Examples of life around a deep-sea hydrothermal vent

Up until around 35 years ago, scientists believed that all life relied on energy gained from the photosynthesis process. However, with specialised deep-sea submarines, scientists discovered ecosystems deep down in the ocean, much further down than light can penetrate. These ecosystems are gathered around hydrothermal vents that produce large amounts of heat and expel chemicals and minerals. The producers in these hydrothermal habitats use the chemicals and minerals to produce chemical energy in a process known as chemosynthesis and are known as **chemotrophs**. This discovery has lead scientists to believe that we may find life in places such as Europa (a moon of Jupiter) that has a liquid water ocean under a thick layer of ice that light cannot penetrate.

Types of consumers

In every ecosystem, there are many different types of animals that eat a wide variety of things. Usually we do not eat the same food for every meal of every day. The types of food that we eat, or consume, place us into special groups. If you only eat plants, you are called a **herbivore**, if you eat both plants and animals, you are known as an **omnivore** and if you only eat other animals, you are called a **carnivore**. The one thing that all these groups have in common is that they are all consumers.

chemotroph
an organism that obtains energy through chemical processes in its environment

herbivore
an animal that eats only plants

omnivore
an animal that is naturally able to eat both plants and meat

carnivore
an animal that eats only meat

Most herbivores, carnivores and omnivores display similar features to others in their group. These features allow biologists to identify their eating habits without observing them eating. For example, one of the main tools biologists can use to identify the diet of a mammal is to look at its teeth.

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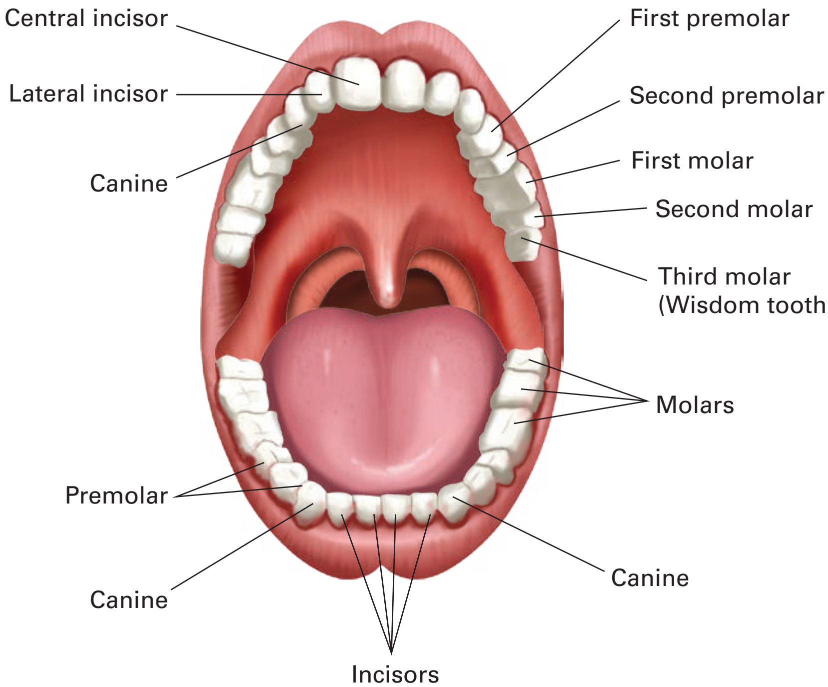

Figure 10.11 Human teeth identify us as omnivores.

Humans are natural omnivores, which means that we have evolved to eat both plant and animal products. Because of this, we have a range of different teeth in our mouths. Starting at the front are the incisors. These are sharp, flat, cutting teeth, like scissors. They are used to bite off pieces of food. Herbivores use these teeth to nibble away at plants and, as they are used constantly, they tend to wear down. Due to this, the incisors of animals like rabbits and wombats continue growing throughout their lives.

Figure 10.12 A rabbit's incisors keep growing throughout its life.

The long, sharp, pointed teeth next to incisors are called canines. They are near the front of the mouth and are used to hold and tear at food. Carnivores have large well-developed canines that they use to catch and kill their prey. Many herbivores lack canines as they do not hold and tear at the food they eat.

The flat teeth at the back of your mouth are known as molars. These teeth are for chewing and grinding and are found in herbivores, carnivores and omnivores. Herbivores have large, almost flat molars that allow them to grind plant material into very small pieces before swallowing.

Figure 10.13 This leopard is showing off her impressive canines.

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Figure 10.14 A cow using her molars to chew some grass

Try this 10.3

Animal teeth

Ask your teacher if you can view a random selection of animal skulls. You may be able to identify some of the animals you see but take on the role of a scientist and check their teeth. Do they have incisors? Canines? Molars? Can you confirm what the animal might eat and therefore have more evidence as to what the animal is? You may like to tabulate your observations and then compare with your classmates.

Quick check 10.4

1 Define the term 'consumer' in your own words.
2 There are three main types of consumer.
 a Name the three types.
 b State what each group eats.
3 Examine the images in Figure 10.15 and for each determine:
 i the type of teeth
 ii the structure and function
 iii the animal types in which those kinds of teeth are found.

Figure 10.15 Images of different types of teeth

VIDEO Create the food web for one of these animals

Food chains: Who eats whom?

In an ecosystem, it is important to know what eats what. This allows scientists to follow the flow of energy starting from the Sun, to the producers and making its way through the consumers. This flow of energy is known as a **food chain**.

food chain
the flow of food energy through an ecosystem passing from plants and bacteria to consumers

An example of a simple food chain would be:

grass → mouse → hawk

The food chain in Figure 10.16 introduces some new terms, which are explained in Table 10.3.

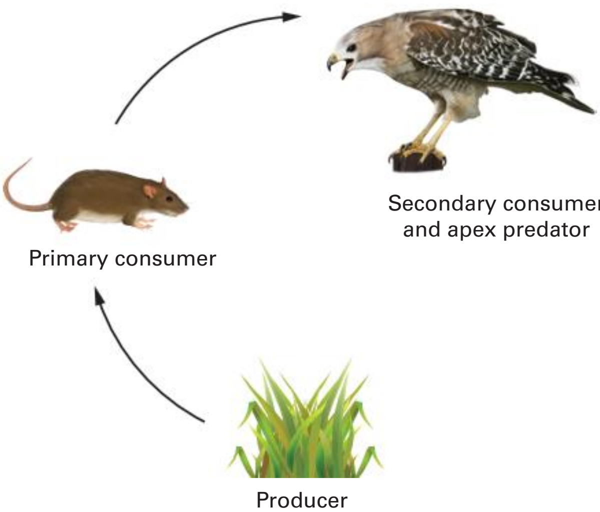

Figure 10.16 A hawk is an example of an apex predator as it has no natural predators.

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Term	Definition	Example
Primary consumer	The first consumer in the food chain that eats the producer and is therefore always a herbivore.	Termites eat a wattle tree (producer)
Secondary consumer	A consumer that eats the primary consumer or herbivore; usually carnivores, but can be omnivores.	Echidna eats the termites (primary consumer)
Tertiary consumer	A consumer that eats the secondary consumer.	Dingo eats the echidna (secondary consumer)
Apex predator	A consumer at the top or end of the food chain that usually only has humans as a possible predator.	Dingo

Table 10.3 Consumers can be classified into these groups, based on their position in a food chain.

primary consumer an animal that eats plants

secondary consumer an animal that eats other animals

tertiary consumer an animal that eats secondary consumers

apex predator a predator at the top of a food chain

As you learned at the start of this chapter, you are at the top of your food chain. You are an apex predator. But you are not just at the top of one food chain, you are at the top of many. You are at the top of the broccoli food chain and also the burger food chain.

Figure 10.17 Broccoli food chain

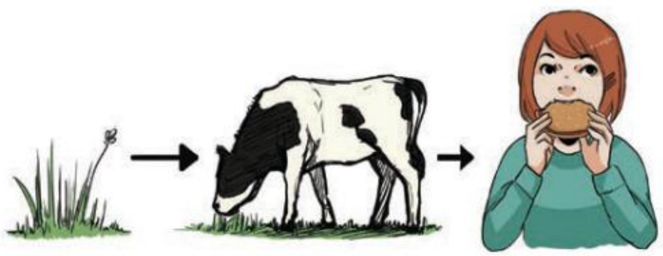

Figure 10.18 Burger food chain

Try this 10.4

What food chains can tell us

Consider the food chain below to answer the questions.

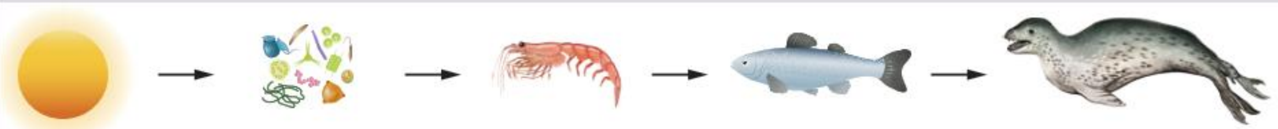

Figure 10.19 What does this food chain tell us?

1 State what the arrows show the flow of.
2 Identify where all the energy originally comes from.
3 Identify the producer, first consumer, second consumer, tertiary consumer and apex predator.
4 Identify the herbivore.
5 Predict what would happen if:
  a fairy penguins moved into the area and ate all the krill before the fish could get to it
  b a local commercial fishing company over-fished the area
  c chemicals running off farmland killed all the phytoplankton.

Quick check 10.5

1 Define the term 'food chain' in your own words.
2 Recall where the Sun fits in a food chain and why.
3 Draw an Australian food chain of your choice and identify the producer, primary consumer, secondary consumer, tertiary consumer and apex predator.
4 Recall what sort of information you can find out from looking at a food chain.

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Food webs

There are many different types of organism in any habitat. There are also many food chains that are interlinked. These interlinked food chains are known as a **food web**.

food web
a group of interweaving food chains

trophic level
refers to an organism's level or position in a food web. It is based on an organism's feeding habits, where producers occupy the first trophic level, primary consumers the second trophic level, and secondary consumers the third trophic level, etc.

10% rule
when energy is passed from one trophic level to another, only 10% of the energy will be passed on

If you look at the food web in Figure 10.20, you can see the interaction between many Australian organisms found in an ecosystem. You might notice that although there are many food chains displayed in this particular example, there is a maximum of four organisms in each food chain. This is because energy is lost from each **trophic level** of the food chain as it passes from the Sun to the producer and consumer. Generally speaking, only 10% of the energy is passed on to the next level. This is the **10% rule**. Each organism uses up most of the energy it consumes in the following ways:

- carrying out processes like growing, moving and reproducing
- lost as heat when the organism uses the food to fuel its living processes such as respiration
- lost in bodily waste as the organism does not digest and use all the food it eats.

This means that there can only be a limited number of animals at the top of the food chain as less energy is getting to them. Figure 10.21 shows this loss of energy. Note that kcal is a unit of energy. It is equal to about 4000 joules.

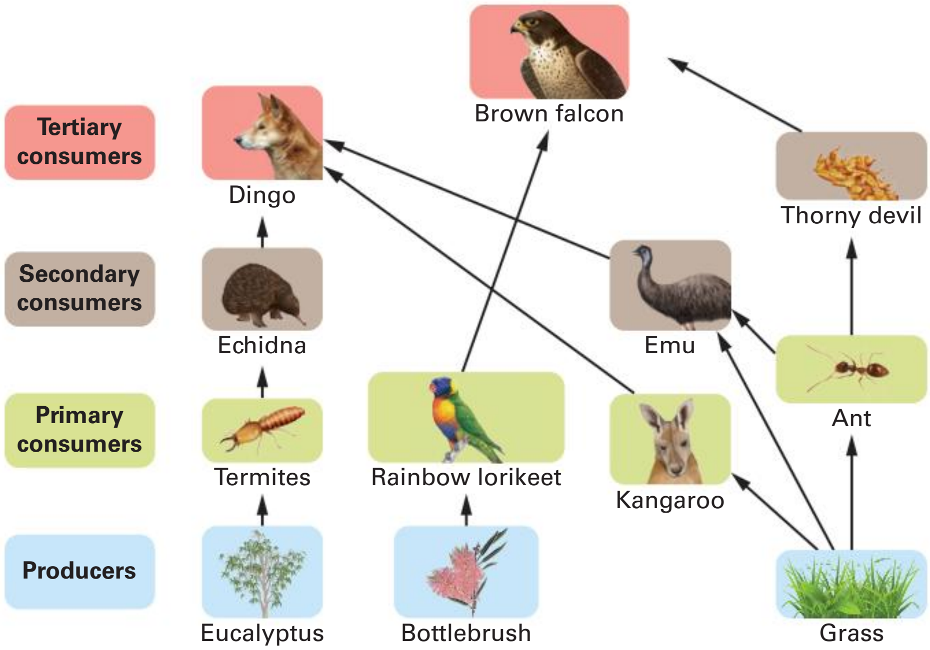

Figure 10.20 An example of an Australian food web

Quick check 10.6

1. Explain what a food web is.
2. Recall what organisms need energy for.
3. Describe how energy is lost from an organism or a food chain.
4. Summarise what you notice about the amount of energy (kcal) that is passed on from the producers to the primary consumers and from the primary consumers to the secondary consumers.
5. *Challenge question*: Using Figure 10.21, calculate how much energy is passed on as a percentage of the original amount of kcal.

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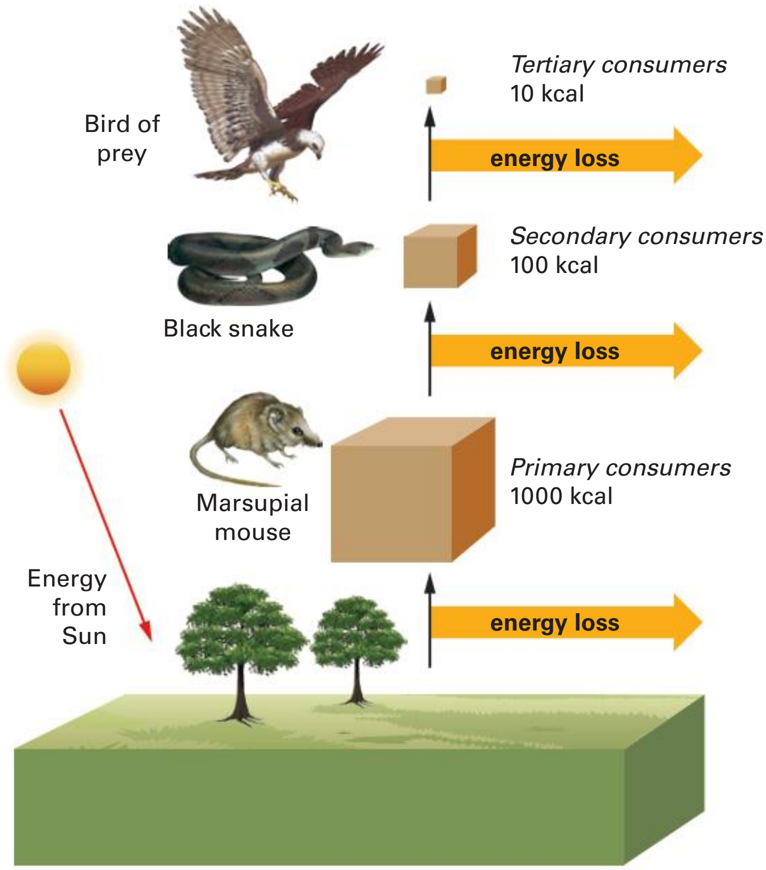

Figure 10.21 The energy flow and loss through a food chain

Worked example 10.1

Use Figure 10.21 to answer the following questions.

a If the snake consumes 350 kcal of energy, and it is eaten by the eagle, calculate how much energy would be available to the eagle.

b Calculate how much energy was originally available to the mouse from the producers.

Working	Explanation
a energy for eagle = 10% × 350 kcal $= \frac{10}{100} \times 350$ kcal OR 0.1 × 350 kcal = 35 kcal	By the 10% rule, only 10% of 350 kcal will be available to the eagle. 10% is equivalent to $\frac{10}{100}$ or 0.1.
b 350 kcal $= \frac{10}{100} \times$ energy for mouse energy for mouse $= \frac{100}{10} \times 350$ kcal = 10 × 350 kcal = 3500 kcal	If the snake had 350 kcal available, and that was 10% of what had been available to the mouse, then the mouse would have had 3500 kcal available to it.

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Practical 10.2

Food web model

To model the flow of energy in food webs from producer to consumers.

Materials

- photos of producers, primary consumers, secondary consumers, tertiary consumers and apex predators, in the normal ratio of these types of organisms in the wild
- different coloured balls of yarn
- scissors

Procedure

1. Each student will be allocated a photo.
2. Stand in a circle as a class. A student with a photo of a producer will take the end of the piece of yarn. The piece of yarn will represent the flow of energy along the food chain.
3. The producer should choose what primary consumer it wishes to be eaten by, and pass that person the ball of yarn. (The producer should keep hold of the end of the yarn.)
4. The primary consumer will then choose the secondary consumer they wish to be eaten by, and pass them the ball of yarn.
5. Repeat this process with the secondary consumer.
6. When the yarn reaches the apex predator, cut it, but each person in the chain should keep hold of it.
7. Take a photo each time a food chain is made, so that the development of the web can be seen.
8. Start a new chain, by starting a new piece of yarn in a different colour. Try to pick different organisms at first, but you can also re-use organisms. Repeat this process many times, starting with different producers.
9. A complex web will form between you and your classmates.
10. Discuss the complex nature of the food web you have produced as a class.
11. Ask one organism in the food web to 'die' by dropping the string. Discuss as a class the effect that the loss of that organism from the ecosystem would have on the remaining organisms.

Discussion

1. Follow one of the threads of yarn and write down a food chain.
2. Describe the effect that removing a producer from this food web would have.
3. Explain why an ecosystem with many types of organisms would be able to cope with the loss of one species.
4. Critique whether your model of a food web accurately depicts a real ecosystem.
5. Propose one way in which this model could be improved.

Explore! 10.2

How wolves changed the course of a river

Yellowstone National Park is a national park in the USA. Wolves were once one of the apex predators found in the park but the population was wiped out by the government in the 1920s.

Although other predators such as grizzly bears and cougars remained, the park was left without wolves for 70 years. They were reintroduced into the area in 1995 to help control a growing elk population.

This reintroduction gave biologists a unique opportunity to study how the return of an apex predator affects an ecosystem. The results showed a bigger change than the scientists ever thought possible.

Figure 10.22 Grey wolf in Yellowstone National Park

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Without wolves, the elk population in Yellowstone grew unchecked. This meant that they consumed too much food such as willow trees that were needed by other species. This included beavers, whose numbers then started to drop. To help restore the population of beavers, 129 beavers were released into drainages. When park-wide aerial surveys began in 1996, there were 49 beaver colonies. When the wolves began reducing the elk population, the number of beaver colonies had risen to around 100 in 2015.

Beavers are famous for building dams and that is exactly what they have done. There are now many more dams found in Yellowstone, which can even out water flow when storms hit and provide cold shaded water for fish. As there are more willows, there are more trees to provide habitats for birds.

Figure 10.23 Elk crossing a river

Figure 10.24 Loss of habitat for beavers.

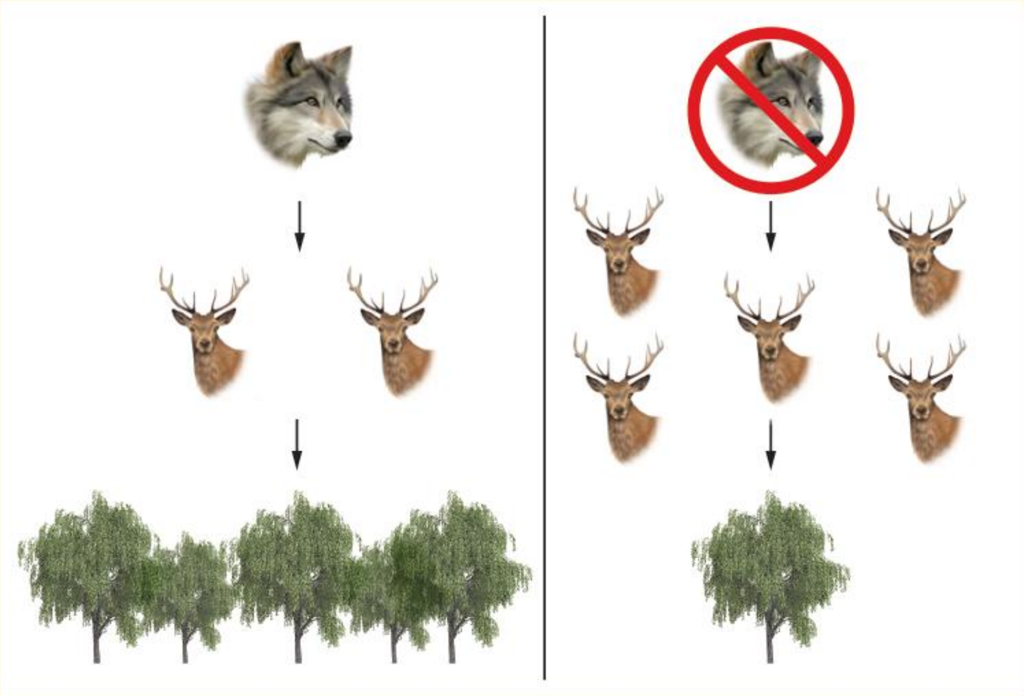

Figure 10.25 A pictorial representation of how the wolves have brought balance back to Yellowstone National Park.

Research this amazing change brought about by the reintroduction of wolves.

1. Name four organisms that were affected by the presence of wolves.
2. Draw as many food chains as you know to exist in Yellowstone Park.
3. Explain how the reintroduction of wolves saved the Yellowstone Park ecosystem.
4. 'The impact of producers on an ecosystem is greater than that of apex predators.' Evaluate this statement and give your opinion.

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Section 10.2 questions

Remembering

1 **State** how the flow of energy is represented in a food chain.
2 **State** the process by which plants produce their own food.
3 **Name** the components that plants need to make food.

Understanding

4 **Define** these terms.
  a Carnivore
  b Herbivore
  c Omnivore.
5 **Outline** why all food chains must contain a producer.

Applying

6 Look at the food web in Figure 10.26.
  a **Identify** and **draw** three food chains in the food web.
  b **List** the producers and apex predators based on the diagram.
  c **State** the organisms that dingoes eat.
  d **Name** any organisms that are secondary and tertiary consumers.
  e **Describe** the impact on this ecosystem if a fungus killed all the grasses.

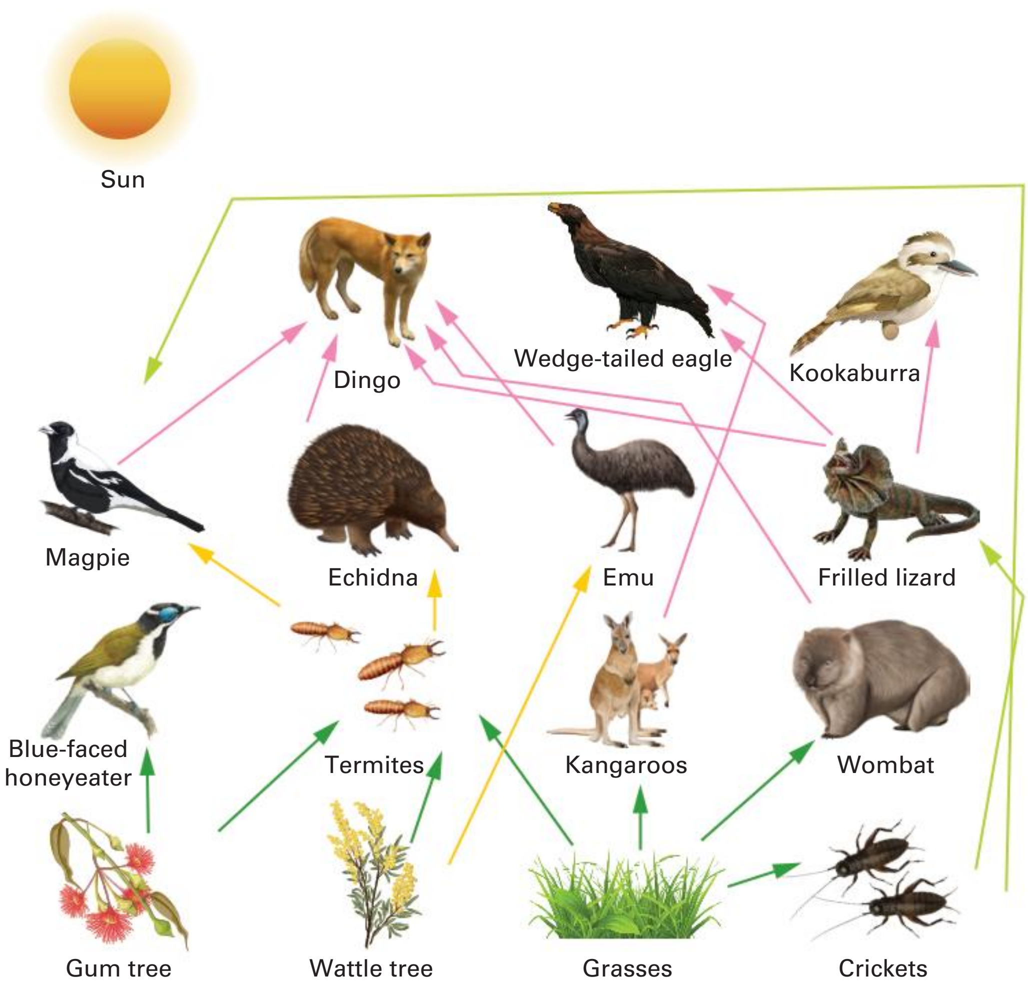

Figure 10.26 A food web

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Analysing

7 **Compare** a herbivore to an omnivore.

8 **Distinguish** between food chains and food webs and then determine why food webs are more useful to scientists.

9 Look at the ecosystems in Figure 10.27 and decide which one is more likely to survive an environmental disaster. **Explain** your choice.

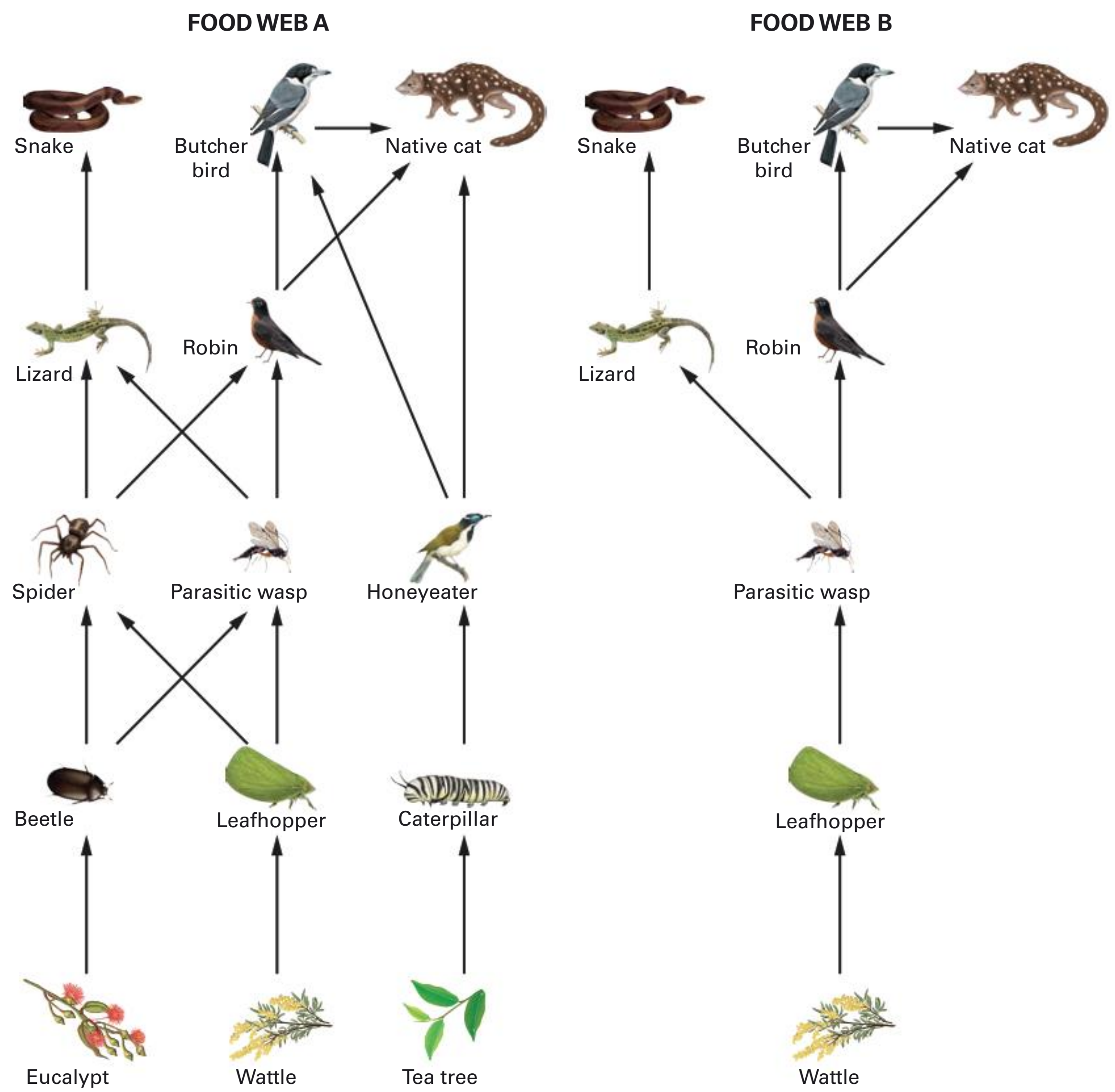

Figure 10.27 Two different ecosystems support these two food webs.

Evaluating

10 **Propose** a reason that a herbivore would not be able to eat meat easily.

11 **Suggest** two effects of removing a predator from a food web.

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10.3 Recycling in ecosystems

Learning goals

1 To describe the possible beneficial role of microorganisms in an ecosystem.
2 To describe the possible harmful effects of microorganisms in an ecosystem.
3 To explain the importance of recycling in ecosystems.

DOC WORKSHEET

scavenger an organism that feeds on dead animals that it has not killed itself

detritivore an organism that feeds on dead or decaying organic matter

decomposer an organism such as a bacterium or fungus that makes dead plant and animal material decay

All living things within an ecosystem fall into three categories:

- organisms that make their own food (producers)
- organisms that eat other living organisms (consumers)
- organisms that contribute to recycling dead organisms (**scavengers**, **detritivores** and **decomposers**).

Scavengers

Scavengers start the recycling process of dead and decaying animals. They can be found anywhere in the world – on land and in marine environments. In Australia, they include monitors (carnivorous lizards), spotted-tail quolls, dingoes and crows. The role of scavengers is vital for any ecosystem as they contribute to the decomposition process. Scavengers do not use energy to kill their prey, but they use their sense of smell and their vision to find their food. Decomposers and detritivores, which you will learn about shortly, are responsible for completing the process of breakdown and returning the nutrients to the ecosystem.

Decomposers

Decomposers gain their energy by breaking down already dead organisms. Bacteria and fungi are examples of decomposers. They secrete chemicals called enzymes that break down the dead organisms. They then absorb the broken-down substances.

When decomposers break down dead organisms, the decay returns much needed nutrients back into the soil, which plants then use to grow. This makes them a vital part of the circle of life.

Figure 10.29 Decomposers and detritivores hard at work

Figure 10.28 Scavengers: Torresian crows (left) and dingoes (right) in Australia

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Most decomposers on Earth are **microorganisms** – organisms so small that they can only be seen with a microscope. Microorganisms are around us all the time, floating through the air or lying on a surface. Most of these microorganisms are harmless and only begin to grow and spread when an organism dies.

Figure 10.30 Bacteria are an example of a microorganism, in this case, growing on agar in a Petri dish.

Did you know? 10.2

Echinoderms like sea urchins, sea stars and sea cucumbers hunt for their own food, but they are also detritivores. They can move around and consume decaying organic matter.

Some sea worms such as the Christmas tree worm, *Spirobranchus giganteus*, even have feathery appendages that can spread out in the water to collect this matter.

Figure 10.31 Christmas tree worm (*Spirobranchus giganteus*)

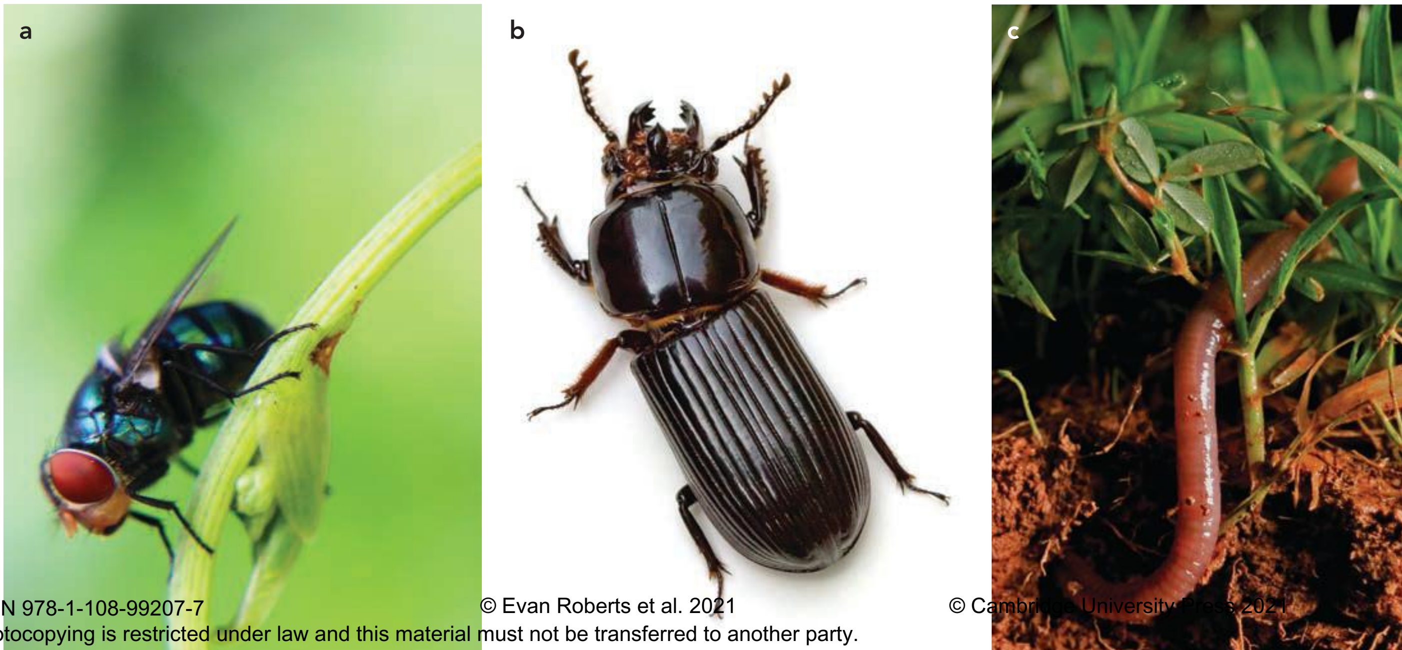
Detritivores

Detritivores are also involved in recycling nutrients. They have mouthpieces which help speed up decay by ingesting and digesting **detritus** (dead and decaying material). The detritus is excreted as smaller sized pieces which increases the surface area available for decomposers like bacteria and fungi to feed off. Detritivores include insects such as beetles, flies, slugs, snails and earthworms. Marine detritivores include crabs, lobsters, sea stars and sea cucumbers.

microorganism
a living thing that on its own is too small to be seen with the naked eye

detritus
waste or debris

Figure 10.32 Examples of detritivores: **(a)** flies, **(b)** beetles and **(c)** earthworms.



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Quick check 10.7

1 Define the terms 'scavenger' and 'decomposer' in your own words.
2 Define the term 'detritivore'.
3 Explain why plants rely on decomposers.
4 Distinguish between detritivores and decomposers.

Practical 10.3

Friendly bacteria

Be careful
Do not open the experimental container once the experiment begins. Do not consume any food products in the lab. Ensure all materials are disposed of in the appropriate manner.

Aim
To design a method to investigate how different types of yoghurt affect the growth of harmful bacteria.

Time period
Approximately 1.5 weeks

Prior understanding
Pathogenic bacteria are in the air and on all surfaces around us. Raw food, such as fruits bought at the grocery store, can be contaminated by pathogenic bacteria due to handling. These **pathogens** do not usually cause a problem: when the fruit is consumed, the bacteria are destroyed either by acidic environment of the stomach or by the good bacteria that live in each person's intestine. However, some bacteria evade these immune defenses and cause food poisoning.

pathogen
an organism that can cause illness

It is recommended that fruits be washed well before consumption to avoid food poisoning. However, this is not easily done with soft fruits such as strawberries. Another option has been presented and requires investigation. Could covering fruit with yoghurt (which contains cultures of good bacteria) be used to disinfect soft fruit before consumption?

Materials
- different types of cultured yoghurt (3 types recommended)
- 1 strawberry or another type of soft fruit
- 4 sealable food containers
- 1 small paint brush

Planning
1 Develop a research question for this investigation.
2 Identify the dependent variable and state how it will be measured.
3 Identify the independent variable and describe the different groups that will be set up for the experiment.
4 Develop a hypothesis by predicting how a change to the independent variable will affect the dependent variable.
5 Identify the controlled variables and describe how these will be managed to prevent any controlled variables from affecting the measurements.

Procedure
1 Label each container with the following information:

Group number:
Type of yoghurt:
Date:
Student/s name:

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2 Cut each strawberry into four pieces vertically as shown.
3 Leave one piece of strawberry untouched to use as a control (comparison) and paint each of the three remaining pieces with a different type of yoghurt.
4 Place each piece of strawberry in a separate container labelled with the yoghurt type.
5 Seal the container by placing the lid on tightly.
6 Monitor the experiment for nine days, recording observations and taking photographs of each container, every three days.
7 If any part of the set-up is changed, note the reason for this.

Results

1 Collect each container but DO NOT OPEN for safety reasons.
2 Measure the amount of bacterial growth (in terms of area) for each group and record the results. Your teacher may direct you to create a table and graph on a spreadsheet or on paper.
3 Calculate the mean measurement for each *independent variable* group.
4 Calculate the range for each independent variable group on the table.
5 Graph the mean of each group's data.

Discussion

1 Describe any trends, patterns or relationships in your results.
2 Describe how much variation was observed between the measurements within each group.
3 Discuss whether the controlled variables were managed properly to ensure they did not change and affect the measurements.
4 Describe changes that could be made to the method to improve the quality of the data in future experiments.

Conclusion

Discuss which yoghurt (if any) could best be used to disinfect soft fruit instead of washing it. Justify your answer by discussing your experimental results.

Green and brown food chains

You already know consumers get their energy from producers or other consumers, and that producers get their energy from the Sun. You also know that producers use this light energy, along with carbon dioxide and water, to form glucose through the process of photosynthesis. Green plants form the base of the green food chain, but not all parts of a plant may be available to eat. For example, the woody parts or some roots may be inaccessible. So what happens to all the energy stored in this plant material that does not get eaten? It becomes detritus and forms the base of the brown food chain.

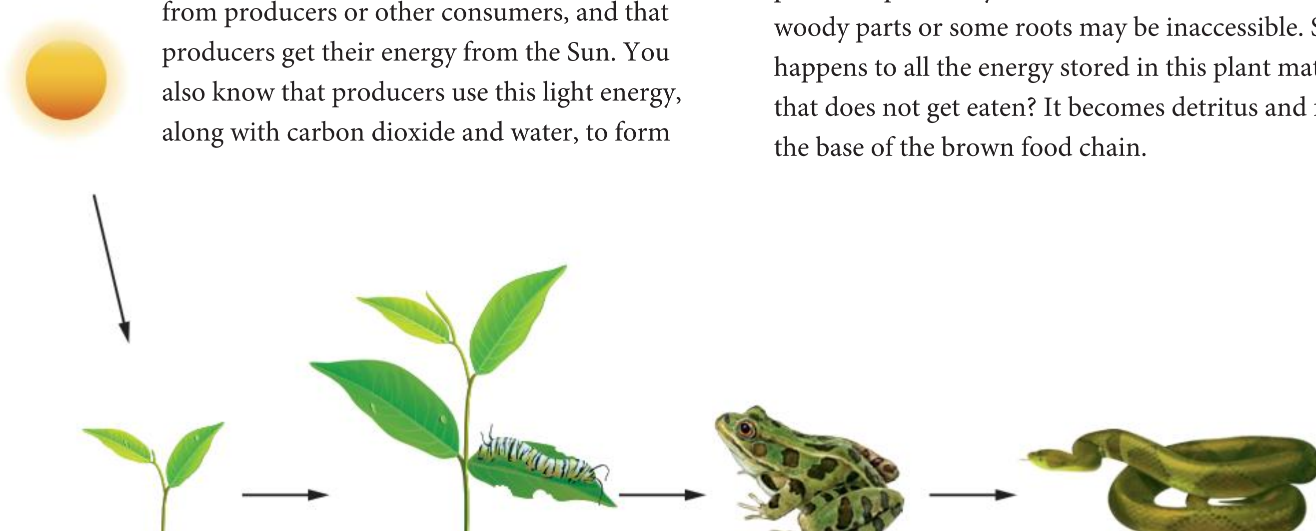

Figure 10.33 Green food chain

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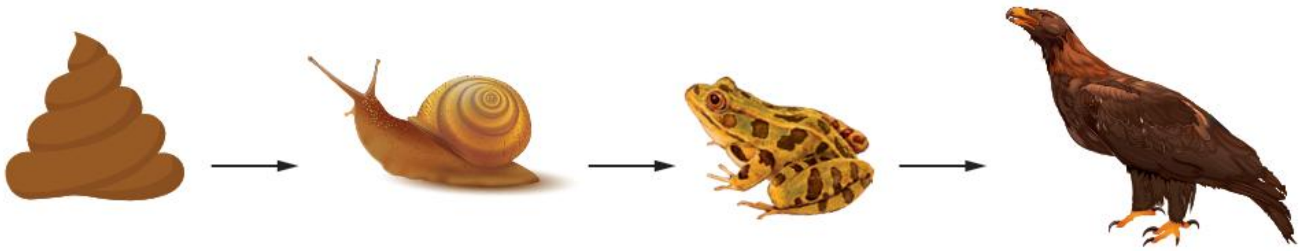

Figure 10.34 Brown food chain

All other dead organisms add to this brown food chain, as well as all the waste they excrete throughout their lives. As humans, we are rather squeamish when it comes to dead and rotting material, as we did not evolve eating waste and it can make us very sick. However, many organisms on Earth get at least some of their energy directly from detritus. Species within the Lagomorpha family such as rabbits and hares produce a hard and a soft type of faeces. These animals will reingest their soft faeces to extract more nutrients.

The brown food chain is directly linked to the green food webs found in every ecosystem. When detritus is included in a food web diagram, it shows the complex and important interaction that decomposers have in an ecosystem.

Figure 10.35 Pikas (shown here), rabbits and hares are part of the Lagomorpha family. They can produce a different kind of faecal matter called 'caecal matter' that is soft, full of nutrients and can be eaten again.

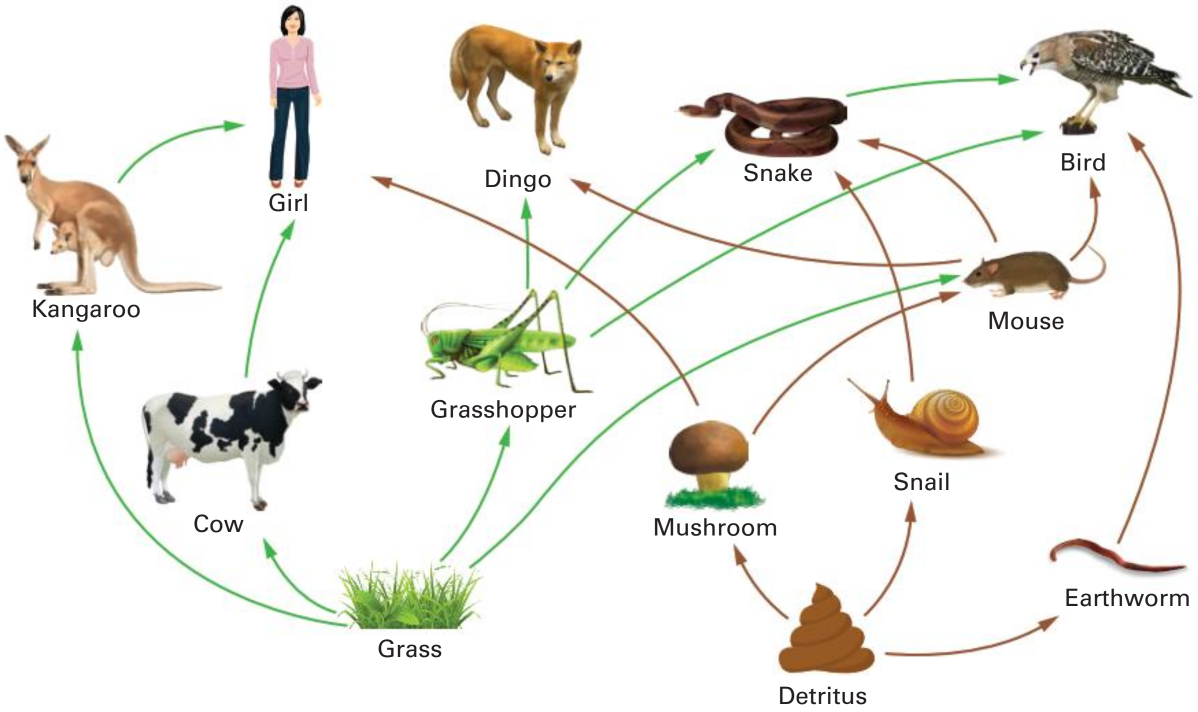

Figure 10.36 Combined green and brown food webs

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Section 10.3 questions

Remembering

1 **State** the percentage of plant matter that is decomposed.
2 **List** three examples of decomposers.

QUIZ

Understanding

3 **Describe** why decomposers are an important part of an ecosystem.
4 **Describe** what could happen to the world if scavengers and decomposers did not exist.

Applying

5 **Design** a brown food chain that could be found on a coral reef.
6 **Classify** each of the organisms in the food chain you have created as decomposer, first order consumer or second order consumer.
7 **Summarise** the role/s that scavengers can play in an ecosystem. Are they only scavengers or can they have other roles too?
8 Look at Figure 10.37 and using your knowledge of decomposers, **describe** what is happening.

