PEARSON

# Science

STUDENT BOOK | NEW SOUTH WALES

Stage

4

NSW SYLLABUS



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We celebrate the richness of Indigenous Knowledge systems, shared with us and with schools Australia-wide.

We pay our respects to Elders, past and present.

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(a division of Pearson Australia Group Pty Ltd)
459–471 Church Street, Level 1, Building B
Richmond, Victoria 3121
PO Box 23360, Melbourne, Victoria 8012
www.pearson.com.au


First published 2026 by Pearson Australia
2029 2028 2027 2026

10 9 8 7 6 5 4 3 2 1



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Printed in Australia by <Newgen to confirm>

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

ISBN 978 0 6557 2071 3

Pearson Australia Group Pty Ltd ABN 40 004 245 943

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## New South Wales
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NSW SYLLABUS



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**Key**

- Working scientifically toolkit
- Observing the Universe
- Forces
- Cells and classification
- Solutions and mixtures
- Living systems
- Periodic table and atomic structure
- Change
- Depth studies

# How to use Pearson Science New South Wales

## Pearson Science components

Each Pearson Science Stages 4 and 5 New South Wales student book provides students with a complete offline version of all corresponding digital lessons in Pearson Digital Hub, while the student companions offer a convenient write-in resource. This blended solution offers teachers and students the perfect balance of online and offline learning.

The Student Book (also available as an eBook) has been provided to minimise digital distraction and screen fatigue. In addition to all the theory lessons, practical investigations and inquiry activities from Pearson Digital Hub, it includes:

- a Working scientifically toolkit
- a valuable prior knowledge lesson at the start of each topic
- completely new questions (prior knowledge, check your understanding, lesson review, topic review)
- new Scifiles and Science in Context features to engage learners with real-world examples and to support differentiation
- working scientifically and data science skills integrated into lessons
- topic summaries and end-of-topic glossaries
- a selection of depth studies at the end of the book.

Pearson Digital Hub: a one-of-a-kind digital product designed to simplify teaching and energise learning, with high-quality content created by experienced Australian educators who know how to engage students.


## Chunking with learning intentions and success criteria

The structure and relationship between the two components in the Pearson Science series (the Student Book and Pearson Digital Hub) have been designed to manage students' cognitive load. Chunking has been used to break complex concepts and strategies into smaller, more manageable sections, defined by the success criteria.

Within the two components, the chunking of content directly supports explicit success criteria in a 'read a little, do a little' approach.

**Learning intentions** are learning goals or objectives aligned to the relevant curriculum. Each of the lessons in Pearson Science New South Wales has been developed around a single purpose for learning. The learning intentions are communicated using student-friendly language and are consistent across the the Student Book (and ebook) and Pearson Digital Hub. They describe what learners should know, understand or be able to do by the end of the lesson.

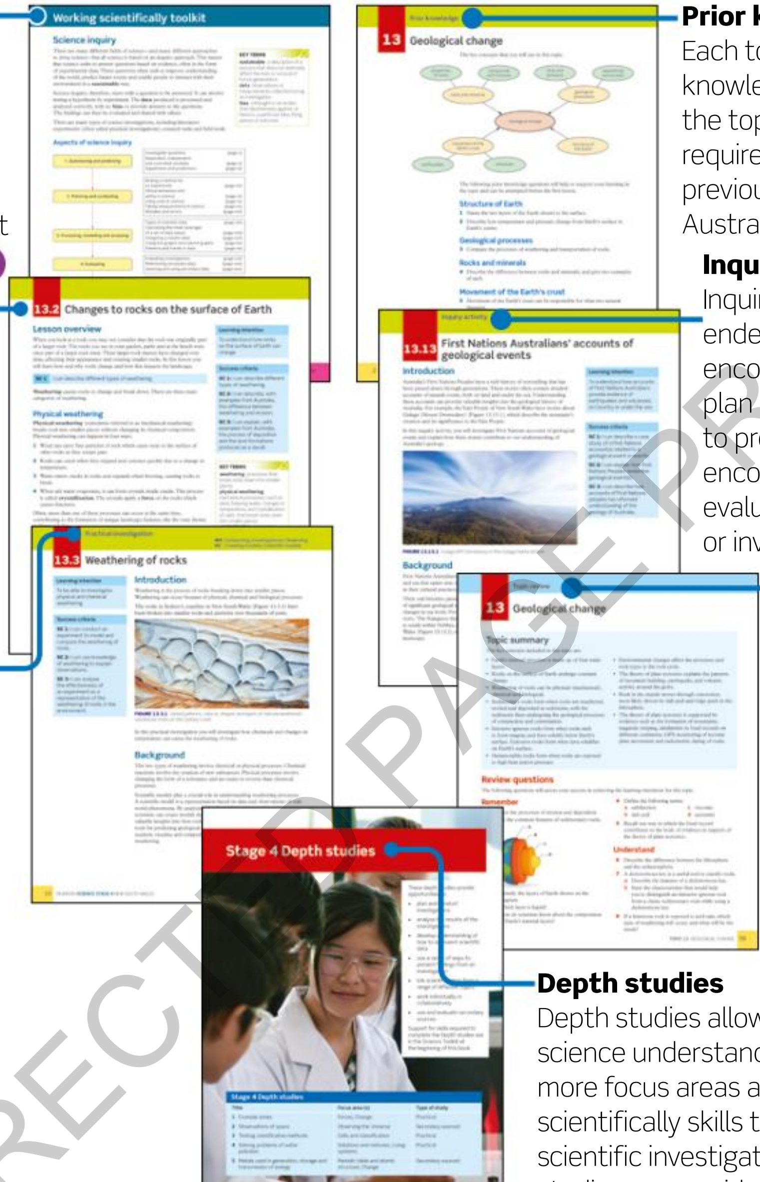

**Success criteria** clarify expectations and describe what success looks like. They are used to determine how well a student has met the learning intention. The Pearson Science lesson design is based on cognitive load principles and, as such, each lesson has 1–3 success criteria. The success criteria are specific, concrete and measurable so learners can actively engage with and reflect on their evidence of learning within each lesson. The success criteria form the basis of both components – the Student Book (and eBook) and Pearson Digital Hub – to ensure they are consistent throughout the lessons and to provide the basis for feedback.

## Student book features

**Working scientifically toolkit**
Science inquiry skills are supported by a Working scientifically toolkit at the beginning of the book, referenced throughout the text with 'Go to' icons. GO TO

**Theory lessons**
Theory lessons provide content in short, accessible chunks. Questions to check learners' understanding are provided at regular intervals throughout the lesson. Each theory lesson ends with a lesson review that includes 3–6 questions.

**Practical investigations**
Practical investigations offer learners the chance to design and conduct experiments, record results, analyse data, and prepare evidence-based conclusions.




**Prior knowledge lessons**
Each topic begins with a prior knowledge lesson linking the topic key concepts to required knowledge from previous years or topics in the Australian Curriculum.

**Inquiry activities**
Inquiry activities are open-ended investigations that encourage learners to plan and design solutions to problems. Learners are encouraged to improve and evaluate their ideas, designs or investigations.

**Topic reviews**
Each topic finishes with a summary to consolidate key ideas from the topic, questions organised by challenge level to address every learning intention in the topic, and a topic glossary.

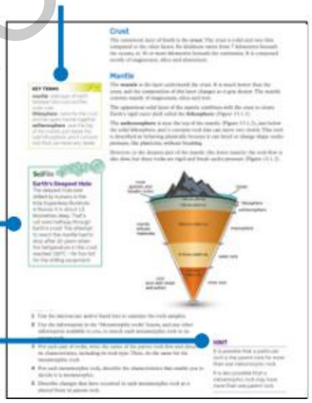
**Depth studies**
Depth studies allow students to apply science understanding from one or more focus areas as well as the Working scientifically skills they have learned to a scientific investigation. Five example depth studies are provided at the end of the book.

## Additional features

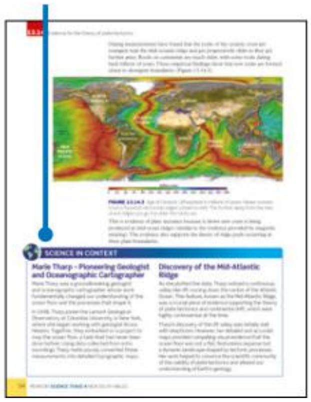
**Key terms**

**Scifiles**

**Hints**



**Science in Context boxes**



**Skillbuilders**

**Worked examples**

# Pearson Science Stage 4

## For the New South Wales Science 7–10 Syllabus (2023)


eBook

Student Book

Pearson Digital Hub

**Your complete science solution for Stage 4, created by education experts to support every teaching style and every learning journey.**

- Offers a new, complete, course that is seamlessly connected across the print and online resources, giving you continuity and the flexibility to support different teaching methods and learning styles.
- Embeds explicit teaching strategies in every lesson to help manage cognitive load and maximise learning outcomes for a range of student abilities.
- Integrates prior knowledge questions, worked examples and questions throughout to check student understanding and progress.
- Includes 1000s of unique questions across the series to give you even more choice and flexibility, and to save you time.
- Provides content written and reviewed by expert Australian classroom educators.
- Supports each lesson with teaching notes, including differentiation support.
- Focuses on the practical aspect of science through practical investigations, inquiry activities, depth studies, skillbuilders and worked examples as well as a chapter-length working scientifically toolkit and integrated data science outcomes embedded through the resource.

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Discover the full series at
pearson.com/en-au/schools/science-nsw

# Working scientifically toolkit

## Introduction

This toolkit includes skills assoctied with Working scientifically, guidance for the application of Data science, and support with how to conduct Depth studies.

## Data science

Some of the Working scientifically processes involve aspects of data science. In Stage 4, these include the following.

- **Sources of data:** Examine a range of sources of data and their applications (Toolkit sections 4.3, 5.1 and 8.5).
- **Scientific questions:** Formulating and investigating scientific questions that can be addressed with data (Toolkit section 2.1).
- **Accuracy and reliability:** Conducting repeated experimental trials to calculate and compare the mean and range of data collected by different groups to discuss the accuracy and reliability of experimental data. (Toolkit sections 4.2 and 6.9).
- **Patterns and predictions:** Analysing data collected from a range of student investigations to look for patterns and test whether data is consistent with an initial prediction (Toolkit sections 2.3 and 6.5).

There are many forms of science inquiry that involve the use of these working scientifically processes, including practical investigations, research tasks and field work.

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(Includes aspects of Data science)

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2 **Questioning and predicting** page xiv
3 **Planning investigations** page xvii
4 **Conducting investigations** page xx
5 **Processing data and information** page xxiv
6 **Analysing data and information** page xxxii
7 **Problem-solving** page xxxix
8 **Communicating** page xl
9 **Data science** page xlvi
10 **Depth studies** page xlix

# Working scientifically processes

Scientific inquiry involves a range of working scientifically processes that are identified as follows.

| Working scientifically processes | Toolkit section |
|---|---|
| **1 Observing**<br>Using scientific tools and instruments for observations | 1.1 Taking measurements in science (page xii)<br>1.2 Mistakes and errors (page xiv) |
| **2 Questioning and predicting**<br>Identifying questions and making predictions to guide scientific investigations | 2.1 Investigable questions and research questions (page xiv)<br>2.2 Dependent, independent and controlled variables (page xv)<br>2.3 Making predictions (page xvi) |
| **3 Planning investigations**<br>Planning safe and valid investigations | 3.1 Writing a method for an experiment (page xvii)<br>3.2 Reducing risk (page xix) |
| **4 Conducting investigations**<br>Following a planned procedure to undertake safe and valid investigations | 4.1 Selecting equipment for accurate measurement (page xx)<br>4.2 Reducing error and improving accuracy (page xxii)<br>4.3 Selecting and using secondary data (page xxiii) |
| **5 Processing data and information**<br>Using a variety of ways to process and represent data | 5.1 Types of scientific data (page xxiii)<br>5.2 Using units in science (page xxiv)<br>5.3 Converting between units (page xxiv)<br>5.4 Calculating the mean (average) of a set of data values (page xxvi)<br>5.5 Designing a results table (page xxvi)<br>5.6 Line graphs and column graphs (page xxvii)<br>5.7 Creating a line graph using a spreadsheet (page xxix) |
| **6 Analysing data and information**<br>Using data to identify trends, patterns and relationships, and draw conclusions | 6.1 Making inferences (page xxxii)<br>6.2 Evaluating investigations (page xxxiii)<br>6.3 Analysing a line graph (page xxxiii)<br>6.4 Outliers and anomalies (page xxxiv)<br>6.5 Trends in data (page xxxv)<br>6.6 Cause-and-effect relationships (page xxxv)<br>6.7 Evaluating precision (page xxxvii)<br>6.8 Evaluating validity (page xxxviii)<br>6.9 Evaluating reliability (page xxxviii) |
| **7 Problem-solving**<br>Identifying problem-solving strategies and proposing solutions | 7.1 Approach to problem-solving (page xxxix) |
| **8 Communicating**<br>Communicating scientific concepts and ideas using a range of communication forms | 8.1 Scientific writing (page xl)<br>8.2 Scientific diagrams (page xl)<br>8.3 Drawing scientific equipment (page xlii)<br>8.4 Writing a practical investigation report (page xliii)<br>8.5 Referencing secondary data (page xliv)<br>8.6 Using artificial intelligence (AI) in science writing (page xlv) |

# 1 Observing

## 1.1 Taking measurements in science

When taking a measurement, make sure the following guidelines are followed.

- Check the measuring instrument, for example, does it read zero correctly? ☐
- Use the most precise measuring device available. For example, to measure around 6 mL of a liquid, do not use a 100 mL measuring cylinder. ☐
- Eyes should be level with the scale when taking readings (see parallax error below). ☐
- Check your measurement. Was the scale measured correctly? ☐
- Record the measurement straight away. Were the measurements recorded correctly? ☐
- Check that the numbers of your data are written in a consistent format. For example, to the same number of decimal places. ☐



### Measuring volume of liquids

When measuring the **volume** of liquids, the surface of a liquid forms a curved shape in containers. For example, in the measuring cylinder shown in Figure 1, the liquid curves down in the middle. This curved surface is known as a **meniscus**.

To take an **accurate** measurement in this example, always measure from the bottom of the meniscus. In this case the value measured would be 220 mL.

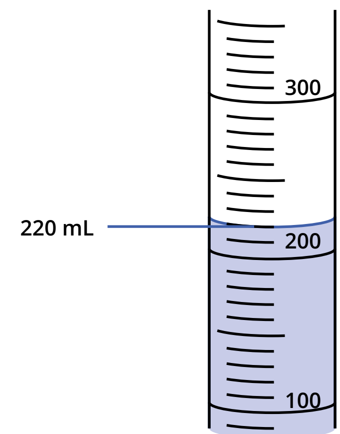



**FIGURE 1** A measuring cylinder containing 220 mL of solution

### Parallax

Parallax **error** is caused by reading dials and instruments from an angle instead of looking straight at the measuring scale, giving inaccurate readings.

***Example***

Three students look at a ruler from three different angles and each one reads a different measurement, between 18 cm and 21 cm (Figure 2).

Always make sure you read instruments straight on so as not to cause parallax error.

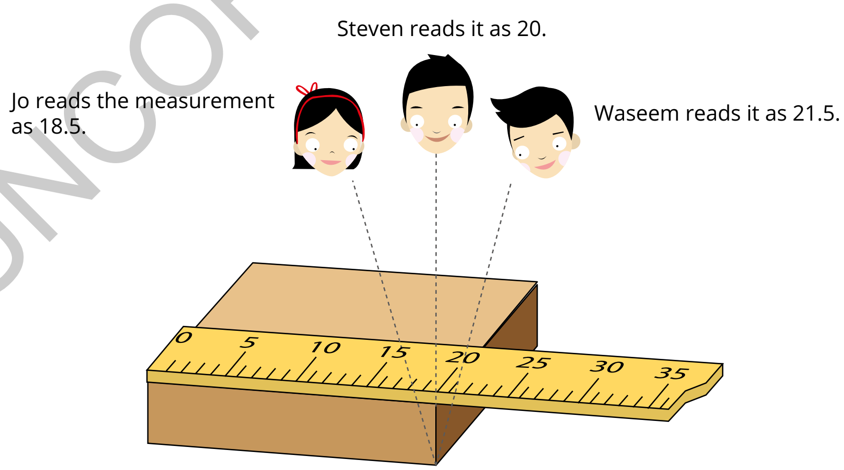



**FIGURE 2** Parallax error is caused by each student reading the measurement from a different angle

**KEY TERMS**

**volume** the amount of space that a substance or object occupies
**accurate** a description of a measurement that is close to the true value
**error** the difference between a measured result and the true value (Toolkit section 4.2)

## 1.2 Mistakes and errors

Mistakes and errors are not the same thing.

Error will always happen in science—it is unavoidable. As a scientist, it is your aim to make errors as small as possible. Errors occur when taking measurements and may be systematic or random errors. See Toolkit section 4.2 for more details on types and causes of error.

Mistakes occur when the experimenter does something incorrectly. Mistakes usually happen because the experimenter did not accurately follow the method or take enough care when taking or recording measurements.

# 2 Questioning and predicting

## 2.1 Investigable questions and research questions

In science, a good question is one that can be answered by carrying out an investigation. This kind of question is called an **investigable question**. Key types of investigable questions are shown in Table 1. Investigable questions that are used in extended projects, or investigations that use **secondary data** are often called **research questions**. The research question acts as the key question which helps to guide the research or project.

**KEY TERMS**

**investigable question** a question that can be answered by carrying out an investigation

**secondary data** data that someone has acquired from an experiment that they have not carried out themselves

**research question** a question that a study or research project aims to answer

**TABLE 1** Types of investigable questions

| Question type | | Examples |
|---|---|---|
| descriptive questions | These ask about facts or descriptions. | • How long is the insect?<br>• How many legs does the insect have? |
| relational questions | These compare things. | • Which insect is the longest?<br>• Are all the legs on the insect the same length? |
| cause-and-effect questions | These ask whether there is a link between two variables. | • Do larger insects have more legs?<br>• Does the colour of the insect depend on the environment it lives in? |

Many scientific investigations seek to answer cause-and-effect questions.

### Developing an investigable question

When you create a question to be investigated, you can use this checklist to help you decide if it is a good investigable question.

- Is the question clear and as simple as possible? ☐
- Is finding the answer to this question going to be interesting? ☐
- Will finding the answer to this question improve understanding? ☐
- Is there a way to find the answer to this question? ☐
- Is it possible to answer this question with the materials, resources and time available? ☐

## Example of creating an investigable question

Rami wanted to investigate friction (the force opposing movement) between the tyres of a mountain bike and the ground. Table 2 shows the approach that you could take to develop a good question to investigate. The thinking column describes the thought processes involved. The working column describes how that thinking can be applied to the problem.

**TABLE 2** The thinking and working involved in creating an investigable question

| Thinking | Working |
|---|---|
| Consider the variables that may affect the problem being examined. | Friction may be affected by the temperature of the surface, the type of surface, the material of the tyre, the air pressure inside the tyre or how wet the surface is. |
| Choose one variable that is interesting and will increase Rami's knowledge. | Rami can consider whether the pressure of the tyre affects the amount of friction between the tyre and the ground. |
| Make sure that the question is clear and as simple as possible. | The question could be 'How does the pressure of the tyre affect the amount of friction between the tyre and the ground?" |
| Check that you are able to answer the question with the resources and time available. | The investigable question can be made more specific, such as 'Which pressure provides the most friction between the tyre and the ground'. |

## 2.2 Dependent, independent and controlled variables

A **variable** is a factor that may affect the results of an experiment.

For example, Lin is investigating the growth of a plant (Figure 3) by measuring how tall the plants are after two weeks of growth. The following factors may affect the growth of the plant:

- temperature of the soil
- type of soil
- amount of water given to each plant
- amount of sunlight received by each plant
- amount of fertiliser applied
- type of fertiliser used
- size of the pot in which the plant is grown.

The **independent variable** is the variable that will be changed by the investigator. Lin chooses amount of sunlight as the independent variable and will investigate how well seedlings grow in the dark, in indirect sunlight and in direct sunlight.

Once the independent variable has been selected, the **controlled variables** are all the other variables that might affect the results. These must be kept the same. This ensures that the investigation is fair (**valid**) as it means that only changes to the independent variable will be affecting the results.

**KEY TERM**

**variable** a factor or condition that can change during an experiment and can influence the experiment

**FIGURE 3** Many variables will affect the growth of these plants

The **dependent variable** is the growth of the plant, which Lin chooses to measure by recording the height of the plants each day. This is called the dependent variable because the height of the plant might 'depend' on the amount of sunlight.

Table 3 shows a summary of the three types of variables.

**TABLE 3** Summary of the three types of variables

| Variable type | | Examples from Lin's investigation |
|---|---|---|
| independent variable | The variable that will be changed by the investigator | the amount of sunlight received by each plant |
| dependent variable | The variable that is being observed and measured in an investigation | the height of the plant |
| controlled variables | The variables that are kept the same to ensure a fair (valid) investigation | temperature of soil<br>type of soil<br>amount of water<br>size of the pot |

## 2.3 Making predictions

Observations can often lead to a question that can be answered using a scientific investigation. To attempt to answer these kinds of questions, predictions can be made by applying prior knowledge or observations.

### Using observations to make a prediction

Scientists use their knowledge and observations of events, to predict what will happen in similar situations. Table 4 describes some of the considerations that need to be applied when using observations or prior knowledge to make predictions.

**TABLE 4** Making predictions based on observations

| Question | Notes |
|---|---|
| Is using prior knowledge a valid way of predicting what will happen? | The earlier event should be similar to the event about which the prediction is being made. |
| Am I sure about the prior knowledge that I am using? | You should be able to trust the observation or source of the information. |
| Can I describe why I have made the prediction? | You should be able to provide evidence for the reason(s) for your prediction |

***Example***

Ada wanted to drop different types of balls on different surfaces to test how high they would bounce. She found an experiment that students had conducted the year before and read their results (Table 5).

**TABLE 5** Average height of bounce of different ball types on different surfaces

| Type of ball | Average height of bounce (cm) when dropped from 1 metre (cm) | | | |
|---|---|---|---|---|
| | Carpet | Concrete floor | Wooden floor | Artificial grass |
| cricket ball | 45 | 65 | 50 | 30 |
| table tennis ball | 50 | 40 | 60 | 40 |
| basketball | 60 | 50 | 70 | 45 |
| soccer ball | 55 | 50 | 60 | 40 |

Ada wants to use these observations to predict which surface a golf ball will bounce the highest. The thinking/working involved is shown in Table 6.

**TABLE 6** Creating a prediction from observations

| Thinking | Working |
|---|---|
| Compare the new situation to prior knowledge to identify a similar situation. | By comparing the golf ball to the balls already tested, Ada will see that the golf ball is most similar in structure to the cricket ball because they are both solid, whereas the other balls are filled with air. Therefore, she can use her observations of the cricket ball to make predictions about the golf ball. |
| Draw on what is known about the similar situation. | The previous experiment shows that the cricket ball bounces highest on the concrete floor in comparison to other floor types, which is a similar ball to the golf ball that she wants to test. |
| Use the known information to make a prediction about the new situation. | Ada can predict that the golf ball will bounce highest on the concrete floor because it has a similar structure to the cricket ball, which was found to bounce highest on the concrete floor in the previous experiment. |

# 3 Planning investigations

## 3.1 Writing a method for an experiment

The method of an experiment is written as a list of numbered steps. These steps should clearly describe the process to be followed.

Your method must be reproducible. This means that other scientists should be able to use your method to repeat the experiment exactly. It is often helpful to include a diagram that shows how the experiment was set up.

Apparatus required for the experiment should be listed separately, and how the apparatus is used should be made clear in the method.

## Writing a method for an experiment

Follow this checklist when writing a comprehensive and accurate method.

- [ ] Consider the order in which the actions must be carried out.
- [ ] Write the method as a series of numbered steps.
- [ ] Include details of the materials, including the sizes and types of equipment and quantities of substances used.
- [ ] Include safety notes where required.
- [ ] Make clear what observations and measurements are required and how they are to be recorded.
- [ ] Check that your apparatus list includes everything required in the method.

### *Example*

Kylie is planning an experiment to investigate the effect of sunlight on seedling growth. Her prediction is that seedlings left in direct sunlight will grow taller in 10 days than seedlings grown in the shade. Her method is given below.

10 seeds are used in case some do not germinate (start to grow).

Kylie has selected a number of plants and ensured that they all start at similar heights.

The size of the pots, the amount of water given to the plants and the amount of soil that they are grown in are **controlled variables** which she is keeping the same.

It is important to include safety notes when needed.

The amount of light is the **independent variable**. Kylie is varying this by placing the plants in different positions.

It is clear what measurements are made, and how **accurate** they should be.

Kylie always clearly states how much water is used.

**Apparatus**

- *10 pea seeds*
- *500 g potting mix*
- *tap water*
- *cotton wool*
- *6 plant pots*
- *30 cm ruler*
- *25 mL measuring cylinder*
- *electronic balance*

**Method**

1 *Germinate 10 pea seeds on damp cotton wool.*

2 *Choose six of the germinated seedlings to grow that have a height of approximately 12 mm each.*

3 *Plant one seedling in each of six pots of the same size. For each pot, use 80 g of quality potting mix, and water with 10 mL of tap water.*

*Safety note: ensure that gloves are worn when handling potting mix, as it may contain harmful microbes.*

4 *Place three pots next to a window that gets direct sunlight. Place the other three pots in a shaded area of the room.*

5 *Using a ruler, measure the height of the tallest part of the plant from the surface of the soil. Draw up a results table and record the results for each pot in the column from the first day.*

6 *Measure the height of the plants in the same way two days later. Record the results for each pot in the column for day 2.*

7 *Immediately after measuring, give each plant 10 mL of water.*

8 *Repeat steps 5 and 6 every two days for the next 10 days, keeping the plants in the same position to maintain lighting conditions.*

## 3.2 Reducing risk

The management of **risk** in experiments is an important part of ethical behaviour in science.

**KEY TERM**

**risk** the likelihood of something harmful occurring

### Identifying risk

Before starting an investigation it is important that you identify and reduce potential risk. Consider the following checklist before conducting an experiment to ensure that all aspects of risk have been considered.

- ☐ The locations for the investigation (e.g. in a laboratory or outside)
- ☐ The equipment and substances that are being used, and how they are being used
- ☐ What clothing and protective equipment should be worn

### Reducing risk

Risk in science can be looked at in three main areas: behaviour, equipment and substance.

### Behaviour risk reduction

When conducting an investigation it is important to follow safety rules and avoid behaviours that increase risk. The following steps can be used to reduce risk.

- ☐ Identify the safety rules and personal protective equipment that need to be followed and used during the investigation.
- ☐ Determine how you will make sure that these rules are followed.
- ☐ Describe how you will follow the safety rules in your experiment method.

***Example***

Sophie is wanting to conduct an experiment that uses a Bunsen burner to heat wax on different types of metals. Behaviours that reduce risk include keeping the bench tidy and wearing protective clothing, such as safety glasses and a lab coat. She will also consider that long hair will need tidying back away from the flame and ensure that no one touches any hot materials after the experiment is finished.

### Equipment risk reduction

When working with equipment, take the following steps to reduce risk.

- ☐ Identify the equipment that you will be using and any potential hazards.
- ☐ Determine how to use each piece of equipment safely.
- ☐ Describe how you will safely use each piece of equipment in your method.

***Example***

Abhi is going to use an electronic balance to weigh mud in glass beakers at the start and the end of an experiment. As mud contains moisture it is important for Abhi to consider the use of electrical equipment near wet substances. Abhi should also consider using glass in this investigation as it can easily break into sharp pieces.

### Substance risk reduction

When working with substances such as chemicals, take the following steps to reduce risk. Information can be located in Safety Data Sheets (SDS) for each substance.

- [ ] Identify the substances that you will be using and any potential hazards.
- [ ] Determine how you will carefully use each chemical
- [ ] Determine how you will safely dispose of each chemical.
- [ ] Describe how you will safely use and dispose of each chemical in your method or risk assessment.

***Example***

Jia is going to use different household chemicals in an investigation. She should consider which substances can cause risk, including corrosive acids, and chemicals that can produce vapours that are harmful when inhaled (breathed in). She also needs to write down how the substances will be disposed of at the end of the experiment. She consults the laboratory technician or teacher about the different chemicals, and they look through the SDS for each substance prior to conducting the experiment.

## 4 Conducting investigations

### 4.1 Selecting equipment for accurate measurement

The equipment used in science experiments includes equipment used for performing tasks, such as a Bunsen burner for heating, and equipment used for taking measurements, such as a measuring cylinder for measuring liquids.

When choosing equipment for taking measurements, the choice of type of the equipment, and the measuring capacity of the equipment, can affect the **accuracy** of measurements.

**KEY TERM**

**accuracy** how close a measurement is to the true value of the quantity being measured

Consider the following when selecting equipment for taking measurements.

- [ ] Will this equipment allow the most accurate measurement?
- [ ] Is the equipment the correct size for measuring the quantities in this experiment?
- [ ] Is there a way to record the data digitally, to increase the accuracy and ease of measuring and recording the data?

***Example 1***

When accurately weighing an object, it is important to use a balance that is accurate enough. Generally, the smaller the quantity the balance can measure, the more accurate the measurement will be. The electronic balance in Figure 4 weighs to two decimal places. Therefore, the increments are 0.01 g for this balance.

***Example 2***

If you need to accurately measure around 40 mL of a liquid, select a measuring cylinder (Figure 5). It is designed to measure volume accurately compared to a beaker, which is only meant to hold liquids, rather than measure them.


**FIGURE 4** This digital balance measure mass in grams to two decimal places.

**FIGURE 5** A 50 mL measuring cylinder would be more accurate in measuring 40 mL of liquid than a 100 mL measuring cylinder.

## Scales and accuracy

The accuracy of measurements will depend on the scales on the measuring equipment. Many scientific instruments use a scale to measure. Examples of equipment that use scales include rulers (distance), measuring cylinders (volume) and thermometers (temperature).

Scales contain label **graduations**, normally spaced an equal distance apart. The difference between one graduation and the next is called an **increment**, as seen in Figure 6.

In the example above, it was said that a measuring cylinder should be used to measure 40 mL of liquid. For the greatest accuracy, a 50 mL measuring cylinder (Figure 5) should be used rather than, for example, a 100 mL measuring cylinder. The smaller the measuring cylinder, the smaller the scale increments between the graduations, which allows for a more accurate reading.

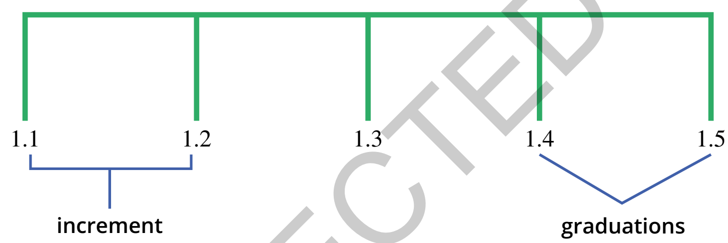



**FIGURE 6** Increments and graduations of a scale

The smaller the increment, the more accurate the reading. See Figures 7 and 8 for examples of different increment sizes in measuring cylinders.

**KEY TERMS**

**graduations** markings that indicate quantities on a scale

**increment** the value of the difference between graduations on a scale


**FIGURE 7** The increments in this 50 mL measuring cylinder are 1 mL as there are 10 graduations between the 40 mL and the 50 mL mark.


**FIGURE 8** The increments in this 10 mL measuring cylinder are 0.2 mL as there are 10 graduations between the 6 mL and the 8 mL mark.

## 4.2 Reducing error and improving accuracy

Errors occur when taking measurements and may be systematic or random errors. Table 7 gives an overview of these types of error.

**TABLE 7** Types of experimental error

| Error type | Definition | Occurrence | Possible cause |
|---|---|---|---|
| random errors | These are not the same every time. The measured value can be greater than the true value of the quantity, or less than the true value. | There will be some random error whenever any measurement is taken. | Using equipment that is not accurate enough. |
| systematic errors | These cause a more predictable error. The measured result is always higher, or always lower, than the true value. | Systematic errors do not always occur when taking measurements. | An instrument that is not used correctly, such as not being re-zeroed. |

**KEY TERMS**

**random error** error that affects measurements in an unpredictable way; measured values can be higher or lower than the true value

**repeat trials** repeat of an individual test or measurement within an experiment or investigation

**systematic error** an error that affects measurements in a predictable way; measured values will always be higher or always lower than the true value

Error can be reduced in the following ways.

To reduce **random error** occurring:

- select the most accurate measuring device available
- learn to use the measuring device correctly
- conduct **repeat trials** and calculate the average of the results.

To reduce the chance of **systematic error** occurring:

- check the measuring device has been reset to zero before taking a reading
- ensure you are measuring only what you intend to measure. For example, make sure that a chemical that you are weighing is not wet as this will increase the measured mass
- ensure all of what you intend to measure is being measured. For example, if some of the chemical is not transferred to the container being weighed, the measured mass will be reduced because not all of the chemical is being recorded.

***Example***

Mai needs to measure the volume of rainwater that she has collected in a plastic cup. She wants to ensure that her measurement is as accurate as possible. Table 8 shows how she has selected an appropriate piece of equipment to take this measurement.

**TABLE 8** Thinking and working used for selection of measuring equipment

| Thinking | Working |
|---|---|
| Mai must select the correct equipment for the task. | Mai knows that the best way to measure volume is using a measuring cylinder. She will use a measuring cylinder to measure the volume of the water she has collected. |
| How can Mai reduce random error? | Mai knows that the bigger the range of the measuring device, the less accurate it is. Therefore, she needs to choose a measuring cylinder that will have a high level of accuracy for the volume of water she has collected. It should not be too big. She should use a 50 mL measuring cylinder and read the measurement carefully. |

| Thinking | Working |
|---|---|
| Mai needs to plan to reduce systematic error by thinking about how to use the equipment correctly. | Mai needs to make sure that she is measuring all of the water she has collected. If any water is left in the cup, or if any water is spilled when tipping the contents of the cup into the measuring cylinder, her measurement will not be accurate. Mai will carefully tip all the water into the measuring cylinder, making sure all water is successfully transferred.<br>She must also take the reading from the bottom of the curve of the surface of the water (the meniscus), making sure their eyes are level with the surface of the water. This will prevent an inaccurate reading of the volume. |
| Mai needs to take steps to avoid making mistakes. | Mai will pay close attention to what she is doing and not be distracted. She will double check that she has recorded the measurement correctly, using the correct units. |

## 4.3 Selecting and using secondary data

When planning and conducting investigations, you will often need to do some research, which will involve the identification and use of **secondary data**.

When looking for resources, try to draw from a wide variety of reputable source, including books, websites, magazines, scientific journals and videos (Table 9). However, the focus should always be on selecting the best resources for the task.

**TABLE 9** Advantages and disadvantages of information sources

| Type of resource | Advantages | Disadvantages |
|---|---|---|
| book | • Information is easy to find through the table of contents and index.<br>• Information has been edited by an editor.<br>• Information is usually well researched and written by an expert. | • Information can be outdated.<br>• Can take time to locate the exact information you require. |
| website | • Provides access to a huge amount of information on the one topic.<br>• Information can be updated easily. | • Anyone can publish on the internet, so it can be difficult to work out what information is accurate and reliable. |
| magazine/ journal | • Information is usually up to date and contains recently researched information. | • Can be very technical and difficult to understand.<br>• Can be biased. |
| video/ documentary | • Can provide first-hand accounts of events and situations.<br>• Engaging and easy to watch. | • Can be difficult and time-consuming to find specific information.<br>• May not be accurate and can be biased. |

# 5 Processing data and information

## 5.1 Types of scientific data

Results that are collected during a science investigation can be either quantitative or qualitative data, as shown in Table 10.

**TABLE 10** Types of scientific data

| Type of data | | Example |
|---|---|---|
| **Quantitative data** is produced when a quantity or amount of something is measured and recorded. Quantitative data can be continuous or discrete. | **Continuous data** can have any value, including a decimal value. | the height of a plant, e.g. 11.5 cm |
| | **Discrete data** can only have separate values (normally whole numbers). | the number of leaves on a plant |
| **Qualitative data** is produced when the characteristic (or 'quality') of something is observed and recorded. | | the colour of the leaves or the smell of the plant |

## 5.2 Using units in science

The International System of Units, or SI units, is a standard way of measuring things that is used by scientists around the world. It is a universal language for measurements based on seven base units. Some examples of these that you will use in science are shown in Table 11.

**TABLE 11** Examples of SI base units used in science

| SI base unit | Used to measure | Notes |
|---|---|---|
| metre (m) | length or distance | 1 m = 100 cm |
| Kilogram (kg) | mass | 1 kg = 1000 g |
| second (s) | time | There are 60 seconds in a minute. |

There are other units that are not base SI units but are commonly used (Table 12).

**TABLE 12** Examples of other common units used in science

| SI base unit | Used to measure | Notes |
|---|---|---|
| degrees Celsius (°C) | temperature | uses the same increments as the SI unit kelvin (K) |
| millilitres (mL) | volume | 1000 mL = 1 litre (L) |
| newtons (N) | force | named after Isaac Newton |

## 5.3 Converting between units

Measurements must be in the same units before you can compare them. Having the measurements in the same units makes the comparison fair. Figure 9 shows some common standard unit conversions.

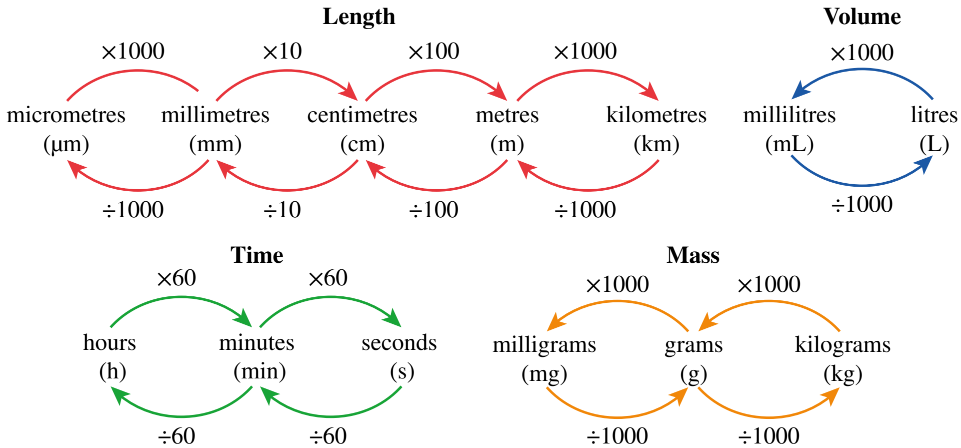



**FIGURE 9** Common conversion measurements for length, time, volume and mass

## Converting a smaller unit to a larger unit

To convert from a smaller unit such as grams (g) to a larger unit such as kilograms (kg), you need to divide the value you have by the number of these units in the larger unit. In this case it is 1000 because there are 1000 g in 1 kg.

***Example***

If you had 1600 g of salt but you needed to know how much salt you had in kilograms, you would divide the mass of the salt by 1000 to convert it to kilograms:

$$\frac{1600}{1000} = 1.6 \text{ kg}$$

## Converting a larger unit to a smaller unit

To convert from a larger unit such as litres (L) to a smaller unit such as millilitres (mL), you need to multiply the value you have by the number of smaller units in the larger unit. In this case it is 1000, because there are 1000 mL in 1 L.

***Example***

If you had a bottle of water that holds 0.5 L of water and you needed to know how much water it holds in millilitres, you would multiply the volume by 1000 to convert it to millilitres:

$$0.5 \times 1000 = 500 \text{ mL}$$

Other examples are shown in Table 13.

**TABLE 13** More examples of unit conversions

| Original measurement | Conversion | New measurement |
|---|---|---|
| 0.656 g of gold | × 1000 | 656 mg of gold |
| 1871 mg of silver | /1000 | 1.871 g of silver |
| 600 mL of water | /1000 | 0.6 L of water |

## Units for time

Time is often measured in minutes (min) and seconds (s). To compare measurements of time or to plot measurements of time on a graph, the times must be converted to just seconds or just minutes. Stopwatches are one method that is commonly used in science classrooms to measure time (Figure 10).


**FIGURE 10** Time recorded on a stopwatch

When you have a measurement of time that includes both minutes and seconds, you can convert the time to seconds by multiplying the number of minutes by 60 and then adding this answer to the number of seconds.

For example, to convert 5 min and 6 s in Figure 10 to seconds, you multiply 5 by 60 and then add the 6 s to the total:

$$\text{Time in seconds} = (5 \times 60) + 6 = 306 \text{ s}$$

## 5.4 Calculating the mean (average) of a set of data values

In science investigations, averages, or means, are used to increase the **accuracy** of results. Averages are calculated from a set of results (a **data set**), in which each individual result is called a **data value**.

### How to calculate mean (average) value

Add the data values together and divide by the number of data values.

***Example***

Shasma used a newton meter to measure the force required to move an object along the ground (Figure 11). She repeated the test four times and results are given in Table 14.

**FIGURE 11** Force being measured with a newton meter

**TABLE 14** Force required to move an object

| Trial | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Force (N) | 5.2 | 4.9 | 5.0 | 5.1 |

Total of data values = (5.2 + 4.9 + 5.0 + 5.1) = 20.2

$$\text{Mean value} = \frac{20.2}{4} = 5.05 \text{ N}$$

Always remember to include a unit in your final answer.

## 5.5 Designing a results table

Results tables are important for the accurate recording of data. The following method should be used to design a results table.

- Identify what is being recorded in the experiment. This is often the **independent variable** that is being changed, as well as the dependent variable.
- For any **quantitative data** used identify the correct units and add to the column or row title.
- Find out or decide how many results will be recorded.
- If **repeat trials** will be conducted, plan to include room in the table to record these results and calculate the average (mean) value.
- Draw up a table that is large enough to fit all the required results.
- Add the names of the two variables being recorded, along with their units, at the top of the appropriate columns as headings. The independent variable is on the left-hand side, and the dependent variable at the top.
- Give the table an informative title and figure number.

***Example***

Rue was investigating the time it takes for sugar to dissolve in water at different temperatures. Rue's results table is shown below (Table 15).

**TABLE 15** The time taken to dissolve sugar in water at different temperatures

| Temperature of water (°C) | Time taken to dissolve 5 g of sugar in 50 mL of water (s) | | | |
|---|---|---|---|---|
| | Trial 1 | Trial 2 | Trial 3 | Average time |
| 20 | 110 | 105 | 102 | 105.7 |
| 45 | 25.0 | 24.0 | 27.0 | 25.3 |
| 80 | 7.0 | 10.0 | 8.0 | 8.3 |

Notes:

- To make it easy to compare values, all the times are giving in the same unit, in this case seconds (not minutes and seconds).
- Units are included in the column headings and not with the data in the table.
- Make sure that table has a title that includes the dependent and independent variable.



## 5.6 Line graphs and column graphs

### Line graphs

These are used to display **quantitative data**. Data values are plotted as points on the graph. A line is then drawn through these points that shows the pattern or trend in the data. A line graph is often used when a set of data is purely numerical.

The axes of a graph are called the ***y*-axis** and the ***x*-axis**.

- The *y*-axis is the vertical axis that points upwards. The **independent variable** is placed on the *x*-axis
- The *x*-axis is the horizontal axis that points across. The **dependent variable** is placed on the *y*-axis.

You can use the following questions as a checklist when drawing graphs.

| | | |
|---|---|---|
| axis | Are the scales on the axes suitable, so that the data takes up at least 80% of the grid space? | ☐ |
| scales | Do the scales have consistent increments? | ☐ |
| variables | Are the variables on the correct axes? | ☐ |
| labels | Is each axis labelled, including correct units? | ☐ |
| data | Is each data point plotted correctly? Are they clearly visible? | ☐ |
| line | Is there a smooth line included that shows the pattern or trend in the data? | ☐ |
| title | Does the graph have a title that includes the dependent and independent variable? | ☐ |

**KEY TERMS**

**quantitative data** data produced by recording a quantity or amount of something (Toolkit section 5.1)
**repeat trial** repeat of an individual test or measurement within an experiment or investigation
**independent variable** the factor that is changed in an investigation to find out how it affects another factor (Toolkit section 1.2)
**dependent variable** the variable that is being measured in an experiment; it can vary as the independent variable changes (Toolkit section 1.2)
**trend** a noticeable pattern or movement in data

***Example***

Jack was investigating whether there was a connection between the mass of an object (he used sandbags) and the force required to pull it along a bench top. His data is shown in Table 16.

**TABLE 16** Force required to move sandbags of different mass across the bench

| Mass of sandbag (kg) | Force required to move the sandbag (N) |
|---|---|
| 0.5 | 4.0 |
| 1.0 | 7.8 |
| 1.5 | 12.0 |
| 2.0 | 15.2 |
| 2.5 | 19.2 |
| 3.0 | 23.0 |

| | |
|---|---|
| Mass is the independent variable, so it needs to go on the *x*-axis. The age data range is from 0.5 – 3.0, so the *x*-axis will need a suitable scale to fit this data. | Force is the dependent variable, so it needs to go on the *y*-axis. The force data range is from 4 – 23, so the *y*-axis will need a suitable scale to fit this data. |

Jack's graph could look like Figure 12.

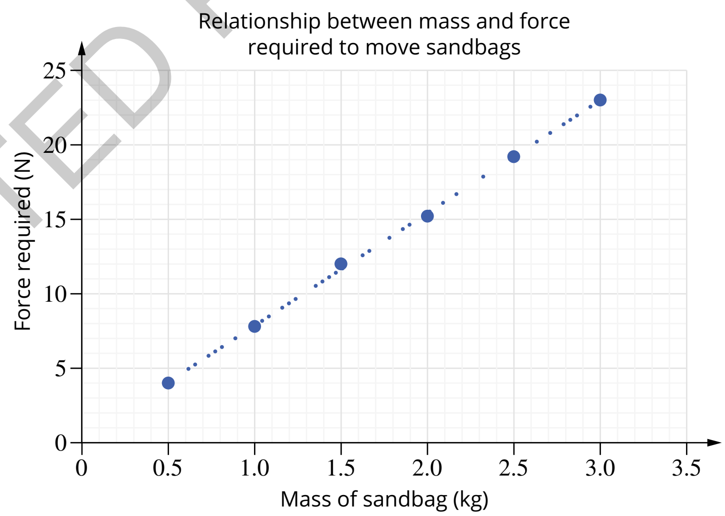



**FIGURE 12** Line graph showing the relationship between force and the mass of sandbags

**KEY TERMS**

**discrete quantitative data** data produced by recording a quantity or amount of something that can only have separate values (normally whole numbers) (Toolkit section 5.1)

**qualitative data** observations that are descriptive only (no quantity or number) (Toolkit section 5.1)

## Column graphs

These are used when some or all of the data is **discrete quantitative data** or **qualitative data**.

- A column graph displays data using bars.
- The length of the bar indicates the data value.
- As in a line graph, the independent variable is placed on the *x*-axis, while the dependent variable is placed on the *y*-axis.

***Example***

Kara carried out a survey of different birds seen in her garden during one afternoon to see which type of bird had the most visits. She set up a webcam and recorded every instance of the appearance of the birds. Her results are shown in Table 17.

**TABLE 17** Bird sightings between 2 pm and 5 pm on July 3

| Bird type | Number of sightings |
|---|---|
| magpie | 4 |
| honeyeater | 7 |
| pigeon | 8 |
| wren | 2 |
| thornbill | 2 |

In this example, the type of bird is qualitative data, so a line graph should not be used.

Kara's graph could look like Figure 13. Note that she has used colour to make it easier to compare the number of bird sightings.

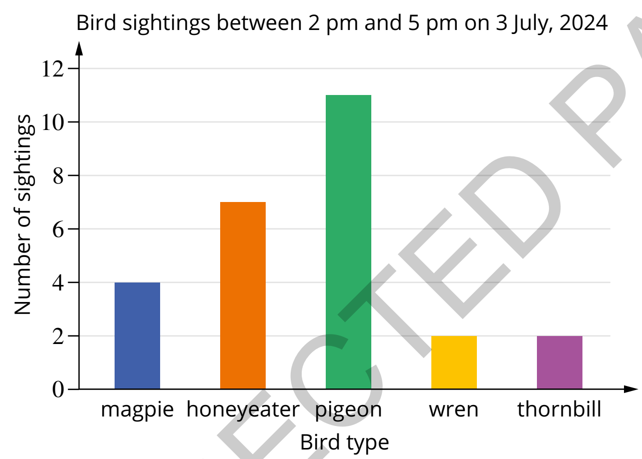



**FIGURE 13** Column graph showing the number of sightings of each different bird type

## 5.7 Creating a line graph using a spreadsheet

Data can be recorded in spreadsheet programs such as Microsoft Excel and Google Sheets. These can be used to create a range of types of graphs (often called charts in these programs). Here, you will learn how to create a line graph using Microsoft Excel, but other programs work in similar ways.

Spreadsheet programs take data from a table and present it as the type of graph (chart) that you select. You can then add the normal requirements for a line graph, such as axis titles and units for scales, a heading, and a trendline to show the pattern of the data. The spreadsheet program will automatically set the ranges on the scales based on the data selected.

| | A | B |
|---|---|---|
| 1 | Mass of object (kg) | Friction force (N) |
| 2 | 1.0 | 3.0 |
| 3 | 1.5 | 4.4 |
| 4 | 2.0 | 5.9 |
| 5 | 2.5 | 7.6 |
| 6 | 3.0 | 9.2 |
| 7 | 3.5 | 10.5 |
| 8 | 4.0 | 11.7 |
| 9 | | |

**FIGURE 14** The independent variable is the mass of the object and the dependent variable is friction force.

## Entering the data

Step 1: Open a new spreadsheet and enter data into the cells. The data for the independent variable should be placed in the first column. The spreadsheet program will automatically place this data on the *x*-axis. The data for the dependent variable should go in the second column. This will automatically be placed on the *y*-axis.

In the example used here the relationship between the mass of an object and the force of friction between the object and the bench surface is being investigated (Figure 14).

## Selecting the graph type

It is important to select the correct graph as otherwise the data might not be displayed correctly.

Step 2: Select the data for the graph by highlighting the two columns (Figure 15).

Step 3: Open the 'Insert' tab (Figure 15).

Step 4: In the Charts group, find the Scatter graphs. Choose the Scatter graph without connecting lines (Figure 15). This will generate a graph that a line can be added to.

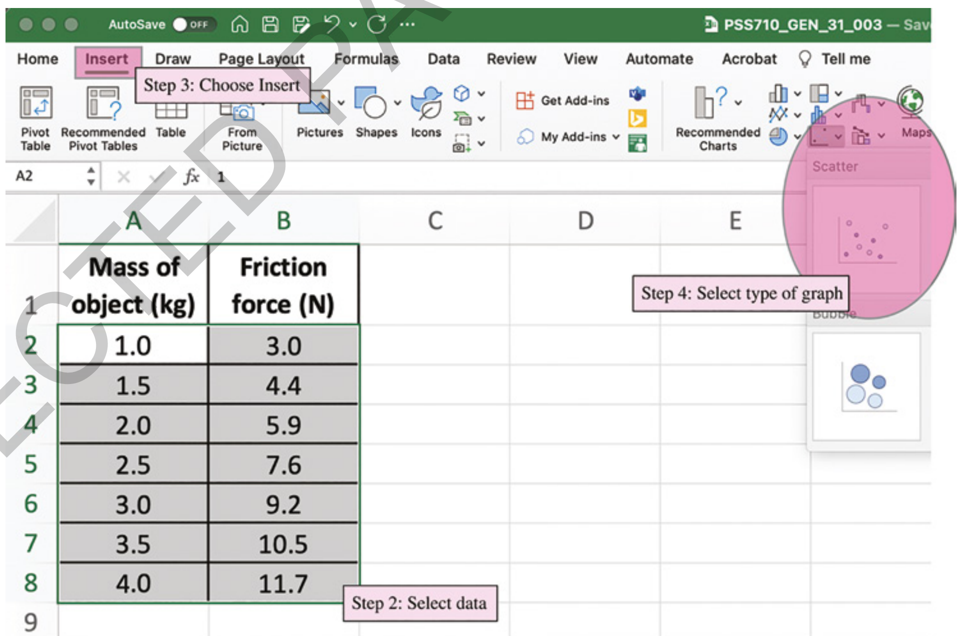



**FIGURE 15** Once the data has been selected, you can choose how to present the data

## Completing the graph

Step 5: With the line graph selected, you will be able to see the Chart Design tab. Click on it (Figure 16).

Step 6: Choose either 'Add Chart Element' or 'Quick Layout' to add components to the graph. You will need to add axis titles (including units) and a chart title (Figure 16).

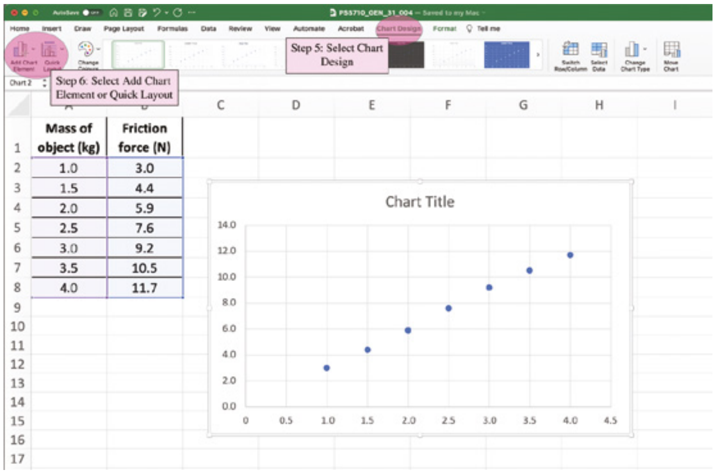



**FIGURE 16** You will need to add the correct labels to the graph after creating it

## Adding a trendline or joining the points

Step 7: If you want to add a **trendline**, click on 'Add Chart Element' (Figure 16) and choose 'Trendline'. If the data points are showing as a straight line, choose 'Linear' (Figure 17).

Double clicking on the trendline will open the 'Format Trendline' box. Here, you can change the 'Trendline Options' to find the one that best fits your data (Figure 17).

**KEY TERM**

**trendline** a line on a graph that shows a noticeable pattern or direction of movement of data

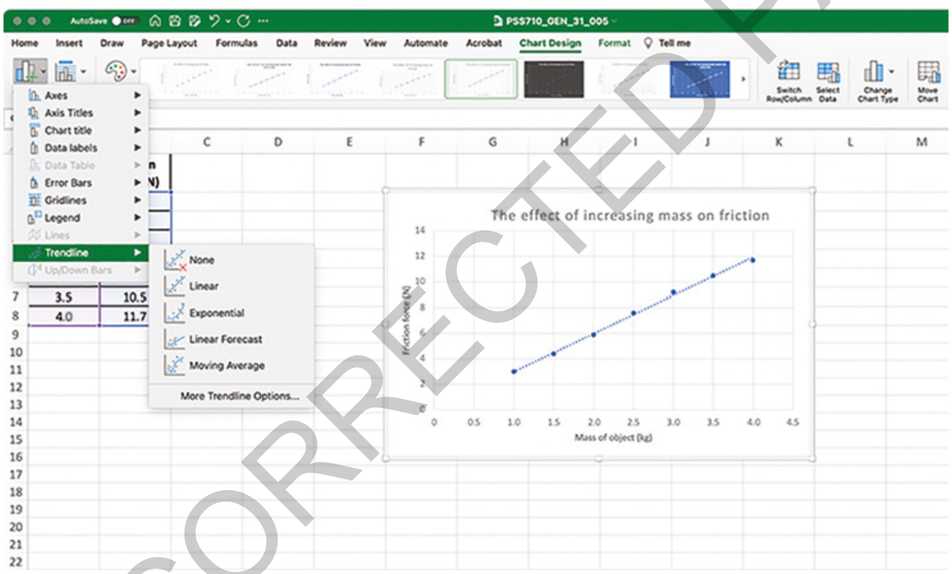



**FIGURE 17** How you show the pattern or trend in your data will depend on the data itself.

## Finalising the graph

Once the graph has been created, changes can be made to improve the clarity of the presentation of data and patterns shown by the data.

Step 8: To change the scale of an axis, click on that part of the graph. This will open the 'Format Axis' box. From here, choose 'Axis Options' (the column chart icon). Under 'Axis Options', you can set the minimum and maximum values for the scale. If you want to change the scale in the other axis as well, click on that axis scale and repeat this step.

Step 9: If you want to change any other components of the chart, you can do so by clicking on that component. In this way, you can edit font, colour, size and many other features.

The final graph is shown in Figure 18. In this version, the axis scales have been cropped to fit the data, the colour of the trendline has been changed, secondary gridlines have been added and the label for the *y*-axis has been aligned horizontally to improve ease of reading.

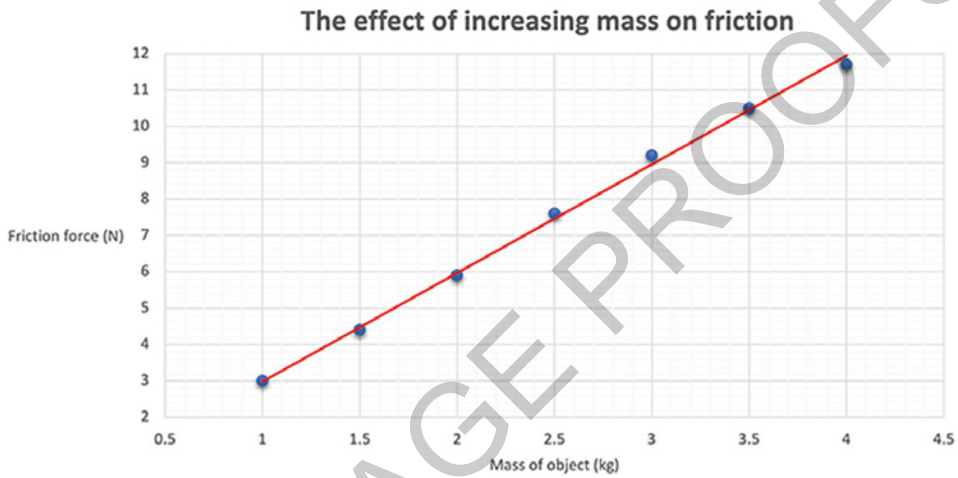



**FIGURE 18** Final graph after adjusting the chart elements.

# 6 Analysing data and information

## 6.1 Making inferences

In science, an **inference** is an educated guess based on observations and prior knowledge. It's a way of figuring out something that isn't obvious from direct observation.

***Example 1***

### Observation

An ice cube is left on the bench top. After a while, you notice that it's turned into a puddle of water.

**FIGURE 19** The observation is that the ice is melting. The inference is that the temperature in the room is higher than the melting point of the ice.

### Inference

The ice melted because the temperature in the room is warmer than melting point of the ice, causing it to change from solid to liquid (Figure 19). The knowledge used is that that ice melts when it gets warm.

***Example 2***

### Observation

You have two plants. You put one in a sunny spot and the other in the dark. After a week, the plant in the sun is healthy, while the one in the dark is wilting.

### Inference

Plants need sunlight to grow properly. Even though you didn't see the process of photosynthesis happening, you can infer from your observations that sunlight is important for plant health.

## 6.2 Evaluating investigations

The aim of most investigations is to produce **data** that does or does not support a hypothesis, often by testing a prediction. Scientists need to have confidence in the data from an investigation before using it as **evidence** to develop conclusions or make decisions. Scientific investigations are evaluated by the quality of the data that they produce.

### How do we evaluate data from investigations?

Data can be evaluated using the four main criteria shown in Table 18.

**TABLE 18** Criteria for evaluating data from investigations

| Criteria | Definition | Example question | Top tip | Notes |
|---|---|---|---|---|
| accuracy | How close a measured value is to its actual value. | Was the most accurate measuring cylinder available used to measure the volume of a liquid? | Use equipment that is best suited to what you are wanting to measure to get accurate measurements. | Accuracy and precision are more about individual measurements. |
| precision | How well multiple measurements of the same thing, made under similar conditions, give similar values | Was the electronic balance checked to see if it gave the same results when it was used to weigh the same object three times? | Take multiple measurements of the same thing to check that your measurements are precise. | |
| reliability | How well repeated experiments, observations or measurements produce similar results. | When the experiment to test the distance that measured the distance a toy driver travelled after a collision, were the results similar in each experiment? | When repeating an experiment, it is important to use the same method and conditions as the original experiment. | Reliability and validity are more about the overall results from the investigation. |
| validity | How well the method used in the investigation tests the question, hypothesis or prediction that it was designed to test. | When investigating a car travelling down a ramp from different heights, were all the controlled variables constant during the investigation (for example, the angle of the ramp) and was only the independent variable changed? | Only change the independent variable and keep all other variables constant. This allows you to measure the effect of the independent variable on the dependent variable (This is what the investigation aims to test). | |

## 6.3 Analysing a line graph

Creating a line graph and analysing its shape can help to show the relationship between two **variables**. Remember that the **independent variable** is placed on the *x*-axis while the **dependent variable** is placed on the *y*-axis.

## Analysing the gradient of a line graph

Use the following dot points to help analyse a line graph.

- If the **gradient** (slope) of the line graph shows an upward pattern, the dependent variable is increasing with the change in the independent variable.
- If there is a downward pattern to the gradient, the dependent variable is decreasing with the change in the independent variable.
- The steeper the gradient, the faster the increase or decrease.
- When the gradient is zero, i.e. the graph is horizontal, there is no change to the dependent variable during this time.

***Example***

Figure 20 shows the change of temperature of water over time as ice is heated.

- Between 20 and 40 seconds, the line is horizontal, so the temperature is not changing. It is remaining constant at 0°C.
- Between 50 and 80 seconds, there is a small positive (upward) gradient. This shows the temperature is increasing slowly.
- Between 90 and 120 seconds, there is a steep positive gradient. This shows the temperature is increasing quickly.
- Between 130 and 160 seconds, the line is once again horizontal. The temperature is remaining constant at 100°C.

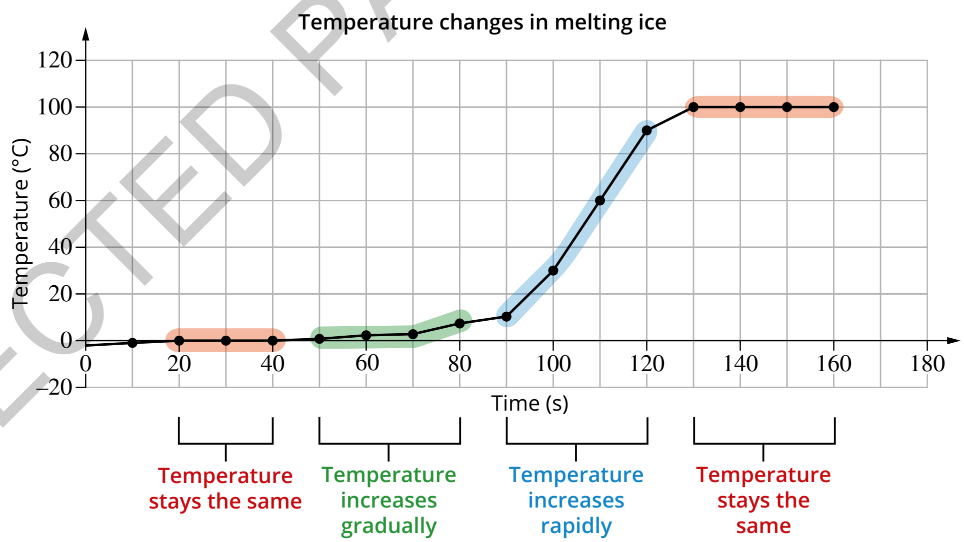



**FIGURE 20** Graph showing how the temperature of water changes over time as ice is heated

## 6.4 Outliers and anomalies

An **outlier** is a value that does not fit the pattern shown by the rest of the data set. Outliers are often caused by a mistake when measuring, recording or processing data. If there is an outlier in your data, include it in the graph, but ignore it when analysing the **trend** of the data.

***Example***

A student was investigating how heart rate changes after exercise. The results are shown in Table 19.

**TABLE 19** Changes in heart rate after exercise

| Time after finishing exercise (min) | Heart rate (beats/minute) |
|---|---|
| 0 | 122 |
| 1 | 108 |
| 2 | 98 |
| 3 | 81 |
| 4 | 87 |
| 5 | 84 |
| 6 | 82 |

This data is displayed as a line graph as shown in Figure 21.

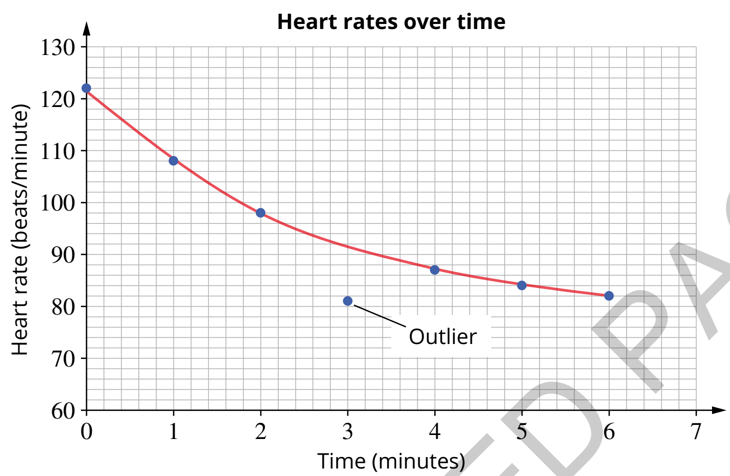



**FIGURE 21** Changes in heart rate for six minutes after exercise

The data point at 3 minutes clearly does not match the trend shown by the other values so it can be considered an outlier. Therefore, the trendline that is drawn does not include this data point.

## Managing outliers

Sometimes an outlier can be removed from the data, especially if there is only one outlier in a large data set. The trial can be repeated if time and resources are available.

# 6.5 Trends in data

A trend is a type of **pattern** in data. A **trend** is seen when the dependent variable changes in one direction (always increasing or always decreasing).

For example, the increasing height of a helium balloon shown here is a trend because the balloon will keep rising. You can see this trend in Figure 22.

# 6.6 Cause-and-effect relationships

When one variable is causing changes to another variable, this is a **cause-and-effect relationship**. Data from an experiment will often find a correlation where there is a link between two variables. However, **correlation** does not always mean that there is a cause-and-effect relationship (see Table 20).