Figure 10.37 A close-up of a forest floor. Can you spot the worm in the middle of the image?

Analysing

9 **Compare** the role of a producer with the role of detritus.
10 **Distinguish** between a decomposer and a detritivore.

Evaluating

11 **Propose** a reason why decomposers can be found wherever there is life.
12 **Consider** how a food web would change if all the decomposers in an ecosystem died. **Justify** your decisions.

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10.4 Human impact on ecosystems

Learning goals

1. To define 'biodiversity'.
2. To explain how humans are impacting on biodiversity.
3. To explain how Aboriginal and Torres Strait Islander peoples' land management practices can be beneficial for biodiversity.

DOC WORKSHEET

Biodiversity

biodiversity
the number and types of plants and animals that exist in an area

When scientists look at all the different types of animals found in an area, they start to talk about **biodiversity**. Biodiversity refers to the variety of all living things found in a specific area. There are three different types of biodiversity.

- **Genetic diversity:** This is the number of differences within one species. Humans are very genetically diverse, as people have many shapes, sizes and abilities. If a species is very genetically diverse, it is thought to be healthy.
- **Species diversity:** This is the variety and abundance (total number) of different species found in an area. Places like coral reefs and rainforests are said to be extremely biodiverse because many different species live in a small area.
- **Ecosystem diversity:** This is the variety of ecosystem types found in an area.

As we discovered in the classification chapter, all life on Earth is categorised into six kingdoms. These kingdoms indicate the species biodiversity on our planet. It is estimated that there are more than 8 million species on Earth, and that number is growing as new species are discovered. About 76% of all species have been classified into the Animal kingdom. This means that the Animal kingdom is the most diverse of all the kingdoms. Within the Animal kingdom, the phylum Arthropoda is by far the most diverse and within this phylum, the class Insecta makes up about 73% of all animal species.

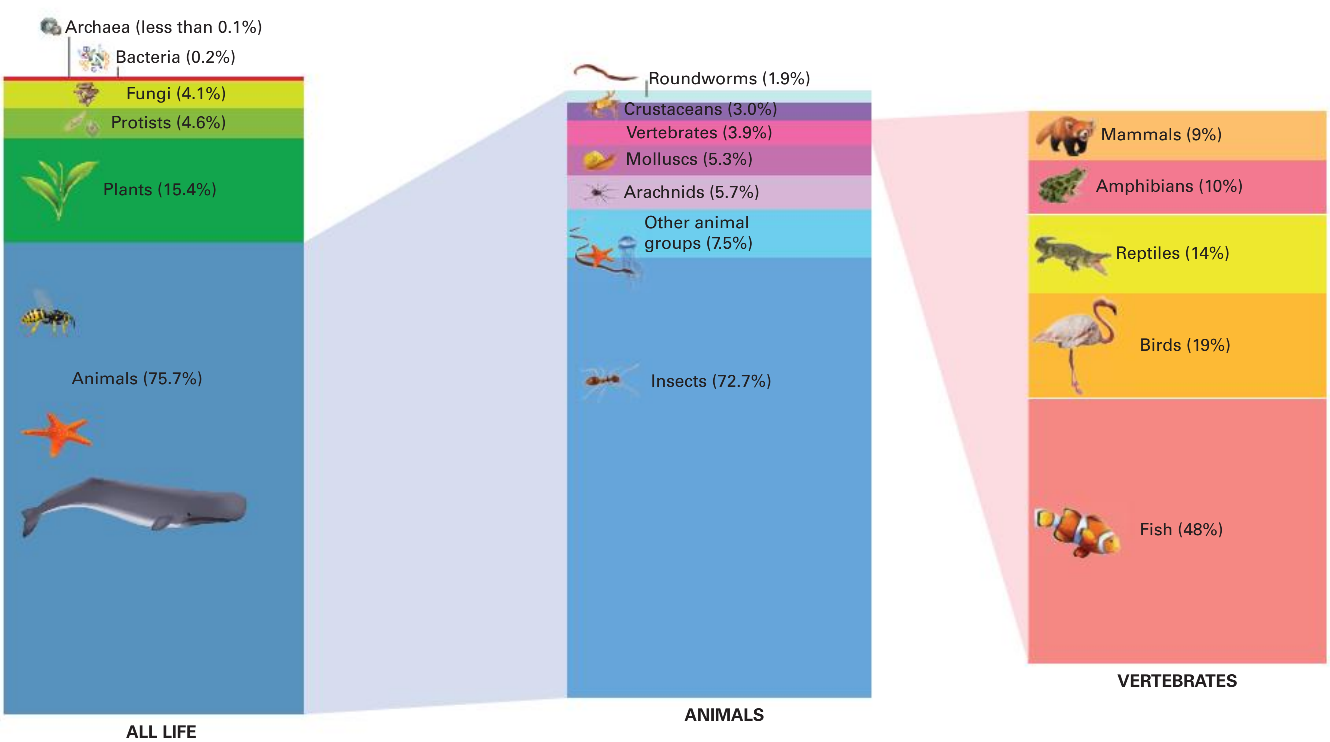

Figure 10.38 Species biodiversity on our planet (approximate percentages shown)

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Threats to biodiversity

It is important to be able to measure the biodiversity of ecosystems and habitats in order to monitor the number of species and individuals found there. The more biodiverse an area is, the more likely it will be able to recover from natural or human-caused threats such as disease, fire, habitat loss or introduced species. Therefore, when an area is extremely biodiverse, it is healthy.

Practical 10.4

Assessing biodiversity at your school

Be careful

Try to avoid biting and stinging insects.

Aim

To compare the biodiversity of two different areas in the school grounds.

Prior understanding

Biodiversity is a measure of how many *different* species live in an area *and* whether these species are equally abundant in numbers, or whether one species dominates the others with a comparatively larger number of individuals. Healthy habitats have a higher biodiversity index.

One biodiversity index that can be used is called the Menhinick index. It can be calculated using the following equation. Higher numbers indicate higher levels of biodiversity.

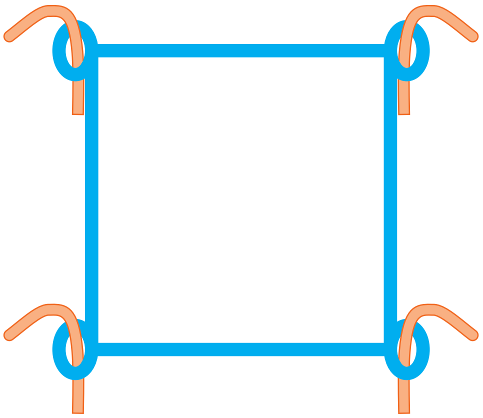
$$\text{biodiversity index} = \frac{\text{number of species in survey area}}{\sqrt{\text{total number of individuals}}}$$

For example, in a survey recording 26 individual invertebrates belonging to five different species, the biodiversity would be

$$\text{biodiversity index} = \frac{5}{\sqrt{26}} = 0.98$$

Materials

- invertebrate identification key
- magnifying glass
- quadrats, if available, or four tent pegs and 4.5 m of fine string-line with loops tied every metre (the tent pegs must be able to fit through the loops). A one-metre quadrat can be created by pegging out the string-line into the shape of a square. Push the tent pegs through each loop to pin the corners to the ground.



Procedure

1. Choose two different survey areas to assess within the school grounds, such as a grassy area and a garden.
2. Take all equipment to the first survey area.
3. Randomly choose a spot to place your quadrat.
4. Take photos of any invertebrates you record. This will help you to later identify any species you cannot name.
5. Repeat steps **3** and **4** in another four random spots.
6. Move to the second survey area and repeat steps **3–5**.

Results

1. Develop a table to record the data from each survey area, including the survey area, type of invertebrate and number of individuals.
2. Identify any unknown invertebrates using an Invertebrate Identification Key. Record this data in the table.
3. Count the number of each invertebrate. Record this data in the table.

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4 Calculate the total number of individual invertebrates found in each survey area.
5 Calculate the Menhinick biodiversity index (how biodiverse an area is) for each survey area by using the equation on the previous page. Show your working for each area.
6 Record the level of biodiversity for each survey area in the table.

Discussion

1 Contrast the Menhinick biodiversity index results for the two areas.
2 Identify the survey area that would be considered more biodiverse.
3 Discuss the reasons for any differences found when comparing the two survey areas.
4 Swap your data with another group to give each other feedback on how easily the table can be used to compare the two survey areas. Your feedback should discuss the following:
   - how well the table is organised to compare the two survey areas
   - how clearly the biodiversity calculations have been written
   - any other suggestions to improve the quality of the data presented in the table.

   After receiving feedback, make alterations to the table to address the identified issues and write up a final copy to present to the class.
5 Compare the level of biodiversity calculated by each of the other groups. Determine how much variation was found between different group results.
6 Compare the different types of species found in each survey area with other groups. Identify species that were not found consistently in each survey area.
7 Discuss if the biodiversity of the two survey areas can be reliably compared, based on your response to the previous question.
8 Decide upon some changes that could be made to the method to improve the quality of the data in future experiments.
9 The equation only takes into account the number of different species, instead of the number of different species and their abundance. Complete some research to find a better equation that can be used to determine the level of biodiversity.

Aboriginal and Torres Strait Islander peoples' land management practices

Bushfires are common in Australia. With our dry climate, they are one of the most dangerous and threatening events that can happen to an ecosystem. However, many Australian ecosystems rely on occasional bushfires to encourage biodiversity.

Bushfires can occur naturally or can be human induced. Some of the natural causes of bushfires are dry conditions, high temperatures, low humidity, strong winds and lightning. Spontaneous combustion due to extremely hot temperatures can also start bushfires, but this is less common than lightning. Humans can light fires either deliberately or accidentally.

Aboriginal and Torres Strait Islander peoples have a deep understanding and connection to the land. They have thrived in a particularly harsh environment using techniques passed down from Elders over many generations. The use of fire is one of the most important techniques that they have used to gather food, shape the landscape and regenerate ecosystems.

Figure 10.39 Lightning naturally starting a bushfire

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Firestick farming

Firestick farming involves burning a small controlled area. Aboriginal and Torres Strait Islander peoples have known for thousands of years that this will promote plant growth, attract new animals to an area and cause any animals hiding in burrows to come out into the open. With animals no longer in their burrows and less vegetation for them hide behind, people were able to hunt easily.

By burning areas of bush, they made room for new plants and activated seeds stored in the ground, which provided new sources of food for animals in the area.

Two types of fires are used for firestick farming.

- **Cool fires** are low intensity and happen regularly to clear the undergrowth. They do not damage the larger plants and are used to clear paths and promote the growth of native plants for both humans and grazing herbivores. This is important because Aboriginal and Torres Strait Islander peoples use many **endemic** plants for both culinary and medicinal purposes. Management of these valuable resources is necessary, especially where **biopiracy** is a potential risk.
- **Hot fires** are used more sparingly as they burn areas of thick vegetation including trees and shrubs, which are important habitats for animals. These fires are very dangerous and destructive, killing everything in their path. Because of this, they are only used in overgrown areas where vegetation is struggling to thrive so as to revitalise the area.

firestick farming
the burning of areas of bush in stages, by the application of firesticks, to encourage new growth

endemic
an organism that is restricted to or unique to a particular area

biopiracy
when naturally occurring biological material is commercially exploited

Figure 10.40 Regrowth of plants after a bushfire

Figure 10.41 Devastating hot fire

Quick check 10.8

1. Propose some causes of fire in Australia before Aboriginal and Torres Strait Islander peoples arrived.
2. Recall three main uses of firestick farming.
3. Describe how firestick farming helps to promote new plant growth.
4. Contrast the two types of fire used in firestick farming.
5. Currently, we use controlled burns in winter to reduce natural bushfires in summer. Predict a problem with disrupting this natural event.

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Advances in science 10.1

Firefighting in virtual reality

Researchers at Deakin University in Australia have created a virtual reality training simulator for firefighters. It is called FLAIM Trainer. The simulator creates a training scenario that uses a touch technology feedback system. The trainee is required to wear a heavy uniform, breathing apparatus and protective clothing that heats up to make the experience extremely realistic.

Thanks to this technology, firefighters will now be able to practise key skills and knowledge in a safe and more cost-effective environment. This makes it safer for firefighters to do their job and more likely that they can save lives and the environment.

Figure 10.42 A helicopter used for fighting fires in Western Australia

Land clearing for palm oil

Rainforests are one of the most important ecosystems. Up until very recently, they stretched like a band around the equator where climate conditions are perfect for their growth. Rainforests are often referred to as the lungs of Earth, as the high volume of plants photosynthesise and produce huge amounts of oxygen. They are also like air filters because they take in carbon dioxide during photosynthesis and store it internally. This is especially important considering the large amount of carbon dioxide humans are producing and the warming effect it has on our planet. Rainforests are also biodiversity 'hot spots' with more than 50% of the world's species living there.

Figure 10.43 Orangutans are treated as pests by farmers in Borneo and Sumatra.

What are we doing?

Unfortunately, humans are cutting down vast areas of rainforest every day. In fact, each year an area bigger than the whole state of Victoria is destroyed. Some of the biggest rainforests closest to Australia can be found in Borneo and Sumatra. These rainforests contain some of the world's last remaining pygmy elephants, Sumatran tigers, rhinoceroses and orangutans. The main threat to these species and the rainforests is palm oil farming.

Figure 10.44 Areas of land like this are often cleared for palm oil farming.

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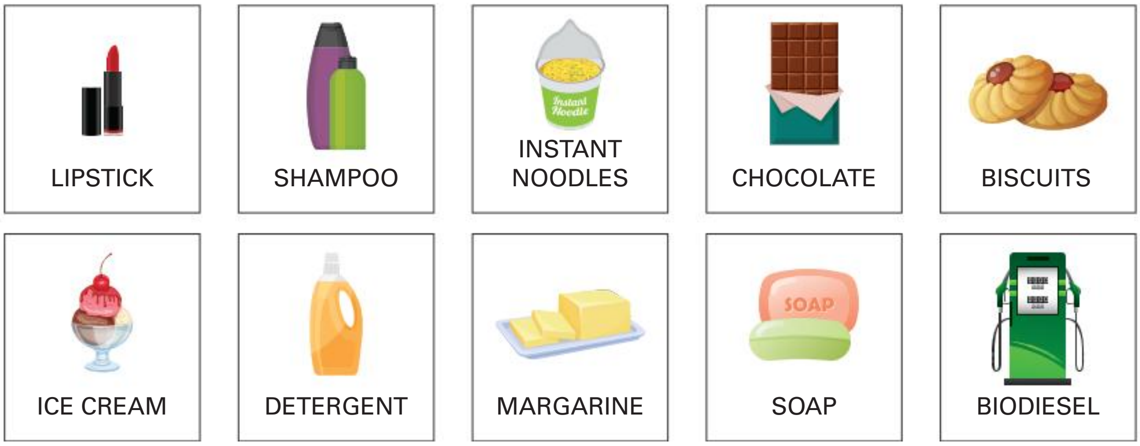

Figure 10.45 These everyday products are likely to contain palm oil.

You may not know it, but you will probably have eaten or used palm oil daily. That is because it is found in many of the products you buy at the supermarket, from shampoo to pizza dough. Palm oil is used by many companies because it is cheap and so the global need for palm oil is growing rapidly. The Borneo and Sumatran rainforests are perfect environments for palm oil trees to grow fast, even though they are originally from West Africa. Many of the citizens in these countries are extremely poor, so palm oil farming is crucial for jobs and the economy of these countries.

Why is it a problem?

As the demand for palm oil increases, more and more areas of rainforest are being cut down to make way for palm oil farms. This means less and less room for already endangered species such as the orangutans, elephants and tigers. Not only are these animals forced out of their homes but if they wander onto the farms they are treated like pest species and killed.

In an attempt to protect the small numbers of Sumatran tigers left, the government of Sumatra opened the Gunung Leuser National Park wildlife reserve in 1934. It was established as a national park in 1980. The Gunung Leuser National Park itself was put on UNESCO's danger list in 2011 due to the 'threats posed by poaching, illegal logging, agricultural encroachment, and plans to build roads through the site'.

deforestation clearing a wide area of trees or natural land

Many people blame the palm oil sector as a main offender in the degradation of the protected areas.

Deforestation is also a threat to the environment of these areas. By removing plants and their roots, the thin layer of soil found in rainforests is easily washed away,

Figure 10.46 Sumatran tiger

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Figure 10.47 Dangerous clearing fires

meaning that nothing will grow in that area again. The pesticides and herbicides used to promote palm oil growth can pollute local waterways.

Much of the clearing that is occurring in the rainforests to produce palm oil tree farms is done using fire. This kills the local wildlife, as well as also releases massive amounts of stored carbon into the air, which contributes to climate change.

Scientists are currently studying different practices to make palm oil farming more environmentally friendly and sustainable. By collecting data from plantations, they can study the effects of cropping practices, such as fertiliser application and the sowing of legume cover crops. This information will help growers make decisions that improve yield and productivity, meaning that forests do not need to be cleared to create land for more farms.

Quick check 10.9

1 Explain why rainforests are referred to as 'Earth's lungs'.
2 Name five products that contain palm oil.
3 Identify why palm oil is widely used in many products.
4 Explain why using palm oil is a problem.
5 Be aware of how palm oil is labelled in ingredient lists. Encourage friends and family to buy products that use sustainable palm oil. Download the POI palm oil barcode scanner and do a home audit. Identify products you use that contain palm oil.

What can we do?

All this information can be upsetting and it might feel like the problem is too big for you to do anything about, especially as you are still in school. Here are a few things that you can start to do that will help the situation.

- Be aware if a product contains palm oil. Palm oil can be called many things on an ingredient list including the items seen in Figure 10.48.

Figure 10.48 Can you spot the various things palm oil may be labelled under?

All of these can be labels for palm oil.

- Encourage friends and family to buy products with sustainable palm oil. This is palm oil that has been grown by companies that promise to protect the environment. Look for products with the logo in Figure 10.49.

CERTIFIED SUSTAINABLE PALM OIL™ · RSPO ·

Figure 10.49 The Roundtable on Sustainable Palm Oil logo

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Invasive species

An **invasive species** is an organism that has been introduced to a new ecosystem by humans. This is usually done by accident but sometimes it is done on purpose. Australia has many invasive species such as foxes, rabbits, goats, and feral cats and pigs. All these species were introduced by European colonists for hunting, farming or to make Australia feel more like Europe. Sometimes invasive species are introduced to help control the numbers of another organism. This is an example of a **biological control**.

invasive species
an organism that is not native to an environment and causes harm to native organisms

biological control
the practice of introducing an organism into an ecosystem with the intention of limiting the spread of another organism

calicivirus
a disease that damages a rabbit's internal organs and can cause bleeding

Explore! 10.3

Rabbit-proof fences

Rabbits are considered a major pest in Australia, so much so that it is illegal to keep a rabbit as a domestic pet in Queensland. In 1995, the **calicivirus** was introduced as a biological control to reduce the massive rabbit population. However, some rabbits were immune to the virus. Also, foxes (another pest) had lost a food source and so were eating native wildlife instead.

Go online to investigate the following.

1. Find out about the rabbit-proof fences erected in Western Australia in the 1900s, as shown in Figure 10.50. Report on how they were used to try to limit the spread of plagues of rabbits.
2. Find out about the myxoma virus and its release in Australia in 1950 in an attempt to control the rabbit population. Summarise your findings.

Figure 10.50 Rabbit-proof fences were erected to try to limit the devastation caused by rabbits.

Disastrous control

The cane toad originally comes from Puerto Rico but was brought to Australia to try to manage beetles that were eating sugarcane crops. The cane toad had been introduced to Hawaii for the same purpose and had done a great job. However, after they were released in the sugarcane plantations of north Queensland in 1935, their population exploded, and they quickly became a huge pest. Cane toads have many ecological impacts such as competing with native species for food and space. They are also poisonous and so kill any predatory native species such as quolls, snakes and crocodiles that eat them.

Effective control

Not all examples of biological controls have gone wrong. European settlers brought a cactus known as the 'prickly pear' to Australia to use as a food source for a beetle. This was not just any old beetle, as it produced a red dye for the production of soldiers' uniforms. The cactus thrived in Australia and soon covered an area larger than Victoria. The cactus moth (*Cactoblastis cactorum*), which eats only the prickly

Figure 10.51 A cane toad

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pear, was then introduced as a biological control to help slow down the spread of the cactus. Another benefit of the moth is that when there is no cactus left, it dies off because the cactus is its only food source. Several years after the introduction of the moth the cactus population was under control, even though it is still around today in smaller numbers. Aboriginal and Torres Strait Islander peoples may use cool fires to control the growth of invasive species such as African Lovegrass (*Eragrostis spp.*) and Lantana (*Lantana camara*).

Figure 10.52 Prickly pear plant

Try this 10.5

Find the PestSmart website online and use it to research three pest animals in Australia. Record your findings in a table like this one.

Name	Areas found	Main problems caused	Control measures

Section 10.4 questions

QUIZ

Remembering

1 **Name** the three types of biodiversity.

2 **List** four examples of an invasive species.

Understanding

3 **Define** the following terms.

   a Species diversity

   b Genetic diversity

   c Ecosystem diversity

4 **Describe** the use of the ‘firestick’ by Aboriginal and Torres Strait Islander peoples.

Applying

5 **Identify** which phyla in the Animal kingdom is most diverse.

6 **Explain** why some introduced species are classified as pests.

7 **Explain** why the cactus moth is referred to as an effective biological control.

8 **Suggest** some of the impact that humans are having on oceanic ecosystems.

Analysing

9 **Compare** the use of ‘hot fire’ and ‘cold fire’ burning techniques by Aboriginal and Torres Strait Islander peoples.

10 Go online and **research** the work a group is doing to counteract the impact humans are having on biodiversity loss. Try to choose a group that you may find interesting. An example could be the Orangutan Foundation.

Evaluating

11 Bushfires naturally occur in Australia and many organisms have adapted to cope with this. Natural bushfires may occur around once every 5–10 years; however, many areas undergo controlled burns yearly to prevent wildfires. **Suggest** how this might damage the ecosystem.

12 **Create** a pros and cons list on the role of invasive species.

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Chapter review

Chapter checklist

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

SCORCHER

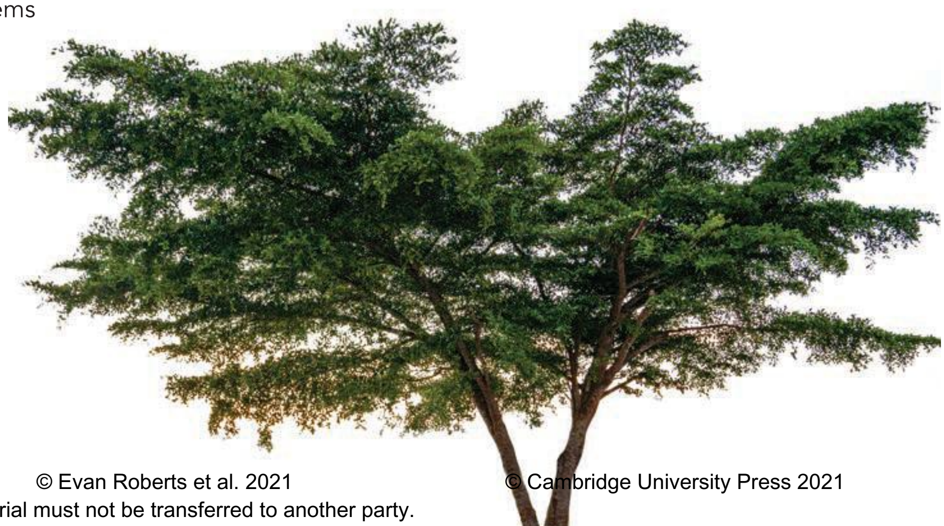
Success criteria		Check
10.1	**I can recognise the difference between abiotic and biotic factors in an ecosystem.** e.g. Organise the following into 'abiotic' and 'biotic': temperature, salinity, dingo, wind speed, fire ant, koala, pH.	
10.2	**I can construct and interpret a food web to show relationships.** e.g. Describe what would happen to an ecosystem if all primary consumers were removed.	
10.2	**I can construct a food chain to show feeding relationships in habitats.** e.g. Describe what the arrows in a food chain show.	
10.2	**I can classify organisms according to their position in a food chain.** e.g. Define the terms 'producer' and 'consumer'.	
10.2	**I can explain the 10% rule for energy transfer in food chains.** e.g. Explain why there are often not more than three trophic levels in a food web.	
10.3	**I can explain the importance of microorganisms in food chains and food webs.** e.g. Compare detritivores and decomposers.	
10.4	**I can explain the impact of human activity on local habitats.** e.g. Describe the impact of deforestation on an ecosystem.	
10.4	**I can describe how living things can cause changes to the environment and impact other living things.** e.g. Describe the impact of cane toads being introduced to Australia.	
10.4	**I can explain how Aboriginal and Torres Strait Islander peoples' land practices can be used to manage ecosystems.** e.g. Explain firestick farming.	

Reflections

1 What **connections** come to mind when you think about interactions in ecosystems and your everyday life?

2 What new concepts have **extended** your thinking about interactions in ecosystems?

3 What information did you find **challenging** or confusing?



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Data questions

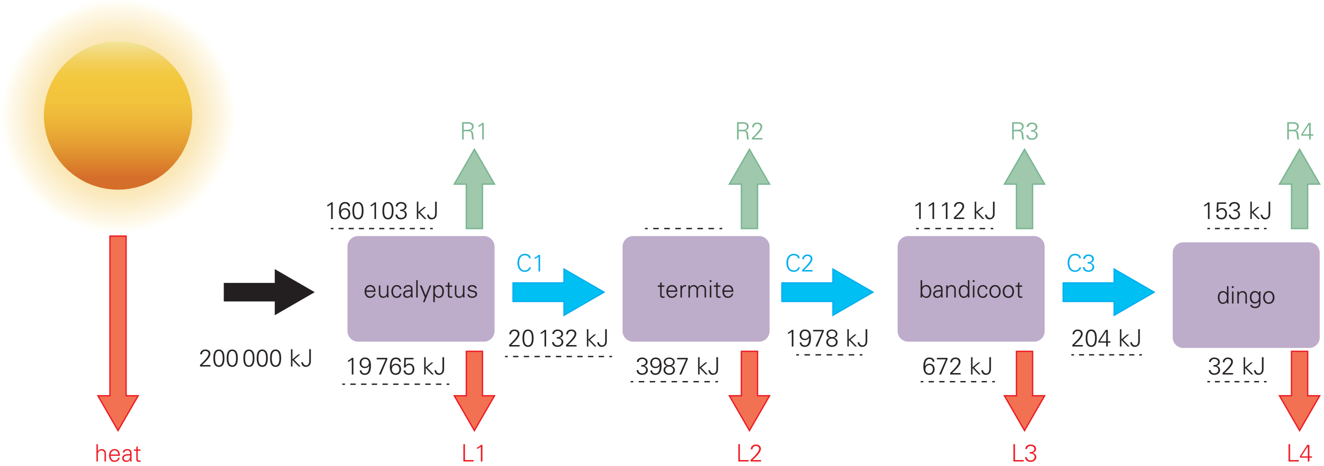

Figure 10.53 Energy transfer in an Australian food chain. Blue arrows (C1–3) represent energy transferred through the food chain; green arrows (R1–4) represent energy lost as heat and through respiration; and the red arrows (L1–4) represent the energy lost as detritus (dead organic matter and waste).

1 **Identify** the secondary consumer in Figure 10.53.
2 **Calculate** the R2 value.
3 **Calculate** the efficiency of the energy transfer through the termite in Figure 10.53.
4 **Organise** the efficiency of energy transfers (C1, C2 and C3) from highest to lowest, using Figure 10.53.
5 **Deduce** why the food chain does not extend further than the dingo. Provide appropriate data to **justify** your response.
6 Geckos will also eat termites. They are far smaller than a bandicoot. **Predict** if the gecko's L3 value would be higher or lower than the bandicoot's L3 value in Figure 10.53.
7 **Justify** your answer to Question **6**.

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STEM activity: Designing a cane toad trap

Background information

Cane toads are a pest in Australia. They are gluttonous feeders and can significantly reduce the population of native creatures. They have a toxic venom in their skin, which protects them from predators. Cane toads have no natural predators and are a threat to native animal species. Only human intervention can control and reduce the population.

Design brief: Create a prototype of a device that can be used to reduce the population of cane toads humanely.

Activity instructions

In this task, you will investigate the different ways you can control the cane toad population. Then you will design and construct a prototype device that could be used by individuals and government organisations to trap cane toads or their tadpoles. You will need to consider the following information and design constraints.

1 The design and construction must be cost-effective.
2 The prototype must be constructed so that no animal (including the cane toad) is harmed.
3 The prototype must be able to be left in a way so that curious people cannot injure themselves by touching the device or possibly touching a captured cane toad/tadpoles.
4 The prototype device must be able to be transported for safe removal of toads/tadpoles.

Suggested materials

- recyclable materials such as plastic bottles, containers, boxes
- duct tape
- scissors
- ruler
- balls the size of cane toads

Research and feasibility

1 Identify other animal species that live in the same ecosystem as cane toads. If necessary, research this information.
2 Research and explain what 'humane' means, and discuss in your group why your prototype design must be humane.

Figure 10.54 A cane toad

3 Research the lifecycle and identify why the cane toad has become such a pest in Australia.
4 Research and identify the ways that the cane toad population can be controlled.

Design

5 Decide in your group the method you are going to use to reduce the population of cane toads. You may want to use a table like this one to list the positives and negatives of each method.

Method of control	Positive	Negative
Adult toad trap		
Tadpole trap		
Barrier		

6 Design your prototype device and label the key components of the design. How do the components of the design help your invention to be humane, safe, effective and affordable?

Create

7 Construct your prototype device using the available materials.
8 Test your prototype device for durability and get other groups to test how well it works.

Evaluate and modify

9 Discuss in your group how well your prototype device worked, and reflect on how effective you think it will be.
10 Evaluate if you now think that other methods of controlling the population would be more effective. Would you like to make any changes to your prototype?
11 Present your prototype to the class and ask your peers how effective the prototype would be where they live, and what suggestions they can offer to improve it.

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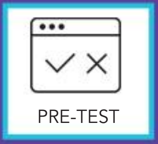
Chapter 11
States of matter

Inquiry questions

What is matter?
Why does matter change state?
How do particles move?



Chapter introduction

This chapter will introduce you to the amazingly tiny world of particles and the idea that everything in our universe is made up of them – yes everything! You will focus on the three states of matter (solids, liquids and gases) and investigate how the particle model can explain not only their changes of state but also the properties they exhibit.

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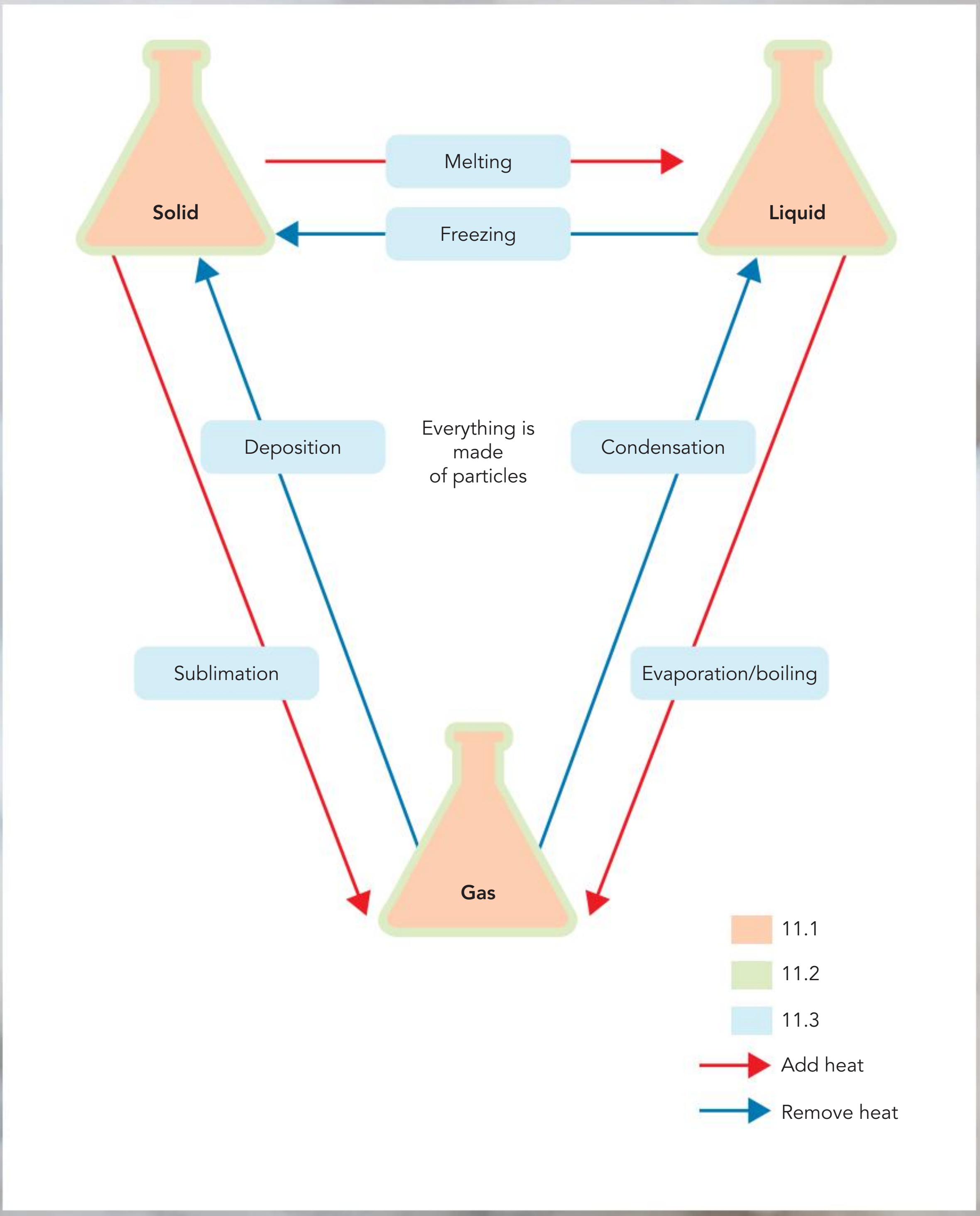
Chapter map



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11.1 Particle model and states of matter

Learning goals

1 To describe the particle arrangement in solids, liquids and gases.
2 To explain why models are used in science.

WORKSHEET

What do cars, milk and oxygen have in common? They are all made up of matter! **Matter** is essentially anything that takes up space and has **mass** and **volume**. Mass is the amount of matter in a substance or object, and volume is the amount of space the substance or object takes up. There are three **states** of matter that are commonly found in our world: solids, liquids and gases. Look at the images in Figure 11.1, and identify the solids, liquids and gases. What do the solids all have in common? What do the liquids all have in common? What do the gases all have in common? What makes them different?

matter
anything that has mass and volume

mass
the amount of substance in an object that never changes, even in space

volume
the space an object occupies

state
one of the distinct forms matter can exist in

Figure 11.1 States of matter: solids, liquids and gases. What are the similarities and differences between the three states of matter illustrated above?

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Did you know? 11.1

Other states of matter
Other than solids, liquids and gases, there is one other naturally occurring state of matter that is common in the universe: plasma! Plasmas are highly energised gases that are not common here on Earth, but stars, including the Sun, are covered in plasma. Plasma can be created by lightning strikes and is even used in plasma TVs in the form of ionised gas. Other 'extreme' states of matter can be created under experimental conditions and are very rare in the universe.

The particle model

The ancient Greeks wondered what would happen if you could keep dividing matter up into smaller and smaller pieces. Would you eventually come to a particle that you could not split? Although they had no way of observing them, they assumed that these particles existed and must explain some of the properties of matter. The **particle model** was born.

Before you get into the nitty gritty, it is important to clarify what a model is. In science, models are used to represent different aspects of real-world objects (like models of trains and cars) and phenomena (like the Earth circling the Sun). Sometimes though, scientists make models to test out ideas, like making model bike helmets and seeing how well they prevent an uncooked egg from breaking when dropped. And other times, scientists use models to represent what they cannot see to try to explain how it might work. This is the case with the particle model.

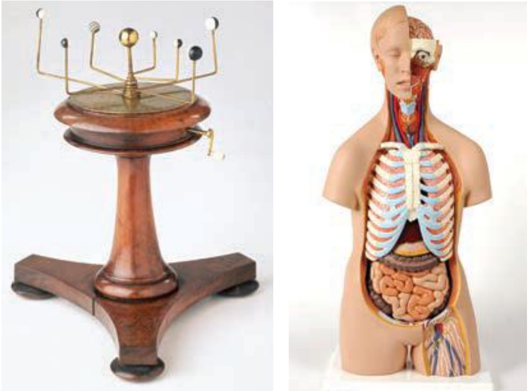

Figure 11.2 Models: a model of the solar system from the 18th century and a modern model of the human body used in schools

So, to better understand what makes a solid a solid or a gas a gas, you will need to begin by looking at the particle model. This model suggests that all matter is made up of extremely small particles that are invisible to the naked eye. These particles are not only different sizes in different substances, but are also arranged differently in solids, liquids and gases. The closer the particles are to one another, the stronger the attraction between them. This helps us to understand why each state of matter has different properties.

According to the particle model, the particles that make up matter are always moving because of the energy they have; that is, the more energy they have, the faster they will move. Heat can also increase the energy of particles and therefore make them move faster. Particles will always have some energy and so will always move, even if it is just a little bit. In solids, the particles **vibrate** in fixed positions, but in liquids and gases, the way particles move is totally random, and in science, this is called **Brownian motion**.

particle model
all matter is made of particles that behave differently depending on whether they are solid, liquid or gas

vibrate
periodic motion of particles

Brownian motion
the random movement of particles in fluids and gases

Explore! 11.1

Brownian motion
Brownian motion is named after the botanist Robert Brown, who first observed this in 1827. Do some research on the internet to answer the following questions.

1. Explain how Robert Brown first discovered that substances are made up of invisible particles.
2. Who also studied Brownian motion? What did they determine about this random movement of particles?

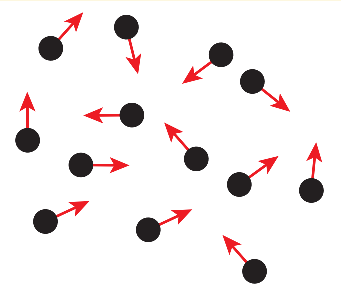

Figure 11.3 A representation of particles randomly moving

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Quick check 11.1

1. Define the term 'matter'.
2. State the three common states of matter.
3. Summarise the key points of the particle model by completing the following sentences.
   a. All matter is made up of ____________.
   b. The particles are always ____________.
   c. Particles move faster if the substance is ____________.

Try this 11.1

States of chocolate

Figure 11.4 One of the states of chocolate

Be careful

No chocolate is to be consumed in a laboratory classroom.

Aim

To demonstrate the three states of chocolate.

Materials

- chocolate buttons
- small beaker
- large beaker
- boiling water

Instructions

Heat the chocolate in a small beaker surrounded by boiling water in a large beaker.

Evaluation

1. After a few minutes, some of the chocolate will be partially melted. How many states of matter can you see?
2. What do you think is happening to the particles as they are heated up?

Solids

In a **solid**, the particles are packed tightly together. Owing to their close proximity, the forces of attraction between particles is very strong. Because of this, the particles in solids cannot move freely; instead, they vibrate in their places.

solid
a substance that has a fixed shape and constant volume

liquid
a substance that flows freely and takes the shape of its container but has constant volume

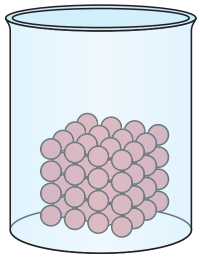

Figure 11.5 Diagram showing the arrangement of particles in a solid. Particles in a solid are very closely packed together and just vibrate in their places.

Liquids

In **liquids**, particles are held together by forces of attraction. As the particles are not as close together as in solids, these attractions are not as strong. This means that the particles do not vibrate in a fixed position but can move freely.

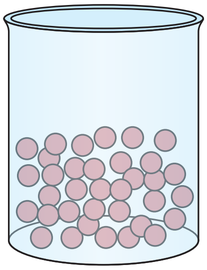

Figure 11.6 Diagram showing the arrangement of particles in a liquid. Particles in a liquid are packed closely together but can still move about and slide over one another. Gravity pulls the liquid into the shape of the container.

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Gases

The particles in a **gas** are in constant motion as they have much more energy than those in solids or liquids. The attraction between the particles in a gas is weak because the particles are so far apart, so the particles spread out to take up any space that is available. The movement of particles from an area of high concentration of particles to low **concentration** of particles is a process called **diffusion**.

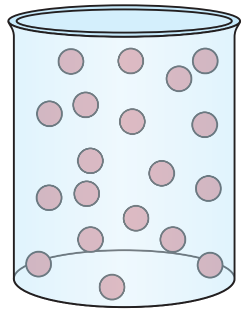

Figure 11.7 Diagram showing the arrangement of particles in a gas. Gas particles are always moving and spreading out to fill any space they are in.

gas
a substance that expands freely to fill space

concentration
the number of particles present in a given volume

diffusion
the movement of particles from an area of high concentration of particles to low concentration of particles

Try this 11.2

Modelling the three states

1. Working with your classmates, role-play what a solid, liquid and gas look like. Make sure you can explain what the particles are doing in each state of matter.
2. Use polystyrene balls and pipe cleaners to make a model of each state of matter. Draw diagrams of what the three models look like.

VIDEO
Animation of water particles in three states

Quick check 11.2

Copy and complete the following table.

State of matter	Describe and explain the strength of attraction between particles	Describe and explain the movement of particles	Diagram of particle arrangement
Solid			
Liquid			
Gas			

Try this 11.3

Balloon pressure

Blow up a balloon slowly. You know the particles of air inside the balloon are gas particles, so they would move in all directions. They collide with one another and with the inside wall of the balloon. The collisions with the balloon wall exert an outward pressure on the wall. As more particles are added, the wall of the balloon will stretch until it cannot stretch any more. What happens when you let go of the fully inflated balloon? Try to use the words 'gas particles' and **pressure** in your explanation.

pressure
the amount of force exerted on a given area

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Practical 11.1

Diffusion

Be careful

Check to ensure that no one suffers from any respiratory conditions before using the aerosol deodorant/perfume.

Aim

To design an investigation into how quickly particles can diffuse through water at different temperatures.

Materials

- aerosol deodorant/perfume
- food colouring
- 4 × 250 mL beakers
- eye dropper
- ice water, cold tap water and hot tap water
- thermometer
- stopwatch

Procedure

1. Spray some aerosol deodorant/perfume in one corner of the room. Move to the opposite corner of the room and record the time it takes for the scent to reach you.
2. Put one drop of food colouring into a beaker of tap water. Observe how the colour spreads and record the time it takes for the colour to spread evenly in the water.
3. Design an experiment to determine if the diffusion of food colouring occurs faster in warm or cold water. In science experiments, every variable is kept the same except for the one being investigated. What are the dependent, independent and controlled variables in this experiment? Consider what you will need to record and how you can do it.
4. Write a hypothesis about what you think might happen.
5. After checking your design with your teacher, carry out your experiment and record your results.

Results

1. Draw a diagram showing how the deodorant/perfume particles moved through the air.
2. Draw a diagram showing how the food colouring particles moved through the water.
3. Draw up a table that summarises your results from your self-designed experiment.

Discussion

1. How do you think the particles of the food colouring were able to spread through the water? Use the terms you have learned in class about the particle model and diffusion.
2. Explain why changing the temperature affected how fast diffusion occurred.
3. Many industries use diffusion to dispose of their waste products either as gases into the air or as liquids into rivers and the sea. Explain whether you think this is a suitable method in the long term.
4. Identify any sources of error and how you might prevent these from occurring again.

Conclusion

Draw a conclusion from this experiment on diffusion, supporting your statement with data.

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Heating and cooling

The particle model suggests that if you heat up a substance, the particles will gain more energy and so they will begin to move more. As the particles start to move more, the distance between the particles increases and they begin to take up more space. Because the particles are further apart, the attraction between the particles decreases. This process of the material (and not the particles) becoming larger is called **expansion**. When heat is applied, gases can usually expand more than solids and liquids because the particles are not held together by strong attractive forces and so are free to spread out.

So how does it work when a substance is cooled? The reverse of the process of expansion occurs: the substance cools down, the particles lose energy, they slow down, and the distance between the particles gets smaller. Because the particles are closer, they become more strongly attracted to one another, except in a gas, in which they are still relatively far apart. This process of the material (and not the particles) getting smaller is called **contraction**.

expansion the process of substances getting larger: the atoms of a substance move further apart as they heat up

contraction the process of substances getting smaller: the atoms of a substance move closer together as they cool

Figure 11.8 In a hot air balloon, the heated air expands, becomes lighter than the air outside the balloon, so the balloon rises.

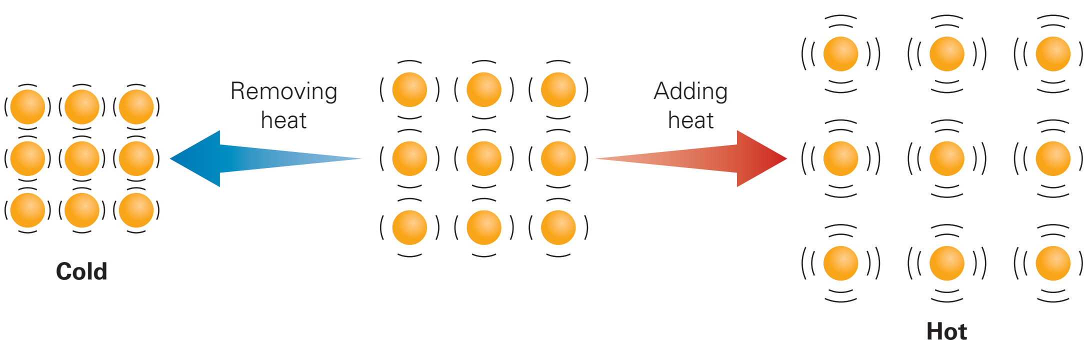

Figure 11.9 Diagram showing the changes experienced by particles with heating and cooling. Note that the size of the particle stays the same, while the space between the particles decreases.