**KEY TERMS**

**continuous data** numerical data that can have any value

**pattern** a repeated occurrence or sequence of data

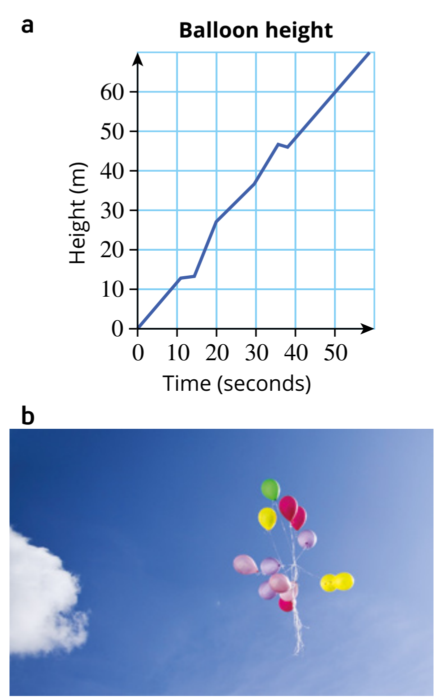



**FIGURE 22** The height of the balloon (a) is showing an upward trend on the graph (b)

**TABLE 20** Comparing cause and effect to correlation

| | Explanation | Example |
|---|---|---|
| Correlation | Sometimes there might be a link between two variables. This is called a correlation. However, correlation does not always mean that there is a cause-and-effect relationship. | The number of ice creams sold is often correlated with the number of sunburns in the same period. Of course, this does not mean that the ice creams cause sun burn. It's more likely that both ice cream sales and sunburns increase during a period of hot weather. |
| Cause-and-effect | When one variable is actually causing changes to the other variable, this is a cause-and-effect relationship. | Eating more sugary foods is related to the amount of tooth decay. This describes a cause-and-effect relationship because evidence shows that sugary food increases bacterial growth that leads to tooth decay. |

Proving that the change in the independent variable is actually causing the change in the dependent variable is more challenging than finding a correlation, and requires the application of scientific knowledge, understanding and the scientific method.

In order to establish whether a relationship is actually a cause-and-effect when undertaking an experiment, the following strategies can be used.

- Ensure that the question that is being investigated is a reasonable one and involves variables that can be measured.
- Develop a hypothesis based on scientific understanding.
- Identify all other variables that need to be kept the same (the **controlled variables**).
- Ensure that only the independent variable is changed, and all controlled variables are kept constant to reduce the risk that anything other than the independent variable is causing the dependent variable to change.
- Reduce sources of error in the experiment to ensure that any change in the dependent variable is not caused by error.
- Where needed, conduct a **control** (see below).

## Control

A control is an experimental test where the independent variable is not changed or not included, and the results compared to the results of the experiment where the independent variable is changed. This helps to ensure that the independent variable is the cause of the effect.

- All other experimental conditions are kept the same.
- The dependent variable is still monitored.
- If the dependent variable changes even when the independent variable remains the same, it is evidence that suggests that it is not the independent variable that is causing the change.
- In this case, it might not be a cause-and-effect relationship.

***Example***

A student is investigating whether there is a cause-and-effect relationship between the amount of fertiliser used and how tall a plant grows (Figure 23). Consider the thinking and working steps shown in Table 21.

**FIGURE 23** The height that seedlings grow could depend on the amount of fertiliser used

**TABLE 21** Thinking and working involved in testing a cause-and-effect relationship

| Thinking | Working |
|---|---|
| Identify the independent and dependent variable. | independent variable: amount of fertiliser<br>dependent variable: height of plant |
| Write a prediction based scientific knowledge. | If more fertiliser is used, the plant will grow taller (based on the knowledge that the fertiliser provides nutrition that is required for growth). |
| Identify all other variables that might affect the growth of plant (controlled variables). | • amount of water<br>• same size seedlings<br>• type of soil<br>• temperature<br>• amount of sunlight<br>• size and shape of plant pots |
| Carry out the investigation keeping controlled variables the same throughout. | The investigation was carried out and it was found that as more fertiliser was used, the plants did grow taller over a time period of five days. |
| Include a control. | A control is carried out where four plants were tested, all with no fertiliser added. |
| Analyse the data to confirm a correlation. | The plants in the control all grew a similar amount. From this we can infer that the amount of fertiliser is causing the difference in growth. |
| Evaluate the results to confirm a cause-and-effect relationship. | There was an increase in the growth of the plants as more fertiliser was used, showing a correlation. The fact that there was no significant difference to the growth when no fertiliser was used, suggests that it is the fertiliser that was causing the different amount of growth. |

Often further experiments, or improvements to the experimental method, may be required to provide more evidence to test a hypothesis about a cause-and-effect relationship.

## 6.7 Evaluating precision

**Precision** is how well multiple measurements of the same thing, made under similar conditions, give similar results. Data points are compared to estimate the level of precision. If the values are similar, the precision is likely high. The smaller the size of the measurements, the closer the results should be to each other.

***Example***

The mass of a bag of 100 one-dollar coins is measured five times, and the results are 912.0 g, 912.1 g, 911.9 g, 912.2 g and 912.1 g. The results are precise because they are very similar to one another.

### Evaluating precision

To measure the level of precision, calculate the **range** of the results. The range is the difference between the highest and the lowest measured value. A low range equals a high level of precision. The range should be compared to the size of the measurements when deciding if the range seems high or low.

In the example above, the range is calculated as follows:

$$\text{range} = 912.2 - 911.9 = 0.3 \text{ g}$$

0.3 g is very small compared to the size of the measurements (over 900 g) Therefore this is a very low range, and the data is very precise.

Note that precise data may not be accurate, as all the measurements may be incorrect.

## 6.8 Evaluating validity

**KEY TERMS**

**valid** the description of an investigation, experiment or method that measures what it set out to measure

**validity** how well an experiment and its results meet the requirements of a fair test

**Validity** is how well the investigation tests the question, hypothesis or prediction that it was designed to test.

In simple terms, a **valid** investigation is a fair investigation. For an experiment to be valid, any variables that might affect the result unintentionally, and thus make the experiment unfair, must be kept the same (**controlled variables**).

To evaluate the validity of the experiment, it is important to identify all the other variables that might affect the results and to ensure that they are kept constant, as well as to ensure that the method is designed to test the aim.

***Example***

An investigation aimed to test the effect of stopping smoking on blood pressure. To try to ensure the experiment is valid, all the blood pressure measurements were taken at the same time of day, after the same amount of rest and using the same method.

When evaluating this investigation, some other variables that could affect the result are identified, for example the kinds of food the person was eating and how much exercise they did. By controlling these variables, the experiment's validity can be improved.

The validity of experiments can also be evaluated by comparing results from other people or teams who have conducted the same experiment (Toolkit section 2.2)

## 6.9 Evaluating reliability

**KEY TERM**

**reliability** a measure of how well the results of an investigation can be consistently reproduced

**Reliability** is how well experiments, observations or measurements produce similar results when repeated. Reliability can be applied to results within an experiment, or to the overall findings of an investigation.

### Factors affecting reliability of results

A number of factors can affect the reliability of results, including the accuracy and precision of the measurements, and the method used for the experiment.

***Example***

The effect of temperature on the melting time of chocolate is being investigated. In this experiment, the factors affecting the reliability of the results include:

- using the same stopwatch for each trial and using it correctly
- using the same amount of chocolate for each trial
- using the same heating method, equipment set-up and temperature
- using the same observation method to determine whether the chocolate has all melted.

The time taken for 5 g of milk chocolate to melt at 60°C, 70°C and 80°C was measured four times. The results are shown in Table 22 below.

**TABLE 22** The time that 5 g of chocolate takes to melt at different temperatures

| Temperature (°C) | Time to melt (s) | | | |
|---|---|---|---|---|
| | Trial 1 | Trial 2 | Trial 3 | Trial 4 |
| 60 | 61 | 64 | 59 | 62 |
| 70 | 53 | 58 | 55 | 56 |
| 80 | 41 | 57 | 42 | 52 |

## Reliable results

Carrying out **repeat trials** as part of an experiment makes it easier to evaluate reliability. If data from each trial is similar each time, then the method is reliable. In this example the results for 60°C and 70°C are reliable, but the results at 80°C are not reliable as they vary considerably from trial to trial.

If a whole experiment is repeated (called a **replicate**) and the overall conclusion is the same, the experiment can be described as reliable. Note that reliability is not the same as **precision**. Precision is about just taking a single measurement that is not affected by other variables.

**KEY TERMS**

**repeat trial** repeat of an individual test or measurement within an experiment or investigation

**replicate** repeat of an entire experiment, often carried out by different people



# 7 Problem-solving

## 7.1 Approach to problem solving

There are many different types of problems we face in science. The following steps will guide you through the process of problem-solving.

| | |
|---|---|
| **Step 1: Understand the problem** | Start by reading the problem statement thoroughly. Make sure you understand what is being asked. Identify key information; highlight or note down important details, such as given data and what you need to find. |

↓

| | |
|---|---|
| **Step 2: Gather background knowledge** | Think about the scientific concepts related to the problem. This might include formulas, definitions, or principles you've learned. If you're unsure about certain concepts, take a moment to look them up in your textbook or online resources. |

↓

| | |
|---|---|
| **Step 3: Plan your approach** | Think of different ways to approach the problem. Evaluate these to decide on the best method to tackle the problem. Divide the problem into smaller, manageable parts if it seems complex. |

↓

| | |
|---|---|
| **Step 4: Execute your plan** | Use the relevant scientific understanding to work through the problem. If you're conducting an experiment, record your observations clearly. |

↓

| | |
|---|---|
| **Step 5: Review and reflect** | Go over your solution to ensure that it makes sense and that you haven't missed any steps. Compare your answer with expected results and/or seek feedback from others. |

↓

| | |
|---|---|
| **Step 6: Communicate your solution** | Present your solution in a clear and organized manner. Use correct scientific language and, if applicable, include diagrams or charts to illustrate your solution. |

↓

| | |
|---|---|
| **Step 7: Learn from the process** | If you made errors, think about what went wrong and how you can avoid them in the future. Ensure you understand why your solution works and how the scientific principles apply. |

Notes:

- Always be open to learning new things and asking questions if you're unsure.
- The more problems you solve, the better you'll get at understanding and applying scientific concepts.

# 8 Communicating

## 8.1 Scientific writing

Scientific writing is factual. This means that it provides information or facts that are known to be true. Factual writing does not use emotions or feelings when describing or explaining things.

***Example***

| | |
|---|---|
| Scientific writing | Sewage, which is wastewater from kitchens and bathrooms, can be recycled to make potable water suitable for human consumption. |
| Non-scientific writing | Sewage which is wastewater from kitchens and bathrooms can be recycled but it is disgusting, and I would not drink it. |

Scientific writing is also formal and does not use 'conversational language'.

***Example***

| | |
|---|---|
| Scientific writing | Children were told the risks of using the Bunsen burner and the importance of using exactly 5 cm of magnesium ribbon for the experiment. |
| Non-scientific writing | The kids were told to watch it using the Bunsen burner and to get about 5 cm of magnesium ribbon for the experiment. |

## 8.2 Scientific diagrams

Scientific diagrams are used to present written information in a simplified, more visual way. A good diagram will provide a lot of information in a concise way that is quick and easy to understand.

| | |
|---|---|
| General drawings and diagrams (Figures 24 and 25) | These are accurate representations reflecting shape, colour and proportions.<br>Labels, notes or a key can describe and identify features.<br>Arrows should be used to show direction of processes (as Figure 24).<br>Arrows should not be used to label parts and features. |
| Experiment report drawings (Figure 25) | These are two-dimensional (2D) with carefully ruled lines, in correct proportions.<br>Equipment is labelled and connected to the object with a pointer line.<br>Labels are written in clear print. |

Figures 24, 25 and 26 demonstrate features of scientific diagrams and drawings.

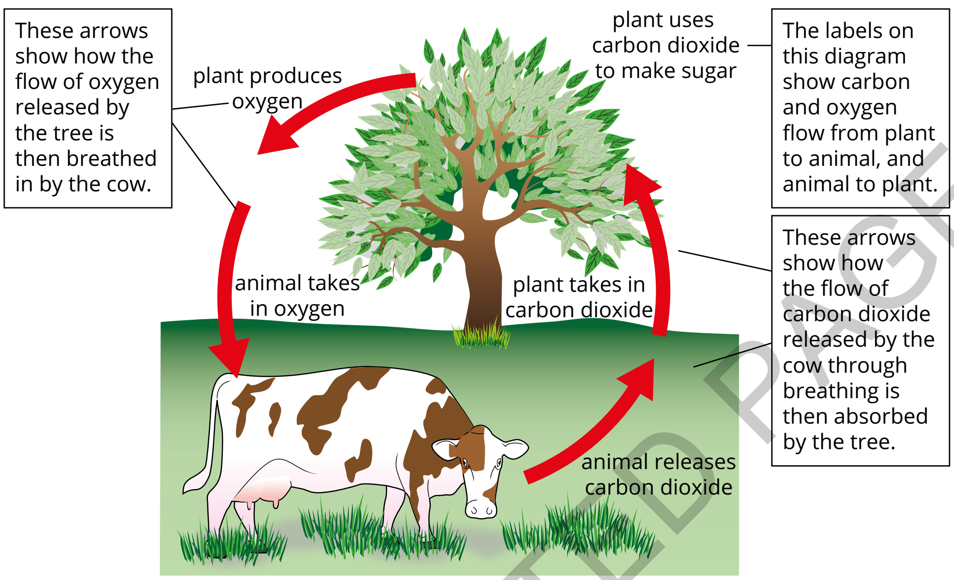



**FIGURE 24** Diagram demonstrating processes in the carbon cycle. It is simple and clearly labelled. The arrows identify the stages in the carbon cycle; different coloured arrows can be used to show movement of carbon dioxide and movement of oxygen.

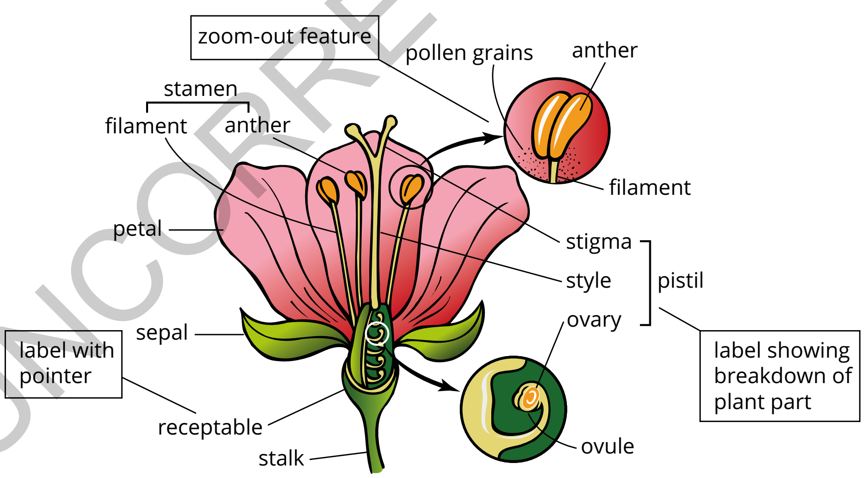



**FIGURE 25** An accurate representation of the parts of a flower. Pointers are used to link to a zoom-out feature. All features are clearly labelled.

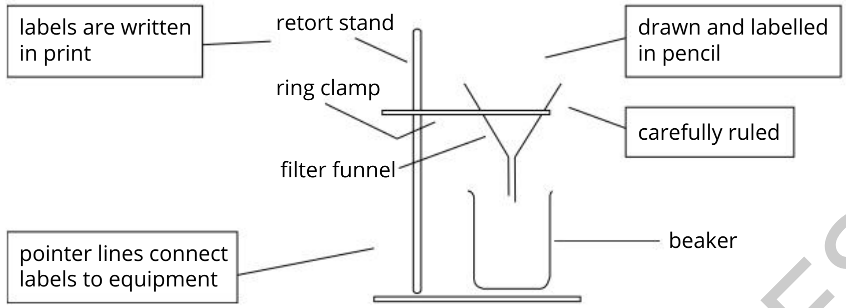


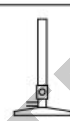

**FIGURE 26** 2D experiment report diagram of equipment set up.

## 8.3 Drawing scientific equipment

School laboratories contain some common equipment that is used for conducting experiments. This equipment includes instruments for measuring, tools, glassware and personal protective equipment.

See Table 23 for examples of how to draw some common science equipment.

**TABLE 23** Examples of scientific diagrams of laboratory equipment

| Equipment name | Illustration | Scientific diagram |
|---|---|---|
| beaker |  |  |
| Bunsen burner |  |  |
| conical flask |  |  |

| Equipment name | Illustration | Scientific diagram |
|---|---|---|
| filter funnel |  |  |
| test tube |  |  |
| tripod and gauze mat |  |  |

Note how each piece of equipment is drawn in simple, two-dimensional (2D) style as a 'cross-section' (splitting the equipment down the middle).

These individual pieces of equipment can be combined to create an image of an experimental set-up. The same style of diagram should be used to show the full set-up (Figure 27).

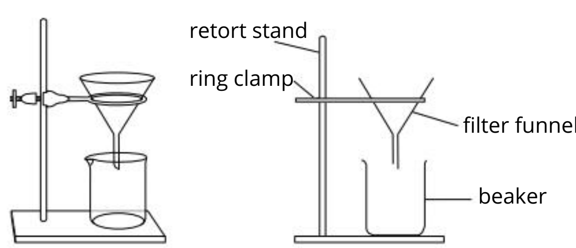



**FIGURE 27** Scientific diagram showing a filtration experiment that uses a retort stand, a filter funnel, a ring clamp and a beaker.

## 8.4 Writing a practical investigation report

The **scientific method** helps scientists report on what they did, what they discovered and how their findings contribute to a better understanding of the subject being investigated. The reports that you complete in class should aim to do the same thing.

A report should include all the key aspects of the investigation, such as include the aim, the hypothesis and/or prediction if required, a materials list, safety notes, the method used with a diagram, results, a discussion that often includes an evaluation of the method and the results obtained and then, finally, the conclusion.

See below for an example of an investigation report.

### *Growing cress from seed*

**Aim**

*To investigate the germination of cress seeds in closed and open environments*

**Prediction**

*If cress seeds are germinated in a container with a sealed lid, then there will be more leaves on the plants after seven days of growth than for seeds that are germinated in a container with no lid.*

**Safety**

*Sometimes fungus, such as mildew, can grow in seed-planting containers. Mould can destroy the seeds and seedlings. The fungal spores are a health hazard if they are breathed in. Wear a dust mask as soon as mould is seen and discard the experiment into a sealed bag for disposal in landfill.*

**Apparatus**

- *2 plastic containers of the same shape and size, one with a lid*
- *1 packet of cotton wool*
- *100 mL measuring cylinder*
- *water*
- *1 packet of cress seeds*
- *dust masks for each person (may not be needed)*

**Method**

1. *Cotton wool was placed into the bottom of two similar plastic containers.*
2. *Using a measuring cylinder, equal amounts of water were added to both containers so the cotton wool in both was equally damp.*
3. *30 cress seeds were spread evenly in each container.*

Reason for doing the investigation.

Prediction specific to the investigation, including what measurements of the dependent variable will be recorded.

Warn of any hazards, why each is a hazard and how you can reduce the risk.

List all materials, including amounts, and any equipment required.

Describe exactly how the experiment was done, with clear, numbered steps.

Record your results. Data can also be shown in graphs, sketches and photographs.

If you take several readings of the dependent variable, you can calculate the mean (average) and remove any outliers. This can help your results to be more reliable.

The discussion can address questions such as:

- is there some reason why the results are not as expected?
- were there any problems during the experiment?
- what did you do to overcome them?
- what improvements could be made to your method?
- do your results suggest areas for further investigation?

This can also include any required calculations, and suggested explanation(s) for the findings can be included.

The conclusion relates back to the aim, and, if there is a prediction, whether the results from the experiment support the prediction.

4 A lid was placed on one container, and then both containers were placed side-by-side on a well-lit windowsill.

5 The water lost by evaporation was replaced so that equal moisture content was maintained in both containers. The amounts of additional water added are shown in the results.

6 Each day, the number of leaves was counted on at least 10–20 plants to avoid errors due to sick or diseased plants.

**Results**

A sample table (only partly shown):

| Time (days) | Number of leaves on each plant | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Covered with lid | | | | | | No cover or lid | | | | | |
| | A | B | C | D | E | Average | A | B | C | D | E | Average |
| 1 | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | |

**Discussion**

*Other groups conducting the same experiment also had similar findings to ours, which indicates that the data is reliable. One plant stopped growing and died during the experiment. If we had used more plants, the effect of one plant failing to grow would have been reduced.*

**Conclusion**

*The results showed that, after 7 days, cress plants in the covered container had more leaves than plants in the uncovered tray. The numerical results were an average of 4.6 leaves per plant when covered, compared to 3.7 leaves per plant when uncovered.*

*Cress seeds grown in a sealed container had 24% more leaves than cress seeds grown in an open container. The results strongly supported the prediction because 24% increase in leaf development is a significant difference and all plants except one in the containers with the closed lids had more leaves on than the plants with no lids.*



## 8.5 Referencing secondary data

**Secondary data** is any information created by someone else, such as books, websites or government statistics. Part of ethical behaviour in science is to acknowledge (give credit for) the work of others by correctly referencing the source of all secondary data used. It is important to understand the data before using it, and to ensure the data isn't accidentally misrepresented or changed.

When using secondary data in an investigation or in research, remember to include the **reference list** of all sources of **secondary data** used (sometimes called a **bibliography**) at the end of your report. This should be formatted in a consistent style and include all necessary information for another person to access the source.

A common referencing style used in Australia and around the world is the American Psychological Association (APA) style. In your work, you might not need to use APA style, but your references must be consistently formatted so that they are easy to understand and use.

There are tools available to help generate your references, such as Microsoft Word's Citations and Bibliography tool (available in the References tab of MS Word).

The key information that should be included in a reference is:

- author or organisation name that produced the information
- date the information was published (use n.d. if not known)
- article title, journal and date of issue
- book title and publisher
- name of the website (if different from the organisation name)
- webpage
- weblink.

***Example***

Sascha was investigating ecosystems and used information from the Atlas of Living Australia to find out about bottlebrush plants (*Callistemon*) (Figure 28).

**FIGURE 28** Bottlebrush plants (*Callistemon*) are native to Australia and found in many regions.

Sascha's reference is shown here. It includes the name of the organisation and website (which is the same in this case), n.d. as the date is not known, the name of the page and the weblink.

*Atlas of Living Australia*. (n.d.). Callistemon R.Br. https://bie.ala.org.au/species/https://id.biodiversity.org.au/taxon/apni/51366602

If Sascha also used a book for her research, the reference would include the author/s, the year and place of publication and the name of the publishers as shown here.

Wrigley, J W, Fagg, M. (2009). *Australian Native Plants*. New Holland Publishers

## 8.6 Using artificial intelligence (AI) in science writing

Generative AI, or just AI, uses chatbots and digital assistants to access information in **large language models**. These can generate text based on inputs, often called prompts, and questions from the user. AI can also be used to generate images, video and audio.

**KEY TERM**

**large language model** a type of artificial intelligence (AI) that can process, understand and generate 'human-type' language

AI can be a good tool for obtaining ideas about investigations and generating questions. You must always follow guidance from your school about if, and how, you can use AI in work. Unauthorised use of AI must be avoided.

It is important to understand the limitations of AI. These include:

- not knowing the amount of plagiarism in the sources used by the AI to generate answers
- the possibility of errors in the content that the AI was trained on, which can lead to misinformation in the output
- the way the AI works will depend on the prompts and the outputs that it has been trained on. This can lead to output that 'sounds good' but it might be explained in language not suitable the audience
- random errors that can creep into the outputs of AI, such as providing the wrong explanation with a particular answer.

Therefore, any content generated from AI needs to be checked for the following:

- [ ] scientific accuracy
- [ ] suitability of language level for the intended audience
- [ ] correct use of scientific terms and language

It is also important to note that when using AI, if possible, it is best to go to the original source of the information, assess its credibility and also reference it correctly.

# 9 Data science

Data science is a field that combines different areas of study to learn from data. It uses tools such as statistics, scientific methods, **algorithms** and systems to find patterns and insights in data. By analysing data, data scientists can discover new information and make predictions about future trends.

Examples of data science include:

- weather prediction, where data scientists use data from satellites and weather stations to predict the weather by analysing patterns in temperature, wind and humidity
- movie recommendations, where streaming services use data science to suggest movies and shows you might like. They analyse your viewing history and compare it with other users to recommend content that matches your interests.

## 9.1 The data science cycle

If the analysis of data leads to new questions or if you need more information, you might need to go back and collect more data or look at your existing data in a new way to keep exploring a scientific question. The steps of this cycle (Figure 29) can be described as shown here.

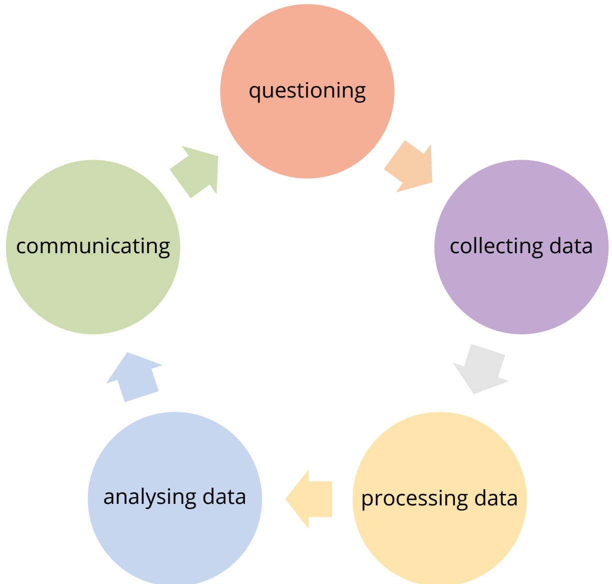



**FIGURE 29** The data science cycle. Results and answers can lead to more questions.

## Questioning

The journey starts with a question about something you're curious about or a problem you want to solve. Imagine asking, "How does the number of hours I spend playing video games affect my sleep?"

## Collecting data

For example, you might gather data by keeping a diary of your sleep patterns for a week. To extend this, you might use bigger sets of data, like information from a sleep study that shows how different activities affect sleep quality.

## Processing data

Once you have your data, you need to organise it so that it makes sense. This could mean putting your diary entries into a table or using a computer program to sort the information. Organising data helps you spot patterns or trends more easily.

## Analysing data

Now it's time to look closely at the data to find answers to your question. You might calculate the average number of hours you sleep each night. Creating graphs or charts can help you see what the data is telling you, making it easier to understand.

## Communicating

The last step is to share what you've learned. This means explaining your discoveries and suggesting what actions to take based on the data. For instance, if you find that playing video games late at night affects your sleep, you might suggest playing earlier in the day. Clear communication helps others understand and use your findings.

## 9.2 Data science and working scientifically

Aspects of data science aligned with working scientifically processes are:

- **Sources of data** (Toolkit Sections 4.3, 5.1 and 8.5)
- **Scientific questions** (Toolkit section 2.1)
- **Accuracy and reliability** (Toolkit sections 4.2 and 6.8)
- **Patterns and predictions** (Toolkit sections 2.3 and 6.5)

Further aspects of **Data science** are described below.

## 9.3 Scientific versus non-scientific

When scientists study natural phenomena they use a scientific approach, which involves asking questions, making observations, forming hypotheses, conducting experiments and analysing results to find answers. This method is systematic and relies on evidence. In contrast, non-scientific approaches might rely on opinions, beliefs or anecdotal evidence without systematic testing.

For example, using controlled experiments to understand why plants grow towards light is scientific because it involves testing and evidence. On the other hand, simply guessing that plants grow towards light because they "like" it, without any testing, is non-scientific.

## 9.4 Scientific models

**FIGURE 30** Three-dimensional model of a cell


**FIGURE 31** Weather patterns

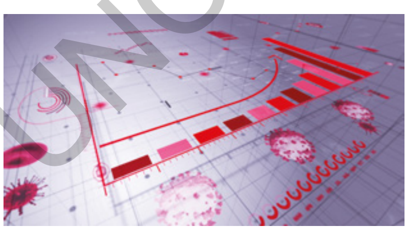


**FIGURE 32** Computer modelling of infection rates in a pandemic can help scientists make predictions and plan actions.

A scientific model is a simplified version of something in the real world, created using data and observations. Models help us understand complex things by breaking them down into more manageable parts.

Scientists use different types of models to study various phenomena. Mathematical models use equations to predict things like population growth, allowing scientists to forecast changes over time. Another example is a cell model (Figure 30), which helps us understand the parts of a cell, such as the nucleus, mitochondria, and cell membrane, by providing a visual representation of something that is too small to be seen in everyday life.

Similarly, analysing a model of a solar system can help us understand the movement of planets and predict events like eclipses.

Analysing a model involves looking at the data it presents to identify patterns, trends and make predictions. For example, by studying a graph showing temperature changes over time (Figure 31), we can predict future weather patterns and understand climate change.

These are benefits of models; however, because they are simplifications, they all have limitations in what they can represent. This does not make the model wrong, just simpler than the phenomenon that is representing.

### Computer-based models

Computer-based models allow scientists to simulate phenomena and easily change variables to see different outcomes. This is useful for testing scenarios that are difficult or impossible to recreate in real life. For example, using a computer model to simulate how a disease spreads can help predict outbreaks and plan interventions (Figure 32).

Changing variables in a climate model can show how different factors, like carbon emissions or deforestation, affect global warming and help develop strategies to mitigate climate change.

### Developing models

To develop a model, scientists gather data and observations from experiments, field studies and existing research. This information helps create accurate representations of real-world phenomena.

For instance, data collected from weather stations, such as temperature, humidity and wind speed, is used to develop climate models that predict weather patterns. Observations of animal behaviour, like migration patterns or feeding habits, can help create models of ecosystems, aiding in conservation efforts.

### Theories from models

Scientists use models to develop theories, which are well-supported explanations of how things work. By testing and refining models, they can create theories that help us understand the world better.

For example, the theory of evolution was developed using models of how species change over time, supported by fossil records and now, genetic data. The theory of plate tectonics was formed by studying models of the movement of Earth's crust, explaining phenomena like earthquakes and volcanic activity.

Physical models can be used to work out whether structures, such as the structures of molecules, are possible (Figure 33).

**FIGURE 33** James Watson and Francis Crick used a model to help discover the structure of DNA in 1953.

## 9.5 Digital footprint

Your digital footprint is the trail of data you leave behind when you use the internet, including websites you visit, social media interactions, and online purchases (Figure 34). It's important to be aware of this footprint and engage safely with digital systems to protect your privacy and reputation.

For example, posting photos online adds to your digital footprint, and sharing personal information on social media can affect your privacy and security. Being mindful of what you share, using strong passwords and understanding privacy settings helps protect your online identity and reduces the risk of cyber threats.

**FIGURE 34** Every time you use the internet you are increasing your digital footprint

# 10 Depth studies

A depth study is an opportunity to explore a topic in detail, allowing you to develop a deeper understanding of an area of science. This guide will help you plan, research and present your study effectively. Five examples of depth studies are provided at the end of this book.

## 10.1 Choosing a topic

You may be given a choice as to the areas of a depth study that you will undertake. If this is the case:

- choose a topic you are genuinely interested in. This will make the research process enjoyable and engaging
- ensure your topic is neither too broad nor too narrow. You should be able to explore it thoroughly within the time and resources available
- consider the availability of resources such as equipment and online materials. Ensure you have access to enough information to support your study.

## 10.2 Planning your study

**FIGURE 35** You can use a range of tools for planning your schedule

Use the following guidelines to help you plan your study.

- Clearly define what you want to achieve with your study. What questions are you trying to answer?
- Create a timeline with specific milestones. Allocate time for research, writing, and revision (Figure 35).
- Develop a structured outline to organise your thoughts and guide your research. This should include sections like introduction, main body, and conclusion.
- Ensure that any risk has been assessed and minimised for any practical activities. (Toolkit section 3.2)

## 10.3 Conducting research

Frame your research by following these points.

- Use a variety of sources and ensure your sources are credible and reliable (Toolkit section 4.3).
- Analyse and evaluate the information you gather. Consider different perspectives and question the validity of your sources (Toolkit section 6.8).
- Take detailed notes and keep track of where you found each piece of information. This will help you when citing sources later.

## 10.4 Writing a study report

The following ideas will ensure that your report captures the key aspects of your study.

- Start with a clear introduction that outlines your topic, objectives and the significance of your study (Toolkit section 8.1).
- Present your findings in a logical order. Use headings and subheadings to organise your content. Include evidence to support your points.
- Summarise your findings and reflect on what you have learned. Discuss the implications of your study and any unanswered questions.

## 10.5 Presenting a study

Consider the following ideas for communicating your findings.

- Write clearly and concisely. Use the correct scientific terms but avoid overly technical language and explain complex ideas in simple terms.
- Use charts, graphs and images to enhance your study and make it more engaging. (Toolkit section 8.2).
- You may also be asked to present your study to a class or a small group of students (Figure 36).
- Include a reference list including all the sources you used. Follow the required citation style (Toolkit section 8.5).

**FIGURE 36** If presenting to fellow students, ensure that the language and the approach is engaging and accessible.

## 10.6 Hints

Finally, following are some hints to improve your overall result.

- Seek feedback from teachers or peers. Use their suggestions to improve your study.
- Keep all your notes and materials organised. This will save time and reduce stress.
- Ask questions and explore different angles of your topic. Curiosity will lead to a more thorough and insightful study.
- Stick to your timeline and avoid last-minute rushes. Consistent work will lead to better results.

# Glossary

**accurate** measured value that is close to the true value

**accuracy** a measure of how close the measured value is to the true value of the quantity that is being measured

**algorithm** a process followed in calculations; used most commonly in computer software to process data

**bibliography** a list of all sources of information that were read in the research process or referred to in a report or presentation

**cause-and-effect relationship** a relationship between two variables in which changes to one variable is the reason behind changes to the other

**continuous data** numerical data that can have any value

**control** an experimental trial where the independent variable is not changed or not included

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

**correlation** a relationship or connection between two or more variables

**data** observations or measurements collected during an investigation

**data set** a set of results from an experiment

**data value** an individual result from an experiment

**dependent variable** the variable that is being measured in an experiment; it can vary as the independent variable changes

**discrete data** data that can only have separate or specific values

**error** the difference between a measured result and the true value

**evidence** data that can be used to support a conclusion or an answer to a question

**gradient** the slope of a line graph

**graduations** markings that indicate quantities on a scale

**increment** the value of the difference between graduations on a scale

**independent variable** the factor that is changed in an investigation to find out how it affects another factor

**inference** an informed guess or logical conclusion based on previous experiences, observations and knowledge

**investigable question** a question that can be answered by conducting a science investigation

**large language model** a type of artificial intelligence (AI) that can process, understand and generating 'human-type' language

**meniscus** the curved surface of a liquid, often seen in narrow containers

**outlier** a value that is much smaller or much larger than the other values in a set of data

**pattern** a repeated occurrence or sequence of data

**precision** how well multiple measurements of the same thing, made under similar conditions, give similar values

**qualitative data** observations that are descriptive only (no quantity or number)

**quantitative data** data produced by recording a quantity or amount of something

**random error** error that affects measurements in an unpredictable way; measured values can be higher or lower than the true value

**range** The numerical difference between the highest and the lowest measured value

**reference list** a list of all sources of information that were used in a science inquiry, also called a bibliography

**reliability** How well repeated experiments, observations or measurements produce similar results

**repeat trials** repeat of an individual test or measurement within an experiment or investigation

**replicate** repeat of an entire experiment; can be carried out by different people

**research question** a question that a study or research project aims to answer

**risk** the possibility of something harmful occurring

**scientific method** the process of establishing facts and improving understanding by carrying out experiments

**secondary data** data that someone has acquired from an experiment that they have not carried out themselves

**systematic error** an error that affects measurements in a predictable way: measured values will always be higher, or always lower than the true value

**trend** a pattern in data that changes in one direction

**trendline** a line on a graph that shows a noticeable pattern or direction of movement of data

**valid** a description of an experiment where all controlled variables are kept the same and the experiment can be considered a fair test

**validity** how well the investigation tests the question, hypothesis or prediction that it was designed to test

**variable** a factor or condition that can change during an experiment and can influence the experiment

**volume** the amount of space that a substance or object occupies

***x*-axis** the horizontal axis on a graph

***y*-axis** the vertical axis on a graph

TOPIC 1

# The nature and practice of science

Science is all about exploring the world around us, asking questions and finding answers through careful observation and experimentation. In this topic, we will dive into the fascinating world of scientific inquiry. You will learn how to record observations and analyse data from experiments, how to understand the difference between science and pseudoscience, and explore the various branches of science and how they are interconnected. We will also discuss the importance of working collaboratively in science and the difference between scientific theories and laws.

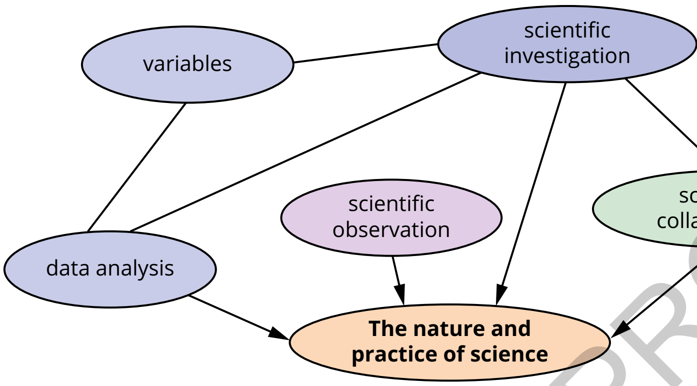
In this topic, you will learn about the importance of reliable data, the role of data in scientific research, and how scientists can make predictions, such as the effects of climate change. You will also explore different types of scientific research and how information technology has revolutionised the way scientists work. Additionally, you will learn about the role of variables in scientific investigations and how to use scientific tools to investigate changes over time. Finally, you will learn how to tabulate and graph data to identify trends and draw conclusions.

## Learning intentions

- ☐ To be able to record observations and analyse data from a scientific experiment **xx**
- ☐ To understand the difference between science and pseudoscience **xx**
- ☐ To understand the different branches of science and their interconnections **xx**
- ☐ To be able to describe and demonstrate the advantages of working collaboratively in science **xx**
- ☐ To understand the difference between scientific theories and laws **xx**
- ☐ To be able to investigate the work of scientists **xx**
- ☐ To be able to measure accurately using a variety of devices **xx**
- ☐ To understand the importance of reliable data in science **xx**
- ☐ To understand the role of data in scientific research **xx**
- ☐ To understand how scientists predict changes to the Earth's climate **xx**
- ☐ To understand different types of scientific research **xx**
- ☐ To understand how information technology has changed the approach to scientific research **xx**
- ☐ To be able to explore the role of variables in scientific investigations **xx**
- ☐ To be able to use scientific tools and instruments to investigate changes over time **xx**

# 1 The nature and practice of science

The key concepts that you will use in this topic:




The following prior knowledge questions will help to support your learning in the topic and can be attempted before the first lesson.

## Scientific observation

**1** Describe what is meant by scientific observation.

**2** Describe how you would use scientific observation to study plant growth.

## Scientific investigation

**3** What would make an investigation scientific?

**4** Give an example of a claim that is not based on science and explain why it is not considered scientific.

## Scientific collaboration

**5** What is scientific collaboration and why is it important?

## Variables

**6** What are variables in scientific investigations?

## Data analysis

**7** How might you analyse data from an experiment on the effect of sunlight on plant growth?

# 1.1 Observation and analysis

## Introduction

The purpose of science is to build knowledge and understanding of the world through observation, experimentation and analysis. Observations come in many forms. Accurate observation and careful recording of these is important so that the evidence (or data) from experiments can be trusted.

**FIGURE 1.1.1** Paediatrician taking temperature with a professional thermometer

In this practical investigation, you will make observations with and without measuring equipment to investigate how the correct equipment can make a difference to the quality of the data that you are recording.

**Learning intention**

To be able to record observations and analyse data from a scientific experiment

**Success criteria**

**SC 1:** I can record accurate observations.

**SC 2:** I can analyse data collected from a scientific experiment.

**SC 3:** I can explain how observations and analyses contribute to scientific knowledge.

## Background

This experiment involves both **qualitative** and **quantitative** observations.

**KEY TERMS**

**qualitative** a description of something that is not measurable by a quantity or number

**quantitative** a description of something that can be measured by a quantity or number, and will include units

## Aim

To compare qualitative with quantitative measurements and to consider how scientific data contributes to science knowledge.

GO TO ➤
For more information variables, see Toolkit section x.x

## Apparatus

- ice
- warm water
- 4 × 250 mL beakers or identical tubs
- thermometer or temperature sensor

## SAFETY NOTES

- Do not use water any hotter than 40°C
- Be careful when handling wet glassware.

## Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

## Method

1. Copy the table from the Results section into your workbook.
2. Fill four beakers and arrange them as shown in Figure 1.1.2.
3. Immerse (place) your left hand in the beaker containing cold water and your right hand in the beaker containing warm water. Leave your hands in the water for 30 seconds or so. (If the beakers are too small for your hands, you can use your fingers)
4. Remove your hands and put each hand into a beaker containing tap water. Leave them there for 30 seconds or so. Does the water feel the same to both hands, or does one feel hotter?
5. In your table, rate what the temperature of the water in each beaker felt like, for example hot, warm, cool or cold.
6. Use the thermometer to measure the actual water temperature of each beaker. Record the temperatures in your table.

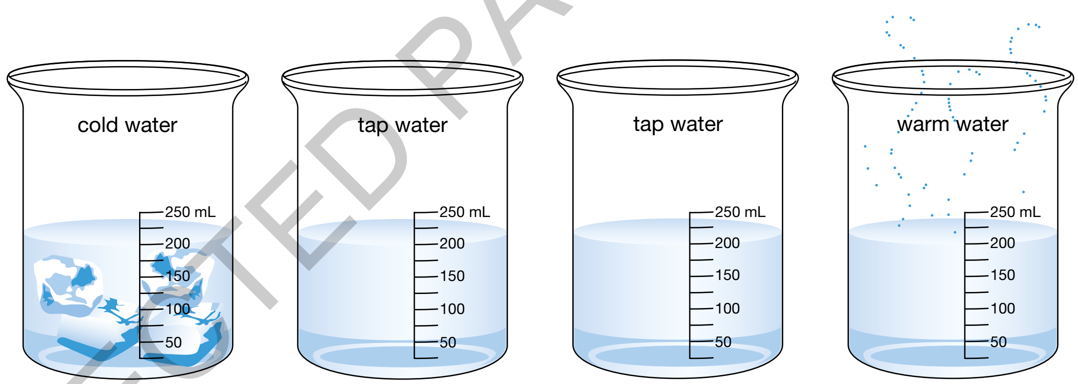



**FIGURE 1.1.2**

## Results

Record your observations in your results table. Give your table a title.

| Beaker | What it felt like (very hot, hot, temperature cool, cold) | Actual temperature (°C) |
|---|---|---|
| water–ice mixture | | |
| tap water 1 | | |
| tap water 2 | | |
| warm water | | |

## Discussion

1 What quantitative observations did you make in this activity?
2 Identify your qualitative observations.
3 How well did your qualitative observations agree with your quantitative ones?

**HINT**

Consider medical or environmental situations.

## Conclusion

1 Suggest any reasons why the qualitative results ('how the water felt') varied from the results measured using the thermometer.
2 Describe three examples from everyday life where it is important to be able to measure temperature accurately.
3 For one of these examples, explain a potential risk (danger) if the wrong temperature is recorded.
4 Suggest a situation where measuring the temperature might contribute to improving scientific understanding.

# 1.2 Science versus pseudoscience

**Learning intention**

To understand the difference between science and pseudoscience

**Success criteria**

**SC 1:** I can compare science and pseudoscience.

**SC 2:** I can evaluate claims to determine if they are scientific or pseudoscientific.

## Lesson overview

In our everyday lives, we often come across various claims about health, technology and the natural world. Some of these claims are based on scientific evidence, while others are not. For example, you might have heard about the benefits of a new diet or a miracle cure for a disease.

It is important to know how to distinguish between science and pseudoscience to make informed decisions. In this lesson, you will learn how to compare science and pseudoscience and evaluate claims to determine if they are scientific or pseudoscientific.

**SC 1** I can compare science and pseudoscience

## Science versus pseudoscience

Science is a systematic approach to understanding the natural world through observation, experimentation, and evidence-based reasoning. It relies on the scientific method, which involves making observations, forming **predictions** conducting experiments, and drawing conclusions based on evidence. For example, scientists studying climate change collect data on temperature, greenhouse gas levels, and other factors to understand how human activities impact the Earth's climate.

**KEY TERM**

**prediction** a statement that suggests what will happen in an experiment

Pseudoscience, on the other hand, is a collection of beliefs or practices that claim to be scientific but lack the rigorous methodology and evidence that characterize true science. Pseudoscientific claims often rely on **anecdotal evidence** that has not been reviewed by scientists and is not testable or falsifiable. An example of pseudoscience is astrology, which claims that the positions of celestial bodies influence human behaviour and destiny but lacks evidence and scientific support.

**FIGURE 1.2.1** Just like astrology, fortune telling, such as with tarot cards, is also pseudoscience.

Pseudoscientific claims, such as those presented from tarot cards (Figure 1.2.1), often rely on anecdotal evidence and are not testable.

To compare science and pseudoscience, consider the following criteria.

**KEY TERMS**

**anecdotal evidence** based on personal accounts rather than facts or research

**empirical evidence** based on observation or experience rather than theory or pure logic

## Evidence and testing

Scientific claims are supported by **empirical evidence** and can be tested through experiments.

## Peer review

Scientific research undergoes peer review, where other experts in the field evaluate the validity of the findings. Pseudoscientific claims typically lack peer review and are not scrutinized by the scientific community.

## Falsifiability

Scientific predictions can be proven false through experimentation. Pseudoscientific claims are often vague and cannot be disproven.

## Reproducibility

Scientific experiments can be repeated by other researchers to verify the results. Pseudoscientific claims are often not reproducible.

### SC 1 CHECK YOUR UNDERSTANDING

Compare the criteria of evidence and testing in science and pseudoscience. How do they differ in their approach to supporting claims?

### Scifile

**The placebo effect**

Did you know that the placebo effect is a real phenomenon where people experience improvements in their condition simply because they believe they are receiving treatment? Some studies have found that patients receiving a sugar pill with no active ingredients often report feeling better.

**SC 1** I can evaluate claims to determine if they are scientific or pseudoscientific

Evaluating claims involves critically assessing the evidence, credibility (trustworthiness) and **methodology** of the sources.

Here are some steps to help you determine if a claim is scientific or pseudoscientific:

1 Examine the evidence: Look for empirical evidence that supports the claim. Scientific claims are based on data collected through observation and experimentation. Pseudoscientific claims often rely on anecdotal evidence or testimonials (people's personal accounts).

2 Check the source: Consider the credibility of the source making the claim. Scientific claims are typically published in peer-reviewed journals and supported by reputable institutions. Pseudoscientific claims may come from non-expert sources or lack credible backing.

3 Evaluate the methodology: Assess the methods used to gather and analyse the data. Scientific research follows a systematic and transparent methodology, such as the scientific method (Figure 1.2.2). Pseudoscientific claims may use flawed or methods that can't be replicated.

**KEY TERM**

**methodology** the way that research has been carried out, including the way that data was collected and analysed

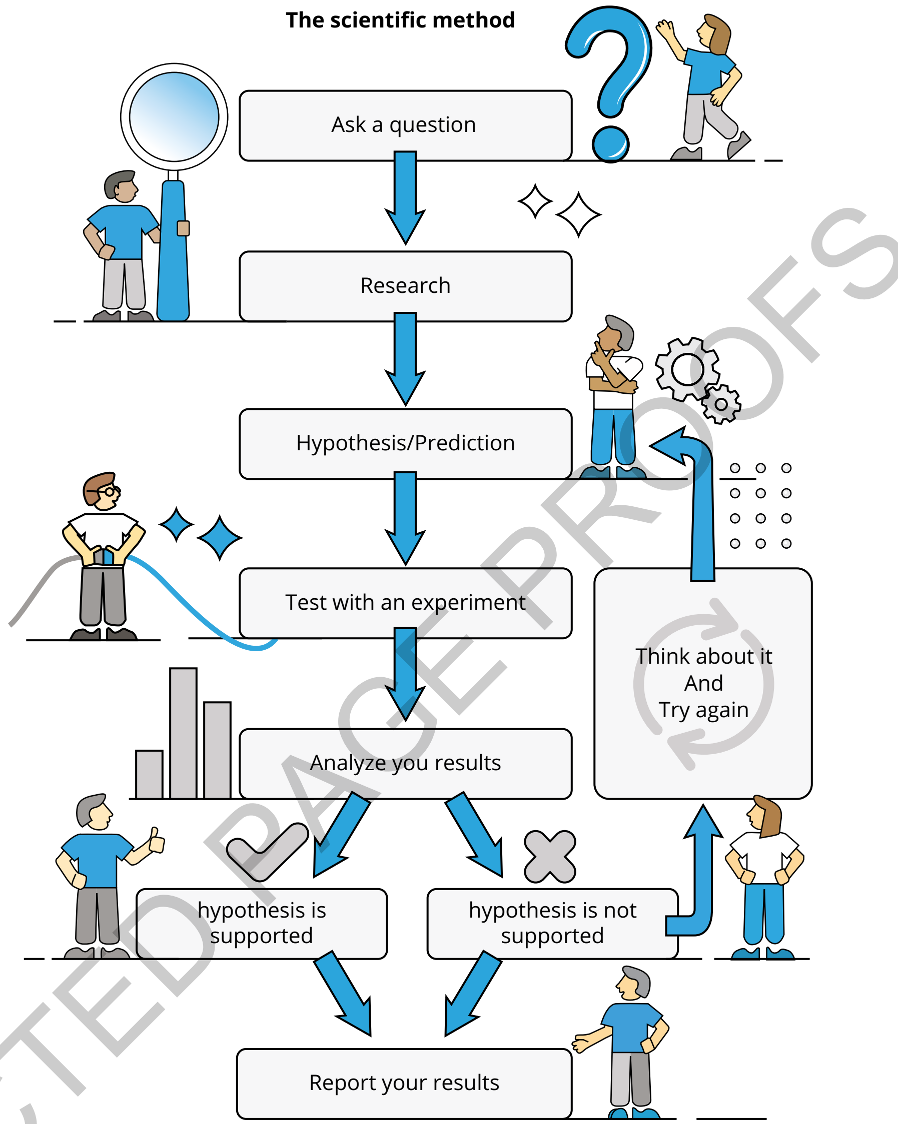



**FIGURE 1.2.2** The scientific method follows a rigorous approach to establish facts through investigation.

**4** Look for peer review: Determine if the claim has undergone **peer review**, where scientific claims are evaluated by other experts in the field before being accepted. Pseudoscientific claims often lack peer review.

**5** Assess falsifiability: Check if the claim can be tested and potentially disproven. Scientific predictions are **falsifiable**, meaning they can be proven false through experimentation. Pseudoscientific claims are often vague and cannot be tested.

## SC 2 CHECK YOUR UNDERSTANDING

Evaluate the following claim: “Wearing a specific type of bracelet can improve your energy levels.”

What steps would you take to determine if this claim is scientific or pseudoscientific?

## SCIENCE IN CONTEXT

### Evaluating health claims

On the internet we often see health claims, from miracle diets to new supplements. It is important to evaluate these claims critically to avoid falling for pseudoscience. For example, some companies claim that their supplements can cure diseases without providing any scientific evidence.

In Australia, the Therapeutic Goods Administration (TGA) regulates therapeutic goods, including medicines and supplements, like those shown in Figure 1.2.3, to ensure they are safe and effective. When evaluating health claims, look for evidence from clinical trials, check if the product is approved by regulatory bodies like the TGA, and consult reputable sources such as medical journals. For more information on evaluating health claims, visit the TGA website.

**FIGURE 1.2.3** In Australia, the TGA ensures that any claims made on supplements and medicines are based on evidence.



## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 Recall the key difference between science and pseudoscience.

2 Explain how peer review contributes to the validity of scientific research.

3 Describe the steps you would take to evaluate a claim about a new health supplement.

4 Explain why reproducibility is important in scientific research.

5 Apply the criteria for evaluating claims to determine if the following statement is scientific or pseudoscientific: 'Drinking a specific type of tea can cure cancer.'

6 Compare the methods used in scientific research with those used in pseudoscientific practices.

# 1.3 Types of science

**Learning intention**

To understand the different branches of science and their interconnections

**Success criteria**

**SC 1:** I can describe the characteristics of a range of branches of sciences.

**SC 2:** I can explain how the branches of science are connected.

**SC 3:** I can explain how science is connected to other areas of study.

**FIGURE 1.3.1** Biologists focus on the study of living things.

**FIGURE 1.3.2** Geologists can learn about our Earth by studying rocks and minerals.

## Lesson overview

Science is a vast field that includes many different branches. For example, you might be familiar with biology, which studies living organisms, or chemistry, which explores the properties of substances. Understanding the different branches of science and how they are interconnected helps us appreciate the complexity of the natural world. In this lesson, you will learn about the characteristics of various branches of science, how they are connected, and how science relates to other areas of study.

**SC 1** I can describe the characteristics of a range of branches of sciences

## Understanding the branches of science

Science is divided into several branches, each focusing on a specific area of study. Following are some of the main branches.

### Biology

Biology is the study of living organisms, including their structure, function, growth and evolution. Biologists study everything from microscopic bacteria to large animals and plants (Figure 1.3.1). For example, a biologist might study how a particular species of bird adapts to its environment.

### Chemistry

Chemistry is the study of the properties, composition and behaviour of substances. Chemists investigate how substances interact with each other and the changes they undergo during chemical reactions. For example, a chemist might study how different chemicals react to form new substances.

### Physics

Physics is the study of matter, energy and the fundamental forces of nature. Physicists explore concepts such as motion, force and energy. For example, a physicist might study how gravity affects the motion of planets.

### Earth science

Earth science is the study of Earth and its processes, including geology, meteorology and oceanography. Earth scientists investigate the structure and composition of Earth, weather patterns and ocean currents. For example, a geologist might study the formation of minerals (Figure 1.3.2).

## Astronomy

Astronomy is the study of celestial objects and phenomena beyond Earth's atmosphere. Astronomers study different parts of the universe, including stars, planets and galaxies. For example, an astronomer might study the properties and composition of distant stars (Figure 1.3.3).

**FIGURE 1.3.3** The Hubble telescope sends information back to astronomers from space.

**SC 1 CHECK YOUR UNDERSTANDING**

Describe the main focus of study for biologists and chemists.

**SC 2** I can explain how the branches of science are connected

## Interconnections between branches of science

The branches of science are often interconnected, with scientists specialising in a blend of two fields. Here are some examples of how different branches of science are connected:

### Biology and chemistry

The study of biochemistry explores the chemical processes within living organisms. For example, biochemists study how chemicals called enzymes help chemical reactions that take place in cells. This research helps us understand how cells function and how diseases develop.

### Astronomy and physics

The study of astrophysics applies the principles of physics and astronomy to understand celestial objects and phenomena. For example, astrophysicists study the behaviour of stars, galaxies and black holes using concepts such as gravity and electromagnetism.

### Chemistry and Earth science

The study of geochemistry explores the chemical composition of Earth and its processes. For example, geochemists study the distribution of elements in rocks and minerals to understand Earth's history and the formation of natural resources (Figure 1.3.4).

**FIGURE 1.3.4** Ancient rocks in the Pilbara, Western Australia. Analysing the chemical composition of the rocks helps scientists to understand when some of the earliest life appeared: a combination of geology, chemistry and biology.

Research groups that include scientists from various branches of science can tackle complex problems more effectively. Each scientist brings their expertise and perspective, leading to a more comprehensive understanding of the issue. For example, a research group studying climate change might include biologists, chemists, physicists and Earth scientists. Biologists can study the impact on ecosystems, chemists can analyse atmospheric changes, physicists can model climate patterns, and Earth scientists can examine geological records. This interdisciplinary approach leads to more robust and well-rounded research findings.

**SC 2 CHECK YOUR UNDERSTANDING**

Explain how the study of biochemistry connects biology and chemistry.

**SC 3** I can explain how science is connected to other areas of study

Science is connected to many other areas of study, and these connections help us solve complex problems and make new discoveries.

## Science and mathematics

Mathematics is essential for scientific research, as it provides the tools for analysing data and creating models. For example, physicists use mathematical equations to describe the motion of objects and predict their behaviour. Similarly, biologists use statistics to analyse the results of experiments and draw conclusions. For example, evolutionary biologists analyse DNA and genes to work out how species and population are related, and how they have changed over time.

## Science and technology

Advances in science often lead to new technologies, which in turn drive further scientific research. For example, the development of the microscope allowed scientists to study cells and microorganisms, leading to discoveries in biology and medicine. Similarly, advances in computer technology have revolutionised fields such as climate science.

**FIGURE 1.3.5** John Bradfield, who received the first doctorate in engineering from the University of Sydney, helped oversee the planning and construction of the Sydney Harbour Bridge.

## Science and engineering

Engineering applies scientific principles to design and build structures, machines, and systems. For example, civil engineers use principles of physics and materials science to design bridges and buildings (Figure 1.3.5). Similarly, biomedical engineers use knowledge of biology and chemistry to develop medical devices and treatments.

**SC 3 CHECK YOUR UNDERSTANDING**

Explain how advances in computer technology have influenced scientific research.

## SCIENCE IN CONTEXT

### The role of biomedical engineers in healthcare

Biomedical engineers play a crucial role in healthcare by applying scientific principles to develop medical devices and treatments. One example of biomedical engineering is the development of prosthetic limbs. Biomedical engineers use knowledge of biology, materials science and mechanics to design prosthetics that mimic the function of natural limbs. These devices help individuals who have lost limbs to regain mobility and independence.

Another example is the development of medical imaging technologies, such as MRI and CT scans. Biomedical engineers design and improve these technologies to provide detailed images of parts of the body that are otherwise hard to study, such as the brain (Figure 1.3.6), helping doctors diagnose and treat diseases more effectively.

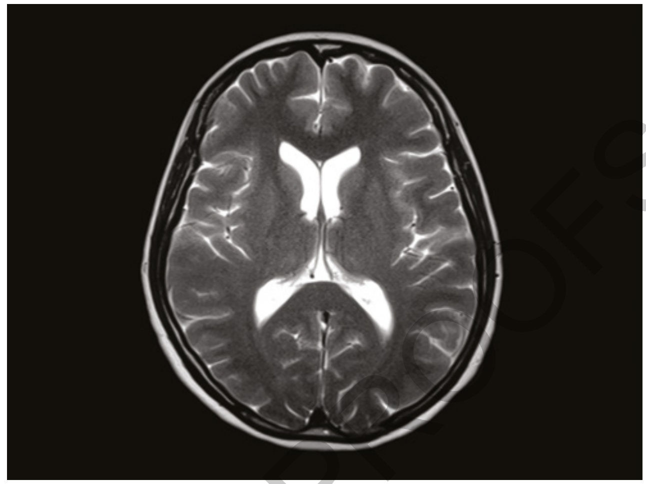


**FIGURE 1.3.6** MRI scans generate images of bones and internal organs, allowing increased accuracy in diagnosis.

For more information on biomedical engineering, visit the Engineers Australia website.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1. List five main branches of science.
2. Describe the focus of study for physicists.
3. Explain how the study of geophysics connects physics and earth science.
4. Describe how biomedical engineers use scientific principles in their work.
5. Explain how the development of the microscope has influenced biological research.
6. Compare the roles of chemists and geochemists in scientific research. How do their areas of study overlap and differ?

# 1.4 Working collaboratively

**Learning intention**

To be able to describe and demonstrate the advantages of working collaboratively in science

**Success criteria**

**SC 1:** I can collaborate effectively in a group scientific investigation.

**SC 2:** I can explain the benefits of collaborative scientific research.

## Introduction

Progress in science is built on collaboration between scientists. This can be working together on the same experiments and projects or working separately and sharing results. When problems need to be solved, teams are often more effective than one person working on their own (Figure 1.4.1).

**FIGURE 1.4.1** A team of medical researchers comparing ideas

In this practical investigation you work as a team to problem solve how to best measure some quantities. You will then evaluate how well you worked as a group and suggest the advantages of scientists working in a collaborative way.

## Background

The situations here have been selected as they provide a challenge to work through to find a solution. Before you start trying to take measurements, you should think about what approach you will take. For example:

- Do you want individuals to think about each situation first?
- Do you want to work as a whole group right from the start?
- Should you allocate specific jobs for each member of the team?
- Do you need a team leader?
- What information do you need to obtain to help you with the tasks?

## Aim

To work as a team to develop ways of taking measurements.

## Apparatus

- small box of Smarties® or M&Ms®
- stack of A4 paper (recycled is okay)
- ruler
- watch or timer

### Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

## Method

1 Design an experiment that will measure the following:
   a the thickness of a single sheet of A4 paper with a normal ruler
   b the time it takes for your heart to do one heartbeat
   c the mass of a Smartie or M&M without using any weighing devices.
2 Work as a team to plan how to take the measurements above.
3 Before you start any practical work, as a group, check that you agree on your approach.
4 Show your teacher your methods. If they approve, then collect all the required apparatus and start work.

## Results

Record every measurement you take and every calculation you made for each of the three tasks.

## Discussion

1 Assess how well your procedure worked for measuring each of the items.
2 Compare your group's results with other groups in the class and comment on whether the results are similar.
3 Suggest reasons for any differences in results between groups.

## Conclusion

1 Explain how working as a team helped you to solve the measuring problems.
2 Describe any problems that you had working as a team, and how you tried to solve these problems as a group.
3 Suggest two advantages of scientists working together when conducting research or problem-solving. If you are able to, you can conduct some research and describe a specific example to support your ideas.

# 1.5 Science theories and laws

**Learning intention**

To understand the difference between scientific theories and laws

**Success criteria**

**SC 1:** I can distinguish between scientific theories and laws.

**SC 2:** I can explain how scientific theories and laws are developed through repeated experiments and observations.

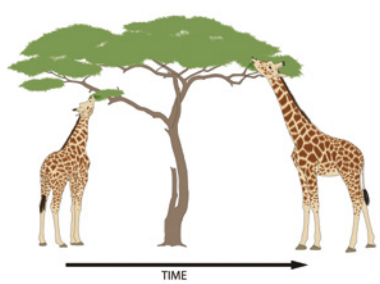



**FIGURE 1.5.1** Giraffes have evolved to be adapted to their habitats, with long necks.

## Lesson overview

In science, we often hear about theories and laws. For example, you might have heard of the theory of evolution or Newton's laws of motion. These concepts help scientists explain and predict natural phenomena. Knowing the difference between scientific theories and laws is very important for understanding how science works.

In this lesson, you will learn to distinguish between scientific theories and laws and understand how they are developed through repeated experiments and observations.

**SC 1** I can distinguish between scientific theories and laws

## Understanding scientific theories and laws

A scientific theory is an explanation of an aspect of the natural world that is based on evidence. Theories are developed through research and experimentation and are supported by a wide range of scientific observations. For example, the theory of evolution explains how species change over time through the process of natural selection (Figure 1.5.1).

In contrast, a scientific law is a statement that describes a consistent relationship observed in nature. Laws are often expressed in mathematical terms and describe how things happen, but do not explain why they happen. For example, Newton's laws of motion describe the relationship between the motion of an object and the forces acting on. This law does not explain why the forces exist. Scientific laws can be used to predict the behaviour of objects under various conditions. Key differences between theories and laws are shown in Table 1.5.1.

**TABLE 1.5.1** Comparison between theories and laws

| | Theories | Laws |
|---|---|---|
| Purpose | Why phenomena occur | How phenomena occur |
| Form | Often complex, involving multiple concepts | Usually simple, can be expressed mathematically |
| Development | Developed through extensive research and experimentation | Based on consistent and universal observations |

**SC 1 CHECK YOUR UNDERSTANDING**

Distinguish between a scientific theory and a scientific law by describing their purposes.

**SC 2** I can explain how scientific theories and laws are developed through repeated experiments and observations

**Scifile**

**The Big Bang theory**

The Big Bang theory is a scientific theory that explains the origin of the universe. It suggests that the universe began as a single point around 13.8 billion years ago and has been expanding ever since. This theory is supported by evidence such as the cosmic microwave background radiation and the movement of galaxies.

## Development of scientific theories and laws

Scientific theories and laws are developed through a rigorous process of experimentation and observation. Scientists make predictions based on their initial observations and then conduct experiments to test these predictions. The results of these experiments are analysed and used to refine the theory or law.

### Example: The development of the theory of gravity

The theory of gravity has evolved over time through repeated experiments and observations. In the 17th century, Sir Isaac Newton formulated the law of universal gravitation, which enables us to mathematically calculate the gravitational force between two objects. Newton's law was based on his observations of the motion of planets (Figure 1.5.2) and falling objects.

In the 20th century, Albert Einstein developed the theory of general relativity, which provided a more comprehensive explanation of gravity. Einstein's theory proposed that gravity is the result of the curvature of spacetime caused by the presence of mass. This theory was supported by observations of the fact that light bends around massive objects, such as stars.

**FIGURE 1.5.2** Gravity holds the planets of the Solar System in orbit around the Sun.

### Example: The development of the law of conservation of mass

The law of conservation of mass states that mass is neither created nor destroyed in a chemical reaction. This law was developed through repeated experiments by scientists such as Antoine Lavoisier in the 18th century. Lavoisier conducted experiments in which he carefully measured the mass of substances before and after chemical reactions. He found that the total mass remained constant, leading to the formulation of the law of conservation of mass.

### Repeated experiments and observations

Repeated experiments and observations are essential for developing scientific theories and laws. They help ensure that the findings are reliable and can be replicated by other scientists. This process of verification and refinement is crucial for building a robust body of scientific knowledge.

**SC 2 CHECK YOUR UNDERSTANDING**

Explain why repeated experiments and observations are important for developing scientific laws.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1. Define a scientific law.
2. Explain the purpose of a scientific theory.
3. Describe the process of developing a scientific theory.
4. Apply your understanding of the development of scientific theories to explain how the theory of general relativity was developed.
5. Compare and contrast scientific theories and laws. How do their purposes and forms differ?

# 1.6 An example of the work of scientists

**Learning intention**

To be able to investigate the work of scientists

**Success criteria**

**SC 1:** I can describe the Working scientifically processes.

**SC 2:** I can describe how Working scientifically processes can be applied to scientific research.

**SC 3:** I can describe an example of collaborative scientific research.

## Lesson overview

Have you ever wondered how scientists work together to solve complex problems? Think about the development of vaccines, like the COVID-19 vaccine. Scientists from around the world collaborated to create and test these vaccines quickly and safely.

In this lesson, you will investigate the work of scientists, focusing on how they use the Working scientifically processes to conduct research and collaborate on scientific projects (Figure 1.6.1).

**FIGURE 1.6.1** Scientists collaborate to solve complex problems.

## Background

Scientists use Working scientifically processes to investigate questions and solve problems. These processes include:

- asking questions and making predictions
- conducting experiments
- recording observations
- processing data
- analysing data
- drawing conclusions and
- communicating findings.

Collaboration is also a key part of scientific research, as scientists often work together to share ideas, resources, and expertise.

## Aim

To investigate the work of scientists and describe Working scientifically processes are used.

## Plan

Plan your inquiry by identifying a scientific research project that interests you. Consider how you will gather information about the Working scientifically processes (Figure 1.6.2) and examples of collaborative research. Think about how you will present your findings, such as in a report, presentation, or poster.