Quick check 11.3

1 Compare the distance between particles in a gas, a liquid and a solid.
2 Use the particle model to explain what happens when a substance gains heat.
3 The particles of a substance in a sealed container are investigated at two different temperatures.
   - At temperature A, the particles are very close together but move about freely at moderate speed in the bottom of the container.
   - At temperature B, the particles are distant from one another and move about freely and very fast in all parts of the container.

   What is the state of the substance at temperature A and at temperature B?

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Practical 11.2

Expansion and contraction

Aim

To observe and explain the expansion and contraction of solids and gases.

Materials

- ball and ring apparatus
- tongs
- Bunsen burner
- bimetallic strip
- 2 metal bars of same size but different material
- wax candle
- stopwatch
- 1 balloon
- felt-tip pen
- ruler or tape measure
- coin
- bucket of ice water
- bucket of hot water

Figure 11.10 A ball and ring apparatus

Procedure

1 Examine the ball and ring apparatus. Does the ball fit through the ring when it is cold? What do you predict will happen when you heat the ball? Heat the ball using the Bunsen burner and see if it still fits through the ring. What happens if you heat the ring and not the ball?
2 Look at the bimetallic strip – predict or hypothesise what will happen when you heat it. Now, heat the bimetallic strip. Describe and explain what happens.
3 Attach a coin to one end of the metal bar with the wax from a candle. Hold the metal bar using tongs and heat the other end of the metal bar with a blue Bunsen flame. Time how long it takes before the coin falls off.
4 Hypothesise what might happen if you used another metal bar of the same length and size but made of a different material. Test this hypothesis by repeating step **3** with the new metal bar.
5 Inflate a balloon. Draw two felt-tip pen lines exactly 10 cm apart on the balloon. Place the balloon in the bucket of ice water. What happens to the lines? Place the balloon in the bucket of warm water. What happens to the lines?

Results

Record all observations and descriptions from each step of the procedure.

Discussion

1 Write a sentence explaining your observations from each step of the method, referring to the particles, their energy, their movement, strength of their attraction etc.
2 Do you think a balloon can be used as a thermometer to measure temperature? Find out about how gas thermometers are made and used.

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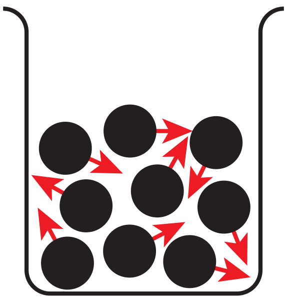
Section 11.1 questions

QUIZ

Remembering



1 **Recall** the four key points of the particle model.
2 **Name** the state in which particles vibrate in a fixed position.
3 **Name** the state shown in the diagram to the right.
4 **Name** the state in which particles have the strongest attractions.
5 **Define** the term 'diffusion'.
6 **Identify** the word that describes the change you expect to see when a metal is heated.

Understanding

7 At room temperature, in which state do the particles of a substance have the most energy? **Justify** your answer by providing evidence for your choice.
8 **Describe** what happens when you heat up particles.

Applying

9 **Distinguish** between solids, liquids and gases. Include a diagram to model the different states. **Compare** the closeness of the particles, the speed at which they move and list some examples.

Analysing

10 Use the particle model to **explain** why food colouring and water mix together but food colouring and ice do not.

Evaluating

11 **Account** for how a mercury thermometer works.

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11.2 Properties of solids, liquids and gases

Learning goals

1 To describe the physical and chemical properties of solids, liquids and gases.
2 To define 'density'.

DOC WORKSHEET

Scientists often refer to properties when they talk about the different states of matter, but what does that mean? The two types of properties scientists refer to are **physical properties** and **chemical properties**.

physical property
the way a substance looks and acts; a characteristic of a substance that can be observed and/or measured without changing it chemically

chemical property
the behaviour of a substance when it reacts with another substance

density
how much matter (mass) is contained in a certain volume of a substance

compress
squeeze to make smaller

	Property	
	Physical	**Chemical**
Definition	The way substances look and act. A characteristic of a substance that can be observed and/or measured without changing it chemically	The behaviour of a substance when it reacts with another substance
Examples	Colour, size, solubility, melting point, hardness, boiling point, conductivity, shape and **density**	Burns or explodes in oxygen, rusts or corrodes, acidity, biodegradability
Picture		

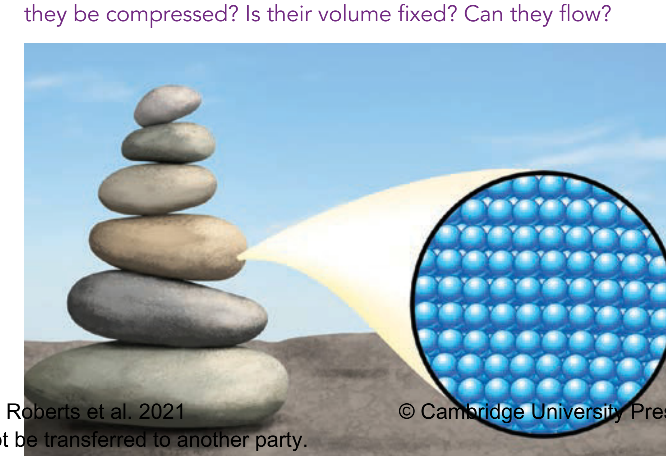
Table 11.1 The two types of properties investigated when looking at matter

If you had a chance to explore the properties of solids, liquids and gases in the previous practical, you will have figured out a number of the key properties of solids, liquids and gases on your own! Let's just run through them and explain them using what you already know from covering the particle model.

Solids

Earlier in this chapter you learned that the particles in a solid are packed so tightly together and the forces of attraction between particles are so strong that the particles cannot move freely; they are fixed. This is why solids usually have a shape and volume that cannot be changed and why they are hard to break apart. This also explains why solids cannot easily be **compressed** (squashed) and cannot be poured.

Figure 11.11 Consider these rocks and the arrangement of their particles shown in the diagram. Are their shapes fixed? Can they be compressed? Is their volume fixed? Can they flow?



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Density

You may have noticed density was mentioned in Table 11.1 on page 446. Density is an important physical property as it allows us to determine whether an object will float or sink. It describes how heavy or light something is for its size, but it is not the same as its weight or mass. For example, 1 kg of steel always weighs the same as 1 kg of feathers (they are both 1 kg), but the space they take up is very different. Density can therefore be defined as the measurement of how much matter (or mass) fits in a certain amount of space (or volume). So, the more dense an object is (like steel), the more mass there is in a particular volume. The relationship between density, mass and volume can be written as a scientific equation:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

Practical 11.3

Calculating density

Aim

To design and conduct an investigation to measure the mass and volume of different objects. Then use this information to calculate the density of the objects and determine whether they would float or sink in water.

Materials

- ruler
- large measuring cylinder
- 8 small random objects

Procedure

When you design your experiment, consider the following questions.

- What measurements do you need to be able to work out the density of an object?
- How will you measure the mass of the random objects you have access to?
- How will you measure the volume of the random objects you have access to? What will you do with objects of regular and irregular shape?
- How will you record your data? Perhaps a table would help.
- How will you calculate density?
- What is your prediction for the results? Which items do you expect will float and which will sink?

Before beginning, your teacher will show you how to determine volume using the water displacement method. You will then write up your intended method step by step, as though it was going to be published in a textbook. Then check with your teacher that you can begin your investigation.

Results

1. Record your prediction.
2. Write your method step by step.
3. Record your measurements in a table using the headers below.

Object	Mass (g)	Volume (cm^3)	Float or sink?	Density (g/cm^3)

4. Using the equation for density, calculate the density of the objects you had access to.

Discussion

1. The density of water is 1.00 g/mL. If an object has a density of less than 1.00 g/mL, it should float in water. If an object has a density of greater than 1.00 g/mL, then the object should sink when placed in water. Did your results show these statements to be true?
2. Were your predictions correct?
3. Identify the advantages and disadvantages of using the water displacement method for determining volume.
4. Would your results be different if you used a different liquid to water? Explain your reasoning.
5. Were there any steps of the practical that you would do differently if you were to repeat the task? How would you improve them next time?

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Quick check 11.4

1 List some properties of a solid.
2 Copy and complete the table below.

Properties of a solid according to particle model	Behaviour of a solid as a result of property
Packed tightly together	
	Hard to break apart
Particles in solids cannot move freely; they vibrate in one spot, which is called a fixed position.	

3 A substance like sand can be poured and does not have a fixed shape. Is it a solid? Explain.
4 a Explain the relationship between mass and density.
b Explain the relationship between volume and density.

Liquids

Liquids are held together by the forces of attraction between particles, but these forces are not as strong as in solids. The particles of a liquid can move more freely and flow (be poured) and therefore take on the shape of the container they are in. Due to gravity, the shape the liquid takes on will always be at the bottom of the container into which it is placed. Although their shape can change, liquids have a fixed volume and mass. Like solids, they cannot be compressed into 'much' smaller spaces. The particles can actually be pushed a tiny bit closer together, but it takes a massive effort, and so we generally say that the particles in a liquid are so closely packed that they cannot be compressed.

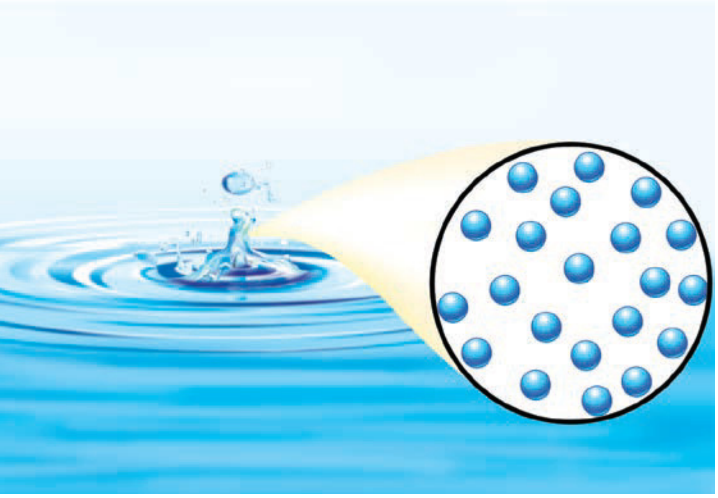

Figure 11.12 Consider the tap water and the arrangement of its particles shown in the diagram. Is its shape fixed? Can it be compressed? Is its volume fixed? Can it flow?

Remember, you learned about the idea of density being a physical property of solids earlier in this section. Density is also a physical property of liquids (and gases)! What is interesting to note, is that the density of a liquid is affected by temperature – the hotter a liquid is, the less dense it will be. Think about what you know about the particle model; how could you explain this?

Try this 11.4

Make your own lava lamp!

Search the internet for instructions on how to make your own lava lamp at home. It is safe and easy to do. Begin by measuring the mass of a cup of oil and a cup of water (this is an equal volume). Which one is heavier? So, which one is more dense? How can you explain this using the particle model and your understanding of density? Think about how an effervescent tablet was used to power your lamp – what is used in real life? Explain how temperature affects the density of substances.

Figure 11.13 A lava lamp demonstrates density, one of the physical properties of liquids.

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Gases

Scientists know the force of attraction between the particles in a gas is weak because the particles are far apart. This means that gases have no fixed shape or volume – they spread out to take up any space that is available. Keep in mind though, that if the container you put a gas in does not have a lid, the gas particles will bounce off the walls and spread out by diffusion. Due to the large spaces between gas particles, there is plenty of space for the particles of a gas to be squashed together or compressed.

VIDEO
Why does an aerosol can get colder when sprayed?

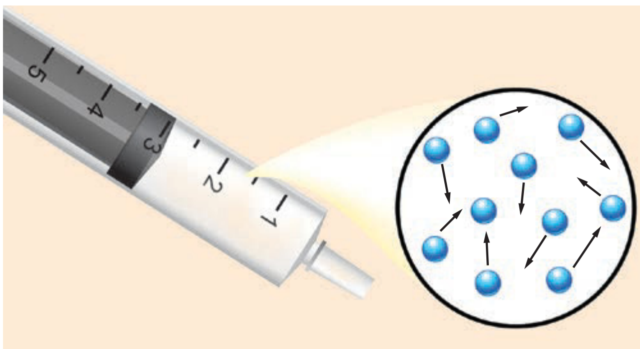

Figure 11.14 Consider the air in the first 3 cm of this syringe and the arrangement of the air particles shown in the diagram. Is its shape fixed? Can it be compressed? Is its volume fixed? Can it flow?

Quick check 11.5

1 Define the terms 'volume' and 'mass'.
2 Contrast the shape and volume of solids, liquids and gases.
3 Copy and complete the following table to describe the particle structure and properties of solids, liquids and gases.

State	Examples	Particle diagram	Properties
Solid			
Liquid			
Gas			

Explore! 11.2

Gases can be compressed because there is a lot of space between the particles. There are lots of different places where you can see the result of such compression; for example, oxygen tanks for diving, air freshener sprays, deodorants and fire extinguishers that are filled with carbon dioxide.

1 Why is carbon dioxide a good choice for extinguishing fires?
2 Use the particle model to explain why gases can be compressed.
3 Explain why carbon dioxide in a fire extinguisher is under a lot of pressure.

Figure 11.15 You may find a common fire extinguisher in the home and at school.

Try this 11.5

Making oobleck

Find a recipe on the internet for making oobleck (cornflour and water) and make some to play with. Ask yourself these questions.

- Can it be rolled into a ball? Can it be stretched? Does it flow and take the shape of its container? What happens when a ball of oobleck is dropped?
- What are the physical properties of oobleck?
- Based on its properties, is it a solid or liquid?

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Section 11.2 questions

QUIZ

Remembering

1 **Describe** how a liquid behaves in a container and what happens if it is put in a different container.

2 **Describe** how a gas behaves in a container and what happens if it is put in a different container.

3 **Outline** how particles in a solid behave. Use these terms in your answer: fixed, vibrate, shape, compressed, attraction.

Understanding

4 **Summarise** the properties of a gas in two sentences.

5 **Explain** why steam can be compressed but ice cannot.

Applying

6 **Organise** the following statements into the correct place to describe solids, liquids and gases. Some statements may apply to more than one state. You may use a Venn diagram.

Strong attraction between particles that are not as close	Particles that are free to move, no strong attraction	Strong attraction between close particles
Easy to compress	Definite shape	Can be poured
Expand to fill a container	Particles in a fixed position	Difficult to compress
Fixed volume	Not a fixed shape	

7 Imagine a single grain of sand. It is hard and has a definite shape. If you scoop up a handful of dry sand, you can pour it out of your hand, which sounds like liquids, not solids. It is very difficult to build a sand castle with dry sand. However, if you wet the sand, you can shape it into a sand castle.

a **Justify** why you might classify sand as a solid.

b **Justify** why you might also classify sand as a liquid.

Figure 11.16 Sand seems to have different properties when it is wet and when it is dry.

Analysing

8 A plastic toy unicorn floats in liquid X but sinks in liquid Y. **Explain** what this tell us about the densities of the unicorn, liquid X and liquid Y.

9 The table on the right lists the densities of several materials. Which material will float in water? **Justify** your answer referring to the materials in the table as evidence.

Material	Density (g/mL)
Plastic	0.90
Water	1.00
Sulfur	2.07
Steel	7.80
Rubber	1.20

10 **Outline** two ways you could find out if a material is a solid.

11 The metal lid of a glass jar is stuck and cannot be undone. Kim runs the lid under hot water, and now the lid can be unscrewed. Using your understanding of the particle model and the properties of matter, **explain** why Kim used the hot tap.

Evaluating

12 **Discuss** how and why the properties of a liquid are different from the properties of a gas.

13 Office chairs, like the one shown in Figure 11.17, usually have a lever on the side for adjusting their height. The stand contains a cylinder and a piston that can move up and down inside it and consequently, the chairs often feel quite springy when you sit on them. Would the cylinder contain a solid, a liquid or a gas? **Justify** for your answer.

Figure 11.17 An office chair

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11.3 Changing states

Learning goals

1 To explain how matter changes state.
2 To describe the processes of evaporation, sublimation, boiling, freezing, melting, condensation and deposition.

Under the right conditions, all matter can change from one state to another; for example, from a solid to liquid, liquid to gas, or liquid to solid. This may occur because of a change in temperature or pressure, which may be naturally occurring or caused by humans.

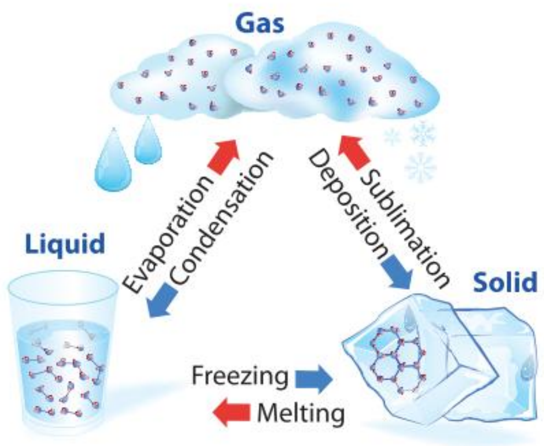

Figure 11.18 Changes in the state of water

Adding heat

You know that heating up a substance causes an increase in temperature, but did you know that if enough heat is added, the substance can actually change its state!

Melting: when heat causes a solid to become a liquid. Remember that heating a substance gives the particles of that substance more energy and this makes the particles move or vibrate faster. Well, if you add enough heat to the particles, the edge of the solid will eventually vibrate so much that the forces of attraction between the particles will be reduced slightly and some of them will break free. The temperature at which this occurs is called the **melting point** of the substance. Different substances respond to heat differently and therefore have different melting points. It is not surprising that when a substance changes from a solid to a liquid (by melting), its properties also change; however, the substance remains the same. For example, melting ice involves solid water forming a liquid form of water and the properties are very different (hardness, ability to be poured, shape), but they are both water.

DOC WORKSHEET

WIDGET Metals and melting points

Evaporation (or vaporisation): where heat causes a liquid to become a gas. Adding heat, and therefore energy, to a liquid causes the particles of the liquid to move faster and spread out, and this increased distance decreases the attraction between particles. If there is enough heat added to the liquid, the particles at the liquid's surface can vibrate or move so fast they break away from the rest of the particles and form a gas.

melting
when heat causes a solid to become a liquid

melting point
the temperature at which a specific solid melts

evaporation
when heat causes liquid to become gas

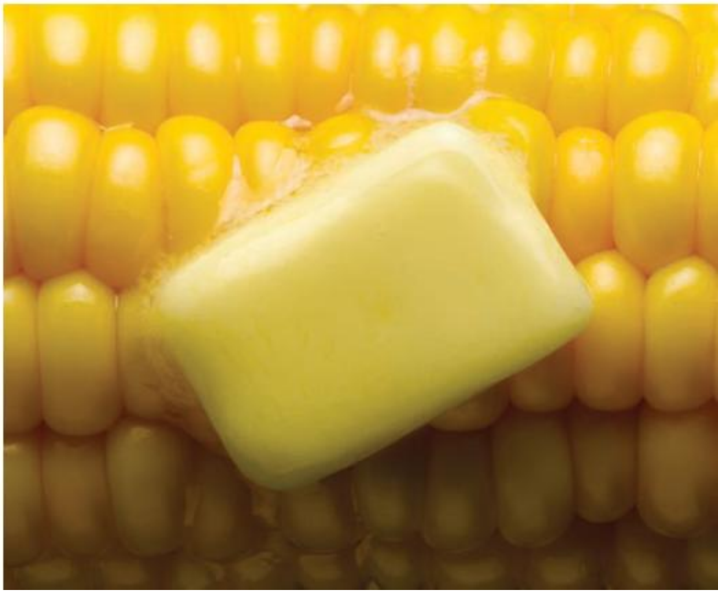

Figure 11.19 Melting butter on a hot cob of corn involves a solid forming a liquid. The properties may change but it is still butter.

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For example, at a natural hot spring, water changes state from liquid to vapour, and some of it changes back to liquid droplets forming clouds. Evaporation can, however, occur at a range of temperatures. Consider the clothes you hang on the line to dry. They will dry by the water evaporating from the surface of the clothes. Drying is faster when it is sunny and hot, but clothes still dry on cooler cloudy days.

boiling
the rapid vaporisation of a liquid which occurs when it is heated to a temperature called the boiling point

Boiling: the rapid vaporisation of a liquid which occurs when it is heated to a temperature called the boiling point. When a substance reaches this temperature, it is very obvious that the substance is boiling. Vaporisation is starting to occur not just on the exposed surface but at various points throughout the liquid where bubbles of vapour form. You may have watched water boil at 100°C in a transparent kettle or saucepan. Bubbles containing water vapour begin to form low down in the water, which then expand, rise and break at the surface.

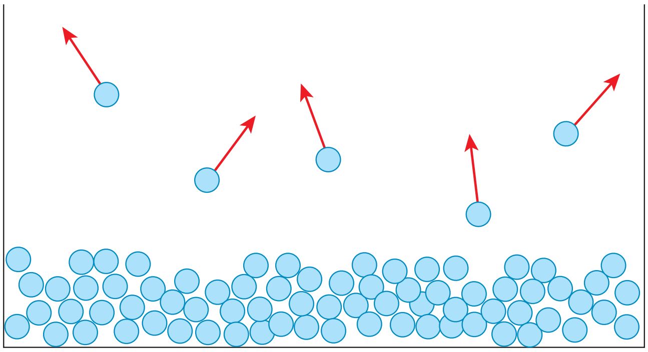

Figure 11.20 When heated, particles gain energy and spread out, allowing them to break free from the liquid and form a gas.

Figure 11.21 The bubbles in boiling water form low down in the liquid, then expand and rise to the surface.

Explore! 11.3

As with melting points, different substances have different boiling points too.

1 Find out the melting and boiling points of some different substances.
2 Draw up a table to record the melting point and boiling point of each of the substances you investigated.

Did you know? 11.2

Melting and boiling points can change!

Melting and boiling points depend on how far above sea level you are. The higher up you are, the lower the melting and boiling points would be. Even in Bathurst, which is only around 650 metres above sea level, the boiling point of water is around 97.7°C. Can you think of why this is the case?

sublimation
where heat causes a solid to become a gas, without passing through the liquid state

freezing
where heat is lost and a liquid becomes a solid

Sublimation: where heat causes a solid to become a gas. Most substances go through the process of melting and evaporating when heated; however, there are a few rare substances that skip the liquid state at room temperature. Dry ice (solid carbon dioxide) is an example you may be familiar with.

Removing heat

You know that cooling a substance causes a decrease in temperature, and, if enough heat is lost, the substance can change its state.

Freezing (or solidification): where heat is lost causing a liquid to become a solid. The process of freezing is the reverse of melting. As liquid cools, the particles lose energy and move or vibrate slower. If you remove enough energy, the particles will end up just vibrating in a fixed position, and due to their closeness, the particles will form stronger attractions with their neighbours than before, and a solid is formed. The point at which this occurs is called the freezing point. Different substances have different freezing points. For example, the freezing (and melting) point of water is 0°C, while the freezing (and melting) point of oxygen is –218.8°C.

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Figure 11.22 Snowflakes form when the liquid water turns into the solid ice.

Figure 11.23 Condensation forms on a window as the air cools.

Condensation: where heat is lost causing a gas to become a liquid. As a gas cools, the particles of gas lose energy and slow down. When they have slowed down enough, the particles come close enough together that they begin to attract one another, and consequently form a liquid. An example you may see every day is when the steam from your shower condenses on the mirror of the bathroom as the water vapour (gas) hits the cool mirror and forms a liquid.

Deposition (also known as reverse sublimation or desublimation): where a reduction in heat causes a gas to become a solid, without passing through the liquid state. Like sublimation, deposition is rare. However, it can be seen when, in sub-freezing air, water vapour changes directly to ice without first becoming a liquid.

condensation
where heat is lost causing a gas to become a liquid

deposition
where a reduction in heat causes a gas to become a solid, without passing through the liquid state

Try this 11.6

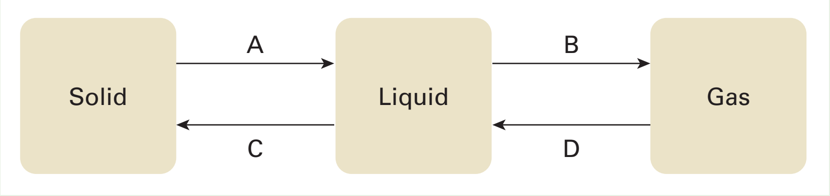
Changing state

Working with your classmates, role-play what heating a solid (a change in state between a solid and a liquid, liquid and a gas) would look like. Make sure you can explain what the particles are doing. What would occur if you were to enact what happens when a gas cools down?

Quick check 11.6

1 In your own words, define the processes of: melting, evaporation, boiling, sublimation, freezing, condensation and deposition. Add these terms to your glossary.

2 Solids, liquids and gases can change their state. In the diagram below, each arrow represents a change in state. Answer the following questions.



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...continued

a Which letter represents melting?
b What is the name of the process represented by the letter B?
c What happens to the particles in a solid when it becomes a liquid?
d What is the name of the process represented by the letter C?

3 Use the particle theory to explain these questions.
a What happens when you increase the temperature of a cube of frozen juice?
b What happens when you increase the temperature of liquid water?

Practical 11.4

Heating and cooling curves

Be careful

Take care when using the Bunsen burner, heatproof mat, tripod and glass thermometer. Be aware of the boiling water.

Aim

To investigate and construct the heating and cooling curves for stearic acid.

Planning

1 Complete some research and write a short summary about kinetic theory, energy and changes of state.
2 Write a risk assessment for this investigation.

Materials

- stearic acid (octadecanoic acid): There should be enough to fill approximately a quarter of a boiling tube. Solidified stearic acid can be stored in the boiling tubes and reused.
- boiling tube
- 250 mL beaker
- Bunsen burner
- tripod
- gauze mat
- heatproof mat
- thermometer/temperature probe
- retort stand and clamp
- stopwatch
- matches
- safety glasses

Procedure

1 Wearing your safety glasses, set up the equipment as shown in Figure 11.24.
2 Fill the beaker with 150 mL of water.
3 Heat the beaker on a tripod and gauze mat until the water just starts to boil. Maintain this at a gentle boil, pulling the Bunsen burner aside if it becomes too vigorous.
4 Record the temperature of the stearic acid every 30 seconds until it reaches 70°C. Make a note on your results table when the stearic acid starts to melt.
5 Carefully remove the boiling tube from the beaker using the clamp and record the temperature of the stearic acid every 30 seconds as it starts to cool.
6 Continue until it reaches 30°C. Make a note on your results table when the stearic acid starts to solidify.

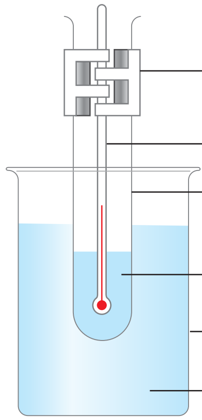

Figure 11.24 The equipment set-up you will need

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Results

1 Draw a suitable results table for this investigation.
2 Draw a line graph to show how the temperature of the stearic acid changed over the total time you took measurements. You should plot both sets of results on the one graph. Use a blue pencil to plot your cooling data and a red pencil to plot your heating data.

Discussion

1 Analyse your graph to deduce the freezing point of stearic acid.
2 Compare this temperature with the melting point temperature indicated on the graph.
3 Explain what is happening to the particles in the solid stearic acid as they are melting.
4 Explain why parts of the graph are horizontal lines. Think about what is happening. Shouldn't the temperature be increasing if the Bunsen burner is still on? Where is the energy going?
5 Identify any potential sources of error in this experiment.
6 Suggest any changes that could be made to the method to improve the quality of the data in future experiments. Justify your suggestions by explaining how each change will improve the data quality.

Conclusion

Draw a conclusion from this investigation regarding kinetic theory and energy. Justify your answer with data.

Advances in science 11.1

Is hot water different from cold water?

You have just been investigating the three states of water – solid ice, liquid water and water vapour (gas). However, our understanding of the states of water is changing! In April 2016, an international team of scientists revealed that they had found signs that liquid water might actually come in two different states. The researchers were surprised to find a number of physical properties of water change their behaviour between 50°C and 60°C. This could have a massive impact on our understanding of biology and environmental science.

Section 11.3 questions

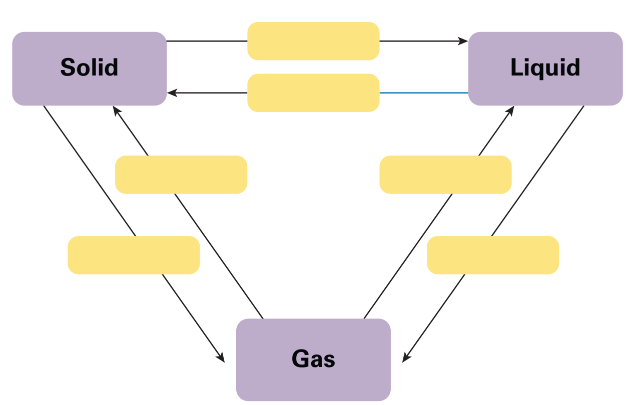
Remembering

1 **Recall** what happens to the closeness and energy of particles when you heat up something. What about cooling something instead?

QUIZ

Understanding

2 Copy this diagram and **label** the yellow boxes with the name of the process (for example, melting, evaporation). Then colour over the arrows with blue or red pen/pencil to indicate whether you add heat (red) or take it away (blue) to achieve that change of state.



Applying

3 For each of the following processes, **state** whether energy is added or taken away.
 a Sublimation
 b Evaporation
 c Freezing
 d Condensation
 e Deposition
 f Melting

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4 **Describe** the process of ice melting and water boiling, using the following terms.

boil	boiling point	decrease
evaporate	gas	heat
increase	liquid	melt
melting point	particle	solid
space	speed	temperature

5 You get a can of creamy soda out of the fridge and leave it on the bench while you run to get a glass from the cupboard. When you return to your can, it has beads of water on the outside. **Explain** where the water came from and what change of state occurred.

Analysing

6 Answer the following questions using the information in Figure 11.25.
   a **Determine** which process that is happening between 2 and 4 minutes.
   b **Determine** which state of matter that is present at U.
   c **Determine** the temperature of the boiling point.
   d **Describe** the time period at which the whole substance is in liquid form.

7 Use the information in Table 11.2 to answer the following questions.
   a **Determine** which substance has the highest melting point.
   b **Determine** which substance has the lowest melting point.
   c **Order** the substances from lowest boiling point to highest boiling point.
   d **Name** one substance that is a gas at 20°C.
   e **Name** one substance that is a liquid at 20°C.
   f **Name** one substance that is a solid at 20°C.

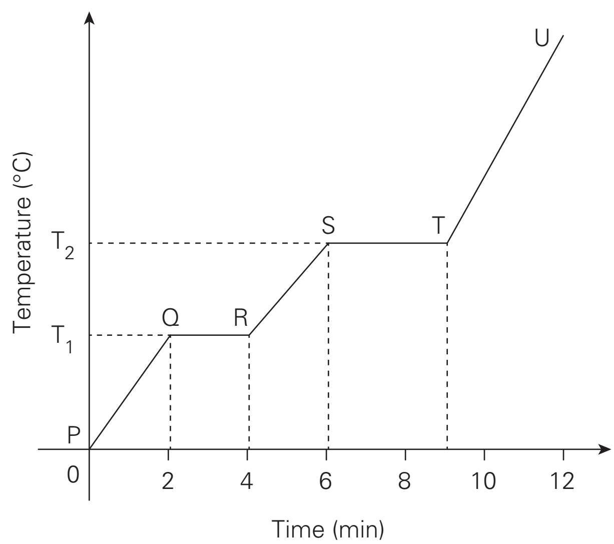

Figure 11.25 Heating curve of a substance that exists as a solid at time 0 minutes

Substance	Melting/freezing point (°C)	Boiling point (°C)
Water	0	100
Aluminium	660	2467
Iron	961	2212
Alcohol	–130	78
Helium	–272	–268

Table 11.2 Melting, freezing and boiling points of different substances

Evaluating

8 In cold countries, rock faces can sometimes have pockets of water trapped inside cracks after it rains. **Assess** what might happen if the trapped water freezes when the temperature drops.

9 Dry ice is often used in filmmaking to make creepy horror cemetery scenes. **Propose** how dry ice is useful in this case. Include the state change involved.

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Chapter review

Chapter checklist

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

Success criteria		Check
11.1	**I can recall the particle model.** e.g. Define 'Brownian motion'.	
11.1	**I can describe the three states of matter.** e.g. Describe the arrangement and motion of particles in solids, liquids and gases.	
11.2	**I can describe the properties of different solids, liquids and gases.** e.g. Distinguish between physical and chemical properties.	
11.3	**I can describe how matter can change state.** e.g. Construct a diagram that links the following terms together: melting, condensation, boiling, freezing, deposition, evaporation and sublimation.	

Reflections

1 What **connections** come to mind when you think about states of matter and your everyday life?
2 What new concepts have **extended** your thinking about states of matter?
3 What information did you find **challenging** or confusing?

Data questions

Water exists naturally on Earth in three states: solid (ice), liquid (water) and gas (water vapour). Figure 11.26 shows the point at which water changes between these states at different temperatures and pressures.

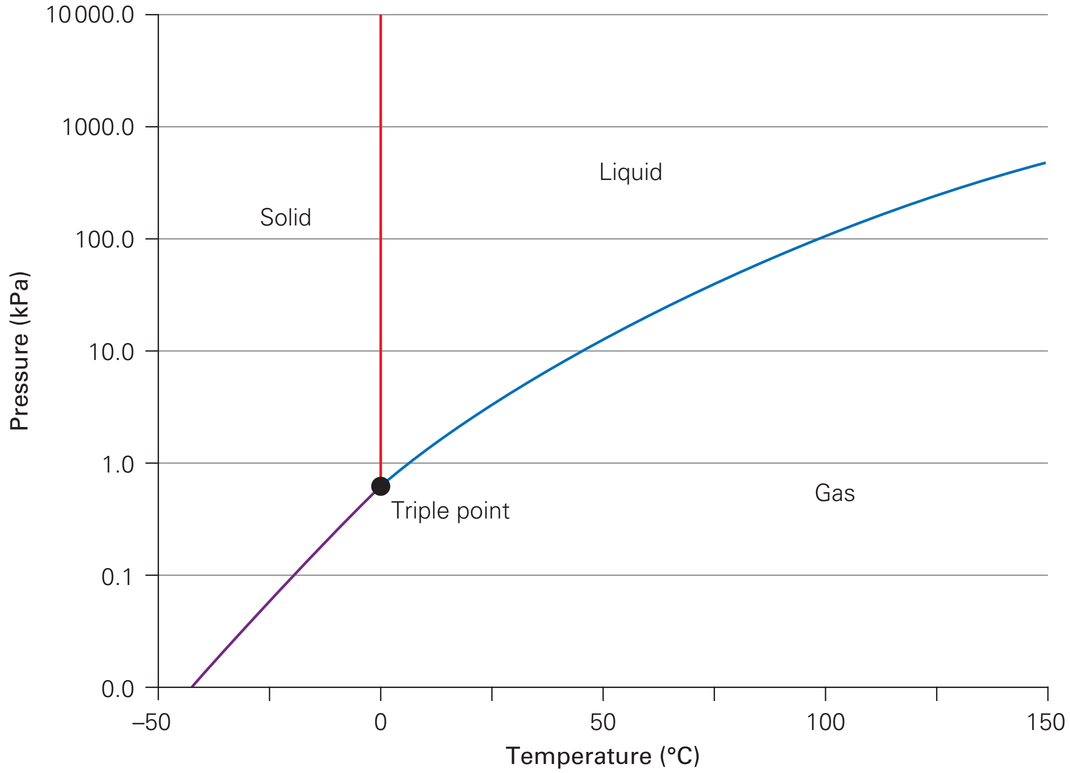

Figure 11.26 State changes of water at different temperatures and pressures. The purple line illustrates sublimation, the red line melting and the blue line the evaporation.

1 **Identify** the state of water at 50°C and 100 kPa.
2 **Identify** the temperature of freezing at 1000 kPa.
3 **Contrast** the boiling point of liquid water at 10 kPa pressure and 100 kPa pressure.
4 **Infer** what is meant by the 'triple point'.
5 Given that atmospheric pressure (the pressure at sea level) is approximately 101 kPa, **explain** why we tend to encounter water in its liquid state in our daily lives (puddles, rain, rivers, lakes, coming out of taps etc.).
6 **Predict** at what temperature liquid water will freeze at 20 000 kPa pressure.
7 **Justify** that, at atmospheric pressure (101 kPa), snow should melt, and not sublime.
8 Starting at atmospheric pressure (101 kPa), **deduce** whether the pressure needs to be increased or decreased at 0°C for ice to sublime.
9 **Deduce** whether it is possible for water to exist as a liquid above 100°C.

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STEM activity: Prosthesis design

Background information

Your skeleton protects your organs and gives your body shape and structure. Your skeleton is necessary for you to move, make blood cells, store calcium and more! You would look very different without it. For various reasons, not everyone has all the bones that complete their skeleton. Biomedical engineers act to combine engineering principles and problem-solving strategies for healthcare purposes. In this case, a biomedical engineer would study the strength and durability of our bones so that they can replicate them to make prostheses (artificial devices that replace body parts).

Design brief: Construct a lower-leg prosthesis that can assist in movement.

Activity instructions

In teams, you will become a biomedical engineer and investigate the technology of prosthetics.

Figure 11.27 Components of an artificial lower leg

Suggested materials

- ruler or tape measure
- scissors
- prosthetic structural materials from home, e.g. cardboard tubes, sponges, pants, shoes, rope
- roll of duct tape

Research and feasibility

1 Conduct research to find out what types of materials are used to manufacture prostheses, the physical properties of the materials, and design considerations of the prosthesis.

2 Consider important design factors using the table below. You can also add other design considerations.

Design consideration	Why this is important	Rank of importance
Aesthetics (how it looks)		
Cost of materials		
Customisation of the prosthesis (socket that connects the prosthesis)		
Usability (how easy it is to use)		

Design

3 Design a lower leg prosthesis and label all the design features. Consider the types of materials available, their durability and how it attaches to the limb to allow movement.

Figure 11.28 An artificial limb restores functionality and independence.

Create

4 Construct the lower leg prosthesis you have designed using the materials available.

Evaluate and modify

5 Create a reflection chart as shown below. Make sure you reflect on the strength, durability, usability, and comfort of the prototype.

Positives	Negatives	Interesting
e.g. Ankle movement is realistic and the ankle has a 60° range.	e.g. Cardboard tubing used was not strong and broke when tested.	e.g. The foam used around the tubing was a strong support for the tubing.

6 Explain the improvements and modifications you would make to the prototype in a presentation to the class.

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Chapter 12
Elements and compounds

Inquiry questions

What are atoms made of?

Why do all elements have different properties?

How do compounds form?

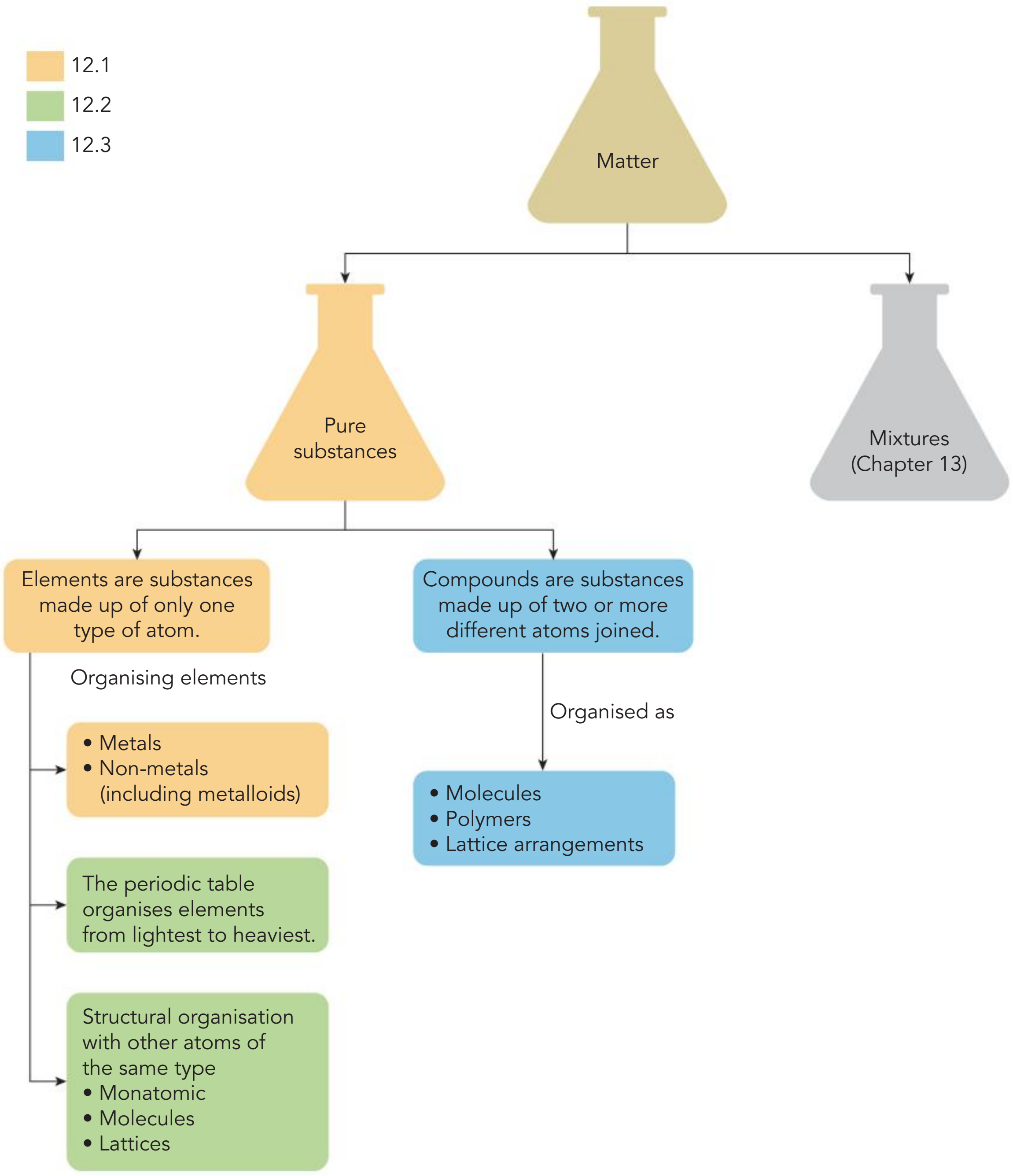
PRE-TEST

Chapter introduction

This chapter goes beyond the idea of there being many small particles in matter and further into the exciting world of chemistry. You will look at atoms, elements and compounds, the arrangement of the particles in these substances and compare their characteristics. You will also learn about their symbols and how to write chemical formulas. It's like learning a brand new language!

ISBN 978-1-108-99207-7

Chapter map



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12.1 Atoms and elements

Learning goals

1. To compare an element and a compound.
2. To describe a pure substance.
3. To describe the properties of metals and non-metals.

DOC WORKSHEET

In the last chapter, you learned about the particle theory of matter, and the relationship between solids, liquids and gases. Scientists refer to some of these tiny particles using the scientific term '**atom**'. This word comes from an ancient Greek word that means 'indivisible'. As you go through secondary school, you will learn more about atoms, but we are going to keep it simple for now. If you want to imagine how small atoms are, there are about 10 000 000 000 000 000 atoms in the dot at the bottom of this exclamation mark!

atom
the smallest possible piece of any substance; it makes up all matter

pure substance
material that is made up of either one type of atom or the same groups of atoms (molecules or compounds)

chemical bond
strong force of attraction that joins atoms together

element
substance made up of only one type of atom

molecule
two or more atoms joined together by strong covalent bonds

Try this 12.1

Cut a strip of paper 28 cm × 1 cm. Now cut it in half, and you will have two 14 cm lengths of paper. This is cut 1. Repeat this as many times as you can, counting your cuts as you go.

How many cuts were you able to make? Name one item that is the same size as the paper with 1 cut, 3 cuts, 5 cuts. How do you think you could keep cutting the paper smaller and smaller? Imagine this: it takes 31 cuts to get a piece of paper the size of an atom!

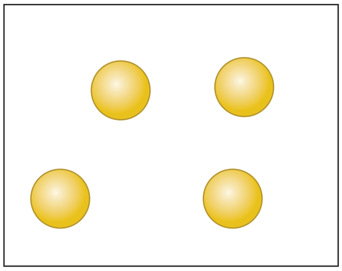
Pure substances and mixtures

In chemistry, substances are often classified into pure substances or mixtures. A **pure substance** is made up of only one type of atom or the same groups of atoms. Atoms don't usually exist on their own – often there are two or more atoms joined together. In this case, the strong force of attraction used to join atoms is called a **chemical bond**. There are several different types of chemical bonds: covalent bonds (a bond usually between two non-metal atoms), metallic bonds (bonds between metal atoms) and ionic bonds (a bond usually between a metal and a non-metal atom).

In this chapter, you will learn about two types of pure substances: elements and compounds.

An **element** is a substance made up of only one type of atom. These can be single atoms or atoms that are bonded together, but they are all the same type of atom. For example, gold is an element and is made up of many single gold atoms joined by metallic bonds. A combination of atoms are held together by strong covalent bonds is called a **molecule**. Atoms of the element hydrogen tend to bind together to form molecules, each with two hydrogen atoms joined by covalent bonds.

Atoms of an element



Molecules of an element

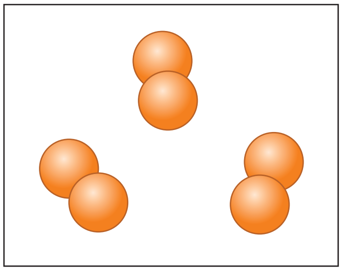


Figure 12.1 In an element, all the atoms are the same.

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A **compound** is a substance made up of two or more different types of atoms bonded together. For example, water is a covalent molecular compound, as it is made up of two hydrogen atoms bonded to one oxygen atom, joined by strong covalent bonds.

A **mixture** is a substance that is made up of two or more different pure substances (compounds or elements) that are not bonded together. For example, air is a mixture of several different elements and compounds.

compound
substance made up of two or more different types of atoms

mixture
a substance made up of two or more different pure substances (compounds or elements) that are not bonded together

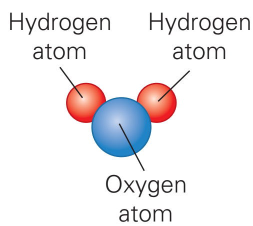


Figure 12.2 A water molecule is a compound, because it has two different types of atoms: one oxygen atom bound together with two hydrogen atoms. Water is also a pure substance, as it is made up of only one type of molecule, the one shown here.

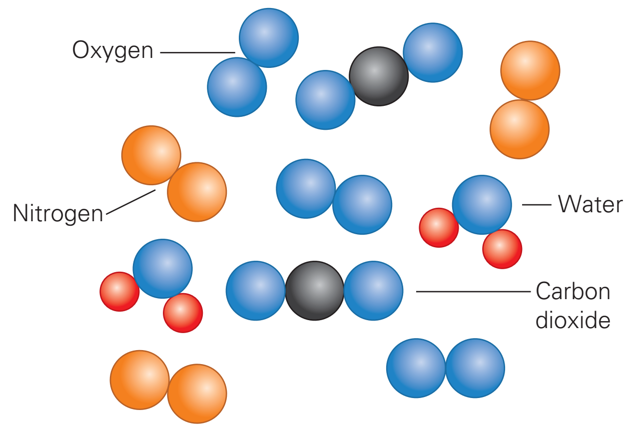
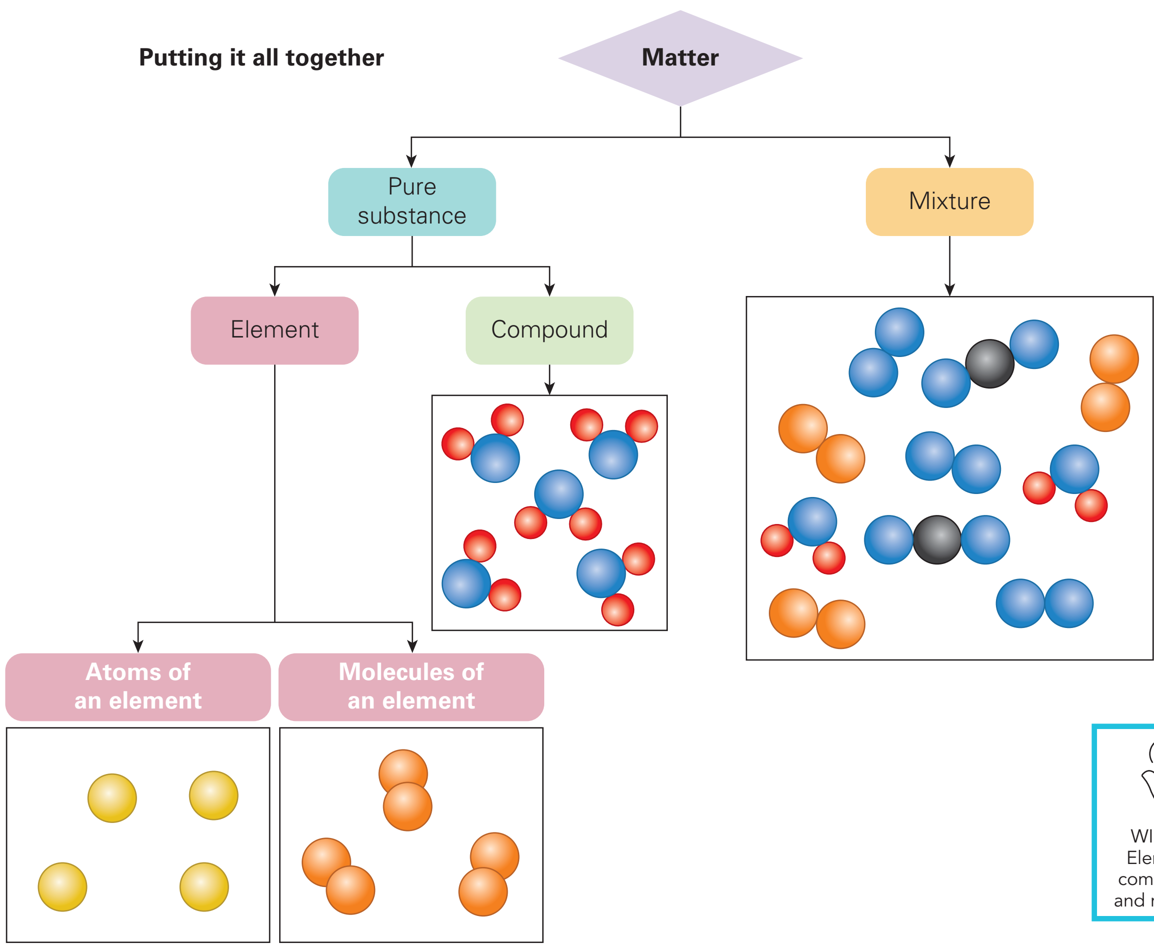


Figure 12.3 Air is a mixture of nitrogen, oxygen, argon, carbon dioxide, water vapour and very small amounts of other gases.



WIDGET
Elements, compounds and mixtures

Figure 12.4 Putting it all together: matter is made up of pure substances (elements and compounds) and mixtures.

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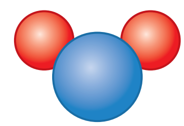
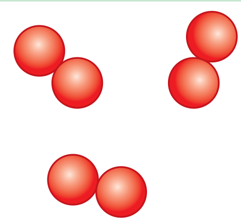
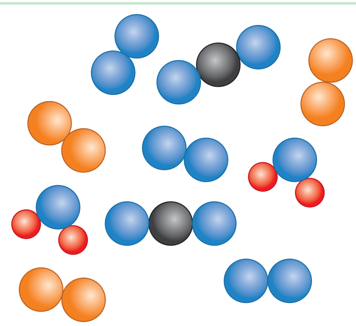
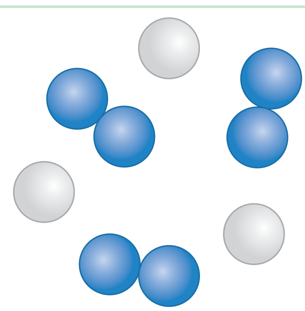
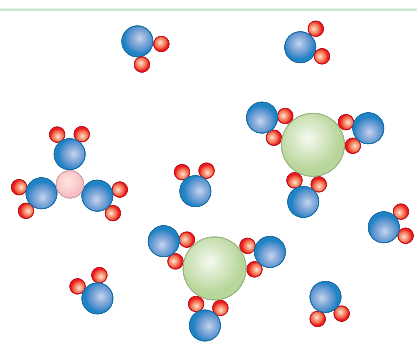
Quick check 12.1

1 Rewrite the following terms matched with their correct definitions.

Molecule	The smallest piece of substance you can have; it makes up all matter
Compound	Substance made up of only one type of atom
Chemical bond	Substance made from two or more different types of atoms
Element	Two or more atoms (same or different) joined together by covalent bonds
Atom	Strong force of attraction that holds atoms together

2 Rewrite the following table, matching each term and example with the correct diagram (A–E).

Term	Example	Diagram
Mixture of elements	Oxygen and helium	**A** 
Pure compound	Water	**B** 
Element	Hydrogen	**C** 
Mixture of compounds	Salt and water	**D** 
Mixture of elements and compounds	Air	**E** 

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Did you know? 12.1

Scanning tunnelling microscopes

You cannot see an atom with a light microscope, which is the type of microscope you may have at school. In 1981, a type of microscope called a scanning tunnelling microscope (STM) was developed that allowed scientists to finally see atoms. Since then, the technology has improved further, and in 2018, the world record for the highest resolution microscope was achieved by researchers at Cornell University, USA. Their transmission electron microscope (TEM) measures down to an impressively small one billionth of a metre.

Figure 12.5 Transmission electron microscopic (TEM) image of coronavirus OC43, a member of the same family of viruses that causes SARS-CoV-2 (the novel coronavirus that causes coronavirus disease 2019, or COVID-19).

Figure 12.6 This scanning transmission electron microscope in the USA is able to see single atoms.

VIDEO
How does a scanning tunnelling microscope work?

Elements

You have learned that elements are an example of a pure substance that is made up of just one type of atom or one type of molecule. Elements make up everything we know of. But what makes the elements differ from each other? They are made of different types of atoms.

Elements such as gold, tin, copper and iron have been used since antiquity, thousands of years ago. Since then, more and more elements have been discovered in the Earth's rocks, soil, air and water. Can you find out how many elements have been found in nature? Scientists have also made synthetic elements, but these artificial elements are highly radioactive and, because they are so heavy, most of them break down almost as soon as they are created.

Advances in science 12.1

In 2016, scientists announced that four new elements had earned a permanent place in the periodic table: elements 113, 115, 117 and 118. They are called nihonium (Nh), moscovium (Mc), tennessine (Ts), and oganesson (Og). The search is now on to synthesise elements 119 and 120, but this is harder than it sounds! A potential recipe for element 119 would be to take a tiny mass of berkelium, a rare radioactive metal, and then blast the berkelium with a beam of titanium ions for about a year. It could take 10 quintillion (10^{18}) titanium ions hitting the berkelium and a lot of luck to potentially make an atom of element 119, and even then, it would only exist for a fraction of a second.

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Figure 12.7 These rods are made of steel, a metallic compound made up of iron and carbon. Steel is ductile – it can be made into long thin rods and wires.

Grouping elements

Metals and non-metals

As in other areas of science, in chemistry we like to classify things into groups: pure substances/mixtures, solids/liquids/gases and so on. One of the first steps in classifying elements is to determine whether the substance is a **metal** or a **non-metal**. To do this, scientists look at the general properties that the elements have in common (see Table 12.1).

Metalloids

Some of the elements in the non-metal group look like metals. One example is silicon (see Figure 12.8). Silicon can conduct heat and electricity a little, but it cannot be bent or made into wire. It is shiny when polished but is brittle and can shatter like glass. When an element has properties of both metals and non-metals, it is called a **metalloid**. There are eight metalloids: antimony, arsenic, astatine, boron, germanium, polonium, silicon and tellurium.

metal
a substance that is shiny, can conduct electricity, can be bent, is usually silver/grey and is ductile

non-metal
a substance that is dull, cannot usually conduct electricity, is brittle and is not ductile

metalloid
a substance that has some of the properties of both metals and non-metals

lustre
the ability of a substance to become shiny when polished

conductivity
the ability of a substance to conduct or carry electricity or heat

malleability
the ability of a substance to be bent or flattened into a range of shapes

ductility
the ability of a substance to be drawn into a wire

Property	Metals	Non-metals
State at room temperature	Solid (exception is mercury)	Solid, gas or liquid
Colour	Silver/grey	A range of colours, including colourless
Lustre	Shiny when polished	Usually dull
Conductivity	Conducts electricity and heat	Cannot usually conduct electricity or heat
Malleability	Can be bent or flattened	Cannot be bent or flattened. Often brittle
Ductility	Can be made into a wire	Cannot be made into a wire
Melting point	Usually high temperature (exception is mercury)	Usually low temperature

Table 12.1 The general properties of the metal and non-metal elements

Figure 12.8 Three examples of metalloids. Left: Silicon is shiny and brittle, and can conduct electricity but not as well as a metal. Middle: Antimony is shiny like a metal, but brittle like a non-metal. Right: Boron conducts electricity but is brittle.

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Did you know? 12.2

Conductors and semiconductors

Some non-metals are good conductors. Carbon in the form of graphite is both a good heat and electrical conductor, and surprisingly, carbon in the form of diamond is the best known thermal conductor, with a conductivity five times higher than copper!

Metalloids have a heat conductivity between metals and non-metals, and if they can conduct electricity, this usually can only occur at higher temperatures. Metalloids that are good electrical conductors at high temperatures are called semiconductors. Silicon is an example of a semiconductor.

After oxygen, silicon is the second most abundant element in Earth's crust, but is rarely found naturally in its pure form. Instead, it can be extracted from silica sand, a combination of silicon and oxygen.

You may have heard of Silicon Valley in California and may think it's because of a number of technology company headquarters being located there. However, originally it was named after the silica sand found in the area.

Practical 12.1: Teacher demonstration

Metals vs. non-metals

Be careful

Electrical shocks may occur.
Elements may become hot.
Ensure the voltage output is not exceeded. Turn the power supply off when changing the circuit.

Aim

To investigate the properties of metals and non-metals.

Materials

- light bulb (LEDs can also be used)
- connecting wires and alligator clips
- battery or power pack
- fine sandpaper
- samples of six metals and non-metals – for example, sulfur, magnesium, silicon, copper, iron/steel, tin, zinc, aluminium, carbon

Procedure

1. Draw up a table like the one in the Results section. Include the six metals and non-metals you are investigating. Also select a property you would like to investigate as well as those already listed.
2. Use the fine sandpaper to rub each substance and determine its lustre – is it shiny or dull? Record your observations in your table.
3. Try to bend each of the substances – is it malleable or not? Record your observations in your table.

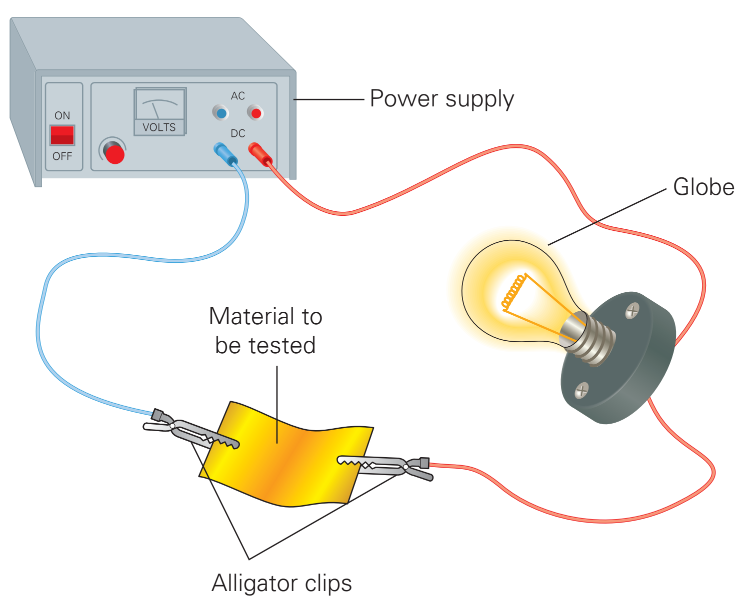

Figure 12.9 Experimental set-up for testing the electrical conductivity of different substances

4. Make a prediction about the electrical conductivity of each of the substances.

continued…

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...continued

5 Connect each substance as shown in Figure 12.9. Does it allow electricity to pass through, making the globe glow? Record your observations in your table.

6 Investigate your choice of property.

Results

Element	Lustre	Malleability	Electrical conductivity	Your choice of property
			Prediction:	
			Observation:	
			Prediction:	
			Observation:	
			Prediction:	
			Observation:	
			Prediction:	
			Observation:	
			Prediction:	
			Observation:	
			Prediction:	
			Observation:	

Discussion

1 Which of the substances you tested were metals and which were non-metals? Were there any exceptions? List them and name the group that these exceptions belong to.

2 Explain how you tested for your choice of property.

3 Recall the difference between a physical property and a chemical property. Then, summarise the physical properties that metals have in common and the physical properties that non-metals have in common. Name some exceptions and state how they are different.

4 Are the substances you tested elements, compounds or mixtures? Explain your answer by including definitions of these terms.

5 Imagine you have discovered a new element. What tests would you carry out in order to determine whether the substance was a metal or a non-metal?

Quick check 12.2

1 Define the following key terms: element, metals, non-metals, metalloids, malleability, lustre, conductivity, ductility. Provide examples where possible.

2 Demonstrate your knowledge of metals and non-metals by rewriting the following properties in the correct columns.

Metals	Non-metals
Solid, liquid or gas	Usually dull
Solid	Shiny surface
Usually unable to conduct electricity or heat	Can conduct electricity and heat
Ductile	Unable to be made into a wire
Low melting temperature	Malleable
High melting temperature	Unable to be bent

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Section 12.1 questions

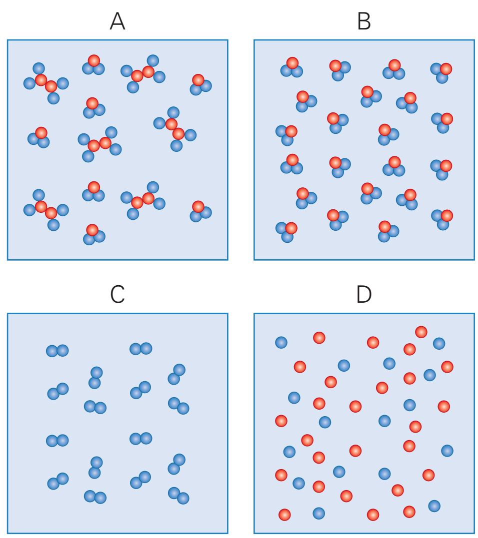
QUIZ

Remembering

1 **Name** the smallest part of an element.
2 **Define** the terms 'pure substance' and 'mixture', providing examples of each.
3 **List** three properties of metals and three properties of non-metals.
4 **Name** what holds two or more atoms together in a molecule.

Understanding

5 **Describe** how elements are like Lego® blocks.
6 Look at diagrams A to D below.



Select which diagram is:
- a an element
- b a compound
- c a mixture of elements
- d a mixture of compounds.

Applying

7 **Distinguish** between:
- a an atom and a molecule
- b an atom and an element
- c an element and a compound
- d a molecule and a compound.

8 **Summarise** three of the tests you can do to find out whether a substance is a metal or a non-metal. Provide a diagram if necessary.
9 **Explain** why carbon dioxide does not appear in the periodic table.

Analysing

10 **Distinguish** between chemical properties and physical properties, and include examples.
11 **Classify** each of the following substances as an element, a compound, a mixture of elements, a mixture of compounds, or a mixture of elements and compounds. Some of the substances are named, and some are provided as diagrams.

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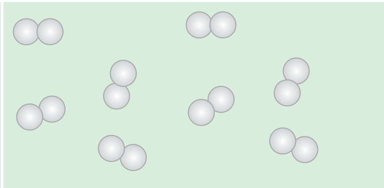
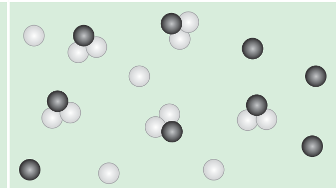
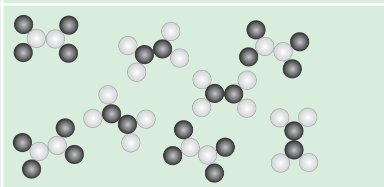
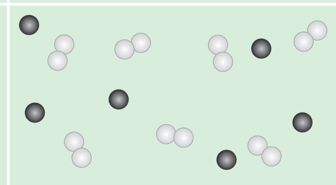
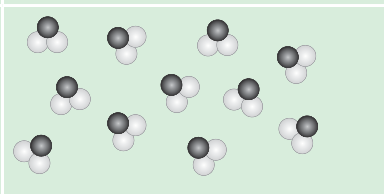
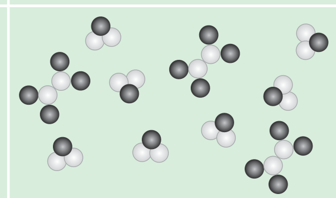
a	Chicken soup	b	Bismuth (Bi)
c	Dry ice (CO_2)	d	Concrete
e		f	
g		h	
i		j	

Evaluating

12 a Imagine using symbols, such as ❏, ♦ and ❖, to represent different atoms. **Deduce** how many different molecules can be made by joining these atoms together two at a time. How many can you make by joining three at a time?

b Consider what elements are and what compounds are. **Discuss** why there are many more compounds than there are elements.

13 **Justify** why the metalloids are considered a separate group from the metals and non-metals. Use an example to illustrate your point.

14 Here are the answers to some questions. **Propose** three options for what the question could be, for each answer.

a Properties

b Atom

c Conducts electricity

d Compound

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12.2 Organising elements

Learning goals

1. To explain why symbols are used to represent the elements.
2. To describe the molecular structure of pure substance.

Symbols for elements

Chemistry has its own language, with all the elements represented by symbols. It is a shorthand way of writing the name of the element so that every scientist in every country can understand it.

In Table 12.2, notice that sometimes an element's symbol comprises of the first and second letters of the English name. For example, the symbol for hydrogen is H, and the symbol for Helium is He. This is because if helium were to also have the symbol H, it would be confused with Hydrogen. Note that the first letter of the symbol is always capitalised and the second letter is never capitalised. But what about chlorine? You would think that chlorine would have the symbol Ch, but it is actually Cl. In this case it is distinguished by its third letter.

DOC WORKSHEET

Sometimes the letters from the element's Latin or Greek name are used. For example, the symbol for copper is Cu. The Latin word for copper is *cuprium* and this is where its symbol comes from. Another example is mercury, which has the symbol Hg, taken from its Latin name *hydragyrum*, which means 'shining water'. Some elements are also named after famous people or places, like einsteinium and francium.

Element	Symbol	Metal/non-metal	Melting point (°C)	Year of discovery
Hydrogen	H	Non-metal	−259	1766
Helium	He	Non-metal	−272	1895
Lithium	Li	Metal	180	1817
Beryllium	Be	Metal	1278	1798
Boron	B	Metalloid	2300	1808
Carbon	C	Non-metal	3500	Ancient
Nitrogen	N	Non-metal	−210	1772
Oxygen	O	Non-metal	−219	1774
Fluorine	F	Non-metal	−220	1886
Neon	Ne	Non-metal	−249	1898
Sodium	Na	Metal	98	1807
Magnesium	Mg	Metal	650	1755
Aluminium	Al	Metal	660	1825
Silicon	Si	Metalloid	1410	1824
Phosphorus	P	Non-metal	44	1669
Sulfur	S	Non-metal	119	Ancient
Chlorine	Cl	Non-metal	−101	1774
Argon	Ar	Non-metal	−189	1894
Potassium	K	Metal	64	1807
Calcium	Ca	Metal	850	1808

Table 12.2 Twenty elements, their symbols and some of their properties

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Quick check 12.3

1. Explain why not all the elements are named after the first letter of their name.
2. Recall the reason for using symbols instead of the elements' full names.
3. Refer to Table 12.2 on page 471 with the 20 elements listed.
   a. Name the elements with the following symbols: K, S, Mg, Be, B
   b. Identify the element with the lowest melting point.
   c. Identify the most recently discovered element.
4. Demonstrate your understanding of symbols by matching the following elements with their correct symbol.
   Names: hydrogen, carbon, oxygen, nitrogen, helium, sulfur, magnesium, aluminium
   Symbols: Mg, O, Al, S, N, H, C, He

Periodic table

A list of all the known elements and their symbols is called the **periodic table** (see Figure 12.10). It shows the elements in order from lightest to heaviest (also known as its mass), and even clearly shows which elements are metals, which are non-metals and which are metalloids. It can even give us clues to determine an elements internal structure.

periodic table
a list of all the known elements and their symbols

We know scientists like grouping similar things together, but imagine the challenge it would have been to organise 118 elements according to size and properties! Some elements are naturally occurring, and others have been created by humans. Some elements are radioactive.

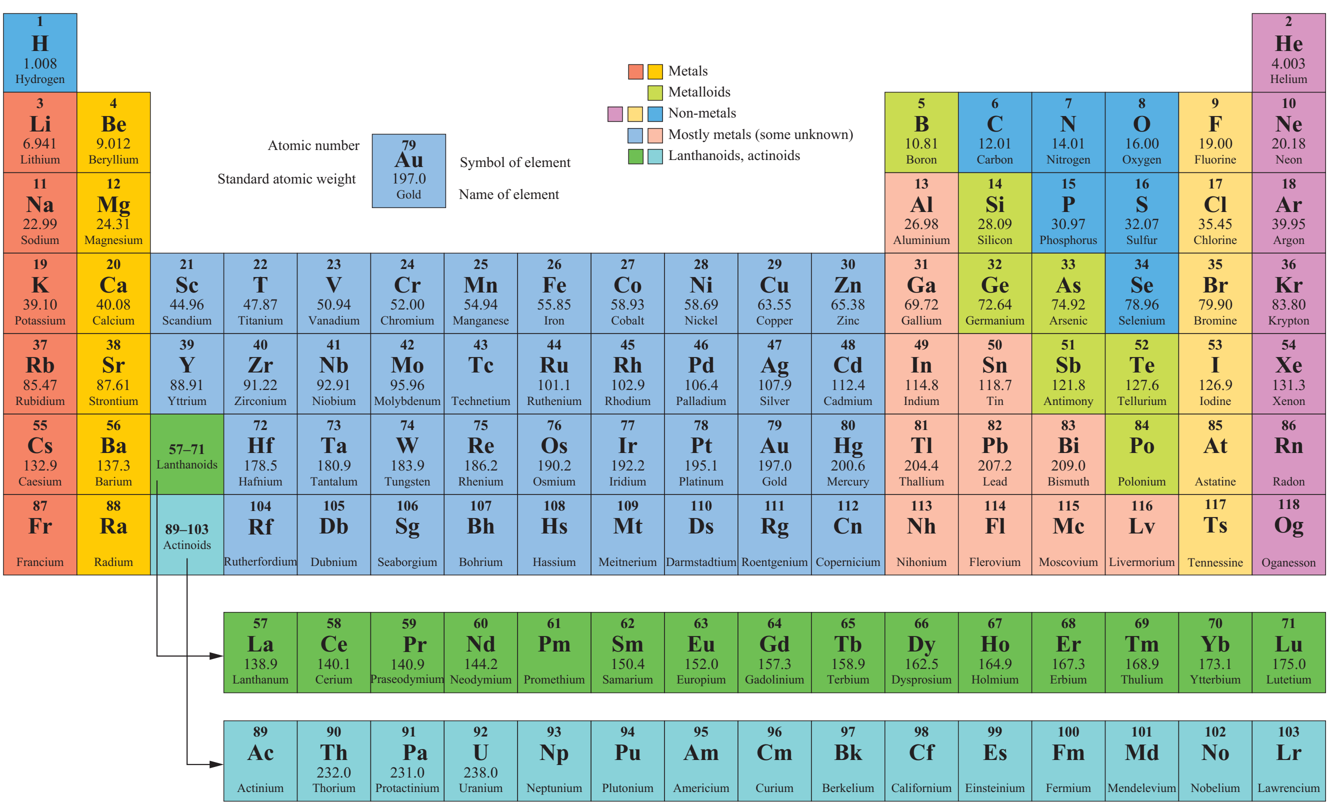

Figure 12.10 This periodic table includes all 118 known elements as of the year 2021.

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Try this 12.2

Look at the periodic table in Figure 12.10. Begin by finding some of the metalloids you know of, like boron (B), silicon (Si) and germanium (Ge). What colour are they in the periodic table? All the metalloids are the same colour. What are the symbols for the other metalloids?

Next, identify some of the metals you know of. Where are they in relation to the metalloids? What about the non-metals – where are they positioned in the table?

Quick check 12.4

1 Recall the purpose of the periodic table.

2 Here are some of the symbols in the periodic table that start with C or S. State the full element name for each symbol.

C	Si
Cl	S
Ca	Sc
Cr	Se
Co	Sr
Cu	Sn
Cd	Sb
Cs	Sm
Ce	
Cm	
Cf	

Practical 12.2

Flame tests

Be careful

Ensure appropriate personal protective equipment is worn.

Aim

To investigate the colour that a flame will go when an element is heated, and use this information to determine the metal element in four unknown samples.

Materials

- 5 M hydrochloric acid in labelled test tubes
- known test solutions in a test tube rack:
  - barium (barium chloride)
  - calcium (calcium chloride)
  - copper (copper(II) chloride)
  - strontium (strontium chloride)
  - sodium (sodium chloride)
  - four unknown samples
- heatproof mat
- Bunsen burner
- 10 flame test wires

Figure 12.11 A substance burning in the flame of a Bunsen burner, producing an orange flame

Procedure

1 Clean your flame wires by holding the metal loop in the hottest part of the blue Bunsen burner flame. If it is not clean, a coloured flame will appear, so clean it by dipping it into the hydrochloric acid provided and then holding the loop in the Bunsen burner flame again.

continued…

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...continued

2 Dip the clean flame test loop into one of the known test solutions, then hold the metal loop in the hottest part of the Bunsen burner flame. Record the colour of the flame in your results table.
3 Clean the flame test wire, then test another known test solution. Keep going until you have recorded the colour for all the known solutions.
4 Flame test the four unknown solutions and record their flame colours in a second results table.
5 Work out which metals are in each of the unknown samples and record in your table.

Results

Flame colours of known substances

	Barium	Calcium	Copper	Strontium	Sodium
Flame colour					

Flame colour of each unknown substance, and the metal indicated by the colour

	Sample 1	Sample 2	Sample 3	Sample 4
Flame colour				
Metal				

Discussion

1 Suggest why a blue flame, not a yellow flame, on the Bunsen burner is necessary.
2 List the elements that produced the most easily identified colours. Were there any colours that were tricky to identify?
3 Based on your observations, would this method be useful to determine the identity of metals that are in a *mixture*? Why or why not?
4 Give at least two reasons why the flame test may not always provide the right answer.
5 Describe some sources of faults for this experiment and the improvements you would make if you were to repeat this task.

A closer look at the organisation of elements

In Section 12.1, you learned that elements are substances made up of only one type of atom. These can be single atoms or molecules, but all are the same type of atom. Let's now look at the different ways that elements can be organised: as single atoms (**monatomic**), as molecules and as **lattices**.

monatomic made up of single atoms, all of one type

lattice a three-dimensional shape of atoms that pack together very tightly and form bonds that are extremely strong because the atoms bond to each other in all directions

diatomic element a molecule consisting of two atoms of the same type

Monatomic

Monatomic literally means 'single atom'. A monatomic element is made up of single atoms. There aren't many of these elements in the periodic table, and all of them are non-metallic gases. You are probably most familiar with neon, as neon signs are everywhere! But perhaps you are not as familiar with the monatomic elements helium (He), argon (Ar), krypton (Kr), xenon (Xe) and radon (Rn). Can you see where these elements all sit in the periodic table? (Refer back to Figure 12.10 on page 472.)

Molecules

Most non-metal elements have atoms organised as molecules. We are discussing elemental molecules, and so the atoms in these molecules are all the same type. Some gases, such as hydrogen and oxygen, form **diatomic elements**. These molecules have two atoms of the same type bonded together.

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Other elements exist in **polyatomic** form. Sulfur exists as S_8 and phosphorus exists as P_4. Oxygen can also exist as ozone (O_3).

Some examples of different molecular elements are shown in Figure 12.12. It is important, as you look at the diagram, to notice not only the range of molecules, but also how to write the chemical formula for elements that are molecules. For example, look at the oxygen molecule. It has two oxygen atoms, so we write O_2, where O is the elemental symbol for oxygen, and the subscript 2 shows how many atoms are joined by bonds in the molecule.

Lattices

polyatomic element a molecule containing more than two atoms of the same type

All metals in their solid state (and some non-metals, such as carbon and silicon) are organised in what we call a lattice formation. A lattice is a three-dimensional shape that allows the atoms to pack together very tightly and form the strongest bonds. The bonds are extremely strong because the atoms bond to each other in all directions, and so it is hard to separate them completely. With metals, it is easier to make them slide past each other, provided they stay in contact with each other. What properties of metals does this behaviour remind you of?

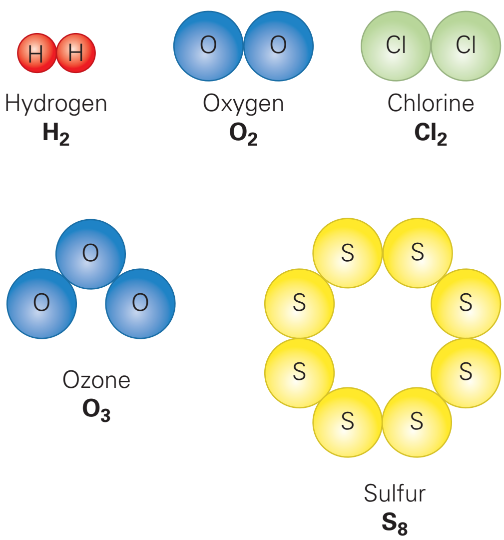

Figure 12.12 Some elemental molecules: hydrogen, oxygen, chlorine, ozone and sulfur

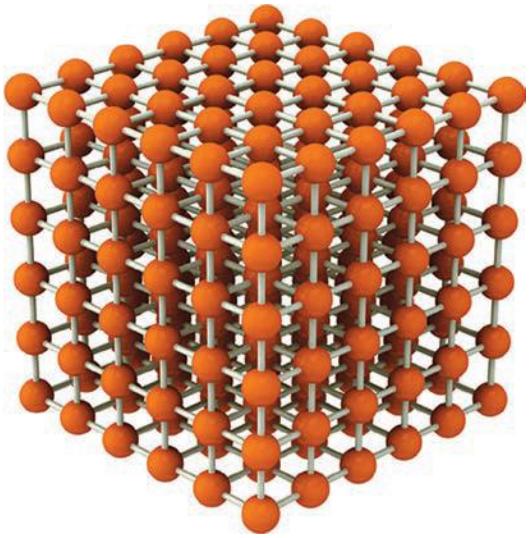

Figure 12.13 A lattice structure: every atom is attached tightly to other atoms in all directions

Try this 12.3

To imagine how metal atoms pack together and form a lattice, imagine marbles that need to be packed in a box. The marbles would be placed on the bottom of the box in neat, orderly rows and then a second layer of marbles would move into the spaces between marbles in the first layer. Give this a try, and you will model the lattice formed by metal atoms.

Figure 12.14 Stacking glass marbles of the same size in a box can be used to model how metal atoms pack together and form a lattice.

Quick check 12.5

1 Describe the three ways in which elements can be organised.
2 Draw a simple diagram to show the arrangement of atoms in a monatomic element, a molecule of an element and a lattice of an element.

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Explore! 12.1

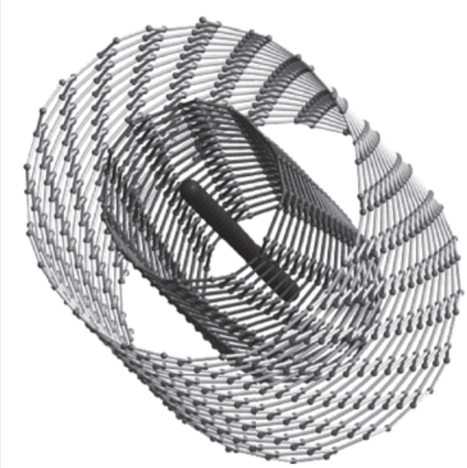
Carbon is an element that occurs in many different forms. They all consist solely of carbon atoms, but the way the atoms are organised differs. This affects the properties of the different forms.

1 Investigate one of the hardest substances in the world: diamond. Find out its uses and its properties.
2 Investigate the substance that is in the middle of your pencil: graphite. Find out its uses and its properties.
3 Investigate the coolest-sounding molecules: buckyballs. Find out their uses and their properties.
4 Compare the structure of the lattices of diamond, graphite and buckyballs. Do this by describing what each looks like and including a picture.

Advances in science 12.2

Carbyne

Carbon comes not just as diamond and graphite, and not just as buckyballs and nanotubes, but also carbyne! In 2013, Mingjie Liu and her team in the USA calculated the properties of this superstar material and discovered that it would have more strength than any known material. In 2016, scientists in Austria were able to make carbyne. It is difficult to build, as it is a long, one-dimensional chain of carbon atoms that are linked to each other, and it is unstable – as quickly as it is made, it is destroyed. The Austrian scientists got around this by building the carbyne inside a tube made of graphene (another form of carbon).



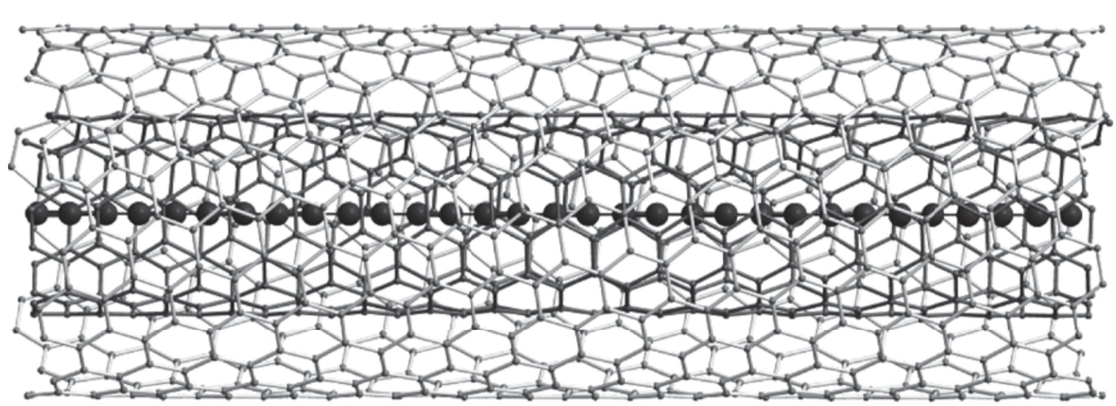


Figure 12.15 Scientists have made carbyne, a very strong material that lasts for a very long time.

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Section 12.2 questions

QUIZ

Remembering

1 **State** the chemical symbol for the following elements.
- a Carbon
- b Oxygen
- c Hydrogen
- d Silicon
- e Sodium
- f Copper
- g Chlorine
- h Potassium

2 **Name** these elements.
- a Ag
- b Au
- c Sn
- d Si
- e Hg
- f Na
- g Zn
- h Pb

3 **List** all the elements in the periodic table that have symbols beginning with the letter 'A'.

Understanding

4 Complete the sentences below by **selecting** the appropriate word from this list: elements, compound, symbol, properties, sulfur, pure, letters, carbon dioxide, periodic table.
- a An element's name can be written as a ________________ , which consists of one or two ________________ .
- b Elements are organised in the ________________ .
- c Two or more elements chemically combined make a ________________.
- d ________________ is an example of an element and ________________ is an example of a compound.
- e Elements and compounds are called ________________ substances because they have specific chemical and physical ________________.

5 **Identify** each of the following as either an element (E) or a compound (C).
- a Silver
- b Water
- c Wood
- d Plastic
- e Tin
- f Silicon dioxide
- g Chromium
- h Arsenic
- i Carbon dioxide
- j Sodium chloride (table salt)

Applying

6 **Classify** the following elements as monatomic, molecular or lattice: helium, diamond, hydrogen, aluminium, oxygen, argon, chlorine, copper, neon.

Analysing

7 **Distinguish** between a monatomic element and an elemental molecule.

8 **Distinguish** between an elemental molecule and a lattice. Include examples in your answer.

Evaluating

9 We use symbols to describe elements. **Propose** why we do this.

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12.3 Compounds

Learning goals

1. To name and identify common compounds such as water and carbon dioxide.
2. To use naming conventions to correctly name compounds.

DOC WORKSHEET

Compounds

At the start of this chapter, it was mentioned that in chemistry, substances are grouped into either pure substances or mixtures. Elements and compounds are both examples of pure substances. In Section 12.2, you learned about elements. Now you will look at compounds. To recap: a compound is a substance made up of two or more different types of atoms. For example, water is a compound. It is made up of two hydrogen atoms bonded to one oxygen atom, so it has two different types of atoms. Just as the 26 letters of the alphabet can form thousands of words, elements can form millions of compounds.

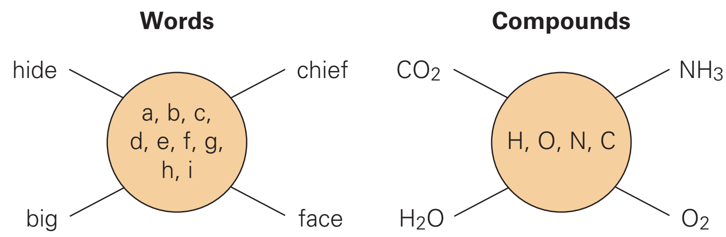

Figure 12.16 Elements are like the letters of the alphabet – letters can form thousands of words, and elements can form millions of compounds.

Compounds can be *covalent* or *ionic* – these terms describe the types of bonds that hold the compound together. Covalent compounds consist of units called molecules (e.g. water) while ionic compounds consist of units called ions (e.g. sodium chloride). The properties of a compound can be affected by the elements that are in the compound, the types of bonds between atoms and how they are arranged. For example, the properties of carbon vary depending on the arrangement of the carbon atoms. You learned about some of the different forms of carbon in *Explore! 12.1*: graphite, diamond and buckyballs. Hydrogen has the following properties: it is colourless, odourless, tasteless, non-toxic, non-metallic and highly combustible. However, the properties of the compounds formed from carbon and hydrogen are very different from the two elements on their own. Figure 12.17 shows examples of the uses and properties of compounds made of only carbon and hydrogen.

Figure 12.17 Substances that contain only carbon and hydrogen. From top to bottom: methane (natural gas); hexane (solvent in glue for shoes); octane (a component of automobile fuel)

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Organisation of compounds

A molecular compound is always the same size and shape, and it always has the same elements and number of atoms. It can be relatively small – a few atoms joined together – or it can be huge, like plastics that are made up of thousands of atoms and stretch for metres. The atoms in compounds can be arranged in three different ways: as a molecule, a **polymer** or a lattice. These are summarised in Table 12.3.

polymer
a long molecule made of a chain of atoms in a pattern that repeats

Arrangement	Description	Examples
Molecule	Groups of different atoms held together by covalent bonds. A particular compound always has the same elements in the same ratio.	Carbon dioxide (CO_2) Water (H_2O)
Polymer	A long molecule made of a chain of atoms in a pattern that repeats.	Plastics Natural fibres (e.g. cotton) Proteins
Lattice	A 3D continuous network of atoms in a fixed arrangement, held together by chemical bonds. However, most compounds that exist as lattices are ionic, so the lattices are made up of positive and negative ions rather than atoms.	Sodium chloride (NaCl) Silicon dioxide (SiO_2)

Table 12.3 The atoms in a compound can be arranged into a molecule, a polymer or a lattice.

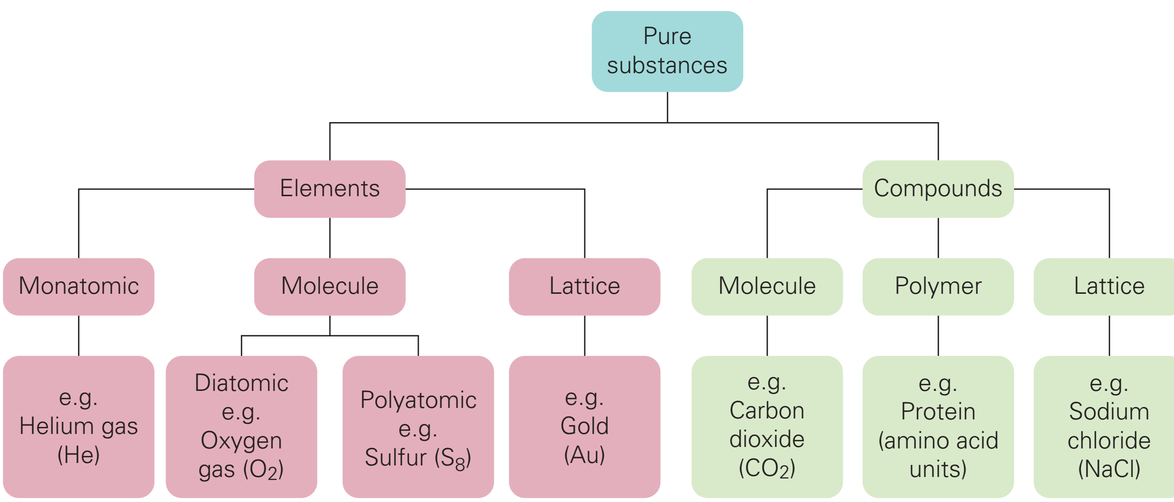

Figure 12.18 Summing up: the organisation of atoms in elements and in compounds

Did you know? 12.3

Polymer bank notes
In 1988, Australian scientists at the CSIRO developed the polymer bank note – the first in the world. Now polymer bank notes are also used in thirty other countries. Australian bank notes start out as plastic pellets, which are melted and blown into a bubble three storeys high! The walls of the bubble are pressed together and cooled to form laminated polymer film.

Figure 12.19 Australian polymer bank notes

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Quick check 12.6

1 Define the terms 'compound' and 'molecule'.
2 Explain why the properties of elements, and the compounds made up of those elements, are different.
3 Name two examples of compounds that have a molecular structure, two that have a polymer structure and two that have a lattice structure.

Symbols for compounds

A **chemical formula** is a shorthand way of describing the elements that are in a compound. The formula tells you which elements are present in the compound, and how many atoms of each element are present in one molecule or one basic unit of that particular compound.

chemical formula
a symbol for a compound that shows which elements, and how many atoms of each element, are present in one molecule or one basic unit of that compound

Figure 12.20 Sodium sulfate is a compound used in common household detergents.

Here are some examples.

- Carbon dioxide in the air has the chemical formula CO_2. This means that one molecule of the compound carbon dioxide has two elements in it: carbon (C) and oxygen (O). There is one carbon atom and two oxygen atoms.
- Sodium sulfate, found in common detergents, is an ionic compound and has the chemical formula Na_2SO_4. This means that one basic unit of the compound has three elements in it: sodium (Na), sulfur (S) and oxygen (O). Each basic unit of sodium sulfate contains two atoms of sodium, one atom of sulfur and four atoms of oxygen.

Try this 12.4

Consider the compound sodium bicarbonate, more commonly known as baking powder, $NaHCO_3$. First, identify the elements in one basic unit of the compound, and then how many atoms there are of each of the elements.

What if the formula has a bracket in it? Consider the compound aluminium carbonate. Its formula is $Al_2(CO_3)_3$. The brackets tell us that there is more than one CO_3 unit. In this case there are three units of CO_3. So, from the formula, we can see that there are three elements in each molecule of this compound: aluminium (Al), carbon (C) and oxygen (O). Each unit of aluminium carbonate is made of two atoms of aluminium, three atoms of carbon and nine atoms of oxygen.

Naming compounds

When naming a compound, there are some rules to follow depending on whether the compound contains a metal and a non-metal, or only non-metals.

Metal and non-metal compounds

1 If there is a metal in the compound, it gets named first. For example, $CaCl_2$ is calcium chloride. Calcium is the metal, so it is named first.
2 If the non-metal present is a single element, it will usually be named with a suffix, -ide. Again, Consider $CaCl_2$. As the non-metal present is only chlorine it will be named second as chlor*ide*.
3 When the non-metal component of a metal and non-metal compound contains more than one element, it usually takes a special name ending in -ate. Some common examples include; nitrate (NO_3), carbonate (CO_3), sulfate (SO_4) and phosphate (PO_4). For example, $CaCO_3$ would be named, calcium carbonate.