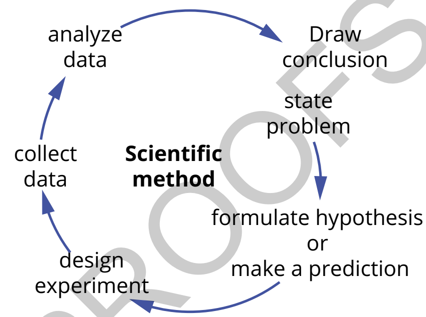



**FIGURE 1.6.2** Example flowchart of the scientific method

## Design

1 Choose a scientific research project that interests you. This could be a historical project or a current one.

2 Identify the key steps in the Working scientifically processes used in the project.

3 Find examples of how scientists collaborated on the project.

4 Plan how you will gather information, such as through online research, books, or interviews.

5 Decide how you will present your findings, such as in a written report, presentation, or poster.

## Conduct

Conduct your inquiry by gathering information about the scientific research project you chose. Look for details about the Working scientifically processes and examples of collaboration. Use reliable sources to ensure the accuracy of your information. Good sources of information include the journals *Nature*, *National Geographic* and the Centres for Disease Control.

## Improve

1 Review your findings and ensure you have detailed information about each step of the Working scientifically processes.

2 Check that you have clear examples of collaboration in the scientific research project.

3 Make sure your presentation is well-organised and easy to understand.

4 Ask for feedback from a teacher or peer and make any necessary improvements.

## Discussion

1 Reflect on what you learned about the Working Scientifically processes and collaboration in scientific research.

2 Consider what went well in your inquiry and what could be improved.

3 Think about how you could apply what you learned to future scientific investigations.

**Scifile**

**The Human Genome Project**

The Human Genome Project was a collaborative scientific research project that aimed to map all the genes in the human genome. It involved scientists from around the world working together to share data and resources. The project was completed in 2003 and has since led to many advances in medicine and genetics.

# 1.7 Measuring accurately

**Learning intention**

To be able to measure accurately using a variety of devices

**Success criteria**

**SC 1:** I can use analog measuring devices correctly.

**SC 2:** I can use a variety of digital measuring devices correctly.

**SC 3:** I can compare the accuracy and sensitivity of a variety of different measuring devices.

**KEY TERM**

**accurate** description of a measured value that is close to the true value of the quantity being measured

## Introduction

Scientists use a range of devices to measure and record data. They choose the device which will give the most **accurate** measurement. It is also important that results can be taken relatively quickly, especially if many readings need to be taken. Therefore, the device should also be easy to use. Figure 1.7.1 shows a type of electronic balance commonly found in school science laboratories which gives an instant readout of a mass in grams, accurate to one decimal place.

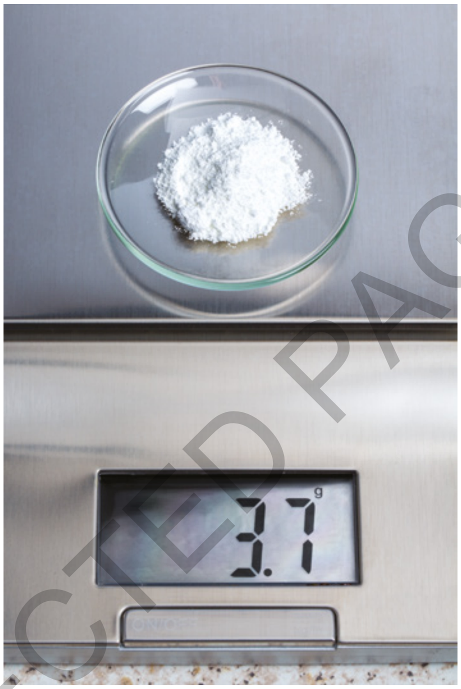



**FIGURE 1.7.1** White zinc oxide powder weighed on a digital balance

In this practical investigation you will make measurements using a range of types of measuring equipment. You will be able to use your experience and the results that you obtain to compare the characteristics, advantages, and disadvantages of the various measuring devices.

## Background

Measuring devices can be classified as analog or digital devices.

Analog devices are generally ones that are not powered by electricity. However, the description 'analog' actually means that the device can measure **continuous data**, which is data that can have any value.

Digital devices are generally ones that are powered by electricity and display the measurement on a screen or other form of digital readout. However, the description 'digital' actually means that the device will convert the measurement into **discrete data**, which means it can only have certain values.

**KEY TERMS**

**continuous data** numerical data that can have any value

**discrete data** numerical data that can only have certain values

Measuring devices can also be described in terms of their **range** and **sensitivity**.

GO TO ➤
For more information on types of data, see Toolkit section x.x.

## Range

The range of a measuring device is the difference between the lowest measurement and the highest measurement that the device can make. For example, the balance shown in Figure 1.7.1 has a range of 0–100 g.

The range of a set of results is the difference between the lowest measurement and the highest measurement of the set of data.

## Sensitivity

The sensitivity is the smallest amount of change that can be detected by the measuring device. For example, the balance shown in Figure 1.7.1 measures mass (in grams) to one decimal place. This means that it can detect a change as small as 0.1 g. The higher the sensitivity of the measuring device, the more accurate the measurements are likely to be.

# Aim

To accurately use a range of measuring devices and to compare their characteristics

# Apparatus

A selection of the following may be available for this experiment:

- ice
- warm water
- small blocks for weighing
- 4 × 250 mL beakers or identical tubs
- glass thermometer or
- digital thermometer
- infrared thermometer
- temperature sensor
- digital balance
- analog weighing scale
- access to computer or tablet
- smart watch with heart rate monitor
- measuring wheel.

## Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

**SAFETY NOTES**

- Do not use water any hotter than 40°C
- Be careful when handling wet glassware.

## Method

Note that this experiment can be carried out in a group.

1 Copy a version of the table below into your workbook. Alternatively, construct a spreadsheet with similar columns to the table. Give your table or spreadsheet a title.

2 The following are list of measurements to take, and a suggestion of how they can be measured. Depending on your teacher's instructions, measure some or all of these.

Ensure that you have:

- used at least one analog and one digital measuring device
- taken the same measurements of the same object using two different devices
- measured each as carefully as possible
- repeated each measurement up to four times, depending on time available.

You may also be asked to carry out other additional or alternative measurements or choose your own measurement, subject to the approval of your teacher. Alternative measurements may include:

- length of the laboratory using a metre ruler
- length of the laboratory using a measuring device on a smartphone or tablet
- mass of a small block using weighing scales
- mass of a small block using a digital balance
- temperature of tap water using a glass thermometer
- temperature of tap water using a digital thermometer
- number of heartbeats in a minute using a stopwatch
- number of heartbeats in a minute using a heart rate monitor
- time it takes for a pen to drop 2 metres to the floor
- time it takes for a flat piece of A4 paper to flutter from a height of 2 metres to the floor.
- Length of the side of a building using a measuring wheel
- Length of the side of a building using GPS on a smartphone, tablet or smart watch.

3 Calculate the average of multiple tests and include in your results table.

GO TO ➤
For support with calculating averages, see Toolkit section xx.

## Results

1 Use your results table or spreadsheet to record all the measurements made by your team. One example has been included for you.

| Measurement | Method | Measured values | | | | Average | Unit |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | | |
| temperature of tap water | digital thermometer | 24.5 | 25.0 | 24.8 | 25.1 | 24.85 | °C |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

2 Calculate the **range** of results obtained in each of your set of measurements.

3 Where possible, include the **sensitivity** of the measuring device.

## Discussion

1 Comment on the quality of the results from each of the measuring devices that you used. You can include:

- the size of the range of repeated results
- the sensitivity of the results (for example, how many decimal places did the device give to the results to?)
- whether any individual results were very different to the other repeated measurements
- the ease of use of the device.

2 Where you measured the same object using two different devices, compare the results obtained. Suggest, with an explanation, which device gave the most accurate results.

GO TO ➤
For support with accuracy, see Toolkit section x.x

## Conclusion

1 From your observations in this experiment describe three ways that scientists can improve the accuracy of measured data.

2 Complete the table below that compares analog and digital measuring devices.

| Measuring devices | Example | Advantages | Disadvantages |
|---|---|---|---|
| analog | | | |
| digital | | | |

# 1.8 Reliable data in science

**Learning intention**

To understand the importance of reliable data in science

**Success criteria**

**SC 1:** I can define accuracy and reliability in scientific data.

**SC 2:** I can compare the accuracy and reliability of observations using the senses with those made using measuring equipment.

**FIGURE 1.8.1** Accuracy is as important to carpenters as it is to scientists!

## Lesson overview

In science, reliable data is essential for drawing conclusions. When you conduct experiments, you need to ensure that your data is both accurate and reliable.

In this lesson, you will learn about the importance of accuracy and reliability in scientific data and how to compare observations made using senses with those made using measuring equipment.

**SC 1** I can define accuracy and reliability in scientific data

## Understanding accuracy

Accuracy refers to how close a measurement is to the true or accepted value. For example, if you are measuring the length of a table and the actual length is exactly 2 metres, an accurate measurement would be very close to 2 metres (Figure 1.8.1).

## Understanding reliability

Reliability refers to the consistency of measurements. If you measure the length of the same table multiple times and get the same or very similar results each time, your measurements are reliable.

### Examples of accuracy and reliability

Imagine you are measuring the temperature of boiling water. An accurate measurement would be close to 100°C. If you use a thermometer and get readings of 99.8°C, 100.1°C and 100.0°C, your measurements are both accurate and reliable. However, if you get readings of 90°C, 95°C and 100°C, your measurements are less reliable.

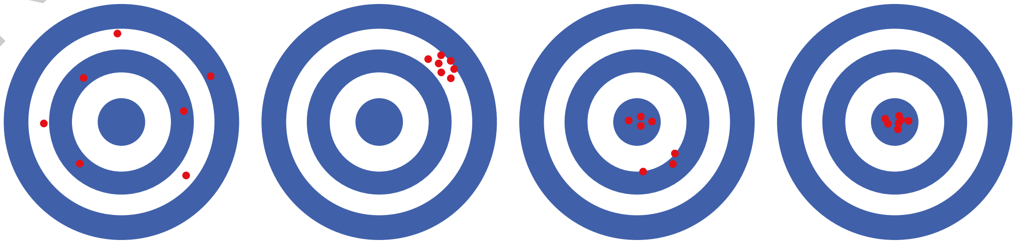



**FIGURE 1.8.2** Accuracy and reliability can be visualised using an archery board.

**SC 1 CHECK YOUR UNDERSTANDING**

Explain why it is important for scientific data to be both accurate and reliable.

**SC 2** I can compare the accuracy and reliability of observations using senses with those made using measuring equipment

## Observations using senses

Qualitative observations are those made using the senses. They involve using sight, touch, taste, smell, and hearing to gather data. While these observations can be useful, they are usually less accurate and reliable than measurements made using scientific equipment. For example, if you try to estimate the temperature of water by touching it, your sense of touch will not be precise enough to give an accurate measurement.

## Observations using measuring equipment

**Qualitative** observations are made using measuring equipment, such as thermometers, rulers, and scales, provide more accurate and reliable data. These devices are designed to give precise measurements that can be consistently replicated. For instance, a school science thermometer can measure the temperature of water to within a degree, providing a much more accurate reading than your sense of touch.

## Comparing accuracy and reliability

When comparing observations made using the senses with those made using measuring equipment, it is clear that measuring equipment provide more accurate and reliable data. For example, if you are measuring the length of a table, using a ruler will give you a precise measurement, whereas estimating the length by sight will not be as accurate.

**SC 2 CHECK YOUR UNDERSTANDING**

Compare the reliability of measuring the mass of coffee beans using your sense of touch versus using a digital balance.

**Scifile**

**Accurate clocks**

Did you know that the most accurate clocks in the world are atomic clocks? They use the vibrations of electrons to keep time and are accurate to within a few billionths of a second.

**FIGURE 1.8.3** Home aquarium owners also need to keep accurate temperature measurements, to ensure the health of their fish.

**Scifile**

**Sensing temperature**

Did you know that humans can sense temperature changes as small as 0.1°C?

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1. Define accuracy in scientific data.
2. Explain why reliability is important in scientific data.
3. Compare the accuracy of observations made using senses with those made using measuring equipment.
4. Describe an example where measuring equipment provides more reliable data than using senses.
5. Apply the concept of accuracy and reliability to explain why a doctor uses a stethoscope instead of listening to a patient's heartbeat directly.
6. Evaluate the importance of accuracy and reliability in scientific experiments.

# 1.9 Science, data and big data

**Learning intention**

To understand the role of data in scientific research

**Success criteria**

**SC 1:** I can describe key aspects of data science.

**SC 2:** I can recognise that data science can be used to develop knowledge from data.

**KEY TERMS**

**algorithm** a set of rules or processes that are followed in calculations to solve problems

**machine learning** artificial intelligence that allows computers to learn similarly to humans, and perform tasks without being programmed to

## Lesson overview

Data plays a crucial role in scientific research. Scientists collect and analyse data to make discoveries and solve problems. For example, when studying climate change, scientists gather data on temperature, rainfall and carbon dioxide levels to understand how the Earth's climate is changing. In this lesson, you will learn about the key aspects of data science and how data science can be used to develop knowledge from data.

**SC 1** I can describe key aspects of data science

## Understanding data science

Data science uses scientific methods, mathematics and statistics to help us understand phenomena and to explain them. Data scientists collect, organise, analyse and interpret information. They use tools and processes such as **algorithms** and **machine learning**.

Data scientists communicate their findings clearly through data visualisation, such as presenting it charts of graphs. When the data sets are large and complex, they are often referred to as **big data** (Figure 1.9.1).

**FIGURE 1.9.1** Computers help scientists to analyse data when it is complex and involves large data sets.

## Key aspects of data science

### Data collection

The first step in data science is gathering data. This can be done through surveys, experiments, the use of sensors, as well as other methods. For example, scientists might collect data on air quality using sensors placed in different locations.

## Data analysis

Once data is collected, it needs to be analysed to identify **patterns** and **trends**.

Data scientists use statistical methods and algorithms to analyse data. For example, they might use regression analysis to understand the relationship between temperature and carbon dioxide levels.

**KEY TERMS**

**pattern** repeated occurrence or sequence of data

**trend** a pattern in data where the data is changing in the same direction, for example always upwards, or always downwards

## Data interpretation

After analysing the data, scientists interpret the results to draw conclusions. This involves understanding what the data means and how it can be used to solve problems or make decisions. For example, interpreting climate data can help scientists predict future climate changes.

## Big data

Big data refers to extremely large data sets that often cannot be easily processed or analysed using traditional methods such as spreadsheets. Big data can be described by the Five V's as listed here.

1. Volume: The amount of data.
2. Velocity: The speed at which data is generated and processed.
3. Variety: Types of data, which could be structured or unstructured.
4. Veracity: The accuracy and reliability of the data.
5. Value: The economic benefits of the analysis big data.

Big data raises many challenges including information security, data storage and the tracking of individuals use of social media. However, it can be used to improve medical diagnosis and monitor risks to the environment as it can utilise such a range of information.

**SC 1 CHECK YOUR UNDERSTANDING**

Describe the three key aspects of data science.

**SC 2** I can recognise that data science can be used to develop knowledge from data

## Developing knowledge from data

Data science helps scientists develop knowledge by identifying patterns, trends, and relationships in data. For example, by analysing data on rainfall and temperature, scientists can understand how climate change affects weather patterns. This knowledge can be used to predict future weather conditions and develop strategies to mitigate (make less severe) the impact of climate change.

## Using data science in research

Data science is used in various fields of research, including biology, physics and social sciences. For example, biologists use data science to analyse genetic data and understand how genes influence traits and diseases.

## Real-world applications

Data science has many real-world applications. For example, in agriculture, data scientists analyse data on soil quality, weather conditions and crop yields to develop strategies for improving crop production.

### SCIENCE IN CONTEXT

#### Data science in environmental conservation

Data science is crucial for environmental conservation. Scientists collect and analyse data on wildlife populations, habitat conditions and pollution levels to develop strategies for protecting ecosystems. For example, data scientists analyse data on endangered species to identify factors that threaten their survival and develop conservation plans. The Wollemi Pine (Figure 1.9.2) is one of the world's oldest and rarest trees and is critically endangered. It was thought to be long extinct until spotted by a bushwalker in the Blue Mountains of NSW in 1994. Data science is critical in ensuring its continued survival, monitoring genetic diversity and modelling potential impacts of natural disasters on its survival.

Another example of how data science can help the preservation of species is the Australian lungfish. It's unique amongst fish: even other lungfish varieties have two lungs, whilst the Australian lungfish has only one. Like the Wollemi Pine, it is ancient, and scientists are carrying out genetic research and radiocarbon dating to try and ensure its continued survival. Incredibly, researchers have found that the Australian lungfish has the largest genome (complete DNA sequence) of any organism studied- it's 14 times larger than that of humans!

**FIGURE 1.9.2** The Wollemi pine is known as a living fossil, dating back to the age of the dinosaurs.



**SC 2 CHECK YOUR UNDERSTANDING**

Explain how data science can be used to develop knowledge from data.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 Define data science.
2 Explain the importance of data collection in data science.
3 Describe how data science can be used in agriculture.
4 Explain how data science helps in predicting future weather conditions.
5 Apply the concept of data science to explain how it can be used to improve public health.
6 Evaluate the role of data interpretation in scientific research.

# 1.10 Predicting changes to the climate

### Learning intention

To understand how scientists predict climate changes

### Success criteria

**SC 1:** I can explain how observations lead to inferences.

**SC 2:** I can make inferences and predictions from climate change data.

## Lesson overview

Climate change is a significant issue that affects our planet. Scientists use various methods to predict how the climate will change in the future. For example, they observe current weather patterns and use computer models to make predictions about future climate conditions. These predictions help us understand the potential impacts of climate change and develop strategies to mitigate its effects. In this lesson, you will learn how observations lead to inferences and how to make testable predictions based on data.

**SC 1** I can explain how observations lead to inferences

## Understanding observations and inferences

Observations are the act of noting and recording something with instruments or senses. For example, observing that the sky is cloudy is an observation. Inferences are conclusions drawn from observations. For instance, if you observe that the sky is cloudy, you might infer that it will rain soon.

### Examples of observations and inferences

Consider a scientist studying the melting of glaciers (Figure 1.10.1). The observation might be that the glacier's size has decreased over the past decade. The inference could be that rising global temperatures are causing the glacier to melt.

**FIGURE 1.10.1** Unlike melting sea ice, melting glaciers contribute to rising sea levels.

## The role of observations in scientific research

In scientific research, observations are crucial as they provide the data needed to make inferences. For example, observing changes in temperature, sea levels, and weather patterns helps scientists infer the effects of climate change.

**SC 1 CHECK YOUR UNDERSTANDING**

Give an example of how an observation can lead to an inference.

**SC 2** I can make inferences and predictions from climate change data

## Climate change models

Climate change models are computer programs that simulate the Earth's climate system. These models use mathematical equations to represent the interactions between the atmosphere, oceans, land surface and ice. By inputting data such as greenhouse gas emissions and solar radiation levels, scientists can predict how the climate will change over time.

Climate change models use various types of data, including temperature records, carbon dioxide levels, and sea ice extent. By analysing this data, scientists can identify trends and patterns that indicate how the climate is changing.

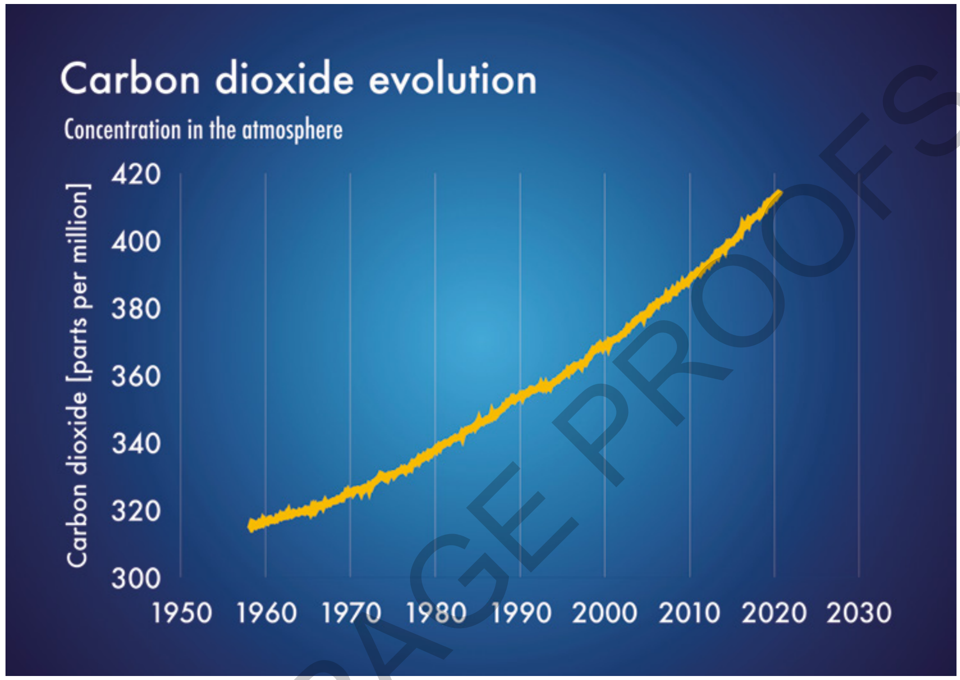



**FIGURE 1.10.2** Combustion of fossil fuels releases carbon dioxide into the atmosphere. Presenting the data in a graph makes it easier to visualise that the concentration of carbon dioxide in the atmosphere is increasing.

## Analysing trends from climate change models

When analysing climate change models, scientists look for trends such as rising temperatures, increasing sea levels and changing precipitation patterns. For example, a trend of increasing global temperatures over several decades shows that Earth is warming, as shown in Figure 1.10.3.

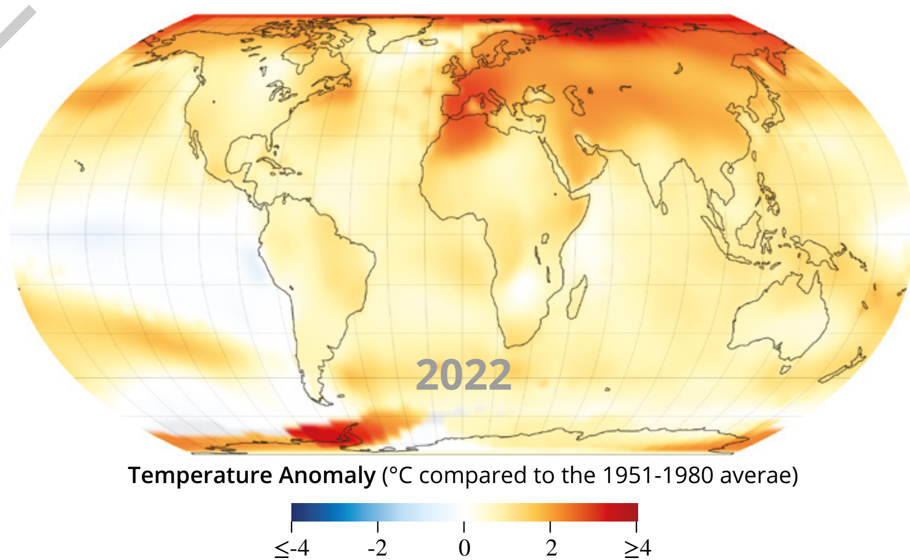



**FIGURE 1.10.3** Temperature anomalies are changes to a certain reference point. This graph from 2022 represents the firth-equal hottest year on record.

## Making inferences from climate change models

Inferences are conclusions drawn from data and observations. For example, if a climate change model shows that sea levels are rising, scientists might infer that coastal areas will be at increased risk of flooding.

## Testable predictions in climate science

Testable predictions are those that can be verified through further observations and experiments. For example, if a climate change model predicts that a certain region will experience more frequent droughts, scientists can test this prediction by monitoring rainfall and soil moisture levels in that region over time.

| Drought Stages | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2018 | | | | | | | 2019 | | | | | | | | 2020 | | | | | | | | | | | | 2021 | | | |
| | Oct | Oct | Oct | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | Mar | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr |
| Murray | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Lower Darling | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 |
| Murrumbidgee | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Lachlan | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Belubula | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 1 |
| Macquarie | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Cudgegong | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Lower Namoi | 2 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 1 | 1 | 1 | 1 |
| Upper Namoi | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 |
| Peel | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 2 | 2 | 1 | 1 | 1 | 1 |
| Gwydir | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 |
| Border rivers | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 |
| Barwon-darling | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 |
| Bega and Brogo | | | | | | | | | | | | | | | 2 | 4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Murray | | | | | | | | | | | | | | | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Murray | | | | | | | | | | | | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

| | | | |
|---|---|---|---|
| 1 | Normal Operations | 3 | Severe Drought |
| 2 | Emerging / Recovering Drought | 4 | Critical Drought |

**FIGURE 1.10.4** The drought between 2017 and 2020 was the worst in NSW to date.

### SC 2 CHECK YOUR UNDERSTANDING

Make a testable prediction based on increasing levels of carbon dioxide in the atmosphere.

# Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1. Define an observation in scientific research.
2. Describe the role of data in climate change models.
3. Explain how testable predictions are made using climate change models.
4. Apply the concept of testable predictions to explain how scientists might predict the impact of climate change on a specific region.
5. Evaluate the importance of identifying trends in climate change models.

# 1.11 Investigating types of science research

**Learning intention**

To understand different types of scientific research

**Success criteria**

**SC 1:** I can describe different approaches to scientific research.

**SC 2:** I can compare how different research approaches contribute to scientific knowledge.

**FIGURE 1.11.1** Bats are tagged by biologists to help them understand the bats' behaviour.

**KEY TERM**

**cause-and-effect relationships** a relationship between two variables in which changes to one variable is the reason behind changes to the other

## Lesson overview

In our daily lives, we encounter the benefits provided by various forms of scientific research, from the development of new medicines to the creation of more efficient technologies. Understanding the different approaches to scientific research helps us appreciate how these discoveries are made and how they impact our world. For example, when you use your smartphone, you are benefiting from years of scientific research in fields like physics, chemistry, and engineering. In this lesson, you will learn about the different approaches to scientific research and how they contribute to our knowledge of the world.

**SC 1** I can describe different approaches to scientific research

### Descriptive research

This type of research involves observing and describing the behaviour of a subject without influencing it in any way. It is often used in fields such as biology and social sciences. For example, a biologist might observe the behaviour of a group of animals in their natural habitat to understand their social structures and interactions or tag them to monitor their movements and changes to the population (Figure 1.11.1).

### Experimental research

This type of research involves manipulating one or more variables to determine their effect on another variable. It is commonly used in fields such as chemistry, physics, and psychology. For example, a chemist might conduct an experiment to test the effect of different temperatures on the rate of a chemical reaction. Experimental research allows scientists to establish **cause-and-effect relationships** between variables.

### Longitudinal research

This type of research involves studying the same group of subjects over an extended period of time. It is often used in fields such as medicine and education. For example, a medical researcher might study the long-term effects of a new treatment on patients with a chronic illness.

**SC 1 CHECK YOUR UNDERSTANDING**

Explain how descriptive research differs from experimental research.

**SC 2** I can compare how different research approaches contribute to scientific knowledge

## Contribution of descriptive research

Descriptive research provides a detailed account of the subject being studied, which can generate new questions and predictions for further research. For example, Jane Goodall's (Figure 1.11.2) observations of chimpanzees in Tanzania. She observed and recorded the behaviour of chimpanzees in their natural habitat for over 50 years, providing valuable insights into their social structures and interactions. Her work revealed complex social behaviours that were previously unknown, leading to new questions about primate behaviour and evolution. Descriptive research is essential for building a foundation of knowledge in a particular field.

**FIGURE 1.11.2** Jane Goodall's approach to studying chimpanzee behaviour was groundbreaking.

## Contribution of experimental research

Experimental research allows scientists to establish cause-and-effect relationships between variables. It is crucial for testing predictions and developing new technologies and treatments. For example, experimental research in chemistry has led to the development of new materials and drugs. In physics, experiments have confirmed the existence of fundamental particles and forces, advancing our understanding of the universe.

## Contribution of longitudinal research

Longitudinal research provides valuable information about how subjects change over time, which is essential for understanding long-term effects and trends. For example, the Framingham Heart Study (Figure 1.11.3) has identified risk factors for cardiovascular disease, such as high blood pressure and cholesterol levels, by following participants over several decades. Longitudinal research is crucial for studying the progression of diseases and the impact of interventions.

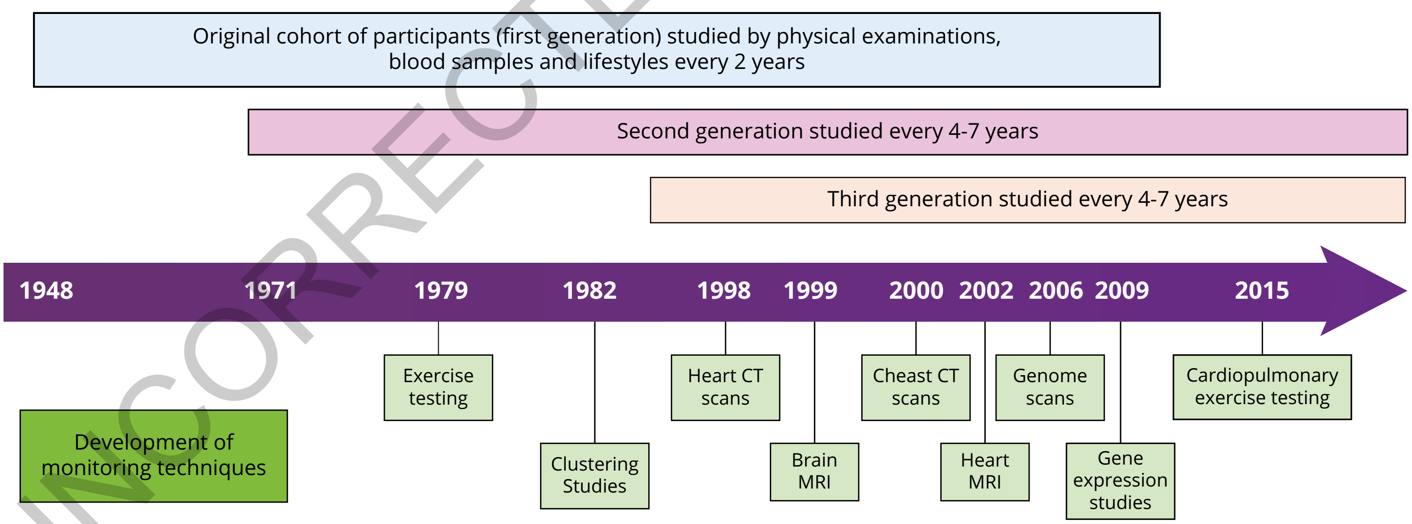



**FIGURE 1.11.3** The pioneering Framingham Heart study

### SC 2 CHECK YOUR UNDERSTANDING

Describe the contributions of experimental research to scientific knowledge.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1. List the three types of scientific research discussed in this lesson.
2. Explain the main goal of longitudinal research.
3. Describe how experimental research contributes to scientific knowledge.
4. Apply your understanding of research approaches to suggest a suitable type of research for studying the impact of a new educational program on student performance over several years.

# 1.12 The changing use of information technology in science

## Lesson overview

Information technology (IT) has revolutionised many aspects of our lives, including how scientific research is conducted. From the use of powerful computers to analyse vast amounts of data to the development of sophisticated software for simulations, IT has transformed the way scientists work. For example, when you use a search engine to find information, you are using technology that relies on complex algorithms and data analysis. In this lesson, you will learn how information technology has changed scientific research methods and the importance of engaging safely with digital systems.

**Learning intention**

To understand how information technology has changed the approach to scientific research

**Success criteria**

**SC 1:** I can describe how information technology has changed scientific research methods.

**SC 2:** I can recognise the importance of engaging safely with digital systems.

**SC 1** I can describe how information technology has changed scientific research methods

## Data collection and analysis

Information technology has greatly enhanced the ability of scientists to collect and analyse data. Modern sensors and instruments can collect vast amounts of data quickly and accurately. For example, meteorologists use satellite technology to gather data on weather patterns, which is then analysed using powerful computers to predict future weather conditions.

## Simulations and modelling

Another significant change brought about by IT is the use of simulations and modelling. Scientists can create computer models to simulate complex systems and predict their behaviour under different conditions. For example, climate scientists use computer models to simulate the Earth's climate and predict the impact of various factors on global warming.

## Communication and collaboration

Information technology has also transformed how scientists communicate and collaborate. The internet allows researchers from around the world to share data, publish findings, and collaborate on projects in real-time. For example, the Human Genome Project, which mapped the entire human genome (all of an organism's genetic information), involved scientists from multiple countries working together using digital communication tools.

## Automation and robotics

Automation and robotics have become integral to scientific research, particularly in fields like biology and chemistry. Automated systems can perform repetitive tasks with high precision, freeing up scientists to focus on more complex aspects of their research, like shown in Figure 1.12.1.

**FIGURE 1.12.1** Robotic machines can assist scientists: for instance, by carrying out highly accurate blood tests.

**SC 1 CHECK YOUR UNDERSTANDING**

Describe one way in which information technology has improved data collection and analysis in scientific research.

**SC 2** I can recognise the importance of engaging safely with digital systems

## Digital footprint

A digital footprint refers to the trail of data left behind while using the internet, including websites visited, emails sent, and social media interactions. It is important because it forms an online identity that can be accessed by others, including potential employers, marketers, and cybercriminals. Being aware of your digital footprint is important for protecting personal information.

## Cybersecurity

Engaging safely with digital systems is crucial to protect sensitive information and maintain the integrity of scientific research. Cybersecurity involves implementing measures to protect computer systems and networks from cyber-attacks. For example, scientists must ensure that their data is stored securely by using strong passwords and encryption of data.

## Ethical considerations

Ethical considerations are also important when engaging with digital systems. Scientists must ensure that their use of IT respects the privacy and rights of individuals. For example, when conducting research that involves personal data, such as medical records, researchers must obtain informed consent from participants and ensure that any data that they collect is made anonymous.

## Responsible use of social media

Social media can be a valuable tool for scientists to share their research and engage with the public. However, it is important to use social media responsibly to avoid spreading misinformation and to maintain professional integrity. Scientists should ensure that the information they share is accurate and based on evidence.

**SC 2 CHECK YOUR UNDERSTANDING**

Explain why cybersecurity is important in scientific research.

# Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1. List three ways in which information technology has changed scientific research methods.
2. Explain how simulations and modelling are used in scientific research.
3. List ways that someone's digital footprint can be increased.
4. Suggest how information technology could be used to improve research in a field of your choice.
5. Evaluate the potential risks and benefits of using social media for scientific communication.

# 1.13 Exploring variables

## Introduction

In science, a good question is one that can be answered by carrying out an investigation. These can include questions about whether there is a link between two variables.

Many science investigations seek to find out how certain things are affected by other **variables**. For example, 'Does the colour of an insect affect its chances of survival in a particular environment?' or 'Does temperature affect how well sticky tape sticks to a surface?'

In this experiment you will be testing whether the type of surface affects the height of the bounce of a ball.

## Background

Many science investigations test whether a change in the **independent variable** results in change to the **dependent variable**.

An effective way to test this is to make a prediction as to what will happen based on your knowledge, and then conduct the experiment to test this prediction.

In this investigation, the surface is the independent variable that you can change and the height of the bounce is the dependent variable that you will be measuring.

## Aim

To conduct an experiment that tests a prediction based on the relationship between variables

## Prediction

How do you think that the different surfaces will affect the height that the ball bounces? Before you go any further with this investigation, write a prediction in your workbook based on the surfaces that you will be testing.

## Apparatus

- a ball, such as tennis ball, rubber ball, basketball
- access to a range of surfaces that can include wood or wooden floor, carpet, concrete, bitumen, grass, synthetic grass, ceramic tiles
- metre ruler
- optional: camera, smart phone or tablet

**Learning intention**

To be able to explore the role of variables in scientific investigations

**Success criteria**

**SC 1:** I can conduct an experiment that tests the relationship between two variables

**SC 2:** I can identify the independent variable and control other variables.

**SC 3:** I can use scientific tools to observe a change in the dependent variable.

**FIGURE 1.13.1** A number of factors (variables) will affect how high a tennis ball will bounce.

GO TO ➤
For more information on variables, see Toolkit section x.xx

GO TO ➤
For support with making predictions, see Toolkit section x.x.

**SAFETY NOTES**

- Ensure that there is enough space for your experiment.
- Remove any trip hazards from the experiment areas.

## Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

## Method

1. List all the variables that are likely to affect the bounce height of a ball.
2. Describe how you will measure the maximum bounce of the ball using the metre ruler and digital technology if available.
3. Copy the results table below into your notebook and write in all the surfaces that you plan to test.
4. Under the results table, describe how you will keep other variables listed in part 1 of the method the same so that they do not affect the result of the experiment. For example, you will need to drop the balls from the same height each time.
5. Carry out your experiment, conducting each test up to four times.

## Results

1. Construct and complete a table of your results.

| Surface | Height of ball bounce (cm) | | | | Average height of bounce (cm) |
|---|---|---|---|---|---|
| | Trial 1 | Trial 2 | Trial 3 | Trial 4 | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

2. Calculate the average bounce height for each surface.

## Discussion

1. Describe any problems that you had measuring the height of the bounce (the dependent variable) and explain how you solved these problems.
2. Describe any problems that you had keeping the other variables the same and explain how you solved these problems. (These are called the **controlled variables**).
3. Place the surfaces in order from the highest bounce to the lowest bounce.
4. Compare your findings with other groups that tested the same surfaces.

## Conclusion

Comment on how well your results supported your predictions.

If your predictions were correct, suggest why you think those surfaces caused the highest and lowest bounce.

If the results did not match your predictions, suggest why you think that was.

# 1.14 Change over time

## Introduction

Scientific tools can be used to measure and record data over a period of time. It is important to choose appropriate equipment and use it correctly to ensure that all measurements are accurate from the start to the finish of the experiment.

In this experiment you will test the rate of cooling of a range of different drinks.

**Learning intention**

To be able to use scientific tools and instruments to investigate changes over time

**Success criteria**

**SC 1:** I can use scientific tools and instruments to make accurate observations.

**SC 2:** I can analyse and explain changes observed during an investigation.

## Background

There are a number of factors (variables) that affect how quickly hot liquids will cool down. This experiment is not about choosing one variable and investigating that. The focus is on analysing your experimental results and suggesting the reasons for any differences between the three types of drinks used.

**FIGURE 1.14.1** A number of factors will affect how quickly the hot chocolate in this mug will cool down.

## Aim

To make a series of observations over time to compare the rates at which different hot drinks cool

## Prediction

Which do you think will cool faster—a cup of tea, coffee, or drinking chocolate? What about if it was in a cup or a mug, a large cup or a small cup? Before you go any further with this investigation, write a prediction in your workbook based on the drinks that you will be using.

## Apparatus

You will be provided with some or all of the following:

- access to a kettle
- tea bags, instant coffee powder, drinking chocolate
- milk (optional)
- sugar
- up to 3 thermometers
- cups, mugs or beakers
- teaspoons
- washing up equipment

**SAFETY NOTES**

- Do not boil the water, use hot but not boiling water.
- Do not pick up any beaker of hot water with your bare hands. Use special tongs made for beakers or use insulated gloves.
- Do not drink any of the drinks.

**HINT**

When measuring temperature with a thermometer, read and record the measurement before you take the thermometer out of the drink.

**HINT**

If working in a group, each member of the team can test a different drink to obtain results more quickly.

## Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

## Method

1. Create a results table similar to that in the Results section in your workbook.
2. Follow the instructions from your teacher to prepare three different drinks. Note that the drinks can be in the same type of cup, or different types of container and the volume of each drink does not have to be the same.
3. Measure the starting temperature of your first drink and record in your results table.
4. Measure and record the temperature of the drink every minute for five minutes.
5. Repeat steps 3 and 4 with the other drinks that you are testing.

## Results

1. Record all your temperatures in a results table similar to this.

   Include a title for your table.

| Time (min) | Temperatures (°C) | | |
|---|---|---|---|
| | Cup of tea | Beaker of coffee | Mug of drinking chocolate |
| 0 (at the start) | | | |
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |

2 Plot the results of each drink as a line graph on an axis similar to that shown in Figure 1.14.2. Give your graph a title.

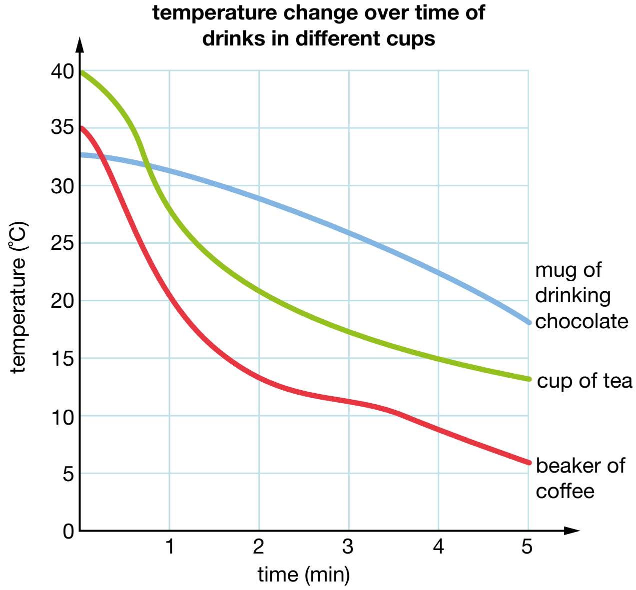



**FIGURE 1.14.2** Sample graph and data

## Discussion

1 Describe the trends or patterns that the graph showed. Were they increasing, decreasing, constant or unpredictable?

2 Which drink cooled the:

a fastest?

b slowest?

3 List as many factors as you can to explain why the drinks cooled at different rates.

## Conclusion

1 a Construct a conclusion for your investigation.

b Assess whether your prediction was supported or not.

2 Explain whether you think the results would be more helpful if you had continued recording for a longer period of time.

# 1 The nature and practice of science

## Topic summary

The key concepts included in this topic are:

- Scientific observations and data analysis are essential for understanding experiments and drawing conclusions.
- Science relies on evidence and systematic investigation, while pseudoscience lacks rigorous testing and evidence.
- There are various branches of science, such as biology, chemistry, and physics, which are interconnected.
- Collaborative work in science leads to more comprehensive research and innovative solutions.
- Scientific theories and laws are developed through repeated experiments and observations.
- Accurate measurements and reliable data are crucial for scientific research.
- Data science plays a significant role in developing knowledge from large datasets.
- Predicting climate changes involves analysing data and making inferences based on observations.



## Review questions

The following questions will assess your success in achieving the learning intentions for this topic.

### Remember

**1** Define the following terms:

- **a** pseudoscience
- **b** data science
- **c** inference
- **d** independent variable

### Understand

**2** Explain why it is important to record accurate observations in a scientific experiment.

**3** Explain the difference between a scientific theory and a scientific law.

**4** Explain how scientists use observations to make inferences about climate change.

**5** Explain how the scientific method helps distinguish between science and pseudoscience.

**6** Explain how information technology has changed the way scientific data is processed and presented.

### Apply

**7** Describe how you would you use knowledge from both physics and biology to understand how birds fly.

**8** Describe how scientists in different countries use information technology to allow them to collaborate on a research project.

**9** How would you design an experiment to test the effect of different amounts of sunlight on plant growth?

**10** Imagine you are part of a team investigating the impact of pollution on local water sources.

- **a** Explain the benefits of working collaboratively on this investigation.
- **b** Describe the different branches of science that might be involved in this investigation and how they are interconnected.
- **c** Discuss how information technology can be used to enhance your research methods.

## Analyse

**11** Compare the accuracy and sensitivity of an analog thermometer with a digital thermometer.

**12** Compare the effectiveness of using tables versus graphs to present scientific data.

**13** You are investigating a claim that a new herbal supplement can improve memory.

  **a** Compare how you would evaluate this claim using scientific methods versus pseudoscientific methods.

  **b** Describe the types of scientific research you would conduct to test the effectiveness of the supplement.

  **c** Explain how you would use data science to analyse the results of your research.

## Extension: Research task

**14** Research how different branches of science contribute to climate change models and explain their roles.



## Topic reflection

The learning intentions for this topic are given in each lesson and at the beginning of the topic. Consider how well you have achieved them. Note down any areas that you are confident in, and others where you are not so sure.

# 1 Glossary

**accuracy** description of a measured value that is close to the true value of the quantity being measured

**algorithm** a set of rules or processes that are followed in calculations to solve problems

**anecdotal evidence** based on personal accounts rather than facts or research

**big data** large and complex sets of data

**cause-and-effect relationships** a relationship between two variables in which changes to one variable is the reason behind changes to the other

**continuous data** numerical data that can have any value

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

**dependent variable** the variable that is being measured in an experiment

**discrete data** numerical data that can only have certain values

**empirical evidence** based on observation or experience rather than theory or pure logic

**falsifiable** a claim that can be proven false through experimentation

**independent variable** the factor that is changed in an investigation to find out how it affects another factor

**machine learning** artificial intelligence that allows computers to learn similarly to humans and perform tasks without being programmed to

**methodology** the way that research has been carried out, including the way that data was collected and analysed.

**pattern** repeated occurrence or sequence of data

**peer review** the process where scientific claims are evaluated by other experts in the field before being released

**prediction** a statement that suggests what will happen in an experiment

**qualitative** a description of something that is not measurable by a quantity or number

**quantitative** a description of something that can be measured by a quantity or number, and will include units

**range** the difference between the lowest measurement and the highest measurement that the device can make

**sensitivity** the smallest amount of change that can be detected by the measuring device

**trend** a pattern in data where the data is changing in the same direction, for example always upwards, or always downwards

**variable** a factor or condition that can change during an experiment and can influence the experiment

TOPIC 2

# Space science

In this topic, you will learn about Earth, Sun and Moon systems, and how their interactions are experienced on Earth, such as the changing seasons, eclipses and tides.

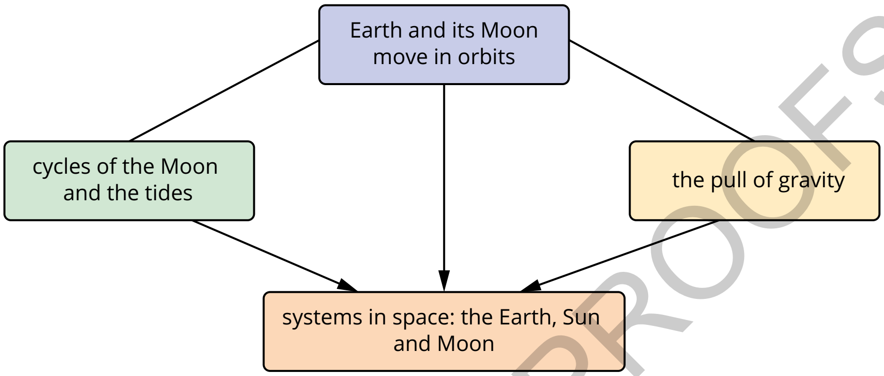


## Learning intentions

- ☐ To understand how solar system models have evolved over time **xx**
- ☐ To understand the causes of day and night **xx**
- ☐ To understand the cause of a lunar eclipse **xx**
- ☐ To understand the cause of a solar eclipse **xx**
- ☐ To be able to create and use a model to describe the phases of the Moon **xx**
- ☐ To understand how the position of Earth and the Moon causes tides **xx**
- ☐ To understand how information about tides is used in society **xx**
- ☐ To understand the similarities between accounts by First Nations Australians and mainstream scientific explanations of the Moon's phases and tides **xx**
- ☐ To understand how the position and motion of Earth causes seasons **xx**

# 2 Space science

The key concepts that you will use in this topic:




The following prior knowledge questions will help to support your learning in the topic and can be attempted before the first lesson.

## Earth and the Moon move in orbits

**1** How long does it take Earth to spin (rotate) once?

**2** Describe the motion of Earth around the Sun.

## The pull of gravity

**3** Describe the force of gravity acting between Earth and the Moon.

## Cycles of the Moon and the tides

**4** Describe the daily cycle of the tides.

**5** Explain the main cause of the tides in Earth's oceans.

**6** How is the Moon's motion related to the phases of the Moon seen from Earth?

**7** How did the cycles of the Moon and the tides help people survive in the distant past?

# 2.1 Models of the solar system

## Lesson overview

The solar system has fascinated humans for centuries. Ancient civilizations created models to explain the movements of the Sun, Moon and planets. Over time, these models evolved as new evidence was discovered. For example, early models placed Earth at the centre of the universe, while modern models correctly position the Sun at the centre of our solar system.

In this lesson, you will explore how these models have changed over time, understand the current model, and learn how new evidence has led to these changes.

**Learning intention**

To understand how solar system models have evolved over time

**Success criteria**

**SC 1:** I can describe historical models of the solar system.

**SC 2:** I can describe the current model of the solar system.

**SC 3:** I can compare and discuss how new evidence has led to changes in these models.

### SC 1 I can describe historical models of the solar system

The earliest models of the solar system were geocentric, meaning they placed Earth at the centre. One of the most famous geocentric models was proposed by the ancient Greek philosopher Ptolemy around 150 AD. In Ptolemy's model, the Earth was stationary, and the Sun, Moon and planets moved in complex paths called epicycles around it (Figure 2.1.1). This model was widely accepted for over a thousand years.

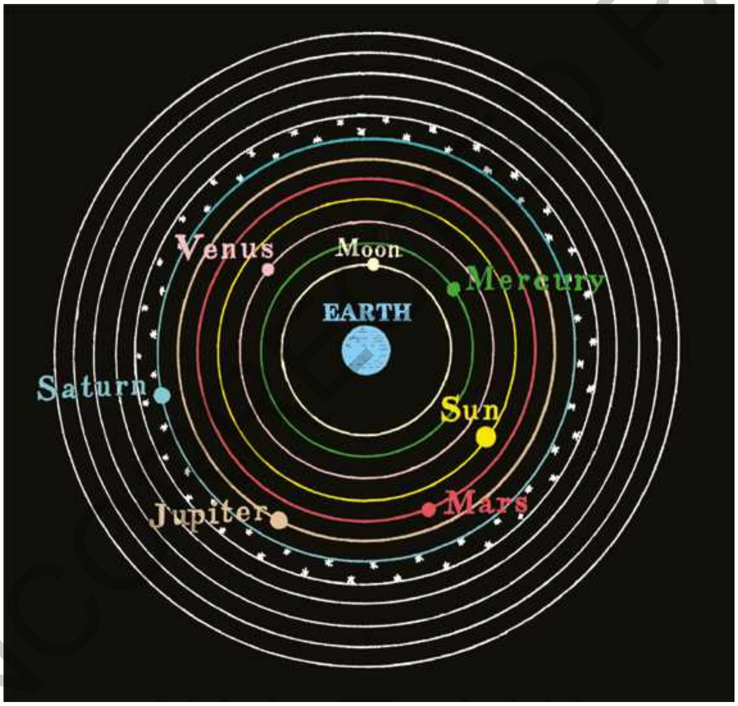



**FIGURE 2.1.1** Coloured historical artwork of the Earth-centred (geocentric) Ptolemaic model of the heavens

In the 16th century, the Polish **astronomer** Nicolaus Copernicus proposed a revolutionary idea: the heliocentric model. In this model, the Sun is at the centre of the solar system, and Earth and the other planets orbit around it (Figure 2.1.2). This was a significant shift from the geocentric model and laid the foundation for modern astronomy.

**KEY TERM**

**astronomer** a scientist who studies objects and events in space

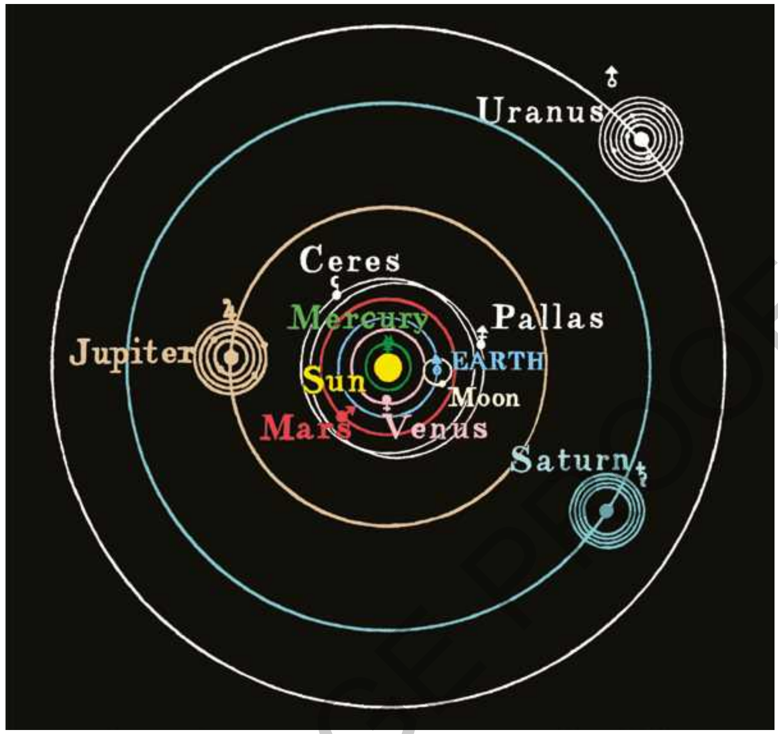



**FIGURE 2.1.2** Copernicus's heliocentric model with the Sun at the centre and planets orbiting around it.

Later, in the early 17th century, the Italian scientist Galileo Galilei used a telescope to make observations that supported the heliocentric model. He observed the phases of Venus and the moons of Jupiter, which provided strong evidence that not everything orbits Earth.

**SC 1 CHECK YOUR UNDERSTANDING**

Explain how Galileo's observations supported the heliocentric model.

**SC 2** I can describe the current model of the solar system

The current model of the solar system is based on the heliocentric model proposed by Copernicus, but it has been refined with modern scientific knowledge. In this model, the Sun is at the centre, and the planets, including Earth, orbit around it in elliptical paths. This model is known as the heliocentric model.

The solar system consists of the Sun, eight planets, their moons, and other objects like asteroids and comets (Figure 2.1.3). The planets are divided into two groups: the inner planets (Mercury, Venus, Earth and Mars) and the outer planets (Jupiter, Saturn, Uranus and Neptune). The inner planets are rocky and smaller, while the outer planets are gas giants and much larger.

The Sun is a star, and it provides the energy that sustains life on Earth. It is composed mainly of hydrogen and helium and generates energy through nuclear fusion. The planets orbit the Sun due to the force of **gravity**, which keeps them in their paths.

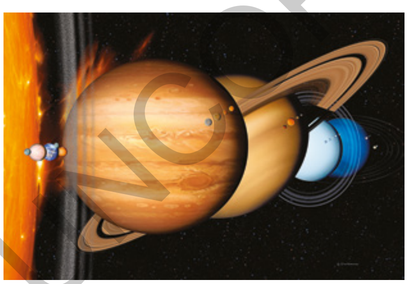


**FIGURE 2.1.3** The eight planets of the solar system arrayed from left to right in their order from the Sun (partly seen at left). The sizes of the Sun and planets are to scale.

Each planet has unique characteristics. For example, Earth is the only planet known to support life, while Jupiter is the largest planet in the solar system. Saturn is famous for its stunning ring system, and Neptune has strong winds and storms.

**SC 2 CHECK YOUR UNDERSTANDING**

Describe the main difference between the inner and outer planets.

**SC 3** I can compare and discuss how new evidence has led to changes in these models

The evolution of solar system models is an example of the power of scientific inquiry and evidence. The shift from the geocentric model to the heliocentric model was driven by new observations and careful measurements. For example, Galileo's observations of the phases of Venus and the moons of Jupiter provided strong evidence that not everything orbits the Earth (Figure 2.1.4).

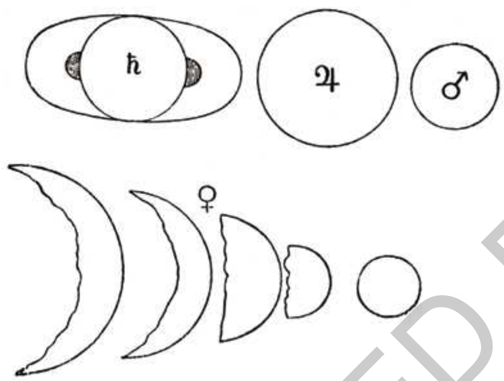



**FIGURE 2.1.4** From left to right: Saturn, Jupiter, Mars and Venus (showing its different phases) as sketched by Galileo in 1610

As technology advanced, so did our understanding of the solar system. The invention of the telescope allowed astronomers to make more detailed observations. For instance, the discovery of Uranus by William Herschel in 1781 expanded the known boundaries of the solar system. Later, the discovery of Neptune in 1846 and Pluto in 1930 further refined our understanding.

In the 20th century, **space** exploration provided direct evidence about the solar system. Missions like the Apollo moon landings, the Voyager probes, and the Mars rovers have sent back valuable data and images from the Moon, planets and outer limits of the solar system. These missions have confirmed the heliocentric model and provided new insights into the characteristics of planets and other objects in the solar system.

New evidence continues to refine our understanding. For example, the discovery of **exoplanets** has shown that our solar system is just one of many in the universe. The study of these exoplanets helps scientists understand the formation and evolution of planetary systems.

**SC 3 CHECK YOUR UNDERSTANDING**

Discuss how the discovery of exoplanets has impacted our understanding of the solar system.

## Scifile

### Pluto's status

Pluto was once considered the ninth planet of the solar system. However, in 2006, it was reclassified as a dwarf planet by the International Astronomical Union because it does not clear its orbit of other debris.

**KEY TERMS**

**space** the immense and limitless area beyond Earth's atmosphere, containing stars, planets, galaxies, and other cosmic matter

**exoplanets** planets outside our solar system

## SCIENCE IN CONTEXT

In the modern era, space telescopes like Hubble have captured stunning images of planets, stars, and galaxies, expanding our knowledge of the universe. Robotic missions, such as the Mars rovers, have explored the surface of other planets, sending back valuable data and images.

The Hubble Space Telescope (Figure 2.1.5), launched in 1990, has been one of the most important tools in modern astronomy. It orbits Earth and has taken detailed images of distant galaxies, nebulae, and planets in our solar system. Hubble has helped scientists determine the rate of expansion of the universe and study the atmospheres of exoplanets.

**FIGURE 2.1.5** The Hubble Space Telescope has captured detailed images of distant galaxies, nebulae and planets.

Another significant space telescope is the James Webb Space Telescope (JWST), launched in December 2021. JWST is the largest and most sensitive space telescope ever built, with a primary mirror that is over six times larger than Hubble's. It observes the universe in infrared light, allowing scientists to study the formation of stars and galaxies, and search for signs of life on exoplanets. An example of the high resolution, detailed images that it produces can be seen in Figure 2.1.6.

**FIGURE 2.1.6** JWST image of the open star cluster NGC 3324 in the Carina Nebula. NGC 3324 lies about 7,500 light years from Earth.

In Western Australia, the Square Kilometre Array (SKA) project is set to revolutionize our understanding of the wider universe. The SKA will be the world's largest radio telescope, capable of detecting faint signals from the early universe. It will help scientists study the formation of galaxies, stars and planets, and search for signs of extraterrestrial life.



## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 Name the ancient Greek philosopher who proposed the geocentric model of the solar system.

2 Explain why the geocentric model was widely accepted for over a thousand years.

3 Discuss how Galileo's observations challenged the geocentric model.

4 Predict how the discovery of a new planet in our solar system would impact the current model.

5 Compare the impact of the invention of the telescope with the impact of space exploration on our understanding of the solar system.

# 2.2 Day and night

## Lesson overview

The cycle of day and night is caused by the rotation of Earth on its axis. As Earth spins, different parts of the planet are exposed to sunlight, creating the alternating periods of light and darkness. For example, when you wake up in the morning, the Sun rises because your location on the Earth is turning towards the Sun.

In this lesson, you will learn about the positions of the Sun, Earth and Moon, and how Earth's rotation causes day and night.

**SC 1** I can describe the relative positions of the Sun, Earth and the Moon

The Sun, Earth and the Moon are the three celestial bodies that play crucial roles in the cycle of day and night. Understanding their relative positions helps us understand how these cycles occur.

The Sun is the star at the centre of our solar system. It is a massive ball of hot gas that emits light, heat and particles, providing the energy necessary for life on Earth. The Earth is a planet that **orbits** the Sun at an average distance of about 150 million kilometres. The Moon is Earth's natural satellite, orbiting our planet at an average distance of about 384 400 kilometres.

The Earth orbits the Sun in an elliptical path, taking approximately 365.25 days to complete one orbit. The Moon orbits Earth in a nearly circular path, taking about 27.3 days to complete one orbit (Figure 2.2.1). The Moon's phases (known as **lunar phases**), such as full moon and new moon, are caused by its position relative to Earth and the Sun.

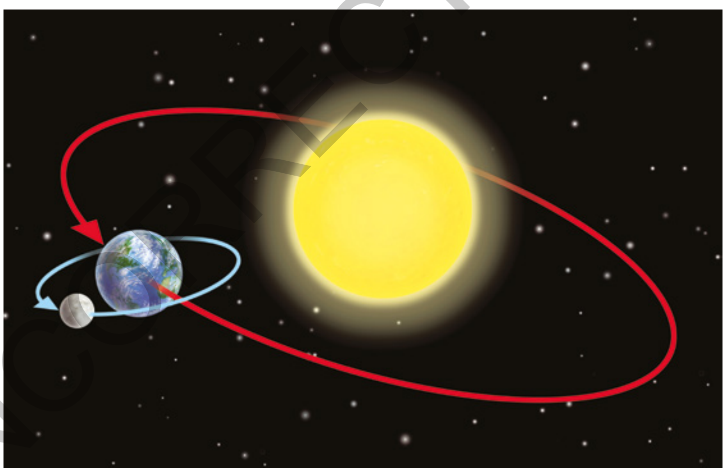


**FIGURE 2.2.1** Earth's orbit around the Sun and the Moon's orbit around Earth.

### SC 1 CHECK YOUR UNDERSTANDING

Compare the duration of the Moon's orbit around Earth with the duration of the Earth's orbit around the Sun.

### Learning intention

To understand the causes of day and night

### Success criteria

**SC 1:** I can describe the relative positions of the Sun, Earth and the Moon.

**SC 2:** I can explain how Earth's rotation causes day and night.

### Scifile

#### Rotation of the Moon

The Moon rotates at the same rate as it orbits Earth – this means that we only ever see the same side of the Moon from Earth. The crew of the Apollo 8 mission in 1968 were the first people to ever see the far side of the Moon, although it had been photographed in 1959 by a Soviet probe.

**SC 2** I can explain how Earth's rotation causes day and night

Earth's **rotation** is the primary cause of day and night. Earth rotates on its axis, an imaginary line that runs from the North Pole through the centre of Earth to the South Pole. This rotation takes approximately 24 hours to complete, resulting in the cycle of day and night.

As Earth rotates, different parts of the planet are exposed to sunlight. When a region of Earth faces the Sun, it experiences daylight. As Earth continues to rotate, that region moves away from the Sun and enters darkness, experiencing night as seen in Figure 2.2.2. This continuous rotation creates the alternating periods of light and darkness that we observe as day and night.

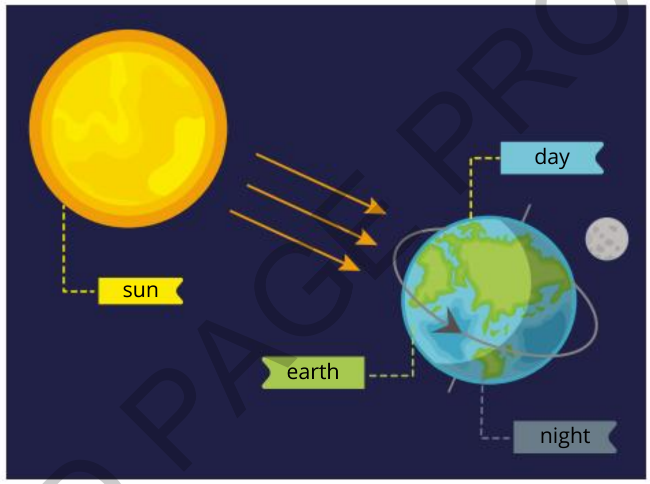



**FIGURE 2.2.2** The rotation of Earth and the cycle of day and night

The axis of Earth is tilted at an angle of approximately 23.5 degrees relative to its orbit around the Sun. This tilt is responsible for the changing length of day and night throughout the year. During summer, the tilt causes longer days and shorter nights, while during winter, it causes shorter days and longer nights.

## SCIENCE IN CONTEXT

### Length of days

In New South Wales, the amount of daylight varies with the seasons from over 14 hours in summer in Sydney, to less than 10 hours in winter. Further south, Hobart has over 15 hours of daylight in summer but less than 9 hours in winter. In contrast, Darwin has much less variation in day lengths throughout the year, with only around an hour's difference between summer and winter.

**Scifile**

**Earth's speed**

Earth rotates at a speed of about 1,670 kilometres per hour at the equator.

The rotation of Earth also leads to the phenomenon of time zones (Figure 2.2.3). As Earth rotates, different regions experience daylight at different times. To standardise time, the world is divided into 24 time zones, each representing one hour of Earth's rotation. For example, when it is twelve midday (Australian Eastern Standard Time) in Sydney, it is ten o'clock (Australian Western Standard Time) in the morning in Perth. Additionally, NSW has daylight saving time from October to April, where clocks are set one hour ahead of standard time.

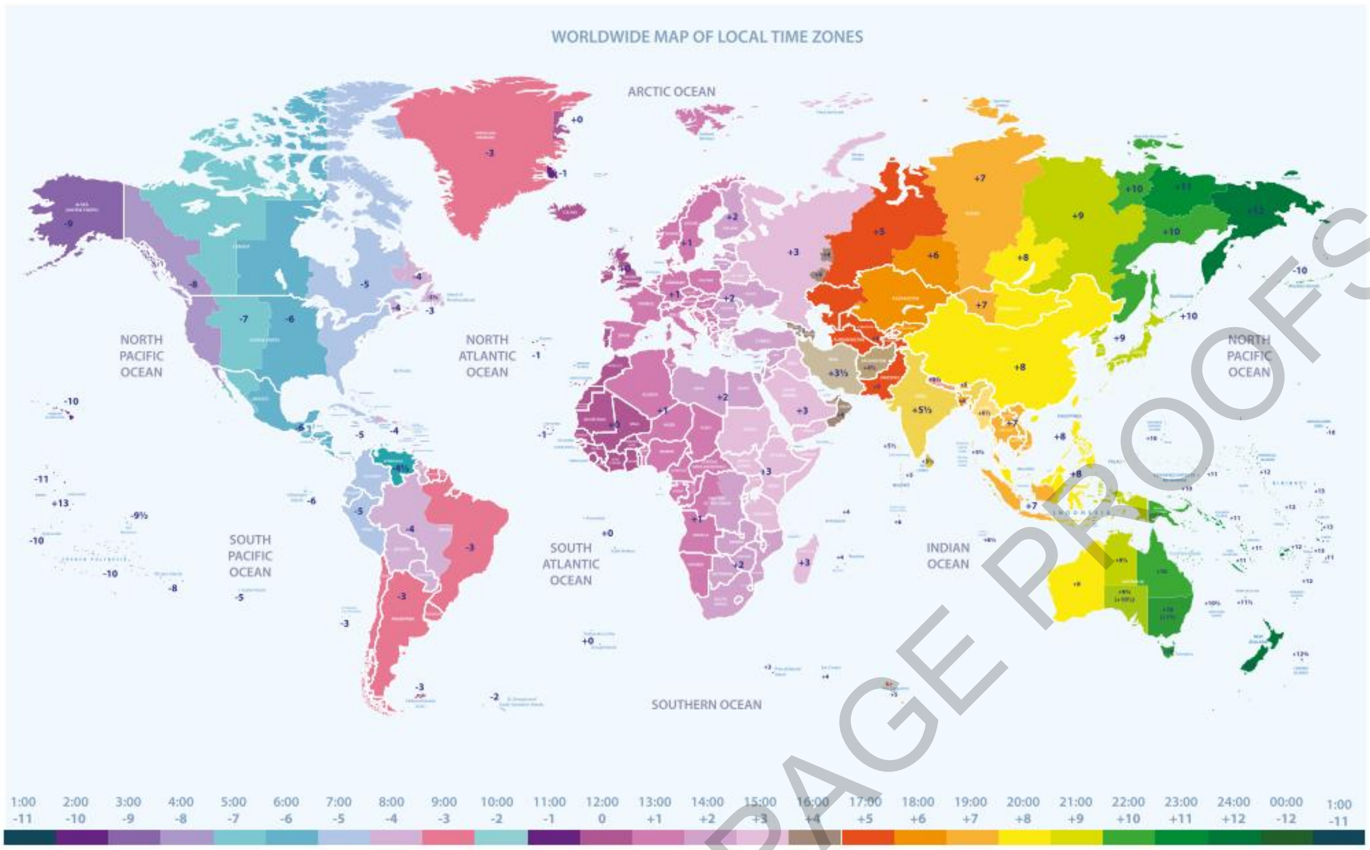



**FIGURE 2.2.3** Time zones across the world, with each zone being shown in the same colour

**SC 2 CHECK YOUR UNDERSTANDING**

Explain how Earth's rotation causes day and night.