Non-metal and non-metal compounds

4 When you are working with only non-metals, such as oxygen (O) and chlorine (Cl), the start of the second element word changes based on how many atoms there are in the compound. For example, CO_2 contains one carbon atom and two oxygen atoms, and so the second word starts with a prefix di- and is called carbon dioxide. Another example would be the compound CO, which would be named carbon monoxide, as the second element starts with the prefix mono-. Table 12.4 summarises the prefixes used, depending on how many atoms of the second element there are in the compound.

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5 In some cases, there is more than one atom of the first non-metal element present, and in these cases the prefix is also used for the first element. For example, H_2O would be named dihydrogen monoxide, although you will be more familiar with its common name of water!

Number of atoms of second element	Prefix (start) of second element word	Example
1	Mono-	Monochloride
2	Di-	Dichloride
3	Tri-	Trichloride
4	Tetra-	Tetrachloride
5	Penta-	Pentachloride

Table 12.4 Prefixes used at the start of the second element when naming compounds containing only non-metals

Practical 12.3

Making a compound

Be careful
Do not look directly at the reaction. The reaction is very bright and can damage your eyes.

Aim

To make a compound from two elements, and to practise using elemental symbols and naming compounds.

Materials

- strip of magnesium ribbon (approximately 5 cm)
- fine sandpaper
- crucible with lid
- pipeclay triangle
- tripod
- safety glasses
- wooden tongs
- Bunsen burner and matches
- heatproof mat

Procedure

1 Examine the piece of magnesium and record its properties. If it isn't shiny and clean, gently use the sandpaper to remove any imperfections from the surface.
2 Coil the ribbon up and place it in the crucible with the lid. Place the crucible on the pipeclay triangle, as shown in Figure 12.21.
3 Put on your safety glasses. Heat the crucible with a blue flame, and every so often, monitor the reaction by using the tongs to carefully lift the edge of the crucible lid.
4 When the reaction has finished, the magnesium ribbon will no longer be recognisable. Turn off the Bunsen burner and let the crucible cool down.
5 Record what you see in the crucible.

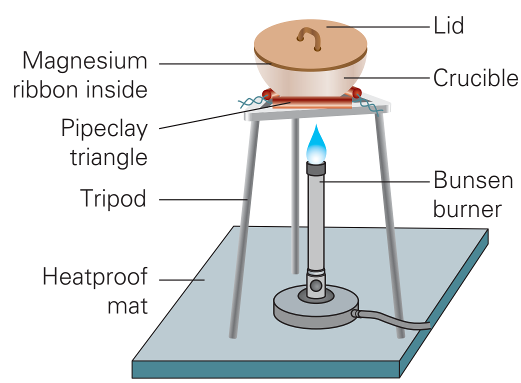

Figure 12.21 Experimental set-up

Results

Record your observations.

Discussion

1 Magnesium is an element. What is its elemental symbol?
2 When magnesium is heated, it reacts with something. What is the other element, and what is its elemental symbol? (Hint: think about what is in the air around you.)
3 Describe what you saw in the crucible after heating, and decide whether it is an element or a compound. Explain your answer.
4 Work out the chemical formula for this compound and the name of the substance formed in the crucible.

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Quick check 12.7

1 Complete the following table to identify the elements and number of atoms present in each compound.

Compound	Scientific name	Formula	List of elements	Number of atoms of each element
Natural gas	Methane	CH_4	Carbon, Hydrogen	C 1 H 4
Petrol	Octane	C_8H_{18}		
Alcohol	Ethanol	C_2H_6O		
Aspirin	Acetylsalicylic acid	$C_9H_8O_4$		
Eggshells	Calcium carbonate	$CaCO_3$		

2 State the formula for each of the following compounds.
  a Hydrochloric acid – contains one atom of hydrogen and one atom of chlorine
  b Glucose – a sugar, contains six carbon atoms, twelve hydrogen atoms and six oxygen atoms
  c Rust – contains two atoms of iron and three atoms of oxygen.

3 Determine the names of the following compounds.
  a One carbon atom and four chlorine atoms
  b Two hydrogen atoms and one oxygen atom
  c One magnesium and one oxygen atom.

Practical 12.4

Breaking down a compound

Be careful
Safety glasses must be worn at all times.
Wash hands thoroughly at the end of the experiment.

Aim
To investigate the breakdown of copper carbonate.

Materials
- copper carbonate
- limewater
- 3 test tubes
- straw
- Bunsen burner
- matches
- heatproof mat
- wooden tongs
- paper towel
- retort stand and clamp
- delivery tube and stopper
- spatula

Procedure
1 Half fill a test tube with limewater. Using the straw, blow into the limewater so it bubbles. Record your observations when CO_2 from your breath is bubbled through limewater.

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...continued

2 Use the diagram in Figure 12.22 as a guide to the steps that follow.

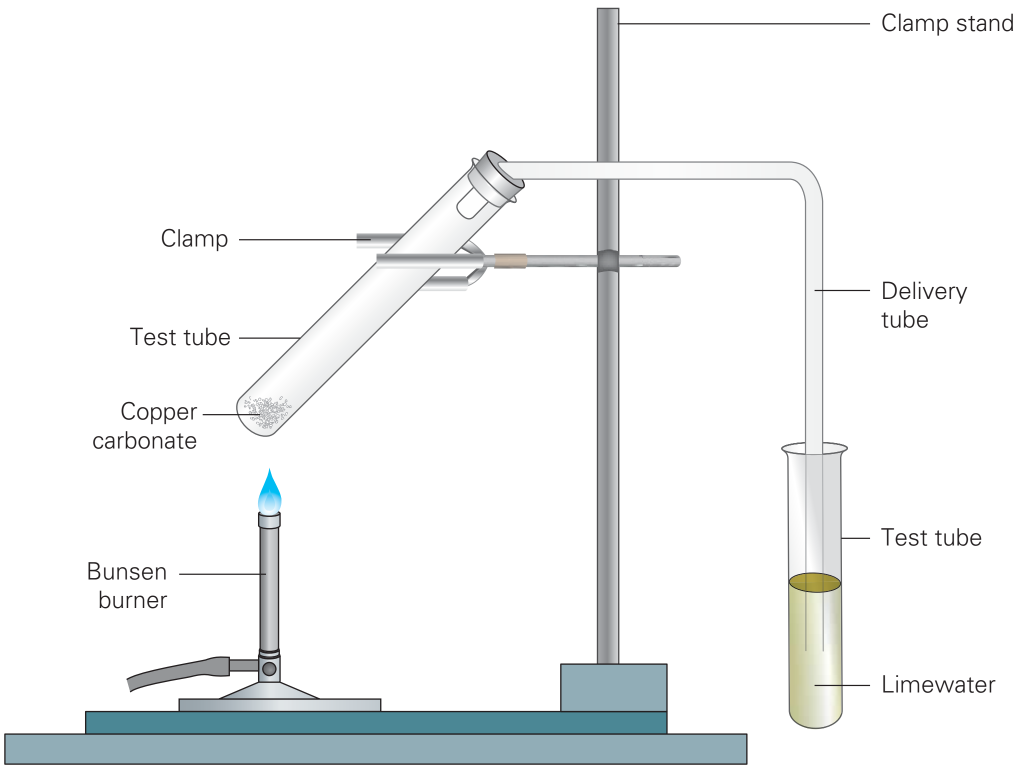

Figure 12.22 Experimental set-up

3 Place a small amount of the copper carbonate in a large test tube and fit it with the gas delivery tube and stopper. Clamp the test tube to a retort stand.
4 Record the appearance of the copper carbonate.
5 Half fill another test tube with limewater and place the gas delivery tube in it.
6 Using a small blue flame on the Bunsen burner, gently heat the copper carbonate.
7 Observe and record the changes in the copper carbonate and the limewater.
8 Remove the limewater solution before turning off the Bunsen burner.
9 Allow to cool.

Results

Record your observations of the limewater after bubbling, the copper carbonate before heating, and the substance and the limewater after heating.

Discussion

1 What caused the change in the limewater when you blew into it?
2 Describe the copper carbonate before and after heating. Mention the changes you observed in the limewater.
3 What is the evidence that copper carbonate is a compound and not an element?
4 Why is it important to remove the delivery tube from the limewater as soon as heating is stopped?
5 Why do some gas bubbles pass through limewater when heating is first started?
6 Identify any faults in the method for this experiment and how the experiment could be improved if it were to be carried out again.

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Section 12.3 questions

QUIZ

Remembering

1 **Define** the following key terms related to the organisation of compounds: molecule, polymer, lattice.

Understanding

2 **Explain** what has to happen to separate a compound into its elements.

Applying

3 Copy and **complete** the following table.

Name	Formula	Number of different elements in the compound	Number of atoms in each molecule
Water	H_2O	2	3
Carbon monoxide	CO		
Sulfuric acid	H_2SO_4		
Nitric oxide	NO		
Nitrous oxide			
Methanol	CH_3OH		

4 Use the information you provided in your answer to the previous question to answer the following questions.
  a **Describe** the difference between nitric oxide and nitrous oxide.
  b **Explain** which is bigger: a molecule of sulfuric acid or a molecule of carbon monoxide.
  c **Describe** the ways that nitrous oxide and water are similar.

5 **Write** the formula for the following compounds.
  a Marble, which contains one calcium atom, one carbon atom and three oxygen atoms
  b Propane, which contains three carbon atoms and eight hydrogen atoms
  c Sucrose, which contains 12 carbon atoms, 22 hydrogen atoms and 11 oxygen atoms.

6 **Identify** the names of the following compounds:
  a Sand, which contains one silicon atom and two oxygen atoms
  b Epsom salts, which contain one magnesium atom, one sulfur atom and four oxygen atoms
  c One phosphorus atom and three chlorine atoms.

Analysing

7 Write some statements or dot points to **compare** between compounds and mixtures. You may draw a Venn diagram to present the information.

8 A tiny sample of quartz contains 1 000 000 atoms of silicon and 2 000 000 atoms of oxygen. **Determine** what the formula would be, based on this information.

Evaluating

9 Substances A, B and C were tested and were found to have the following chemical compositions:
A: 70% oxygen, 30% carbon
B: 60% hydrogen, 40% carbon
C: 60% oxygen, 40% carbon
Determine whether any of these two of these substances the same compound. **Justify** for your answer.

10 We can use the letters of the alphabet to make up words, sentences, paragraphs and more. Using this analogy, what would best represent compounds, mixtures and elements – letters, words or paragraphs? **Justify** each of your answers.

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Chapter review

Chapter checklist

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

Success criteria		Check
12.1	**I can define the following key terms: atom, molecule, element, pure substance, compound, mixture.** e.g. Construct a diagram that shows how the following terms are connected to each other: atom, molecule, element, pure substance, compound, mixture.	
12.2	**I can distinguish between metals, non-metals and metalloids.** e.g. Recall some properties of metals.	
12.2	**I can describe monatomic, diatomic, molecular and lattice structures.** e.g. Describe the structure of a lattice.	
12.3	**I can recall some rules that are required when naming compounds.** e.g. Determine the name of a compound that has one carbon atom and four chlorine atoms.	

SCORCHER

Reflections

1 What **connections** come to mind when you think about elements and compounds and your everyday life?
2 What new concepts have **extended** your thinking about elements and compounds?
3 What information did you find **challenging** or confusing?

Data questions

Refer to the melting points and boiling points for various elements shown in Table 12.5 and Figure 12.23 overleaf.

Classification	Element	Melting point (°C)	Boiling point (°C)
Non-metals	Carbon	3550	4827
Non-metals	Nitrogen	−210	−196
Non-metals	Oxygen	−219	−183
Noble gases	Helium	−272	−269
Noble gases	Neon	−249	−246
Halogen	Fluorine	−220	−188
Halogen	Chlorine	−102	−34
Halogen	Bromine	−7	59
Halogen	Iodine	114	184
Metal	Magnesium	650	1091
Metal	Iron	1538	2861
Metal	Nickel	1455	2913
Metal	Copper	1085	2560
Metal	Silver	962	2162
Metal	Platinum	1768	3825
Metal	Gold	1064	2836
Metal	Mercury	−39	357

Table 12.5 Classification, melting and boiling point of various elements

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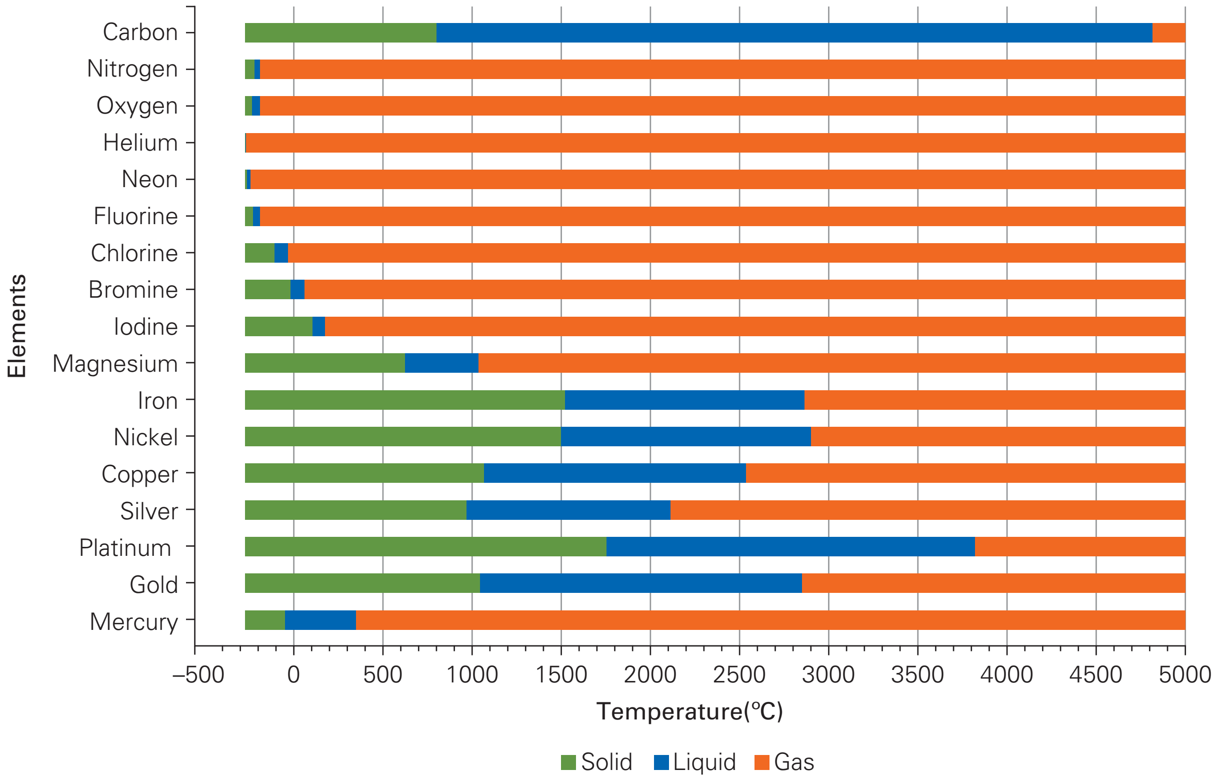

Figure 12.23 States of various elements at different temperatures

1 **Calculate** the difference in temperature between the melting and boiling point of elemental mercury.
2 **Identify** the element with the lowest melting point.
3 **Identify** which elements in Table 12.5 are classified as halogens.
4 **Contrast** the general melting point of the noble gases and the metals in Table 12.5.
5 **Identify** the element where the data does not match that of similarly classified elements.
6 **Categorise** the halogen elements as either 'gas at 25°C' or 'not gas at 25°C'.
7 Given the data in Table 12.5, **deduce** whether the noble gases can exist in the liquid state.
8 Argon is another noble gas element. **Predict** whether the boiling point of elemental argon is closer to 3000°C, 100 °C or −150°C.

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STEM activity: Reduce, re-use, repurpose, recycle

Background information

Waste is a huge issue for the whole world. Theoretically, all materials can be recycled if they can be separated out or converted back into their original elements or compounds. However, this is very difficult and sometimes not feasible.

Being a zero-waste society involves rethinking how we use our resources to eliminate all waste products.

Design brief: Design an educational poster for the NSW Government to distribute through schools about zero waste and the science behind making a zero waste society.

Activity instructions

Your group has been employed by the NSW Government to produce an educational poster about zero waste for primary school children. It should include the science behind how different waste products are made, and how different items can be re-used, repurposed and recycled, as well as include the reasons behind why certain products must be avoided.

Figure 12.24 The zero waste personal hygiene items shown have minimal plastic elements.

Suggested materials

- pens/pencils
- butchers paper
- PowerPoint/poster-making software

Research and feasibility

1 Research, discuss in your group and list different types of waste produced by society.

2 Discuss in your group which types of waste you think should be the focus of your poster and research how they are made, used and then re-used/repurposed/recycled.

3 Create a table like the one shown below, to help determine which types of waste are easiest or most difficult to become zero waste.

Waste	Household/ society quantity	Can this product be made zero waste?	How? Level of difficulty
E.g. cling wrap	Varies depending on household	Yes	It can be recycled, but it is more difficult, and should be avoided as a product.

Design and sustainability

4 Decide, as a group, five key ideas you want to have on your poster, and discuss if you have enough important research to help convince students of their importance.

5 Sketch, as a group, different poster designs and annotate the locations of the most important information. Discuss as a group if the poster is effective visually.

Create

6 Use butcher's paper or a computer to create your information poster. Remember this is a poster designed for primary school children.

Evaluate and modify

7 Present your poster to your class as a group, and encourage questions and feedback from your class.

8 Evaluate the effectiveness in transforming the message of zero waste to your class.

9 Discuss modifications you would make to your poster based on feedback from the class.

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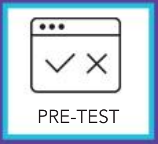
Chapter 13 Mixtures

Inquiry questions

What is the difference between heterogeneous and homogeneous mixtures?

Why does filtration not always separate substances from a solvent?

How can mixtures be separated?



Chapter introduction

Our world is an amazing place. It is made up of many different substances like wood, food, metal, fibres, air, glass, plastic and ceramics. Some of these substances are pure substances, while others are mixtures. This chapter will help you understand how to identify pure substances and mixtures and the differences between them, and the role of chemistry in helping us separate mixtures into their parts. You will also look at mixtures and their separation in your home, as well as how people in different occupations use separation techniques.

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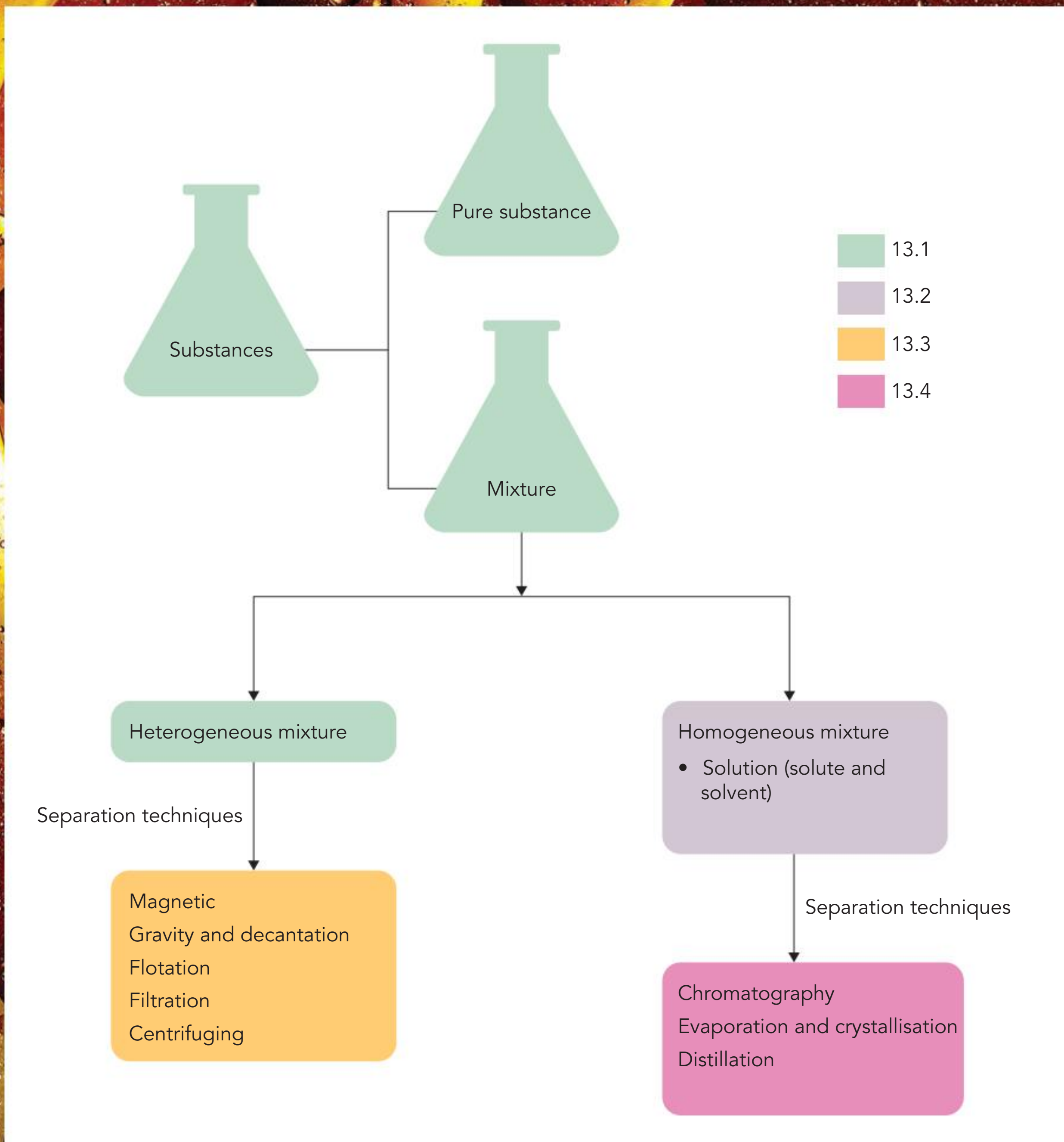
Chapter map



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13.1 Pure substances and mixtures

Learning goals

1. To distinguish mixtures from pure substances.
2. To identify heterogeneous and homogeneous mixtures.

DOC WORKSHEET

Look around you. What do you see? It does not matter where you are or what you are looking at, almost everything that you can see is a mixture of different pure substances. In science, the area where you find out more about pure substances and mixtures is called chemistry.

Try this 13.1

What is this?
Gather some everyday substances such as tea, milk, cheese and peppercorns. List their unique physical properties in a way that your classmates could guess the substance from the physical description.

Pure substance

pure substance
material that is made up of either one type of atom or the same groups of atoms (molecules or compounds)

mixture
material made up of two or more different substances

dissolve
cause to become mixed in a substance so that it cannot be seen

So, what is a pure substance? And how is it different from a mixture? Well, a **pure substance** is a substance that is made up of just one type of material or one type of particle, for example, pure water, pure gold and oxygen. Every pure substance has unique physical properties such as different states, densities, size, magnetism, colour, mass, melting points and texture. Scientists need an understanding of these different physical properties to be able to distinguish one type of material from another.

Mixtures

Mixtures are substances made from two or more different substances mixed together that can be physically separated. Mixtures can be separated because they are not combined in a chemical way. Some examples of mixtures that you may be familiar with include soft drinks (a mixture of sugar, water, carbon dioxide, flavours and colouring), a cup of tea (a mixture of tea leaves and water), tap water (a mixture of water, fluoride salts, salts **dissolved** from ground water and chlorine), spaghetti bolognaise (a mixture of pasta, tomatoes, beef, garlic, chillies and thyme) and healthy fruit salad (a mixture of kiwi fruit, apples, bananas and raspberries).

Figure 13.1 Spaghetti bolognaise sauce is a mixture you may love to eat.

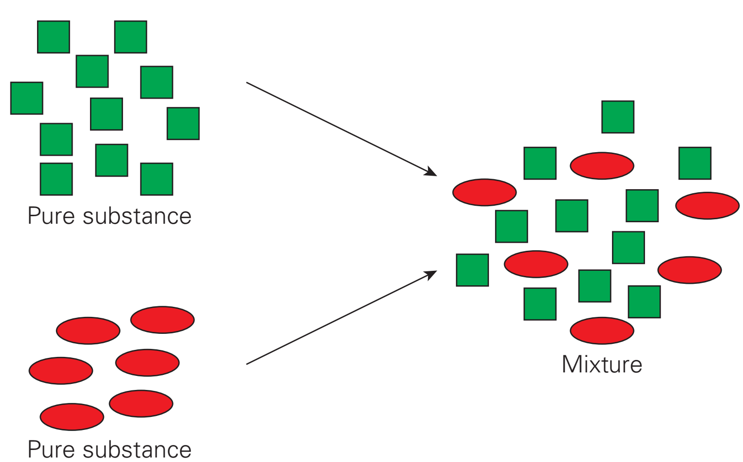

Figure 13.2 A mixture is made of two or more substances.

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Quick check 13.1

1 Define the terms 'pure substances' and 'mixtures' in your own words.
2 Draw up a table with the headings 'pure substances' and 'mixtures' and classify the names of the following substances by writing them into the correct column.

smoke	pen ink	iron
soft drink	aluminium foil	cough medicine
trail mix	margarine	filtered water
hand cream	chocolate milk	jelly
salt water	ice cream	cheese
oxygen	carbon dioxide	blood

Classifying mixtures

Mixtures can be broadly classified into two categories: **homogeneous mixtures** and **heterogeneous mixtures**. You need to understand these terms because they help you determine the properties of mixtures, and you need to know these before you can even attempt to separate a mixture into its components.

Homogeneous mixtures are mixtures where you cannot tell that two or more substances have been mixed together as they don't settle or separate out when left to stand. The components of the mixture are all evenly distributed and the entire mixture has the same properties. For example, air, tap water and soft drinks are all homogeneous mixtures, because wherever you take a sample from, the properties of the samples will be the same. Solutions are homogeneous.

Heterogeneous mixtures are mixtures that can be easily separated into their parts, and those parts retain their original properties. The mixture is not blended together evenly and is not the same consistency throughout, so if you were to take a sample from different parts of the mixture, you would find all of your samples have different properties. Examples include trail mix, fruit salad, pizza, choc chip cookies, **smog** and salad dressing.

homogeneous mixture
a mixture where components are evenly distributed

heterogeneous mixture
a mixture that can be easily separated into its parts, and those parts retain their original properties

smog
a mixture of smoke, gases and chemicals, especially in cities

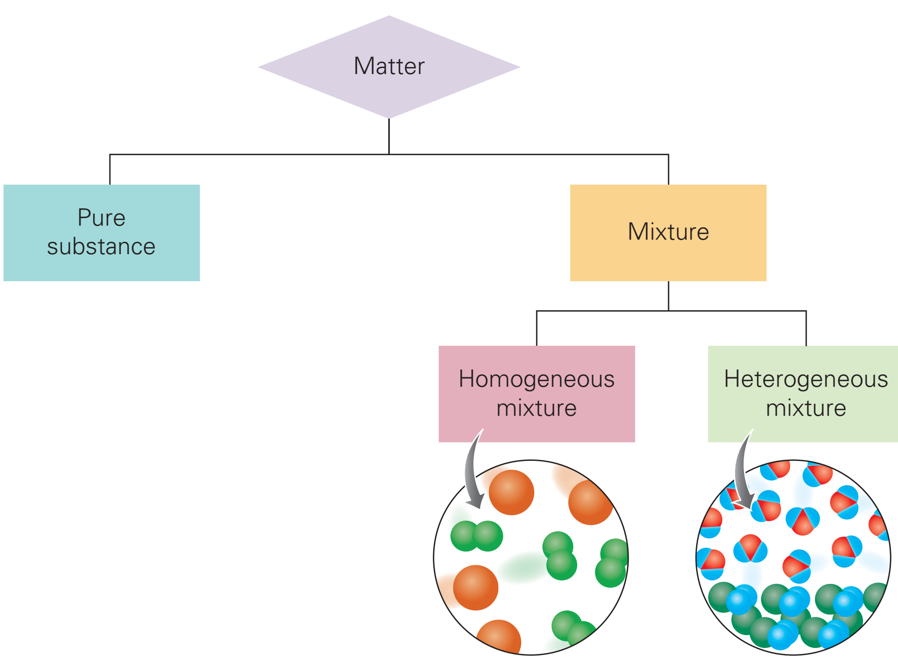

Figure 13.3 How particles may be organised in a heterogeneous mixture and a homogeneous mixture

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Quick check 13.2

1 Define the term 'heterogeneous'.
2 Recall the characteristics that allow you to identify if a mixture is heterogeneous.
3 Define the term 'homogeneous'.
4 Recall the characteristics that allow you to identify if a mixture is homogeneous.
5 Research online to find out about your local recycling process and then describe the properties of the different components of the recycling that allow the parts to be separated.

Section 13.1 questions

QUIZ

Remembering

1 **Identify** which of the following would be described as a pure substance: smoke, air, water, hair gel.

Understanding

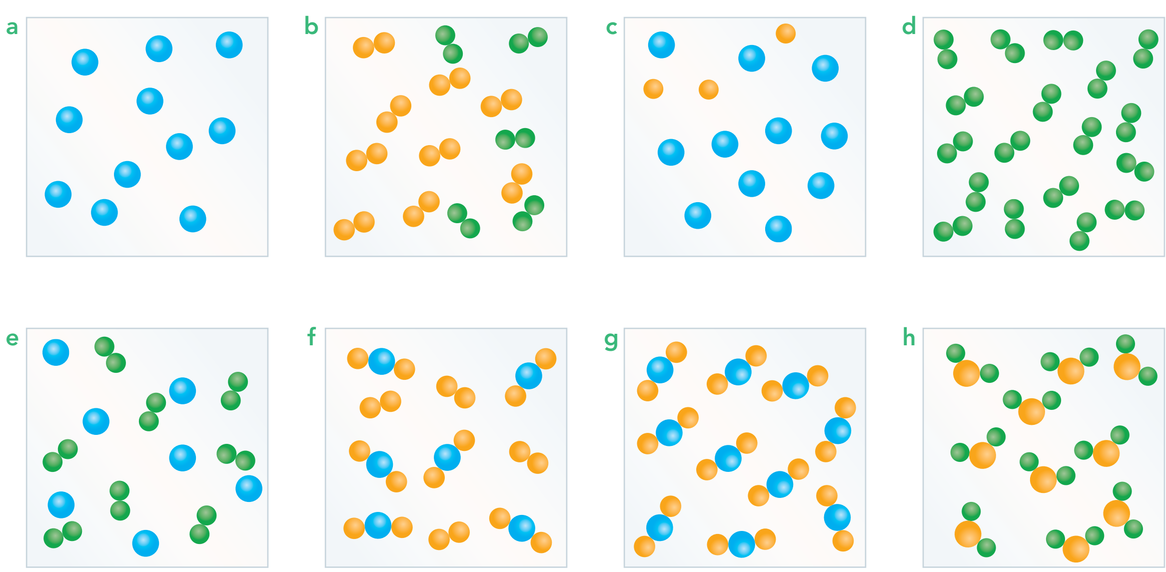
2 **Summarise** the differences between pure substances and mixtures. Give two examples of each.
3 **Outline** the differences between heterogeneous mixtures and homogeneous mixtures. Give two examples of each.

Applying

4 Is 100% pure carrot juice a pure substance? **Explain** using the definitions you have learned.
5 You add a powdered substance to a liquid in a container and shake the container. You then place the container on a table and observe it over time. **Outline** how can you tell if it is a homogeneous mixture or a heterogeneous mixture.

Analysing

6 **Classify** the following substances as a homogeneous mixture, a heterogeneous mixture or a pure substance. Substances: pure water, cola, iron nails, green paint, chunky salsa, silver ring, chocolate chip cookies, concrete, orange juice with pulp, table salt.
7 **Select** one or two words from the following list that best describe each of the following particle diagrams: mixture; pure substance; heterogeneous; homogeneous.



Evaluating

8 **Justify** the statement, 'All solutions are mixtures, but not all mixtures are solutions'.

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13.2 Solutes, solvents and solutions

Learning goals
1 To identify and describe solutes, solvents and solutions with relation to particle theory.
2 To explain why water is an important solvent.

WORKSHEET

Solutions

A **solution** is not only the answer to a mathematics question, but also a type of mixture that is formed when the particles of one substance separate and spread out evenly into another substance. This act of separating and spreading out is called dissolving. Recall that the solute is the name given to the substance that dissolves and the solvent is the name given to the substance it dissolves into. A solution is therefore the name given to a mixture of a **solute** dissolved in a **solvent**.

solution
a mixture where one substance is evenly dissolved in another

solute
the component of a solution being dissolved

solvent
the component in a solution capable of dissolving another substance

Figure 13.4 Tap water is a solution because various trace elements from the ground water, plus chlorine and flourine added by water treatment, are dissolved evenly in pure water.

Try this 13.2

Particle theory
Put a sugar cube in a glass of water. Describe what is happening using the terminology you have been learning about. What happens in terms of particles? Where are the particles? What are the particles doing?

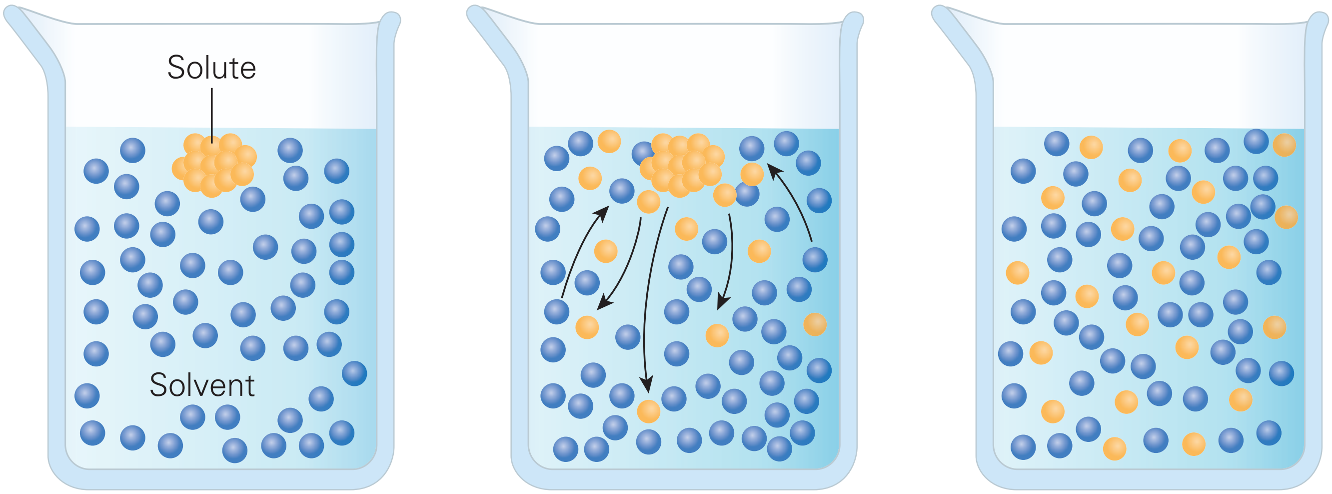

Figure 13.5 Particle diagram of a solid solute dissolving into a liquid solvent to form a solution

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Examples of solutions

An everyday example of a solution is the oxygen dissolved in a fish tank water, where the oxygen is the solute and the water is the solvent. Other examples: the cordial (solute) dissolved in a glass of water (solvent) and the carbon dioxide (solute) dissolved in a fizzy drink water (solvent). You will notice that many of the solutions mentioned so far are made of solutes dissolved in the solvent water. Water is sometimes called the 'universal solvent' due to its versatility to dissolve a wide variety of different solutes. Solutions using water as a solvent are called **aqueous solutions**.

aqueous solution
solutions where the solvent is water

soluble
substances that can dissolve

insoluble
substances that cannot dissolve

dilute
a solution with only a small amount of the solute

concentrate
a solution with a large amount of the solute

Figure 13.6 Oxygen is a solute that is dissolved in the solvent water to form the solution that organisms like fish and plants live in.

Not everything is able to dissolve to form a solution. Substances that can dissolve are called **soluble** and those that are unable to dissolve are called **insoluble**. Substances that are insoluble have very strong forces of attraction between their particles. The solvent cannot break apart those particles and thus the substance remains undissolved.

Solution concentrations

A solution that has very little of a substance (solute) added to the solvent is said to be **dilute**. It is also described as a solution with a low concentration. For example, a friend asks you to make a weak glass of cordial. You would need to add only a little of the cordial (solute) and a lot of water (solvent) to make a weak or dilute solution.

A solution that has a lot of a substance (solute) added to the solvent is called **concentrated**. It is also described as a solution with a high concentration. How would you make your friend's cordial drink in this case?

Figure 13.7 The more dilute solutions are on the left, while the more concentrated solutions are on the right.

Quick check 13.3

1. Copy the following incomplete sentences. Complete each using the correct word from the list below.
   aqueous solution, dissolves, soluble, solute, solution, solvent.
   When sugar is mixed with water it __________, and this shows that sugar is __________ in water. When it dissolves, it forms a __________. The sugar is called the __________. This type of solution, where water is the __________, is called an __________.
2. Define these terms and give a named example of each: solution, solvent, solute, aqueous solution.

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Try this 13.3

Investigating solubility

Investigate the solubility of household substances in water, at home or in class.

1 Collect seven containers of the same size. (Alternatively, use test tubes in a rack from your science laboratory.)
2 Add a teaspoon of one of seven common household substances to each container and label the container. Typical substances are sugar, salt, bicarbonate of soda, flour, coffee, sand and jelly crystals.
3 Add a couple of tablespoons of cold water from the tap and mix the substances together using a spoon or by carefully swirling or jiggling the test tube.
4 Record your observations of each substance as soluble, partly soluble or insoluble in a results table.
5 Why is it that some substances dissolve in the water but others do not? Can you ever put too much solute in a solvent so it stops dissolving? Try adding more and more solute to one of the containers to find out. Measure (in grams or teaspoons) the amount of solute you can add before it stops dissolving. Notice how some substances are more soluble than others.

Figure 13.8 If you add enough solute to a solution, eventually the solute will no longer dissolve.

Saturation

Did you try adding more and more solute to one of your containers in *Try this 13.3*? When you do this, you will notice that the solution reaches a point where no more solute can dissolve. The solution is now called a **saturated** solution. This is like having a towel saturated with water after you drop it in the pool – the towel just cannot take in any more water. A saturated solution is so concentrated that no more solute will dissolve into the solvent.

saturated
a solution with the maximum amount of solute dissolved

Section 13.2 questions

QUIZ

Remembering

1 **Define** these terms: saturated solution, aqueous solution, dilute solution, concentrated solution.

Understanding

2 **Rewrite** each statement to make it true.
  a Soluble is when a substance cannot be dissolved in a solvent.
  b The solvent dissolves to form a solution.
  c A mixture is when different substances are chemically combined.
  d A saturated solution is a solution in which the minimum amount of solute has been dissolved.
  e In a solution, it is the solute that is unable to dissolve into the solvent.
  f Concentrated solutions have a lot of solvent compared to the amount of solute.
  g A suspension is a mixture in which a solute is dissolved in a solvent to form a transparent liquid.

Applying

3 **Explain** why it is possible to see solid salt crystals in water but not possible to see the dissolved salt particles.
4 **Determine** what the solvent, solute and solution is in the following situations.
  a Fizzy water b Vinegar c Syrup
5 You were given a diluted mug of cordial and a concentrated mug of cordial and asked to work out which was which without looking in the mug. **Determine** how you would achieve this.

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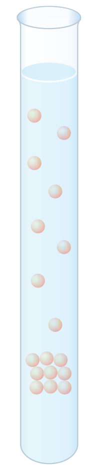
Analysing

6 **Compare** and **contrast** solutions and mixtures. You may like to use a Venn diagram.

7 Are all solutions mixtures? Or are all mixtures solutions? **Justify** for your choice.

Evaluating

8 Look at this diagram of a test tube containing a liquid substance and a soluble solid substance. **Redraw** and **label** the diagram as many times as needed to **illustrate** the following key terms. You may be able to include several terms on one diagram.



dilute solution	concentrated solution
dissolve	aqueous solution
insoluble	soluble
solution	saturated solution

13.3 Separating heterogeneous mixtures

Learning goal

1 To explain how magnetic separation, decantation, flocculation, filtration and centrifuging can be used to separate heterogeneous mixtures.

DOC WORKSHEET

You may recall that earlier in this chapter, you saw that heterogeneous mixtures like fruit salad can be easily separated into their parts, and those parts retain their original properties. So, what are the techniques that are used to separate out the different components?

The easiest way is by hand-sorting, that is, using your fingers to get your favourite lollies out of a lolly bowl, or pulling the strawberries out of the fruit salad. But there are other ways of sorting materials!

Magnetic separation

Magnetic separation is another technique that is easy to use. Imagine you are building a skateboard in woodwork class and you drop some screws on the sawdust-covered floor. Magnets attract iron, nickel and cobalt containing substances (ferromagnetic) like screws, and so you would be able to pull the screws out from under the sawdust as wood does not contain iron. This is how steel cans (containing iron) are separated from the rest of your non-ferromagnetic recycling at the Materials Recovery Facility.

Figure 13.9 Magnets can be used to separate magnetic substances from non-magnetic substances.

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Decantation

If you have dropped a piece of fruit in your drink at a birthday party, the fruit will sink to the bottom of your glass. The process of **decantation** can help you separate your drink from the piece of fruit. Decantation is a technique where you carefully pour the liquid off the top of a solid–liquid mixture or a liquid–liquid mixture, to separate the two components. You may have done this when pouring water off the top of your vegetables once they have been boiled for dinner.

Flocculation

A **flocculant** is a chemical that helps with decanting. It causes suspended particles to clump together so that they sink (forming sediment) and can be separated from the liquid they were suspended in by decantation. For example, you collect muddy water from a river and let the sediment settle to the bottom but the water is still cloudy. A flocculant would help clear the water by causing the particles to clump and sink. It is also used to clarify water in swimming pools.

Flotation

Flotation is another separation technique but, in this case, the components of a mixture are separated based on their density or capacity to float.

For example, oil floats on water so this allows for the clean-up of ocean oil spills. Firstly, booms (floating barriers) are placed around the oil to help contain it. Skimmers (boats with vacuum machines, sponges, cork or oil absorbent ropes) then soak up the spilled oil from the surface within the booms. It can then be stored and disposed of.

Filtration

Filtration is a technique used to separate the components of a mixture based on their size and solubility, by passing them through a filter. You may have heard of filter baskets in pools that catch the leaves, or filters used in your vacuum cleaner so that the air pumped out is cleaned, or perhaps the filters used in cafes when making coffees. The holes in the filter will be different sizes depending on what is being filtered. For example, a filter basket in a pool has holes that you can see as leaves are not microscopic; however, the holes in a coffee filter are much smaller as the coffee granules are smaller.

decantation
the process of separating by using gravity

flocculant
a substance that causes particles to clump together

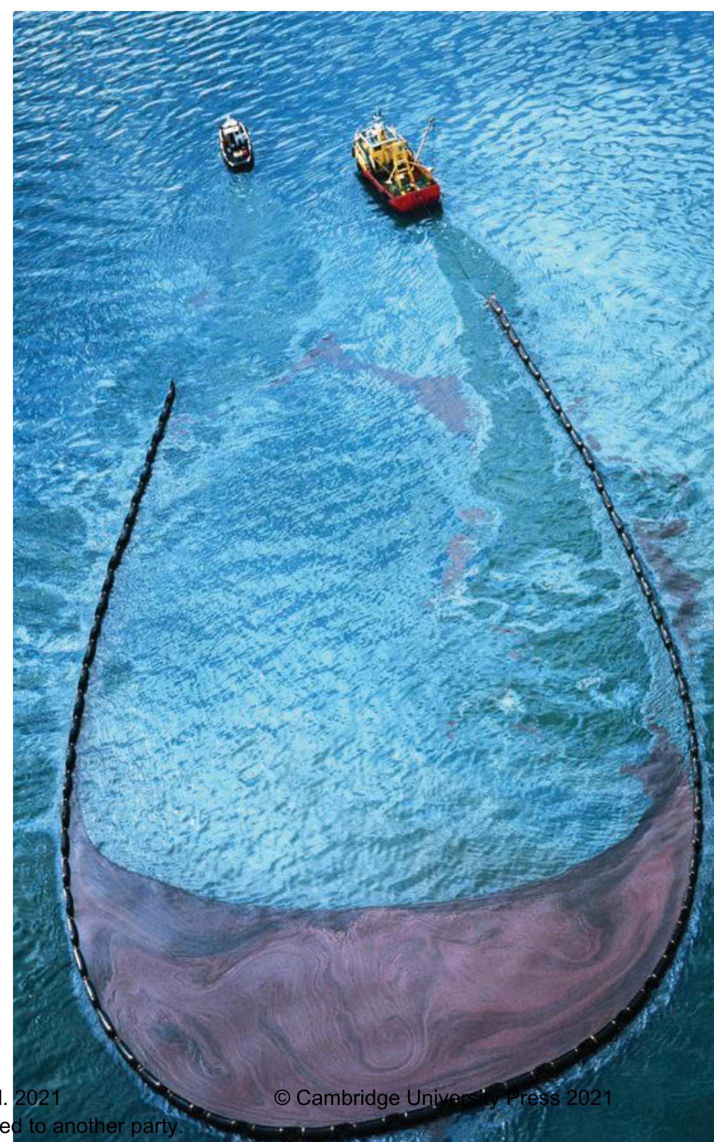
flotation
separating a mixture based on the capacity to float

filtration
separating a mixture by passing through a filter

Sieving is another name for filtration and is perhaps a lot more familiar to you – watching your fish and chips being pulled out of hot oil using a wire basket, sifting flour when baking a cake or straining your spaghetti by pouring it through a colander.

VIDEO
Explain how spills in the ocean are cleaned up

Figure 13.10 Booms and skimmers helping to clean up an oil spill using the separation technique known as flotation



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Quick check 13.4

1. Recall what you should use to separate a mixture of sand and iron.
2. Explain what might prevent a magnet being useful to separate the components of a mixture.
3. Identify a situation when hand-picking would be the most appropriate way to separate a mixture.
4. Explain the separation technique of decantation.
5. Explain the relationship between density and the separation technique of flotation.

Figure 13.11 Flocculants can be used to help clean pool water.

Did you know? 13.1

Combustion engines in cars have very fine filters that can trap extremely small carbon particles and stop them from polluting the atmosphere.