## SCIENCE IN CONTEXT

### Time zones

Time zones are essential for coordinating activities across different regions of the world. They ensure that everyone follows a standardised time, making communication and travel more efficient. For example, when you fly from Sydney to Perth, you need to adjust your watch to match the local time zone.

Australia has several time zones due to its vast size (Figure 2.2.4). The eastern states, including New South Wales, follow Australian Eastern Standard Time (AEST), which is 10 hours ahead of Coordinated Universal Time (UTC+10). The central states, including South Australia, follow Australian Central Standard Time (ACST), which is 9.5 hours ahead of UTC (UTC+9.5). Western Australia follows the Australian Western Standard Time (AWST), which is 8 hours ahead of UTC (UTC+8).


**FIGURE 2.2.4** Australian time zones (without daylight saving)

Coordinated Universal Time (UTC) is the primary time standard by which the world regulates clocks and time. It is based on the time at the Prime Meridian (0 degrees longitude) in Greenwich, England. UTC does not change with the seasons, unlike local time zones that may observe daylight saving time.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 Name the celestial body that emits light and heat, providing energy for life on Earth.

2 Describe how Earth's axial tilt affects the length of day and night throughout the year.

3 Explain how time zones are related to Earth's rotation.

4 Predict what would happen to the cycle of day and night if Earth stopped rotating.

# 2.3 Lunar eclipses

## Lesson overview

Usually, when the Moon is visible in a clear sky, it appears bright white, and the phase of the Moon is recognisable. Other times the Moon looks very different; it may be covered or partially covered by Earth's shadow, and it changes colour.

In this lesson, you will learn how the relative positions of Earth, the Sun and the Moon cause lunar eclipses which then change the appearance of the Moon from Earth.

**SC 1** I can describe what the Moon will look like during a lunar eclipse

### Learning intention

To understand the cause of a lunar eclipse

### Success criteria

**SC 1:** I can describe what the Moon will look like during a lunar eclipse.

**SC 2:** I can describe the relative positions of Earth, the Moon and the Sun during a lunar eclipse.

**SC 3:** I can explain, using a two- or three-dimensional representation, how Earth casts a shadow on the Moon during a lunar eclipse.

## Lunar eclipse

A lunar eclipse occurs when the Moon passes through Earth's shadow and Earth temporarily blocks the Sun's light from reaching the Moon. A lunar eclipse only occurs during the full moon phase when the Moon appears as a full circle in the sky.

During a lunar eclipse, the appearance of the Moon from Earth changes depending on which part of Earth's shadow the Moon passes through. Figure 2.3.1 shows the two parts of Earth's shadow:

The **penumbra** – a diffuse, outer portion of the shadow which extends away from Earth at an angle.

The **umbra** – the dark, inner portion of the shadow directly behind Earth.

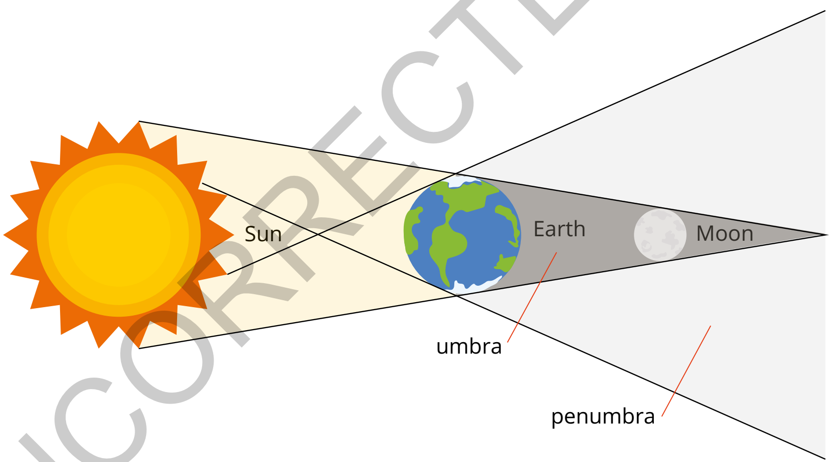



**FIGURE 2.3.1** The arrangement of the Sun, Earth and the Moon during a lunar eclipse and the regions within Earth's shadow

## Penumbral lunar eclipse

A penumbral eclipse occurs when the Moon only moves through the penumbra of Earth's shadow and not through the umbra. The penumbra of Earth's shadow is very faint, and the appearance of the Moon doesn't change much during a penumbral lunar eclipse. A penumbral eclipse is hard to detect because the brightness of the Moon will only be subtly reduced.

**FIGURE 2.3.2** Part of the Moon is covered by Earth's umbra during a partial lunar eclipse

## Partial lunar eclipse

During a partial lunar eclipse, the Moon is only partly covered by Earth's shadow and some direct sunlight is still able to reach the Moon. Only part of the Moon moves through the dark inner shadow (the umbra), the rest of the Moon is in the faint shadow (the penumbra). The part of the Moon under the umbra appears dark and the rest of the Moon under the penumbra still reflects light (Figure 2.3.2).

A partial lunar eclipse can look a bit like the phases of the Moon during which some of the side of the Moon facing Earth is in darkness. A partial lunar eclipse only lasts for a short amount of time, less than two hours, and occurs only during the full moon phase.

## Total lunar eclipse

**FIGURE 2.3.3** The phases of a lunar eclipse

During a total lunar eclipse, the Moon is completely covered by Earth's umbra and no direct sunlight reaches the Moon. The Moon is still visible during a total eclipse because some sunlight still reaches the Moon indirectly through Earth's atmosphere. The image in Figure 2.3.3 shows a time lapse of the full progression of a total lunar eclipse beginning and ending with a partial eclipse and reaching a total eclipse in the middle.

## Colour of the Moon

**FIGURE 2.3.4** The orange colour of an eclipsed moon

During some stages of a lunar eclipse, the Moon can change to a reddish orange colour. This is caused by sunlight interacting with Earth's atmosphere which filters and scatters different wavelengths of light. Blue light wavelengths are filtered out by particles in the atmosphere more than red light wavelengths. Therefore, the sunlight falling on the Moon's surface is mostly orange to red, so that's the colour the Moon appears to us.

A total lunar eclipse is sometimes referred to informally as a 'blood moon' due to the Moon's change in colour (Figure 2.3.4).

## Viewing a lunar eclipse

A lunar eclipse can be seen by anyone on the night side of Earth so long as their view of the Moon isn't obstructed by physical objects on Earth or clouds in the sky. The number of lunar eclipses per year is not always the same but the average is two per year. A lunar eclipse can last up to six hours, but totality (when the moon is completely in the umbra) ranges from a few minutes for short eclipses, to over 90 minutes for long eclipses.

**SC 1 CHECK YOUR UNDERSTANDING**

Describe how you would identify a total lunar eclipse in the night sky.

**SC 2** I can describe the relative positions of Earth, the Moon and the Sun during a lunar eclipse

## When the Sun, Earth and the Moon align

A lunar eclipse can only occur when the Sun, Earth and the Moon are aligned with the Sun and the Moon on opposite sides of Earth (Figure 2.3.5). This formation only occurs during the full moon phase. A full moon occurs every moon cycle which is about once a month.


**FIGURE 2.3.5** The Sun, Earth and the Moon are directly aligned during a full moon and a lunar eclipse

Lunar eclipses can only occur during the full moon phase, but they do not happen every full moon.

This is due to the direction of the Moon's orbit around Earth. The Moon's orbit is slightly tilted at about 5° to the Earth's orbit. The tilt of the Moon's orbit is shown in Figure 2.3.6.

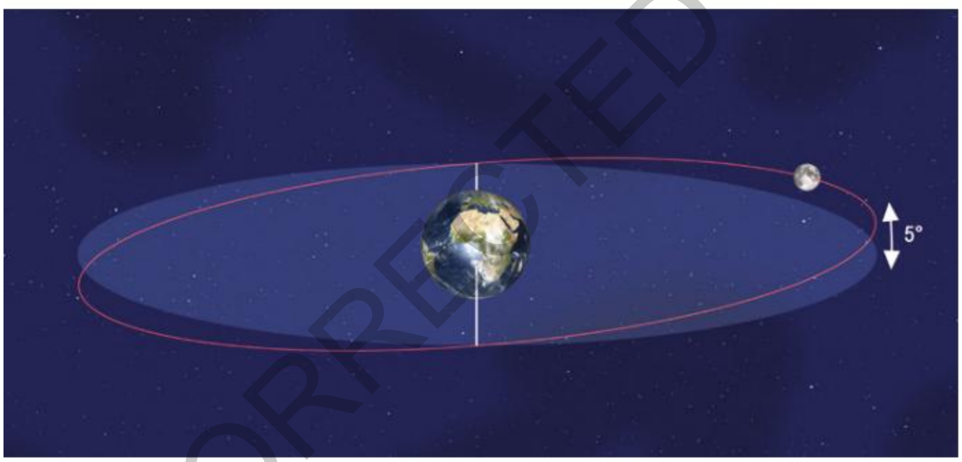



**FIGURE 2.3.6** The Moon is only aligned with Earth's shadow occasionally due to the tilt of its orbit, so lunar eclipses do not happen often.

As Earth and the Moon travel around the Sun, the tilt of the Moon's orbit causes it to appear above or below the Sun when observed from Earth.

At times this means that the Moon might be slightly above or below Earth in space during the full moon phase and will orbit Earth without passing through Earth's shadow.

## Geometry of a lunar eclipse

When the Moon's orbit is directly aligned in the same plane as Earth's orbit and the Sun, the Moon passes through Earth's shadow.

First, the Moon passes through the penumbra, and a penumbral then partial lunar eclipse occurs. Then, the Moon moves directly behind Earth through the umbra, and a total lunar eclipse occurs. The diagram in Figure 2.3.7 shows the relative positions of the Sun, Earth and the Moon during a lunar eclipse.

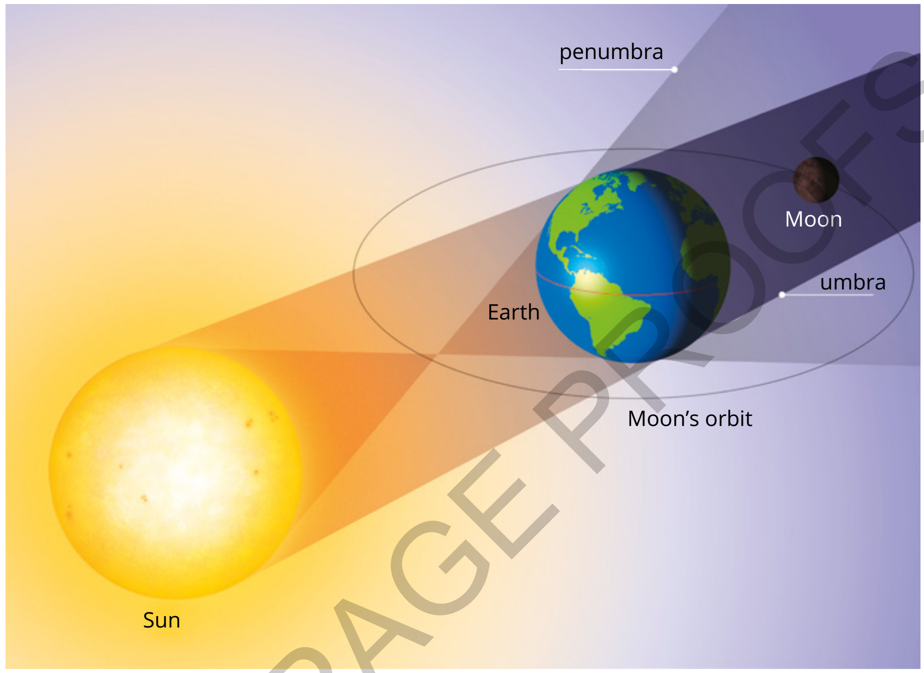



**FIGURE 2.3.7** The relative positions of the Sun, Earth and the Moon during a lunar eclipse

**SC 2 CHECK YOUR UNDERSTANDING**

Describe the position of the Moon relative to Earth and the Sun during a total lunar eclipse.

**SC 3** I can explain, using a two- or three-dimensional representation, how Earth casts a shadow on the Moon during a lunar eclipse

## Using models

Using a model is a helpful way to understand why a lunar eclipse occurs.

A lunar eclipse is not visible all the time because they only occur a couple of times a year and can only be viewed when the sky is clear. There is also only one view of the lunar eclipse from Earth's surface.

Creating a model allows for the visualisation of a lunar eclipse at any time and to see how it might look from space.

A model of a lunar eclipse should include representations of the Sun, Earth and the Moon.

## 2D vs 3D models

A two-dimensional (2D) model, such as a diagram or illustration, is a flat representation of Earth, the Sun and the Moon. Arrows can be used to explain movement and direction.

A three-dimensional (3D) model, such as that in Figure 2.3.8, uses physical objects to represent Earth, the Sun and the Moon and can include physical movement.

**FIGURE 2.3.8** A 3D model of the Sun-Earth systems

## Scale

When making a model, the elements are ideally made to scale and are the right sizes and distances in relation to each other, but this is not always practical. When making 2D or 3D models of Earth, the Sun and the Moon, the sizes and distances of the objects are too extreme to be made to scale.

In a lunar eclipse model, it is most important to ensure:

- the Sun is bigger than Earth
- Earth is bigger than the Moon
- the Moon is closer to Earth than it is to the Sun.

## Light

All the Sun's rays cannot be drawn in a 2D model, but the direction of light must be represented. Light and shadow can be represented by colour, shading or lines radiating out from a light source. In a 3D model, actual light sources that emit visible light and create shadows can be used.

**SkillBuilder**

## Using models in Earth and space science

### Models in science

Scientific models can be used to describe or explain things that are either too small or too big to be seen directly by humans.

Models can be 2D diagrams, 3D models, computer simulations, or even just thoughts or ideas.

What makes a good scientific model?

A scientific model should be based on correct science. For example, light travels in straight lines and planets orbit around the Sun.

A scientific model can be used to make predictions.

Modelling systems in space: Dealing with scale

When scaling down from the vast scale of space, keep relative sizes and times as close to reality as possible. For example:

- keep Earth bigger than the Moon.
- keep the distance of Earth to the Sun much larger than the distance to the Moon.
- keep the time for Earth to orbit the Sun much longer than the time for the Moon to orbit Earth.

For example, Fabrice was asked to draw a 2D model that shows the orbital motion of the Moon and Earth around the Sun. They were told that Earth's orbit around the Sun takes 365 days and that the Moon's revolution around Earth takes 27 days. Fabrice's diagram looked like the one depicted in Figure 2.3.9.

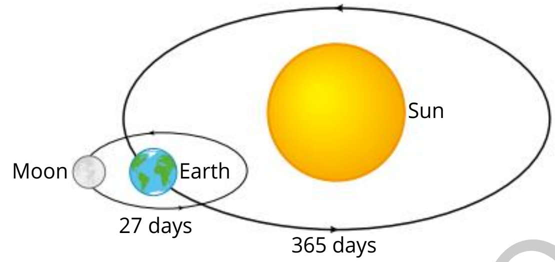



**FIGURE 2.3.9** A 2D model of the Sun, Earth and Moon systems

**SC 3 CHECK YOUR UNDERSTANDING**

Describe how you would use a 3D model to show the positions of Earth, the Moon and the Sun during a lunar eclipse.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 If you observe the Moon gradually darkening and then turning red, what type of eclipse are you witnessing?

2 Compare different types of lunar eclipses.
   a How does the Moon's appearance differ during a partial and a total lunar eclipse?
   b What are the similarities between partial and total lunar eclipses?
   c Evaluate the visual impact of a total lunar eclipse compared to a partial lunar eclipse.

3 Explain why a lunar eclipse does not occur every full moon.

4 Compare different representations of a lunar eclipse in terms of their strengths and weaknesses.
   a How does a 2D diagram compare to a 3D model when explaining a lunar eclipse?
   b Evaluate which model (2D or 3D) might be more effective for different learning objectives.

# 2.4 Solar eclipses

## Lesson overview

Every so often the Moon briefly obstructs the view of the Sun. If you are in the right place at the right time, you can observe this from Earth.

In this lesson, you will learn how the relative positions of Earth, the Sun and the Moon cause solar eclipses which change the appearance of the Sun from Earth.

| | |
|---|---|
| **SC 1** | I can describe what the Sun will look like during a solar eclipse |

### Learning intention

To understand the cause of a solar eclipse

### Success criteria

**SC 1:** I can describe what the Sun will look like during a solar eclipse.

**SC 2:** I can describe the relative positions of Earth, the Moon and the Sun during a solar eclipse.

**SC 3:** I can explain, using a two- or three-dimensional representation, how the Moon casts a shadow on Earth during a solar eclipse.

## Solar eclipse

A **solar eclipse** occurs when the Moon passes between the Sun and Earth. The Moon temporarily blocks the Sun and casts a shadow on a part of Earth's surface. A solar eclipse only occurs during the new moon phase when the Moon appears dark in the sky and is not visible from Earth. The Moon is smaller than Earth, so it only casts a shadow on a small part of Earth's surface.

During a solar eclipse, the appearance of the Sun from Earth changes depending on which part of the Moon's shadow is cast over a particular location.

As with lunar eclipses, the shadows cast by the Moon on Earth have two distinct parts: the penumbra (the diffuse, outer portion of the shadow) and the umbra (the dark, inner portion of the shadow). The penumbra and umbra of a solar eclipse are shown in Figure 2.4.1.

**KEY TERM**

**solar eclipse** when the Moon blocks sunlight from reaching Earth

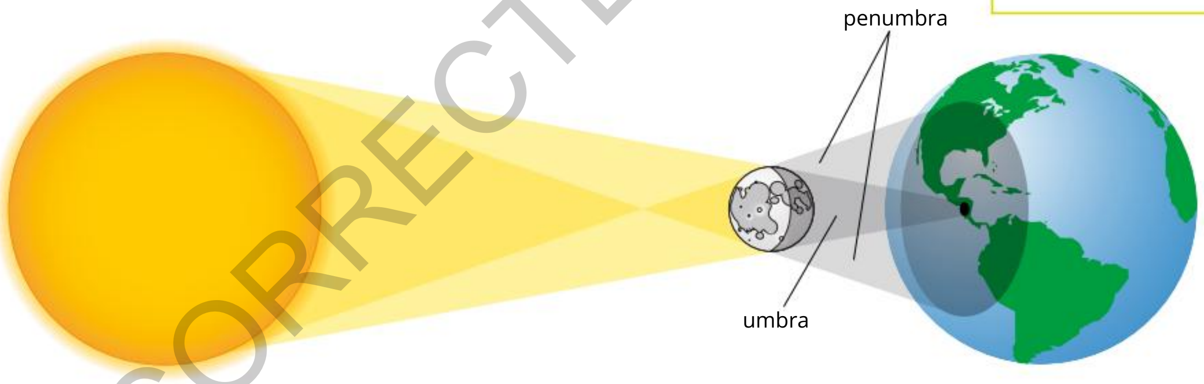



**FIGURE 2.4.1** The shadow of the Moon on Earth has a darker area where all light from the Sun is blocked (umbra) and lighter areas where some of the light from the Sun is blocked (penumbra).

## Partial solar eclipse

During a partial solar eclipse, the Sun is only partly covered by the Moon (Figure 2.4.2). Only the outer part of the Moon's shadow, the penumbra, is cast over part of Earth's surface. Part of the Sun is covered by the Moon and the Moon's penumbra falls on Earth.

**FIGURE 2.4.2** A partial eclipse during sunrise

## Total solar eclipse

During a total solar eclipse, the Sun is completely blocked by the Moon (Figure 2.4.3). The sky darkens and the Sun cannot be seen. Only the glow of the Sun's outer atmosphere (the corona) is visible. A total solar eclipse can only be seen from the part of Earth that is in the path of the Moon's umbra – the dark shadow directly behind the Moon.

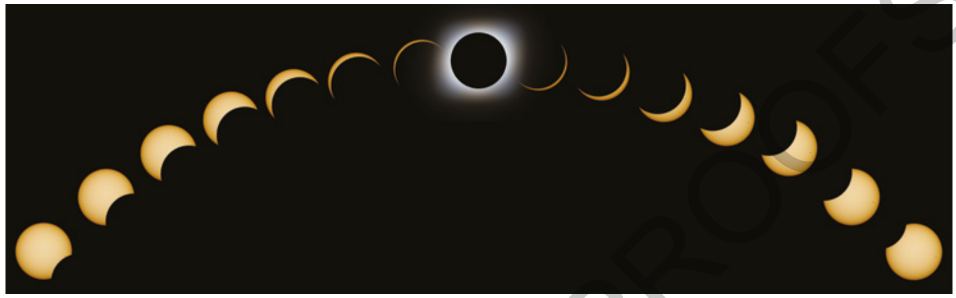


**FIGURE 2.4.3** A time series of the full progression of a total solar eclipse beginning and ending with partial eclipses and reaching a total eclipse in the middle

## Annular solar eclipse

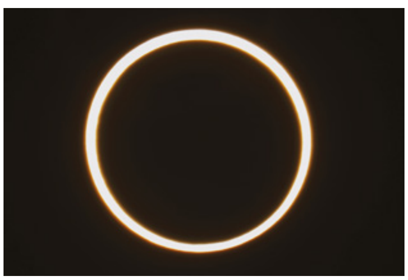


**FIGURE 2.4.4** An annular eclipse

The word annular comes from the Latin word for ring. During an annular solar eclipse, the Moon moves directly in front of the Sun, but the Moon doesn't completely cover the Sun (Figure 2.4.4). The Moon appears as a smaller disk over the top of the disk of the Sun.

An annular solar eclipse happens when the Moon is at its farthest point from Earth during its orbit. The Moon's orbit is an ellipse (oval-shaped) so it can be slightly closer or farther from Earth depending on where it is in its orbit. When the Moon is farther away, it appears smaller in the sky and doesn't completely cover the Sun.

## Solar eclipse safety

**FIGURE 2.4.5** You can view the Sun safely using eclipse glasses

Safety is an important consideration when viewing a solar eclipse. Looking directly at the Sun can cause eye damage, so always view the Sun through a filter, such as eclipse glasses (Figure 2.4.5), or a projection like a pinhole camera.

**SC 1 CHECK YOUR UNDERSTANDING**

What are the different types of solar eclipses?

**SC 2** I can describe the relative positions of Earth, the Moon and the Sun during a solar eclipse

## When the Sun, the Moon and Earth align

A solar eclipse can only occur when the Sun, the Moon and Earth are aligned, with the Sun and Earth on opposite sides of the Moon (Figure 2.4.6). This formation only occurs about once a month during the new moon phase. A new moon occurs every moon cycle.


**FIGURE 2.4.6** The Moon must be directly between the Sun and Earth to cause a solar eclipse

## The Moon's tilted orbit

Solar eclipses can only occur during the new moon phase, but they do not happen every new moon. This is due to the shape of the Moon's orbit around Earth. The Moon's orbit is slightly tilted at about 5° to the plane of Earth's orbit (Figure 2.4.7). Recall that this tilt of the lunar orbit is also responsible for lunar eclipses not occurring every full moon.

As Earth and the Moon travel around the Sun, the tilt of the Moon's orbit changes direction relative to the Sun. During the Moon's orbit, the Moon may be slightly above or below Earth during the new moon phase, so the Moon's shadow won't fall on Earth.

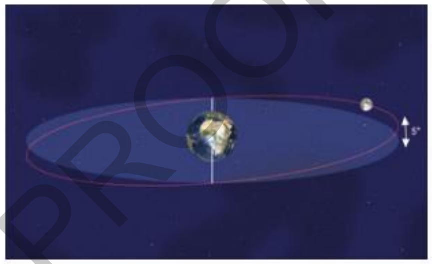


**FIGURE 2.4.7** Solar eclipses do not happen often due to the tilt of the Moon's orbit

## Geometry of a solar eclipse

A partial eclipse is observable by someone on Earth if they are located within the penumbra shadow (Figure 2.4.8). A total eclipse is observable from Earth if someone is located within the umbra. Any locations that are not in the path of the Moon's shadow will not see a solar eclipse at all. On average, there are two to five solar eclipses each year. Whether you can see the eclipse depends on where you are on Earth.

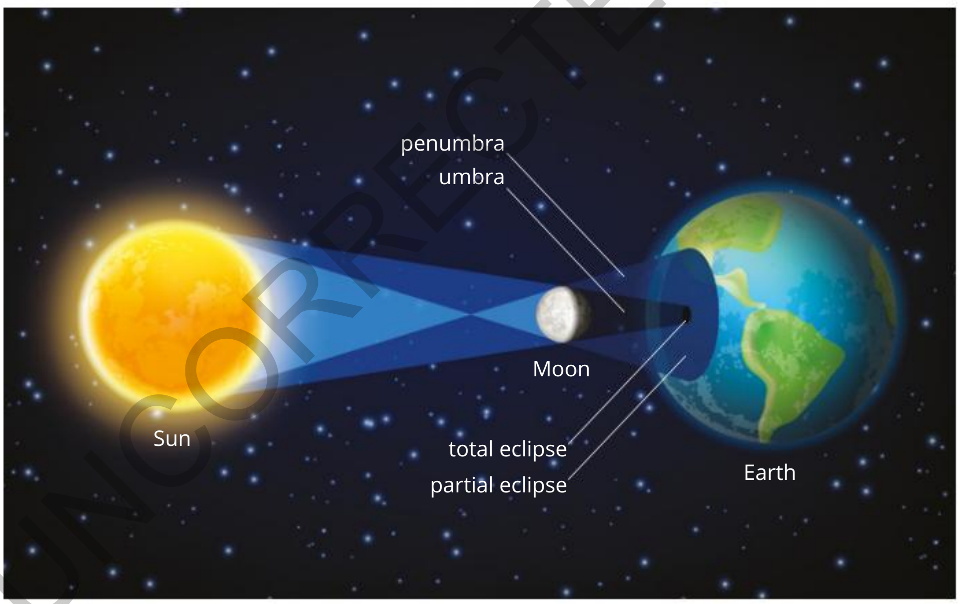



**FIGURE 2.4.8** The image is a view from space of the umbra and penumbra during a solar eclipse

**SC 2 CHECK YOUR UNDERSTANDING**

Explain how the alignment of Earth, the Moon and the Sun causes a solar eclipse.

**SC 3** I can explain, using a two- or three-dimensional representation, how the Moon casts a shadow on Earth during a solar eclipse

## Modelling a solar eclipse

Using a model is a helpful way to understand why a solar eclipse occurs.

A solar eclipse is not always visible because solar eclipses:

- only occur a couple of times a year
- can only be viewed from places on Earth in the path of the Moon's shadow
- can only be viewed when the sky is clear.

Creating a model allows you to visualise how a solar eclipse might look from space or on Earth at any time. A model of a solar eclipse should include representations of the Sun, Earth and the Moon.

In the model shown in Figure 2.4.9 the eye of the observer represents Earth. This model only shows how the light from the Sun is blocked by the Moon.

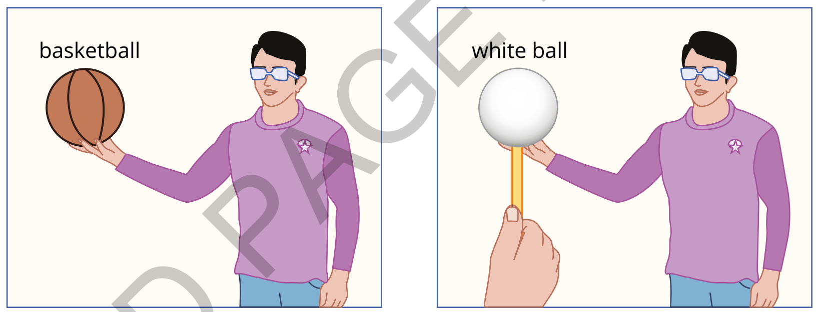



**FIGURE 2.4.9** This model shows how the white ball (Moon) can block the light of the Sun (basketball)

## Scale

When making a model, the elements are ideally made to scale (that is, the right sizes and distances in relation to each other), but this is not always practical. When making 2D or 3D models of Earth, the Sun and the Moon, the sizes and distances of the objects are too extreme to be made to scale.

In a solar eclipse model, it is most important to ensure:

- the Sun is bigger than Earth
- Earth is bigger than the Moon
- the Moon is closer to Earth than it is to the Sun.

Altering the distance between your eye (Earth) and the Moon can make this model simulate an annular or partial eclipse.

**SC 3 CHECK YOUR UNDERSTANDING**

Describe features of a solar eclipse that would be more clearly shown by a 2D diagram rather than a 3D model.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

**1** Describe what is seen of the Sun during a total solar eclipse?

**2** Think about why the Sun is obscured during a solar eclipse.

- **a** Why does the Sun become obscured during a total solar eclipse?
- **b** How does the Moon's position affect the Sun's appearance during an eclipse?
- **c** Explain the difference between a partial and a total solar eclipse.

**3** Compare the positions of Earth, the Moon and the Sun during a solar eclipse and a lunar eclipse.

**4** Consider the shadows cast during a solar eclipse.

- **a** How does the umbra of a solar eclipse differ from the penumbra?
- **b** Describe the appearance of the Sun when viewed from the umbra of the eclipse.

**5** Imagine creating a three-dimensional model of a solar eclipse.

- **a** What objects would you use to represent Earth, the Moon and the Sun?
- **b** How would you position these objects to show a solar eclipse?
- **c** What steps would you take to demonstrate the transition from penumbra to umbra?

# 2.5 Phases of the Moon

**Learning intention**

To be able to create and use a model to describe the phases of the Moon

**Success criteria**

**SC 1:** I can select appropriate materials to create a model that demonstrates the phases of the Moon.

**SC 2:** I can use a model to communicate an understanding of the phases of the Moon.

**SC 3:** I can evaluate a model that represents the phases of the Moon.

## Introduction

In the field of science, a model can be a representation of ideas, objects or processes that occur in real life.

In this practical investigation you will create a model to represent the position of the Moon in relation to Earth and the Sun to understand why different phases of the Moon are visible from Earth.

## Background

The Moon does not emit light, but it reflects light from the Sun. From Earth, the appearance of the Moon changes because different portions of the Moon are illuminated by the Sun at different times during the Moon's orbit around Earth. The changes in the appearance of the Moon are called phases.

This investigation uses a model of the Moon, the Sun and Earth to investigate the relationship between the position of the Moon in relation to Earth and the Sun, and the appearance of the Moon as seen from Earth.

## Aim

To model the movement of the Moon in relation to the Sun and Earth to understand why Moon phases occur.

## Plan

Write a list of materials that you will use for your investigation. You will need items to represent Earth, the Moon and the Sun in space and a way to record what you see.

**HINT**

You can use your own head to represent Earth.

You will need a light source to represent the Sun.

If you can place the item that represents the Moon on a stick it will be easier to see.

### Assessment of risk

Ensure you are aware of the risks of this inquiry activity and have considered how safety can be improved before carrying out the activity.

**SAFETY NOTE**

- When using light bulbs, be aware that they can get very hot.

## Design

1. Place your light source, or 'Sun,' on a table or desk that you can stand nearby.
2. Turn on your 'Sun' (light source).
3. Darken the room as much as you can.

**HINT**

Copy the results table into your notebook or construct a digital table in which you can add photos.

## Conduct

1 Face toward the 'Sun' and hold your 'Moon' out in front of you.

2 Record the amount of light you can see on the side of the 'Moon' that faces you in this position – Position 1 in your table. You can take a photo or complete a drawing.

3 Slowly start turning clockwise on the spot (to your right) and stop when you have turned $\frac{1}{8}$th of the way around.

4 Record the amount of light you can see on the side of the 'Moon' facing you in this position.

5 Continue turning clockwise and stop every $\frac{1}{8}$th of a turn to record the amount of light you can see on the side of the 'Moon' facing you in each position.

### HINT

Remember your head is 'Earth'.

## Results

Record your results in your copy of this table.

| | Position | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| View of the 'Moon' | | | | | | | | |

## Discussion

1 Name each of the objects used in the experiment to represent the Sun, Earth and the Moon and explain why each was used.

2 Explain the purpose of using a model in this experiment.

## Improve

Consider limitations of the model and any changes you could make to give a more accurate representation of the real system in space.

## Conclusion

Write your conclusion to this investigation. Include answers to the following questions.

1 What happened to the amount of light you could see on the 'Moon' between position one and position five?

2 What happened to the amount of light you could see on the 'Moon' after position five?

3 How would you describe the relative position of 'Earth,' the 'Moon' and the 'Sun' at position five?

4 Compare the results of position three and position seven and describe what you observed.

5 Figure 2.5.1 shows a 2-D visual model of the phases of the Moon and relative positions of Earth, the Sun and the Moon. The phases of the Moon are labelled. Match the phases in the image with each position of the 'Moon' from your experiment and identify each phase for positions one to eight.

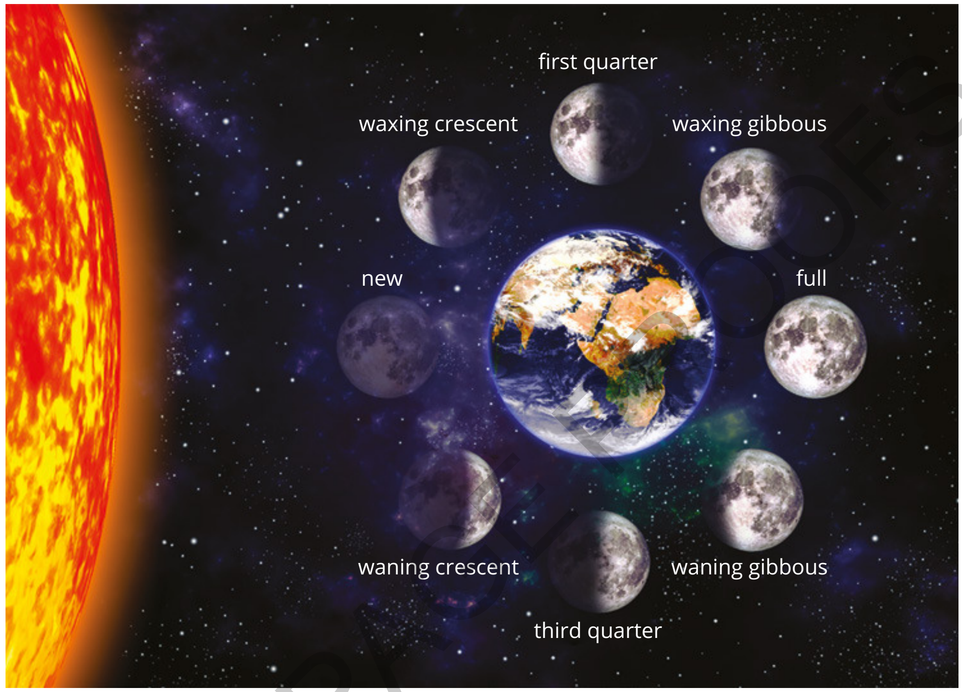



**FIGURE 2.5.1** The phases of the Moon depend on the location of the Moon with respect to Earth and the Sun

# 2.6 Tides

## Lesson overview

If you put your towel close to the water's edge when spending a day at the beach, you may have to move it later in the day to stop your towel going under water (Figure 2.6.1). This is because of the changing tide; the level that the sea rises and falls over the course of a day. The changing tides are caused by the gravitational pull and the rotation of each of the Moon, Sun and Earth. In this lesson you will learn how the positions and interactions of Earth, the Sun and the Moon cause tides.

| | |
|---|---|
| **SC 1** | I can explain how the forces of gravitational attraction of the Moon and the Sun affect water in Earth's oceans |

**Learning intention**

To understand how the position of Earth and the Moon causes tides

**Success criteria**

**SC 1:** I can explain how the forces of gravitational attraction of the Moon and Sun affect water in Earth's oceans.

**SC 2:** I can explain the cause of neap and spring/king tides.


**FIGURE 2.6.1** Ocean tides cause dramatic changes in sea level

## The Moon's rotation

Just like Earth, the Moon rotates on an axis. However, the Moon's rotation is much slower than that of Earth. It takes the Moon just over 27 days to complete a full rotation on its axis whereas Earth's rotation takes place in one day, or 24 hours.

## The Moon's orbit

The Moon orbits Earth as Earth orbits the Sun. The force of gravity between the Earth and the Moon keeps the Moon in this path. The Moon's orbit takes about the same time as its rotation. As the rotation and orbit time is the same, it results in the same side of the Moon always facing towards Earth. From Earth, it looks like the Moon is not spinning at all, but this is just because people on Earth only ever see one side of the Moon.

Figure 2.6.2 shows the Moon's orbit around Earth and its rotation on its axis. As the Moon orbits Earth, one side of the Moon continually faces Earth.

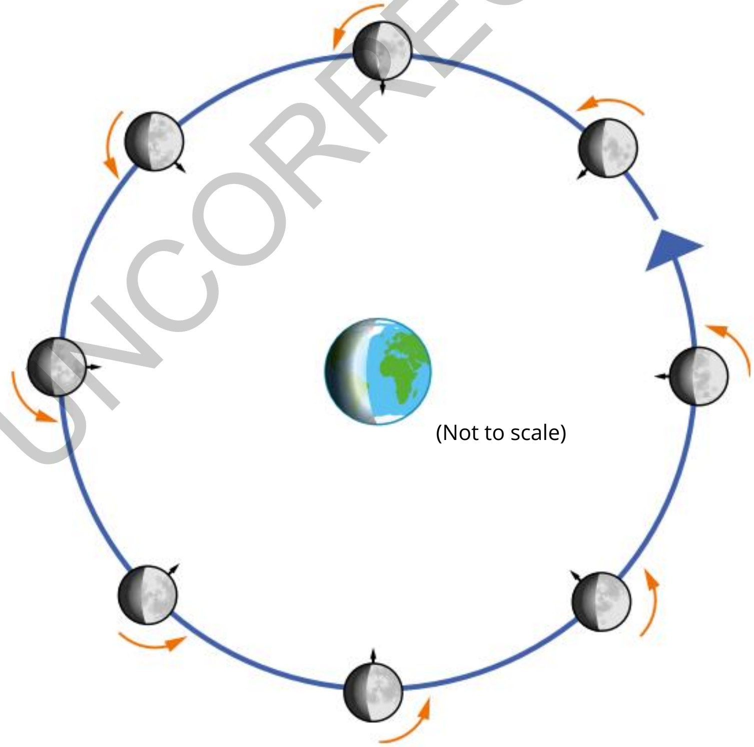



**FIGURE 2.6.2** During one orbit the whole surface of the moon spends time both in sunlight and in shadow so there is no dark side of the moon. An unrealistically large mountain is shown on the Moon to highlight how the Moon rotates as it orbits Earth.

**KEY TERMS**

**tide** the rising and falling of water levels in large bodies of water such as the ocean and lakes, caused by the gravitational pull of the Moon on Earth

**gravitational force** the force on an object due to gravity; can be described as the 'weight' of object

## High tide, low tide

**Tides** are the regular rise and fall of the level of the sea at a certain location. The sea reaches its highest level at the shore during high tide and falls to its lowest level at low tide. Figure 2.6.3 shows the same shore at high (left) and at low tide (right).

**FIGURE 2.6.3** High and low tide on a rocky shore

## Forces and tides

Tides are caused by the **gravitational forces** between Earth, the Moon and the Sun. The Sun and the Moon both exert a gravitational force on Earth. The Moon is much closer to Earth than the Sun, so the changes made to the oceans due to the Moon's gravitational pull are more noticeable. The effect of the Moon's gravity on Earth's oceans changes with location and time of day as Earth rotates on its axis.

## Ocean bulges

The gravitational force of the Moon acts on the whole Earth – water and land. Water is fluid, so it is more easily moved by gravity than solid masses of land. The Moon's gravitational force is strongest at the side of Earth facing the Moon. Water is pulled toward the Moon causing the water in oceans on the side of Earth nearest the Moon to bulge outward (a high tide).

There is also a bulge (high tide) in the ocean on Earth's surface on the side opposite the Moon. The Moon's gravitational force is weakest at that point. Earth's surface hasn't been pulled as close to the Moon here as on the side closest to the Moon.

## Frequency of tides

Most coastal areas on Earth experience two tidal cycles per day, two high tides and two low tides. A location on Earth experiences a high tide bulge once when the location is closest to the Moon and again when it is furthest away from the Moon (Figure 2.6.4).

Between each high tide, a location will experience a low tide. High tide and low tide are not at the same time each day at the same location. This is because the length of a full tidal cycle is slightly longer than a day (about 24 hours and 50 minutes).

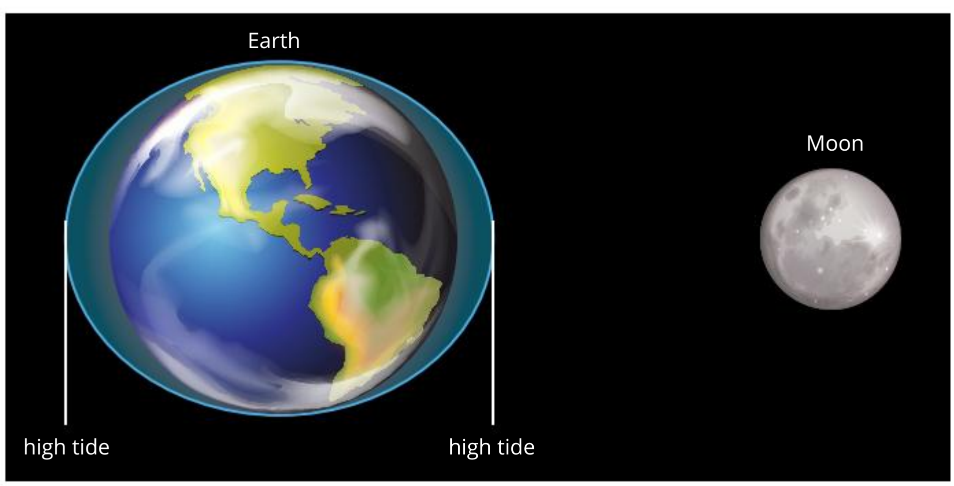



**FIGURE 2.6.4** Two high and two low tides occur each day as Earth rotates on its axis, caused by gravitational force of the Moon

**SC 1 CHECK YOUR UNDERSTANDING**

Consider the causes of tides.

a How does the Moon's gravity create tides?

b Describe the effect of the Sun's gravity on tides.

**SC 2** I can explain the cause of neap and spring/king tides

## Interaction of the Sun and the Moon

The Moon's gravitational force creates bulges of water on each side of Earth causing **lunar** tides. The Sun also exerts a gravitational force on Earth's water, causing bulges or **solar** tides. The Sun's gravitational pull is only about half as strong as the Moon's because even though it is much more massive, the Sun is so much farther away from Earth.

When Earth, the Sun and the Moon are aligned in space, the gravitational forces of the Sun and the Moon are combined causing more extreme bulges. This results in extreme high and low tides called spring tides. When the positions of the Sun, Earth and the Moon form a right angle, their gravitational forces counteract each other, resulting in moderate tides called neap tides.

**KEY TERMS**

**lunar** related to the Moon
**solar** related to the Sun
**new moon** the phase of the moon where most of the moon seen from Earth is not illuminated by the Sun and only a very thin crescent of the moon's illuminated surface can be seen
**full moon** the phase of the Moon when the whole of the Moon seen from Earth is illuminated by the Sun

## Spring tide

Spring tides, or king tides, occur twice a month when the Moon lines up with Earth and the Sun (Figure 2.6.5). This happens during a **new moon**, when the Moon is positioned between Earth and the Sun, and during a **full moon**, when Earth is positioned between the Sun and the Moon. The combined gravitational forces of the Sun and the Moon cause greater changes in ocean levels: higher high tides and lower low tides. A spring tide is not related to the season spring; its name refers to the *springing forth* of the tide.

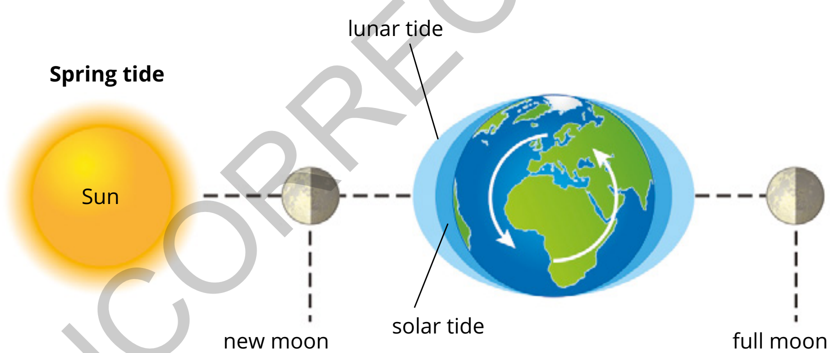



**FIGURE 2.6.5** Spring tides occur at full and new moons; at these times, the gravitational attraction of the Sun and the Moon combine to increase the difference between low and high tide

## Neap tides

During the periods between spring tides, neap tides occur. Neap tides happen about seven days after spring tides, twice a month when the gravitational attraction of the Moon and the Sun act at right angles to each other (Figure 2.6.6).

This occurs when the Moon is either in its first or third quarter and the gravitational forces of the Moon and the Sun are working in different directions. The opposing forces of the Sun and the Moon cause less change in ocean levels and a smaller difference between high and low tide.

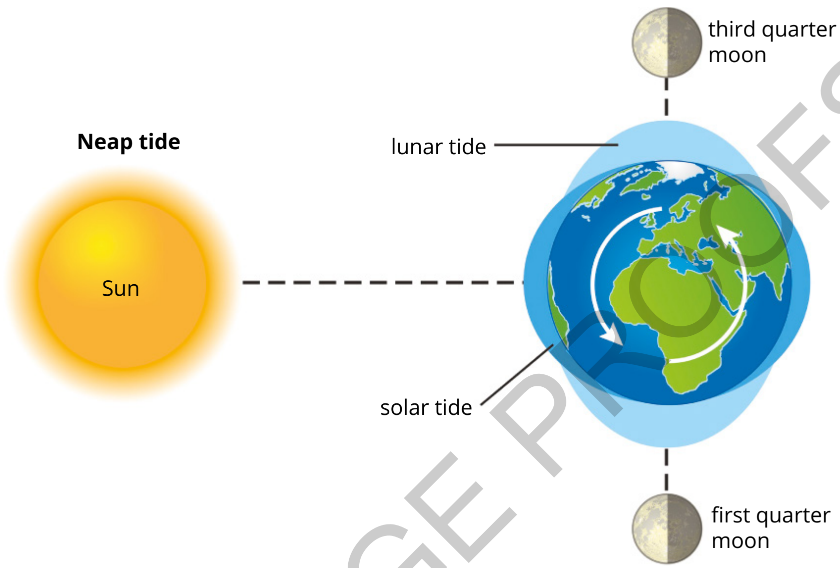



**FIGURE 2.6.6** Neap tides occur when the Moon's gravity pulls at right angles to the Sun's

### SC 2 CHECK YOUR UNDERSTANDING

Consider the types of tides.

a What are spring tides and when do they occur?

b Describe the conditions that lead to neap tides.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 Compare the Moon's rotation and orbit around Earth with Earth's rotation and orbit around the Sun.

2 Describe what you would observe if the Moon did not rotate on its axis.

3 Compare the size of the Moon's gravitational force that acts on Earth's oceans to cause the tides, to that of the Sun. Include how distance and mass affect the size of the force acting.

4 Explain why neap tides are less extreme than spring/king tides.

# 2.7 First Nations use of astronomy

## Lesson overview

First Nations Australians have rich traditions and stories that explain the phases of the Moon and the tides, identify weather events and predict plant and animal behaviour.

These accounts are not only culturally significant but also align with mainstream scientific explanations.

In this lesson, you will explore these accounts and compare them with scientific explanations.

**Learning intention**

To understand the use First Nations Australians' observations of space and how they compare with mainstream scientific explanations

**Success criteria**

**SC 1:** I can describe First Nations Australians' accounts of the Moon's phases and tides.

**SC 2:** I can compare First Nations Australians' accounts of the Moon's phases and tides with mainstream scientific explanations.

**SC 3:** I can explain how First Nations Australians use observations of stars to identify specific seasonal changes and predict weather events.

**SC 1** I can describe First Nations Australians accounts of the Moon's phases and tides

First Nations Australians have a profound connection to the natural world, and their cultural stories often reflect their observations of celestial events. These stories are passed down through generations and serve as a way to explain natural phenomena. The phases of the Moon and the behaviour of the tides are two such phenomena that are richly described in First Nations Australians' accounts.

The Yolngu people of Arnhem Land, for example, have a story about the Moon being a man named Ngalindi. Ngalindi was punished by his wives for being lazy, and he gradually wasted away, which explains the phases of the Moon. When Ngalindi is full and strong, it is the full Moon. As he weakens, the Moon wanes (decreases in brightness) until it disappears, representing the new Moon.

The Yolngu also have stories about the tides. High tides fill the moon as it rises, and then when water drains out of the moon the tides fall. This process of filling the moon repeats with the next high tide. These stories reflect their observations of the natural world and their understanding of the Moon's connection to the tides.

Other First Nations groups have similar stories. The Boorong people of Victoria have a story about the Moon being a man named Mityan. Mityan was a hunter who was banished to the sky for his misdeeds and is still on the run with no fixed place.

**SC 1 CHECK YOUR UNDERSTANDING**

Describe how the Yolngu people explain the phases of the Moon.

## SCIENCE IN CONTEXT

### Cultural astronomy

Cultural astronomy is the study of how different cultures understand and use the sky. First Nations Australians have a rich tradition of cultural astronomy. They use the stars, Moon, and Sun for navigation, to mark the seasons, and to tell stories. These stories are passed down through generations and are an important part of their cultural heritage.

For example, the Wiradjuri people of New South Wales have stories about the Emu in the Sky. The Emu is formed by the dark patches of the Milky Way. When the Emu is seen lying down in the sky, it is time to collect emu eggs. This story reflects their deep understanding of the sky and its cycles.

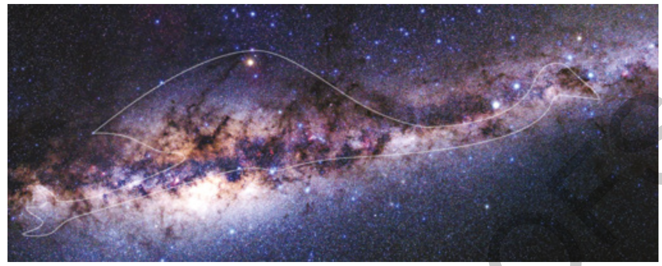


**FIGURE 2.7.1** This area of the Milky Way has a distinctive shape that has been described in Australian Aboriginal astronomy as The Emu. The head of the emu is the Coalsack with the Southern Cross directly above.



**SC 2** I can compare First Nations Australians accounts of the Moon's phases and tides with mainstream scientific explanations

## Mainstream scientific explanations of the Moon's phases and tides are based on observations and evidence

The phases of the Moon are caused by its position relative to Earth and the Sun. As the Moon orbits Earth, different portions of its surface are illuminated by the Sun, creating the phases. When the Moon is between Earth and the Sun, we see the new Moon. When Earth is between the Sun and the Moon, we see the full Moon. The first and third quarters occur when the Moon is at a right angle to the Sun and Earth.

The tides are caused by the gravitational pull of the Moon and the Sun on Earth's oceans. When the Moon is full or new, its gravitational pull is strongest, causing higher tides known as spring tides. When the Moon is in its first or third quarter, its gravitational pull is weaker, causing lower tides known as neap tides.

Comparing these mainstream scientific explanations with First Nations Australians accounts reveals similarities. Both explanations recognise the Moon's influence on the tides and the changing appearance of the Moon. The stories of Ngalindi and Mityan reflect observations of the Moon's phases, while the understanding of spring and neap tides aligns with scientific explanations.

**SC 2 CHECK YOUR UNDERSTANDING**

Compare the Yolngu explanation of the tides with the scientific explanation.

**SC 3** I can explain how First Nations Australians use observations of stars to identify specific seasonal changes and predict weather events.

## Light from stars

When light from stars enters the Earth's atmosphere, winds and variation of temperature and density of the atmosphere can all affect it. Twinkling is the result of the light from a star traveling to us through more than one path, this is caused by the light bending when it enters the atmosphere. This is why observing light from stars can provide evidence for changes in the atmosphere, which are very often linked to seasonal variations and changes to the weather. (Figure 2.7.2)

**FIGURE 2.7.2** Changes to the appearance of stars, including twinkling, can be caused by changes to the Earth's atmosphere, which often indicate current or future seasonal changes.

## Seasonal changes and weather events

One example is the Wiradjuri People of New South Wales have used the sky to predict rainfall along the Murrumbidgee River. They observed the colour, brightness, and twinkling of stars to know when rain was likely to come. When the stars appeared to twinkle more than usual, it was a sign that rain was on the way. The Meriam People of the Torres Strait Islands also use the twinkling of stars to predict the change from the hot season to the wet season. An increase in moisture and windspeed in the atmosphere can cause certain stars to twinkle more rapidly and appear jagged. This helps the community get ready for the wet season, which can bring heavy rains and strong winds.

## Regular Appearance of Stars

The Pitjantjatjara People of Central Australia use the appearance of a particular star cluster, known as the Pleiades or Seven Sisters (Figure 2.7.3), to predict when winter frost will begin. When this star cluster rises in the early morning sky, it is a sign that the cold season is starting.

**FIGURE 2.7.3** The Pleiades star cluster, also known as the Seven Sisters can be used to predict the coming of the cold season.

Torres Strait Islander Peoples also use the appearance of the yam star, called Kek, to know when to harvest yams. When this star appears in a certain part of the sky, it is the right time to dig up yams, which are an important food source.

**SC 3 CHECK YOUR UNDERSTANDING**

Explain how the twinkling of stars can help Aboriginal or Torres Strait Islander Peoples predict a change in the weather.

# Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 Name the Yolngu story that explains the phases of the Moon.

2 Explain how the Boorong people describe the phases of the Moon.

3 Describe the scientific explanation for spring tides.

4 Compare the Yolngu explanation of the Moon's phases with the scientific explanation.

5 Explain how the scientific understanding of the Moon's phases can help predict the best times for fishing.

6 Compare how the Pitjantjatjara People and the Meriam People use the stars to predict environmental changes.

# 2.8 Seasons

## Learning intention

To understand how the position and motion of Earth causes seasons

## Success criteria

**SC 1:** I can explain why different parts of Earth experience different seasons at different times of the year.

**SC 2:** I can explain why Earth's tilt on its axis causes different light intensities on different parts of Earth at times.

**SC 3:** I can predict the season at a particular place on Earth based on Earth's tilt relative to the Sun.

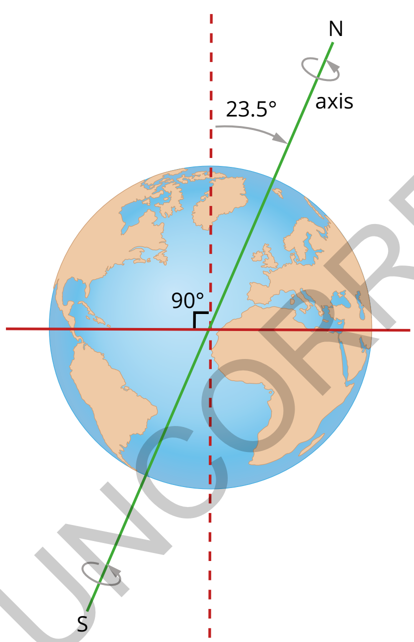



**FIGURE 2.8.2** Earth's axis is tilted in space at a fixed angle of 23.5°.

## Lesson overview

As **seasons** change there are changes in the lengths of day and night, temperature, weather patterns and the environment (Figure 2.8.1). The seasons are caused by the movement of Earth in space throughout the year. Different seasons are recognised in different ways, in different places on Earth. In this lesson you will learn how Earth's motion and position in space causes seasonal changes.

**FIGURE 2.8.1** The same tree during all four seasons

**SC 1** I can explain why different parts of Earth experience different seasons at different times of the year

## Earth's axis

Each day Earth completes a full rotation on its axis – the imaginary line through the North and South poles. Figure 2.8.2 shows how **Earth's axis** is not completely upright; it is tilted at an angle of about 23.5° with the axis always pointed in the same direction in space.

This tilt means that Earth travels around the Sun at an angle, so the way sunlight reaches different places on Earth changes throughout the year. As Earth completes an orbit around the Sun, either the Northern or Southern Hemisphere becomes tilted toward the Sun (Figure 2.8.3). The part of Earth that is tilted toward the Sun receives more direct sunlight and longer hours of daylight. Meanwhile, the part of Earth tilted away from the Sun receives less direct sunlight and shorter hours of daylight.

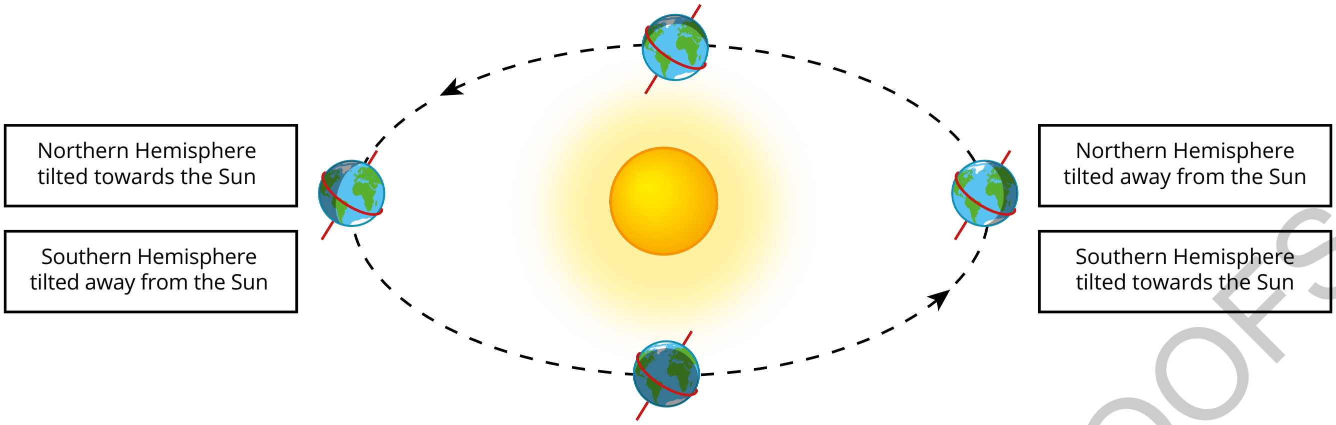



**FIGURE 2.8.3** Earth's seasons are caused by its orbit and the tilt of its axis of rotation.

Throughout the year, the times of sunrise and sunset change because of Earth's relative position to the sun. The day that has the most amount of daylight is called the summer solstice and occurs on or near December 21 each year. The day with the least amount of daylight is the winter solstice and occurs six months after the summer solstice in late June. In between these dates are two days when the length of day and night are the same: these are the equinoxes.

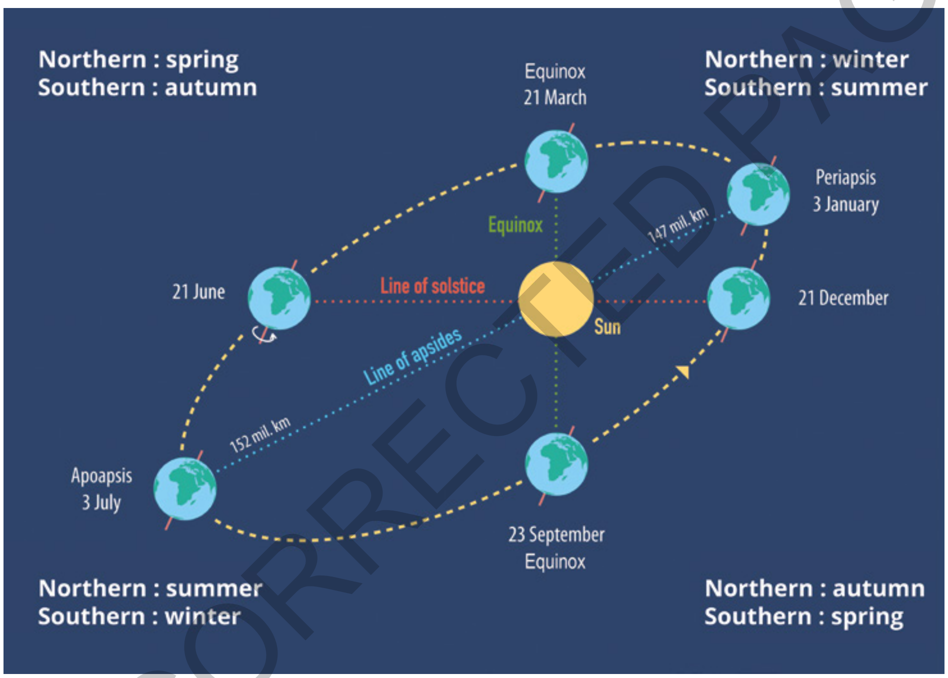



**FIGURE 2.8.4** Earth's elliptical orbit with solstice, equinox and change of seasons in the Northern and Southern Hemispheres

If Earth's axis were not tilted and Earth travelled around the Sun in an upright position, there would be no seasonal changes on Earth because light would reach each place on Earth in the same way all year round. It is important to remember that Earth's seasons are not caused by changes in distance to the Sun. If seasons were caused by the proximity of Earth to the Sun, then both hemispheres would experience the same season at the same time.

**KEY TERM**

**seasons** on Earth, summer, autumn, winter and spring; caused by the tilt of a planet's axis

## Earth's seasons

Changes in weather, temperature and daylight are noticeable throughout the year. These changes occur regularly each year and are known as **seasons**. Depending on where you live, you probably recognise the seasons as summer, autumn, winter and spring, with summer being the hottest season with the longest daylight hours and winter being the coldest season with shortest daylight hours. The seasonal changes that a location on Earth experiences depends on that place's position in relation to the Sun's rays.

## Seasons in Australia

Australia is in the Southern Hemisphere. When the Southern Hemisphere is tilted toward the Sun, the Southern Hemisphere experiences summer (Figure 2.8.5). Summer in Australia occurs between December and February. At the same time, the Northern Hemisphere is tilted away from the Sun and experiences winter. So, if you were to visit North America during the Australian summer holidays, then you would need to pack warm clothes for winter.

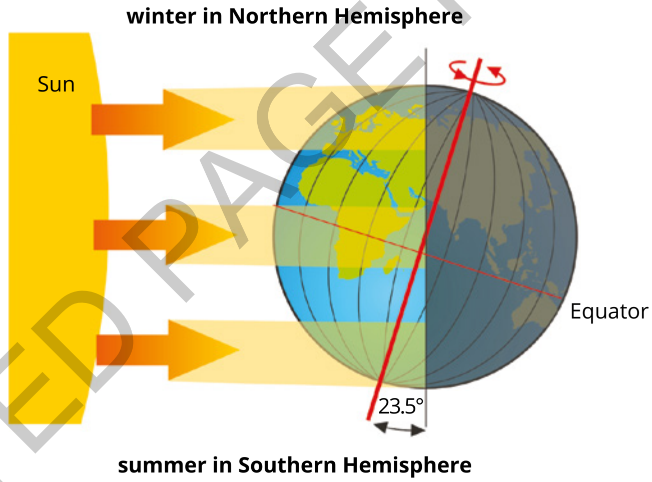



**FIGURE 2.8.5** Earth's position during Southern Hemisphere summer and Northern Hemisphere winter.

When the Southern Hemisphere is tilted away from the Sun, the Southern Hemisphere experiences winter (Figure 2.8.6). Winter in Australia occurs between June and August. At the same time, the Northern Hemisphere is tilted toward the Sun and experiences summer.

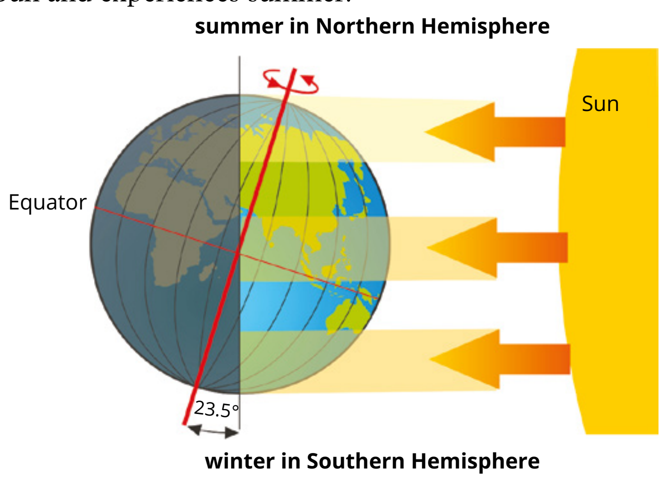



**FIGURE 2.8.6** Earth's position during Northern Hemisphere summer and Southern Hemisphere winter

Spring is the season that follows winter and is caused by the changing orientation of Earth's tilt toward the Sun. In spring, the hours of daylight and temperature begin to increase.

Autumn is the season that follows summer and is caused by the changing orientation of Earth's tilt away from the Sun. In autumn the hours of daylight and temperature begin to decrease.

**SC 1 CHECK YOUR UNDERSTANDING**

Explain why it is summer in Australia when it is winter in the Northern Hemisphere.

**SC 2** I can explain why Earth's tilt on its axis causes different light intensities on different parts of Earth at times

## Energy from the Sun

The Sun provides Earth with most of its energy. Solar energy from the Sun reaches Earth as light and heat.

Not all parts of Earth receive the same amount of solar energy. The amount of solar energy that a particular location receives also changes throughout the year.

## Direct and indirect sunlight

Earth receives more solar energy near the **equator** than at Earth's poles. Because Earth is round, sunlight strikes Earth more directly at the equator, specifically at an angle close to 90°. Sunlight strikes Earth at the poles indirectly, or at a much lower angle. These parts of Earth receive less solar energy.

From the equator towards the poles, sunlight reaches Earth at lower and lower angles and the amount of solar energy received decreases. This is shown in Figure 2.8.7. The amount of solar energy received at each pole also changes depending on which hemisphere is tilted toward or away from the Sun.

**KEY TERM**

**equator** an imaginary horizontal line that divides Earth into the Northern and Southern Hemispheres

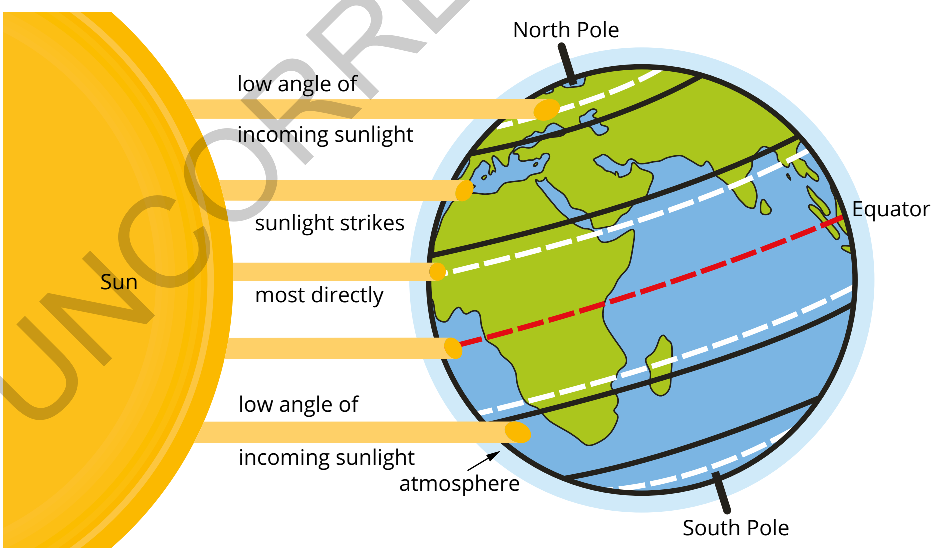



**FIGURE 2.8.7** Sunlight strikes Earth's surface at different angles at different positions on Earth.

## The angle of sunlight and Earth's tilt

The closer to 90° that a location on Earth is toward the Sun, the more direct sunlight, or the higher light intensity it receives. When the angle of sunlight is lower the amount of the Sun's energy reaching a location is spread over a larger area. This reduces light intensity and temperature (Figure 2.8.8).

The angle of sunlight in relation to a location on Earth varies throughout the year due to Earth's tilt and orbit. As Earth completes an orbit around the Sun, each hemisphere is tilted toward or away from the Sun for part of the year.

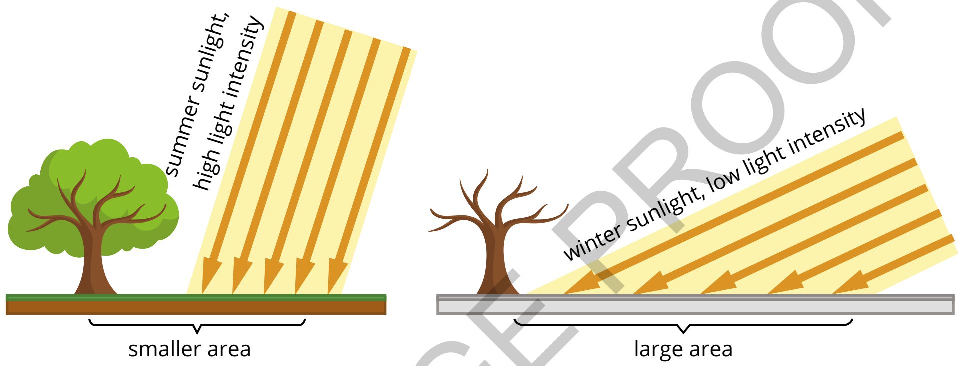



**FIGURE 2.8.8** The intensity of sunlight changes throughout the year due to Earth's tilt

## Light intensity and seasons

During winter, the angle of Earth's axis causes the Sun's rays to reach a location at a lower angle, resulting in lower light intensity. In contrast, during summer, the Sun's rays hit the same location at a more direct angle (closer to 90 degrees) which leads to higher light intensity.

The angle of the Sun's rays can be related to its position above the horizon at a specific place on Earth and at a specific time of day. At midday in summer, the Sun is high in the sky, and sunlight reaches Earth at a more direct angle. In contrast, at midday in winter, the Sun appears lower in the sky, and sunlight reaches Earth at a shallower angle. Light intensity is at its peak in summer, moderate in spring and autumn and lowest in winter (Figure 2.8.9).

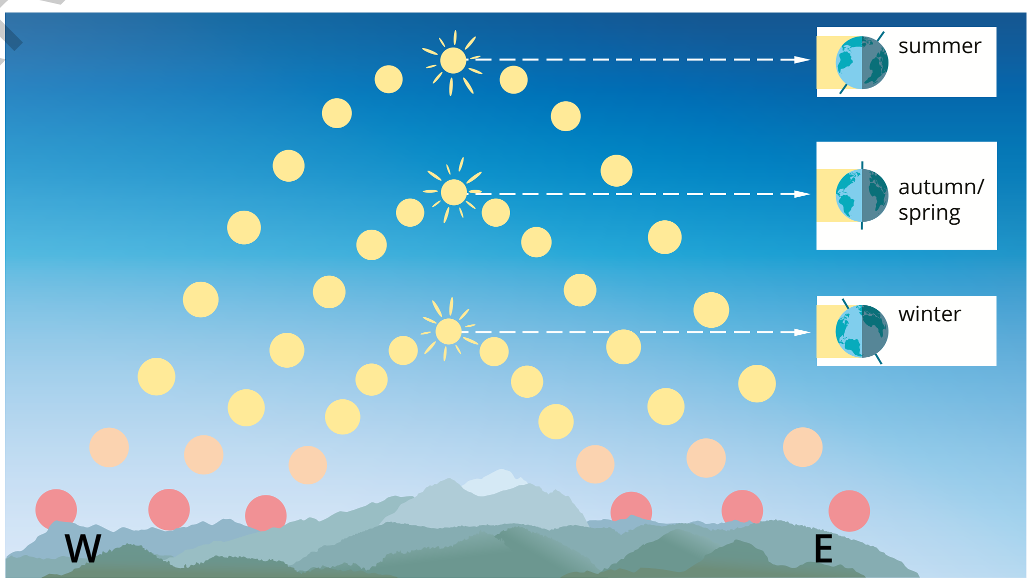



**FIGURE 2.8.9** The Sun is higher in the sky in summer and lower in winter, so the light from the Sun is more intense in summer and less intense in winter.

**SC 2 CHECK YOUR UNDERSTANDING**

Explain how Earth's tilt affects the intensity of sunlight received at different parts of Earth.

**SC 3** I can predict the season at a particular place on Earth based on Earth's tilt relative to the Sun

## Earth's tilt

In the tropics, around the Equator, every day of the year is similarly hot and there is little seasonal change. In the Arctic and Antarctica polar areas, every day is cold and there is some seasonal change. The most extreme seasonal changes are in the mid-latitudes between the poles and tropics. There are four seasons in these regions. The way in which a place experiences seasons depends on its latitude, which is its distance north or south from the equator (Figure 2.8.10).

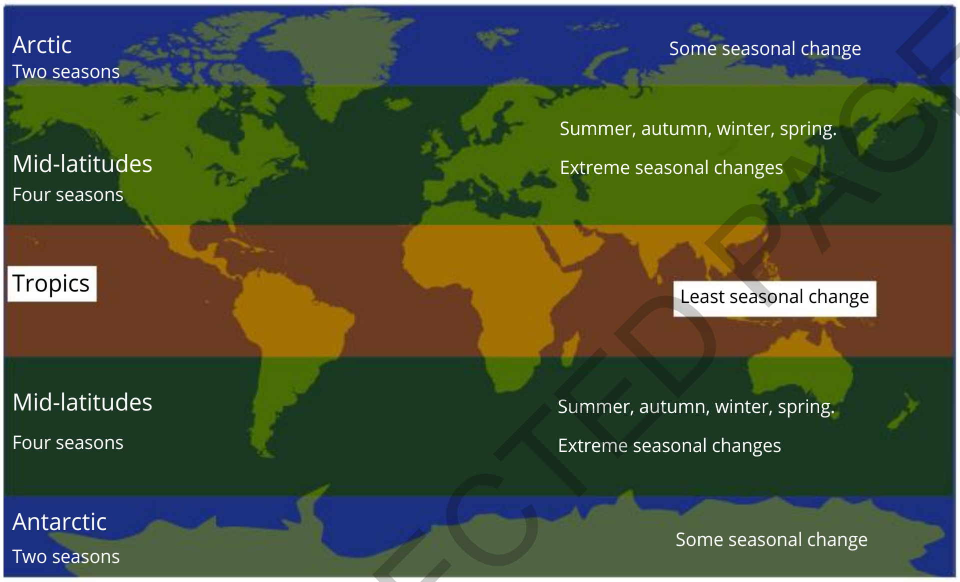



**FIGURE 2.8.10** The intensity of sunlight varies with latitude, and this determines how extreme seasonal changes are throughout the year

## At the equator

The tropical regions around the equator receive the most direct, intense sunlight all year round. Earth's tilt does not greatly change the angle at which sunlight reaches the equator. Here, temperature and day length don't change much throughout the year. The typical seasons of spring, summer, autumn and winter are not representative of the seasonal changes in this region. Seasons are more often characterised by changing levels of rainfall in alternating wet and dry seasons.

**Scifile**

### Solar panels

Solar panels work best when they are angled towards the Sun. By adjusting the angle to match the Sun's position, they can produce more electricity. This is why some solar panels can move.

## Mid-latitudes

Mid-latitudes are regions situated between the equator and the poles. These areas experience distinct seasons – summer, autumn, winter and spring – each marked by changes in day length, light intensity and temperatures (Figure 2.8.11).

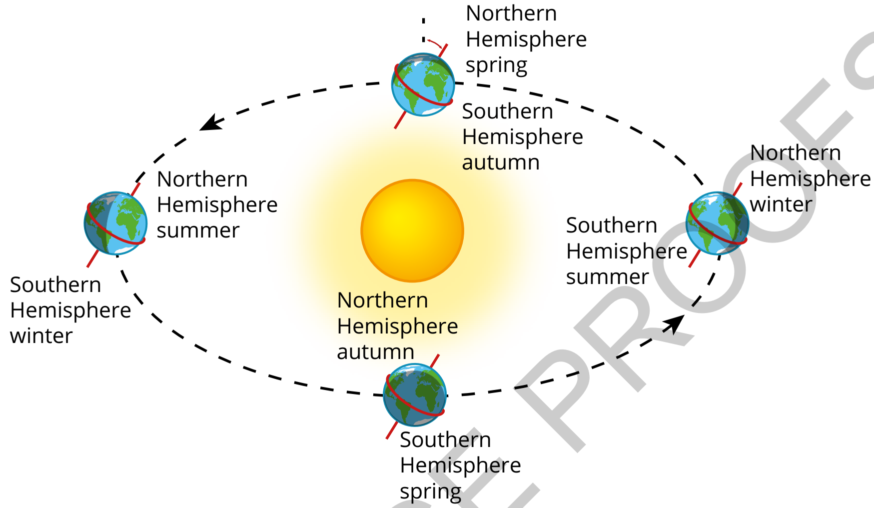



**FIGURE 2.8.11** The mid-latitudes experience the greatest variation in the intensity of sunlight so the seasons are most evident there

## At the poles

Polar regions, the Arctic in the Northern Hemisphere and Antarctica in the Southern Hemisphere, are dramatically affected by Earth's tilt and experience extreme changes in day length throughout the year. The polar regions only experience two seasons – winter and summer. Polar summers have less light intensity and lower temperatures than summers in the mid-latitudes.

When the North Pole is tilted toward the Sun in the middle of its summer, the Arctic experiences continuous sunlight because the Sun does not drop below the horizon. At the same time, at South Pole the Sun does not rise above the horizon and Antarctica experiences continuous darkness. So, in summer at the poles, the Sun does not set, and in winter the Sun does not rise. This situation is reversed six months later when it is winter in the Arctic and summer in the Antarctic.

Temperatures are always low throughout the year at both poles, even in summer, as the poles receive very little direct light, and sunlight strikes at a very low angle.

### SC 3 CHECK YOUR UNDERSTANDING

Identify the season in the Northern Hemisphere when:

a the Northern Hemisphere is tilted towards the Sun

b the Southern Hemisphere is tilted towards the Sun.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

**1** Consider the causes of Earth's seasons.

- **a** Explain how Earth's tilt affects the seasons.
- **b** Describe what happens to the seasons when Earth orbits the Sun.

**2** Compare the seasons experienced in the Northern Hemisphere to those in the Southern Hemisphere.

**3** If Earth's axis were not tilted, what would happen to the seasons?

**4** Compare light intensity at different latitudes.

- **a** How does the light intensity at the equator compare to that at the poles?
- **b** How does light intensity change with the seasons at mid-latitudes?
- **c** Figure 2.8.10 shows how the different latitude ranges experience differing seasonal patterns. Predict which latitude ranges will be most affected by rising global temperatures if the areas most affected will be those which experience the most direct sunlight.

# 2 Space science

## Topic summary

The key concepts included in this topic are:

- The current model of the solar system developed over time with contributions from many scientists
- The Moon orbits Earth, and both Earth and the Moon orbit the Sun.
- A lunar eclipse is caused by the Moon travelling through the shadow of Earth.
- A solar eclipse is caused by the Moon passing between the Sun and Earth.
- The gravitational pull of the Moon and Sun on Earth's oceans causes tides.
- The orbit of the Moon around Earth changes how much of the lit surface of the Moon you can see resulting in the phases of the Moon.
- Earth's axis is tilted. This means, as it orbits the Sun, one hemisphere is tilted towards the Sun, receiving more direct sunlight and experiences summer.



## Review questions

The following questions will assess your success in achieving the learning intentions for this topic.

### Remember

1 Outline the current model of the solar system.

2 What is the relationship between the Moon's rotation around its axis and the orbit of the Moon?

3 How are the positions of Earth and the Moon different during lunar and solar eclipses?

4 Write the name of the key phase of the Moon when:

a the Moon appears round

b the Moon cannot be seen from Earth.

5 Identify what causes different parts of Earth to experience different seasons.

### Understand

6 How does the length of day and night vary throughout the year in NSW?

7 Explain how the intensity of sunlight is responsible for a location on Earth experiencing summer and then winter six months later.

8 In what ways are scientific models and First Nations stories of the tides similar?

9 Plan how you could use a model to demonstrate the phases of the Moon.

### Apply

10 Describe how Earth's seasons would change if the north pole of Earth pointed directly facing the Sun in January, and then in July, Earth's south pole pointed directly facing the Sun.

11 How would Earth's tides be different if the Moon was much closer to Earth than it is?

### Analyse

12 Compare neap tides and spring tides in terms of their causes and effects.

**13** Kylie made a model to demonstrate an eclipse. Her model is shown below. Explain which type of eclipse this model would represent.


## Extension: Research

**14** Research and describe how the phases of the Moon affect nocturnal animal behaviour.

**15** How do architects in Australia design buildings and homes to improve building efficiency in relation to the seasonal positional changes of the Sun?

## Topic reflection

The learning intentions for this topic are given in each lesson and at the beginning of the topic. Consider how well you have achieved them. Note down any particular areas that you are confident in, and others where you are not so sure.

# 2 Glossary

**Earth's axis** the line connecting the North Pole with the South Pole; Earth rotates around this axis

**astronomer** a scientist who studies objects and events in space

**exoplanet** a planet that orbits a star other than our Sun: it is outside the solar system

**full moon** the phase of the Moon when the whole of the Moon seen from Earth is illuminated by the Sun

**gravitational force** the force on an object caused by gravity. can be described as the 'weight' of an object.

**gravity** a force of attraction between any two objects

**lunar** related to the Moon

**lunar phase** the appearance of the Moon from Earth as it changes over the course of a month

**Moon** a natural satellite that orbits Earth

**new Moon** the phase of the Moon when it is near the Sun in the sky and is very difficult to see since the side of the Moon facing Earth is not illuminated

**orbit** curved path a planet takes around a star, or that a Moon or artificial satellite takes around a planet; orbits can be circular or elliptical

**penumbra** less dense shadow of an eclipse

**planet** roughly spherical ball of rock or gas that orbit (move around) the Sun. they do not generate their own light.

**rotation** spinning motion of an object around a central line, called an axis of rotation

**seasons** on Earth, summer, autumn, winter, spring; caused by the tilt of a planet's axis

**solar** related to the Sun

**solar eclipse** when the Moon blocks Sunlight from reaching Earth

**solar system** the Sun and all the planets, satellites, asteroids, comets and other bodies revolving around it

**space** the immense and limitless area beyond Earth's atmosphere, containing stars, planets, galaxies, and other cosmic matter

**Sun** a massive, luminous ball of hot gas located at the centre of the solar system. it emits light, heat, and energy that reach Earth and other planets

**tide** the rising and falling of water levels in large bodies of water such as the ocean and lakes, caused by the gravitational pull of the Moon on Earth

**umbra** full, dark shadow of an eclipse

**weir** a low barrier built across a river which can be used to raise the level of water upstream and control the flow of the river

TOPIC 3

# Forces and simple machines

Forces can act when objects are in contact with each other, but some forces can act between objects that are not touching. Forces can cause objects to change speed, change direction or change shape. Examples of forces include gravity, friction and magnetism. Understanding how forces affect the motion of objects is essential for understanding the world around us.

In this topic, you will learn about the effect of different types of forces. You will learn how forces can be used, measured and represented, and how to predict their effects.

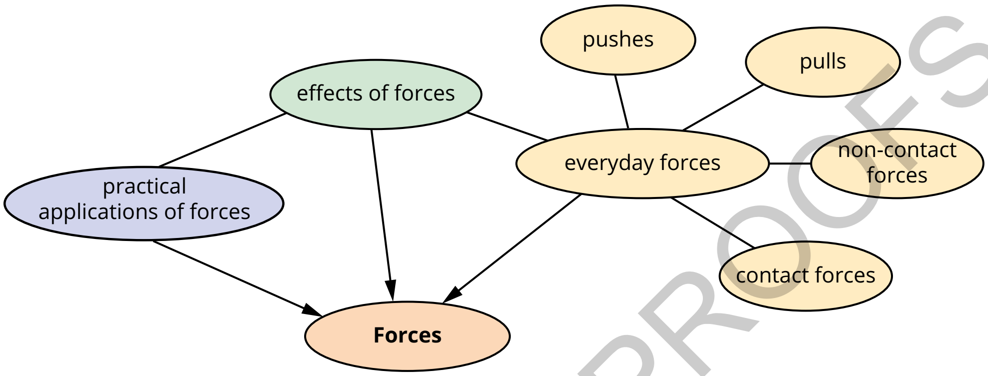


## Learning intentions

- ☐ To be able to identify forces and their effects on objects around us **xx**
- ☐ To understand that arrows can be used to represent the magnitude and direction of forces **xx**
- ☐ To understand that forces on an object can combine to result in balanced and unbalanced forces **xx**
- ☐ To be able to conduct an investigation on increasing or reducing frictional forces **xx**
- ☐ To understand how safety features help reduce the impact of forces **xx**
- ☐ To understand the cause and effects of gravitational fields **xx**
- ☐ To be able to investigate the effects of electrostatic forces **xx**
- ☐ To be able to conduct reproducible investigations to answer questions and test predictions **xx**
- ☐ To be able to observe and model the effects of magnetic fields **xx**
- ☐ To understand the forces involved in simple machines **xx**
- ☐ To understand how levers can change the magnitude or direction of a force **xx**
- ☐ To be able to analyse data to identify relationships between force and distance **xx**
- ☐ To be able to describe the use of simple machines by First Nations Australians **xx**
- ☐ To be able to design and construct a model of a simple machine **xx**

# 3 Forces and simple machines

The key concepts that you will use in this topic:




The following prior knowledge questions will help to support your learning in the topic and can be attempted before the first lesson.

## Everyday forces

1 A tennis ball is sitting on the ground at rest. Explain what will happen to the ball if a force pushes it to the right.

2 Dropped objects always fall towards the ground. Explain why gravity always makes objects fall 'down'.

3 If you push or pull on an object with your hand, you are applying a contact force. Magnetic forces on the other hand are considered non-contact forces.
   a Contrast contact and non-contact forces.
   b Identify whether gravity is a contact or non-contact force. Provide an example that supports your answer.

## Effects of forces

4 When a ball is rolled across the ground it will eventually come to a stop. Explain why this occurs.

5 Imagine walking on ice or a very slippery surface. Describe the presence of friction when walking on these surfaces.

## Practical applications of forces

6 Skydivers fall through the air quickly when they jump from the plane. Parachutes are used to slow their fall before they land. Explain why using a parachute reduces the speed of the skydiver.

7 When flying a kite, you need a steady breeze to keep it in the air. Using the words 'push' and 'pull':
   a describe the forces acting on the kite from the wind
   b describe the forces acting on the kite from the string
   c explain why these two forces act together to keep the kite in the air.

# 3.1 Introduction to forces and types of motion

## Introduction

There are many different types of forces that you see in action every day. Forces are a 'push' or 'pull', and may change the shape, speed or direction of travel of an object.

In this practical investigation, you will experience a range of forces, learn how to describe their effects and classify them as direct (contact) or indirect (non-contact) forces.

## Background

**Forces** act all around you, all the time. Whenever an object's shape or motion changes, you know that a force caused that change. The following section will help you describe changes in motion in this investigation.

### Speed and velocity

**Speed** is how fast an object is moving. **Velocity** is also how fast something is going. However, if you describe the velocity, you must also include the direction the object is travelling in.

### Acceleration

**Acceleration** is when an object is increasing in speed or velocity. Acceleration can happen when an object begins to move. For example, when you kick a ball (Figure 3.1.1) or drop something, it begins to accelerate. When a vehicle moves faster, it accelerates.

### Deceleration

**Deceleration** is when an object is decreasing in speed or velocity. Deceleration includes when an object stops moving. For example, when a bike hits a barrier, it decelerates really quickly (Figure 3.1.2).

**Learning intention**

To be able to identify forces and their effects on objects around us

**Success criteria**

**SC 1:** I can describe situations of acceleration, deceleration and constant velocity.

**SC 2:** I can give examples of direct (contact) and indirect (non-contact) forces.

**SC 3:** I can describe the effects of forces on everyday objects.

**KEY TERMS**

**force** any interaction that will change the motion of an object; for example, a push or a pull
**speed** the rate of change of distance
**velocity** the speed and direction of an object
**acceleration** increase in speed or change of direction
**deceleration** decrease in speed

**FIGURE 3.1.1** The soccer ball is just about to accelerate towards the goal.

**FIGURE 3.1.2** The bike decelerated very quickly!

**KEY TERM**

**constant velocity** the movement of an object at the same speed and in the same direction

**FIGURE 3.1.3** As a table tennis ball is light, only a small force is required to keep it in the air

## SAFETY NOTES

- Follow the instructions for each task carefully.
- Keep water away from electrical appliances.
- Turn the hair dryer off after use so it does not overheat.
- Ensure the water from the bucket does not create a slip hazard.

## Constant velocity

If the velocity of an object is not changing, it is described as having **constant velocity**. It is not accelerating or decelerating. It stays at the same speed travelling in the same direction. If an object stays exactly still, it has a constant velocity of zero. For example, if a table tennis ball remains exactly still in the flow of air from a hair dryer (Figure 3.1.3), it can be described as having zero velocity.

## Aim

To observe a range of forces in action and to describe the effect of the forces using correct scientific language

## Apparatus

- lump of modelling clay or plasticene
- hair dryer
- ruler
- textbook
- table tennis ball
- paperclip
- tennis ball
- balloon
- bucket
- woollen fabric
- drinking straw
- spring with hanging mass
- pencil case
- magnet
- retort stand and clamp

## Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

## Method

1. Copy the table in the Results section below into your notebook and use it to record your observations. Consider the instructions for each task in the table.
2. Complete each task in the table, recording your observations as you work through the experiment.
3. Use scientific terms such as force, speed, velocity, acceleration, deceleration and direction in the descriptions of your observations as much as possible.

## Results

| Task | Changes observed in the motion or shape | What produced the force? |
|---|---|---|
| Prop up one end of a textbook with your pencil case or another object to make a ramp. Roll a tennis ball down the ramp. | | |
| Rub woollen fabric against an inflated balloon and bring the balloon towards someone's hair. | | |
| Point an end of a bar magnet towards a paperclip. | | |
| Drop a tennis ball and try to catch it when it bounces. | | |
| Blow a table tennis ball across a bench using a clean drinking straw. | | |
| Using a ruler, push a book or other solid object across the bench at a constant speed. | | |
| Squash a lump of modelling clay/plasticene. | | |
| Push an inflated balloon into a bucket of water and then let the balloon go. | | |
| Suspend a hanging mass from a spring fixed to a retort stand. Carefully pull the mass down 2 cm, stretching the spring, and then release the mass. | | |
| Balance a table tennis ball in stream of warm air directed upwards from a hair dryer. | | |



## Conclusion

As observed in this investigation, forces can be categorised as direct (contact) forces, where the objects must touch to apply the force, or indirect (non-contact) forces, where the objects do not need to touch. Some common contact and non-contact forces are included in Table 3.1.1.

**TABLE 3.1.1** Examples of contact and non-contact forces

| Direct (contact) | Indirect (non-contact) |
|---|---|
| frictional force | gravitational force |
| air resistance force | magnetic force |
| applied force | electrostatic force (static electricity) |
| spring force | |

### HINT

Remember that forces may change the shape, speed or direction of travel of an object.

1 Write your conclusion to the experiment and include answers to the following.

Review your results table and describe:

a at least three situations where forces caused objects to accelerate

b at least two situations where forces caused objects to decelerate

c at least one situation where forces caused objects to change direction

d at least one situation where forces caused objects to change shape

e at least one situation where there was no change to the object’s speed, direction or shape

f all the direct forces that you observed in action

g all the indirect forces that you observed in action.

# 3.2 Representing forces

## Lesson overview

Forces act all around you. They can have different directions and strengths. Often multiple forces act on the same object at once. Some forces involve direct contact, such as a hand pushing a door. Others act at a distance, such as gravity pulling a plane towards Earth.

With so many types, strengths and directions of forces at play, scientists use a clear and simple way to represent them. In this lesson, you will learn how to use arrows called vectors to represent forces (Figure 3.2.1). This will help you understand which forces are acting and predict their effects.

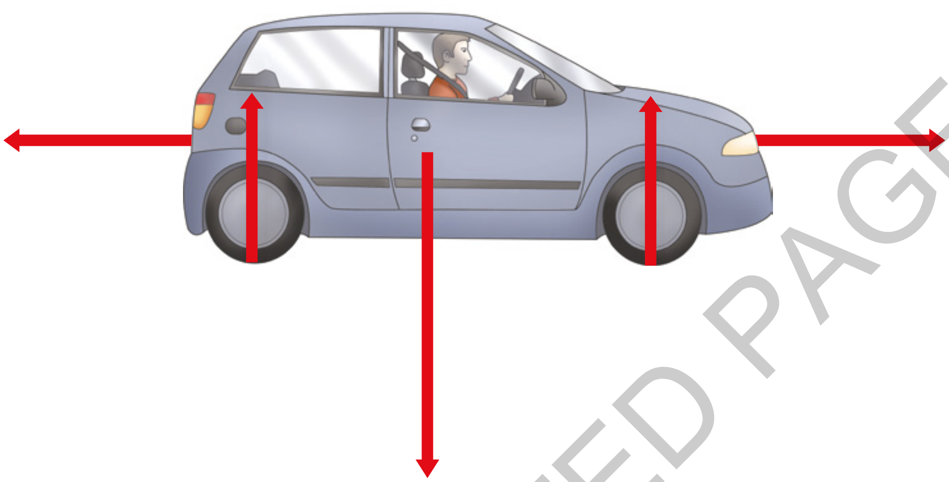


**FIGURE 3.2.1** There are lots of different forces acting on this car.

**Learning intention**

To understand that arrows can be used to represent the magnitude and direction of forces

**Success criteria**

**SC 1:** I can represent forces of different magnitude using force arrows of different length.

**SC 2:** I can represent contact and non-contact forces using force arrows.

**KEY TERMS**

**magnitude** a measure of the size or strength of something

**force diagram** a diagram that uses arrows to show one or more forces acting on an object

**vector** a quantity that has magnitude and direction

| SC 1 | I can represent forces of different magnitude using force arrows of different length |
|---|---|

## Representing forces

Forces can range from large forces, such as those required to get a car moving, to the small force that a driver uses to turn the steering wheel to keep the car moving in the correct direction. When representing forces in diagrams, it is important to show the different **magnitude** (or strength) of the forces, as the strength of the force will determine the effect of the force. The strength of forces is measured in newtons (N).

## Representing forces in a diagram

Forces are represented as arrows in a **force diagram**. An arrow shows the direction in which a force is acting. The arrows should be straight lines. Arrows that show the direction of something are often called **vectors**. The length of the line represents the magnitude (size) of the force. If the strength of a force is known, the arrow can be labelled with the strength (Figure 3.2.2).

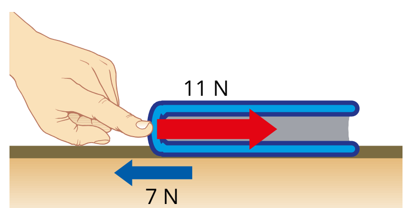



**FIGURE 3.2.2** The applied force (longer red arrow) must be stronger than resisting forces (such as friction; shorter blue arrow) to make an object accelerate.

## SkillBuilder

### Drawing a force diagram

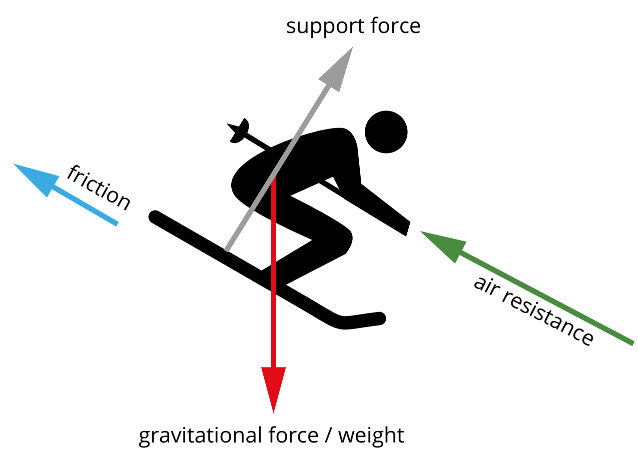
1. Identify the object that the forces are acting on.
2. List all the forces that are acting on this object.
3. Work out the direction of each of the forces acting on the object and draw one arrow for each force.
4. Draw the arrows so they start at the place where the forces are acting. (For drag forces such as air resistance, the arrows can finish at the place where they are acting or start from the centre of mass.)
5. Label each arrow with the type of force it represents, and if known, the size of the force in newtons (N).
6. If you know the strengths of the forces, the length of the arrow should represent the strength of the force. For example, stronger forces should be represented with a longer arrow than weaker forces.
7. Check that you have included all the forces acting on the object.

### Example

Chloe was asked to draw a force diagram showing the forces acting on a skier travelling down a snowy slope. She was told that the main forces acting were:

- a small amount of friction between the skis and the snow
- the weight of the skier
- the force of the snow supporting the skier
- air resistance that was about twice as strong as the friction force.

Chloe created the following force diagram to represent the forces acting on the skier.




### SC 1 CHECK YOUR UNDERSTANDING

Explain how the length of a force arrow relates to the magnitude (strength) of the force.

**SC 2** I can represent contact and non-contact forces using force arrows

Forces cause the movement of objects to change. In force diagrams, it is important to show the position at which the force acts on an object, as this helps explain how the force will affect the object. The **scientific convention** used for where to draw force arrows is described below for contact and non-contact forces.

## Contact forces

If the force is a **contact force**, the tail of the arrow should start at the point where contact between the two objects is causing the force, as shown in Figure 3.2.3.

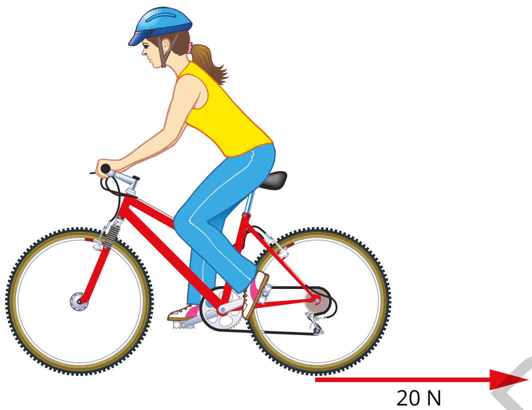



**FIGURE 3.2.3** The wheels of a bike push along the ground, creating a contact force.

## Non-contact forces

If a force is a **non-contact force**, the arrow should start at the centre of the object affected by the force, as shown in Figure 3.2.4.

### SC 2 CHECK YOUR UNDERSTANDING

Describe where the tail of a force arrow should be placed when drawing a contact force.

**KEY TERMS**

**scientific convention** an agreed way to carry out an action or communicate information

**contact force** force that acts between two objects that touch each other

**non-contact force** force that acts on an object from a distance

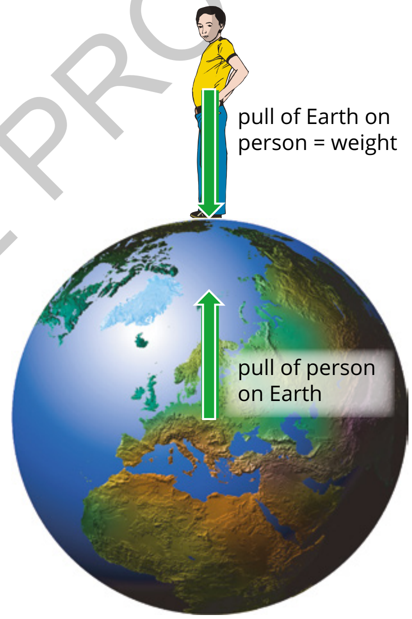



**FIGURE 3.2.4** Gravitational forces are non-contact forces between objects that have mass.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 Describe what is meant by direction when drawing force arrows.

2 Contrast two force arrows, one representing a 3 N force and another representing a 6 N force.

3 Draw a force diagram to show a soccer ball being kicked to the right.

4 Draw a force diagram to show the gravitational force acting on a falling apple.

# 3.3 Balanced and unbalanced forces

## Learning intention

To understand that forces on an object can combine to result in balanced and unbalanced forces

## Success criteria

**SC 1:** I can use force diagrams to show balanced and unbalanced forces acting on objects.

**SC 2:** I can calculate the size and the direction of the net force and predict the action of this force.

**KEY TERMS**

**unbalanced forces** forces acting on a single object where the force in one direction is not equal to the force applied in the opposite direction

**gravitational force** the force on an object due to gravity; can be described as the 'weight' of an object

**balanced forces** forces acting on a single object where the force in one direction is equal to the force applied in the opposite direction

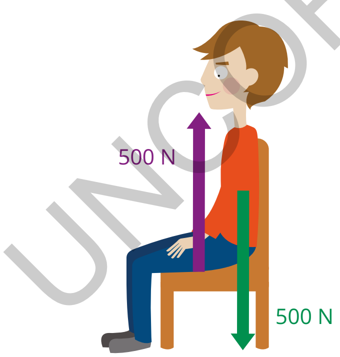



**FIGURE 3.3.2** The balanced forces acting on the student mean they will remain in the chair.

## Lesson overview

In almost all situations, more than one force is acting on an object. How the object will move will depend on the combined effect of the forces.

In this lesson you will learn about how forces can combine to result in balanced and unbalanced forces. You will then be able to predict the effect of these forces.

| SC 1 | I can use force diagrams to show balanced and unbalanced forces acting on objects |
|---|---|

When more than one force is acting on an object, there will be multiple arrows shown in the force diagram. In Figure 3.3.1, there is a pushing force of 30 newtons (N) acting to the right and a force of 20 N acting to the left. These forces are **unbalanced forces** because the forces are different strengths.


**FIGURE 3.3.1** The unbalanced forces acting on the object will make it accelerate to the right.

In Figure 3.3.2, there is a **gravitational force** of 500 N acting downwards and a support force of 500 N acting upwards. These forces are **balanced forces** because the forces are the same strength and act in opposite directions.

## Forces in multiple directions

Often there will be forces acting on an object in more than two directions. An example is the bike and its rider in Figure 3.3.3.

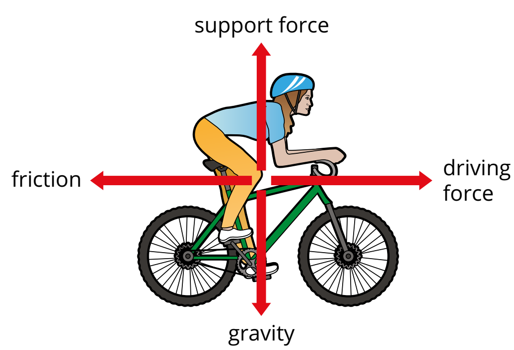



**FIGURE 3.3.3** The forces acting on the bike and its rider when riding at constant velocity are equal in size and opposite in direction.

In this situation, there is the driving force to the right, **friction** to the left, **gravity** downwards and the support force of the road upwards. To determine if the forces are balanced or unbalanced, you must consider the forces in pairs; the right and left pair, and the down and up pair.

In this case, the right and left pair (driving force and friction) are balanced because the length of the arrows is the same. The down and up pair (gravity and support force) are also balanced. We say that the forces acting on the cyclist cancel each other out.

**KEY TERMS**

**friction** force that acts against an object's motion

**gravity** force of attraction between any two objects

**SC 1 CHECK YOUR UNDERSTANDING**

Explain the difference between balanced and unbalanced forces.

**SC 2** I can calculate the size and the direction of the net force and predict the action of this force

## Net force

When multiple forces act on a single object, the combined effect of these forces is called the **net force**.

If forces are balanced, the net force is zero because the forces cancel each other out. If forces are unbalanced, you can calculate the net force by adding up the magnitude (strength) of all the forces acting on the object. You must remember that if the forces act in opposite directions, this must be considered.

**KEY TERMS**

**net force** the combination of multiple forces acting on a single object; also called resultant force

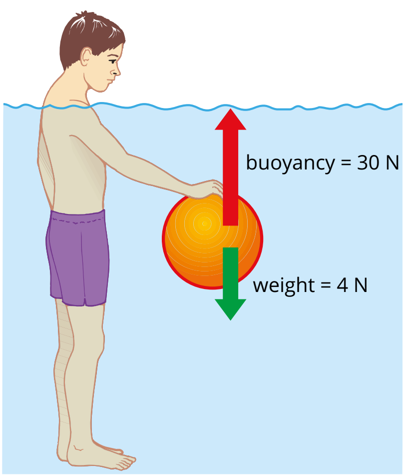
## SkillBuilder

### Calculating net force on an object

#### How to calculate net force

Identify all the forces acting on the object.

1. Identify the object that the forces are acting on.
2. Sketch a diagram showing the strength and direction of these forces.
3. Decide how you will describe the direction of the forces (for example: up / down / North / South / forwards / backwards / to the right / to the left).
4. If forces are acting in the same direction, add the values of the forces together to calculate the total force in that direction.
5. If forces act in opposite directions, subtract the smaller force from the larger one to calculate the net force.
6. State the value and the direction of the net force.




#### Example

Reuben was asked to calculate the net force acting on a ball that had been pushed under the surface of a swimming pool and let go. The buoyancy force was 30 N (upwards) and the force due to gravity was 4 N (downwards), as shown in the figure. Since the forces act in opposite directions Reuben calculated the net force by subtracting the weaker force from the stronger one.

net force = 30 − 4 = 26 N upwards


**FIGURE 3.3.4** Equal and opposite forces act on a student sitting still in a chair.

**FIGURE 3.3.5** Though the cyclist may be moving very fast, unbalanced forces are required to make them change velocity (accelerate).

# The effect of net force on objects

## Balanced forces

If the forces on an object are balanced in a given direction, the net force on the object is zero in that direction.

### Stationary objects with zero net force

Consider the situation where a zero net force acts on a stationary object. In this situation, the motion of the object will not change – it remains still such as the sitting student in Figure 3.3.4.

### Moving objects with zero net force

If the object is moving, it will stay moving at the same speed and in the same direction because there is no net force to change the motion of the object. This is called constant velocity. If the force due to gravity acting on a cyclist and bike (Figure 3.3.5) is balanced with friction, there is a net force of zero. They will move at constant velocity.

## Unbalanced forces

When the forces on an object are not balanced, there will be a net force acting on the object, which will cause a change in the motion of the object.

### Net force on a stationary object

If the object is stationary, it will start to move in the direction of the net force. For example, the net force on the book in Figure 3.3.6 is 4 N to the right, so the book will start to move to the right.

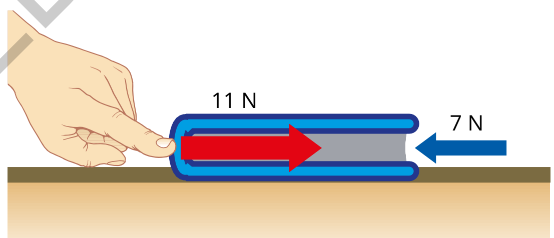



**FIGURE 3.3.6** The book will accelerate in the same direction as the larger force.

**FIGURE 3.3.7** The skydiver will accelerate until they reach a maximum speed (called terminal velocity).

### Object moving in the same direction as the net force

If an object experiences a push or pull in the direction it is already travelling, it will accelerate in the direction of travel. In Figure 3.3.7, the force due to gravity is greater than the air resistance acting on the skydiver. The net force is acting in the same direction as the movement. Therefore, the skydiver accelerates towards Earth.

### Objects moving in the opposite direction to the net force

If an object experiences a net force in the opposite direction to which it is travelling, it will slow down. In Figure 3.3.8, the net force on the car is in the opposite direction to its movement. It will decelerate and possibly stop.

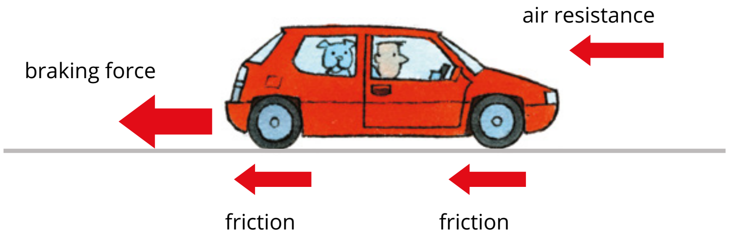



**FIGURE 3.3.8** All forces acting on the car are opposite the direction of motion.

**SC 2 CHECK YOUR UNDERSTANDING**

Explain how to determine the direction of the net force when multiple forces act on an object.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 Draw a force diagram to represent the forces acting on a stationary box on a flat surface.

2 Compare force diagrams of balanced and unbalanced forces acting on an object by describing the length and direction of the force vectors.

3 Calculate the net force acting on an object if it experiences a 10 N force to the right and a 4 N force to the left.

4 You are studying the fall of a feather.

a Describe the forces acting on the feather as it falls (assume there is no wind).

b You notice that the feather is falling at a constant speed. What does that tell you about the forces acting on the feather?

# 3.4 Investigating friction

**Learning intention**

To be able to conduct an investigation on increasing or reducing frictional forces

**Success criteria**

**SC 1:** I can develop an investigable question and make reasoned predictions around friction in a real-life situation.

**SC 2:** I can design an investigation, including constructing appropriate representations to record and organise data.

**SC 3:** I can identify the strengths and limitations of an investigation on frictional forces.

**KEY TERMS**

**inquiry question** a question that can be answered by conducting an investigation; also described as an investigable question
**variable** a factor or condition that can change during an experiment or can influence the experiment
**independent variable** the variable that is being changed in an experiment
**dependent variable** he variable that is being measured in an experiment; it changes as the independent variable changes

## Introduction

Friction is a contact force. A range of factors, or variables, will increase or decrease the strength of the force of friction.

In this inquiry activity, you will construct a question around the strength of friction. You will then design and conduct an investigation to answer that question.

## Background

Before a scientist investigates anything, they normally start with an **inquiry question**. This question will define the investigation, so it is very important to ask the right question.

### Investigating friction

In this activity you will have the opportunity to answer a question related to the effect of friction. You can select a situation that interests you and a **variable** to investigate.

### Factors affecting friction

Several variables may affect the strength of friction between two surfaces. These include the size of the surfaces, the materials and the wetness of the surfaces.

## Aim

To select a situation where friction is involved, write an inquiry question about how changing a variable will affect the strength of friction and then collect data from an experiment to answer this inquiry question

## Plan

### Situation

Choose a situation that involves friction that you would like to investigate. Check with your teacher once you have decided on a situation.

### Independent variable

Decide on the **independent variable** that you will be investigating. Choose something that can be changed using the resources available to you.

In this investigation the **dependent variable** is the strength of the friction.

### Inquiry question

Once you have chosen your situation and independent variable, write a question that you want to investigate.

## Design

You now need to design an investigation that will answer your inquiry question.

Make sure that you have a way to measure the strength of friction. Also, be sure this measurement can be easily repeated so that you can obtain enough data to answer your question.

### How to measure the strength of friction

Plan how you will measure the force of friction in your investigation. This may involve the use of **newton meters** to directly measure the amount of force, or there are other indirect ways that the amount of friction can be compared.

### Controlled variables

To start designing your experiment, you will need to decide what the **controlled variables** will be.

### Independent variable

The independent variable is what you will change in your investigation. Once you have decided which variable you will change, decide how to change it during the investigation. Decide on the range of values you will use and how many trials you will use.

**KEY TERMS**

**newton meter** a device used to measure the strength of a force; often called a spring balance

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

## Method

Once you have identified how to change your independent variable, measure the strength of friction and keep the controlled variables the same, write a step-by-step method for your investigation. Include the apparatus that you will use and a table for your results.

### Assessment of risk

Ensure you are aware of the risks of this inquiry activity and have considered how safety can be improved before carrying out the activity.

## Prediction

Use your knowledge of friction and any other relevant observations to predict the result of your experiment.

## Conduct

Conduct your investigation following your method. If you need to alter your method to improve accuracy or safety, make changes and note down what you changed and why you changed it. Ensure that all data is recorded accurately in your results table.

## Conclusion

Write a conclusion using your experiment's results to answer your inquiry question. Include actual data from the experiment to support your ideas.

# 3.5 Vehicle safety

**Learning intention**

To understand how safety features help reduce the impact of forces in vehicle collisions

**Success criteria**

**SC 1:** I can explain how safety features reduce the impact of forces in vehicle collisions.

**FIGURE 3.5.1** Seatbelts securing passengers in a fire truck

**FIGURE 3.5.2** Modern cars have multiple airbags, including above and to the side of the passenger, not only directly in front.

## Lesson overview

From seatbelts to airbags, various safety features are designed to reduce the impact of forces during a collision (crash). Technological innovations to increase safety when travelling in vehicles continue to be developed and tested.

In this lesson you will learn about different safety features in vehicles and how they help reduce the impact of forces.

**SC 1** I can explain how safety features reduce the impact of forces in vehicle collisions

As a vehicle is moving, the vehicle and its occupants have movement energy, often called kinetic energy. The greater the speed of the vehicle, the more energy it has, and the greater the forces required to stop the vehicle. These stopping forces don't make the energy disappear, but they do change the movement energy into other forms of energy such as heat and sound. Safety features in vehicles operate to shield the occupants from the very large forces that occur during a collision.

### Seatbelts

Seatbelts (Figure 3.5.1) reduce the impact of forces by restraining passengers so that their bodies slow down with the car. When a car suddenly stops, the seatbelt stretches slightly, increasing the time over which the passenger comes to a stop.

By restraining passengers, seatbelts stop them from flying forward when the car stops, reducing the risk of passengers hitting the dashboard or steering wheel, or even going through the front windscreen. This allows them to slow down with the car as it decelerates.

### Airbags

Airbags reduce the impact of forces by providing a cushion that absorbs some of the energy from a collision. When a crash occurs, the airbag inflates rapidly (Figure 3.5.2), creating a barrier between the passenger and the hard surfaces inside the vehicle. This barrier spreads the force of the impact over a larger area and increases the time over which the passenger comes to a stop. As a result, the force experienced by the passenger is reduced, lowering the risk of injury.

### Crumple zones

Crumple zones reduce the impact of forces by absorbing some of the energy from a collision. These zones are designed to crumple in a controlled manner upon impact (Figure 3.5.3). This crumpling absorbs energy that would otherwise be transferred to the passengers. By absorbing the energy, crumple zones reduce the force experienced by the occupants, lowering the risk of injury.

**FIGURE 3.5.3** In a collision, the force acting on the car is absorbed in deforming the metal of the crumple zones designed into the car, shielding the occupants from the worst of the forces.

**SC 1 CHECK YOUR UNDERSTANDING**

Explain how seatbelts and airbags work together to reduce the impact of forces during a collision.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 Describe how the force of a collision affects the energy of a vehicle.

2 Discuss the role of airbags in reducing the impact of forces during a collision.

3 Consider safety features for bicycles and motorcycles. Name one safety feature that reduces forces on a rider during an accident and explain how it works.

4 Suggest why seat belts are increasingly used on buses and coaches.

# 3.6 Gravitational fields

**Learning intention**

To understand the cause and effects of gravitational fields

**Success criteria**

**SC 1:** I can describe gravitational fields.

**SC 2:** I can describe how gravitational force affects the motion of objects, including in orbits.

**SC 3:** I can use the expression F = mg to calculate the force on an object and other unknowns.

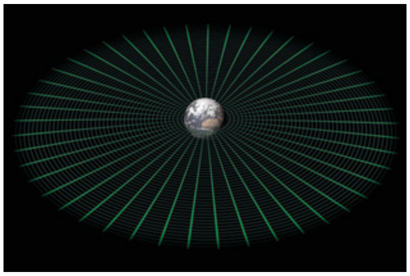


**FIGURE 3.6.1** Gravitational field lines (green) fan out from Earth and white arrows show the direction a mass will move when in the gravitational field of Earth.

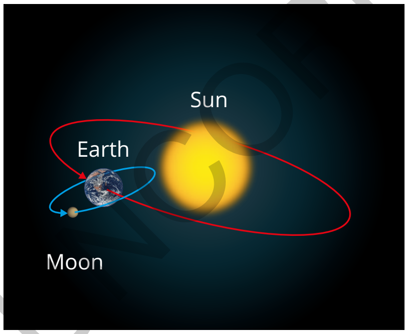



**FIGURE 3.6.2** Earth is influenced by the Sun's gravitational field so it orbits the Sun, and the Moon is influenced by Earth's gravitational field so it orbits Earth.

## Lesson overview

Gravitational fields are forces that pull objects toward each other. They are created by any object that has mass. However, you need to have an object with a lot of mass, such as a planet, to feel the effects of gravity.

In this lesson you will explore how gravitational fields form and how they affect the motion of objects, and learn to calculate gravitational forces.

**SC 1** I can describe gravitational fields

Gravitational fields are regions of space around an object where another object experiences a gravitational force. These fields are formed due to the presence of mass. The larger the mass, the stronger the gravitational field it creates. This is why planets, stars and moons have significant gravitational fields. Earth, for example, has a gravitational field that pulls objects toward its centre.

The concept of gravitational fields can be visualised using field lines, which are imaginary lines that show the direction and strength of the gravitational force (Figure 3.6.1). These lines are closer together near the mass, indicating a stronger force. As you move away from the mass, the lines become more spread out, indicating a weaker force.

**SC 1 CHECK YOUR UNDERSTANDING**

Explain how the mass of an object affects the strength of its gravitational field.

**SC 2** I can describe how gravitational force affects the motion of objects, including in orbits

Gravitational force is the attraction between two masses. On Earth, this force is what makes objects fall when dropped. The greater the mass and the closer the objects, the stronger the gravitational force.

An example of gravitational fields in action is the way the Moon orbits Earth. The Moon is kept in orbit by Earth's gravitational field, which pulls it toward the planet. However, the Moon's velocity keeps it moving forward, resulting in its orbit around Earth. Likewise, Earth is kept in orbit around the Sun due to the Sun's gravitational field (Figure 3.6.2).

### Explaining orbits

Imagine standing on a tall mountain as represented in Figure 3.6.3. If you throw a ball away from you it will fall to the ground due to gravity. If you could throw it really fast, it would keep moving away from you but still be falling. If it was fast enough and there was no air resistance to slow it down, it would fall but would keep travelling around Earth without landing on it. The ball would now be in orbit.

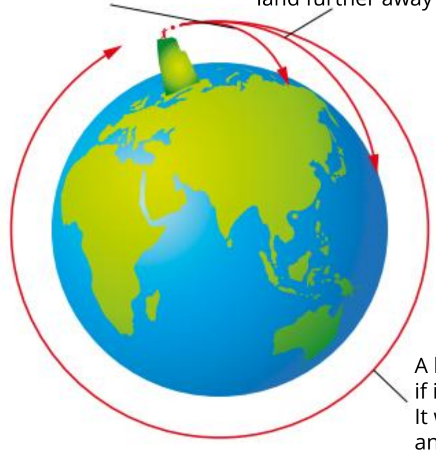



**FIGURE 3.6.3** Throw a ball slowly and it will land back on Earth. However, if you throw it really fast, then it will continue to fall and keep 'missing' the planet. The ball will then be in orbit around Earth.

Orbits are paths that objects follow due to gravitational forces. These paths can be circular or **elliptical**. For example, satellites orbit Earth in a circular path, while comets often have elliptical orbits around the Sun (Figure 3.6.4).

**SC 2 CHECK YOUR UNDERSTANDING**

Describe how gravitational force affects the orbit of a planet around a star.

**SC 3** I can use the expression F = mg to calculate the force on an object and other unknowns

## Calculating gravitational force

**Weight** is defined as the force on an object caused by gravity. The weight of an object is related to its **mass**. If there is no gravity, the object becomes 'weightless'. The formula below is used to calculate the gravitational force (F) acting on an object:

$$\text{force (F)} = \text{mass} \times g$$

where 'g' is the acceleration due to gravity. This is a measure of the rate at which the velocity of an object increases and is dependent on the strength of gravity.

This formula can be written as

$$F = mg$$

where 'm' represents the mass of the object in kilograms (kg).

On Earth, the value of g is approximately 9.8. The unit for acceleration is metres per second per second, which can be written as $m/s^2$ or $m\ s^{-2}$). This means that for every second of falling, the velocity of the object increases by 9.8 metres per second. The calculated force will be in the unit of newtons (N).

For example, if you have a rock on Earth with a mass of 2 kg, you can calculate the gravitational force acting on it by multiplying the mass by the gravitational acceleration:

$$F = 2\ \text{kg} \times 9.8\ \text{m s}^{-2} = 19.6\ \text{N}$$

**Scifile**

**Gravity in space**

Astronauts in space appear to float because they are in a state of continuous freefall around Earth, creating the sensation of weightlessness.

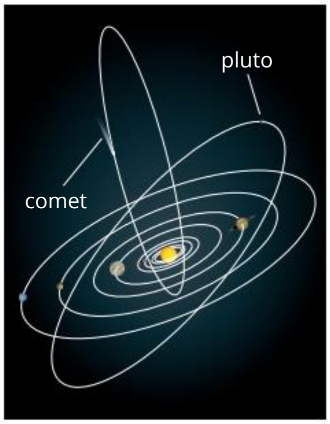



**FIGURE 3.6.4** The comet and Pluto have clearly elliptical orbits, whereas other planets such as Earth and Neptune have obits that are closer to being circular.

**KEY TERMS**

**elliptical** the shape of an ellipse, which is an elongated circle, stretched into an oval

**weight** the force of gravity pulling on an object; measured in newtons (N)

**mass** the amount of material in an object; measured in kg

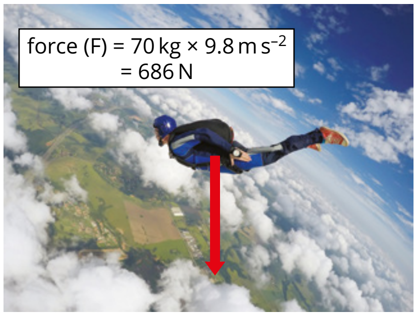



**FIGURE 3.6.5** The gravitational force on a skydiver (their weight) can be calculated using F = mg.

> **Scifile**
>
> **Weight vs mass**
>
> Your weight changes depending on where you are in the universe but your mass stays the same.

This formula is not only useful for objects on Earth (Figure 3.6.5) but also for understanding gravitational forces in other environments.

For example, on the Moon the acceleration due to gravity is about 1.6 m s$^{-2}$, so the force on the same rock would be:

$$F = 2 \text{ kg} \times 1.6 \text{ m s}^{-2} = 3.2 \text{ N}$$

The formula can also be used to calculate the mass or the acceleration of an object that is affected by a gravitational field.

The relationship $F = m \times g$ can be rearranged to give:

or $F = \frac{m}{g}$

or:

acceleration due to gravity = $\frac{\text{force}}{\text{mass}}$ or $g = \frac{f}{m}$

## Examples

**1** Calculate the mass of a person who weighed 120 N on the Moon.

$$\text{mass} = \frac{\text{force}}{g} = \frac{120}{1.6} = 75 \text{ kg}$$

**2** An astronaut with a mass of 86 kg was found to have a weight on the surface of Mars of 318 N. Calculate the acceleration due to gravity (g) on Mars.

$$g = \frac{F}{m} = \frac{318}{86} = 3.7 \text{ ms}^{-2}$$

**SC 3 CHECK YOUR UNDERSTANDING**

Calculate the gravitational force on a 5 kg object on Earth using F = mg.

# Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

**1** Define ‘gravitational field’.

**2** Explain why the Moon stays in orbit around Earth.

**3** Describe how field lines represent the strength of a gravitational field.

**4** Explain how the formula F = mg is used to calculate gravitational force of an object.

**5** Predict how the orbit of a satellite might change if Earth’s gravitational force increased.

**6** Compare the weight of a 10 kg object on Earth and on the Moon.

# 3.7 Electrostatic forces

## Introduction

Electrostatic forces are non-contact (indirect) forces between objects that are electrically charged. The action of cling wrap is an example of electrostatic attraction (Figure 3.7.1). The act of unrolling the cling wrap charges the plastic that it is made from.

In this practical investigation, you will create some electrostatic forces using a variety of materials and observe and explain their effects on objects.

**Learning intention**

To be able to investigate the effect of electrostatic forces

**Success criteria**

**SC 1:** I can observe and describe the effect of electrostatic forces.

**SC 2:** I can explain attraction and repulsion in terms of electric charges.

**FIGURE 3.7.1** Cling wrap is attracted to materials due to electrostatic forces.

## Background

All substances are made of tiny particles called atoms, which are made up from protons (positive charge), electrons (negative charge) and neutrons (no charge). You will learn more about protons, electrons and neutrons and the structure of atoms in Chapter 10. Normally, objects have equal numbers of protons and electrons, so they're neutral (have no electric charge).

If electrons move from one object to another, they create an imbalance:

- more protons than electrons = positively charged object (+)
- more electrons than protons = negatively charged object (–)

One way for electrons to move from one substance onto another is two rub two different materials together. In some materials, such as the rubber used for balloons and the plastic in a hair comb, the materials will remain charged after being rubbed (Figure 3.7.2).

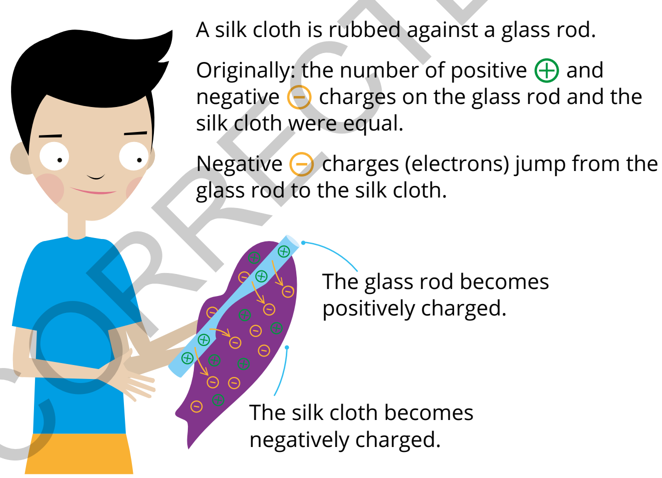



**FIGURE 3.7.2** Electrons are rubbed from a glass rod and jump onto a silk cloth. As a result, the glass rod becomes positively charged and the silk cloth is negatively charged.

## Aim

To create, observe and compare the effect of electrostatic forces

## Apparatus

- plastic comb
- sheet of paper
- woollen material
- balloons
- string
- retort stand and clamp

### Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

## Method

1. Rub the plastic comb vigorously on the woollen material. Bring it close to some tiny pieces of paper. Write down what happens.
2. Turn a water tap on and carefully turn it down to get the finest stream that you can of steadily flowing water. Rub the comb with the woollen material and hold it close to the stream of water. Draw a diagram to show what you observe.
3. Blow up a balloon and rub it with the woollen material. See if you can make the balloon 'stick' to the wall.
4. Blow up a second balloon. Attach a piece of string to each of the balloons and then tie these to a retort stand. Rub both balloons with the woollen material. Draw a diagram to show what happened.

## Results

Record your observations for each step from the method in your notebook.

## Conclusion

1. Explain why you could pick up the pieces of paper with the comb.
2. Describe what happened to the stream of water when the charged comb was brought near to it. Suggest what you can infer about water based on this observation.
3. Propose an explanation for your observations when the two balloons were rubbed with the material and hung close together.

# 3.8 Magnetic fields

## Introduction

Magnetic fields are invisible areas around magnets where the magnet can exert a force. These forces could be a pull or push on other magnets or objects that are made of metals than can be magnetised, such as iron.

Magnetic fields are used in many situations, including electric motors and medical scanning devices such as magnetic resonance imaging (MRI).

In this practical investigation you will explore the properties of magnetic fields and learn how they can be represented.

### Learning intention

To be able to observe and describe magnetic fields

### Success criteria

**SC 1:** I can identify the poles of a magnet.

**SC 2:** I can observe and record the interactions between magnets.

**SC 3:** I can identify and represent the magnetic field around a magnet.

## Background

The ends of a magnet are called poles, and these are where the magnetic field is the strongest. The magnetic field can be represented by **magnetic field lines**. These are visual representations of a magnetic field's strength and direction (Figure 3.8.1).

The north pole of a magnet is defined as the end with magnetic field lines coming out of it. The opposite end of the magnet is the south pole. You can imagine magnetic field lines as emerging from a magnet's north pole and entering its south pole, forming loops that never cross. Field lines show the shape and direction of the magnetic field. The pattern of the field lines indicates the strength of the magnetic field: the closer lines indicate a stronger field, while wider spacing indicates a weaker field.

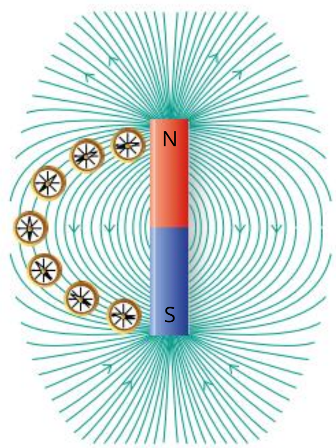



**FIGURE 3.8.1** Magnetic field lines do not cross and always run from the north pole to the south pole of a magnet.

## Aim

To observe and describe magnetic fields

## Apparatus

- two bar magnets
- retort stand and clamp
- 50 cm cotton thread
- stiff, transparent plastic
- white paper
- iron filings
- plotting compass

## Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

## Method

1 Identify the approximate direction of north using the compass.
2 Suspend one of your bar magnets horizontally from the clamp and stand using the cotton, ensuring that it is free to rotate.
3 Identify the end of the magnet that is pointing in a northerly direction. This is the north pole of the magnet.
4 Untie the first magnet and place it onto the bench surface close to the second magnet. Describe your observations.
5 Place one magnet on a sheet of paper and place the plastic sheet over the top.
6 Sprinkle about a teaspoon of iron filings onto the plastic sheet.
7 Lightly tap the sheet to spread the iron filings. Draw the pattern formed by the iron filings.
8 Carefully gather up all the iron filings and remove the plastic sheet.
9 Leave the magnet on the paper and place the compass somewhere on the paper (Figure 3.8.2). The compass will point in the direction of the magnetic field at that place on the paper. Draw a small arrow on the paper to mark the direction that the compass is pointing. Move the compass to a new position and repeat. Continue until you have marked the direction of the field over most of the paper. You can connect the dots to show the field lines running from the magnet's north pole to its south pole.

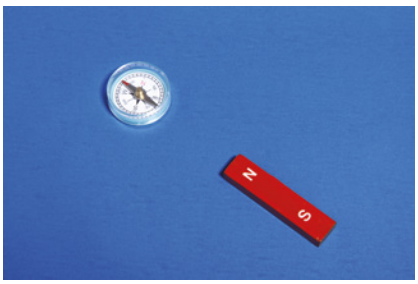


**FIGURE 3.8.2** Using a compass to map a magnetic field

## Results

Record your results in your notebook.

## Discussion

Describe why it was useful to use two methods to map the magnetic field.

## Conclusion

List five key facts about ma gnetic fields that you learned from this investigation.

# 3.9 The strength of magnetic fields

## Introduction

The forces of attraction or repulsion between two magnets are examples of non-contact forces.

In this practical investigation, you will measure the magnitude of the repulsive (pushing away) force between two magnets depending on their distance apart.

## Background

Magnets exert a force on each other and on certain materials such as iron. When the north pole ends of two magnets are placed close together a force of repulsion will act between them. The same applies when two south poles are brought together. When a north and a south pole are brought together a force of attraction will act between them.

## Aim

To measure the force of repulsion between two magnets in relation to the distance between them

## Apparatus

- two bar magnets
- 20 cm length of transparent (clear) vinyl tubing with an internal diameter just larger than the bar magnets
- masses of marked mass (e.g. 50 g) that will fit inside the vinyl tube
- ruler
- retort stand and clamp

### Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

## Prediction

Write a detailed prediction of what you expect to observe as more mass is placed on the magnets that are repelling one another.

## Method

1 Take two bar magnets and place them on the surface of the desk in front of you. Slowly bring them together end-to-end. What do you observe? Write down your observation.

2 Now rotate only one of the magnets through 180 degrees so that the opposite end is close to the other magnet. Again, bring the magnets slowly together and record what you observe.

3 Now rotate only the other magnet through 180 degrees. Again, bring the magnets slowly together and record what you observe.

**Learning intention**

To be able to observe and model the effects of magnetic fields

**Success criteria**

**SC 1:** I can observe and record the interactions between magnets.

**SC 2:** I can identify the magnetic field around a magnet.

**SAFETY NOTE**

- Only bar magnets should be used in this experiment. Rare earth magnets (e.g. neodymium) pose pinch, shattering and swallowing risks and should be avoided in junior secondary settings.