Filtrate and residue

When you talk about the process of filtration, you use words like **filtrate** and **residue**. The filtrate is the name of the substance that passes through the filter. For example, the clean air coming out of an air conditioner. The residue is the name of the substance left behind in the filter after the process of filtration. For example, the dust in the air that enters the air conditioner from outside.

filtrate
the substance that passes through the filter

residue
the substance that is left in the filter

Figure 13.12 Cafes use filters when making coffee.

Did you know? 13.2

Toothless whales have filters

The humpback whale, and other toothless whales, possess a unique feeding adaptation called baleen. The baleen is a wide plate in the whale's mouth, made up of hundreds of long, fringed blades made of the same substance in our hair and nails. The blades filter small animals such as krill, plankton and small fish out of the sea water.

Figure 13.13 The mouth of a humpback whale contains baleen which allows them to filter the ocean water for krill.

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Try this 13.4

Drawing a filter

Draw a cartoon strip, make an animation using PowerPoint or make a stop-motion short film demonstrating the movement of different-sized particles through a filter with fixed-sized holes.

Practical 13.1

Separating heterogeneous mixtures

Aim

To compare the effectiveness of *different* separation techniques for cleaning contaminated water.

Be careful

Do not test water by consuming it.

Prior understanding

Separation of heterogeneous mixtures relies on each different substance having a unique set of physical or chemical properties. Each difference in property (e.g. one substance is magnetic and the others are not) is used to simultaneously remove one substance from a mixture while the other substances are left behind.

Real-life example: an excellent application of this can be seen by researching the winner of the 2019 Google Science Fair, who was a school student who discovered a way to remove microplastics from sea water safely using a ferrofluid.

Materials

- alum (potassium aluminium sulfate) or equivalent
- contaminated creek water (simulated) – water from a fish tank (water left over from cleaning the filter is ideal), sand, clay, mud
- 3 glass beakers
- 2 glass cylinders
- metal spoon
- stirring rod or spoon
- funnel
- filter paper
- retort stand and clamp and optional: microscope with dropper, slide and coverslip to observe water

Procedure

Use each of the following methods separately to identify which substances are removed by the process and the physical or chemical property that was used to isolate one substance from another.

1 Draw the table shown in the results section in your science book.
2 Test each of the following methods and record the results in the table for comparison.

Decantation

3 Measure 100 mL of water into a cylinder.
4 Stir the water until it appears cloudy.
5 Leave the mixture undisturbed for 5–10 minutes so that solid substances can settle on the bottom.
6 Very carefully, pour the liquid off the top of the solid substances into a beaker so that they remain in the cylinder.
7 Record your observations in the results table.

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Flocculation

8 Measure 100 mL of water into a cylinder.
9 Transfer into a beaker.
10 Stir the water until it appears cloudy.
11 Measure 3 mL of alum solution and stir the mixture for 2 minutes.
12 Leave the mixture undisturbed for 15 minutes.
13 Record your observations in the results table.

Filtration

14 Fold your filter paper as shown in Figure 13.14.
15 Set up your equipment as shown in Figure 13.15.
16 Measure 100 mL of water into a cylinder.
17 Stir the water until it appears cloudy.
18 Pour the mixture through the funnel and let it filter through the paper.
19 Record observations in the table.

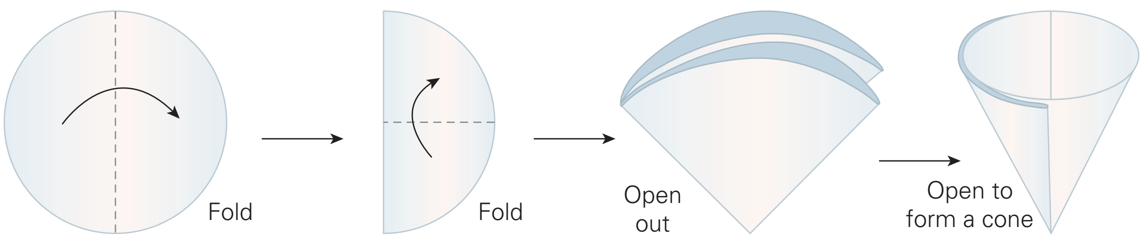

Figure 13.14 How to fold your filter paper

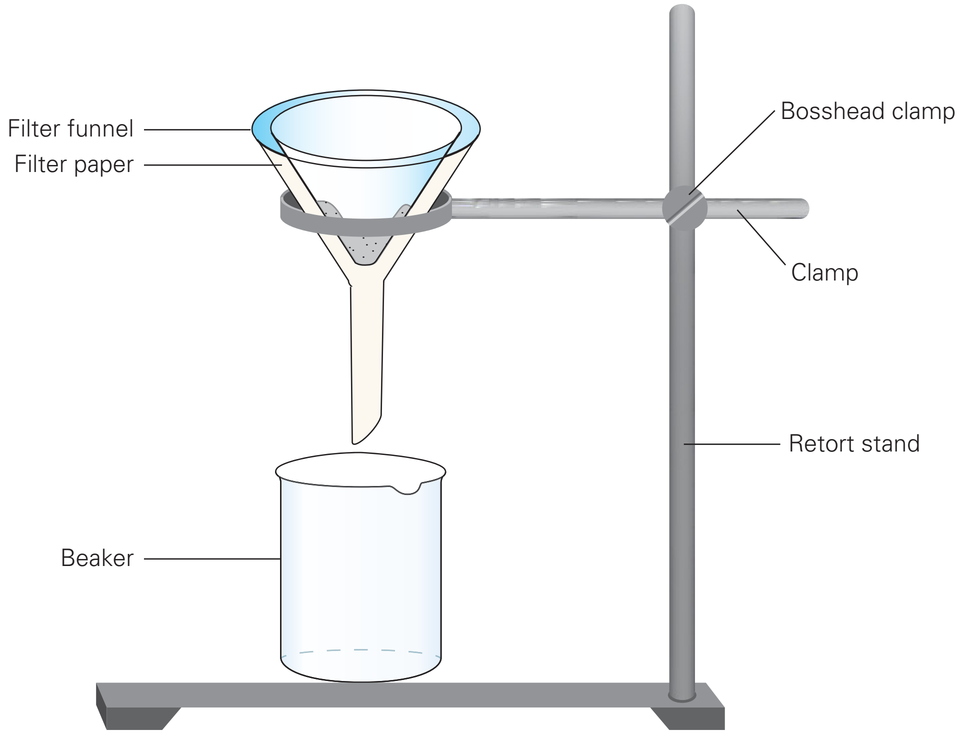

Figure 13.15 Experimental set-up

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Results

Independent variable: Separation technique	Dependent variable: Water quality		
	Describe the initial condition of the water	Number of contaminants removed	Issues that may have affected the results e.g. speed, incomplete removal of substance
Decantation			
Flocculation			
Filtration			

Discussion

1 Critique the effectiveness of each method by considering the number of contaminants removed and any issues that were found when testing it.
2 Describe how you could use these three methods in combination to remove contaminants from water.
3 Compare the results with other class groups. Determine how much variation was found in the results.
4 Identify the method which was the most reliable at separating out a contaminant based on the response in the previous question.
5 Discuss whether these three methods effectively clean the water so that it could be consumed by humans.
6 Optional: place a drop of the contaminated water under a microscope and observe. Review the answer to Question **3** above.
7 Propose any changes that could be made to the method to improve the quality of the data in future experiments.

Did you know? 13.3

Our kidneys have filters

After your body has processed the nutrients you consume, waste products are formed. One of the main jobs of the kidneys is to filter this waste out of the blood. Your blood supply circulates through the kidneys about 12 times every hour. Each day, your kidneys process around 200 litres of blood. Each of your kidneys has more than a million mini filters called nephrons.

If, for any reason, your kidneys cannot remove enough waste from your blood, you may experience the following symptoms:

- reduced urine
- nausea
- vomiting
- swelling
- fatigue.

If this is the case, haemodialysis can be used to clean the blood. The machine filters the blood, acting like an artificial kidney. This is not a permanent cure and must be done regularly.

Figure 13.16 The haemodialysis machine filters blood by trying to mimic what your kidneys do.

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Quick check 13.5

1 Use the following information to answer the questions or to complete the sentences.
Charcoal and salt are accidentally mixed together. The mixture is placed in water and stirred before being passed through filter paper.
- a What will remain in the filter paper?
- b What will pass through the filter paper?
- c The filtrate is the ____________.
- d The residue is the ____________.
- e The residue is found in the ____________.
- f The filter paper can separate the two substances in the mixture because those two substances have different ____________.

Advances in science 13.1

The Sydney Desalination Plant

The Sydney Desalination Plant, in Kurnell, annually provides relief to the water supply of Sydney. When needed, it can supply over 1.5 million people a day with drinking water. The plant provides a source of water which is unaffected in times of drought or flooding, and has been filtered over several steps of purification. After sea water has been drawn in through an underground pipe, the water is first filtered to remove any sand and other solid substances. The second filtration technique, called reverse osmosis, then starts. This is where the filtered sea water is forced through an ultra-fine membrane that contains extremely small pores, which only let water particles through. The salt particles are too large to pass through and so are returned to the sea as a concentrate, and fresh water continues on in the process to be treated and then distributed.

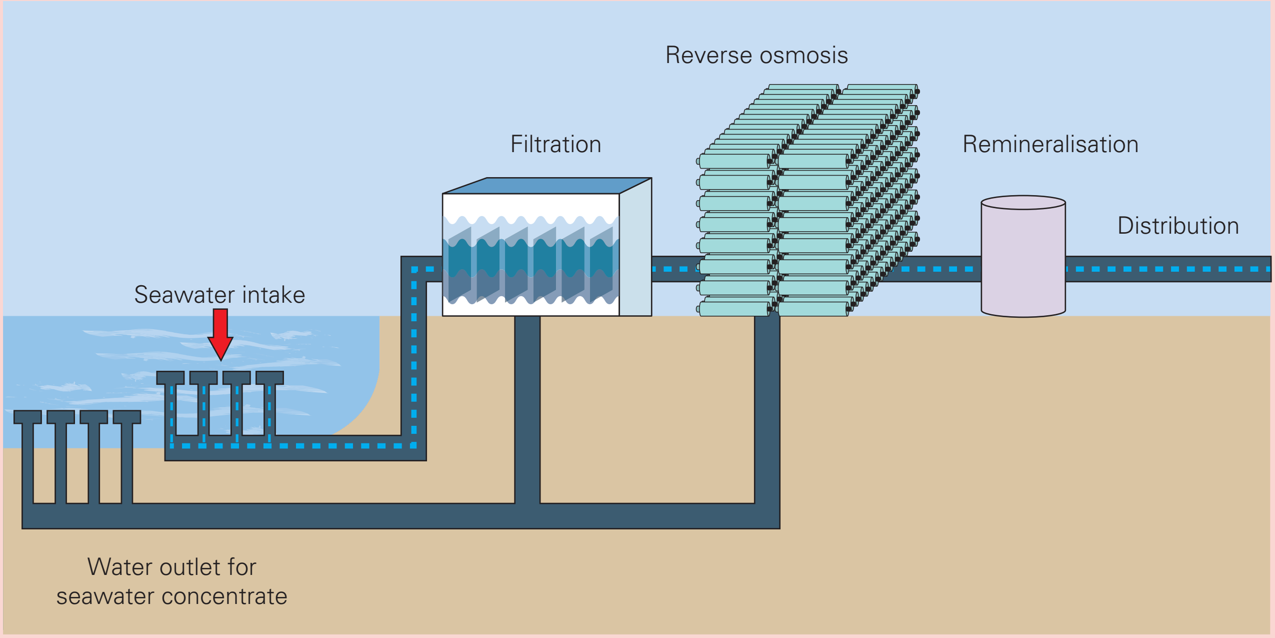

Figure 13.17 Desalination process

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Centrifuging

A **centrifuge** is a device that can separate substances based on their mass (how heavy they are) by spinning them very fast. High-speed centrifuges can spin up to 20 000 times a minute! It is like your washing machine spin cycle or a salad spinner, where the water and the items inside are separated.

centrifuge
a device that uses speed to separate substances based on mass

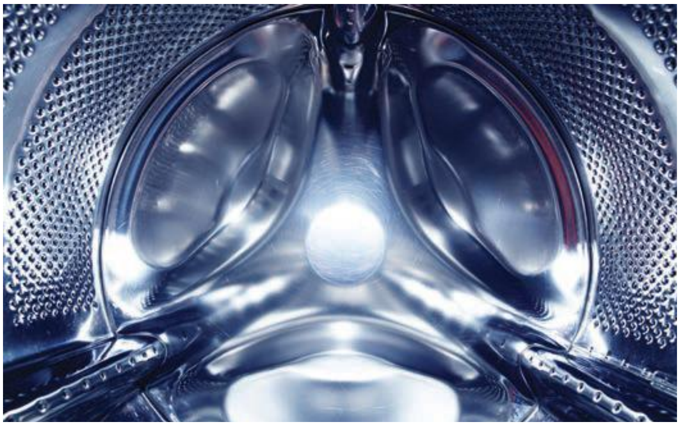


Figure 13.18 Both the inside of your washing machine and a salad spinner are designed to spin so fast that the water moves outwards through the holes, while the clothes or salad remains in the centre.

Did you know? 13.4

Blood has different components

Blood fractionation is the process of separating the blood from your body into its components, using centrifugation. When you spin blood, the heaviest components (red blood cells) move to the bottom and the lightest components (plasma) move to the top. White blood cells and platelets are often found in the middle. What does that suggest about their mass?

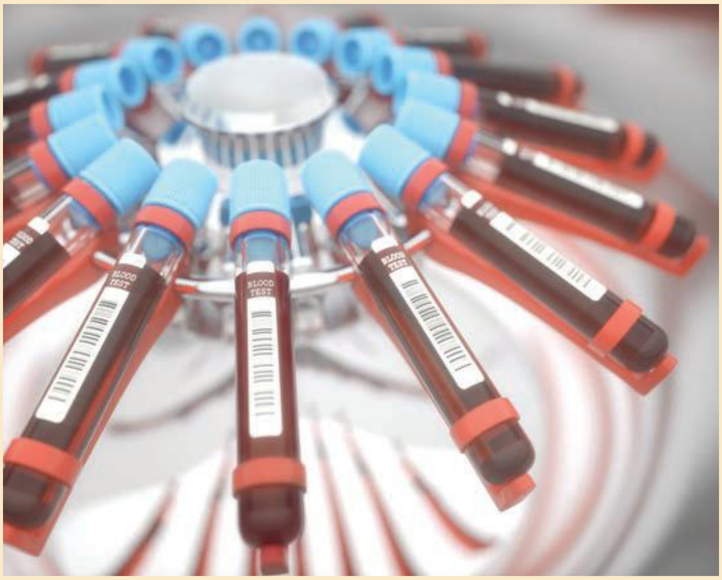


Figure 13.19 Whole blood being centrifuged to separate the components (left), and the resulting separation of components within the tube (right)

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Section 13.3 questions

QUIZ

Remembering

1 **State** which of the following cannot be separated using a centrifuge: components of blood, water on lettuce leaves, salt from sea water.

Understanding

2 Does filtering always work? **Explain** why you may sometimes find flies in your house despite having flyscreens on the windows.

3 **Explain** why filtering water doesn't mean that it is pure.

Applying

4 **Explain** why you cannot filter dissolved sugar out of water. Include the terms you have learned earlier in this chapter in your answer.

5 **Explain** how you could separate a solute from a solution.

Analysing

6 a All of the filters (**a–f**) shown below are used in the home. For each, consider its role and **identify** the:
- components of the mixture
- residue
- filtrate.

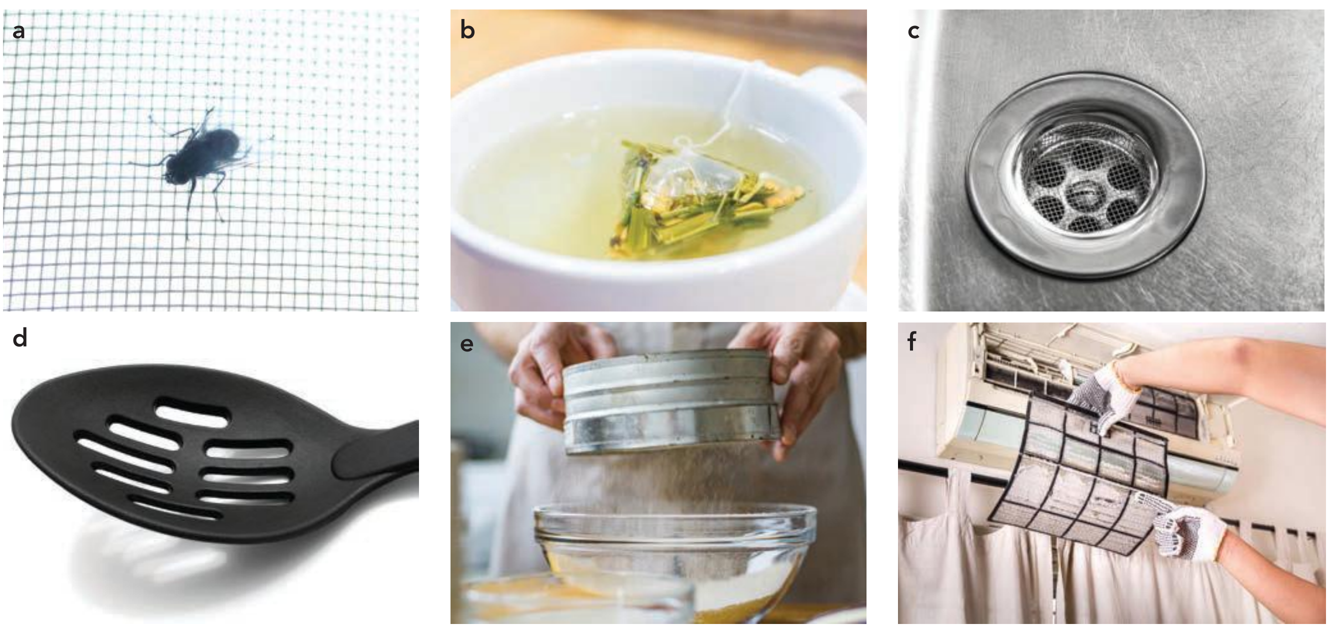

Figure 13.20 Filters

b Each of the filters has a different mixture to separate. **Explain** how this affects the different-sized holes of each of the filters, and the different-shaped holes of each of the filters.

c **Order** the filters from largest holes to smallest holes.

Evaluating

7 Gas masks are becoming more and more sophisticated to combat the development of dangerous nerve gases. Nerve gases interfere with the nervous system. This means you may lose your ability to move your muscles, including those muscles that help you breathe. **Propose** why a paper-filter mask will not work with nerve gases.

Figure 13.21 A modern-day gas mask

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13.4 Separating homogeneous mixtures

Learning goal

1 To explain how chromatography, evaporation, crystallisation and distillation can be used to separate homogeneous mixtures.

WORKSHEET

VIDEO Predict what colours each ink will separate into

VIDEO Why is one of the yellow components longer?

There are a variety of separation techniques that can be used to separate homogeneous mixtures. Think back: what does 'homogeneous' mean?

Chromatography

Chromatography is a technique used to separate the substances in a mixture based on their solubility, which is their ability to dissolve in a solvent (and also their attraction to a solid material, for example paper). Look at Figure 13.22. This is the common set-up for carrying out paper chromatography, in this example, to separate the colours that make up the ink in felt-tip marker pens. The mixture (components of ink) is made to move by a solvent (often water or methylated spirits), through another substance that stays still (filter paper) until the components separate. The more soluble the components of the ink are in the solvent, the more quickly they will move up the filter paper in the solvent.

The 'mobile phase' is the name given to the solvent moving with the soluble parts of the mixture in it. The substance that stays still is called the 'stationary phase' (filter paper).

Chromatography is used a lot in various industries, although it is probably not something you commonly hear about. These are some examples.

- In forensics, chromatography allows you to analyse and separate the components of ink in pens to catch the forger or the writer of a ransom note.
- In toxicology, gas chromatography is used to separate the components of a poison so that it can be identified and neutralised.
- In pharmacology, chromatography allows for the testing of the purity of medicines and drugs.
- In fashion, chromatography helps break down the different components of the dyes in clothing.
- In athletics and other sports, gas chromatography is used to check if the sportsperson has been using any prohibited substances.
- In archaeology, chromatography allows for organic materials to be separated from inorganic materials. This can help experts learn more about how people lived in the past, e.g. identifying what kind of diet ancient people had or what clothes they wore.

chromatography
a technique to separate substances based on movement at different rates due to solubility

Figure 13.22 Paper chromatography: the separation of the components of ink. Note that the green ink is made up of yellow (less soluble) and blue (more soluble) components.

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Practical 13.2

Separating the pigments in water-soluble colour marker pens

Aim

To separate the pigments from water-soluble marker pen ink using chromatography.

Materials

- water
- large beaker
- long strips of filter paper
- ice block sticks
- paperclips
- ruler
- water-soluble colour marker pens

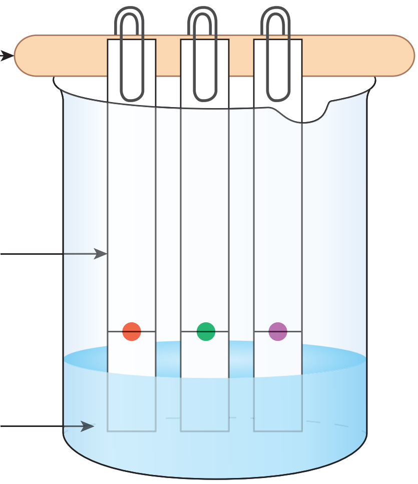

Figure 13.23 Experimental set-up

Procedure

1. Use a pencil to draw a line across each filter paper strip 1.5 cm from the bottom. Label the ice block sticks A, B and C – one position for each of three strips of filter paper.
2. Add enough water to the beaker so that the pencil lines will sit above the water line.
3. Using the water-soluble colour marker pen, draw a small dot on the filter paper in the middle of your pencil line.
4. Fold the paper strips over the ice block stick, as shown, and clip them on using the paperclips.
5. Repeat the first four steps this time using different coloured marker pens.
6. Lower the three samples into the water in the beaker, making sure the ink spot is above the water and the end of the paper stays in the water.
7. Leave the strips for about 10 to 20 minutes after placing them into the water.
8. Remove the paper strips (called chromatograms) from the beaker when the water has reached approximately 2 cm from the top of the paper and leave them to dry somewhere safe.
9. Label the solvent front on each of your chromatograms (this is where the solvent has reached on the filter paper).

Results

Stick your dried chromatograms into your science book (or take a photo and upload it to your practical report file).

Discussion

1. The chromatogram formed is unique for each type of pigment. Discuss what you found out about the different pigments in the ink of the different coloured pens.
2. Identify possible sources of error when using this separation technique.
3. Discuss how you could minimise the impact of these sources of error in the future.

Conclusion

Copy and complete this statement in your science book. From this activity we can claim that pen ink ______________. This is supported through observations that ______________. Therefore, it can be concluded that ______________.

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Did you know? 13.5

Drug screening

Gas chromatography is one of the most common methods of testing urine and blood samples for drugs. In gas chromatography, the sample is converted into a vapour in the presence of a gaseous solvent and placed into a special machine. Each component of the sample will dissolve differently in the gas and will only stay in the gas phase for a unique time, called the retention time. When the sample is analysed, it is compared to known samples of different drugs, so that specific drugs can be identified in the urine or blood samples.

Figure 13.24 Samples being prepared for analysis using gas chromatography

Evaporation and crystallisation

Evaporation is a change in state from a liquid to a gas, but it can also be used as a separation technique. Evaporation can be used to separate a dissolved substance (solute) from its solvent in a solution, by heating the mixture up so the liquid part turns into gas. For example, the water in salt water will evaporate when heated, leaving behind salt crystals – the water and the salt are separated by evaporation. Can you think of some examples where evaporation has been used in your home to separate substances? Examples include wet clothes drying in the sun on the clothes line or dehydrated baby peas in the pantry.

Crystallisation

Often when you use the process of evaporation to separate a mixture, crystals form after the solvent has evaporated. This is called **crystallisation** and occurs because as the solvent forms a gas or evaporates, the solution left behind becomes more and more concentrated. Eventually the solution is so concentrated that it becomes saturated; that is, not all of the solute can remain in solution. Consequently, some of the solute will start to come out of the solution in the form of crystals. The crystals grow as the solvent continues to evaporate. The amazing thing about crystals is that they come in amazing shapes and sizes depending on the solute and how quickly evaporation occurs.

evaporation
when heat causes liquid to become gas

crystallisation
solidification of a substance into a highly structured form

Have you seen salt crystals forming on your skin as you dry off after a swim in the ocean? Very slow evaporation of the solvent, like the water in a crystallisation pond, can form even bigger crystals of salt.

Figure 13.25 Crystals of salt can be formed and harvested by slow evaporation of water from a salt crystallisation pond.

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Try this 13.5

Invisible ink

Use lemon juice as invisible ink to write a message on paper. After it is dry, deliver it to a friend. Under the supervision of an adult, they can 'cook' the juice gently with an iron, near the flame of a candle or with a heat lamp to read your message.

Did you know? 13.6

Painting uses evaporation as a separation technique

Paints, you may recall, are a type of mixture. Wet paint is a mixture of colour pigments suspended in a binding medium (allows the paint to stick to surfaces and remain solid once it dries) and a solvent. Sometimes, there are also additional additives to make the paint dry quicker or allow it to be used on sailing boats or on railings prone to rust or to resist being broken down by sunlight. When the solvent dries and evaporates, only the colour pigment is left behind, suspended in the binding medium. It is the evaporation of the solvents that creates the distinctive smell of paint drying.

Figure 13.26 A common binding agent used in paints is gum arabic.

Quick check 13.6

1 Select the correct term from the list that will complete the sentences: filter, pigments, solvent, water. Chromatography is a technique that can separate different components of a mixture, such as different ____________ in ink or in a leaf. Samples of different mixtures are put on a piece of ____________ paper, and the paper is put into a solvent. If the mixture dissolves in water, then ____________ can be used for the solvent. If the mixture does not dissolve in water, then a different ____________ such as methylated spirits, must be used.

2 Number the following statements to indicate the order they occur in the process of paper chromatography.

   ____________ Place your sample in the centre of the pencil line.
   ____________ Place a small volume of water into a beaker (about 1 cm deep).
   ____________ Make sure the sample dot does not go below the surface of the liquid in your beaker.
   ____________ Leave for 20 minutes until the solvent reaches the top of the filter paper.
   ____________ Draw a line using a pencil across a filter strip 1 cm from the bottom.
   ____________ Fold the paper strips over the ice block stick, clip them, and lower them into the water in the beaker.

3 Define the key terms 'evaporation' and 'crystallisation'.

4 Develop a method that would allow you to separate salt and ground pepper (which can float) when they are all mixed up together. Include the concepts of 'evaporation' and 'crystallisation' in your explanation.

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Practical 13.3

Using evaporation to separate mixtures

Be careful

Observe general fire safety.

Wear safety equipment.

Aim

To analyse the mass of salt contained in a concentrated salt solution.

Prior understanding

Homogeneous mixtures contain particles too small to be seen with the naked eye. Solutions are mixtures where one substance is dissolved into another. Separation of substances in a solution relies on each substance having a unique set of physical or chemical properties. One unique property of substances is their boiling point. When a mixture is heated, each substance will evaporate at different temperatures, leaving the other substances behind.

Materials

- concentrated salt water
- measuring cylinder
- 250 mL beaker
- Bunsen burner
- tripod
- matches
- heatproof mat
- gauze mat
- safety glasses
- scales

Procedure

1. Copy the results table into your science book.
2. Weigh the mass of the beaker using the scales. Record in the table.
3. Measure 100 mL of concentrated salt water into the beaker.
4. Set up the tripod and gauze over the Bunsen burner.
5. Place the beaker on the gauze.
6. Light the Bunsen burner as described in Practical 1.1 in Chapter 1.
7. Allow the mixture to boil until there is 25 mL of water left in the beaker.
8. Turn off the gas.
9. Leave the beaker on the tripod to cool.
10. When cool, pack up the equipment and leave beaker in a warm place to allow the remainder of the liquid to evaporate for a few days.

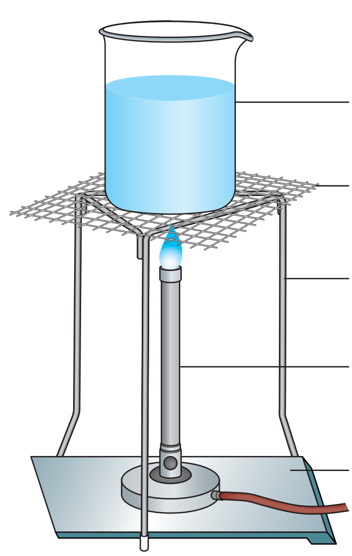

Figure 13.27 Experimental set-up

continued…

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...continued

Next lesson

11 Weigh the beaker and record the mass.

12 Calculate the change in mass.

Results

Mass (grams)	Group result	Class mean
Empty beaker		
Beaker + salt		
Salt in beaker (= mass of salt in beaker)		

Draw a labelled diagram that clearly shows how to set up the equipment for this separation method.

- Follow the rules for drawing scientifically.
- Use a sharp pencil.

Peer review

1 Swap experimental diagrams with another group and give each other feedback on how clearly the diagram communicates how to set up the separation method. Your feedback should discuss the following:
   - how well the diagram follows the rules for scientific drawing
   - any other suggestions to improve the quality of communication.

2 After receiving feedback, make alterations to the diagram to address the identified issues and write up a final copy to present to the class.

Discussion

1 Compare your result with the actual mass of salt that was dissolved in the water (your teacher has this information).

2 Compare your result with other groups. How much variation was observed between the final results for the mass of the salt?

3 Calculate a class mean for the mass of salt that was dissolved in 100 mL of water.

4 Determine if a reliable conclusion could have been drawn about the mass of salt per 100 mL based on the mean class results.

Most natural water sources contain a variety of dissolved salts.

5 Discuss how this would affect the validity of the conclusion drawn about the mass of salt that was dissolved into the water to make the test solution.

6 Propose changes to the method to improve the quality of the data in future experiments.

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Distillation

You may have thought about the process of evaporation and how when you separate salt from salty water, all the water is lost into the atmosphere as water vapour. But what if you could catch it so that you could use it? This is where **distillation** comes in. It is a technique that uses evaporation (heating) and condensation (cooling) to separate the components of a liquid mixture according to their boiling temperatures. All components of the mixture are retained. The solute remains in the flask, while the solvent evaporates and is caught as it forms the distillate in the beaker at the end. In order for the distillate to make its way into the beaker, it must first go through the condenser. A condenser is an important piece of equipment that has an outer jacket full of water. This helps to cool and condense the solvent vapour back into its liquid form.

Figure 13.28 Distillation equipment used for the food and beverage industry

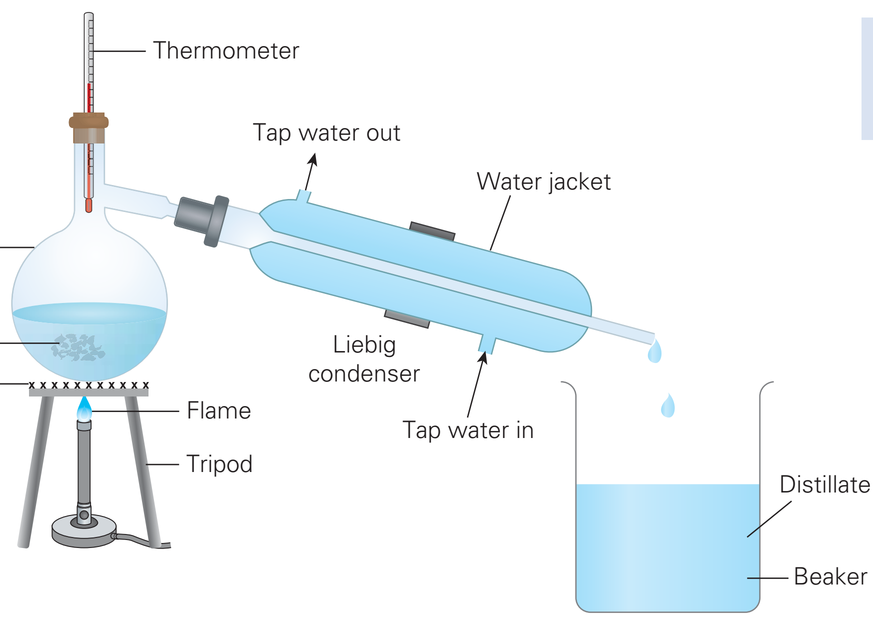

Figure 13.29 A Liebig condenser is used for the process of simple distillation.

distillation
a technique to separate substances in a liquid using evaporation through boiling and condensation

WIDGET
Choosing the best method for separating mixtures

Explore! 13.1

Essential oils

The formation of essential oils and perfume relies on the separation technique of distillation.

1 Investigate the role of distillation in the creation of essential oils and perfume.
2 Compare the distillation process used to make essential oils and perfume to the one used in your classroom.
3 Summarise how and why three other industries use distillation.

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Practical 13.4: Teacher demonstration

Distillation

Aim

To observe the process of distillation.

Be careful

The distillation apparatus can become extremely hot during the experiment. Ensure water pressure is slowly increased so as not to introduce internal stress to the condenser.

Materials

- water
- table salt
- 2 × 250 mL beakers
- Bunsen burner
- distillation apparatus
- spatula
- tripod
- safety glasses

Procedure

1. Set up the equipment for distillation as shown in Figure 13.29.
2. Wear safety glasses.
3. Put 100 mL of water into one of the beakers. (The other one will collect the distilled water.)
4. Use the spatula to add salt and stir.
5. Continue adding salt until the solution is very concentrated but not saturated. Pour the concentrated salt solution into the round-bottomed flask of the distillation apparatus.
6. Turn on the water that circulates in the condenser.
7. Heat the salt solution.

Results

Describe your observations of this process. How did the original solution look? What substance was left behind in the round-bottomed flask?

Discussion

1. Why was it necessary to heat the salty water solution?
2. Explain how the condenser works.
3. Which part is the distillate?
4. What were possible sources of error when using the different separation techniques?
5. How could you minimise the impact of these sources of error in the future?

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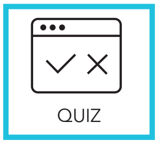
Section 13.4 questions



Remembering

1 Copy and **label** the parts of the Liebig condenser and other equipment indicated in Figure 13.30.

Understanding

2 **Define** the terms 'distillation' and 'evaporation'.

3 **Describe** the difference between distillation and evaporation.

Applying

4 **Explain** what happens to particles during the process of evaporation and the process of condensation. Draw pictures of the particles to help in your explanation.

Analysing

5 **Compare** and **contrast** evaporation and crystallisation.

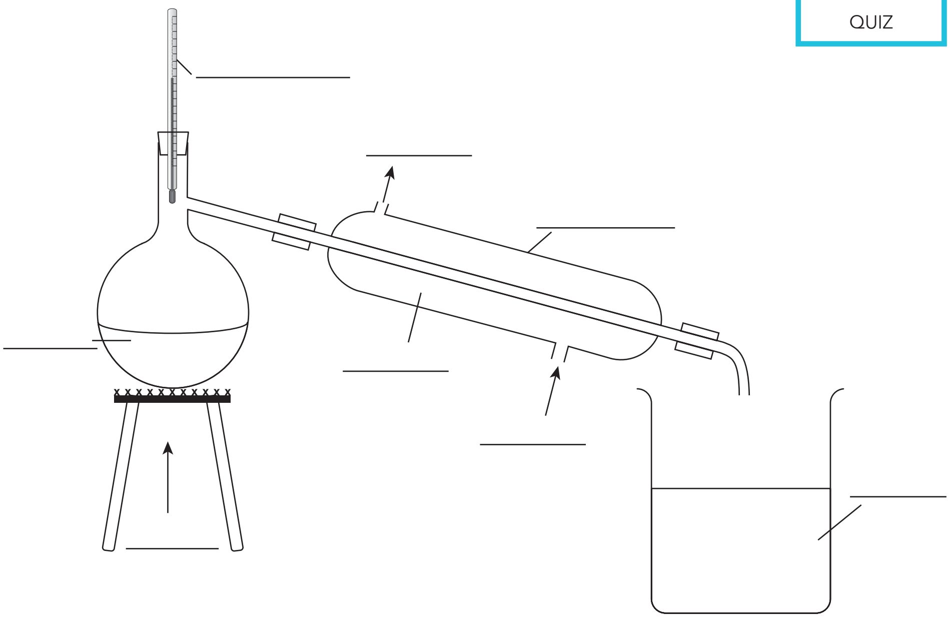


Figure 13.30 Liebig condenser and other equipment

Evaluating

6 a Copy and **label** the diagram shown in Figure 13.31.
b **Explain** what is meant by 'mobile phase' and 'stationary phase'.
c Write the colours in **order** from least to most soluble in the solvent.
d **Explain** why the bottom line should be marked in pencil and not in pen.

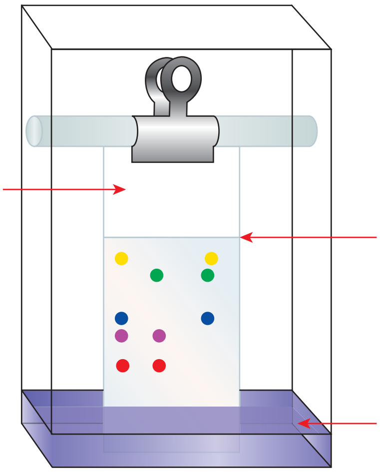


Figure 13.31

7 Substances X, Y, Z, W and sugar were mixed in water. The properties of each substance are listed below.

Substance	Solubility in water	State at room temperature	Boiling temperature (°C)
Sugar	Soluble	Solid	> 110
X	Soluble	Liquid	86
Y	Soluble	Liquid	68
Z	Insoluble	Solid	> 800
W	Insoluble	Solid	86

Determine the steps for how you would separate the mixtures.

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Chapter review

Chapter checklist

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

Success criteria		Check
13.1	**I can identify and describe the differences between pure substances and mixtures.** e.g. Define 'pure substance' and 'mixture'.	
13.1	**I can contrast homogeneous and heterogeneous mixtures.** e.g. Identify an example of both a homogeneous and a heterogeneous mixture.	
13.2	**I can identify solvents, solutes and solutions.** e.g. Define 'solvent', 'solute' and 'solution'.	
13.3, 13.4	**I am able to describe a range of physical separation techniques.** e.g. Describe the process of chromatography.	

Reflections

1 What **connections** come to mind when you think about mixtures and your everyday life?
2 What new concepts have **extended** your thinking about mixtures?
3 What information did you find **challenging** or confusing?

Data questions

Recycling centres separate mixtures of recyclable material on a very large scale. The relative mass of paper and packaging components of the recyclable material sent for processing in a particular area is shown in the Figure 13.32. The mass of glass materials collected for recycling is shown in Figure 13.33.

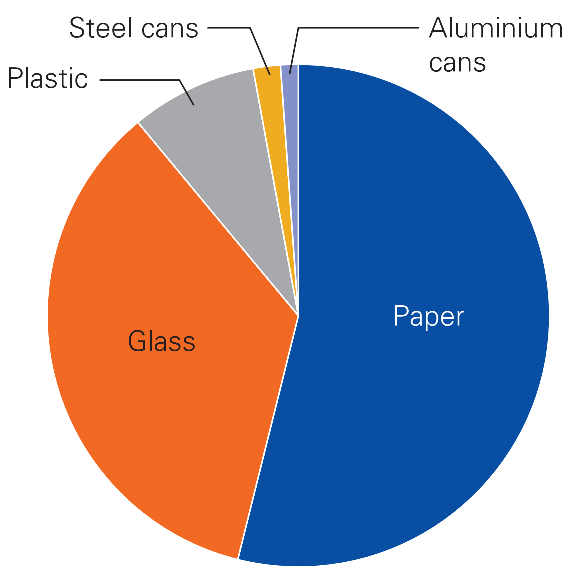

Figure 13.32 Relative mass of paper and packaging materials collected for recycling in a particular area

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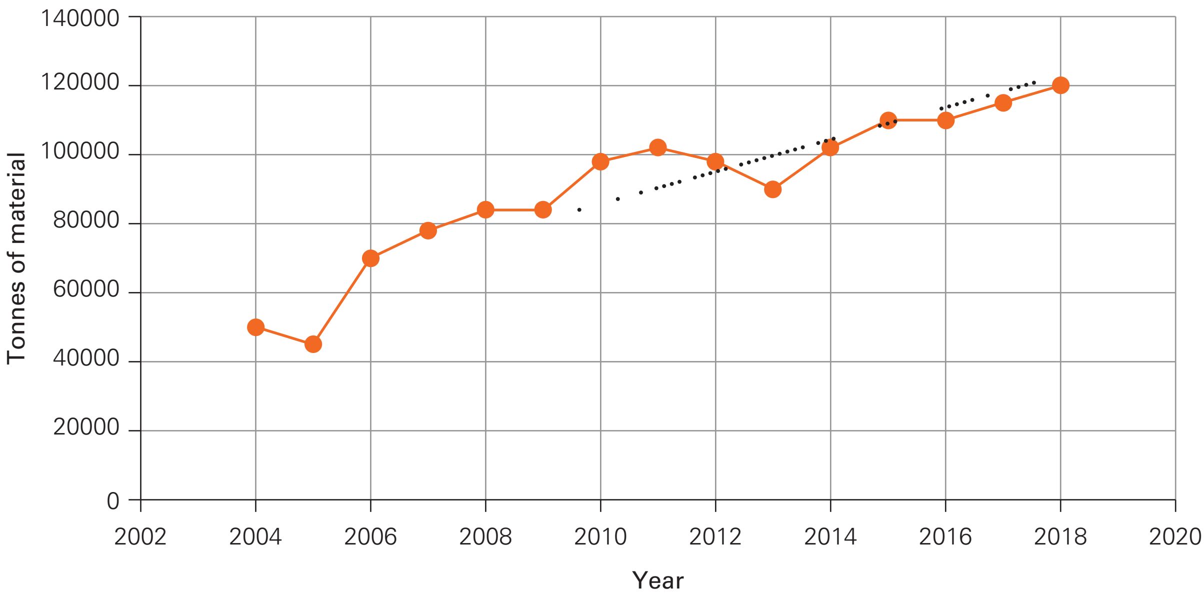

Figure 13.33 Approximate mass of glass collected (orange) for recycling (the trendline is the black dotted line)

Questions 1–3 refer to Figure 13.32.

1 **Determine** which component of the paper and packaging mixture accounts for the smallest mass.

2 **Calculate** the percentage of mass made up of paper if the glass component accounts for 35% of the overall mass, plastic 8% and cans (steel and aluminium) 3%.

3 **Sequence** the components of the paper and packaging mixture in order of decreasing relative mass.

Questions 4–8 refer to Figure 13.33.

4 **Identify** the trend in the mass of glass collected for recycling over the past 15 years.

5 **Distinguish** between the information provided by the orange line and the black dotted line in Figure 13.33.

6 **Predict** how the trend in mass of glass collected for recycling will progress over the next ten years.

7 **Justify** why the trend would progress in the way you have predicted in Question **6**.

8 **Extrapolate** the trendline to the year 2020. What mass of glass can be estimated to be collected for recycling in that year?

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STEM activity: Cleaning up an oil spill

Background information

The Great Barrier Reef is a Natural Wonder of the World. It is home to thousands of different types of fish, soft and hard coral, sharks, rays, turtles and marine mammals. This vulnerable ecosystem is threatened by many external factors, one being oil spills.

In 2010 a cargo ship struck the reef, which not only caused large damage to the reef, but also caused approximately 3 to 4 tonnes of oil to be released into the ocean. This oil slicked on the surface and although chemical dispersants were used to break up the oil, oil tar balls were found washed up on islands nearby. Booms and skimmers could not be used as a physical collection as the weather had caused large waves, making physical collection impossible.

Oil is a low-density substance, which means it floats on water and never mixes into it. Although this is a convenient property, oil also has the property of clinging to anything that is not water, and this is what makes it tricky to clean up – it clings to plants, animals and land, and impacts on marine ecosystems. Oil spills therefore need to be cleaned up very quickly and effectively to lessen the impact. Clean-up strategies used by environmental engineers include first using booms (inflatable barriers to contain the spill), skimming (scooping the oil off the surface using a vacuum), absorbing (soaking up the oil using sponges and absorbent rope), and dispersing the oil (breaking it into smaller droplets). Some of these methods are more effective than others.

Figure 13.34 A dolphin swims next to an oil spill

Design brief: Determine the most effective way to clean an oil spill from the Great Barrier Reef.

Activity instructions

In this task you will play the role of an environmental engineer and work together in your group to determine the most effective way of cleaning oil from the Great Barrier Reef. You will carry out a simulation of an oil spill and how it can be cleaned up. You will collect data about the oil removal and consider the effectiveness and cost of each method. You will present your findings in either a report or a presentation for the local government, which includes the perspective of the oil company.

Figure 13.35 Booms and skimmers helping to contain and clean up the oil spill

Research and feasibility

1 Copy and complete the table by listing all the possible ways of cleaning up an oil spill and what materials you have access to that could do the job. For each material, consider whether they are a skimmer, absorber or dispersant. Find out how much each unit or packet of material costs at the supermarket. Estimate how much of it you need and the total cost to clean one cup of an oil spill.

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Material	Effect on oil spill	Skimmer, absorber or dispersant (and cost)
Detergent		
Cotton balls		
Plastic spoon		
Small sponge		
Paper towel		

2 Consider how you will record your data on effectiveness of oil removal and cost.

3 Predict which material will be most effective at removing oil.

Design

4 Design a method in your group for the three different techniques of oil spill clean-up

- **a** using a skimmer
- **b** using an absorber
- **c** using a dispersant.

Note: You may want to pour your oil from a beaker into the tray and then as you collect the oil, place it back into the beaker to help you measure before and after amounts to compare how effective the removal was. You should try to collect all the oil before it reaches the coastline.

Create

5 Using your set-up reef, place the ship in an agreed location (group consensus), and pour your oil mixture onto the water slowly. Try to completely remove the oil mixture using the skimmer technique. Spill the oil back into the water, then repeat for the absorber, and then the dispersant. Record your results in the table you designed in Step 2.

Evaluate and modify

6 Analyse your results. Begin by drawing a graph showing the effectiveness of each clean-up method, and another showing the cost of each clean-up method.