4 Place both magnets inside the clear vinyl tube with their north poles together so that they repel each other.

5 Use the retort stand and clamp to clamp the clear vinyl tube upright so that its base is on the desk, as shown in Figure 3.9.1. (If no retort stand is available a member of your group can hold the tube in place.)

6 One magnet will be at the bottom of the tube, resting on the desk, the other will be floating above it.

7 Using the ruler, measure the distance between the magnets and record your answer.

8 Place an additional weight on top of the top magnet and record the weight you have added and the new distance between the magnets.

9 Continue adding weights, taking measurements and recording results until the magnets appear to be touching (or you run out of weights).

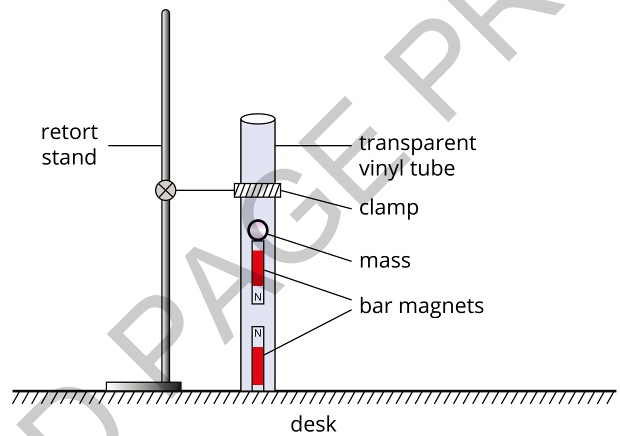



**FIGURE 3.9.1** Setting up your experiment

## Results

Copy this table into your notebook and use it to record your results. The masses you are using may not be 50 g; ensure that you record the correct values.

| Mass added (g) | Distance between magnets (mm) |
|---|---|
| 0 | |
| 50 | |
| 100 | |
| 150 | |

## Discussion

List any sources of inaccuracy or error in your experiment with the magnets in the tube and describe how could you have reduced these.

## Conclusion

1 What did you observe about the relationship between the weight applied and the distance between the magnets?

2 What does this suggest about the shape of the magnetic field near the end of the magnet?

# 3.10 Making an electromagnet

## Introduction

Electromagnets are used in many everyday devices, like cranes that lift scrap metal and in speakers inside audio devices. Because their magnetic strength can be controlled, they are versatile for different applications.

In this practical investigation, you will construct an electromagnet and investigate how the number of coils affects the strength of the magnetic field produced by the electromagnet.

### Learning intention

To be able to construct and compare electromagnets

### Success criteria

**SC 1:** I can safely construct an electromagnet.

**SC 2:** I can test the effect of changing the number of coils on an electromagnet.

## Background

When electric current flows through a wire, it generates a magnetic field around it. By coiling the wire around a metal core—in this case, an iron nail—and passing current through it, the metal becomes magnetised.

Paperclips are made of steel, which is mainly iron, so they will be affected by a magnetic field.

## Aim

To make an electromagnet and test how its strength can be increased

## Apparatus

- 6 V battery or a power pack
- large nail (at least 7 cm long)
- compass
- paperclips
- switch
- 2 insulated wires (one long, one short) with alligator clips
- retort stand
- boss head and clamp
- piece of string about 30 cm long

### SAFETY NOTE

- The circuit is a short circuit that will generate a large current resulting in the wires getting hot. Ensure that no more than 6-volt power supply is used.

### Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

## Prediction

Predict the effect of increasing the number of coils used to magnetise the iron nail.

## Method

1 Copy the table from the Results section into your notebook.

2 Test to see if the nail on its own will pick up any paperclips.

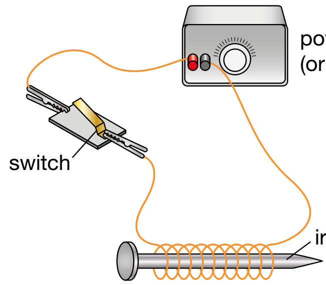



**FIGURE 3.10.1** Setting up your circuit with the electromagnet

### HINT

A compass needle will point towards the south pole of a magnet.

3. Suspend a paperclip from a retort stand so that it hangs just above the benchtop.
4. Connect the short wire from the battery or power pack to the switch.
5. Carefully wind the long wire 10 times around the nail as neatly as you can. Make sure that you only wind the wire in one direction along the nail.
6. Connect one end of the long wire to the switch and the other to the power supply, as shown in Figure 3.10.1.
7. If using a power pack, set it to 6 volts DC and switch on the power.
8. Move the retort stand with the paperclip towards the electromagnet until the paperclip is deflected towards the electromagnet. Measure the distance between the electromagnet and the paperclip when this deflection first occurs, and record this distance in the results table.
9. Repeat steps 4–7, increasing the number of coils as shown in the results table.
10. Test which end of the nail is the north pole and which is the south pole using a compass.
11. Reverse the connections to the power supply and repeat step 10.

## Results

Copy this table into your notebook and use it to record your results.

| Number of turns on wire | Minimum distance before deflection (cm) |
|---|---|
| 0 | |
| 10 | |
| 20 | |
| 30 | |
| 40 | |
| 50 | |

## Discussion

1. Suggest why the nail was tested on its own to see if it picked up any paperclips.
2. Suggest another way to test the strength of the magnetic field.

## Conclusion

1. State the effect of the number of turns of the wire on the minimum distance for an effect on the paperclip.
2. Compare your result to your prediction.
3. Describe what happened to the poles of the electromagnet when the connections were reversed.

# 3.11 Action of simple machines

## Lesson overview

In our daily lives, we encounter simple machines that make many tasks easier. Simple machines were used extensively in the past before the introduction of powered machines such as cranes, forklift trucks and tractors. These machines help by multiplying or redirecting force or distance.

In this lesson, you will explore how inclined planes, screws, wedges, pulleys and gears work, and how they have helped us perform tasks more efficiently.

**SC 1** I can explain how simple machines help with tasks by acting as force multipliers

### Learning intention

To understand the forces involved in simple machines

### Success criteria

**SC 1:** I can explain how simple machines help with tasks by acting as force multipliers.

### KEY TERMS

**distance multiplier** machine that converts a small input distance into a large output distance or vice versa

**force multiplier** machine that increases the force applied for a task, such as a second-class lever

## Simple machines

Simple machines are devices that make work easier by allowing us to apply less force over a greater distance. They can be categorised as **force multipliers** or **distance multipliers**. The **mechanical advantage** is a measure of how much a simple machine makes work easier.

Simple machines offer numerous benefits by making tasks easier and more efficient. They reduce the amount of force needed, change the direction of force, and increase the distance over which force is applied.

### Inclined planes

An inclined plane is a flat surface set at an angle to another surface. It allows us to move objects to a higher or lower height with less effort. For example, a ramp is an inclined plane (Figure 3.11.1). Instead of lifting a heavy object straight up, you can push it up the ramp. This reduces the force needed but increases the distance over which the force is applied. An inclined plane is a force multiplier, since it allows a smaller force to do a job that would require a larger force without the use of this simple machine. Before the use of powered cranes, ramps where used extensively in building construction.

The mechanical advantage of an inclined plane is calculated by dividing the length of the slope by the height of the inclined plane. The longer the slope compared to the height, the less force is needed to move the object.

**FIGURE 3.11.1** Using a ramp (an inclined plane) to move a heavy object

SCIENCE IN CONTEXT

## Inclined planes in construction

Inclined planes are widely used in construction to move heavy materials to higher levels. For example, construction sites often use ramps or conveyor belts to transport building materials like bricks and cement (Figure 3.11.2). These ramps reduce the effort needed to move heavy loads, making the construction process more efficient.

**FIGURE 3.11.2** A conveyor belt is an inclined plane used to raise building materials to the top of a roof.

**FIGURE 3.11.3** A screw-type car jack in use. It is a force multiplier that allows the smaller force that a person can exert on the jack handle to be converted into a larger force powerful enough to lift a car.

## Screws

A screw is an inclined plane wrapped around a cylinder. It converts rotational force (a force applied around an object) into linear force (a force that acts in a straight line). Screws are used to hold objects together or lift them. For example, a screw jack can lift a car by turning the screw (Figure 3.11.3). The mechanical advantage of a screw is determined by the spacing of the threads and the length of the inclined plane that makes up the screw.

## Wedges

A wedge is a device that is thick at one end and tapers to a thin edge at the other. It is used to split, cut or lift objects. An axe is a common example of a wedge (Figure 3.11.4). When you swing an axe, the force you apply is concentrated at the thin edge, allowing it to split wood. The mechanical advantage of a wedge is determined by the ratio of its length to its thickness. A longer, thinner wedge requires less force to do the same amount of work as a shorter, thicker wedge.

**FIGURE 3.11.4** An axe used to split wood is working as a wedge

## Pulleys

Pulleys are simple machines that can effectively multiply force, making it easier to lift heavy loads. By using a system of pulleys, sometimes known as a block and tackle, the force required to lift an object is distributed across multiple ropes (Figure 3.11.5). Each additional pulley reduces the amount of force needed by increasing the mechanical advantage. For instance, with two pulleys, the force needed is halved (Figure 3.11.5b), allowing a person to lift heavier objects with less effort. This principle is based on the trade-off between force and distance; while the force is reduced, the distance over which it is applied increases.

You can see many examples of pulley systems in old mines (Figure 3.11.6), where they are used to raise and lower lifts for miners and equipment.

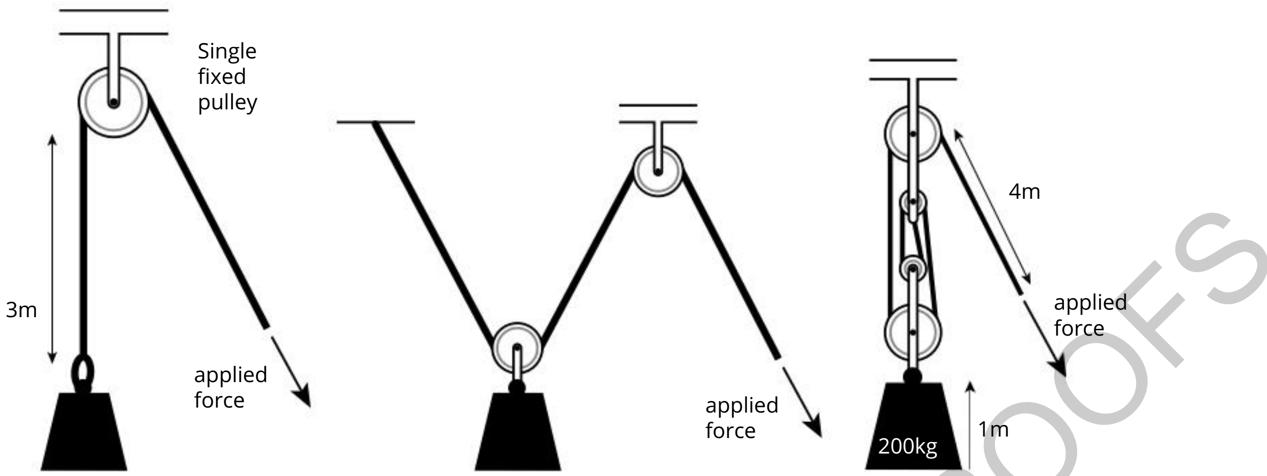



**FIGURE 3.11.5** Three pulley set-ups: (a) a single pulley changes the direction of the force; (b) a double pulley halves the strength of the force required to lift the object; (c) a four-pulley system reduces the force required by a factor of 4, with the applied force moving four times further than the distance that the object is lifted.

**FIGURE 3.11.6** The headframe and winder from the old Chesney mine at Cobar Miner's Heritage Public Park in New South Wales

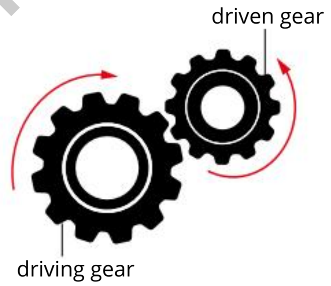



**FIGURE 3.11.7** Gears showing the 'driving gear' to which the force is applied and the 'driven gear', which is turned by the driving gear and passes on the force to where it is used

## Gears

Gears are wheels with teeth that interlock (Figure 3.11.7). They can change the direction of force, increase speed or multiply force. The mechanical advantage of gears is determined by the ratio of the number of teeth on the driving gear to the number of teeth on the driven gear. A larger driving gear compared to the driven gear increases force, while a smaller driving gear increases speed.

### SC 1 CHECK YOUR UNDERSTANDING

Explain how a ramp (inclined plane) can be considered a force multiplier.

# Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 Identify a simple machine used to split wood.

2 A pulley system with only one pulley does not act as a force multiplier. Explain why this type of pulley system can still be described as a machine.

3 Describe the benefit of using gears in a bicycle.

4 Explain why the action of a screw is similar to the action of an inclined plane.

# 3.12 Simple machines: Levers as force multipliers

## Learning intention

To understand how levers can change the magnitude or direction of a force

## Success criteria

**SC 1:** I can identify first-, second- and third-class levers.

**SC 2:** I can explain how levers change the magnitude of a force.

**KEY TERMS**

**lever** simple machine consisting of a rigid part that pivots about a point
**fulcrum** point about which a lever pivots
**effort** force applied to a lever to overcome the load
**load** a force, often a weight, on a lever or material

## HINT

The positions of the fulcrum and the forces in the three types of levers can be remembered as:

'Eiffel the elf fell over'

(first-class: effort fulcrum load; second-class: effort load fulcrum; third-class: fulcrum effort load)

Or you can devise your own mnemonic (a pattern of letters) to remember the differences between the three types of levers.

## Lesson overview

Machines are things that make a task easier to do. They can be complex like a car or a computer. They can be simple like a ramp or a wheel. Not all machines involve forces but many of the ones that do are able to make the output force larger. This means that a relatively small input force can have a relatively large effect, such as the force applied by scissors in Figure 3.12.1.

In this lesson, you will learn about how different types of levers can help you to perform tasks more easily.

**FIGURE 3.12.1** A pair of scissors is a simple machine.

**SC 1** I can identify first-, second- and third-class levers

## Components of levers

All **levers** have two main components: a long rigid object, such as a rod, beam, stick or bar, and a point where this long object moves (or pivots) around. This point is called the **fulcrum**.

To understand how a lever works, you must consider two forces.

- The input force that is applied to the lever. This is called the **effort**.
- The output force from the lever. This force acts on the **load**.

If you can identify the fulcrum, the effort and the load of a lever you can work out what type of lever it is (Figure 3.12.2).

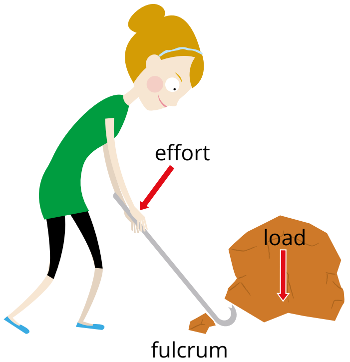



**FIGURE 3.12.2** A crowbar acts as a lever; it increases the force you can supply, making it easier to move the rock

## First-class levers

In a **first-class lever**, the fulcrum is always between the effort and the load. The effort acts in the opposite direction to the force on the load, as seen in Figure 3.12.3.

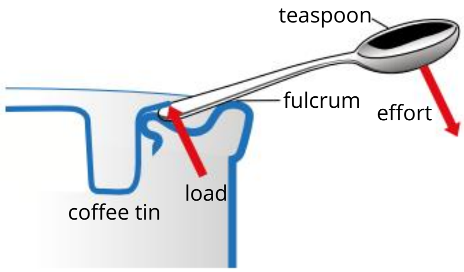



**FIGURE 3.12.3** Using a spoon to open a coffee tin lid is an example of a first-class lever.

**KEY TERMS**

**first-class lever** lever with effort and load located at each end, and fulcrum in the centre

**second-class lever** lever with the fulcrum at one end, the load in the centre, and the effort applied at the other end

**third-class lever** lever with the fulcrum at one end, the effort in the centre, and the load at the other end

## Second-class levers

In a **second-class lever**, the fulcrum is always at one end of the lever. The load is closest to the fulcrum and the effort is further away. In a second-class lever, the effort acts in the same direction as the force on the load, as seen in Figure 3.12.4.


**FIGURE 3.12.4** Wheelbarrows are a common example of second-class levers used to lift heavy loads.

## Third-class levers

In a **third-class lever**, the fulcrum is always at one end of the lever. The effort is closest to the fulcrum and the load is further away. In a third-class lever, the effort acts in the same direction as the force on the load, as seen in Figure 3.12.5.

**SC 1 CHECK YOUR UNDERSTANDING**

Explain the difference between a first-class lever, a second-class lever and a third-class lever.

**SC 2** I can explain how levers change the magnitude of a force

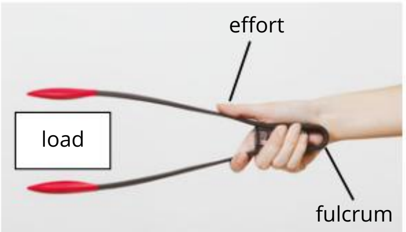



**FIGURE 3.12.5** Tongs are a third-class lever as the fulcrum is the furthest point from the load.

Many simple machines, such as levers, can increase the strength of an input force (the effort). These are called force multipliers.

## How can a lever increase force?

Force multipliers work by using a weaker force acting over a longer distance to create a stronger force acting over a shorter distance. For this to happen in a lever, the effort must be further away from the fulcrum than the load. This means that the effort force will always be acting over a longer distance than the load. This makes the force acting on the load stronger than the effort force.

### First-class levers

A first-class lever can act as a force multiplier if the effort force—in this case, the effort pushing down on the pole in Figure 3.12.6—is further away from the fulcrum than the load—in this case, the rock. Note that a downwards effort (force) changes to an upward force on the load because of the position of the fulcrum.

**FIGURE 3.12.6** A weaker effort force applied at a greater distance will help move the heavy rock.

## Second-class levers

All second-class levers are force multipliers as the effort is always further away from the fulcrum than the load, as seen in Figure 3.12.7.

The longer the lever, the greater the force benefit. This is shown in a bottle opener (Figure 3.12.8) where the load is very close to the fulcrum, and by comparison, the applied force is a long way away. Note that in Figure 3.12.8, the fulcrum is where the bottle opener presses down on the bottle top. The load is where the bottle opener lifts the edge of the bottle top. The effort's direction is the same as the force on the load.

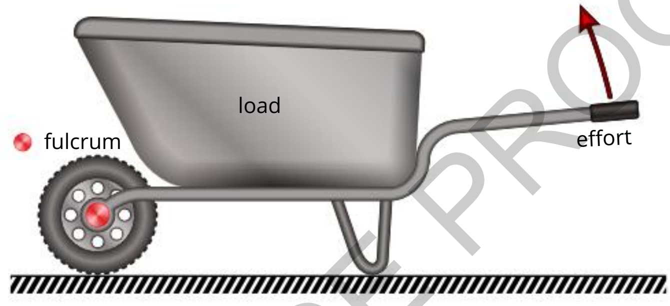



**FIGURE 3.12.7** The handle of a wheelbarrow is further from the fulcrum than the load, making it a force multiplier.

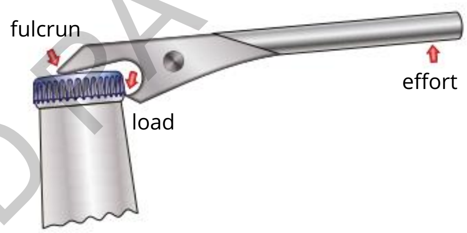



**FIGURE 3.12.8** Bottle openers have long handles to open tight bottlecaps with ease.

## Third-class levers

Third-class levers cannot act as force multipliers as the load is always further away from the fulcrum than the effort.

**SC 2 CHECK YOUR UNDERSTANDING**

Describe how a first-class lever can be used as a force multiplier.

# Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1. Explain how the positions of the fulcrum, load and effort determine the type of lever.
2. Explain why second-class levers are always force multipliers.
3. Compare the ability of first-, second- and third-class levers to act as force multipliers.
4. Discuss the advantages of using levers as force multipliers in everyday tasks.

# 3.13 Force and distance in a lever

## Introduction

If you have ever sat on a seesaw or seen people on a seesaw, you might know that the distance a person is from the centre of the seesaw (the fulcrum) will change the effect that person has on the balance of the seesaw. For example, a lighter person can balance a heavier person if the lighter person is further away from the fulcrum (Figure 3.13.1).

In this practical investigation you will investigate the relationship between the distance of an object from the fulcrum and the effect of that object.

## Background

Seesaws are an example of first-class levers. In first-class levers the load and the effort (applied force) are on either side of the fulcrum. This experiment uses a model of a seesaw to investigate the relationship between the distance of an object from the fulcrum and the effect of the weight force from that object.

## Aim

To investigate how the force required to balance a load on a seesaw is affected as it is moved closer to the fulcrum

## Apparatus

- 1 m ruler
- stiff cardboard square
- 2 plastic cups
- 25 × 10 g masses (such as slotted masses)
- masking tape
- scissors

## Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

## Method

1 Use scissors and ruler to score two lines so the cardboard square is divided into thirds. Bend the cardboard to make a triangular prism to use as a fulcrum, as shown in Figure 3.13.2.

2 Tape one of the plastic cups (cup 1) to the ruler so that the centre of the cup is at the 10 cm mark of the ruler.

3 Position the ruler so that the fulcrum is half-way along its length. Cup 1 will now be 40 cm from the fulcrum.

### Learning intention

To be able to analyse data to identify relationships between force and distance

### Success criteria

**SC 1:** I can record and process data.

**SC 2:** I can describe trends in data obtained from modelling a seesaw.

**SC 3:** I can analyse data to identify relationships between mass and distance from the fulcrum in a lever.

**FIGURE 3.13.1** A seesaw is a first-class lever.

### HINT

Before you begin, copy the table in the Results section into your notebook. Alternatively, construct a spreadsheet with similar columns.

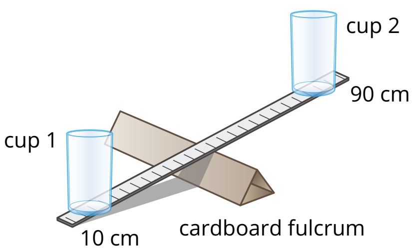



**FIGURE 3.13.2** Setting up your experiment

**HINT**

It can be very tricky to get the ruler to balance exactly! If it won't exactly balance, get it as close as possible to balancing and record the total mass.

**HINT**

Always measure the distance from the fulcrum to the centre of cup 2.

Be careful not to be confused by the measurements on the ruler. They are from the end of the ruler, not the fulcrum.

Throughout the experiment, ensure that the fulcrum is still positioned at the half-way point of the ruler (50 cm mark).

4 Place cup 2 on the other side of the seesaw, 40 cm from the fulcrum (this sho uld be at the 90 cm mark).

5 Add 50 g of masses to cup 1.

6 Add mass to cup 2 until the seesaw is balanced.

Record the mass in cup 2 in your results table or spreadsheet (column 4), and then empty cup 2.

7 Move cup 2 so that it is 33 cm from the fulcrum (this should be at the 83 cm mark).

8 Add masses to cup 2 until the seesaw is balanced and record the total mass in cup 2.

9 Repeat this process with cup 2 at 25, 20 and 10 cm from the fulcrum (the 75, 70 and 60 cm marks).

## Results

Copy the following table into your notebook and use it to record your results or record your results in a spreadsheet.

| 1<br>Mass in cup 1 (g) | 2<br>Distance of cup 1 from fulcrum (cm) [D1] | 3<br>Mass in cup 1 × distance [D1] | 4<br>Mass in cup 2 (g) | 5<br>Distance of cup 2 from fulcrum (cm) [D2] | 6<br>Mass in cup 2 × distance [D2] |
|---|---|---|---|---|---|
| 50 | 40 | | | 40 | |
| 50 | 40 | | | 33 | |
| 50 | 40 | | | 25 | |
| 50 | 40 | | | 20 | |
| 50 | 40 | | | 10 | |

## Discussion

Suggest two improvements for how the data can be measured more accurately in this experiment.

## Conclusion

Write your conclusion to this experiment. Include answers to the following questions.

1 Was more or less mass required to balance the load as the effort (cup 2) moved closer to the seesaw's fulcrum?

2 Compare the results in column 3 and column 6 of the results table and describe what you observe.

3 Describe a mathematical relationship between the mass required in cup 2 and the distance of cup 2 from the fulcrum.

WS Communicating
DS Patterns and prediction

# 3.14 Simple machines used by First Nations Australians

## Introduction

First Nations Australians have been using simple machines for thousands of years in their daily lives, from hunting and gathering to building shelters.

In this inquiry activity, you will investigate how First Nations Australians have used simple machines and describe how these machines alter the direction or magnitude of forces.

**Learning intention**

To be able to describe the use of simple machines by First Nations Australians

**Success criteria**

**SC 1:** I can use a variety of data sources to find information about the use of simple machines by First Nations Australians.

**SC 2:** I can describe how simple machines used by First Nations Australians alter the direction or magnitude of forces.

## Background

Simple machines are fundamental devices that make work easier. For example, the Wiradjuri people of New South Wales have used a type of lever known as a woomera. The woomera is a spear-throwing device that acts as an extension of the arm, allowing the user to throw a spear with greater force and distance. This simple machine increases the magnitude of the force applied, making it easier to hunt.

The Eora people of New South Wales have used stone axes, which are a type of wedge. These stone axes were used for various tasks, including cutting wood, shaping tools and in the preparation of food.

## Aim

To investigate and describe the use of simple machines by First Nations Australians

## Plan

Begin by researching the different types of simple machines used by First Nations Australians. Use reliable sources to gather information. Decide, based on guidance from your teacher, how you will present your findings, such as through a written report, a presentation or a visual display.

## Design

1 Identify and list some types of simple machines used by First Nations Australians.

2 You can use the following websites or others to gather information:
- Australian Institute of Aboriginal and Torres Strait Islander Studies
- National Museum of Australia
- Aboriginal Culture
- Creative Spirits

Ensure that you acknowledge the sources that you have used in a bibliography or reference list.

GO TO ➤
For guidance with referencing secondary data see Toolkit section x.x.

## Conduct

1 Select one type of simple machine from your list.
2 Write detailed descriptions of how this type of machine has been used by First Nations Australians.
3 Create diagrams or find images that illustrate the use of these machines.
4 Following guidance from your teacher, organise your findings into an engaging presentation or report.

## Improve

1 Review your notes and ensure all information is accurate and relevant.
2 Check that your descriptions clearly explain how the simple machines alter the direction or magnitude of forces.
3 Ask a peer to review your work and provide feedback.

## Discussion

1 Reflect on the effectiveness of your research process. Did you use a variety of sources?
2 Evaluate the quality of your diagrams or images. Are they helpful in understanding the use of this simple machine?

# 3 Forces and simple machines

## Topic summary

The key concepts included in this topic are:

- Force is measured in newtons (N)
- Forces can be classified as contact (direct) or non-contact (indirect) forces.
- Forces can be represented on force diagrams using the length and direction of the arrow.
- If the forces acting on an object are balanced, the object will continue being at rest or moving at a constant velocity.
- If the forces acting on an object are unbalanced, the object will speed up, slow down or change direction.
- Objects with mass cause a gravitation field. The strength of the gravitational field reduces with increased distance from the object.
- Electrostatic forces occur between charged particles. Opposite charges attract and similar charges repel.
- A magnetic field can be defined (mapped) using magnetic field lines.
- The force exerted by magnets increases with decreasing distance from the magnets.
- Certain materials can be magnetised as part of an electromagnet.
- Simple machines allow forces or motion to be multiplied.
- Levers can be categorised depending on where the effort, fulcrum and load are located.
- Increasing the distance between the effort and the fulcrum of a lever can magnify the effect of the applied force.
- First Nations Australians demonstrate knowledge in aerodynamic principles as evidenced by their use of boomerangs.



## Review questions

The following questions will assess your success in achieving the learning intentions for this topic.

### Remember

1 State the unit of measurement for force.

2 Identify the three classes of levers.

3 Define:

a electrostatic force

b frictional force.

4 Describe magnetic field lines.

### Understand

5 Explain how the length of a force arrow relates to the magnitude of the force.

6 State the difference between direct (contact) and indirect (non-contact) forces and provide examples of each.

7 Describe how seatbelts in motor vehicles manage the forces acting on the occupants in the case of an accident.

8 Explain the importance of controlling variables in an investigation.

9 You have a bar magnet and several different materials: iron nails, copper wire, plastic beads and wooden blocks. You place each material near the magnet one at a time.

a Predict what will happen when each material is placed near the magnet. Explain the reasoning behind your predictions.

b Predict what will happen if another bar magnet was brought close to the magnet. Explain the reasoning behind your predictions.

## Apply

**10** Compare the ability of first- and second-class levers to act as force multipliers.

**11** A folder initially at rest on a table experiences an applied force of 10 N to the right and a frictional force of 5 N to the left.

- **a** Draw a force diagram of the applied force and frictional force acting on the folder.
- **b** Calculate the net force acting on the folder.
- **c** Determine if the forces are balanced or unbalanced.
- **d** Identify what will happen to the motion of the folder.

**12** The acceleration due to gravity (g) on the surface of Mars is 3.7 m $s^{-2}$. Calculate the weight of an astronaut who has a mass of 75 kg, on the surface of Mars.

## Analyse

**13** Frictional forces play a significant role in motion.

- **a** Explain how frictional forces are important in everyday activities such as walking or driving.
- **b** Outline an investigation that could be undertaken to test the effect of frictional forces from different surfaces.

**14** Indigenous knowledge has significantly contributed to scientific advancements, particularly in aerodynamics.

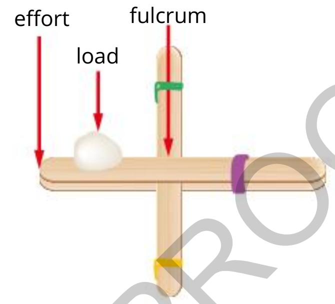
- **a** Identify who David Unaipon was.
- **b** Explain how David Unaipon used cultural knowledge of boomerang aerodynamics to propose a vertical lift machine.

## Extension: Design a device

**15** Catapults are medieval weapons that allow heavy objects to be thrown great distances. They are an example of a force-multiplying first-class lever, as the effort is applied at a greater distance from the fulcrum than the load.

For this extension task, you will design your own catapult using icy-pole sticks, elastic bands and cotton balls.

Make the catapult shown in the diagram below. Test your device before continuing and make any final adjustments to your elastic bands.




- Arrange your device so that the fulcrum is in the centre of your icy-pole sticks. Launch your cotton ball and record the distance travelled.
- Adjust the elastic bands to change the distance between the effort and the fulcrum. Compare the distance between the effort and the fulcrum to the distance your cotton ball travels. Record any patterns in your data.
- Make additional tweaks to the design to explore ways to increase the launch distance of your catapult. Document any changes you make.
- Compete with other students in your class to see who designed the catapult with the greatest launch distance. You might even explore other parameters, such as the stability of the catapult designs.

## Topic reflection

The learning intentions for this topic are given in each lesson and at the beginning of the topic. Consider how well you have achieved them. Note down any areas that you are confident in, and others where you are not so sure.

# 3 Glossary

**acceleration** increase in speed

**balanced forces** forces acting on a single object where the force in one direction is equal to the force applied in the opposite direction

**constant velocity** the movement of an object at the same speed and in the same direction

**contact force** force that acts between two objects that touch each other; also called a direct force

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

**deceleration** decrease in speed

**dependent variable** the variable that is being measured in an experiment; it changes as the independent variable changes

**distance multiplier** machine that converts a small input distance into a large output distance or vice versa

**effort** force applied to a lever to overcome the load

**elliptical** the shape of an ellipse, which is an elongated circle, stretched into an oval

**first-class lever** lever with effort and load located at each end, and fulcrum in the centre

**force** any interaction that will change the motion of an object; for example, a push or a pull

**force diagram** a diagram that uses arrows to show one or more forces acting on an object

**force multiplier** machine that increases the force applied for a task, such as a second-class lever

**friction** force that acts against an object's motion

**fulcrum** point about which a lever pivots

**gravitational force** the force on an object due to gravity; can be described as the 'weight' of an object

**gravity** force of attraction between any two objects

**independent variable** the factor that is changed in an investigation to find out how it affects another factor (the dependent variable)

**inquiry question** a question that can be answered by conducting an investigation

**lever** simple machine consisting of a rigid part that pivots about a point

**load** a force, often a weight, on a lever or material

**magnetic field lines** visual representation of a magnetic field's strength and direction

**magnitude** a measure of the size or strength of something

**mass** the amount of material in an object; measured in kg

**mechanical advantage** a measure of how much a simple machine makes work easier

**net force** the combination of multiple forces acting on a single object; also called resultant force

**newton meter** a device used to measure the strength of a force; often called a spring balance

**non-contact force** force that acts on an object from a distance; also called an indirect force

**scientific convention** an agreed way to carry out an action or communicate information

**second-class lever** lever with the fulcrum at one end, the load in the centre, and the effort applied at the other end

**speed** the rate of change of distance

**third-class lever** lever with the fulcrum at one end, the effort in the centre, and the load at the other end

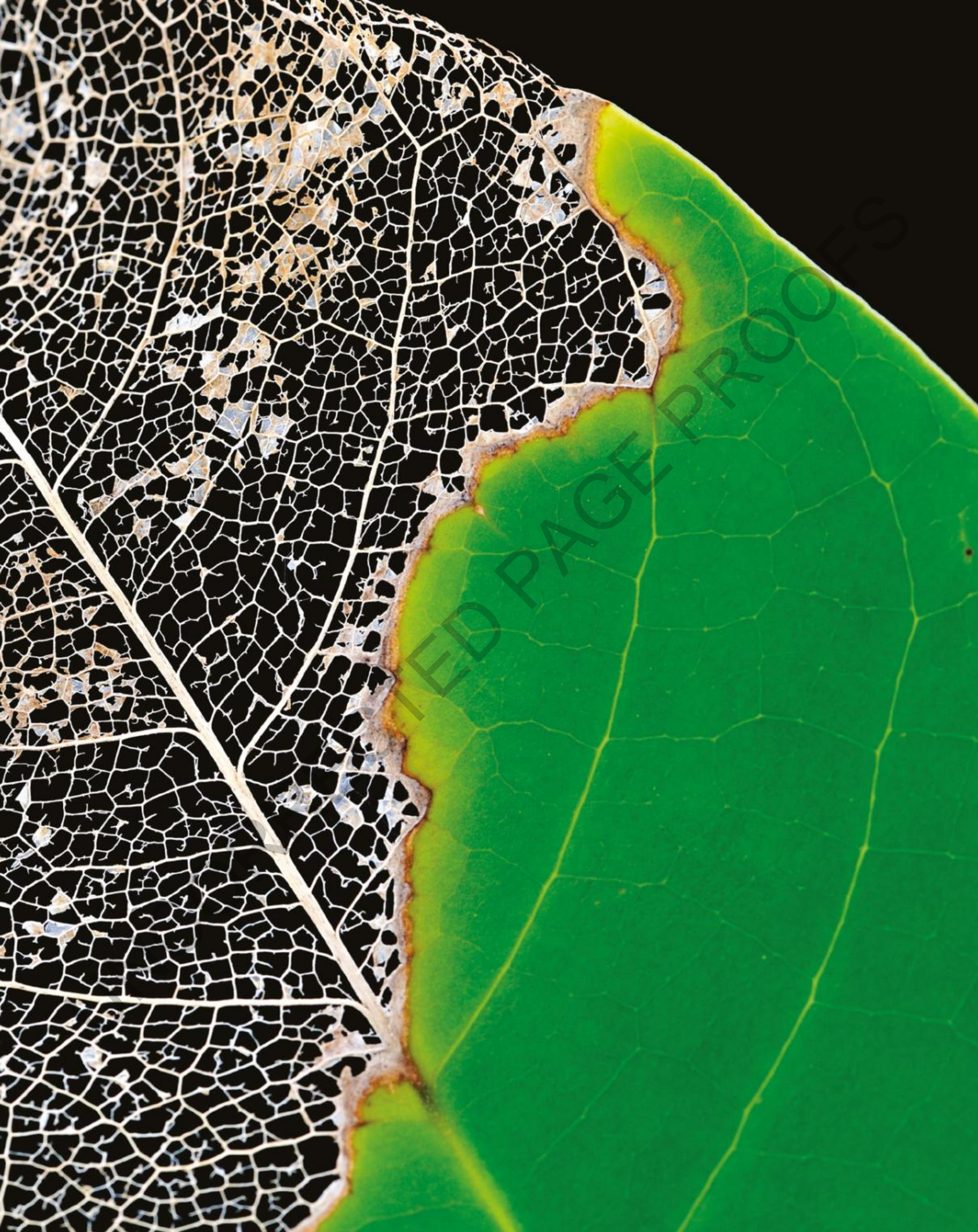
**unbalanced forces** forces acting on a single object where the force in one direction is not equal to the force applied in the opposite direction

**variable** a factor or condition that can change during an experiment or can influence the experiment

**vector** a quantity that has magnitude and direction

**velocity** the speed and direction of an object

**weight** the force of gravity pulling on an object; measured in newtons (N)



**TOPIC 4**

# Cells

For many thousands of years, humans in Australia and around the world have studied the behaviour of living things from the plant and animal kingdoms: how they moved, found food, and protected themselves from the environment.

It is only since the development of the microscope, less than 500 years ago, that scientists were able to see living matter at a scale small enough to make a huge discovery.

Living things, from great white sharks to white ants, from Blue Gum trees in Tasmania to Blue Leschenaultia plants in Western Australia, are all made up of cells. Some living things are made of just one cell, while other living things are made up of trillions of cells.

It is the features and functions of these cells that support the growth and survival of the living things that the cells create.

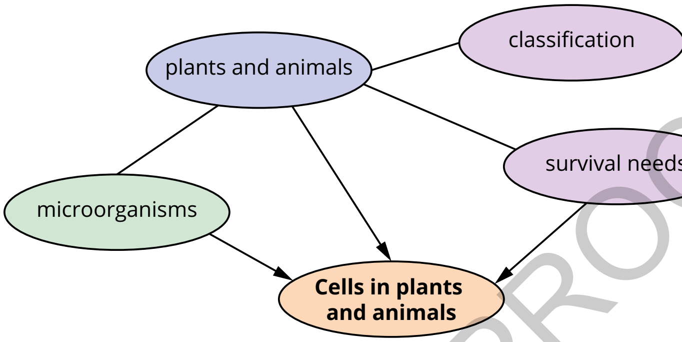
In this topic you will learn about the features and functions of cells and how they function to allow for the survival of organisms.

## Learning intentions

- ☐ To understand that cells are the basic unit of living things **xx**
- ☐ To be able to use a microscope to generate data and information **xx**
- ☐ To understand the key role of the nucleus in the function of cells **xx**
- ☐ To understand the roles of the cell wall and cell membrane in the function of cells **xx**
- ☐ To be able to investigate the action of a cell membrane **xx**
- ☐ To understand the role of the cytoplasm in cellular function **xx**
- ☐ To understand the roles of mitochondria and chloroplasts in cellular function **xx**
- ☐ To understand the similarities and differences between animal and plant cells **xx**
- ☐ To be able to identify and describe the functions of cell organelles **xx**
- ☐ To be able to use microscopes to observe, record and compare unicellular and multicellular organisms **xx**
- ☐ To understand the role of specialised cells in multicellular organisms **xx**
- ☐ To be able to observe and compare specialised cells under a microscope **xx**

# 4 Cells

The key concepts that you will use in this topic:




The following prior knowledge questions will help to support your learning in the topic and can be attempted before the first lesson.

## Classification

**1** Classify each of the following as living or non-living.

- **a** dogs
- **b** tables
- **c** people
- **d** bacteria
- **e** grass
- **f** soil
- **g** insects
- **h** viruses

## Microorganisms

**2** Name two types of organism that are made up of only one cell.

## Plants and animals

**3** Draw a table to show differences and similarities between plants and animals.

**4** What substance in plant cells causes plants to be green? Explain this substance's function.

## Survival needs

**5** Explain why some organisms have many cells, including at least one example in your answer.

**6** Name two different body systems and briefly explain their function.

# 4.1 Introduction to cells

## Lesson overview

Cells in biology are the small building blocks that form something much larger and more complex. Every living organism, including humans, is made up of biological cells. If life exists beyond Earth, it is likely to also be built from cells.

In this lesson you will learn about how cells are the building blocks of life and how they are part of all living systems.

**Learning intention**

To understand that cells are the basic unit of living things

**Success criteria**

**SC 1:** I can describe cells as microscopic units of living things.

**SC 2:** I can explain the difference between unicellular and multicellular organisms.

**SC 1** I can describe cells as microscopic units of living things.

All living things are made up of **cells**. Cells are the smallest living unit and can be thought of as tiny factories that carry out the functions needed for a living thing, or **organism**, to survive. These functions include releasing energy from food, removing waste products and making copies of themselves so that the organism can grow.

## Cell theory

Key ideas about cells were proposed in the mid-nineteenth century, and in 1855 these ideas were brought together to produce what is described as **cell theory**.

- All living things are made up of one or more cells.
- Cells are the basic building blocks of all living things.
- New cells are produced from existing cells.

Like most scientific theories, cell theory has evolved as new discoveries have been made. Over time, it has expanded to include additional functions and structures of cells that were unknown a century ago. Modern cell theory now provides greater detail on inheritance, cell composition, and energy transfer within cells. Many of these advancements were made possible by improvements in **microscopes**, allowing scientists to observe cellular features with greater precision.

Most organisms are **multicellular**, meaning they are made up of many cells. Many of the life processes of multicellular organisms are completed by different sections (organs and tissues) of the organism. This means the entire body of cells work in partnership for the multicellular organism to function properly. Some organisms, however, are only made up of one cell where all their life process occur. These organisms are called **unicellular**.

Multicellular organisms, such as humans, are highly complex, consisting of interconnected **body systems**. For example, the circulatory system transports essential substances through the blood.

Body systems are composed of **organs**, such as the heart, which in turn are made up of **tissues**, such as muscle. Each tissue is formed by specialised cells suited to its function—for example, muscle tissue consists of muscle cells. This hierarchical organisation of life is shown in Figure 4.1.1.

**KEY TERMS**

**cell** the building blocks of all living things
**organism** a living thing that functions as an individual
**cell theory** the idea that all living things are made up of one or more cells that come from pre-existing cells
**microscope** an instrument used to make very small things look bigger
**multicellular** an organism that is made up of many cells
**unicellular** an organism that is made up of one cell
**body system** a group of interconnected organs and tissues that perform functions in the body
**organ** a structure that contains at least two different types of tissues that work together to complete a function
**tissue** a group of cells of the same type that carry out the same function in the body

**cells** → **tissues** → **organs** → **systems** → **multicellular organisms**

A muscle cell.

Muscle tissue that is made of many muscle cells.

A heart is an organ that contains several tissue types, including muscle, nervous and connective tissues. The tissues work together to do the task of pumping blood.

The circulatory system is a body system that uses the heart, blood, veins and arteries to carry oxygen, nutrients and wastes to and from other body parts.

A human (multicellular organism) that is made up of many different body systems.

**FIGURE 4.1.1** The organisation of multicellular organisms

> **KEY TERM**
>
> **organelle** the smaller parts of a cell; found in the cytoplasm and have a variety of important functions

## What is inside cells?

The shapes you can see inside cells under a microscope are called **organelles**. These are parts of the cell that perform certain roles, such as providing energy and containing the genetic information (DNA) for the organism. You will learn more about organelles later in this topic.

**SC 1 CHECK YOUR UNDERSTANDING**

List the three components of the cell theory.

**SC 2** I can explain the difference between unicellular and multicellular organisms.

## Number of cells in the human body

Some living things, such as bacteria, are made up of only one cell and are called unicellular organisms. If a living thing is made up of two or more cells, it is called multicellular.

Humans are multicellular organisms made up of approximately 30 trillion (30 000 000 000 000) cells.

## What cells do

In multicellular organisms, different functions are carried out by different types of cells, or groups of cells working together, in a variety of systems. You can see some examples of these different cell types in Table 4.1.1.

**TABLE 4.1.1** Cell types and functions in humans

| Cell type | Functions in humans |
|---|---|
| red blood cells | carry oxygen around the body |
| muscle cells | provide support and allow movement |
| egg cells (ova) | involved in reproduction |
| nerve cells (neurons) | carry messages around the body |
| fat cells | store fat that can be used as energy when the body needs it |
| stem cells | have the ability to develop into many different cell types |

Skin, which is an organ, contains some of these types of cells. Figure 4.1.2 shows the different types of cells found in human skin.

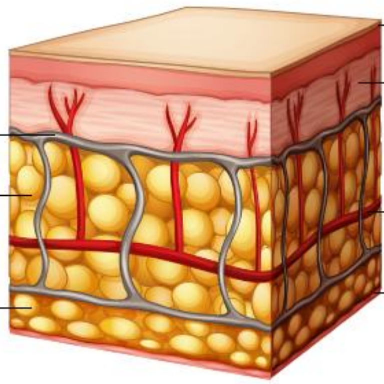



**FIGURE 4.1.2** Tissue types found in human skin.

## Unicellular organisms

In unicellular organisms, a single cell carries out all essential functions, including nutrient intake, waste removal, energy production, environmental response, and reproduction.

Bacteria are an example of unicellular organisms. Unlike plants or animals, bacteria belong to the Monera kingdom, which consists of single-celled organisms without a distinct nucleus. They reproduce by creating identical copies of themselves, known as clones.

Some bacteria can cause disease, such as *Staphylococcus aureus* (Figure 4.1.3), which may lead to skin infections and, in rare cases, serious conditions like septicaemia (blood poisoning). These bacteria are commonly known as golden staph.

However, not all bacteria are harmful—many play beneficial roles in human health and the environment.

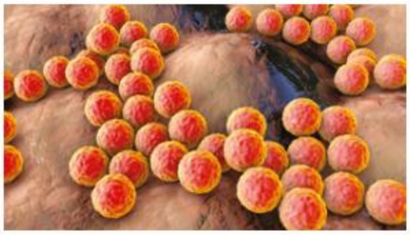


**FIGURE 4.1.3** The red spheres are a representation of *Staphylococcus aureus* bacteria, which is a unicellular organism.

## SCIENCE IN CONTEXT

### Good bacteria

Probiotic yogurt contains beneficial bacteria, such as Lactobacillus and Bifidobacterium, which help maintain a balanced gut. Maintaining a balanced gut is essential for overall health and well-being. This balance is dependent on the ratio of beneficial bacteria to potentially harmful ones.

A well-balanced gut improves digestion, including allowing for better absorption of nutrients and more efficient removal of waste. A large proportion of the body's immune cells are located in the gut, so a well-balanced gut helps to maintain a strong immune system, reducing the risks of disease.

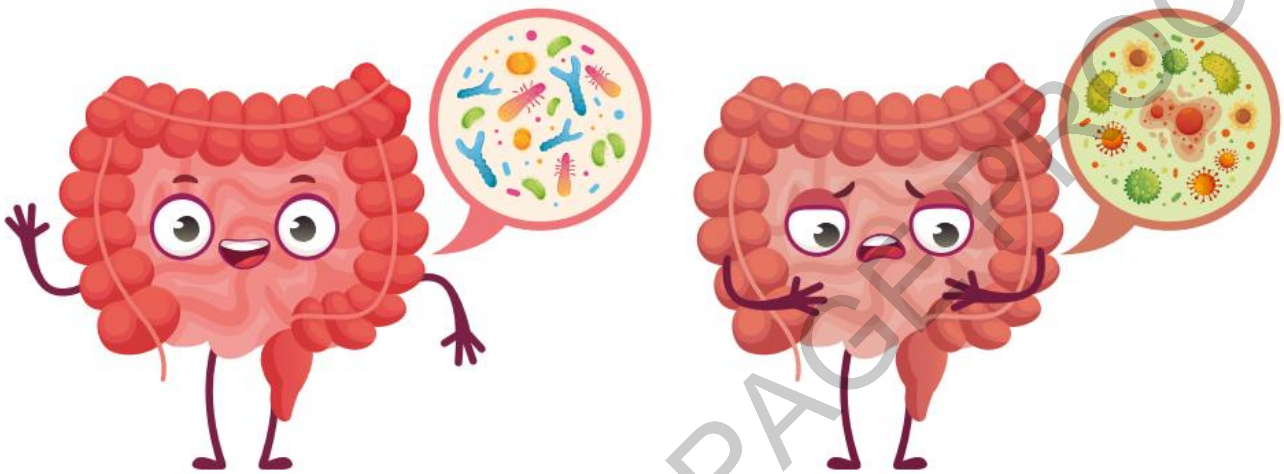


**FIGURE 4.1.4** The bacteria in probiotic yoghurt can keep your gut healthy.



**SC 2 CHECK YOUR UNDERSTANDING**

Name the term that is used to describe organisms that are made up of only one cell and the term for organisms that are made up of many cells.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 List the following terms in order of their biological hierarchy (from least to most complex): human, muscle cells, muscle tissue, circulatory system, heart.

2 Define an 'organ system'.

3 A group of different types of cells was examined under a microscope. They all appeared to be working together. What is the name of the term used to describe what was observed?

4 Classify each of the following as unicellular or multicellular.

a birds

b bacteria

c mammals

5 Ralph took a sample of water from a local creek, and he then observed the water under a microscope. He could not see anything in the water when he collected it, but he noticed that there were many small simple organisms vibrating around when he looked at the sample under the microscope. Is it more likely that Ralph observed multicellular or unicellular organisms? Explain your choice.

# 4.2 Using a microscope

## Introduction

Microscopes have been essential in the discovery of cells, the development of cell theory, and the advancement of cellular biology. While there are many types of **microscopes**, they all serve the same fundamental purpose: allowing scientists to observe details beyond the limits of the naked eye.

In this practical investigation, you will learn how to use a light microscope and how to calculate the magnification of a microscope when viewing specimens.

## Background

Things that we can see with the naked eye might be measured in centimetres (cm) or millimetres (mm), or larger units. Microscopes are used because most cells cannot be seen with the naked eye. Their size is usually measured in **micrometres** (μm), or smaller. The type of microscope used in schools and many science laboratories is a **light microscope**. You will probably use a microscope like the one shown in Figure 4.2.1. A light microscope with one **eyepiece** (or ocular lens) is called a monocular microscope, and one with two eyepieces is called a binocular (or stereo) microscope. The parts of a light microscope can be seen in Figure 4.2.1.

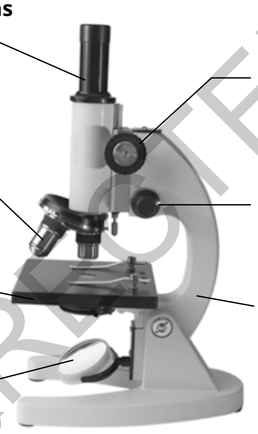



**FIGURE 4.2.1** The key parts of a light microscope and their functions

### SkillBuilder

### Converting between centimetres, millimetres and micrometres

It is useful to convert lengths from one unit to another. The units of centimetres, millimetres and micrometres are all fractions of a metre.

1 metre (m) = 100 cm = 1000 mm = 1000 000 μm

1 cm = 10 mm = 10 000 μm

1 mm = 1000 μm

### Learning intention

To be able to use a microscope to generate data and information

### Success criteria

**SC 1:** I can identify key parts of a light microscope and describe their functions.

**SC 2:** I can calculate the total magnification of a light microscope.

**SC 3:** I can safely use a microscope to observe and record observations of specimens at a range of magnifications.

### KEY TERMS

**micrometre** unit of measurement that is 1 millionth of a metre

**light microscope** a microscope that uses light to focus on the specimen being viewed

**eyepiece** the lens, or combination of lenses, at the viewing end of a microscope or telescope

If we want to convert from a large unit to a smaller one, we multiply.

If we want to convert from a smaller unit to a larger one, we divide.

### Example

Jack measured a cell as being of length 3 cm. To compare this to other cells he had seen, Jack needed to convert this length to µm. To do this he remembered that he had to multiply by 10 000 when converting from centimetres to micrometres.

Conversion rate: 1 cm = 1 × 10 000 µm.

Jack's calculation: 3 cm = 3 × 10 000 µm = 30 000 µm.

The length of the cell Jack measured was 30 000 µm.

## Microscope magnification

The light microscope uses light and a system of lenses to magnify the image. One **lens** is called the eyepiece (or ocular lens). This is the lens closest to your eye. The other lens is the **objective lens**. It is closer to the specimen. Microscopes that have two lenses are called compound microscopes.

The **magnification** of the microscope tells you how much bigger the image is than the real object. If the microscope has a magnification of 10×, then the image is ten times bigger than the actual object.

The **field of view** refers to how much of a specimen is visible when looking through a microscope. As magnification increases, a smaller portion of the specimen is seen, reducing the overall field of view. This means that zooming in on a specific area provides more detail but reveals less of the whole object.

The maximum magnification of a light compound microscope is about 1000 times bigger than the specimen when seen with the naked eye. At this magnification, some of the largest bacteria are just visible. The maximum magnification of stereo microscopes is about 100×.

**KEY TERMS**

**lens** can be used to magnify and focus an object being viewed under the microscope

**objective lens** the lens in a microscope or telescope that is nearest to the object being viewed

**magnification** the ratio of the size of an image compared to the size of the object

**field of view** the amount of the specimen seen through a microscope

## SkillBuilder

### Calculating the magnification of a microscope

Most microscopes used in school have two lenses: the eyepiece (or ocular lens) and the objective lens. The total magnification of the microscope is the combined effect of the two lenses.

To calculate the total magnification, you multiply the magnification of the eyepiece by the magnification of the objective lens.

total magnification = eyepiece magnification × objective lens magnification

### Example

Stephanie was using a microscope with an eyepiece magnification of 10×, and an objective lens of 4× was in place. To calculate the total magnification, she multiplied the magnification of the eyepiece by the magnification of the objective lens.

total magnification = eyepiece magnification × objective lens magnification

total magnification = 10 × 4 = 40

The correct way to write the magnification is with a multiplication symbol after the number, so Stephanie's microscope had a magnification of 40×.

## Aim

To become familiar with the workings of a microscope by observing common objects at various magnifications

## Apparatus

- small samples suitable for viewing under a microscope, such as sugar crystals (both plain and caster), salt, copper sulfate crystals, strand of hair, clothing fibres, small section of a leaf, writing sample, small newsprint
- light microscope
- microscope lamp (if the microscope does not have an inbuilt light source)
- glass microscope slides
- tweezers

### Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

**SAFETY NOTE**

- Ensure that you follow the correct way to focus the microscope so that you do not damage the specimen or the objective lens.

## Method

1 Place the sample carefully in the middle of a microscope slide. Place the microscope slide on the stage, holding it in position using the clips.

2 Adjust the mirror and/or light source so that the maximum amount of light is passing through the slide.

3 Select the objective lens with the lowest magnification.

4 Looking at the microscope from its side, adjust the coarse focusing knob to bring the stage and objective lens as close as possible to each other without touching.

5 Looking through the eyepiece, turn the coarse focusing knob so that the stage and objective lens move further apart.

6 Keep doing this until the specimen is in focus.

7 If you miss the point of focus, go back to step 4 and start again.

8 Use this procedure to observe each specimen using the microscope.

## Results

Draw a table in your notebook, like the one below. In the table, sketch a diagram of your observations for each specimen. Record the magnification used to obtain the clearest image of the object and describe any observations that would not have been possible without the microscope.

| Specimen | | Sketch |
|---|---|---|
| Magnification | | |
| Microscopic observations | | |

## Discussion

1 List three parts of the light microscope and briefly explain their function.

2 Outline how the magnification of a lens affects the field of view in a light microscope.

3 Explain why it is important to know the total magnification when using a microscope.

4 What is multiplied when calculating the magnification of a specimen viewed under a light microscope?

5 Compare the total magnification when using a 10× eyepiece with a 4× objective lens versus a 40× objective lens.

6 Outline how you would record your observations when viewing a specimen under different magnifications.

# 4.3 The functions of the nucleus in cells

## Lesson overview

The **nucleus** of a cell can be described as the information centre for the cell. The nucleus contains all the genetic information required for that cell. Almost every other cell in the organism also contains this same genetic information. This genetic information is vital for the survival of the cell and the organism that the cell belongs to.

Figure 4.3.1 shows the nucleus (pink) of an animal cell surrounded by the other components of the cell.

In this lesson you will learn how to identify the nucleus of a cell and explain what the key functions of the nucleus are.

**Learning intention**

To understand the key role of the nucleus in the function of cells

**Success criteria**

**SC 1:** I can identify the nucleus from a visual representation of a cell.

**SC 2:** I can explain the function of the nucleus of a cell.

**FIGURE 4.3.1** An illustration of an animal cell; the nucleus is shown in pink

**SC 1:** I can identify the nucleus from a visual representation of a cell.

The first organelle to be identified within a cell was the nucleus. Both plant and animal cells contain a nucleus, like the ones in Figure 4.3.2 where the nuclei (the plural of nucleus) look like dots in the middle of the cells.

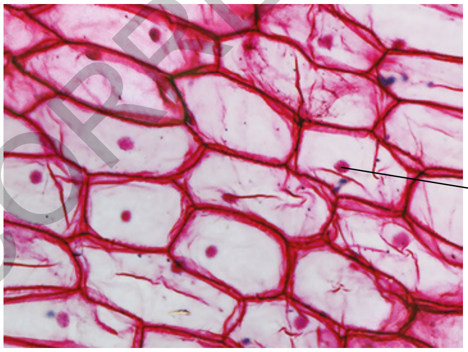



**FIGURE 4.3.2** Stained cells showing the nucleus in the central location

Cells that contain a nucleus are called **eukaryotic cells** (Figure 4.3.3).

The nucleus is normally drawn as a circular or oval shape in the centre of a cell diagram. Sometimes a smaller circle can be seen within the nucleus. This structure is called the **nucleolus**.

**Ribosomes**, which are involved in the production of proteins, are produced in the nucleolus of eukaryotic cells.

**KEY TERMS**

**nucleus** where the DNA of the cell is kept
**eukaryotic cell** a cell that contains a nucleus
**nucleolus** organelle within a cell nucleus that produces ribosomes
**ribosome** an organelle the does not contain a membrane and which is involved in the production of proteins

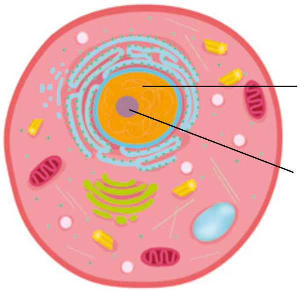



**FIGURE 4.3.3** A diagram of an animal cell containing a nucleus

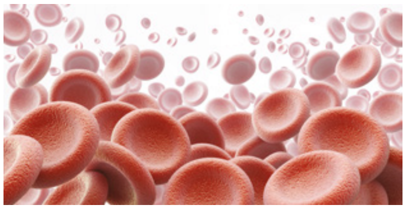


**FIGURE 4.3.4** Red blood cells do not have a nucleus and use all their space to carry oxygen.

**KEY TERMS**

**prokaryotic cell** a cell that does not have a nucleus

**cytoplasm** everything contained within a cell membrane except the nucleus

**DNA (deoxyribonucleic acid)** the genetic code within cells that provide instructions for the proteins that the cell requires

## DISCOVER MORE

Genes are small sections of DNA code that contain the instructions for your cell to build a protein. Proteins can be structural or functional and they make you look the way you do.

**Scifile**

### DNA storage

Inside the nucleus, DNA is neatly packaged into structures called chromosomes. If you stretched out all the DNA in a single human cell, it would be about 2 metres in length.

## Not all cells have a nucleus

Not all cells have a nucleus. For example, the DNA of bacteria (**prokaryotic cells**) is not packaged in a nucleus—it floats freely in the cell's **cytoplasm**.

Another example is red blood cells, which carry oxygen around the body. Not having a nucleus allows red blood cells to carry more oxygen (Figure 4.3.4). They start off with a nucleus but lose it as they mature. This means that red blood cells cannot grow or reproduce; they survive for only 100–120 days.

**SC 1 CHECK YOUR UNDERSTANDING**

Describe the location of the nucleus in a eukaryotic cell.

**SC 2** I can explain the function of the nucleus of a cell.

The nucleus is often referred to as the 'control centre of the cell'. It is called this because it contains **deoxyribonucleic acid**, **DNA**, which provides the instructions for the cell, including for the chemical reactions in the cell, how the cell develops and how the cell reproduces.

Every nucleus in nearly every cell of an organism, whatever the function of the cell, contains the same DNA. The nucleus is surrounded by a membrane that protects the nucleus and the DNA inside it. The DNA of animal and plant cells is so long that it needs to be tightly packaged into chromosomes so that it fits inside the nucleus (Figure 4.3.5). DNA is made up of small sections called genes.

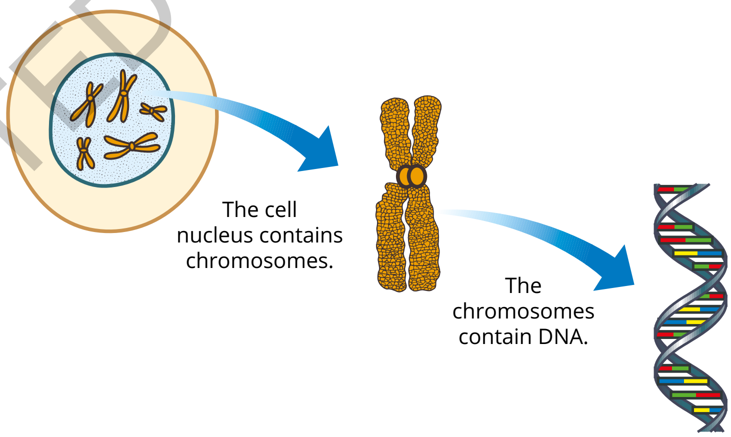



**FIGURE 4.3.5** The nucleus of the cell contains chromosomes, which contain tightly packed DNA

**SC 2 CHECK YOUR UNDERSTANDING**

Outline the main function of the nucleus.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 Describe what the nucleus looks like in a typical cell diagram.
2 List the key cell functions that the nucleus controls.
3 Explain the key difference between how DNA is stored in eukaryotic cells and prokaryotic cells.
4 Explain the benefit of red blood cells lacking a nucleus.

# 4.4 The roles of the cell wall and cell membrane

## Lesson overview

Imagine collecting the shopping in a paper bag. The bag helps keep everything together. A cell membrane is a bit like a paper shopping bag. It keeps things together, but there are some things, like water, that can pass through the bag from the inside out, or from the outside in.

If you wanted to stack a lot of shopping, it might be better to put the bags inside a cardboard box. The box provides strength. The box is a bit like a cell wall. It gives the cell a fixed shape and protects the materials inside the cell, including the membrane.

In this lesson, you will learn about the functions of the cell membrane and the cell wall. You will also find out more about why plant cells need cell walls, but animal cells do not.

**SC 1** I can identify the cell membrane and cell wall of a cell from a photomicrograph, model or other visual representation.

### Learning intention

To understand the roles of the cell wall and cell membrane in the function of cells

### Success criteria

**SC 1:** I can identify the cell membrane and cell wall of a cell from a photomicrograph, model or other visual representation.

**SC 2:** I can describe the functions of cell membranes and cell walls.

### KEY TERMS

**cell wall** a rigid layer on the outside of a plant cell or prokaryotic cell; provides the skeleton of a plant
**cell membrane** thin layer that separates the cell from its surroundings and controls what can move in and out of the cell
**micrograph** image taken using a microscope

## Cells in animals

Cell membranes in animals and plants act as barriers to the outside environment of a cell and only certain materials can pass across them. Both animal and plant cells have cell membranes.

Animal cells do not have a **cell wall**. This allows the cells to be flexible. Think of red blood cells, which need to squeeze through different places in the body to deliver oxygen. Many animals that need to have support will have some form of skeleton or shell that can provide that structure to the overall organism. The **cell membrane** can be seen in diagrams (Figure 4.4.1) and **micrographs** (Figure 4.4.2) as the edge or border of the cell.

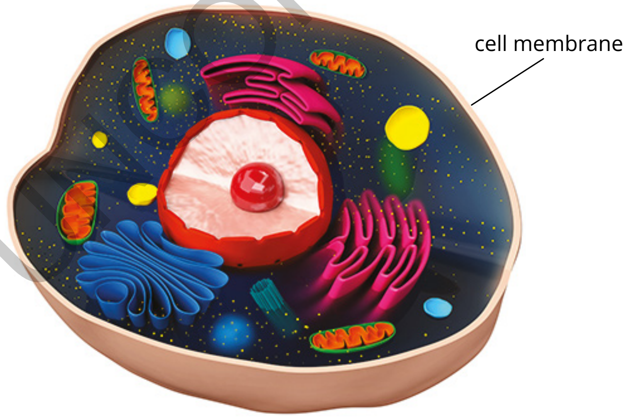



**FIGURE 4.4.1** A representation of a typical animal cell

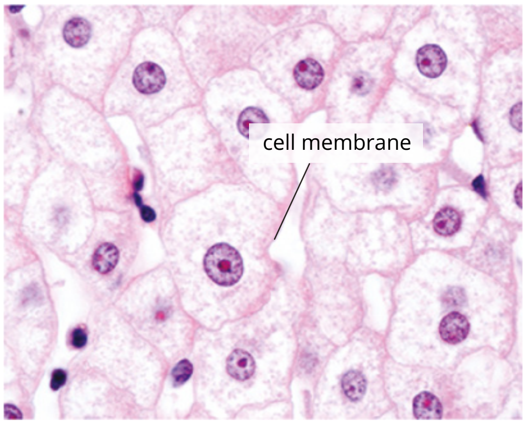



**FIGURE 4.4.2** A micrograph showing stained human liver cells; the cell membrane is the structure surrounding each cell

## Cells in plants

Plant cells have a cell wall and a cell membrane. In plant cells, it can be difficult to see the cell membrane as separate from the cell wall. The cell wall is the thicker structure surrounding the plant cell, and the cell membrane is inside the cell wall, as shown in the diagram (Figure 4.4.3) and photo (Figure 4.4.4).

**FIGURE 4.4.3** A diagram showing the cell wall and cell membrane of a plant cell.

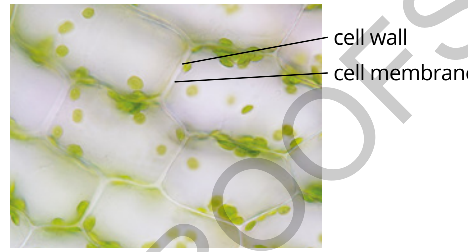



**FIGURE 4.4.4** A micrograph of leaf cells under a light microscope; the cell wall is the thicker structure surrounding the cell, and the cell membrane is inside the cell wall

**SC 1 CHECK YOUR UNDERSTANDING**

Describe the position of the cell wall and cell membrane in a plant cell.

**SC 2** I can describe the functions of cell membranes and cell walls.

**KEY TERMS**

**semi-permeable membrane** a thin layer of material that only certain particles can pass through

**osmosis** process by which particles of water pass through a semi-permeable membrane from a less concentrated solution into a more concentrated one

## Cell membrane

Every cell is enclosed by an external covering that keeps it separate from the environment around it. This is the cell membrane (Figure 4.4.5). The cell membrane controls what comes into and goes out of the cell

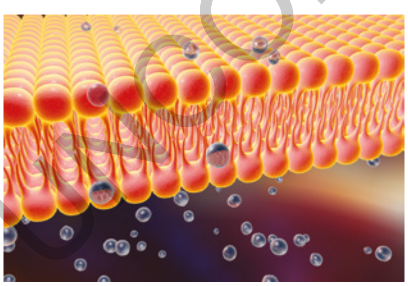


**FIGURE 4.4.5** A close-up cross-section of a cell membrane; some substances are moving into and out of the cell through the cell membrane

### Controlling what moves into and out of a cell

The cell membrane is considered a **semi-permeable membrane** because only some substances can pass through the membrane, while otherscannot.

In Figure 4.4.6 you can see water molecules are able to pass in and out of the cell, but sugar molecules cannot. The movement of water molecules in and out of the cell is known as **osmosis**. The particle size and other factors relating to a substance will restrict the movement of the substance across the cell membrane.

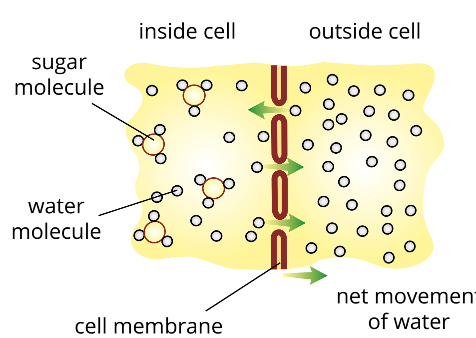



**FIGURE 4.4.6** Representation of osmosis; the smaller water molecules can pass through the membrane, while the larger sugar molecules cannot

## Cell wall

All cells have a cell membrane, but plant, fungal and prokaryotic cells also have a cell wall that surrounds the cell membrane. The cell wall helps support the plant or fungus and gives it shape (Figure 4.4.7).

Plants and fungi need this extra support to protect them from external environmental exposure or physical damage. Cell walls need to be semi-permeable to allow for transport of substances, but they do not control what goes in and out of the cell in the way that cell membranes do.

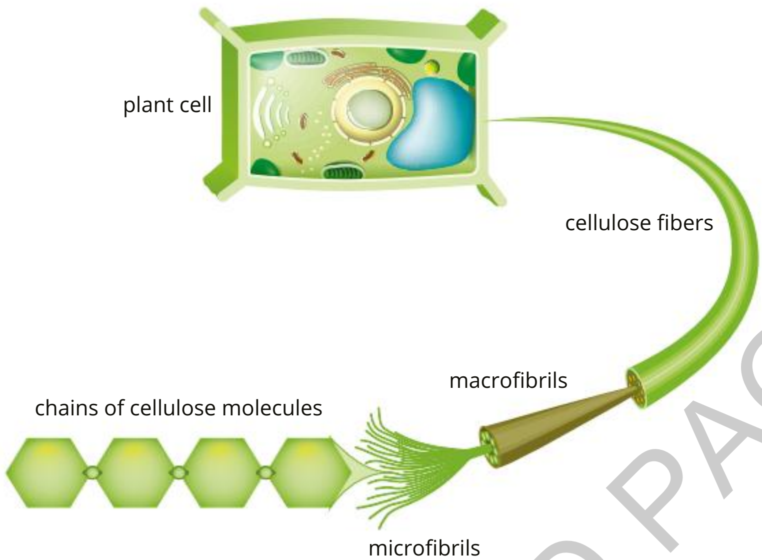



**FIGURE 4.4.7** Plant cell walls have a more rigid structure and are made up of a sugar molecule known as cellulose

**SC 2 CHECK YOUR UNDERSTANDING**

Define the term semi-permeable membrane.



## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 Describe the purpose of the cell wall in plant cells.
2 Name the term used to describe the movement of water in and out of the cell.
3 Explain the differences in appearance and location between the cell membrane and the cell wall.
4 Outline how the cell membrane and cell wall work together in plant cells.
5 If a cell contained a large amount (high concentration) of water and was put into a beaker of sugary water solution, is water more likely to move in or move out of the cell membrane? Explain your answer.

**WS** Processing data and information, Analysing data and information
**DS** Analysis of models

# 4.5 Action of a cell membrane

### Learning intention

To be able to investigate the action of a cell membrane

### Success criteria

**SC 1:** I can develop a prediction around the movement of water through a membrane.

**SC 2:** I can measure and record masses and volumes with a high level of precision.

**SC 3:** I can use knowledge of cell membranes to explain experimental results.

**FIGURE 4.5.1** The membrane of the egg is just under the shell

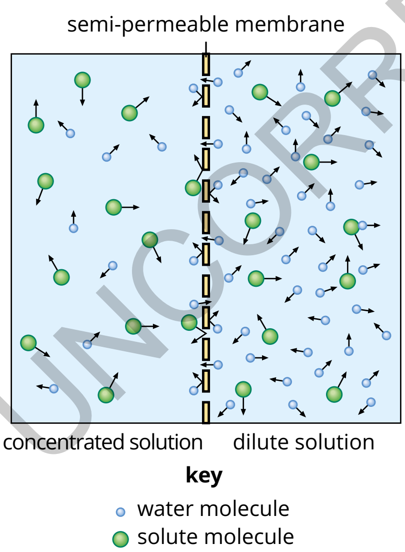



**FIGURE 4.5.2** Particles involved in osmosis through a membrane

## Introduction

Cell membranes are a vital part of all plant and animal cells. They control what goes in, what stays in, and what leaves the cell. The cell membrane can be thought of as the 'skin' of the cell.

In this practical investigation, you will investigate how adding salt to water affects the flow of water into and out of a cell through a membrane

## Background

Hens' eggs contain only one cell. This cell is surrounded by the yellow yolk of the egg, which is a collection of nutrients, including fat, proteins and carbohydrates. The egg white is 90% water, with proteins and other chemicals dissolved in the water.

When you break an egg, you can sometimes see a very thin skin just under the shell (Figure 4.5.1). This is not a cell membrane; it is the membrane of the egg. Nevertheless, an egg's membrane behaves in a similar way to a cell membrane. In this experiment, these similarities are taken advantage of to investigate the action of a cell membrane using an egg.

### Osmosis

Membranes like the one that surrounds an egg allow only very small particles, like water, to pass through the membrane. These membranes are called semi-permeable membranes because they allow some substances to cross but not others.

The process of water passing through a membrane is called osmosis. The overall direction of the flow of water through the membrane is from the side with a lower concentration of solute to the side with a higher concentration of solute, as shown in Figure 4.5.2.

A result of water passing through the membrane to the side with a higher concentration of chemicals, is that concentration will be reduced.

## Aim

To investigate the movement of water through a cell membrane

## Prediction

Read the method and write a prediction for what will happen to the mass of the eggs (one in salt water and one in distilled water) and the volumes of water in this experiment.

## Apparatus

- 2 eggs
- 500mL white vinegar
- 1 tablespoon salt
- 500mL distilled water (pure water with no chemicals dissolved in it)
- electronic balance
- 200mL measuring cylinder
- container large enough to hold two eggs immersed in vinegar
- 2 × 500mL beakers
- plastic wrap

### SAFETY NOTES

- Wear eye protection when using the vinegar in the first part of the experiment.
- Students should ensure that they let their teacher know if they have food allergies; if so, a different experiment can be conducted.

### Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

## Method

1. In your notebook, copy Tables 4.5.1 and 4.5.2 and their titles from the Results section.
2. Place the two eggs in a container of vinegar so that both eggs are completely covered.
3. Leave the eggs undisturbed for two days. By this time the vinegar should have dissolved the eggshell. The membrane inside the shell becomes the outer layer of the egg.
4. Carefully remove the eggs from the vinegar and rinse them. Pat them dry with paper towels.
5. Label the two glass beakers 'salt water' and 'distilled water'.
6. Make a concentrated salt solution by adding a tablespoon of salt to 250 mL of distilled water.
7. Measure out 200 mL of the salt water and pour it into the beaker labelled 'salt water'.
8. Measure out 200 mL of the distilled water and pour it into the beaker labelled 'distilled water'.
9. Use a balance to find the mass of each egg. Record each mass in the Day 0 column of Table 4.5.1.
10. Place one egg in each beaker of water and cover with plastic wrap.
11. Each day, for the next three days, measure and record the mass of the eggs.
12. On Day 3, measure and record the volume of water remaining in each of the beakers. Record this in the Day 3 column of Table 4.5.2.

### HINT

When you measure the mass of the eggs, take only one egg at a time from the solutions. This will ensure that each egg is returned to the correct solution.

## Results

Record your results in your notebook/in the tables below.

**TABLE 4.5.1** Changes in the mass of eggs in salt water and distilled water

| Treatment | Mass of egg (g) | | | | |
|---|---|---|---|---|---|
| | Day 0 | Day 1 | Day 2 | Day 3 | Total change in mass (g) |
| distilled water | | | | | |
| salt water | | | | | |

**TABLE 4.5.2** Changes in the volume of salt water and distilled water

| Treatment | Volume of water (mL) | | |
|---|---|---|---|
| | Day 0 | Day 3 | Total change in volume (g) |
| distilled water | 200 | | |
| salt water | 200 | | |

GO TO ➤
For further information about **reliability**, **validity** and **accuracy**, go to Toolkit, sections x.x, x.x and x.x

**KEY TERMS**

**reliability** how well experimental results conducted by different people or done at different times produce the same results

**validity** How well the experiment is designed and measures what you want it to measure

**accuracy** how close the experimental results are to what theory suggests they should be

## Discussion

Evaluate your investigation and the quality of the data with reference to **reliability, validity** and **accuracy**.

## Conclusion

Answer the following questions in your notebook to construct a conclusion to the experiment.

1 Describe any changes that took place in the two eggs.
2 Describe any change in the volume of the water in the two beakers.
3 Compare the actual results with your prediction.
4 Consider the process of osmosis and explain what you think was happening to the eggs in each solution and the role the membrane played.

# 4.6 The functions of the cytoplasm in cells

## Lesson overview

Cells are mini systems in which each component works together and the place where they do this is called the cytoplasm of the cell. Cytoplasm was discovered around 1865 when microscopes were able to create sufficiently detailed images.

The word 'cytoplasm' comes from 'cyto-', for 'cell', and '-plasm', for 'being formed into a shape'.

In this lesson, you will learn about the location, contents and functions of the cytoplasm (Figure 4.6.1).

**Learning intention**

To understand the role of the cytoplasm in cellular function

**Success criteria**

**SC 1:** I can describe the components that are contained in the cytoplasm of a cell.

**SC 2:** I can describe the functions of the cytoplasm of a cell.

**FIGURE 4.6.1** The cytoplasm is enclosed by the membrane of the cell

**SC 1** I can describe the components that are contained in the cytoplasm of a cell.

The cytoplasm is mostly made up of water, salts, proteins and organelles (Figure 4.6.2). Some of the organelles contained in the cytoplasm are:

- ribosomes, where proteins are made
- mitochondria, where chemical energy from food is transformed into energy for the cell, and
- chloroplasts, where sunlight is used to create nutrients through **photosynthesis**.

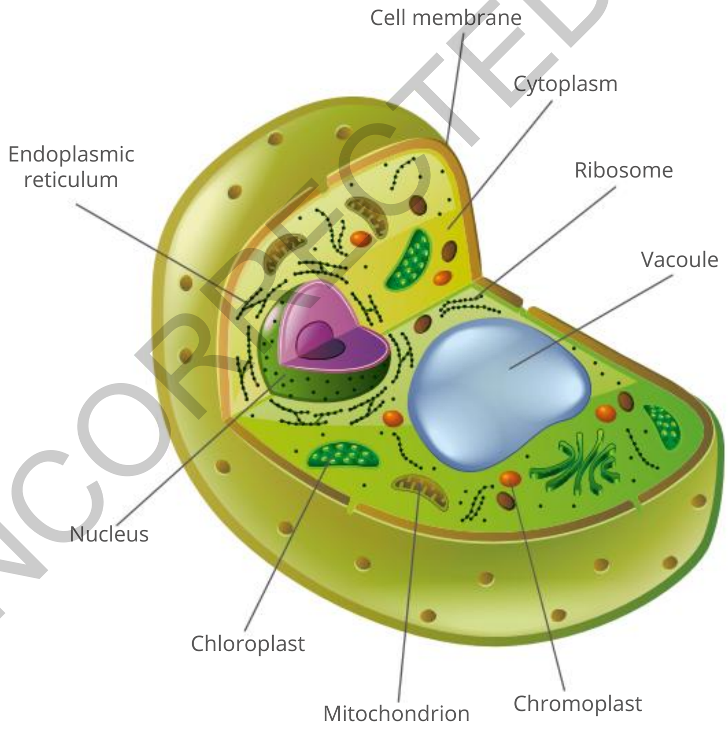



**FIGURE 4.6.2** The plant cell contains ribosomes for protein production, mitochondria for energy production and chloroplasts for sugar production, as well as other organelles.

**KEY TERM**

**photosynthesis** the chemical reaction in plants that converts carbon dioxide and water into oxygen and glucose using energy from sunlight

**KEY TERM**

**cytoskeleton** a network of proteins in the cytoplasm

## Supporting the cell

The cytoplasm fills out a cell and gives it shape and internal structural support. A network of proteins in the cytoplasm acts like a cellular 'skeleton', providing structure and holding organelles in place. This network of proteins in the cytoplasm is known as the **cytoskeleton** which can be seen in the cells in Figure 4.6.3.

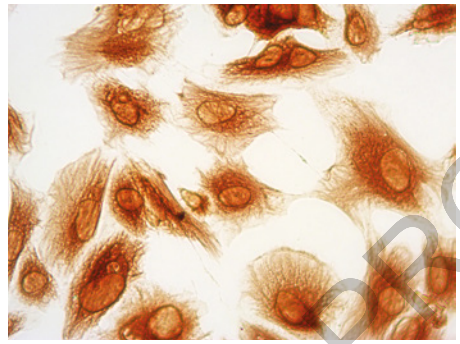


**FIGURE 4.6.3** A light microscope image of stromal cells, which connect tissue in organs. The brown stain helps to show the protein cytoskeleton within the cells

### SC 1 CHECK YOUR UNDERSTANDING

List the organelles that are found within the cytoplasm of the cell and briefly outline their function.

**SC 2** I can describe the functions of the cytoplasm of a cell.

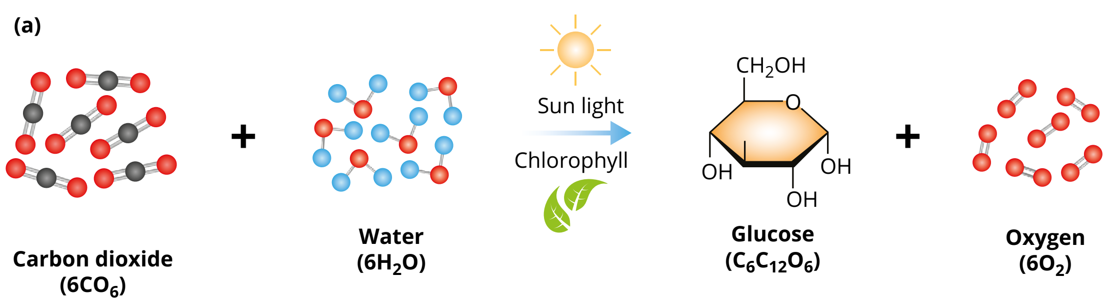
Many important cellular processes occur in the organelles contained in the cytoplasm, some of which include chemical reactions and processes involved in cell growth.

### DISCOVER MORE

Both photosynthesis and cellular respiration can be described by chemical equations.

Figure 4.6.4 shows two of the most important chemical processes that can occur. Photosynthesis occurs in the chloroplast organelle in autotrophs. The generation of energy can occur either with or without oxygen. If oxygen is present, most of these energy generating reactions occur in the mitochondria, but if there is no oxygen present, the reaction occurs solely in the cytoplasm of the cell.

The mitochondria and the chloroplasts are discussed further in Lesson 4.7.



(b)

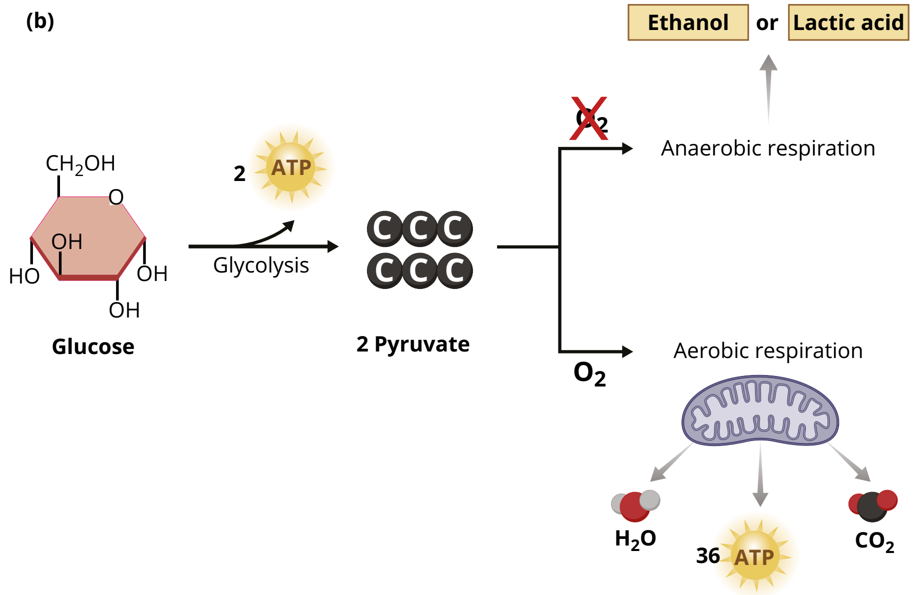



**FIGURE 4.6.4** a) Autotrophs undergo the cellular process of photosynthesis, which occurs in the chloroplast. b) All cells require energy and this can be done in cellular respiration with or without oxygen. If oxygen is present, most of these reactions occur in the mitochondria.

The cytoplasm also allows materials to move around the cell—material taken in from outside the cell travels through the cytoplasm to reach the organelles, and products created by the organelles travel through the cytoplasm to exit the cell through the cell membrane.

## How does the cytoplasm move things?

Parts of the cytoplasm can move around to change the position of organelles. In plant cells where chloroplasts use sunlight to create nutrients, the cytoskeleton is used to move these organelles to the areas of the cell that are exposed to the most sunlight. This helps maximise photosynthesis for the plant.

Some unicellular organisms can use their cytoplasm for movement as the cells respond to the environment around them. For the whole cell to travel, the cytoplasm can be extended to move in one direction.

**SC 2 CHECK YOUR UNDERSTANDING**

Explain one key function of the cytoplasm in the cell.

**Scifile**

**Fake Limbs**

The *Amoeba proteus* can use its cytoskeleton to create fake limbs known as 'pseudopods. The pseudopods allow the amoeba to move around and bring it closer to nutrient sources.

**KEY TERM**

**cytosol** fluid found in the cytoplasm of a cell

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 Define the term 'cytoplasm'.

2 Name one component found in the cytoplasm.

3 The cytoplasm is made up of different parts. Identify the key features of:
   a the **cytosol**
   b the cytoskeleton.

4 The cytoplasm contains a range of different substances. Explain the importance of the cytoplasm having this feature.

# 4.7 The functions of mitochondria and chloroplasts in cells

**Learning intention**

To understand the roles of mitochondria and chloroplasts in cellular function

**Success criteria**

**SC 1:** I can describe the functions of the mitochondria and chloroplasts of a cell.

**SC 2:** I can compare and contrast the presence and functions of the mitochondria and chloroplasts in cells.

**KEY TERMS**

**mitochondria** organelles where energy is released from food through the process of cellular respiration

**Cellular respiration** a biochemical process that uses glucose and oxygen to build ATP (adenosine triphosphate), a molecule which the cell uses to store and release energy.

**chloroplast** an organelle within the cell where photosynthesis takes place

## Lesson overview

Humans, like all animals, survive by eating plant and animal material that has been passed along the food chain. Only plants can create food from carbon dioxide and water, using the energy from sunlight. They do this in their chloroplasts.

Both plants and animals have specialised organelles within their cells known as mitochondria to help make energy for their cells from glucose.

In this lesson, you will learn about how chloroplasts and mitochondria carry out their roles in cells and how they have more things in common than you might think.

**SC 1** I can describe the functions of the mitochondria and chloroplasts of a cell.

**Mitochondria** (singular, mitochondrion) are organelles that can convert glucose from food into energy that the cell can use.

Mitochondria release energy using a series of chemical reactions called **cellular respiration**. The type of cellular respiration that takes place in the mitochondria is called aerobic respiration because it involves oxygen.

Mitochondria are found in both plant and animal cells. The number of mitochondria in a cell is related to how much energy the cell needs. Very active cells, such as heart muscle cells and neurons in the brain, have thousands of mitochondria. The structure of mitochondria is complex with an inner and outer membrane that act together to control the movement of chemicals within the mitochondria (Figure 4.7.1).

**FIGURE 4.7.1** Cutaway representation of a mitochondrion showing the inner (bright-yellow wavy structure) and outer (beige) membranes

## The function of chloroplasts

**Chloroplasts** use energy from sunlight to make food for the plant. This process is called photosynthesis (Figure 4.7.2).

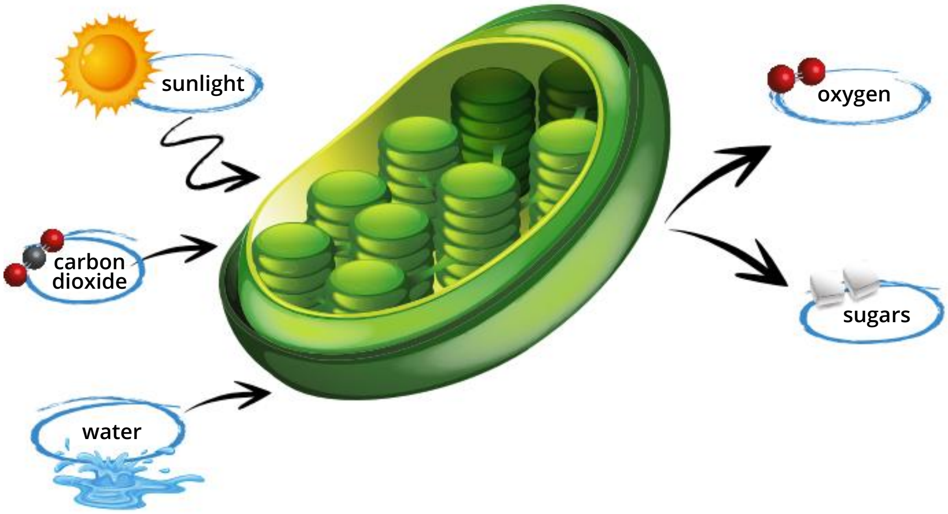



**FIGURE 4.7.2** The process of photosynthesis; the inputs for photosynthesis are water and carbon dioxide. The outputs are food in the form of sugars (nutrients for the plant) and oxygen.

Chloroplasts are typically located in the cells of plant leaves and stems. The green colour of plants is from a pigment inside chloroplasts called **chlorophyll**. Chloroplasts are found in plants and some protists (single celled eukaryotic organisms) but not in animals or fungi.

**SC 1 CHECK YOUR UNDERSTANDING**

Describe the function of chloroplasts within plant cells.

**SC 2** I can compare and contrast the presence and functions of the mitochondria and chloroplasts in cells.

## Similarities between mitochondria and chloroplasts

Look at Figure 4.7.3. You will see that mitochondria and chloroplasts both have an inner and outer membrane and have structures inside the inner membrane. Chemical processes occur within these structures, so both mitochondria and chloroplasts act like mini factories, with inputs (energy and/or substances going in) and outputs (energy and/or substances going out).

## Differences between mitochondria and chloroplasts

The main difference between mitochondria and chloroplasts is the processes occurring inside them. In photosynthesis chloroplasts use carbon dioxide ($CO_2$) and water ($H_2O$) to make glucose ($C_6H_{12}O_6$) using energy from sunlight and producing oxygen ($O_2$) as a by-product.

In cellular respiration, mitochondria convert glucose and oxygen back to carbon dioxide and water, building the chemical ATP, which can be used when the organism requires energy.

**KEY TERM**

**chlorophyll** the substance found in plant leaves that make leaves green and collects energy from the Sun for photosynthesis

**Scifile**

**The origins of mitochondria and chloroplasts**

Scientists have long proposed that mitochondria and chloroplasts originated as unicellular prokaryotic organisms that were engulfed by a larger cell. Both organelles contain their own DNA, have cell membranes, and reproduce in a way similar to prokaryotic organisms, supporting this theory.

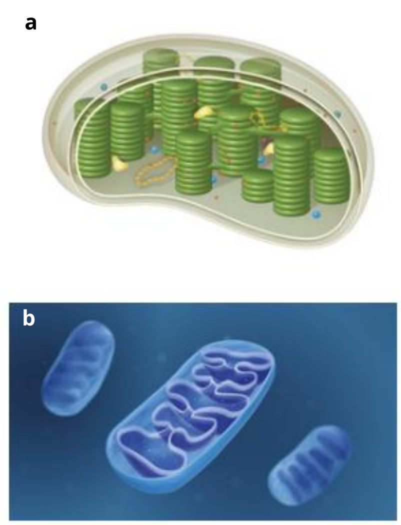



**FIGURE 4.7.3** (a) Cross-section illustration of a mitochondrion showing its internal 'wavy' structure; (b) Cross-section illustration of a chloroplast showing its internal stacked structures

Therefore, the chemical action of chloroplasts and mitochondria are opposite to each other (Figure 4.7.4). It is also important to understand that all living organisms require energy, so all organisms will carry out some sort of respiration, (with or without oxygen) but only autotrophs can use photosynthesis to make the required glucose.

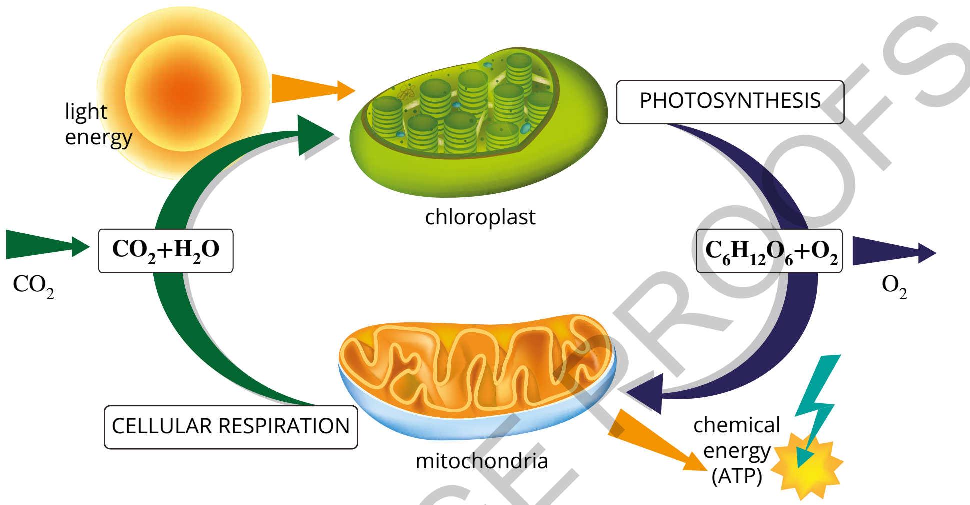



**FIGURE 4.7.4** The relationship between the chemical processes occurring in mitochondria and chloroplasts

**SC 2 CHECK YOUR UNDERSTANDING**

Describe the chemical relationship between mitochondria and chloroplasts within plant cells.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

**1** Name the colour chloroplasts would be when viewing untreated plant cells under a simple microscope.

**2** Identify the types of cells that contain chloroplasts.

**3** Identify and briefly explain the two different processes that occur in mitochondria and chloroplasts.

**4** Emad was viewing different types of body cells under the microscope. He recorded the approximate number of organelles that he saw in each type of cell viewed. He noted that the skin cells and nerve cells (also known as neurons) had comparatively very different numbers of mitochondria. Predict which cell type Emad viewed that had more mitochondria and explain why this would be the case.

# 4.8 Comparing plant and animal cells

## Lesson overview

Animals and plants have different survival needs.

Because animals and plants survive and grow in different ways, the cells in plants and animals must have different functions.

In this lesson, you will explore plant and animal cells to describe and explain their similarities and differences.

**Learning intention**

To understand the similarities and differences between animal and plant cells

**Success criteria**

**SC 1:** I can compare the structure of plant and animal cells.

**SC 2:** I can explain the similarities and differences between plant and animal cells.

**SC 1** I can compare the structure of plant and animal cells.

## Comparing plant and animal cells

Animal and plant cells are very similar. However, there are also several differences between them. These differences arise because of the different ways these multicellular organisms react to and utilise their environments. The main differences between the functions of the organelles in plant and animal cells are summarised in Table 4.8.1 below and illustrated in Figure 4.8.1.

**TABLE 4.8.1** Summary of the functions of organelles in animal and plant cells

| Function | Organelle | Present in animal cells | Present in plant cells |
|---|---|---|---|
| Making and processing proteins | nucleus | ✓ | ✓ |
| | ribosomes | ✓ | ✓ |
| Energy and food production | mitochondria | ✓ | ✓ |
| | chloroplasts | ✗ | ✓ |
| Storage and structure | vacuole | ✓ small | ✓ large |
| | cell wall | ✗ | ✓ |
| | cell membrane | ✓ | ✓ |

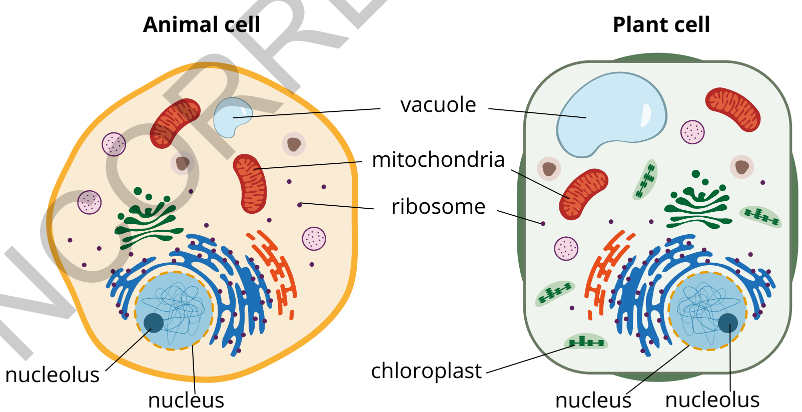



**FIGURE 4.8.1** A diagram of an animal cell and a plant cell, showing their organelles

**SC 1 CHECK YOUR UNDERSTANDING**

State two ways plant cells can be distinguished from animal cells.

**SC 2** I can explain the similarities and differences between plant and animal cells.

## Organelles common to all eukaryotic cells

Each organelle has a special job or function. As can be seen in Figure 4.8.1, some organelles are found in both plant and animal cells, including:

- cell membrane
- cytoplasm
- nucleus
- mitochondria.

## Animal cell organelles

Some organelles are found only in animal cells. These are:

- **lysosomes**, 'garbage disposal' units that get rid of waste from the cell
- **centrioles**, barrel-shaped structures made from microtubes that help a cell split into two during cell division.

### Plant cell organelles

Like animal cells, plants cells have a cell membrane, cytoplasm, nucleus and mitochondria. They also have the following organelles that are unique to plant cells:

- Cell wall. Plant cells have a cell wall outside the cell membrane. The cell wall helps support the plant and gives it shape.
- Large **vacuoles**. Both plant and animal cells have vacuoles, but the vacuole in a plant cell is much larger than in an animal cell.
- Chloroplasts. Chloroplasts carry out photosynthesis and can be found in cells in the leaves of plants

**KEY TERM**

**vacuole** space in a cell; in a plant cell, vacuoles stores water, nutrients and waste products and plays a role in maintaining turgor within the plant

**SC 1 CHECK YOUR UNDERSTANDING**

Animal and plant cells have some similar structures and some different structures. Take one structure from both the animal and plant cell that is similar and explain why both cells would need this structure.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1. Identify the organelles that are found in both animal and plant cells.
2. When comparing animal and plant cells, list the organelles that would only be seen in a model of:
   a. an animal cell
   b. a plant cell.
3. Explain why plant and animal cells contain different organelles.
4. With reference to organelles, compare how plants and animals obtain energy.

# 4.9 Organelles under the microscope

## Introduction

All cells have cell membranes that work as 'gate keepers' allowing only certain substances into and out of the cell. The cytoplasm is where all the organelles complete their tasks whilst the nucleus holds the genetic information of the cell. Two very important organelles are the mitochondria (present in both plant and animal cells) and the chloroplasts (in cells only).

In this lesson, you will apply what you have learnt about using a microscope and common organelles throughout the chapter, to identify the organelles in real cells.

## Background

Plant and animal cells have many organelles; some are common to both and others are unique to that type of cell. Generally, not all organelles can be viewed under a microscope because the organelles are so small.

## Aim

To identify which organelles in a cell can be seen when using a light microscope

## Apparatus

- prepared microscope slide of a plant cell and an animal cell
- light microscope
- microscope lamp (if the microscope does not have an inbuilt light source)

### Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

## Method

1. Place the microscope slide on the stage, holding it in position using the clips.
2. Adjust the mirror and/or light source so that the maximum amount of light is passing through the slide.
3. Select the objective lens with the lowest magnification.
4. Looking at the microscope from its side, adjust the coarse focusing knob to bring the stage and objective lens as close as possible to each other without touching.
5. Looking through the eyepiece, turn the coarse focusing knob so that the stage and objective lens move further apart.
6. Keep doing this until the specimen is in focus.
7. If you miss the point of focus, go back to step 4 and start again.
8. Use this procedure to observe both a plant cell and an animal cell using the microscope. Refer to the list of organelles that we have explored throughout the chapter and see which organelles you can identify.

**Learning intention**

To be able to identify and describe the functions of cell organelles

**Success criteria**

**SC 1:** I can identify cell organelles under a microscope.

**SC 2:** I can describe the functions of the cell membrane, cytoplasm and nucleus.

**SC 3:** I can explain the roles of DNA, mitochondria and chloroplasts in cells.

**SAFETY NOTE**

- Ensure that you follow the correct way to focus the microscope so that you do not damage the specimen or the objective lens.

## Results

Draw a table in your notebook, like the one below. In the table, sketch a diagram of your observations for plant cells and animal cells at the highest magnification. Record the magnification used and describe any observations that would not have been possible without the microscope.

| Specimen | | Sketch |
|---|---|---|
| Magnification | | |
| Microscopic observations | | |

## Discussion

**1** List the organelles that you were able to identify using a light microscope in

- **a** the plant cell
- **b** the animal cell

**2** Explain why you could not identify every organelle that we have studied throughout the chapter.

**3** Tharusha was studying a cell under a light microscope. He described what he could see as a cell that was irregular in shape but had a circular dark spot roughly in the centre. Identify what cell type Tharusha was viewing and justify your answer.

# 4.10 Key features of unicellular organisms and the cells of multicellular organisms

## Introduction

Light microscopes continue to be used by scientists to study cells and unicellular organisms.

In this practical investigation, you will use your microscopy skills to examine a range of unicellular and simple multicellular organisms found in pond water, like the one in Figure 4.10.1. You will have the opportunity to practise preparing a wet mount, obtaining high-quality observations at a range of magnifications and recording your observations using scientific drawing.

### Learning intention

To be able to use microscopes to observe, record and compare unicellular and multicellular organisms

### Success criteria

**SC 1:** I can use a microscope, with the appropriate magnification, to observe a variety of unicellular and multicellular organisms.

**SC 2:** I can record observations, including the magnification used, of unicellular and multicellular organisms using a microscope.

**SC 3:** I can evaluate the experimental method used to observe cells and organisms at the microscopic scale.

## Background

Microscopes can be used to view tiny structures in pond water that are not visible to the naked eye, such as unicellular organisms and the organelles inside cells. The common pond water species *Euglena*, *Paramecium*, *Amoeba* and *Spirogyra* are useful organisms to view under the microscope because of their interesting and easy-to-view structures. *Euglena*, *Paramecium* and *Amoeba* are freshwater protists (a single-celled organism with a distinct nucleus), and *Spirogyra* is a type of green algae.

Organisms that might be observed in the pond water are shown in Figure 4.10.2. You can use this diagram to help identify the organisms you observe.

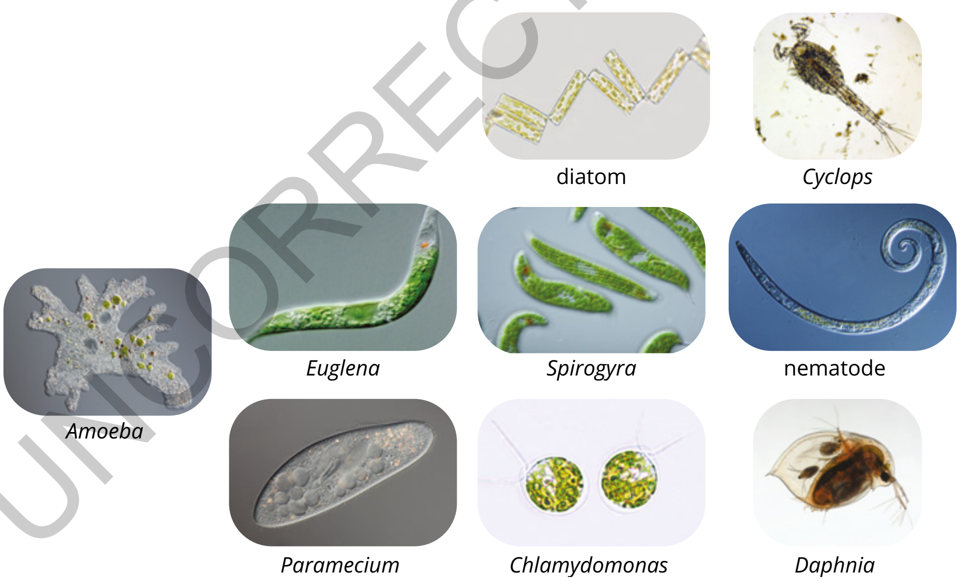



**FIGURE 4.10.2** Various microscopic organisms found in pond water

**FIGURE 4.10.1** A cyclops is an example of a multicellular animal that lives in pond water and is difficult to see without a microscope

## Aim

To view unicellular and multicellular organisms under a light microscope and identify cell structures and organelles

## Apparatus

- sample of pond water, or separate samples of microorganisms such as *Euglena*, *Paramecium* and *Spirogyra*
- glass microscope slides
- glass coverslips
- plastic Pasteur pipettes
- forceps
- toothpicks
- cotton wool
- light microscope

### SAFETY NOTES

- Handle glass slides and coverslips with care. If they break, inform your teacher and they will direct you on the correct method of disposal.
- Do not taste the pond water.

## Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

### SkillBuilder

### SkillBuilder: Preparing a wet mount

To prepare a wet mount, follow the steps below.

1. Place a drop of water onto the specimen on the microscope slide. If a stain is being used, it can be added to the drop of water at this stage.
2. Place one edge of the coverslip on the slide and lower it carefully using a toothpick, tweezers or your finger to avoid trapping air bubbles, as seen in Figure 4.10.3.

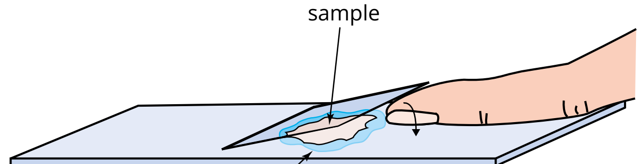



**FIGURE 4.10.3** Lowering the coverslip onto the specimen

3. Soak up any excess water or stain with a piece of filter paper or tissue.
4. The specimen is now ready to be observed using the microscope.

## Method

1. Place your sample in the centre of a slide. For the pond water, Euglena and Paramecium, use the plastic Pasteur pipette to place a drop of the sample onto the slide. For Spirogyra, use the forceps to place a segment of leaf onto the slide.

2 For specimens in water, tease out a few fibres of cotton wool and place them on the slide. The fibres will slow the movement of the organisms to help with observations.
3 Prepare the wet mount as described in the SkillBuilder: Preparing a wet mount.
4 Place the slide on the microscope stage. Make sure the light of your microscope is turned on.
5 Rotate the 4× objective lens over the stage. Adjust the coarse focus and then the fine focus until the sample can be seen clearly through the eyepiece.
6 Rotate the next-highest objective lens (10×) over the sample and adjust the focus.
7 Rotate the 40× objective lens over the sample and adjust the focus. Make some observations about what you see.

### HINT

Check with your teacher to make sure you have correctly prepared your slides and correctly set up the microscope.

## Results

Copy the table below in your notebook for each organism. In the table, record your observations. Include a sketch of the organism under observations, including any information about the structure and movement of the organism or any cell structures or organelles that you observed.

| **Organism name** | | **Observations** |
|---|---|---|
| **Unicellular or multicellular** | | |
| **Magnification** | | |

### HINT

To calculate total magnification, multiply the magnification of the eyepiece (ocular lens) by the magnification of the objective lens.

## Discussion

Evaluate your practical investigation by considering the following questions:

1 Describe any difficulties you had observing the organisms.
2 How did you overcome these difficulties?
3 Suggest other improvements that could be made to the experiment.

## Conclusion

Write your conclusion to the experiment by answering the following questions in your notebook.

1 Explain why some organisms, such as *Euglena* and *Spirogyra*, are green.
2 Describe how some of the organisms move, as seen under the microscope.
3 You might have seen spaces called vacuoles inside cells in your specimens. What is the function of vacuoles?

# 4.11 Specialised cells in tissues and organs

## Learning intention

To understand the role of specialised cells in multicellular organisms

## Success criteria

**SC 1:** I can explain the function of a range of specialised cells.

**SC 2:** I can explain why specialised cells are needed for multicellular organisms.

**KEY TERM**

**specialised cell** cell that has unique structures that enable it to perform specific functions

**FIGURE 4.11.1** The biconcave shape of red blood cells is very effective for carrying oxygen around the body

## Lesson overview

Specialised cells are cells that have a specific role or function within an organism. For example, think about how your heart beats. The heart is made up of muscle cells that are specialised to contract and pump blood throughout your body.

In this lesson, you will learn about different types of specialised cells, their roles, and how they contribute to the functioning of tissues and organs in multicellular organisms.

**SC 1** I can explain the function of a range of specialised cells.

**Specialised cells** are crucial for the functioning of multicellular organisms. Each type of specialised cell has a unique structure that enables it to perform a specific function.

For example, red blood cells are specialised to carry oxygen throughout the body. They have a biconcave shape (Figure 4.11.1), which increases their surface area for oxygen absorption.

Another example of a specialised cell is a nerve cell, or neuron, which is specialised to transmit electrical signals. Neurons have long extensions called axons and dendrites that allow them to communicate with other cells.

This communication is essential for processes such as movement, sensation, and thought. Some different types of neurons are shown in Figure 4.11.2. The different tasks of the different neurons means that they have different shaped structures.

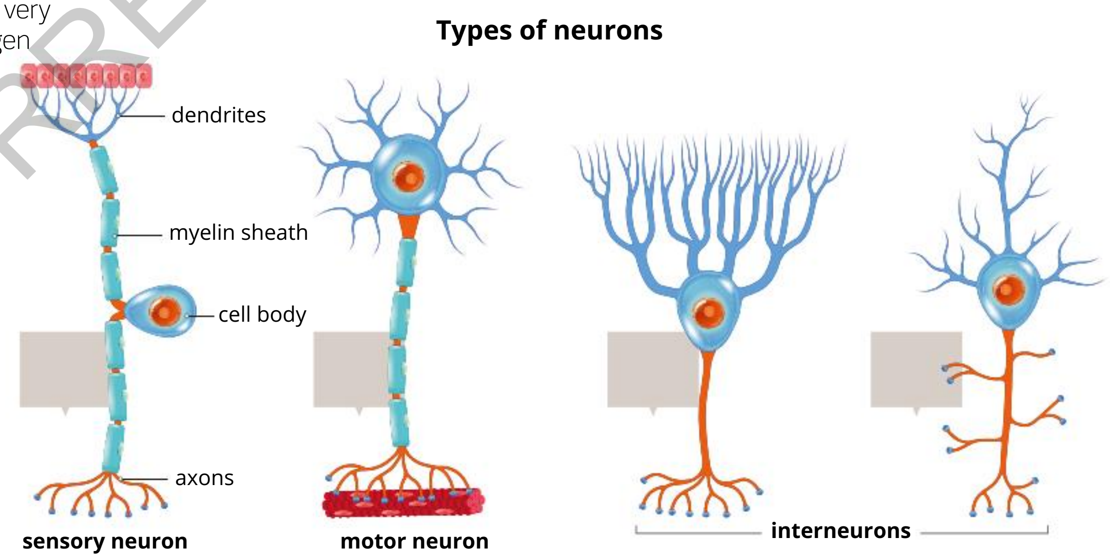



**FIGURE 4.11.2** Different types of neurons: sensory neurons, motor neurons and interneurons. Each neuron is specialised to complete its specific job.

## Specialised cells and tissues

Specialised cells work together to form tissues. A tissue is a group of cells that perform a common function. For example, muscle tissue (Figure 4.11.3) is made up of muscle cells that contract to produce movement.

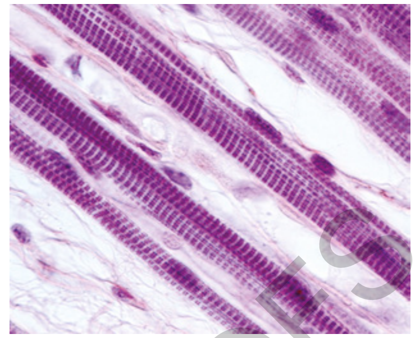


**FIGURE 4.11.3** Striated muscle tissue

Epithelial cells form the lining of surfaces and cavities in the body. For example, the epithelial cells in the intestines have microvilli (Figure 4.11.4) that help absorb nutrients from food by significantly increasing the surface area of the cell membrane.

In the respiratory system, epithelial cells have hair-like cilia that move in to sweep mucus and trapped particles out of the airways, helping to keep the lungs clean.

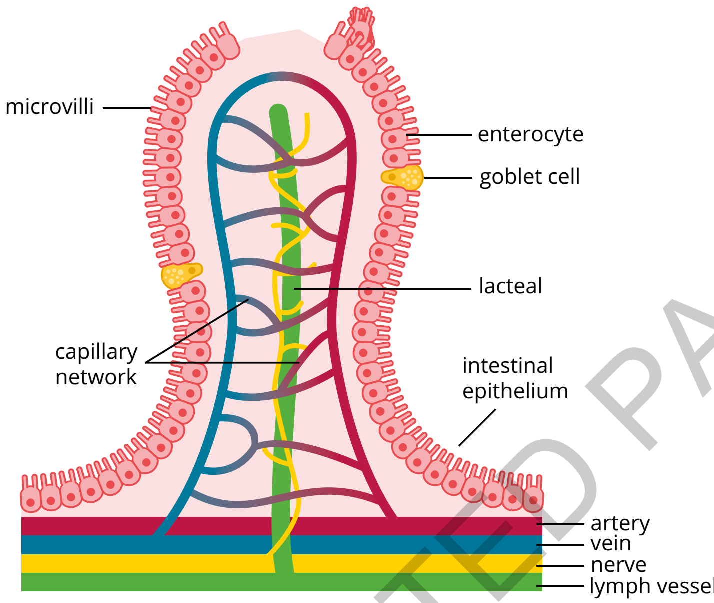



**FIGURE 4.11.4** Intestinal villi with microvilli on their surface. These increase the surface area of the cell, which enhances the cell's ability to absorb nutrients.

## Specialised cells in plants

In plants, specialised cells also play a vital role and some work together to form tissues. For example, xylem tissue consists of specialised cells that are used to transport water and nutrients from the roots to the rest of the plant.

Phloem tissues, on the other hand, transport sugars produced during photosynthesis to different parts of the plant and so have different structures.

Figure 4.11.5 shows how some plants bundle the xylem and phloem tissue together.

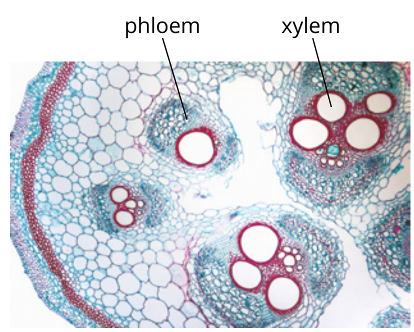



**FIGURE 4.11.5** A cross section showing the xylem and phloem specialised tissues within the stem of a plant

Specialised cells have unique structures that enable them to perform specific functions. Some of their specialisations are outlined below.

**SC 1 CHECK YOUR UNDERSTANDING**

Explain how the structure of red blood cells is related to their function.

**SC 2** I can explain why specialised cells are needed for multicellular organisms.

As organisms grow larger, it is efficient to have different tissues and organs be responsible for different tasks and then work together to enable the entire organism to survive. This means individual cells do not have to do every different task but can become very efficient at the specific tasks they do.

This can be seen in humans where the circulatory system and the respiratory system are located in a similar area within the body and are joined by special arteries and veins (Figure 4.11.6).

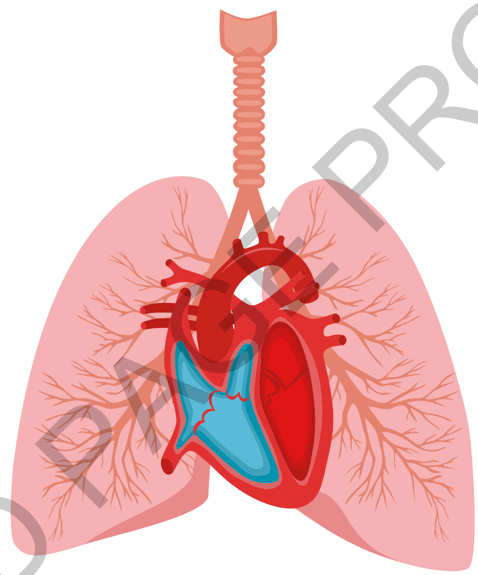


**FIGURE 4.11.6** In animals, the lungs and heart are very close to each other and work efficiently to bring in oxygen and disperse it to cells, whilst removing waste such as carbon dioxide.

**SC 2 CHECK YOUR UNDERSTANDING**

Explain why multicellular organisms need cells with different specialisations.



## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 Describe the role of specialised cells in multicellular organisms.

2 Explain how the structure of epithelial cells is related to their function.

3 Compare the functions of xylem tissue and phloem tissue in plants.

4 Predict what might happen to the nervous system if neurons were unable to join to each other to send messages.

# 4.12 Comparing specialised cells

## Introduction

We have seen that multicellular organisms are composed of many different organ systems. Each of these systems contains tissues and specialised cells to ensure that they work efficiently and effectively.

In this lesson, you will use your knowledge of different specialised cells to plan how best to compare the features of the cells. You will use your microscope skills to observe the cells in order to enable this comparison.

## Background

Complex multicellular organisms can grow to large sizes because different organ systems will take responsibility for different tasks that ensure survival, and because multicellular organisms have many specialised cells. Some of the specialised cells found in the human body are shown in Figure 4.12.1.

**Learning intention**

To be able to observe and compare specialised cells using a microscope

**Success criteria**

**SC 1:** I can plan how to best compare specialised cells.

**SC 2:** I can observe, identify and compare different types of specialised cells.

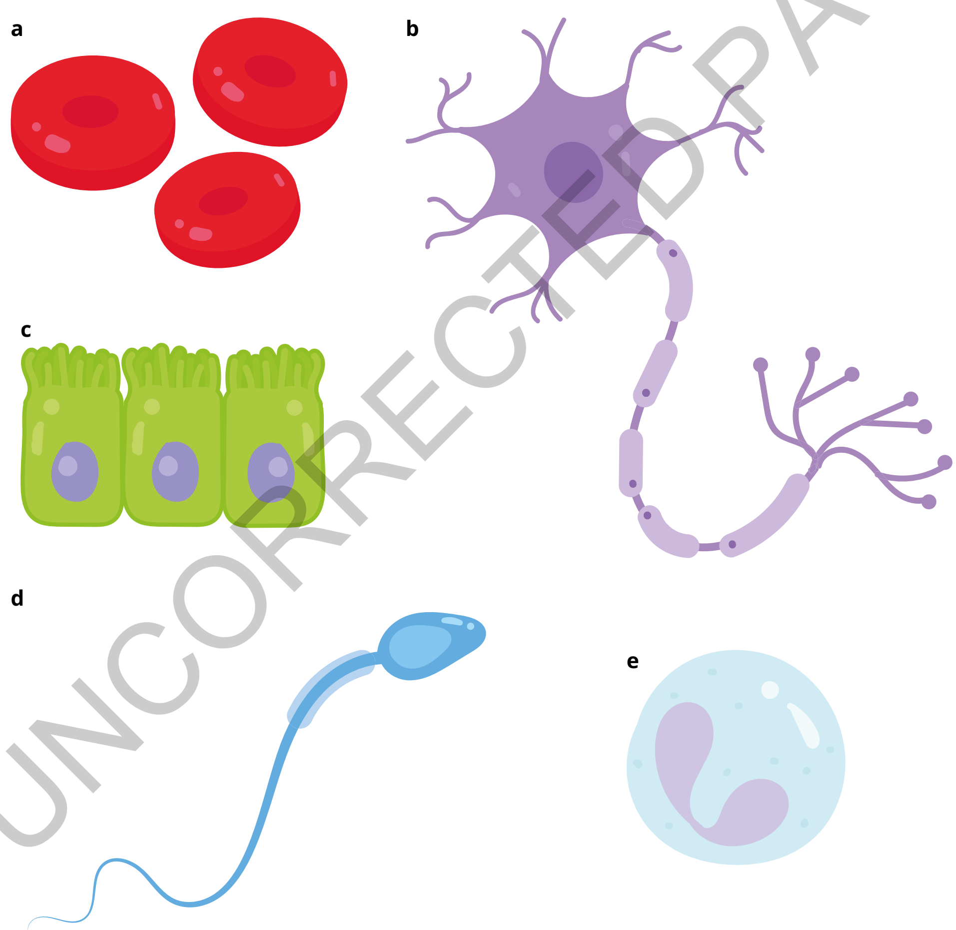



**FIGURE 4.12.1** Diagrams of specialised cells in the human body

As already discussed, red blood cells are specialised as, when mature, they contain no nucleus, which allows more oxygen to be carried per cell (Figure 4.12.1a).

Neurons are specialised to carry electrical messages quickly through the nervous system, which enable the body to respond to stimuli almost instantaneously (Figure 4.12.1b).

Epithelial cells within the small intestine have villi and microvilli to maximise the absorption of nutrients into the blood stream (Figure 4.12.1c).

Sperm cells are built only to carry genetic information in the form DNA, and to move quickly within the female reproductive tract to meet up with an ovum, using their flagella (Figure 4.12.1d).

White blood cells can carry granules containing chemicals such as histamines, which can be released when foreign bodies have been identified (Figure 4.12.1e).

## Aim

To identify and conduct an effective method of comparing types of specialised cells, using prepared slides and a light microscope.

## Plan

Along with a light microscope, you should have access to a range of prepared slides of various specialised cells, which could include blood cells, epithelial cheek cells, muscle cells, intestine cells, kidney cells, plant root-tip cells, or other slides.

1 Review the slides that you have available to the comparison activity.
2 Use the information in the background, and your knowledge of cells to decide on the criteria that you will use to compare the cells.

## Design

Create a suitable results table to record your findings.

## Conduct

1 Use your microscope to observe the slides using the most effective magnification.
2 Make a sketch of your observations, including magnification, for each slide you viewed.
3 Record relevant observations based on the criteria that you are using for the comparisons of the cells.

**SAFETY NOTE**

- Handle glass slides with care. If they break, inform your teacher and they will direct you on the correct method of disposal.

## Assessment of risk

Ensure you are aware of the risks of this inquiry activity and have considered how safety can be improved before carrying out this activity.

## Improve

Evaluate your practical investigation by considering how you viewed the different cells and how you could identify different structures within the cell.

Suggest how you could improve activity to provide a more effective way to compare the features of the cells.

## Conclusion

Summarise how you were able to identify the type of specialised cell you were looking at and whether you could identify any specific structures within the cell that helped it function in its specialised manner.

**GO TO ➤**

For more help with evaluating investigations, go to Toolkit, section x.x.

# 4 Cells

## Topic summary

The key concepts included in this topic are:

- Cells are the basic unit of all living things.
- Microscopes can be used to enhance what the human eye can observe.
- Unicellular organisms can survive as a single cell that undergoes all necessary functions to live independently.
- Cells contain organelles that complete different tasks within the cell.
- Plant and animal cells both contain a nucleus and specialised organelles that allow them to survive.
- All cells have a cell membrane that controls what moves in and out of the cell.
- Plant cells have a cell wall to assist with maintaining structure, chloroplasts, and large vacuoles to take in and release substances.
- Multicellular organisms are made up of many different types of specialised cells that are organised into tissues, organs and systems.
- Mitochondria produce ATP during cellular respiration, which acts as an energy store.
- Chloroplasts are used by plants to build glucose from carbon dioxide and water during photosynthesis.



## Review questions

The following questions will assess your success in achieving the learning intentions for this topic.

### Remember

Compare the processes of erosion and deposition.

1 Describe what a cell is.
2 Identify the cell structures that are easiest to see using a light microscope.
3 Name a type of cell that does not contain a nucleus.
4 Describe the function of the cell membrane.
5 List the key features that a plant cell has that an animal cell does not have, and briefly describe the function of each of these features.

### Understand

6 Compare the size of a typical eukaryotic cell (such as plant and animal cells) to prokaryotic cells (such as bacteria).
7 Explain how multicellular organisms differ from unicellular organisms.
8 What are scientists able to observe using an **electron microscope** that they cannot see using a light microscope?
9 Explain why both plant and animal cells need a nucleus and mitochondria to survive?

### Apply

10 Calculate the total magnification of a light microscope if the eyepiece magnification is 10× and the objective lens magnification is 40×.
11 Ben is teaching another student how to use the light microscope to identify different parts of onion cells. How could Ben explain to the student how to tell the difference between the cell wall and the cell membrane?

### Analyse

12 Unicellular organisms carry out all their life functions within one cell. Compare this to how multicellular organisms carry out their life functions.
13 Identify the functions of vacuoles in plant cells.

## Extension: Communication

**14** An average cheek cell is approximately 60 µm in diameter. Draw a diagram of a cheek cell in your book that is one thousand times life size and includes labelled cell features.

## Topic reflection

The learning intentions for this topic are given in each lesson and at the beginning of the topic. Consider how well you have achieved them. Note down any particular areas that you are confident in, and others where you are not so sure.

# 4 Glossary

**accuracy** a measure of how close the measured value is to the true value of the quantity that is being measured

**body system** a group of interconnected organs and tissues that perform functions in the body

**cell** the building blocks of all living things

**cell membrane** thin layer that separates the cell from its surroundings and controls what can move in and out of the cell

**cell theory** the idea that all living things are made up of one or more cells that come from existing cells

**cell wall** a rigid layer on the outside of a plant cell or prokaryotic cell; provides the skeleton of a plant

**cellular respiration** a set of processes in the cells that converts chemical energy from nutrients into energy (ATP) that can be used by cells

**centriole** barrel-shaped structure made from microtubes that is part of the cytoskeleton in animal cells

**chlorophyll** the substance found in plant leaves that make leaves green and collects energy from the Sun for photosynthesis

**chloroplast** an organelle within the cell where photosynthesis takes place

**cytoplasm** everything contained within a cell membrane except the nucleus

**cytoskeleton** a network of proteins in the cytoplasm

**cytosol** fluid found in the cytoplasm of a cell

**DNA** deoxyribonucleic acid, the molecule that contains genetic information for an organism

**electron microscope** a type of microscope that uses beams of electrons to magnify up to a million times; there are two types of electron microscope: transmission electron microscopes (TEM) and scanning electron microscopes (SEM)

**eukaryotic cell** a cell that contains a nucleus

**eyepiece** the lens, or combination of lenses, at the viewing end of a microscope or telescope

**field of view** the amount of the specimen seen through a microscope

**lens** a piece of glass or other transparent material with curved sides used in optical equipment

**light microscope** a microscope that uses light to view specimens

**lysosome** organelles that get rid of waste from animal cells

**magnification** the ratio of the size of an image compared to the size of the object

**micrograph** photograph of an image from a microscope; also known as a photomicrograph

**micrometre** one-thousandth of a millimetre, or one-millionth of a metre

**microscope** an instrument used to make very small things look bigger

**microscopic** describes objects that can be seen only by using a microscope

**mitochondria** organelles where energy is released from food through the process of cellular respiration

**multicellular** an organism that is made up of many cells

**nucleolus** organelle within a cell nucleus that produces ribosomes

**nucleus** organelle that contains the genetic information for the cell (plural nuclei)

**objective lens** the lens in a microscope or telescope that is nearest to the object being viewed

**organ** a structure that contains at least two different types of tissues that work together to complete a function

**organelle** the smaller parts of a cell; they are found in the cytoplasm and have a variety of important functions

**organism** a living thing that functions as an individual

**osmosis** process by which particles of water pass through a semi-permeable membrane from a less concentrated solution into a more concentrated one

**photosynthesis** the chemical reaction in plants that converts carbon dioxide and water into oxygen and glucose using energy from sunlight

**prokaryotic cell** a cell that does not have a nucleus

**reliability** how well repeated experiments, observations or measurements produce similar results

**ribosome** an organelle that produces proteins from amino acids; proteins are required for many functions including growth, repair and controlling chemical reactions

**semi-permeable membrane** a thin layer of material that only certain particles can pass through

**specialised cell** a cell that has specific structures to allow it to perform specific functions

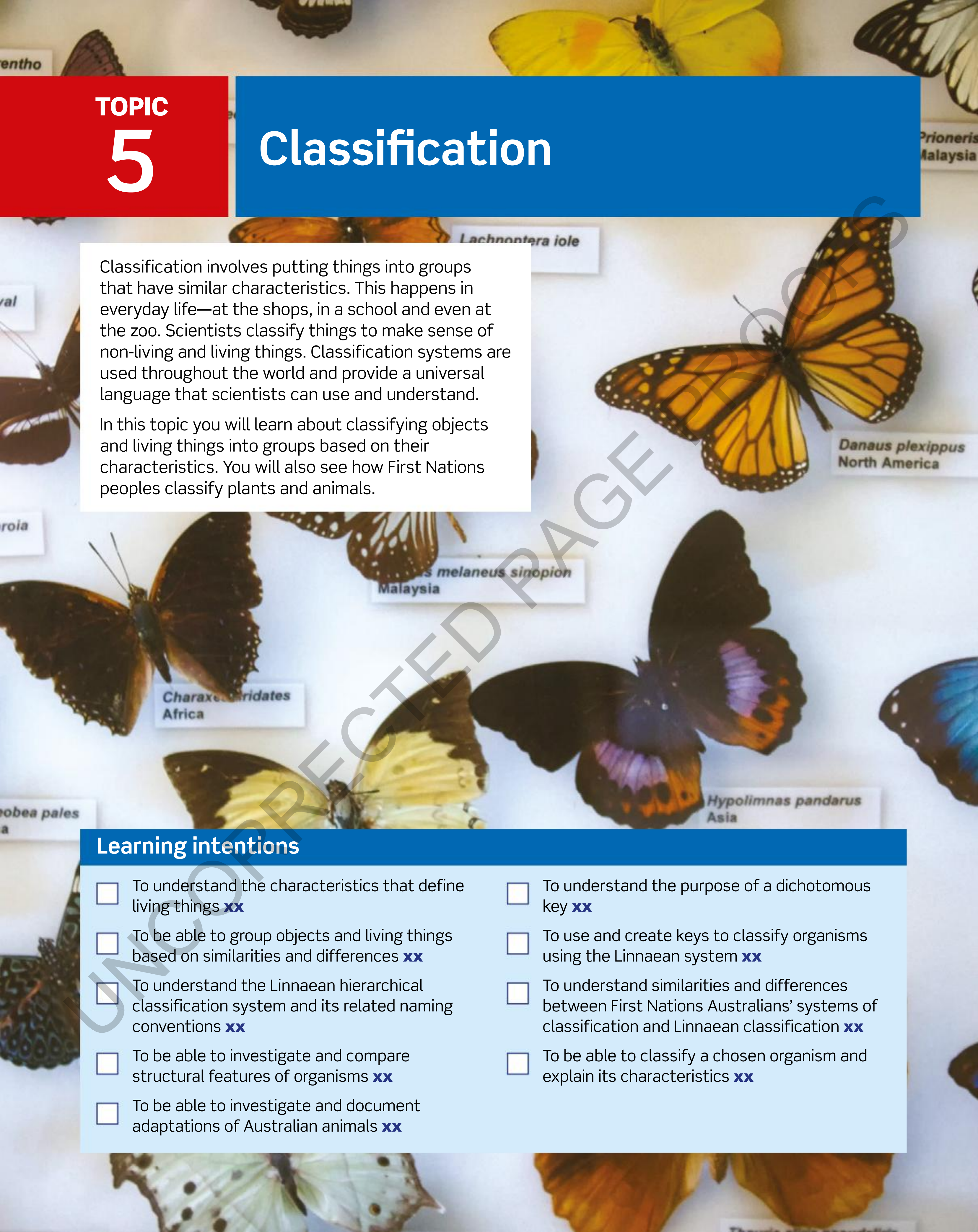
**tissue** a group of cells of the same type that carry out the same function in the body

**unicellular** an organism that is made up of only one cell

**vacuole** a small structure in animal cells that may contain wastes or chemicals, or a large sap-filled structure in plant cells that stores water, wastes and nutrients

**validity** how well the investigation tests the question, hypothesis or prediction that it was designed to test


Sallya pechueli
Africa
Phoebis philea
Columbia
Lachnoptera iole
Malaysia
Heliconius telesiphe
Peru
Malaysia
Africa
Hypolimnas pandarus
Asia
South Africa
Polyura delphus concha
Malaysia
Hamadryas arionome
South America




# TOPIC 5 Classification

Classification involves putting things into groups that have similar characteristics. This happens in everyday life—at the shops, in a school and even at the zoo. Scientists classify things to make sense of non-living and living things. Classification systems are used throughout the world and provide a universal language that scientists can use and understand.

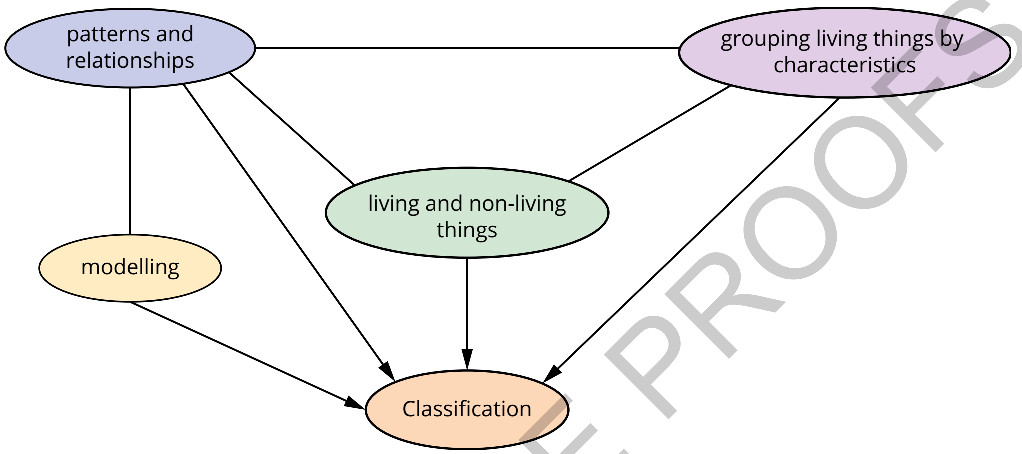
In this topic you will learn about classifying objects and living things into groups based on their characteristics. You will also see how First Nations peoples classify plants and animals.