7 Discuss the effectiveness of each method of cleaning up an oil spill. Did your findings support your hypothesis or not? Were there any sources of error in your experiment? How could you work to prevent these errors from occurring in the future?

8 Consider skimming as a clean-up technique. Hypothesise what impact the ocean waves might have on the effectiveness of this technique. Is it cost effective when you need to have boats with specialised equipment for the task?

9 Consider an absorber as a clean-up technique. Reflect on how you would dispose of absorbers that have soaked up the oil after the clean-up. Have you considered that the oil removed from the ocean must be stored elsewhere? Hypothesise on how effective absorbers would be to remove oil in the ocean.

10 Consider dispersants as a clean-up technique. Explain what the dispersant does to the oil on water. Is it appropriate to be putting more chemicals in the water? Discuss with your group three possible impacts of the dispersants on the marine ecosystem.

11 Compare the measured volume of crude oil spilt into your ocean with the volume of crude oil you removed. What percentage of crude oil did you successfully remove from the ocean? Did one technique prove to be more effective? Explain the possible causes of any differences between the two volumes.

12 You now have enough information to write your report. Prepare a report for local government that summarises your simulation findings. Include:

- **a** the different methods, their effectiveness and their costs
- **b** both points of view: the environmental engineer and the oil company
- **c** which method/s you think should be utilised by environmental engineers in the future when cleaning up an oil spill in a local waterway.

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Chapter 14

Physical and chemical change

Inquiry questions

What causes chemical changes?

Why are new substances formed with a chemical change?

How can chemical changes be identified?

PRE-TEST

Chapter introduction

This chapter introduces you to the physical and chemical changes that occur in our world. You will also learn about how substances react to form new substances, and the evidence that a reaction has occurred. You will look at how glow sticks work, how marshmallows go gooey and delicious over a fire, how fruit ripens, and how fireflies glow in the night.

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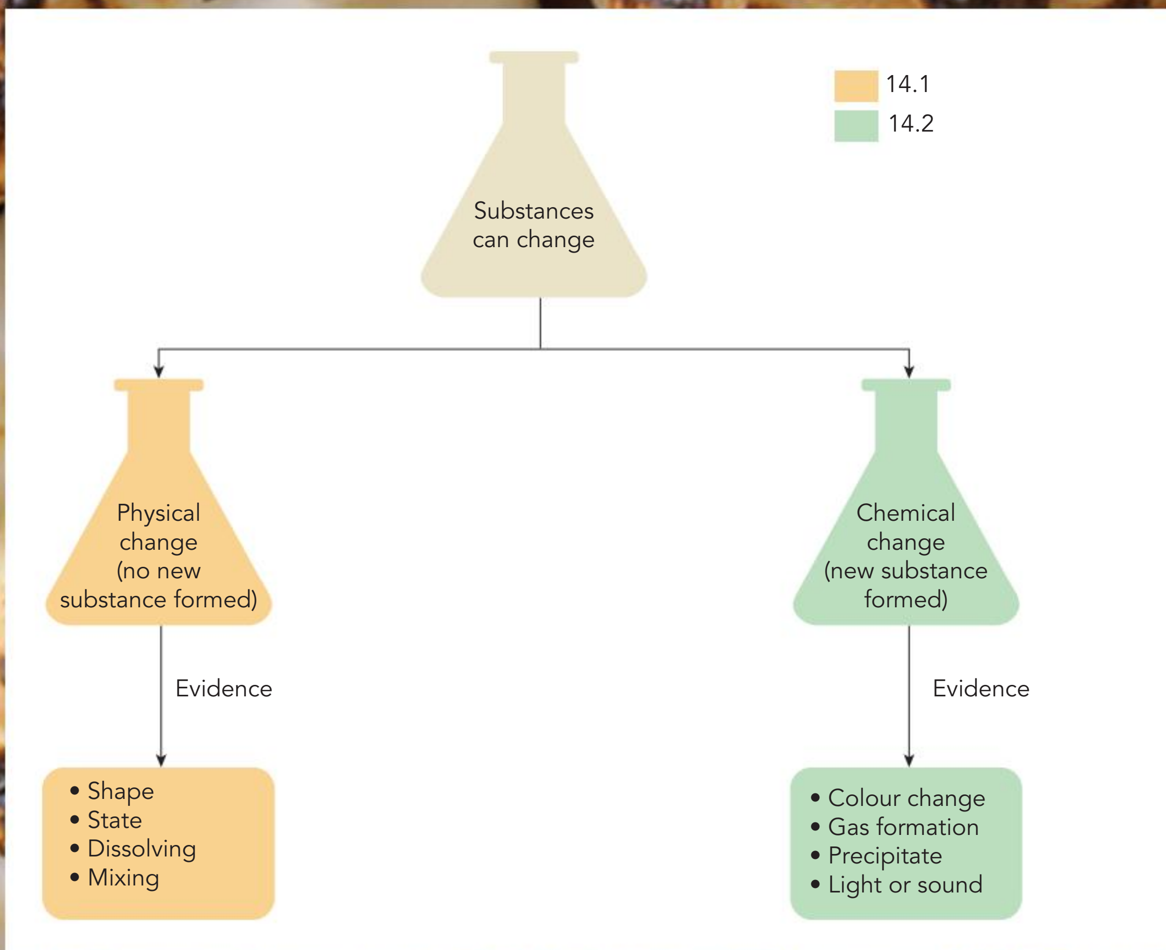
Chapter map



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14.1 Evidence of physical change

Learning goals

1. To identify the features of a physical change.
2. To give examples of different physical changes.

WORKSHEET

Physical change

During a **physical change**, the characteristics of a substance, or its physical properties, change in some way, but no new substance is formed. Examples of physical properties are texture, shape, size, colour, odour, volume, mass, and density. The chemical composition of the substance is unchanged.

physical change
when the physical properties of a substance change in some way, but no new substance is formed; it is reversible

reversible
capable of going in the opposite direction

irreversible
incapable of going in the opposite direction

Physical change can be **reversible** (e.g. ice melting into water can be refrozen) or **irreversible** (e.g. cutting a piece of paper).

When trying to determine whether a physical change has occurred, there are several pieces of evidence to look for, such as:

- a change in shape
- expansion or contraction
- a change in state
- mixing or dissolving occurring
- a non-permanent colour change.

Evidence of physical change

Changing shape

When an object changes shape, we say it has undergone a physical change. For example, when an elastic band is stretched, the physical properties of the elastic band change but not its chemical structure, nothing new has formed and it is reversible. Think about a soft drink can being crushed. Have its physical properties changed? Has its chemical structure changed? Has anything new been made? So is it a physical change?

Figure 14.1 Different types of evidence that a physical change has occurred: change in shape (top left), expansion or contraction (top right), change in state (bottom left) or mixing (bottom right)

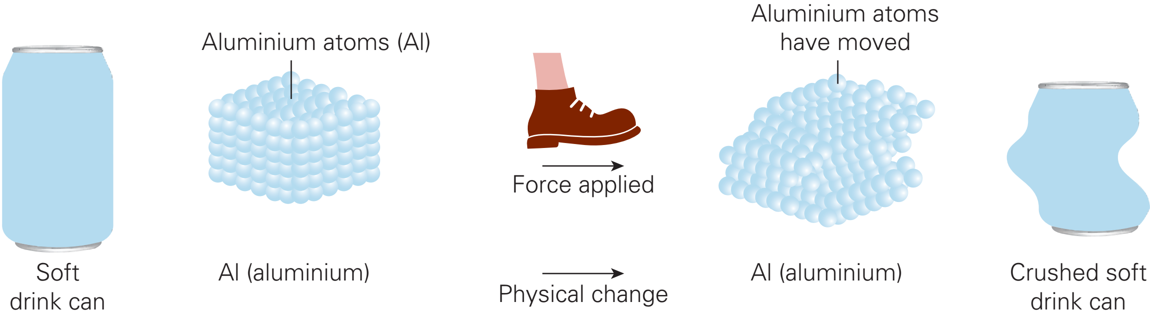

Figure 14.2 When an aluminium can is crushed, the characteristics of the can have changed, but nothing new is formed. Therefore it is a physical change.

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Figure 14.3 An example of a physical change is when glass breaks: its physical characteristics change, but it is still glass.

Breaking glass is another example of physical change. Can you explain why?

Quick check 14.1

1. Define the term 'physical change'.
2. Name four pieces of evidence to look for when determining whether a physical change has occurred.
3. Explain how changing shape is an example of physical change.

Expansion and contraction

In Section 11.1, you learned about the particle model and different states of matter. The particle model, which describes the behaviour of atoms in solids, liquids and gases, suggests that if you heat up a substance, the atoms in the substance will also gain energy, move faster, and expand if the container allows. This means the atoms

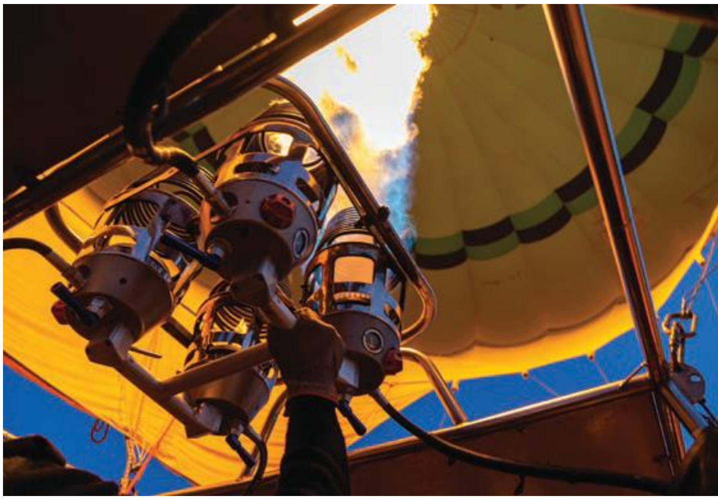

Figure 14.4 When the air inside a hot air balloon is heated, the atoms in the heated air gain energy, move faster, moving away from each one another and therefore taking up more space. This is an example of a physical change occurring and it results in the air being less dense on the inside of the balloon, so the balloon rises.

will gain energy, move more and increase the distance between one another. This process of atoms moving away from one another is called expansion. Expansion is an example of physical change – the properties of the substance have changed (volume increases and density decreases), but no new substance has formed, and it is reversible. Hot air balloons and thermometers are two examples of where we can see evidence of a physical change occurring in this way.

The reverse of expansion is contraction, and this is also evidence of a physical change occurring. The substance cools down, the atoms lose energy, they slow down, and the distance between the atoms gets smaller (volume decreases and density increases).

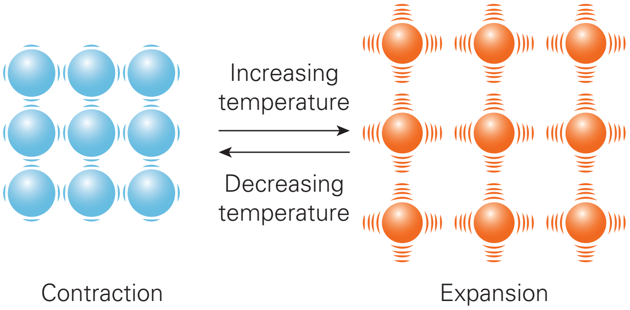

Figure 14.5 The physical changes experienced by atoms during expansion and contraction

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Practical 14.1

Making a model thermometer

Aim

To demonstrate expansion and contraction by making a model thermometer.

Materials

- 250 mL beaker
- 250 mL conical flask
- glass thermometer
- clear narrow plastic straw
- ice-cream container
- red food colouring
- kettle or hotplate
- permanent marker
- modelling clay (or Blu Tack)
- water
- ice

Procedure

1 Half fill the conical flask with water.
2 Add a drop or two of food colouring.
3 Place the straw in the flask, but do not let it touch the bottom. Use the clay to seal the edges of the flask's top with the straw in the middle. The clay will hold the straw in place and prevent it from touching the bottom of the flask.
4 On the side of the flask, use a permanent marker to mark the height of the liquid inside the straw (your thermometer) at room temperature. Record the temperature of the room using the glass thermometer.
5 Place the flask into an ice-cream container with ice and allow to cool. Record the temperature inside the ice-cream container using your glass thermometer and mark the side of the flask to document where the liquid level is.
6 Now heat up some water on the hotplate and add to the ice-cream container. Let the flask sit there for several minutes. Record the new temperature using the glass thermometer and mark the side of the flask to document where the liquid level is.
7 Make a scale on your model thermometer, using the temperatures you have recorded and the marks you have made on the flask.
8 Now test your model thermometer by using it to predict the temperature of different environments, such as a sunny spot in the school, or by changing the ratio of hot and cold water in the ice-cream container. Check your predictions with the glass thermometer.

Results

Record your observations and tabulate your results: the temperature of each environment and the height of the fluid in the straw.

Discussion

1 Compare your model thermometer results with the actual glass thermometer results. How close are they?
2 Explain your results. Why did the fluid move up/down the straw? Use your knowledge of the particle theory to aid in your explanation.
3 Imagine you repeated your experiment but with a narrower straw. How would you expect the measurements to be different for a narrower straw? Explain whether this new thermometer would be likely to be more or less accurate than your first thermometer.
4 Outline possible faults in this experiment, and explain how each could have affected your results.
5 Suggest improvements for this experiment if you were to carry it out again.

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Changing state

In Section 11.3, you learned that solids, liquids and gases can change their state. You know that heating up a substance causes an increase in temperature. If enough heat is added, the substance can change its state. When a substance changes state, it is a physical change – it can be reversed, and the actual substance is still chemically the same, only the physical properties have altered. The different changes of state are summarised in Figure 14.6.

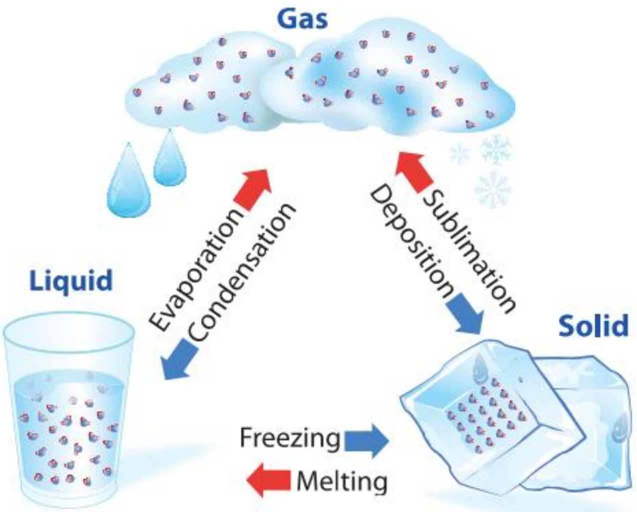

Figure 14.6 When some substances gain or lose heat, they undergo a physical change: no new substance is produced and the substance changes its physical properties but is still the same substance.

Figure 14.7 A snowman melting is an example of physical change. Can you explain why?

Figure 14.8 Condensation is an example of a physical change, as no new substance has formed, it is reversible and it is only the physical properties of the water that have altered, not its chemical make-up.

Advances in science 14.1

Physical changes have happened on Mars too!

Mars has a number of surface features such as dried-out river valleys and gigantic outflow channels that could have been caused by glaciers. Scientists believe that in the distant past, Mars featured a thick atmosphere and lots of surface water, including a huge ocean that may have covered 40% of its northern hemisphere.

As you know, a change of state is an example of physical change, so physical changes have happened on Mars too. Four billion years ago, the atmosphere of Mars started to thin, causing any liquid on the surface to quickly freeze and evaporate.

However, data collected by the European Space Agency's Mars *Express* spacecraft suggests that there is a pool of liquid water buried under layers of ice and dust in the south of Mars. A 2020 study predicted that very salty water (which doesn't freeze as easily) could be found on the surface, and this is only possible for very short periods of time each year, but the water would be a very chilly −48°C!

Figure 14.9 The surface of Mars is thought to have been shaped by physical changes.

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Quick check 14.2

1 Explain how expansion and contraction are examples of physical change.
2 Explain how changing state is an example of physical change.

Mixing and dissolving

When you mix substances or dissolve one substance in another, a physical change occurs. Think about **dissolving** sugar (solute) in water (solvent) to form a solution. The way the molecules of sugar spread out within the water is called diffusion. In Chapter 11, you learned that diffusion is the movement of particles from an area of high concentration to low concentration. When the sugar is all spread out in the water, you still have sugar, but the molecules have been separated and surrounded by water molecules. The characteristics of the sugar have changed from a crystalline, solid structure to one where all the sugar particles can move around freely in the water. No new substance has been formed, and the process is reversible if you evaporate the water. It is for this reason that mixing and dissolving are considered evidence of physical change.

dissolving
the process where individual particles of a solute are separated from one another and surrounded by solvent molecules, causing them to no longer be visible in a solution

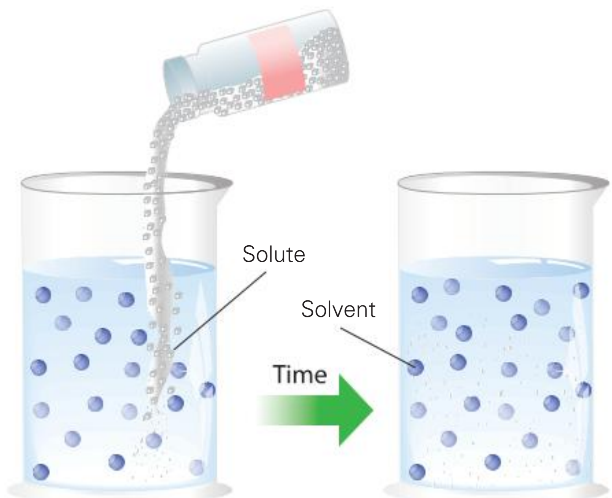

Figure 14.10 Molecules of water (blue) move randomly in a glass. Add sugar (white) and the new, dissolved molecules will eventually become distributed uniformly throughout the water. This is diffusion.

Try this 14.1

Skittles® and diffusion

Note: This activity uses lollies containing food colouring, which may present a risk if students have food allergies. No food items are to be consumed.

Collect the following materials: Petri dish, stopwatch, filter paper or white paper, five Skittles of different colours, and a beaker of water.

Now place the Petri dish on the filter or white paper and place the five Skittles equally spaced in the Petri dish. Slowly pour water into the Petri dish to fill it up, and start timing. Record your observations. Explain your observations using the term 'diffusion'.

Repeat, but this time use warm water. Explain the differences you observe.

Figure 14.11 Skittles can help demonstrate diffusion.

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Quick check 14.3

1 Explain how mixing and dissolving are examples of physical change.
2 Identify which of the following are physical changes.
   - Slicing bread
   - Turning on a light
   - Breaking an egg
   - Mowing grass
   - Setting off fireworks
   - Breaking glass
   - Freezing water
   - Cutting hair
   - Making a fire
   - Drying clothes
   - Burning toast
   - Melting chocolate
   - Colouring hair
   - Yoghurt going 'off'
   - Popping popcorn
   - Squeezing an orange

Explore! 14.1

More physical changes?

Are there other examples of physical change that you have not investigated, or have you covered them all? Your job is to find out what you can about the following three situations, and provide evidence why each is or is not an example of physical change.

1 The heating of an iron bar until it turns red
2 The magnetising of a piece of iron
3 The glowing filament of a light globe.

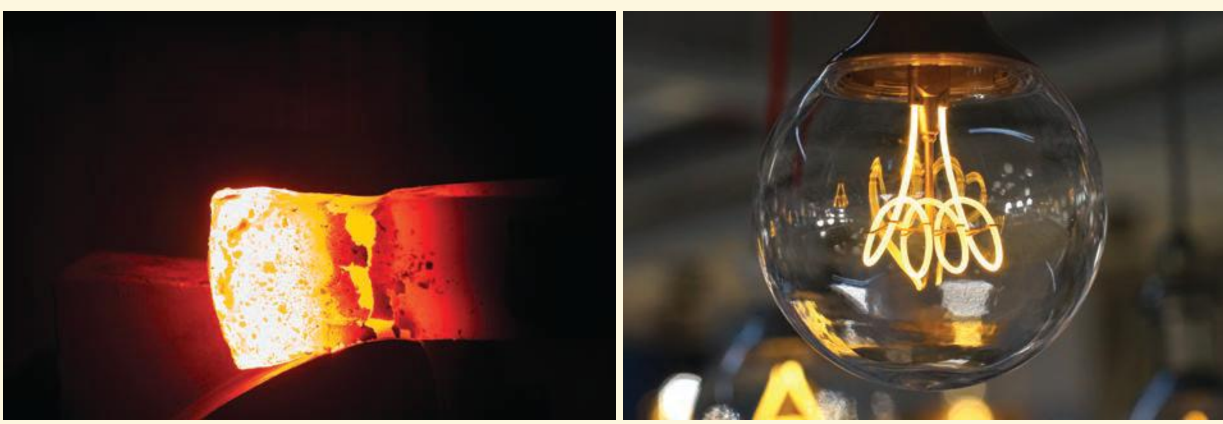

Figure 14.12 An iron bar glows red when heated, and a filament glows in a light globe. Are these examples of physical change?

Explore! 14.2

Recycling

Recycling of waste makes use of the unique physical properties of a range of waste materials to separate components, including cardboard, glass, aluminium cans and magnetic metals. Investigate the design of a recycling plant for the separation of components of waste based on their physical properties.

1 How are paper and cardboard separated from larger plastic bottles using a screening machine?
2 How are magnetic metals separated from non-magnetic components of a mixture?

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Section 14.1 questions

QUIZ

Remembering

1 **Identify** which of the following are examples of physical properties.
- Blue colour
- Odour
- Density
- Sweet taste
- Flammable
- Reacts with air
- Reacts with water
- Boiling point
- Hardness
- Dissolves in water
- Lustre
- Volume

2 **Identify** which of the following are physical changes.
- Cutting an apple
- Milk going 'off'
- Digesting food
- Ice melting
- Cooking pikelets
- Wood rotting
- Reacting with vinegar
- Inflating a bike tyre
- Grass growing
- Silver tarnishing
- Mopping up water
- Milo dissolving in milk

3 **Define** the following terms: reversible, irreversible, expansion, contraction, melting, freezing, evaporation, condensation, dissolving, diffusion.

Understanding

4 **State** whether the following statements are true or false. **Rewrite** the false statements so that they are true.
a During a physical change, the chemical make-up of the substance also changes.
b Melting is a physical change.
c As particles warm up, expansion can occur and this is a physical change.
d Physical changes are never reversible.
e When heat is lost from a substance, the particles can move closer together, and a gas can change to a liquid.
f Cutting up a cake changes the shape and size of the cake – this is a physical change.
g Burning wood in a fire forms charcoal and ash – this is a physical change.
h When a solute dissolves in a solvent, nothing new is formed, so this is a physical change.

5 **Identify** five physical changes that happen in your home.

Applying

6 **Summarise** the following physical changes, using your knowledge of the particle theory.
a Why the tyres on your family car seem more deflated on a cold day
b How a liquid in glass thermometer works
c Why on extremely hot days there are concerns about train tracks not working well

7 **Explain** the process whereby a strong-smelling deodorant is sprayed in one corner of the room but eventually everyone in the whole room can smell it.

Analysing

8 **Propose** how you could you reverse the following physical changes.
a Salt dissolving in water
b Inflating a balloon
c Ice melting
d Glass breaking

Evaluating

9 **Justify** why each of the following is an example of a physical change.
a Blow drying your dog's coat after giving him a bath
b Making cordial from a concentrate and water
c Your lilo getting tight and ready to pop after lying in the sun
d Crushing cereal boxes before putting them out for recycling

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14.2 Evidence of chemical change

Learning goals
1 To identify when a chemical change has occurred.
2 To give examples of different chemical changes.
3 To compare physical and chemical changes.

WORKSHEET

Chemical change

During a **chemical change**, a new substance is formed. This new substance is chemically different from the starting substance as the particles have been rearranged at the molecular level. To help determine whether a new substance has been formed, and therefore a chemical change has occurred, there is evidence you can watch for. Occasionally you will get exceptions to this list, but most of the time, one or more of the following would be observed:

- a permanent colour change
- a gas being given off (as an odour, or smoke or bubbles)
- a solid (called a **precipitate**) forming in a solution
- a change in temperature (increase or decrease)
- energy in the form of light or sound being produced (e.g. an explosion)

Consider the fireworks that light up the night sky each year on New Year's Eve. The bright explosions of colour that we see are actually metals, like magnesium and copper. They change chemically as they burn, producing fantastic colours. What signs are there that a chemical change has occurred? Referring to the previous list, we see colour, light and smoke, we hear cracking and fizzing, and we know the fireworks are dangerous to get close to, because of the heat they produce.

Chemical changes can be irreversible (e.g. burning paper) or reversible (you will learn more about this in senior chemistry). When referring to chemical reactions, 'irreversible' means that the **products** cannot be converted back to the substances that formed them (the **reactants**) within the same reaction. Undoing an irreversible chemical change often requires a different chemical reaction (or many reactions) to take place.

chemical change
where one or more substances undergo a chemical reaction and a new substance is formed; mostly irreversible

precipitate
the solid that forms when two clear solutions are mixed and undergo a chemical change

products
the substances that are present at the end of a chemical reaction

reactants
the substances that are present at the beginning of a chemical reaction

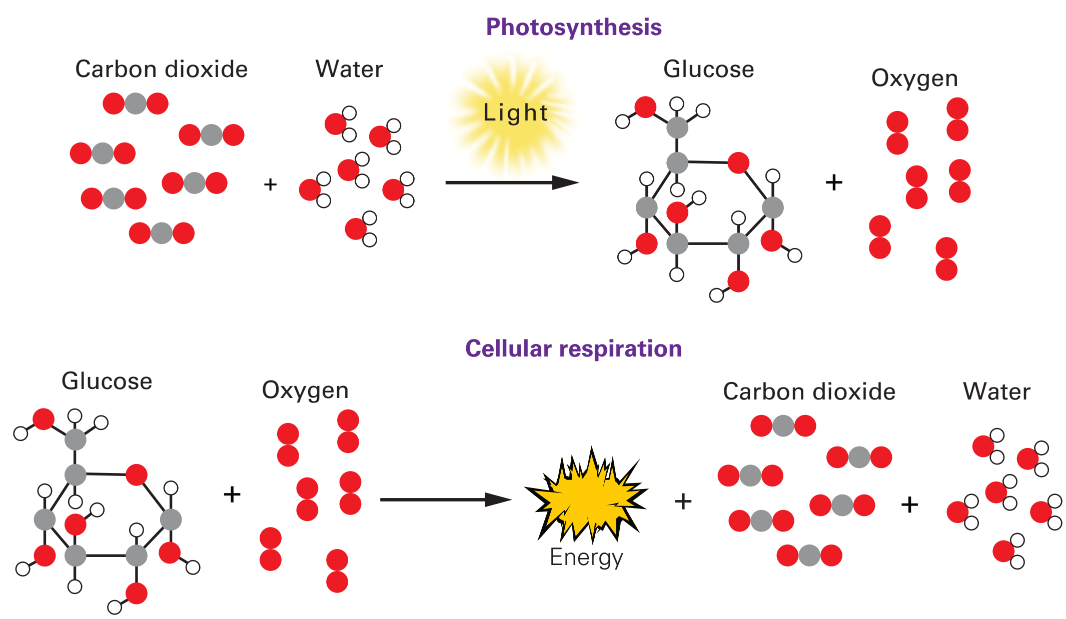

Figure 14.13 The process of photosynthesis and cellular respiration are examples of chemical reactions. Note how the arrangement of the atoms is different in the reactants on the left and the products on the right. Photosynthesis is irreversible, but can be undone by a different chemical process: cellular respiration.

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In other chapters we have discussed important chemical reactions that occur around and inside us every day such as respiration, chemical weathering and photosynthesis. If we look at photosynthesis specifically we can identify the reactants as carbon dioxide and water and the products as glucose and oxygen. Can you identify the reactants and products of cellular respiration?

Quick check 14.4

1 What is the key piece of evidence that a chemical change has occurred?
2 List the five pieces of evidence to look for, to determine whether a chemical change has occurred.
3 What is the evidence that a chemical change has occurred in each of these situations?
   a Leaves turning red in the autumn
   b Sherbet fizzes in your mouth
   c Bread is baking in the oven.

Advances in science 14.2

Chemical reactions caught on film

Scientists are now able to 'film' inter-molecular chemical reactions. They are able to do this using the electron beam from a transmission electron microscope (TEM), like stop-motion or stop-frame filming. This technique can show chemical reactions as they are happening and, among other challenging questions, can help us understand how molecules interact or react with one another at the atomic level. We may also be able to find out why one product, rather than another, forms.

VIDEO Evidence of chemical reactions

Evidence of chemical change

It is finally the school holidays and your family is going camping. One cool evening you are all relaxing around the campfire to keep warm. The adults are cooking sausages on the grill over the flames and damper in the coals beneath. You toast marshmallows using sticks held over the edge of the fire, letting them get all brown, gooey and delicious. On this lovely evening, chemical changes are happening all around you!

Figure 14.14 Damper bread that has been cooked in the coals of a fire shows evidence of a chemical change occurring.

Colour change

Remember: a chemical change is any change that causes a new substance to be formed. For example, when your campfire has burned completely out, ashes are left behind – these are a new substance formed by the burning of wood. This is a chemical change. But what about permanent colour change? This is another indicator that a chemical change has occurred.

Your marshmallows, sausages and damper are all browning on the outside from being exposed to the heat of the campfire flames. This is due to a reaction between amino acids and sugar. This is a permanent colour change, indicating that a chemical change has occurred, although there may also be a new substance (charcoal) forming on the outside if your food is burning! Generally speaking, the changes caused by cooking food are all chemical changes.

The ripening of fruit and vegetables is another example of a colour change indicating that a chemical change has occurred. For example, when a tomato reaches the green stage of its development, it starts to produce ethylene gas (IUPAC name: ethene). The ethylene then

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interacts with the tomato fruit to start the ripening process, which involves chemical reactions, and so it is evidence of chemical change.

Figure 14.15 Tomatoes ripening and changing colour is evidence that a chemical change has occurred.

Rusting, a type of **corrosion**, is a slow and usually unwanted chemical change that causes iron and steel to go flaky and brown. This is not desirable in things like buildings, bridges and train tracks, which are made of iron and steel. Rusting occurs when iron reacts with water and with the oxygen in the air to form iron oxide (rust). This is a new substance forming and so, clearly, rusting is a process producing a chemical change.

corrosion
the gradual and natural process of metals breaking down; an example is rusting

galvanisation
the process of coating iron or steel in zinc to prevent corrosion

Given the widespread use of iron and steel, we need ways to prevent rusting. The word equation for the process of rusting is:

$$\text{iron} + \text{oxygen} + \text{water} \rightarrow \text{iron hydroxide}$$

Iron hydroxide then dehydrates to form iron oxide (rust).

This equation means that all three substances on the left of the arrow are required to produce the substance on the right of the arrow. If iron and steel are not exposed to water and oxygen, then iron oxide cannot be made and rusting is halted. You may have noticed that, in hardware stores, there are two options for stopping water and oxygen coming into contact with the iron and steel:

- a surface protector can be painted onto the iron or steel surface. This is like the paint we put on cars to prevent the metal panels being exposed to the elements
- **galvanisation**, in which the iron or steel is coated in a layer of zinc. If a corrugated iron roof has been galvanised, the zinc coating will corrode before the iron, and so the iron is protected from rusting.

Figure 14.16 Screws exposed to water and oxygen will start to corrode or rust, providing evidence of chemical change.

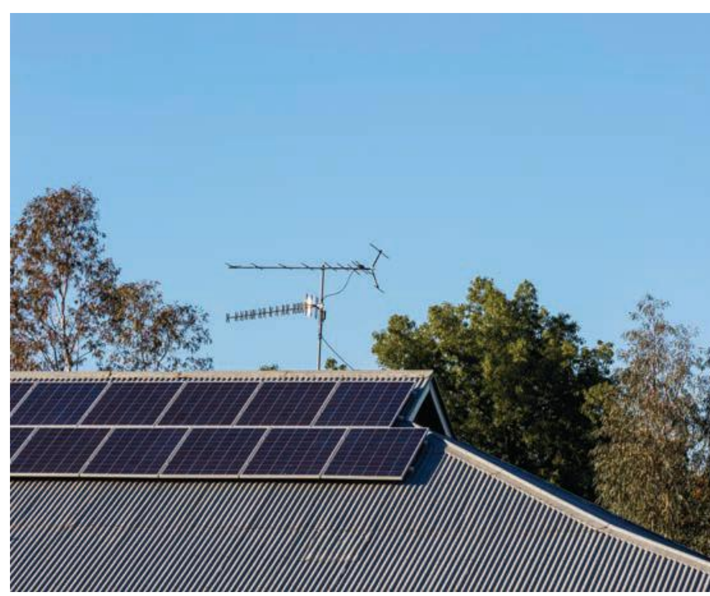

Figure 14.17 A galvanised corrugated iron roof: the zinc coating will corrode before the iron underneath, preventing rusting of the iron.

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Try this 14.2

Steganography

Steganography is the practice of sending hidden messages. For this activity you will need some lemon juice in a small container, white paper, a plastic tray, some cotton buds and access to an iron or a hairdryer. Begin by placing a piece of white paper on your tray. Dip a cotton bud into the lemon juice and write a message on the paper. When your message is dry, your teacher will reveal your message using a heat source (iron or hairdryer). Explain why this is an example of a chemical change.

Practical 14.2

To rust or not to rust

Aim

To determine the conditions required for the chemical change of rusting.

Materials

- steel nails
- sandpaper
- large glass test tubes with stoppers
- vegetable oil
- water

Planning

1 Conduct some background research on the process of rusting. Summarise the process and the factors that affect it.
2 Consider what you learned earlier in the chapter and in your background research about the conditions that are required for the chemical change of rusting.
3 Design an experiment that will demonstrate that the conditions you believe to be required for rusting are indeed essential, using iron nails, oil (to prevent air getting access to water or iron nails), stoppers and test tubes. Think about your independent, dependent and controlled variables as you plan. You will need to leave your experiment overnight.
4 Write a specific and relevant research question for your investigation.
5 Identify the independent, dependent and controlled variables.
6 Write a hypothesis for your investigation.
7 Write a risk assessment for your investigation.
8 Draw a diagram of your method, showing what will be added to each test tube.
9 Check your design with your teacher before starting your experiment.

Results

1 Draw a results table for your experiment.
2 Produce a suitable graph for your experiment.

Discussion

1 Describe any patterns, trends or relationships in your results.
2 Define the terms 'chemical change' and 'rusting'. List any chemical changes you see in this experiment.
3 Write a word equation for the reaction that occurs when rust is produced.
4 Identify any limitations in your investigation.
5 Propose another independent variable that could have been tested, to expand on your results.
6 Suggest some improvements for this experiment.
7 For a super challenge, how can you make the steel nail rust faster? You may like to use salt water, vinegar and soft drinks in your experiment.

Conclusion

Draw a conclusion from this experiment regarding the conditions required for rusting, using data to support your statement.

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Gas is formed

To produce a soft, fluffy loaf of bread or a delicious piece of cake, you need a chemical change to occur. One of the key indicators in this case is a gas being produced. This gas could be in the form of an odour, bubbles or even smoke.

Bread can be made using a substance known as bicarb soda (or sodium bicarbonate), which is added to the main ingredients – flour, salt, oil and water. The ingredients are mixed into a dough before baking. When heated, the bicarb soda breaks down and produces carbon dioxide gas. As the carbon dioxide is released into the dough, it expands with the heat (note that this is a physical change). Large bubbles of gas form in the dough, and this is what gives the bread its spongy texture.

Bread can also be made using microorganisms called yeast. The yeast uses the starch and sugars in the flour to produce alcohol and carbon dioxide. The alcohol escapes during cooking, but the carbon dioxide expands inside the dough, creating bubbles of gas and making the bread rise.

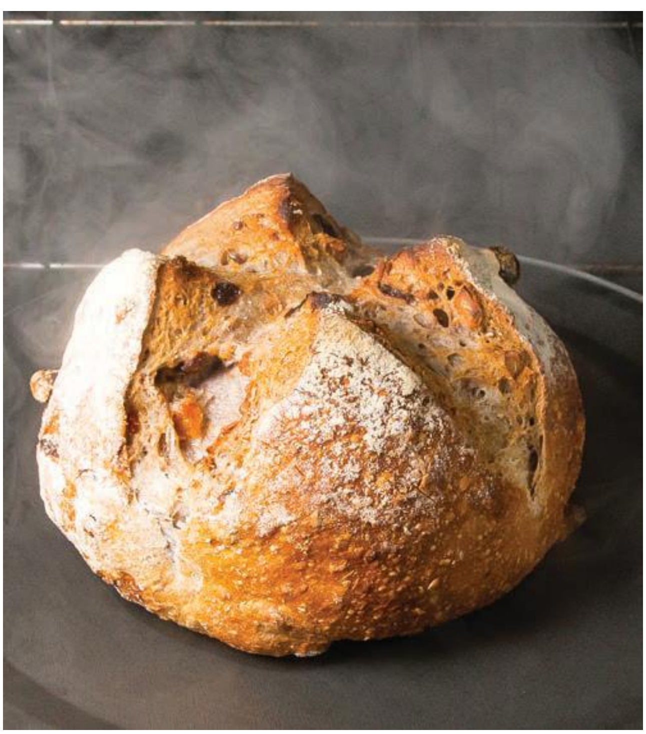

Figure 14.18 Hot bread is a delicious consequence of chemical change.

Rotting things often produce gas, and again, this is a sign that a chemical change is occurring. For example, vegetable scraps in the compost bin are broken down by microorganisms in a process called **decomposition**, and this produces carbon dioxide gas.

decomposition
a reaction in which one substance breaks up into smaller ones

Try this 14.3

Ready, set, bake!

Jump online and find a simple bread recipe. Give it a go at home. Write a word equation for the reaction – that is, write the ingredients that go into the bread, and then an arrow to represent the change, and then write the substances that are formed, to the right of the arrow. What evidence is there that a chemical change has occurred? Also list any physical changes you notice.

Precipitate is formed

Another indicator that a chemical change has occurred is the formation of a precipitate. A precipitate is the name given to a solid that forms when two clear solutions are mixed. The precipitate is unable to dissolve in water and so, when it forms, it makes the solution look cloudy before it settles on the bottom.

Quick check 14.5

1. Name three examples where a colour change indicates that a chemical change has occurred.
2. Recall the process of rusting as a word equation.
3. List two examples where a gas being formed provides evidence of chemical change. In each case, explain the chemical reaction.
4. Define the term 'precipitate'.

Change in temperature

You already know that during a chemical change, new products are formed. But did you know that heat energy may be given off or absorbed during a chemical change? This is another sign that a chemical change has occurred. For example, the burning of natural gas in the kitchen when you are cooking is a chemical change that

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bioluminescence a chemical reaction that produces light in living things

chemiluminescence a chemical reaction that produces light

gives off a great deal of heat. Heat is used in cooking to speed up the many chemical changes that result in a delicious meal. Remember how all matter consists of atoms joined together to form different substances? Heat can help atoms break free of one another and form different substances. For example, when you cook an egg, the heat makes the atoms in the egg white recombine in a different way, and this appears to us as cooked egg!

Essentially, any time you burn something, heat energy is produced, and the increase in temperature indicates that a chemical change has occurred. But the opposite can also happen: heat energy can be absorbed, and the temperature decreases. Chemical ice packs are probably the most common example of this. If you injure yourself, you may be offered an ice pack. You pop a bubble inside the pack and the pack starts to absorb heat from the surrounding environment, making the pack feel cold.

Light or sound produced

Another piece of evidence that a chemical change has occurred is light or sound. Remember the fireworks discussed earlier? During that chemical change, both sound and light are produced. Can you think of other examples where light or sound (or both) are evidence that a chemical change has occurred? The information in *Did you know? 14.1* and *Explore! 14.3* may help you.

WIDGET Physical vs. chemical change

Figure 14.19 When natural gas burns, a lot of heat energy is released, and we use this heat to cook our food.

Did you know? 14.1

Fireflies glow because of chemical reactions!

A chemical reaction occurs in fireflies' abdomens, allowing them to produce light. This process is called **bioluminescence** and is shared by many other organisms, mostly sea-dwelling or marine organisms. (Note that bioluminescence is a type of **chemiluminescence**.)

When oxygen combines with calcium, adenosine triphosphate (ATP) and the chemical luciferin, and a bioluminescent enzyme is also present, light is produced. When oxygen is available, the firefly's light organ glows, and when it is not available, the light goes out. The firefly is able to control the beginning and end of the chemical reaction, and thus start and stop the production of light. Unlike a light bulb, which gets hot when it produces light, a firefly's light is cold light, and so very little energy is lost as heat. This is very lucky for the firefly, because it would not survive getting as hot as a light bulb!

Fireflies light up for a number of reasons. The larvae produce short glows that act as a warning to predators that they taste bad. As adults, many fireflies have flash patterns unique to their species, and use them to discriminate between members of the opposite sex. In males, a higher rate and intensity of flashing has been shown to be most attractive to females in several firefly species.

Figure 14.20 The abdomen of a firefly produces light through a chemical reaction known as bioluminescence.

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Explore! 14.3

Glow sticks

Have you ever played minigolf in the dark with glow-in-the-dark balls? Have you ever celebrated New Year's Eve with glow sticks? It all comes down to chemical reactions.

1 Define the following key terms: fluorescence, chemiluminescence, bioluminescence.
2 Find out about the structure of glow sticks and explain what is involved in the chemical reaction that produces the light. Summarise your findings and include a picture/diagram.

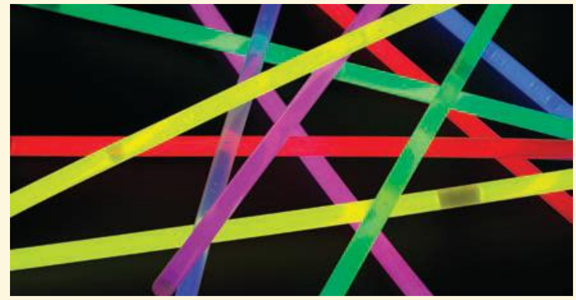

Figure 14.21 Glow sticks work because of chemiluminescence, a chemical reaction that produces light.

Quick check 14.6

1 List some examples of where a change in temperature provides evidence of chemical change.
2 List some examples of where light or sound being formed provides evidence of chemical change.

Practical 14.3

Chemical change

Be careful
Personal protective equipment is to be worn. All waste is to be collected and disposed of appropriately.

Aim
To conduct a series of activities/experiments in order to explore chemical change and be able to identify the evidence of change.

Materials
- 1 M hydrochloric acid
- strontium chloride solution
- copper II sulfate solution
- ammonium hydroxide solution
- lemon juice
- 2 cm strip of magnesium ribbon
- baking soda
- 100 mL glass beaker
- test tubes and test-tube rack
- thermometer
- wooden skewer
- Bunsen burner
- matches

Procedure
1 Copy the following table to record your results.

Activity	Change in colour	Change in temperature (°C)	Gas produced	Light produced	Precipitate produced	Observations
1						
2						
3						
4						

2 Conduct the following four activities.

Activity 1
1 Light the Bunsen burner.
2 Take a wooden skewer and break it in half.

continued...

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...continued

3 Dip the broken-off end of the skewer into the strontium chloride solution.
4 Place the wet end of the skewer into the flame.
5 Record your observations for Activity 1 in your results table and tick which of the pieces of evidence show that a chemical change has occurred.
6 Repeat the above steps with the copper II sulfate solution.

Activity 2

1 Place three eye droppers full of ammonium hydroxide into a test tube in a rack.
2 Add the copper II sulfate solution, drop by drop, no more than 10 drops, into the ammonium hydroxide.
3 Record your observations for Activity 2 in your results table and tick which of the pieces of evidence show that a chemical change has occurred.

Activity 3

1 Place a 2 cm strip of magnesium ribbon into a test tube in a rack.
2 Gently stand a thermometer in the same test tube.
3 Add approximately 2 cm of dilute hydrochloric acid to the test tube.
4 Record your observations for Activity 3 in your results table and tick which of the pieces of evidence show that a chemical change has occurred.

Activity 4

1 Put approximately 40 mL of lemon juice in a 100 mL glass beaker.
2 Gently stand a thermometer in the beaker.
3 Add 1 teaspoon of baking soda to the lemon juice.
4 Record your observations for Activity 4 in your results table and tick which of the pieces of evidence show that a chemical change has occurred.

Results

Complete the results table to show the evidence that a chemical change has occurred.

Discussion

1 Define 'chemical change'.
2 Outline the different pieces of evidence that a chemical change has occurred, and provide an example from your activities.
3 Were there any pieces of evidence that were not demonstrated during these activities? Write an activity that would allow you to demonstrate this piece of evidence of chemical change. You may need to do some online research first.

Try this 14.4

Physical and chemical changes are all around us. Figure 14.22 shows some photos from a family holiday. List the physical and chemical changes you can see in the photos. For every change you notice, state the evidence that a change has occurred or is occurring – for example, colour change, a gas being produced or a new product being formed.

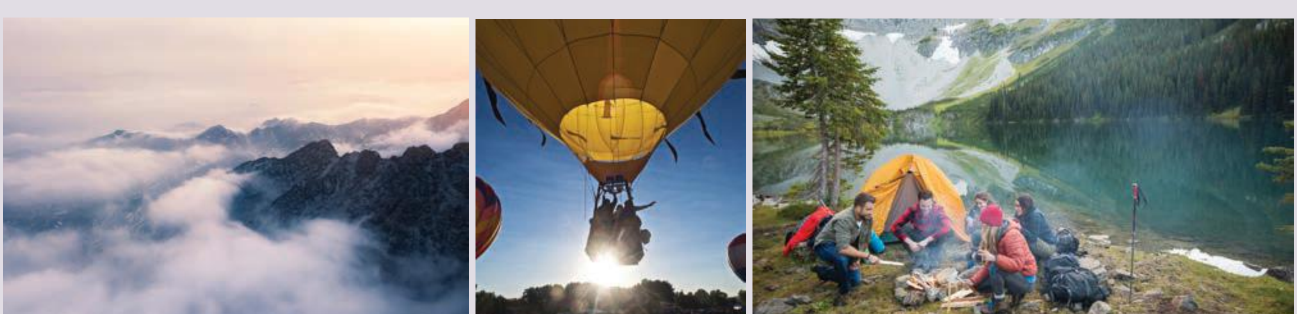

Figure 14.22 Can you spot the physical and chemical changes in these photos from a family holiday?

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Did you know? 14.2

Digestion is all about change!

Thousands of physical and chemical changes take place during the digestion of your food … yes, thousands!

Part of the body	Type of change	Details
Mouth	Physical	Food is chewed by teeth to break it down into smaller pieces so that enzymes have a greater surface area to work on.
	Chemical	An enzyme in saliva (called amylase) starts to break down complex carbohydrates into simpler forms that your body can absorb.
Oesophagus	Physical	As the oesophagus moves food from the mouth to the stomach, the muscles contract, pushing the food along, in a process called peristalsis.
Stomach	Physical	The stomach muscles contract and churn the food to break it into smaller pieces so that enzymes have a greater surface area to work on.
	Chemical	Enzymes start to break down proteins. Hydrochloric acid provides the optimum conditions for this to occur.
Small intestine	Physical	As the small intestine moves food along towards the large intestine, the muscles contract the food to help break it down further. Bile emulsifies fats into smaller droplets so that enzymes have a greater surface area to work on.
	Chemical	Enzymes break down proteins and fats even further, so they can be absorbed into your bloodstream through the walls of the intestine.

Table 14.1 Some of the many physical and chemical changes that occur in the digestive system

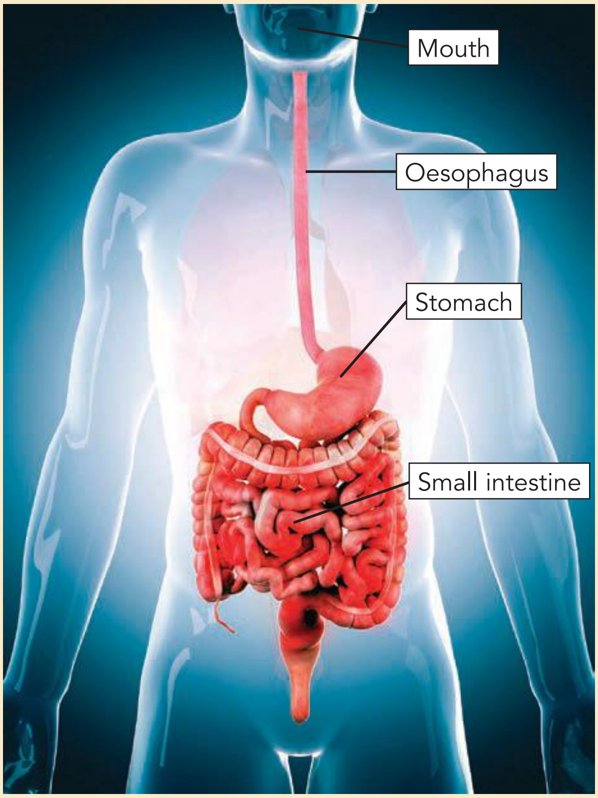

Figure 14.23 The digestive system uses physical changes and chemical changes to break down your food for absorption.

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Advances in science 14.3

Forensic detection of fingerprints

In 2015, an Australian scientist's home was broken into. This inspired him to develop a new technique for fingerprint detection at a crime scene. Fingerprints can be used as an identification tool for suspects as each pattern is unique to each individual. However, while some fingerprints such as those from a dirty hand may be visible, others are often invisible on surfaces.

Dr Kang Liang from the CSIRO found that by adding a drop of liquid containing crystals to surfaces, investigators using a UV light are able to see latent (invisible) fingerprints 'glow' in about 30 seconds. The benefits of the crystals are that they are cheap, react quickly and can emit a bright light. The chemical reaction doesn't create dust or fumes, reducing waste and the risk of inhaling dangerous gases.

Figure 14.24 Detecting latent (invisible) prints left at a crime scene is now easier, with new detection methods involving chemical reactions.

Advances in science 14.4

Synthesis of pharmaceuticals

In this chapter, you have explored four basic types of reactions. However, scientists employ a wide range of other chemical reactions to create new complex molecules. An example of this is the development of pharmaceuticals to specifically target certain diseases.

Scientists are always working to create new vaccines, antiviral and antibiotic agents for a range of new and old diseases. The synthesis of such molecules may require more than 10 or 20 steps of chemical reactions to achieve the complex pharmaceutical.

In early 2020, scientists around the world were hastily using chemical reactions to attempt to create a molecule that would act as an antiviral agent to the SARS-CoV-2 virus.

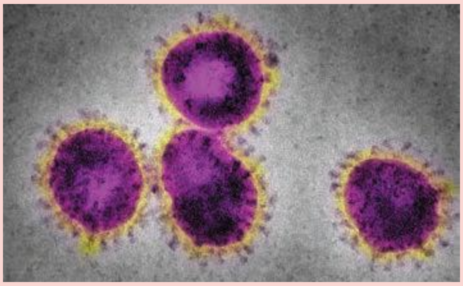

Figure 14.25 The coronaviruses are a family of viruses that includes SARS (shown in the image), MERS and more recently, SARS-CoV-2, which is responsible for COVID-19.

Section 14.2 questions

QUIZ

Remembering

1 Rewrite the following, **matching** each term from the left column with its correct definition from the right column.

Term	Definition
Physical property	a new substance is formed
Physical change	the way substances look and act, e.g. colour, melting point, hardness, boiling point, density
Chemical property	no new substance has been formed
Chemical change	the behaviour of a substance when it reacts with another substance

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2 **State** some examples of physical properties.
3 **State** some examples of chemical properties.
4 **List** the five common signs that a chemical change has occurred.

Understanding

5 **Outline** three examples of chemical change occurring in your home.
6 **Explain** the process of rusting and why it is an example of chemical change.
7 A stoppered test tube of yellow liquid is left on the window sill of a science lab over the weekend. When the students come back to class, they observe that there is condensation on the inside of the tube, the liquid has gone green, and the stopper has popped out. **Explain** whether these observations indicate physical or chemical changes, and how you know.

Applying

8 **Distinguish** between bioluminescence and chemiluminescence.
9 **Classify** each of the following as physical or chemical change.
 a Vegetable scraps breaking down in the compost bin
 b Separating sand from gravel
 c Cutting fingernails
 d Drilling a screw into wood
 e Mulching tree branches
 f A stock cube dissolving in hot water
 g Fruit on the ground going mouldy
 h Crushing a can
 i Trees growing new leaves in spring
 j Breakfast cereal going soggy
 k Rain making the ground muddy
 l Dropping and breaking a plate
 m Baking a quiche
10 **Identify** the types of changes occurring in the following situations. (There may be more than one type.)
 a Pastry is defrosted and then used to make a pie.
 b To make honeycomb, sugar is mixed with water and honey, heated, and then bicarbonate of soda is added.
 c A candle burns and wax drips down the side.

Analysing

11 For each of the following situations, **summarise** the signs of chemical change you would observe.
 a Birthday candles are burning.
 b Glow sticks work when you break them.
 c Sandwiches go mouldy.
 d Baking soda and vinegar are mixed together.
12 **Determine** the reasons why galvanised iron does not rust.

Evaluating

13 **Suggest** why rusting occurs faster on door hinges of boat sheds compared to door hinges a kilometre inland from the beach.
14 For each of the following situations, **identify** whether a physical change, a chemical change, or both, has occurred. **Justify** your answers.
 a Biting, chewing and swallowing noodles
 b Ice cubes melting in your iced chocolate drink
 c Petrol burning in a car
 d Bread dough being kneaded, then rising
 e A steel spoon being left out after being washed and little red spots forming on it
15 In Chapter 4, you learnt about how metals mined from the earth may need to be chemically processed before they can be used. **Propose** how collaboration between different experts is involved in this.

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Chapter review

Chapter checklist:

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

SCORCHER

Success criteria		Check
14.1	**I can describe ways to identify if a physical change has occurred.** e.g. Recall the evidence we can use to identify if a physical change has occurred.	
14.2	**I can describe ways to identify if a chemical change has occurred.** e.g. Recall the evidence we can use to identify if a chemical change has occurred.	
14.2	**I can give examples of chemical changes.** e.g. Give an example of a chemical change.	
14.2	**I can compare physical and chemical changes.** e.g. Explain whether a change of state is a physical or chemical change.	

Reflections

1 What **connections** come to mind when you think about physical and chemical change and your everyday life?
2 What new concepts have **extended** your thinking about physical and chemical change?
3 What information did you find **challenging** or confusing?

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Data questions

A theoretical chemical reaction occurs such that reactant A reacts to form an intermediate product B, which reacts to form a product C. The chemical reactions occurring are:

A → B reaction 1

B → C reaction 2

The mass of each species is plotted in Figure 14.26, with respect to time passed in the reaction.

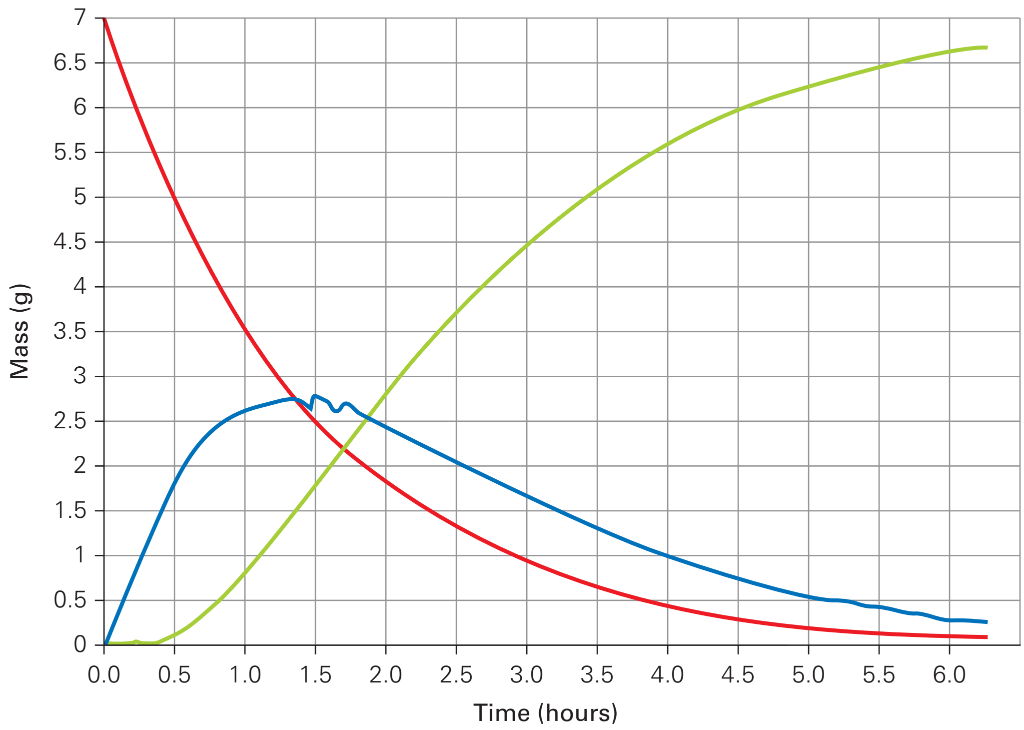

Figure 14.26 Change in mass of each reactant (in red), intermediate (in blue) and product (in green) of time in a chemical reaction

1. **Identify** the colour of the line which represents the reactant A; the line with a mass greater than zero at the beginning of the reaction.
2. **Identify** which coloured line represents the intermediate; the species that is formed in a reaction of A, and then reacts to form C.
3. **Identify** the time at which the mass of intermediate B is greatest.
4. **Identify** the relationship between the mass of reactant A and the mass of product C.
5. **Contrast** the curve for intermediate B and product C and account for the shape of the blue line.
6. **Infer** why the green line does not increase steadily until after 0.5 h.
7. **Justify** what the total mass of all species will be at 3.0 h if the mass of reactant A was 7 g at time zero.
8. **Predict** whether the mass of product C will increase above 7 g.
9. The intermediate, B, has a blue colour when it is produced, and in this reaction this blue colour was only evident when B composed the most mass of all species. **Deduce** which time period after the start of the reaction would the reaction mixture have appeared blue.

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STEM activity: Building a rocket

Background information

Rockets are exciting machines that are designed by engineers and used to explore space. It is amazing to think that someone has worked out how to get these heavy vehicles into space! Rockets depend on a combustion reaction to provide the thrust they need to overcome the force of gravity and shoot up into orbit. Combustion is a fast heat-producing (exothermic) reaction between a fuel and oxygen, in which the fuel is burnt. As you know, during a chemical reaction, new compounds are made – in this case, these compounds are the rocket's exhaust. The exhaust coming out from the bottom of the rocket produces a great thrust or force, and the reaction force to this pushes the rocket upward.

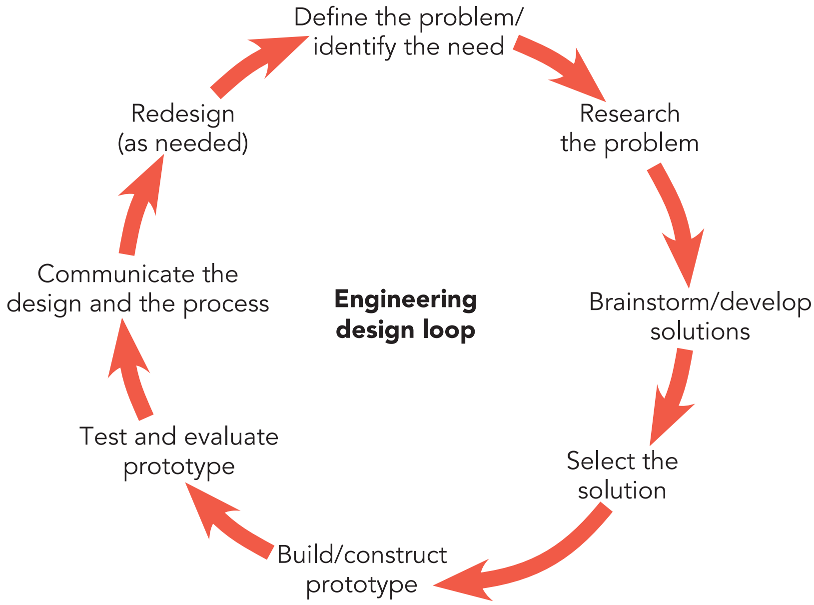

Figure 14.27 Designing and testing of a model comes before construction of the real thing.

Figure 14.28 Space launch

In a process known as the engineering design cycle, aerospace engineers design small-scale models to learn from and experiment with. By testing small-scale models, the engineers make sure the rockets will work, without wasting time and money on testing full-size rockets. They can test the thrust and stability and make modifications, in order to design the best rocket they can.

Design brief: Design, build, test and evaluate a rocket that will launch in a controlled manner in 10 seconds.

Activity instructions

In teams, you will take on the role of aerospace engineers for The Super Fast Rocket Company. You have been hired to design, build, test and evaluate a rocket that will launch safely and repeatedly in 10 seconds. There will be two major factors in solving this problem, first the design of the rocket and second the chemical reaction that will provide the thrust for the rocket.

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Suggested materials

- 35 mm film canister (or anything similar with an internal snapping lid)
- an antacid tablet, such as Alka-Seltzer®
- water
- scissors, sticky tape, marking pens, paper
- chopping board, mortar and pestle, knife, spoon
- safety glasses

Research and feasibility

1 Research the chemical reaction between antacid tablets and water to produce carbon dioxide and find out the impact of temperature, surface area, mass or other factors on the rate of reaction. List these factors in a table.

Factors that affect rate of reaction	Rate of reaction (Increase/ Decrease/No effect)	Ideas on how to use this factor in design
Temperature		
Surface area		
Mass		
Reaction vessel type		

2 Research and discuss, in your team, ideas of how to use the film canister and lid as a reaction vessel: good engineers use existing technology and work on improvements, and also completely reinvent the concept sometimes.

3 Research rocket design and the size ratios of the dimensions of the rocket.

Design and sustainability

4 Discuss in your group how to make the rocket reaction vessel reusable to reduce waste, and think of methods to limit excess production of carbon dioxide.

5 Sketch multiple possibilities of the rocket design and how the rocket would obtain lift from the reaction vessel, making sure that your rocket is not destroyed through the explosion of the reaction vessel.

6 Discuss the sustainability of your design, and as a group decide on a model V1.0 to build.

7 As a group, use your knowledge of chemical reactions to decide on a combination of tests you will use to launch the rocket in 10 seconds. You may find that creating a table is a good way to record your tests. You can do this any way you wish.

Mass (g) or surface area (cm^2) of antacid	Volume of water (mL)	Temperature (°C)	Time to launch (s)

Create

8 Break into two groups, a build team and a discovery team. The build team will construct the rocket, and the discovery team will need to work on discovering the correct amount of antacid and water in the film canister to obtain a time to launch of 10 seconds. The build team needs to ensure the rocket can launch safely, and sustainably.

Evaluate and modify

9 Discuss the different conditions you investigated and what you found out about the effect of temperature, surface area and mass of the antacid tablets on the rocket launch times.

10 Draw a flow chart to show your original design for a 10-second launch and the modifications that followed, ending with your rocket launching at exactly 10 seconds. Highlight the change/improvement you made at each step along the way.

11 Consider both your rocket and the other rockets you observed being launched. Identify and describe the characteristics that make one rocket perform better than another.

12 Discuss what challenges you faced while designing and testing your rocket, and how you overcame these challenges.

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Glossary

Chapter 1

accuracy how close a measurement is to the true value

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

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

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

concave a surface that curves inwards

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

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

convex a surface that curves outwards

data facts or statistics gathered to answer a question or for further analysis

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

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

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

exponential a population that grows at a rate proportional to its size

extrapolation using existing data (such as a line of best fit) outside the original data set to make a prediction

hypothesis a proposed explanation or prediction of an event (e.g. an experiment) based on research and current knowledge

independent variable the variable that is changed during an experiment

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

inference applying a reason or explanation to an observation based on past experiences and known facts

interpolation using existing data (such as a line of best fit) within the original data set to make a reliable prediction

knowledge the understanding of information

line graph a type of graph used to display how a continuous quantitative variable changes over time or in reference to another variable

meniscus the surface of a liquid in a container

nominal data qualitative (categorical) data where the categories have no order, e.g. male, female

observe use senses and tools to notice something significant

ordinal data qualitative (categorical) data where the categories have an order, e.g. small, medium, large

origin the point (0, 0) where the *x*-axis and *y*-axis intercept

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

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

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

precision (referring to measuring tools) the size of the units of measurement that are capable of being read on a measuring tool (e.g. millimetres versus metres)

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

primary source a source of information that comes from your own findings or experiments

qualitative a form of data that is a descriptive measurement

qualitative data data values that are worded/descriptive/categorical in nature

quantitative a form of data that is a numerical measurement

quantitative data a form of data that is a numerical measurement

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

relevant connected to the topic being investigated

reliability the degree of consistency of your experimental measurements. A test is reliable if it gives the same result when it is repeated under the same conditions.

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

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secondary source a source of information that comes from someone else's research or findings

specific clearly defined or identified

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

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

validity a measure of how closely the results of an experiment reflect what they should

variable a component of an experiment that changes or can be changed

Chapter 2

air resistance the frictional force of the air

alloy a substance composed of two or more metals

applied force force that is applied to an object by another object or person

balanced forces forces of the same size but that act in opposite directions

brittle a material that is likely to break or snap when subject to a big enough force

buoyancy force the force experienced by an object that is partially or fully submerged in a fluid, e.g. water or air

drag the frictional force of a liquid or gas

elastic elastic materials bend, stretch or compress when a force is exerted on them; they exert elastic forces when this happens

electromagnet a magnet made by passing electricity through a coil of wire

electrostatic force a non-contact force between positive and negative charges, opposite charges attract, like charges repel

field a region in space in which an object is affected by a force

force a push, pull or twist in a specific direction

friction a contact force opposing motion due to the interaction between two surfaces

gravity a non-contact force describing the pull of any object with mass

impact force a contact force that sometimes only lasts for a short time; often impact forces change an object's speed

magnetic field the space around a magnet where the magnetic force acts

magnetic force a non-contact force between a magnet and another magnet or magnetic metal

mass the amount of substance in an object; mass never changes, even in space

mouldable soft enough to be shaped

net force the sum of all forces acting on an object

newton the unit of force; one newton is roughly equal to the force you need to keep a 102 g apple from falling

pull to exert a force towards something

push to exert a force away from something

repel to force back or apart

rotate to turn or spin on an axis

static electricity a build-up of electric charge

streamlined designed to minimise air resistance or drag

tension the force in a wire, cable or string when being stretched

turning force a force that makes an object start or stop rotating

twist to turn something

unbalanced forces a combination of one or more forces that has an overall effect, and which changes an object's motion

weight the force of gravity on an object; it is measured in newtons and changes in space

Chapter 3

chemical potential energy the energy stored in the bonds between atoms

conductor material that allows electricity to easily flow through it

efficiency the percentage of input energy that is converted to useful energy by a machine

elastic potential energy the energy stored when an elastic material is compressed or stretched

electrical energy energy carried by electricity moving in a wire; voltage is used to measure how much energy is carried by each unit of electricity

electromagnetic spectrum a way of organising electromagnetic waves according to their frequency

energy the capacity to do work; the total amount of energy is conserved in any process

energy transfer the movement of energy from one place or object to another

gravitational potential energy a type of potential/stored energy; the energy an object has because of its height; $GPE = mgh$ where m is the mass of the object in kg, g is acceleration due to Earth's gravity and h its height in metres

heat thermal energy that is in transit due to differences in temperature

insulator material that prohibits electricity from flowing through it

joule the unit of energy or work done

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kinetic energy the energy of moving matter

law of conservation of energy the law that states that energy cannot be created or destroyed

light energy a form of energy that we can see with our eyes; also called visible light; a part of the electromagnetic spectrum

nuclear energy a non-renewable source of energy that uses the energy released by the nucleus of radioactive atoms

potential energy the energy stored in something because of its height above the ground, or because it is stretched or compressed, or in chemical form, etc.

radioactive having or producing the energy that comes from the breaking up of atoms

sound energy a form of travelling wave; sound consists of vibrations in the air

temperature a measure of the average random kinetic energy of the particles in a substance

thermal energy the energy contained within a material that is responsible for its temperature

travelling wave a wave that can carry energy from one place to another

useful energy the output energy that a machine is designed to produce; an efficient machine will maximise the useful energy it creates

waste energy the output energy that a machine creates that is not useful; waste energy is often in the form of thermal energy and sound

wave energy the energy carried by a travelling wave (e.g. an ocean swell) or trapped in a standing wave (e.g. a guitar string)

Chapter 4

asthenosphere the almost liquid, layer under the lithosphere (hard rock)

biological weathering the disintegration of rocks that is caused by living things

breccia sedimentary rock composed of angular broken pieces of rock larger than 2 millimetres

cementation the sticking together of sediment

chemical weathering the disintegration of rocks caused by acidic rainwater

cleavage the tendency of a mineral or rock to break in a particular way because of its structure

compaction the process of parts becoming closely positioned together, using very little space

conglomerate sedimentary rock composed of rounded rock fragments larger than 2 millimetres

crust the solid outer layer of Earth; continental crust is on average 35 km thick and the average thickness of oceanic crust is 10 km

crystal a mineral in which the atoms are arranged in an ordered way to form a geometric shape

deep time the idea first suggested by James Hutton that Earth is very old

deposition process that occurs when eroded particles stop moving and build up to form sedimentary rocks

electrolysis a method of extracting a metal from its ore or purifying it using electricity

erosion the transport of rocks from one place to another as a result of weathering

extrusive describes igneous rocks formed on Earth's surface; also called volcanic rocks

fossil the remains, shape or trace of a bone, shell, microbe, plant or animal that has been preserved in rock for a very long time

geology the study of the rocks and similar substances that make up Earth and other planetary objects

igneous describes rocks made from lava on the surface or magma below the surface

inner core the solid centre of Earth; probably made of iron

intrusive describes igneous rocks formed underground; also called plutonic rocks

karst an area of land formed of rock such as limestone that is worn away by water to make caves and other formations

lava molten rock from inside Earth (called magma) that has reached the surface

lithosphere the solid outer layer of Earth; includes the crust and uppermost mantle

magma molten rock under Earth's surface

mantle the layer of solid and semi-molten rock that surrounds the outer core and extends up to Earth's crust

metamorphic describes rocks that are changed by being exposed to high temperature, pressure or both

meteorite a rock from space (meteor) that has entered the atmosphere as a 'shooting star' and reached the ground

mineral a chemical substance that is formed naturally in the ground

Mohs scale a scale from 1 to 10 that indicates the hardness of a rock

opaque blocking light completely

ore a rock that can be mined and smelted to produce a metal

outer core the liquid layer surrounding the inner core; probably made of liquid iron and nickel

physical weathering the breaking down of rocks into smaller particles by contact with other rocks, wind, water or ice

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radioactivity energy released from the nucleus of an atom when the atom decays; the age of rocks can be determined by measuring their radioactivity

reflection seismology the use of shockwaves to investigate the structure of rocks underground

rock solid material forming Earth's crust; rocks are formed as part of the rock cycle

rock cycle the constant process of change that rocks go through, between igneous, metamorphic and sedimentary forms

sedimentary describes rocks made from deposited materials that are the product of weathering and erosion

sediments sand, stones, etc. that slowly form a layer of rock

smelting the process of getting a metal from rock by heating it to a very high temperature

streak test a test used to help identify a mineral by scratching a rock on a hard ceramic tile

surface mining method of mining that extracts a mineral from the surface, such as by digging an open pit

translucent allowing some light through, but no clear image can be seen through the substance

transparent allowing light to pass through, and a clear image can be seen through the substance

underground mining traditional method of mining by digging tunnels underground to extract ore

Chapter 5

annular eclipse an event when the Moon blocks the Sun but the Moon is further away and the outer edge of the Sun is still visible

apogee the point in the Moon's orbit when it is furthest from Earth

blood moon a name given to the Moon during an eclipse while it is completely in Earth's shadow

dawn the time of day when the Sun rises over the horizon or night turns into day

dusk the time of day when the Sun drops below the horizon or day turns into night

elliptical oval shaped

equator an imaginary line drawn around the middle of Earth equidistant between the North and South poles

far side the face of the Moon that is always turned away from Earth; also called the dark side

geocentric model a cosmological model where Earth was the centre of the universe

gravitational field the region around a large object where another object can experience its gravity or pull

heliocentric model a model with the Sun as the centre of the solar system

horizon the point where the sky appears to meet the land or the sea

leap year a year that happens every four years and has an extra day on 29 February

lunar eclipse a full moon becomes dark as it enters Earth's shadow

mass the amount of substance in an object that never changes, even in space

Northern Hemisphere the half of Earth north of the equator

orbit the curved path of a celestial object or spacecraft round a star, planet or moon

partial eclipse an event when the Sun is partially blocked by the Moon

penumbra the region in a shadow where the light is partially blocked

perigee the point in the Moon's orbit when the Moon is closest to Earth

revolution one complete orbit

solar eclipse an event when the Sun partly or completely disappears from view, while the Moon moves between it and Earth

Southern Hemisphere the half of Earth south of the equator

sunspot feature on the Sun's surface that moves slowly across the surface

synchronous rotation occurs when the rotation of an orbiting body is the same length of time as its revolution around a larger body

syzygy the occurrence in astronomy of three or more objects moving into a straight line

telescope an optical instrument for making distant objects appear nearer and larger, or an instrument that detects electromagnetic radiation from space

total eclipse an event when the Sun is completely blocked by the Moon

umbra the region in a shadow where the light is completely blocked

waning the period of about two weeks where the illuminated part of the Moon is decreasing from a full moon to a new moon

waxing the period of about two weeks where the illuminated part of the Moon is increasing from a new moon to a full moon

Chapter 6

barrage a barrier to generate electricity from tidal power

biomass plant and animal material suitable for using as fuel

blackwater waste water from toilets

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condensation where heat is lost causing a gas to become a liquid

drought a prolonged period of unusually low rainfall that leads to a shortage of water

evaporation when heat causes liquid to become gas

fossil fuel fuels, such as gas, coal and oil, that were formed underground from plant and animal remains millions of years ago

geothermal energy energy from the heat inside Earth

greenhouse gas gases that prevent heat from Earth escaping into space

greywater water that has been used before; for example, from washing, which can be stored and used again for other uses such as toilets

groundwater water that collects beneath Earth's surface

hydroelectricity producing electricity by the force of fast-moving water such as rivers or waterfalls

impermeable not allowing liquid or gas to go through

infiltration to move slowly into a substance

mineral substance formed naturally in the ground

non-renewable existing in limited quantities that cannot be replaced after they have all been used

nuclear energy the energy obtained from changes within the atomic nucleus from nuclear fission or fusion

ocean energy energy harnessed from the ocean such as waves and tides

percolation the process of a liquid moving slowly through a substance that has very small holes in it

permeable allows liquids or gases to go through it

pervious a substance that allows water to pass through via cracks or defects in the rock

photovoltaic able to produce electricity from light

precipitation water that falls from the clouds towards the ground as rain or snow

renewable replenished by natural processes within a human lifetime

resource natural commodity that is valuable in supporting life

runoff water that flows away from high areas to low areas

silt sand or soil that is carried along by flowing water and then dropped usually at a river's opening or bend

solar energy using the energy from the Sun to produce electric power

transpiration the movement of water upwards through a plant to its leaves, from where the water evaporates

urban water cycle a water cycle that includes the consequences of increased development

water cycle the way that water is taken up from the sea, rivers, lakes and soil and then comes back down as rain, snow or hail

Chapter 7

autotroph an organism that produces its own food from light, carbon dioxide, water or other chemicals

bilateral symmetry organism can be divided into two symmetrical halves

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

botanist a scientist who studies plants

characteristic a feature or quality of something

class the taxonomic ranking below phylum and above order

classification the grouping of similar objects or organisms together

dichotomous key a tool for scientists to identify an organism from a series of choices between two characteristics

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

domain the highest taxonomic rank above kingdom and even more broad

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

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

family the taxonomic ranking below order and above genus

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

genus the taxonomic ranking below family and above species

heterotroph an organism that cannot make its own food, instead relying on other organisms for energy

invertebrate does not have a backbone

key a tool used to identify organisms

kingdom the highest classification on the Linnaean taxonomic rankings and the most broad

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

microbiologist a scientist who studies very small living things like bacteria

morphology the study of the size, shape and structure of organisms

non-vascular not containing veins or specialised fluid vessels

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order the taxonomic ranking below class and above family

organism a living creature

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

phylum the taxonomic ranking below kingdom and above class

qualitative a form of data that is a descriptive measurement

quantitative a form of data that is a numerical measurement

radial symmetry organism is symmetrical around a line drawn through the centre in more than one position

sessile an organism that does not independently move its location but may move body parts

species the most specific taxonomic ranking below genus

taxonomy a branch of science that groups organisms

transpiration the process by which plants lose water from their leaves

unicellular consisting of one cell

vascular containing veins or specialised fluid vessels

vertebrate has a backbone

Chapter 8

bacteria very small prokaryotic organisms that have cell walls, but lack membrane-bound organelles and a nucleus

biconcave concave on both sides

binary fission a mode of asexual reproduction by bacteria, where genetic information is copied and the cell splits in half

cell membrane the barrier that separates the inside of the cell from the external environment

cellular respiration a process that occurs inside the mitochondria, where oxygen and glucose react to form carbon dioxide and water, producing useable energy

cell wall a rigid structure that surrounds each cell, shaping and supporting the cell

chloroplast a structure in a plant cell that contains chlorophyll and conducts photosynthesis

cytosol the water-based mixture that fills the cell, containing different molecules, large and small; many chemical processes that happen within a cell occur in the cytosol

differentiation the process by which stem cells become specialised

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

double helix a description of the structure of DNA where two strands wind around each other like a twisted ladder

embryo a fertilised egg cell in the early stages of growth and differentiation

endoplasmic reticulum a network of tubes within a cell that are involved in protein and lipid synthesis

eukaryote any cell or organism that possesses membrane-bound organelles and a nucleus

genetic material the material containing the code that allows the cell to produce copies of itself and to regulate the functions within the cell

Golgi body a structure in a cell involved in the modification, packaging and transport of proteins and lipids

macroscopic visible to the naked eye

microscopic anything that can only be seen clearly with the use of a microscope is described as microscopic

mitochondrion a structure in a cell that converts the energy from food into the form needed by the cell during cellular respiration

mitosis the type of cell division in which one cell divides into two cells that are exactly the same

multicellular made of many cells

nucleus part of a cell that contains the genetic material

organelle a specialised structure in a cell, which has a specific function or job

pathogen an organism that causes disease

prokaryote unicellular organisms that lack membrane-bound organelles and a nucleus

protist a eukaryotic organism that is part of the kingdom Protista

ribosome a structure in a cell that reads genetic information to produce protein from amino acids

stem cell a cell that is able to develop into many different types of cell

steroids compounds made by cells that are used in cell membrane stability and for cell signalling

unicellular made of just one cell

vacuole a structure in a cell that stores water and nutrients

zygote a fertilised egg cell

Chapter 9

alveoli the tiny sacs at the end of bronchioles in the lungs; the site of gas exchange with the capillaries

ammonia a poisonous substance that is produced when protein is broken down

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anus the opening at the end of the digestive tract, through which solid waste leaves the body

aorta the largest vessel leaving the heart, from the left ventricle, carrying oxygenated blood to the body

artery a thick, muscular elastic vessel that carries blood away from the heart

asexual reproduction a method of reproduction in which there is one parent organism and all offspring are genetically identical

atrioventricular node a natural pacemaker that controls the heartbeat and is located in between the atria and the ventricles

atrium one of the two upper chambers of the heart, the left atrium and right atrium

biconcave concave on both sides

bile a substance produced in the liver and stored in the gall bladder, which helps emulsify fats

bladder the organ that stores urine

bolus a lump of partially digested food

bronchi the two branches of the airways that split off the trachea, one main left bronchus to the left lung and one main right bronchus to the right lung

bronchioles smaller branching tubes that branch off the two large bronchi and lead to the alveoli

caecum a pouch that forms the first part of the large intestine

capillaries the smallest blood vessels, one cell thick, and the site of gas exchange with cells

carbon dioxide a waste product produced in respiration

carnivore a consumer (heterotroph) that feeds on animal matter

cellular respiration a process that occurs inside the mitochondria, where oxygen and glucose react to form carbon dioxide and water, producing useable energy

chemical digestion a series of chemical reactions in which enzymes break food into simpler chemical substances that can be used by the body

chyme a partially digested mass of food after it leaves the stomach

cloaca a hole used for defecating, urinating and giving birth that is present in some amphibians, reptiles, birds, fish and monotremes

cross-pollination pollination that occurs by pollen from another flower or plant

diaphragm a dome-shaped muscle that separates the chest and abdominal cavities; it contracts to cause us to inhale

differentiation the process by which cells become specialised

duodenum the first section of the small intestine

embryo a fertilised egg cell in the early stages of growth and differentiation; in humans, this would be from between two and eight weeks after fertilisation

enzyme a protein that can help speed up chemical reactions

ethical relating to ethics, the field of considering what is right and wrong

excretion the process of removing metabolic waste from the blood via the lungs, kidneys and skin

excretory system the body system that is responsible for filtering the blood and removing cellular waste products

function the job that an object does

gall bladder a small gland near the liver that stores bile and secretes it into the duodenum

gametes the sex cells (eggs and sperm), each of which contains half the genetic material required to make an organism

gonads the reproductive organs, where gametes are produced; testes for males and ovaries for females

guard cells cells on either side of a plant stoma that control gas exchange by opening and closing the stoma

haemoglobin the red pigment in blood that binds to oxygen, allowing red blood cells to carry oxygen

herbivore a consumer (heterotroph) that feeds on plant matter

heterotroph any organism that obtains its nutrients by consuming other organisms

hormone a chemical produced by cells that controls and regulates different processes in the body

ileum the third section of the small intestine, where further food breakdown and nutrient absorption occur

intercostal muscles many different groups of muscles that run between the ribs, which help form and move the chest wall

intolerance an inability to eat a food without undergoing adverse effects

jejunum the second section of the small intestine, where food breakdown and nutrient absorption occur

kidneys a pair of organs that filter waste products from the blood and excrete them as urine

large intestine the organ that is connected to the small intestine at one end and the anus at the other

lenticels small slits on trunks or branches of trees that allow gas exchange

liver an excretory system organ that detoxifies poisonous substances in the body

mechanical digestion a series of mechanical processes that breaks food down, such as chewing with teeth, mixing in the stomach and emulsification with bile

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menstruation the cyclical shedding of the unfertilised egg and the uterine lining; also known as the menstrual period

nectar a sweet liquid produced by flowers to attract pollinators

nephron small filter structures that are found in the kidney

neuron a nerve cell

omnivore an organism that eats a variety of plant and animal matter

organ a group of tissues working together to perform a function

organism a living creature, such as a plant or an animal

organ rejection when an organ transplant recipient's immune system recognises the organ as foreign and attacks it

organ transplantation the process of removing a donor organ and then surgically implanting it into a recipient, to improve their organ function or replace a diseased organ

ossification the process of bone formation from cartilage

ovulation the release of an ovum (egg) from the ovary into the Fallopian tube

ovule a structure in a flowering plant where the female gamete is produced and where seeds develop; also used to mean the female gamete

ovum egg, or female gamete

pancreas an organ that secretes pancreatic juices containing enzymes into the duodenum to assist with the digestion of food

peristalsis a wave-like contraction of the muscles of the digestive tract that pushes the food along

pharynx the throat region where the nasal cavity and oral cavity meet, leading into the trachea

phloem vascular tubes that transport sugars and nutrients throughout the plant

plasma the yellow liquid component that makes up 55% of the blood; carries water, dissolved gases and hormones

platelets tiny cells that assist with blood clotting

pollen the male gamete in flowering plants

pollination the process by which pollen sticks to the female structures of a plant and fertilises the ovule

puberty the time of transition from juvenile form to adult form

rectum the second-last section of the large intestine; stores faeces

saliva liquid secreted by the digestive system to lubricate a bolus of food; also contains enzymes to assist chemical digestion

scrotum a sac that encloses the testes

seed a plant embryo enclosed in a protective coating

seed dispersal the spread of seeds away from the parent plant

self-pollination pollination that occurs by pollen from the same flower or from another flower on the same plant

sexual reproduction a method of reproduction in which there are two parent organisms and genetic variation in the offspring

sinoatrial node a natural pacemaker that controls the heartbeat and is located in the wall of the right atrium

skin the biggest organ in the body, which forms a protective outer layer on a person

sperm the male reproductive cell, or gamete

sphincter a muscle that surrounds an opening in the body and can tighten to close it, e.g. at the bottom of the oesophagus, leading into the stomach

stomata tiny pores (holes) in leaves that allow entry/exit of gases such as oxygen and carbon dioxide

structure a physical part of an object

testes the male reproductive gland that produces sperm

tissue a group of cells performing the same function

tissue engineering the combined use of cells and engineering to improve or replace biological tissues

trachea the tube that carries air down to the lungs; also known as the windpipe

urea a substance that is produced by the liver by breaking down ammonia

urine waste product from the body made of water, urea and other excreted wastes

ureter the tube that leads from the kidneys to the bladder

vein a thin-walled vessel with valves that carries blood back to the heart

vena cava the large vessel that returns deoxygenated blood to the heart, emptying into the right atrium

ventricle one of the lower two chambers of the heart, the left and right ventricles

villi finger-like structures in the digestive system that have a high surface area and rich blood supply for absorption of nutrients

xenotransplantation transplanting organs from one species into another

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xylem vascular tubes that transport water in one direction through the plant

zygote a fertilised egg cell

Chapter 10

10% rule when energy is passed from one trophic level to another, only 10% of the energy will be passed on

abiotic relating to the non-living things in an ecosystem

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

apex predator a predator at the top of a food chain

biodiversity the number and types of plants and animals that exist in an area

biological control the practice of introducing an organism into an ecosystem with the intention of limiting the spread of another organism

biopiracy when naturally occurring biological material is commercially exploited

biotic relating to the living things in an ecosystem

calicivirus a disease that damages a rabbit's internal organs and can cause bleeding

carnivore an animal that eats only meat

cellular respiration the chemical process by which cells release energy from food

chemotroph an organism that obtains energy through chemical processes in its environment

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

consumer an organism that obtains food from consuming other organic material

decomposer an organism such as a bacterium or fungus that makes dead plant and animal material decay

deforestation clearing a wide area of trees or natural land

detritivore an organism that feeds on dead or decaying organic matter

detritus waste or debris

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

endemic an organism that is restricted to or unique to a particular area

energy the ability to do work by producing heat or motion

environment the air, water and land conditions in which an organism lives

firestick farming the burning of areas of bush in stages, by the application of firesticks, to encourage new growth

food chain the flow of food energy through an ecosystem passing from plants and bacteria to consumers

food web a group of interweaving food chains

glucose a simple sugar that can be converted into energy inside cells

habitat the natural home of an organism

herbivore an animal that eats only plants

invasive species an organism that is not native to an environment and causes harm to native organisms

microorganism a living thing that on its own is too small to be seen with the naked eye

omnivore an animal that is naturally able to eat both plants and meat

pathogen an organism that can cause illness

photosynthesis the process by which a plant uses the energy from the light of the Sun to produce its own food

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

primary consumer an animal that eats plants

producer an organism capable of producing food from photosynthesis

scavenger an organism that feeds on dead animals that it has not killed itself

secondary consumer an animal that eats other animals

tertiary consumer an animal that eats secondary consumers

trophic level refers to an organism's level or position in a food web. It is based on an organism's feeding habits, where producers occupy the first trophic level, primary consumers the second trophic level, and secondary consumers the third trophic level, etc.

Chapter 11

boiling the rapid vaporisation of a liquid which occurs when it is heated to a temperature called the boiling point

Brownian motion the random movement of particles in fluids and gases

chemical property the behaviour of a substance when it reacts with another substance

compress squeeze to make smaller

concentration the number of particles present in a given volume

condensation where heat is lost causing a gas to become a liquid

contraction the process of substances getting smaller: the atoms of a substance move closer together as they cool

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density how much matter (mass) is contained in a certain volume of a substance

deposition where a reduction in heat causes a gas to become a solid, without passing through the liquid state

diffusion the movement of particles from an area of high concentration of particles to low concentration of particles

evaporation when heat causes liquid to become gas

expansion the process of substances getting larger: the atoms of a substance move further apart as they heat up

freezing where heat is lost and a liquid becomes a solid

gas a substance that expands freely to fill space

liquid a substance that flows freely and takes the shape of its container but has constant volume

mass the amount of substance in an object that never changes, even in space

matter anything that has mass and volume

melting when heat causes a solid to become a liquid

melting point the temperature at which a specific solid melts

particle model all matter is made of particles that behave differently depending on whether they are solid, liquid or gas

physical property the way a substance looks and acts: a characteristic of a substance that can be observed and/or measured without changing it chemically

pressure the amount of force exerted on a given area

solid a substance that has a fixed shape and constant volume

state one of the distinct forms matter can exist in

sublimation where heat causes a solid to become a gas, without passing through the liquid state

vibrate periodic motion of particles

volume the space an object occupies

Chapter 12

atom the smallest possible piece of any substance; it makes up all matter

chemical bond strong force of attraction that joins atoms together

chemical formula a symbol for a compound that shows which elements, and how many atoms of each element, are present in one molecule or one basic unit of that compound

compound substance made up of two or more different types of atoms

conductivity the ability of a substance to conduct or carry electricity or heat

diatomic element a molecule consisting of two atoms of the same type

ductility the ability of a substance to be drawn into a wire

element substance made up of only one type of atom

lattice a three-dimensional shape of atoms that pack together very tightly and form bonds that are extremely strong because the atoms bond to each other in all directions

lustre the ability of a substance to become shiny when polished

malleability the ability of a substance to be bent or flattened into a range of shapes

metal a substance that is shiny, can conduct electricity, can be bent, is usually silver/grey and is ductile

metalloid a substance that has some of the properties of both metals and non-metals

mixture a substance made up of two or more different pure substances (compounds or elements) that are not bonded together

molecule two or more atoms joined together by strong covalent bonds

monatomic made up of single atoms, all of one type

non-metal a substance that is dull, cannot usually conduct electricity, is brittle and is not ductile

periodic table a list of all the known elements and their symbols

polyatomic element a molecule containing more than two atoms of the same type

polymer a long molecule made of a chain of atoms in a pattern that repeats

pure substance material that is made up of either one type of atom or the same groups of atoms (molecules or compounds)

Chapter 13

aqueous solution solutions where the solvent is water

centrifuge a device that uses speed to separate substances based on mass

chromatography a technique to separate substances based on movement at different rates due to solubility

concentrate a solution with a large amount of the solute

crystallisation solidification of a substance into a highly structured form

decantation the process of separating by using gravity

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dilute a solution with only a small amount of the solute

dissolve cause to become mixed in a substance so that it cannot be seen

distillation a technique to separate substances in a liquid using evaporation through boiling and condensation

evaporation when heat causes liquid to become gas

filtrate the substance that passes through the filter

filtration separating a mixture by passing through a filter

flocculant a substance that causes particles to clump together

flotation separating a mixture based on the capacity to float

heterogeneous mixture a mixture that can be easily separated into its parts, and those parts retain their original properties

homogeneous mixture a mixture where components are evenly distributed

insoluble substances that cannot dissolve

mixture material made up of two or more different substances

pure substance material that is made up of either one type of atom or the same groups of atoms (molecules or compounds)

residue the substance that is left in the filter

saturated a solution with the maximum amount of solute dissolved

smog a mixture of smoke, gases and chemicals, especially in cities

soluble substances that can dissolve

solute the component of a solution being dissolved

solution a mixture where one substance is evenly dissolved in another

solvent the component in a solution capable of dissolving another substance

Chapter 14

bioluminescence a chemical reaction that produces light in living things

chemical change where one or more substances undergo a chemical reaction and a new substance is formed; mostly irreversible

chemiluminescence a chemical reaction that produces light

corrosion the gradual and natural process of metals breaking down; an example is rusting

decomposition a reaction in which one substance breaks up into smaller ones

dissolving the process where individual particles of a solute are separated from one another and surrounded by solvent molecules, causing them to no longer be visible in a solution

galvanisation the process of coating iron or steel in zinc to prevent corrosion

irreversible incapable of going in the opposite direction

physical change when the physical properties of a substance change in some way, but no new substance is formed; it is reversible

precipitate the solid that forms when two clear solutions are mixed together and undergo a chemical change

products the substances that are present at the end of a chemical reaction

reactants the substances that are present at the beginning of a chemical reaction

reversible capable of going in the opposite direction

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