## Learning intentions

- ☐ To understand the characteristics that define living things **xx**
- ☐ To be able to group objects and living things based on similarities and differences **xx**
- ☐ To understand the Linnaean hierarchical classification system and its related naming conventions **xx**
- ☐ To be able to investigate and compare structural features of organisms **xx**
- ☐ To be able to investigate and document adaptations of Australian animals **xx**
- ☐ To understand the purpose of a dichotomous key **xx**
- ☐ To use and create keys to classify organisms using the Linnaean system **xx**
- ☐ To understand similarities and differences between First Nations Australians' systems of classification and Linnaean classification **xx**
- ☐ To be able to classify a chosen organism and explain its characteristics **xx**

# 5 Classification

The key concepts that you will use in this topic:




The following prior knowledge questions will help to support your learning in the topic and can be attempted before the first lesson.

## Living and non-living things

1 Identify one characteristic that would classify something as being 'living'.

## Grouping living things by characteristics

2 Explain how a butterfly, a caterpillar and a honeybee could be classified according to how they move.

3 Compare the terms invertebrate and vertebrate, using examples.

## Identifying patterns and relationships

4 The African Elephant lives in Africa while the Asian Elephant lives in Asia. Based on their physical features, how might early scientists have predicted that these two organisms were related?

## Using models to represent data and observations

5 Aboriginal and Torres Strait Islander people classify some plants based on whether they can be food or medicine. Describe an advantage of this classification model.

# 5.1 Characteristics of living things

## Lesson overview

Classification is an important concept in science. It is easier to understand why scientists classify living things when you think about how you organise and locate items in your daily life. Just as files on a computer are sorted or books in a library are categorised, scientists use systems to organise a vast range of objects and substances based on specific criteria.

Imagine strolling through a supermarket where goods are neatly arranged into aisles and shelves. Classification in science is similar to how the aisles and shelves are organised, as it helps scientists work out the complex relationships among species to simplify the study of the **diverse** planet.

In this lesson, you will gain a deeper understanding of classification systems in science, how they are based on characteristics of living things and their critical role in identifying the many living things on Earth.

**Learning intention**

To understand the characteristics that define living things

**Success criteria**

**SC 1:** I can list the characteristics of living things.

**SC 2:** I can describe the characteristics of living things and give examples.

**SC 1** I can list the characteristics of living things

To survive, all living things must eat, grow, move, breathe, get rid of waste, respond to their environment, and reproduce. Each of these characteristics of life is completed differently by different **organisms**. Figure 5.1.1 summarises these characteristics.

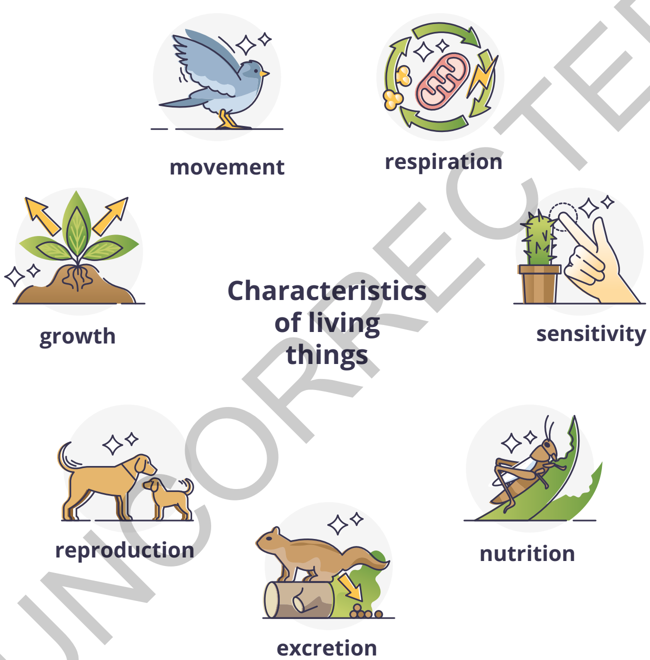



**FIGURE 5.1.1** The characteristics of all living things

**Classification** is used by humans to group things in their everyday lives so that they can make sense of the relationships and connections between them. Scientists, for example, study the **diversity** of living things by grouping them according to similar **characteristics**.

**KEY TERMS**

**classification** the process of putting things into groups

**characteristic** a feature of a living or non-living thing

**KEY TERMS**

**biodiversity** the number and range of species that exist in an ecosystem

**organism** a living thing

**Biodiversity** is the word used to describe the huge variety of life on Earth and, specifically, the number and range of species that exist in an **ecosystem**. Patterns and features are used to classify **organisms**. By classifying organisms into groups at multiple levels, scientists can better understand the survival and behaviour of living things.

Figure 5.1.2 shows a butterfly obtaining its nutrients. Methods for obtaining nutrients, moving and responding to the environment vary in different organisms. These variations allow scientists to classify organisms based on how the organisms perform these characteristics of life.

**FIGURE 5.1.2** The characteristics of different organisms can be compared. This process allows scientists to classify organisms based on their similarities and differences.

**CHECK YOUR UNDERSTANDING**

List the characteristics of living things.

**SC 2** I can describe the characteristics of living things and give examples

The key characteristics of living organisms often appear differently in different organisms. Whilst they are different, all of these characteristics work together to ensure survival of the organism:

1 **Movement.** This can include flight, walking, swimming, and the opening and closing of flowers. Figure 5.1.3 shows that flight can be used for travelling to different places as well as for hunting.

**FIGURE 5.1.3** Movement is seen in different ways in different living things; this eagle uses it to catch prey.

2 **Growth**. All living things grow. This can simply be an increase in size before replication (as seen in bacteria), the growth of a plant from a seed (Figure 5.1.4), or it can be the development of an organism from birth to maturity.

**FIGURE 5.1.4** All living things grow. This is shown by the development of this plant.

3 **Reproduction**. Living things pass their genetic information to the next generation. This is done through reproduction. Reproduction can be as simple as splitting in two, as seen in the bacteria shown in Figure 5.1.5. It can also be a complex process where two individuals are needed to produce offspring, as in some plants and animals.

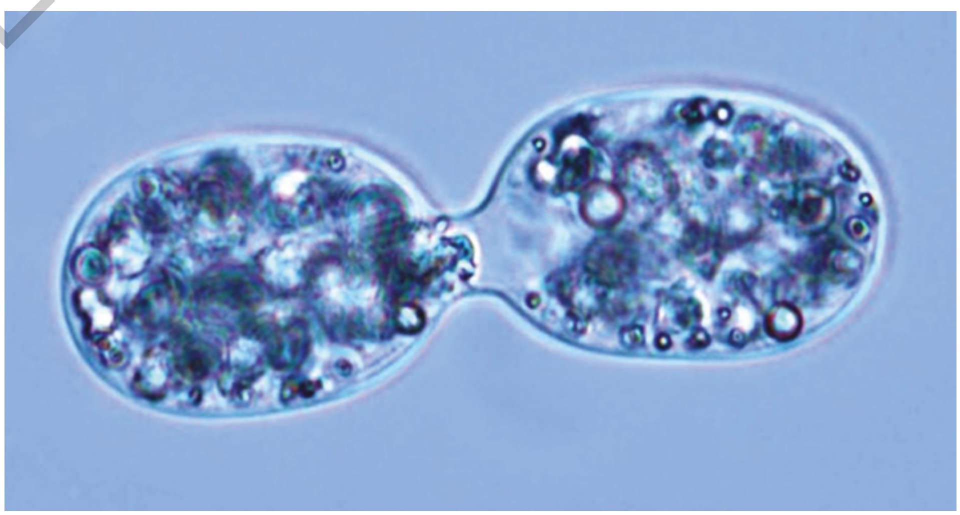


**FIGURE 5.1.5** Bacteria make copies of their genetic material before splitting into two identical cells.

4 **Respiration**. Many living things take in oxygen when they breathe, a process known as respiration. During respiration, the oxygen inhaled and the sugar from consumed food undergo chemical reactions in cells to produce energy. This energy enables the organism to stay alive (Figure 5.1.6). However, some organisms, such as certain bacteria, do not rely on oxygen and instead use other substances for their metabolic processes.

**Respiration**

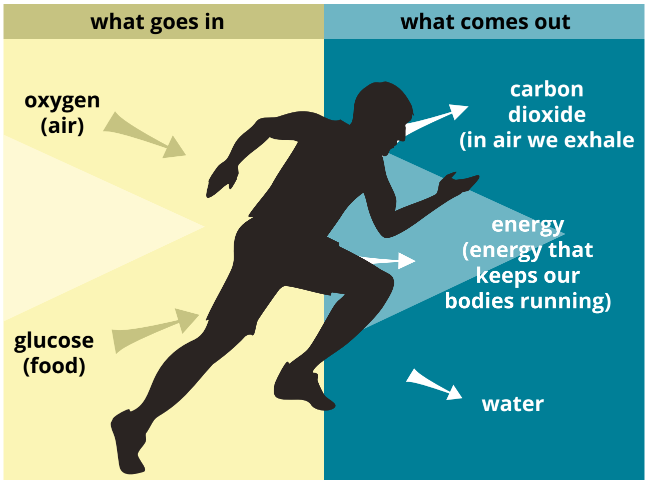



**FIGURE 5.1.6** Living things need energy to live. This energy is released by the chemical reaction between the nutrients they eat and the oxygen they breathe in.

5 **Nutrients**. Obtaining energy requires sugar, but living things also need to bring in other nutrients to keep them healthy. Plants especially need water, carbon dioxide, nitrogen, phosphorus and potassium (Figure 5.1.7). Key nutrients for animals include water, sugars, proteins, fats, vitamins and minerals.

**FIGURE 5.1.7** Living things need different nutrients to help all their body systems work effectively.

6 **Excretion**. It is vital that all living things have a way to remove waste from their body. For humans, this is not limited to removal of fluid and solids but also includes removing waste gases, by breathing out carbon dioxide, and removal of dissolved salts through the action of the kidneys and as a result of sweating (Figure 5.1.8).

**FIGURE 5.1.8** Excretion of waste products is essential for living organisms.

**Sensitivity to the environment**. All living things must respond appropriately to the changes in their environment, or they will not survive. Young sunflowers (Figure 5.1.9) can often be seen tracking the Sun's movement during the day. This provides a number of benefits, including more even growth and being more attractive to pollinating insects due to the flowers being warmer.

**FIGURE 5.1.9** Flowers will follow the movement of the sun throughout the day.

**CHECK YOUR UNDERSTANDING**

State the name and give an example of each characteristic of life.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1. State how many characteristics of living things there are.
2. Outline how a kangaroo would show the seven characteristics of living things.
3. Describe how a plant might respond to its environment.
4. Suggest an animal whose movement and nutrition complement each other to enhance its survival.

# 5.2 Recognising similarities and differences in objects and living things

## Introduction

Have you been to the zoo recently? You may have noticed that the animals seem to be grouped according to the type of animal or where they live in the wild. Botanical gardens group plants according to their environment and even size.

Organisms can be grouped according to their similarities and differences. This makes it easier to classify and identify them.

In this practical investigation you will investigate how to group organisms based on their similarities and differences using the example of fruits and vegetables.

### Learning intention

To be able to group objects and living things based on similarities and differences

### Success criteria

**SC 1:** I can identify differences and similarities in organisms from real objects, images or descriptions.

**SC 2:** I can place organisms with similar features into groups.

## Background

Many people consider all of the items in salads to be vegetables, but some of them, such as tomatoes, are actually fruit. Fruits and vegetables can be classified according to the part of the plant that is eaten. Table 5.2.1 outlines the different classifications for fruits and vegetables.

**TABLE 5.2.1** Classification: fruit or vegetable?

| Classification | Description | Fruit or vegetable? | Example |
|---|---|---|---|
| aggregate fruit | many small fruits, or fruitlets, joined together to make a large fruit | fruit | blackberry |
| berry | fleshy, edible fruit that has seeds embedded within its flesh | fruit | grapes |
| legume | also known as a pod; opens at the side to release seeds | fruit | beans |
| simple fruit | fruit formed around a hard stone or pit which contains a seed | fruit | peach |
| bulb | grows in clusters or layers just below the soil surface with a leafy shoot above | vegetable | leeks |
| leaf | an edible leaf | vegetable | kale |
| root | usually, a long or round root | vegetable | turnip |
| stem | edible stem or stalk of the plant | vegetable | asparagus |
| tuber | grows underground, attached to the root of the plant | vegetable | sweet potato |

## SAFETY NOTES

- Make sure you and your classmates are not allergic to any of the food samples used.
- Do not taste or eat the food items.
- Knives are sharp and can cause injury if not used appropriately.

## HINT

Make sure that you observe colour, texture and whether the food contains seeds to help you to create a method of grouping the items.

**FIGURE 5.2.1** Oranges contain a range of features that help to categorise them. It is important that both the outside and inside features are observed carefully.

## Aim

To investigate the similarities and differences between fruits and vegetables

## Apparatus

- various samples of fruits and vegetables, such as carrot, potato, apple, garlic, onion, snow pea, capsicum, spinach, celery, raspberry, olive and lettuce
- knife
- cutting board

### Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

## Method

1. Use a knife to cut through the food items to reveal the internal characteristics that assist with the correct grouping of the food items, as shown in Figure 5.2.1.
2. Choose two food items that have been supplied and observe them carefully. Write down their features.
3. Use Table 5.2.1 in the background to classify these foods as fruits or vegetables.
4. Create your own table to record the features and classification of the food items you chose.

## Results

Create a results table to record your observations and classify the food items as fruit or vegetable.

Include the name of the fruit or vegetable, the external features observed, the internal features observed and the classification you gave each item. Record your observations and the reasons for the classification decisions you made.

## Discussion

Suggest two ways this investigation was challenging and what could be done to improve it.

## Conclusion

Write your conclusion to this investigation by completing the following tasks.

1. Describe the key features that enable food to be classified as fruit or vegetable.
2. Explain why it is incorrect to classify a tomato as a vegetable.

# 5.3 Linnaean hierarchical classification system

## Lesson overview

Humans have always tried to understand the living things around them. It was essential for survival to know which animals were dangerous and which were safe to eat. People used characteristics like colour and tooth size to distinguish between them, learning from others' experiences.

In this lesson, you'll learn about how past philosophers and scientists developed precise naming systems to classify the vast diversity of life on Earth more scientifically.

**SC 1** I can identify the levels in the Linnaean hierarchical classification system

### Learning intention

To understand the Linnaean hierarchical classification system and its related naming conventions

### Success criteria

**SC 1:** I can identify the levels in the Linnaean hierarchical classification system.

**SC 2:** I can classify species using the Linnaean hierarchical classification system.

## Development of classification systems

Many ancient scientists developed their own ways of classifying the living things around them. One of those was Aristotle, a Greek, who lived from 384 to 322 BCE (Figure 5.3.1). Amongst many other things, Aristotle was a **naturalist**.

Aristotle originally divided all living things into two groups: plants and animals. He then subdivided plants into trees, shrubs and herbs, and animals into groups based on their habitats (water, air and land). He also divided them according to whether they had red blood or not.

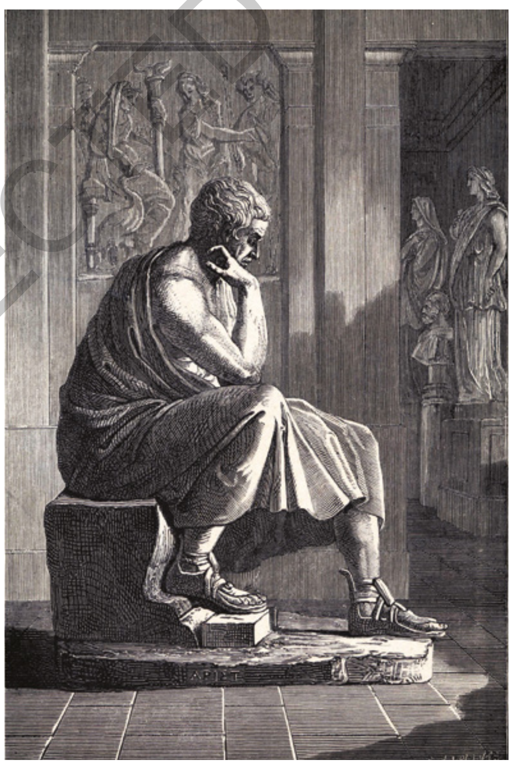


**FIGURE 5.3.1** Aristotle

## The Linnaean system of classification

Carl Linnaeus, a Swedish scientist (1707 to 1778), developed a hierarchical classification system. This **hierarchy**, illustrated in Figure 5.3.2, organises organisms into increasingly smaller groups, with kingdoms containing many different organisms, and species containing only one.

### KEY TERMS

**naturalist** a person who studies the natural world, including the relationships between organisms and the environment

**hierarchy** a classification system that divides organisms based on characteristics from the simplest to the most complex level.

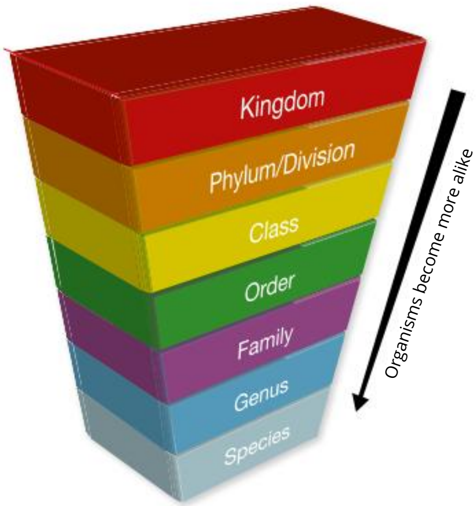



**FIGURE 5.3.2** The Linnaean classification system is a hierarchical system with those organisms which are most closely related belonging to the same species

## Kingdoms

Until quite recently, biologists classified all living things into two **kingdoms**: animals and plants. Then it was realised that fungi were not plants, as they do not make their own food as plants do. In 1968, the five-kingdom classification was developed which included the Monera (mostly bacteria) and the protists (mostly amoeba and algae). In 1990, microbiologist Carl Woese proposed that Monera should be divided in two, thus creating a six-kingdom classification model (Figure 5.3.3) which is now widely used.

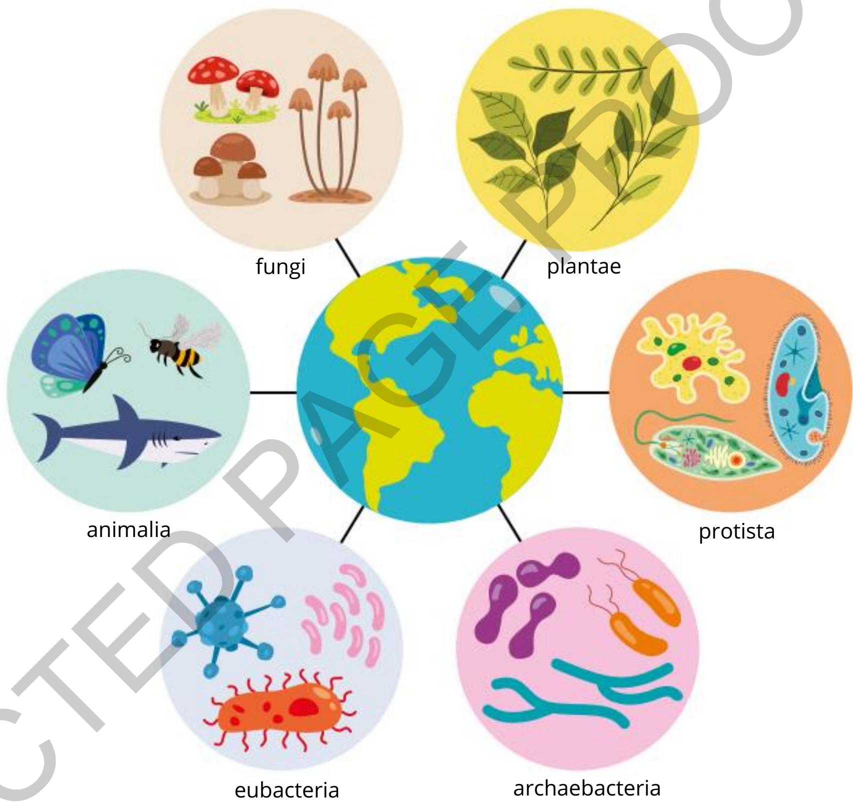



**FIGURE 5.3.3** The six kingdoms of Animalia, Fungi, Eubacteria, Plantae, Protista and Archaebacteria

## Phyla

Each of the kingdoms is then divided into **phyla** (singular form: phylum). For example, animals that have backbones such as humans, snakes, birds and fish are classified in the **Chordata** phylum. Other phyla include the annelids or round worms, the **arthropods**, whichs includes insects and spiders, and the molluscs, such as crabs, snails and squid.

## Classes

Organisms that belong to the same phylum and have more features in common are then divided by **class**. The Chordata phylum, for example, is subdivided into classes based on characteristics including the type of skin an organism has. For example, members of the class of reptiles have dry scaly skin, whereas those in the class of mammals have fur.

## Order

After organisms are classified into a class, they are further divided into **orders**. An order groups together organisms that share a set of similar characteristics. For example, the class Mammalia, or mammals, is divided into various orders based on traits like diet, behaviour, and anatomical features. For example the order Diprotodontia includes **marsupials** that primarily eat plants.

## Family

Within each order, organisms are further divided into families. Families share more specific characteristics and often have a more recent common ancestor. Within the order Diprotodontia, the **family** Macropodidae are characterized by their large hind legs and feet, which are adapted for hopping and leaping. They also have long tails that help with balance.

## Genus

The **genus** that an organism belongs to will have highly specific characteristics and relatively few members compared with the higher levels of classification such as order or family. As with orders, the genus name always begins with a capital letter. The family Macropodidae consists of kangaroos, wallabies, quokkas, pademelons, wallaroos and many tree kangaroos, but there are only a few species within the genus, Macropus. Two of them are the eastern grey kangaroo and the western grey kangaroo.

## Species

The **species** name of an organism is unique to it. No other species within the genus has the exact same characteristics (Figure 5.3.4). For example, the eastern grey kangaroo (*Macropus giganteus*) has the species name giganteus, while the western grey kangaroo (*Macropus fulginosus*) has the species name fuliginosus. The species name always begins with a lower-case letter, and this distinguishes it from any other level of classification.

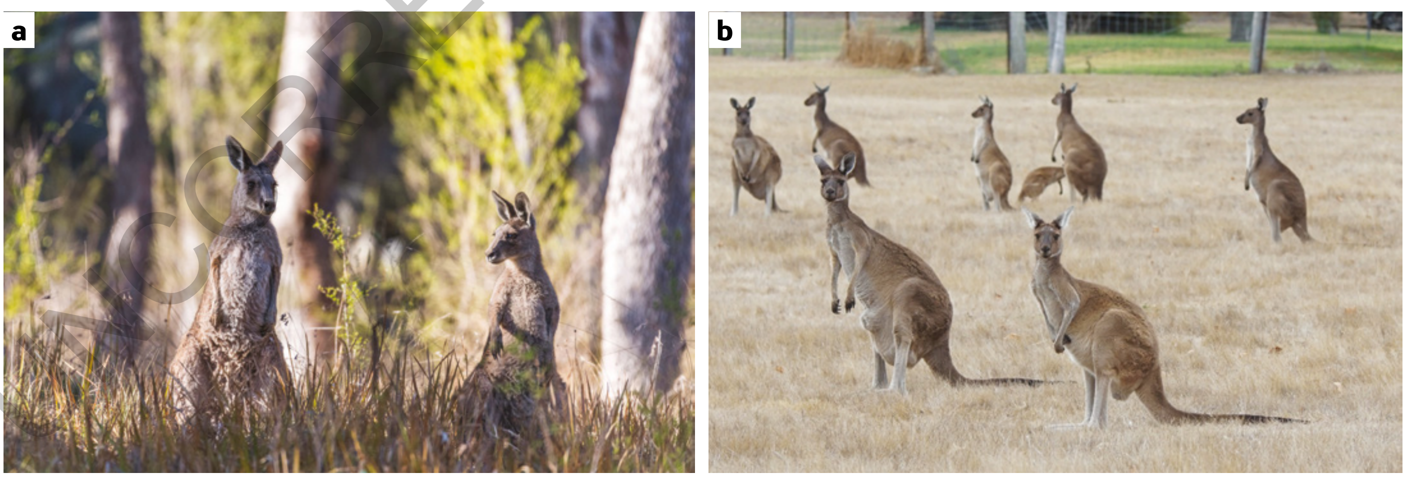



**FIGURE 5.3.4** The only two kangaroos within the genus Macropus, a) the eastern grey kangaroo, *Macropus giganteus* and b) the western grey kangaroo, *Macropus fuliginosus*.

## CHECK YOUR UNDERSTANDING

List the levels of the Linnaean hierarchical classification system from largest to smallest.

**SC 2** I can classify species using the Linnaean hierarchical classification system

**KEY TERMS**

**common name** the name of an organism based on everyday language; can vary with location, language and culture

**scientific name** a Latin name for an organism based on the binomial system

Linnaeus had noted that the same organism might have one name in one country or area, but a different name in a different area. Also, people in different places might give the same name to very different organisms. Figure 5.3.5 shows some different fish that were all given the **common name** 'whitefish' by different people in different areas.

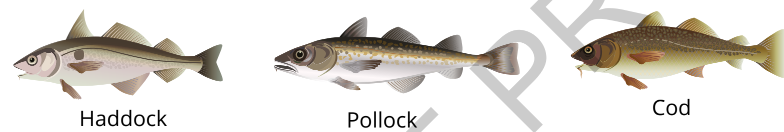



**FIGURE 5.3.5** Haddock, pollock and cod were given the name 'whitefish' by locals.

Linnaeus suggested that that there be one name given to each organism so that all people could know what specific organism was being discussed. He suggested that this was called a **scientific name**.

## How to write a scientific name

Scientific names use a binomial system. Binomial means that two names are used, the genus and the species names. For example the scientific name for the eastern grey kangaroo is *Macropus giganteus* while the western grey kangaroo is known as *Macropus fuliginosus*.

Scientific names are typed in italics. The genus is written first and starts with a capital letter, followed by the species name which starts with a lower-case letter i.e. *Genus species*. For example, the scientific name for humans is *Homo sapiens* where *Homo* is the genus and *sapiens* is the species.

If the name is written by hand, it should be underlined (Homo sapiens). Examples of binomial scientific names along with the commonly used names are shown in Table 5.3.1.

**TABLE 5.3.1** Examples of binomial scientific names and common names

| | | |
|---|---|---|
| The Humboldt penguin, found in South America, has the scientific name *Spheniscus humboldtii*. | The lacy tree fern, *Cyathea cooperi* | The funnel web spider, *Atrax robustus* |
|  |  |  |

## Classifying using the Linnaean classification hierarchy

We can use the Linnaean classification hierarchy to determine the Genus and species name for an organism (Figure 5.3.6). Humans, for example, are animals that belong to the **Chordata** phylum because they have a spinal cord and backbone which protects it.

Humans are then classified as mammals because they share key characteristics with other mammals: they are warm blooded, have fur or hair on their skin and feed their young with milk produced by mammary glands.

Gorillas and monkeys share more features—such as forward-facing eyes—with humans than other mammals, and so humans, gorillas, and monkeys all belong to the primates order.

Humans and gorillas have even more in common than monkeys, so humans and gorillas are classified together in the family hominidae.

Humans then belong to the genus Homo while modern day humans belong to the species sapiens.

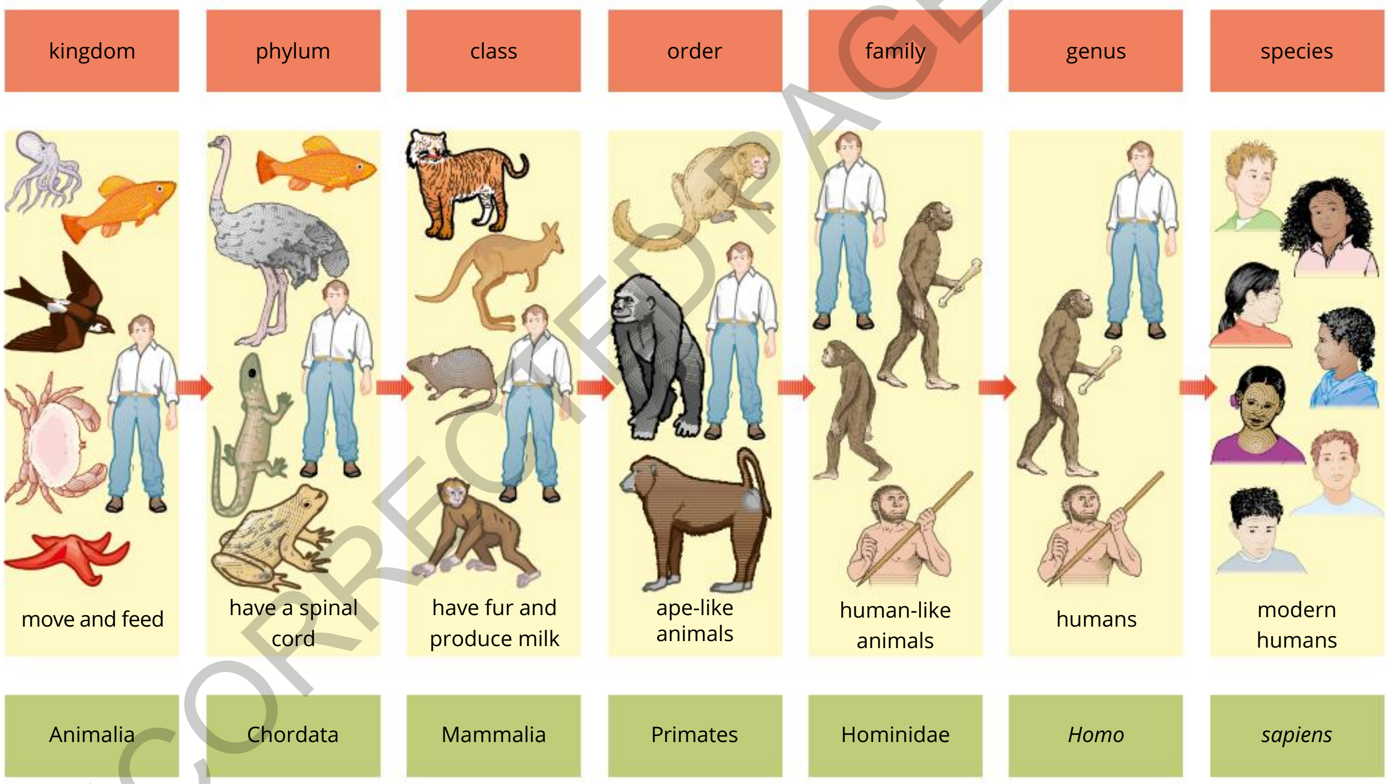



**FIGURE 5.3.6** The Linnaean classification hierarchy for humans

## The classification of Australian native species

Accurately classifying Australia's unique biodiversity allows scientists to create more effective conservation strategies to help protect Australia's unique fauna from threats such as habitat destruction and climate change. The classification of some native Australian species can be seen in Table 5.3.2.

**TABLE 5.3.2** The classification of Australian native species

| | Short-beaked echidna | Red kangaroo | Sydney funnel-web spider | Red-bellied black snake |
|---|---|---|---|---|
| |  |  |  |  |
| Kingdom | Animalia | Animalia | Animalia | Animalia |
| Phylum | Chordata | Chordata | Arthropoda | Chordata |
| Class | Mammalia | Mammalia | Arachnidia | Reptilia |
| Order | Monotreme | Diprotodon | Aranaea | Squamata |
| Family | Tachyglossidae | Macropod | Hexathelidae | Elapidae |
| Genus | *Tachyglossus* | *Magaleia* | *Atrax* | *Pseudechis* |
| Species | *aculeatus* | *rufa* | *robustus* | *porphyriacus* |
| Scientific Name | *Tachyglossus aculeatus* | *Magaleia rufa* | *Atrax robustus* | *Pseudechis porphyriacus* |

## SCIENCE IN CONTEXT

### Wildlife conservation

The Linnaean system is essential for wildlife conservation efforts. Accurate identification of organisms is important for developing conservation strategies that protect endangered species and their habitats.

In Australia, the Linnaean system is used to classify and study native animals like the endangered Tasmanian devil, *Sarcophilus harrisii*, helping conservationists monitor their populations and take action to protect them.

### CHECK YOUR UNDERSTANDING

There are many different types of animals that are native to Australia.

**a** State the phylum that reptiles belong to, giving a reason for your answer.

**b** State the order that echidnas belong to.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

**1** List the levels in the Linnaean hierarchical classification system in order from lowest to highest.

**2** Identify the two hierarchies used when writing a scientific name.

**3** Name the kingdom and phylum of a magpie.

**4** Identify the genus and species name in the scientific name *Macropus rufus*.

**5** Explain the benefit of scientific names over common names.

# 5.4 Structural features of organisms

## Introduction

The structural features of an organism support what the organism does. For example, if you climb trees, then you will need claws or suckers or grasping fingers to help you climb. You may also need a tail or some other means of balance for your climb. There would be no need to have wings if all you did was climb. In this practical investigation, we will observe similarities and differences in the structural features of a variety of organisms. From our observations, we will infer the relatedness of different organisms.

**Learning intention**

To be able to investigate and compare structural features of organisms

**Success criteria**

**SC 1:** I can conduct an investigation to observe the structural features of organisms.

**SC 2:** I can identify similarities and differences in structural features within and between groups of organisms.

## Background

Structural features are the different parts of an organism. These enable the organism to live in its habitat. These structural features are also known as structural adaptations. While these structural features are useful for where the organism currently lives, they may not be useful if the organism is in a different environment.



**SkillBuilder**

### SkillBuilder: Observing structural features of organisms

When observing the structural features of organisms, we begin by looking at whether the organism is a bacteria or a member of one of the five other kingdoms. Refer to Lesson 5.3 to refresh your memory of the Linnaean hierarchy.

If the image shows a plant, fungus, protist or monera, you can just determine what kingdom it belongs to.

If your organism is in the kingdom Animalia, then you need to work through the hierarchies: phylum, class, order. If you can narrow your observations down further than this, continue, but, if not, your groupings should be clear at the Order level. Referring to Table 5.4.1 will help you to determine the class of Chordata that the organism belongs to.

**TABLE 5.4.1** Links between structural features and classification

| Organism | Primary structural feature | Other structural features | Kingdom this organism belongs to | If an animal, list phylum and class |
|---|---|---|---|---|
| Eucalyptus tree | Autotroph that grows very large | Produces flowers and seeds for reproduction | Plantae | - |
| mushroom | Has a stalk and cap and cannot make own food | Produces and releases spores to reproduce | Fungi | |
| seaweed | Autotroph that lives in water | Made up of many parts | Protista | |
| eagle | Warm blooded and has feathers and flies | Lay eggs | Animalia | Chordata, Aves |
| frog | Cold blooded and lives in moist areas | Lays eggs in water | Animalia | Chordata, Amphibia |

| Organism | Primary structural feature | Other structural features | Kingdom this organism belongs to | If an animal, list phylum and class |
|---|---|---|---|---|
| shark | Cold blooded and breathes with gills | Has fins and lives in water | Animalia | Chordata, Chondrichthyes |
| hagfish | Has no jaws and no paired fins | Is very flexible | Animalia | Chordata, Agnatha |
| sunfish | Has jaws and paired fins | Has teeth and simple fins | Animalia | Chordata, Osteichthyes |
| Sea squirt | Lives in water and has a tough outer coat made of cellulose | Adults are fixed in place Does not have a true backbone | Animalia | Chordata, chordat without a backbone |
| goanna | Cold blooded and has scales and breathes air | Moves quickly overland and offspring lay eggs | Animalia | Chordata, Reptilia |
| dog | Warm blooded, has fur and feeds milk to young | | Animalia | Chordata, Mammalia |



## Worked example

### Observing organisms

#### Problem

Use the image in Figure 5.4.1 to observe the structural features of this organism. From your observations, classify the organism into a kingdom. If the organism is an animal, classify it to the level of order. If possible, try to give the common name for your organism.

**FIGURE 5.4.1** The platypus, *Ornithorhynchus* anatinus

#### Solution

| Thinking | Working |
|---|---|
| What kingdom does this organism fit into? | Animalia—as it requires oxygen and food, it moves around and has a skeleton. |
| What is the animal's phylum? | It has a central nerve cord covered by a backbone, so it is in the phylum Chordata. |
| What class and order would this animal be in? | This animal is a mammal and a monotreme. It is a platypus. |
| What are the structural features you observe? | The platypus has an internal backbone. It has fur, a leathery beak, a tail, flippers. |

Try yourself

## Observing organisms

Use the image below to observe the structural features of this organism. From your observations classify it into a kingdom. If the organism is an animal, classify it to the level of order. If possible, try to give the common name to your organism.

**FIGURE 5.4.2** Observe the structural features of this organism and try to determine its classification.

# Aim

Your investigation has two aims:

1 To observe the key structural features of different organisms

2 To classify different organisms into Kingdoms based on the similarities and differences within and between groups

# Apparatus

For both tasks, you will need:

- a set of photos or specimens of different organisms (if animals, they must be chordates)
- a list of the answers for students to check their classification once they have completed their task.

# Method

## Task 1

1 Set up the photos/specimens provided.

2 Observe each sample.

3 Create a list of structural features in each sample.

**HINT**

It is possible that you may see similar structural features in different groups, for example, both bears and eagles have claws.

You will need to determine whether that structure is the structural feature that puts them in the same group, or whether there is a more important structural feature that separates them into different groups.

In the example of the bear and eagle, structural features like feathers, fur and wings would place these two organisms in different groups first. Claws are simply a structural feature that could have developed in each group later on in their evolution.

**GO TO ➤**

For more help with evaluating investigations go to Toolkit section x.x

## Task 2

1. Using the lists of structural features you created in Task 1, group the specimens with the same structural features.
2. Identify what features are different between groups.
3. For the organisms that are plants, fungi or protists, indentify the kingdom; for animals, also give phylum and class classification.

# Results

## Task 1

For each specimen you observed, copy the results table below into your notebook and record your observations in the first three columns.

## Task 2

Identify the group that your specimen belongs to, based on your observations, and place this in column four of your table.

| Organism | Primary structural feature | Other structural features | Kingdom this organism belongs to | If an animal, list phylum and class |
|---|---|---|---|---|
| | | | | |

# Discussion

Evaluate your practical investigation by considering how you could improve the process of observation and determination of important structural features.

# Conclusion

1. Summarise what structural features you were looking for when you were looking at the organisms (Task 1).
2. Explain how you were able to classify the Kingdom the organism belonged to and then, if the organism was an animal, which class of Chordata the organism was in (Task 2).

# 5.5 Adaptations of Australian animals

## Introduction

Australia is a very difficult land mass to survive on. It can be hot and dry, cold and wet, humid and rainy in different environments. To be able to survive, organisms in this country have adapted, over time, to the various challenging environments.

In this lesson, you will investigate the ways that Australian animals have survived because of their unusual adaptations.

## Background

**Adaptations** allow organisms to make the most of their environment. Adaptations can be **structural** (how the animal is built), **behavioural** (how the animal behaves) or **physiological** (how the body of the animal works). Figure 5.5.1 shows a central bearded dragon, which displays many adaptations that allow it to live successfully in its desert environment. It has structural adaptations, such as the claws on its feet, physiological adaptations, such as the way it can change its colour to attract a mate, and behavioural adaptations, such as opening its mouth wide and puffing up its beard when facing an attacker.

An adaptation that is suitable in one environment may endanger the animal in a different environment. Australian animals are unique for both for their ability to survive in the harsh Australian environment and the types of adaptations they have. For example, the central bearded dragon, *Pogona vitticeps*, in Figure 5.5.1 is a reptile and spends a lot of its time basking in the sun to raise its body temperature. This provides the best conditions for processes in its body, such as digestion and the release of energy from food, to occur. This animal would not survive in cold, overcast climates as it would have no way of obtaining vital energy from its environment.

## Aim

To identify the adaptations of one native organism in a typical Australian environment.

To document your observations in a detailed scientific report.

## Plan

1 There are many types of Australian environments. For your investigation in groups, you will explore one typical Australian environment (desert, tropical rainforest, coral reef, rivers and wetlands, mountain ranges, woodland and coastal areas), which will be assigned by your teacher.

2 In your group, discuss and write down the challenging elements of your environment. Work together as a group and separate the identified

**Learning intention**

To be able to investigate and document adaptations of Australian animals

**Success criteria**

**SC 1:** I can identify adaptations of organisms in an Australian habitat.

**SC 2:** I can document findings in a detailed scientific report.

**KEY TERMS**

**structural adaptation**
ways in which the body of an organism is built that enhance its chances of survival in its environment

**behavioural adaptation**
behaviour of an organism that gives it a survival advantage

**physiological adaptation**
also known as functional adaptations; adaptations to the inner workings of an organism's body that enhance its chances of survival in its environment

**FIGURE 5.5.1** A central bearded dragon, *Pogona vitticeps*. This animal has many adaptations that enable it to live successfully in its arid environment.

challenges as either non-living, for example, a limited supply of water, or living, for example, predators.

3 Research your given animal and identify different structural, behavioural and physiological adaptations that give your animal an advantage in its environment.
4 Draw diagrams or find images of your assigned animal. Clearly identify the different adaptations that can be seen on the body of the animal or show how the animal behaves, and then explain what these adaptations are and how they improve the survival of your assigned animal.
5 Document your research in a scientific report.

## Design

1 For your given animal, identify three to five key adaptations. Ensure that you discuss at least one example each of behavioural, structural and physiological adaptations.
2 Record the places where you obtained your images and information in a bibliography.
3 Create a scientific report as either a written report, a slide presentation, a poster or other format that your teacher suggests.
4 Present your presentation to your classmates. Comment on any aspects of your classmates' presentations that could also work in your report.
5 In your group, finalise your report by incorporating any improvements identified after the sharing of ideas by the class.

## Conduct

1 Identify at least two different and trusted sources from which to research your animal.
2 Organise your material into a written summary and then create a presentation from your research.

## Improve

1 Review your classmates' presentations. Describe how effective their presentations were at demonstrating the different adaptations of their animal.
2 What could you do to improve your own report and presentation?

## Discussion

1 Evaluate the way you researched the information about your animal.
2 Did you use effective images that clearly showcased the adaptations you were discussing?

# 5.6 Introduction to keys for identification

## Lesson overview

We have seen scientists organise things according to their similarities and differences. Classification keys are used to identify the group that an object or living thing belongs to. Keys for classifying living things include a series of questions or statements about the features of organisms. By working through the steps in a key, the group that an organism belongs to can be identified.

There are several types of keys that can be used, but the simplest are called dichotomous keys (Figure 5.6.1).

In this lesson, you will learn about classification keys and how they are developed and used to assist with the identification of living things.

**Learning intention**

To understand the purpose of a dichotomous key

**Success criteria**

**SC 1:** I can use a branching dichotomous key to identify objects or organisms.

**SC 2:** I can use a table dichotomous key to identify objects or organisms.

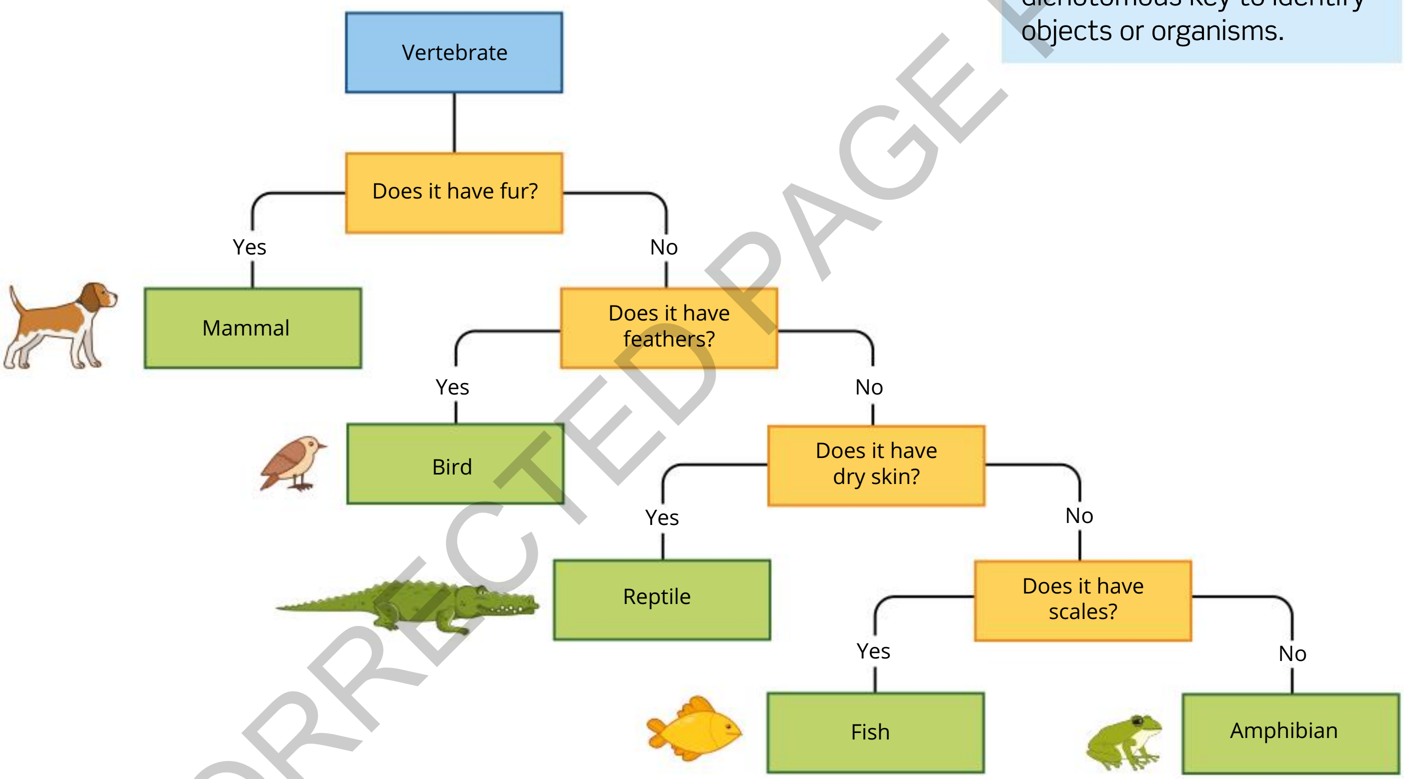



**FIGURE 5.6.1** A dichotomous key used to classify animals with backbones (vertebrates)

**SC 1** I can use a branching dichotomous key to identify objects or organisms

**Taxonomy** is the field of science that classifies living things. **Taxonomists** are scientists who classify living things based on their similarities and differences, naming them so they can be identified and discussed

As we have seen in this chapter, classification is used to group things so that relationships and connections between groups can be used for clear

**KEY TERMS**

**taxonomy** the science of classifying and naming things

**taxonomist** a scientist who specialises in classifying and naming things

**KEY TERMS**

**dichotomous key** a key with two choices at each stage

**classification key** another way of saying dichotomous key

**Scifile**

**Classifying butterflies**

With a dichotomous key, you can identify butterfly species by looking at wing patterns and colours. This tool helps entomologists (scientists who study insects) understand butterfly diversity and track changes in populations.

identification. Scientists use keys to assist with the organisation of objects and organisms. These keys can be used to identify new additions to the group.

Although millions of different species of organisms have been identified by scientists, many more are still likely to be discovered. A **dichotomous key** is a tool used by scientists to help them identify new organisms and compare them to organisms that have already been classified and described. A dichotomous key is also known as a **classification key**. Some dichotomous keys are based on structural features that do not change, such as number of legs or body shape. The prefix 'di' at the beginning of the word means two. In these keys, each stage of the key has two choices, based on the characteristics of the organism.

There are two types of dichotomous keys: branching and tables. Both keys use a series of two criteria to tell the difference between features of objects and organisms.

## A branching dichotomous key

A branching flow chart key, as seen in Figure 5.6.2, is read by starting at the top and working through the descriptions until you can classify the shape.

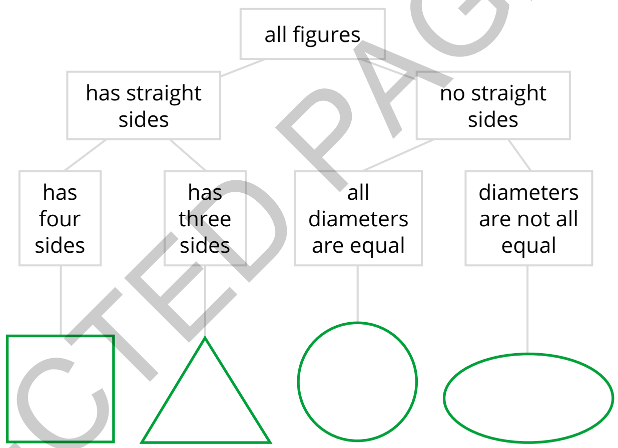



**FIGURE 5.6.2** A branching dichotomous key used to classify shapes

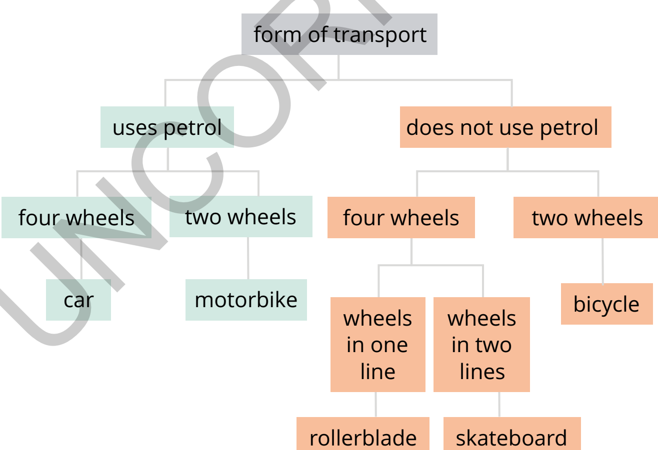



**FIGURE 5.6.3** A branching dichotomous key used to classify modes of transport

### Using a branching dichotomous key

Items and living organisms can be identified or classified using branching dichotomous keys. You always start at the top and move down through the key. By identifying a characteristic, you are then directed to the next options to match with your item.

Consider the branching key in Figure 5.6.3, designed to identify modes of transport. A particular mode of transport was known to have these features: does not need fuel; has four wheels in one line.

By following the options at each stage, the item can be identified. As shown in Figure 5.6.4, the description given of the item at the start allows it to be identified as a rollerblade.

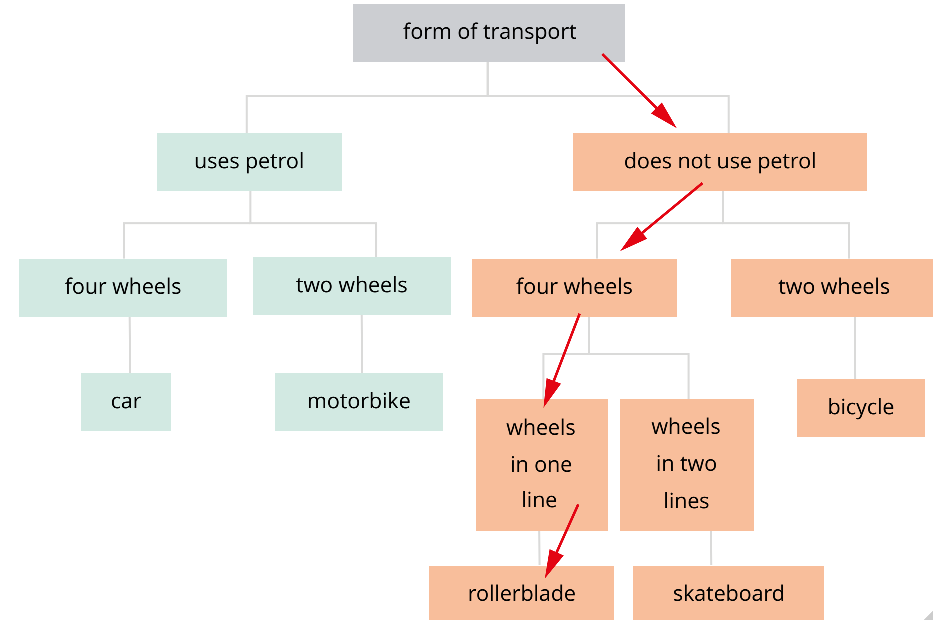



**FIGURE 5.6.4** An example of how a branching dichotomous key can be used to identify rollerblades

## CHECK YOUR UNDERSTANDING

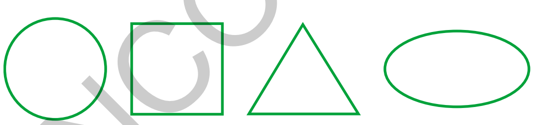
Describe how a branching dichotomous key functions.

**SC 2** I can use a table dichotomous key to identify objects or organisms

## Table dichotomous keys

Table keys use paired questions that start with general characteristics and gradually become more specific. When using dichotomous keys, some observations will be **quantitative**, such as the number of sides an object has, whilst some observations will be **qualitative**, such as describing its shape or what the object looks like.

The four different shapes in Figure 5.6.5 can be classified by referring to the dichotomous table key. Start by reading from the top of the table and working through the questions, until you get to the final name.



| | | |
|---|---|---|
| 1a | Has straight sides | Go to 2 |
| b | No straight sides | Go to 3 |
| 2a | Has four sides | Square |
| b | Has three sides | Triangle |
| 3a | All diameters are equal | Circle |
| b | Diameters are not all equal | Oval |

**FIGURE 5.6.5** A table dichotomous key used to classify shapes

### KEY TERMS

**quantitative** a description of something that can be measured by a quantity or number

**qualitative** a description of something that is not measurable by a quantity or number

### SciFile

### Identifying plants in your garden

In Australia, many gardeners use dichotomous keys to identify native plants. By answering questions about the shape of leaves, the type of flowers, and other characteristics, you can work out what plant you are looking at.

These keys are used in biology so that unknown or newly discovered organisms can be compared to known species and thus identified within a specific group and then named.

## Using table dichotomous keys

Table keys present the observable features in a table where the user starts at the top and works down, matching features and then moving to the next set of options.

Consider the table key for identifying animals that live in and around soil (Table 5.6.1). A creature is found to have 16 pairs of legs and no antennae.

**TABLE 5.6.1** Animals that live in and around soil

| | | |
|---|---|---|
| 1 | 1a Legs ........................................ | *go to 4* |
| | 1b No legs ........................................ | *go to 2* |
| 2 | 2a Antennae ........................................ | *go to 3* |
| | 2b No antennae ........................................ | **worm** |
| 3 | 3a Shell ........................................ | **snail** |
| | 3b No shell ........................................ | **slug** |
| 4 | 4a More than 10 pairs of legs ........................................ | *go to 5* |
| | 4b Less than 10 pairs of legs ........................................ | **beetle** |
| 5 | 5a More than 20 pairs of legs ........................................ | **millipede** |
| | 5b Less than 20 pairs of legs ........................................ | **centipede** |

By following the options at each stage, the item can be identified as shown in Table 5.6.2.

**TABLE 5.6.2** Observation table of how a centipede can be classified

| Observation table | | |
|---|---|---|
| **First observation** | 1a Legs | *go to 4* |
| | 1b No legs | *go to 2* |
| | 2a Antennae | *go to 3* |
| | 2b No antennae | **worm** |
| | 3a Shell | **snail** |
| | 3b No shell | **slug** |
| **Second observation** | 4a More than 10 pairs of legs | *go to 5* |
| | 4b Less than 10 pairs of legs | **beetle** |
| **Third observation** | 5a More than 20 pairs of legs | **millipede** |
| | 5b Less than 20 pairs of legs | **centipede** |

So, the animal is a centipede.

### CHECK YOUR UNDERSTANDING

Describe what a table dichotomous key looks like and how it is used.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 Describe the purpose of a dichotomous key in biology.

2 Identify two features of a branching dichotomous key.

3 Create a dichotomous key question that would separate a house fly and a dragon fly.

4 Explain why a dichotomous key is a useful tool for scientists.

# 5.7 Creating and using keys for Linnaean classification

## Learning intention

To use and create keys to classify organisms using the Linnaean system

## Success criteria

**SC 1:** I can identify features of animals that will enable them to be classified into a class within the phylum of chordates.

**SC 2:** I can create a dichotomous key that will enable the classification of familiar and unfamiliar animals into classes within the phylum of chordates.

## Introduction

You have learned that organisms are grouped according to their similarities and differences so that it is easier to classify and identify them. Dichotomous keys that are created by biologists use specific criteria to identify or classify organisms (Figure 5.7.1). Once the keys are developed, they can be used to classify unfamiliar or new species of organisms.

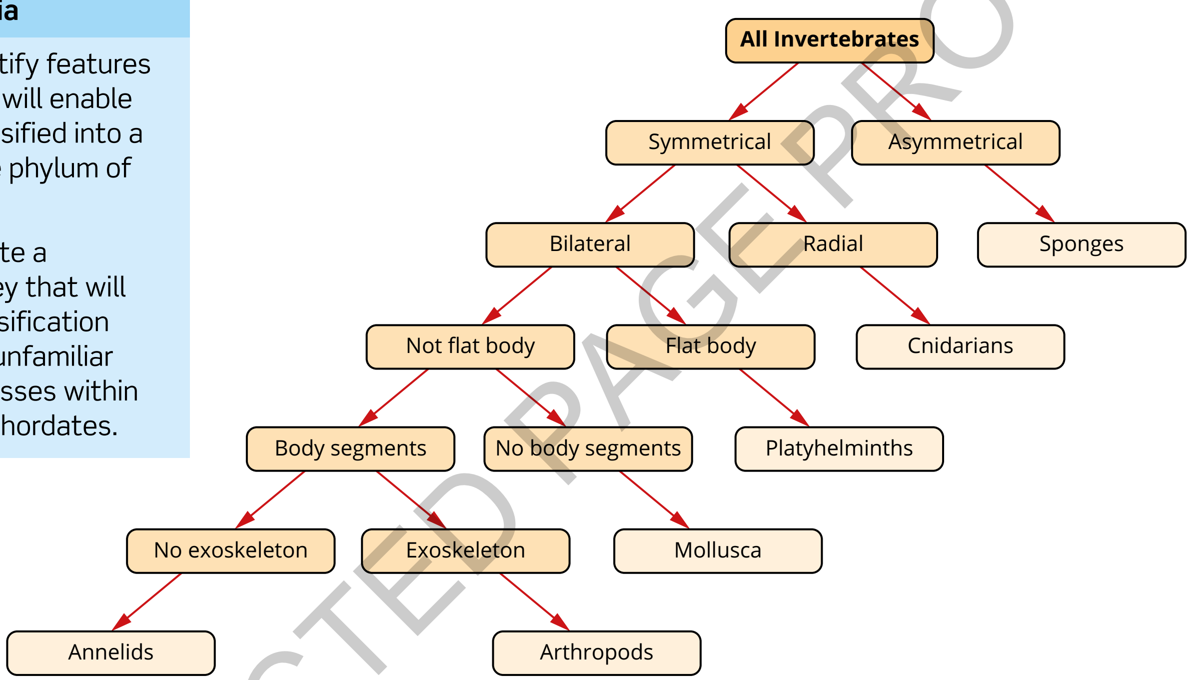



**FIGURE 5.7.1** Branching key used to classify invertebrates

In this practical investigation, you will create branching or table dichotomous keys to group animals into the classes that make up the phylum of chordates.

## Background

All chordates have a nerve cord and most of them have a backbone to protect it.

There are eight classes of chordates. In the past, fish were in a single class but are now divided into three different classes: the Agnatha (jawless fish), Chondrichthyes (cartilaginous fish with jaws), and the Osteichthyes (bony fish). The other classes of chordates include the Amphibia (amphibians), Reptilia (reptiles), Aves (birds), and Mammalia (mammals). Table 5.4.1 can help you review these areas of classification.

Direct observation of the structural features of organisms enables them to be organised into groups according to similarities and differences. This is the basis of classification and the creation of dichotomous keys.

# Aim

To use the structural features of chordates to create dichotomous keys and classify them into classes

## SkillBuilder

### Developing branching flowchart dichotomous keys

Dichotomous keys can be used to classify or identify organisms by a process of elimination. They can be in the form of a branching flow chart, where the user starts at the top of the flowchart and tracks down through the questions until the organism is identified or classified.

#### Identifying and classifying

Identify means that you can find the specific name of the organism (specimens) that you are considering. For example, the naming of bird species, or the identification of species of Eucalyptus trees in the forest.

Classify means that you can find identify the group that the specimens belong to. For example, discovering whether animals are reptiles, amphibians, mammals, birds or fish, or finding the particular family that a tree belongs to.

#### Method

1. Observe and analyse your specimens and list the characteristics or features of your specimens so you can distinguish between them.
2. Choose characteristics that are easy to observe or can be measured.
3. Decide on what you think are the most general characteristics. Start your key with these.
4. Divide your specimens into two groups based on one of these general characteristics. Write a **dichotomous question** that will divide the group of specimens into these two groups.
5. Subdivide each of these first two groups into two more groups based on other characteristics, again drafting a dichotomous question which will divide the specimens. You should now have four groups.
6. Continue subdividing your groups in this way. You will soon have groups that only contain two or three specimens.
7. At this point identify one last characteristic that is different between the two specimens in that group, and you have completed that branch of your key.
8. Repeat the previous steps until all branches have been completed.
9. Test your key (or get someone else to test it) and make changes to the questions if required.

#### Examples

Laila was asked to create a key to identify breeds of dogs. Kai was asked to create a key to name pieces of fruit. Note that there are different ways to draw the flowchart key. Laila used Method 1 and Kai chose Method 2.

**Method 1:** The questions are written at the split in the branch and the new branches are labelled yes or no as shown in Figure 5.7.2, which is used to classify animals. Note that the key is easier to use if you always have the 'yes' branches on one side and the 'no' branches on the other side.

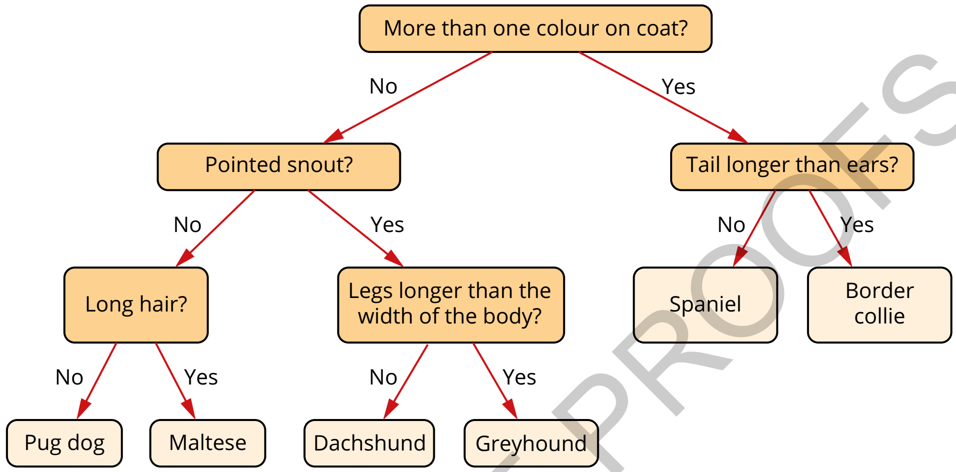



**FIGURE 5.7.2** Laila's key

**Method 2:** Only the answers to each dichotomous question are written on the branch, as shown in Figure 5.7.3, which is used to classify plants.

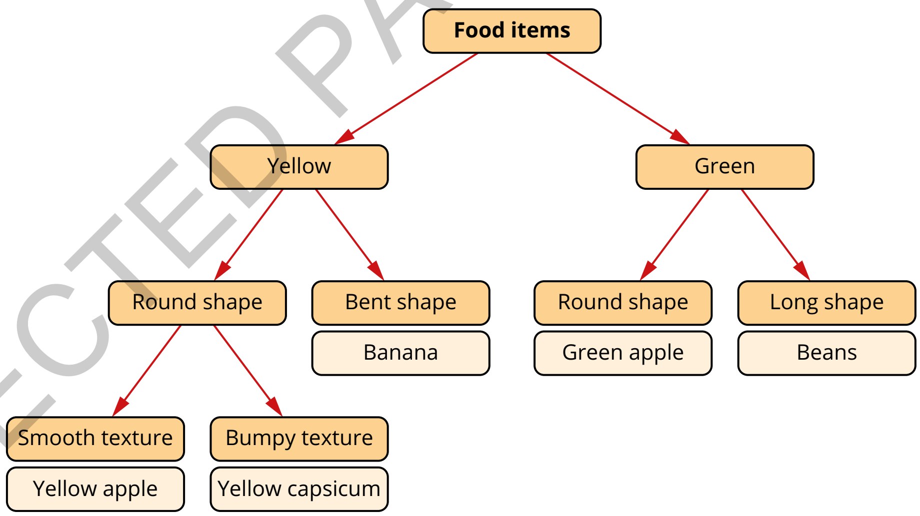



**FIGURE 5.7.3** Kai's key

## SkillBuilder

### Developing table dichotomous keys

Dichotomous keys can be represented in the form of a table where the user starts at the top of the table and follows the directions after each question until the organism is identified or classified. In effect you are following a trail, based on the answers to the questions.

## Method

1 Observe and analyse your specimens and list the characteristics or features of your specimens so you can distinguish between them.

2 Choose a characteristic that is easy to observe or can be measured.

3 Decide on what you think are the most general characteristics. Start your key with these.

4 Divide your specimens into two groups based on one of these general characteristics. Write a dichotomous question that will divide the group of specimens into these two groups.

5 Set up a blank table with three columns, as shown below.

| Step | Descriptions | Action |
|---|---|---|
| 1 | | |
| | | |
| | | |
| | | |

6 Each step in the table is a dichotomous question with two possible answers.

7 For Step 1, write out the two answers to the first question and label these 1a and 1b.

| Step | Descriptions | Action |
|---|---|---|
| 1 | 1a Has fur | |
| | 1b No fur | |
| | | |
| | | |

8 Draft two more questions that will subdivide the groups and add to your table. For example:

| Step | Descriptions | Action |
|---|---|---|
| 1 | 1a Has fur | go to Step 2 |
| | 1b No fur | go to Step 4 |
| 2 | 2a Lays eggs | This is a monotreme |
| | 2b gives birth to live young | Go to Step 4 |
| 3 | 3a has feathers | This is a bird |
| | 2b no feathers | Go to Step 5 |
| | | |
| | | |

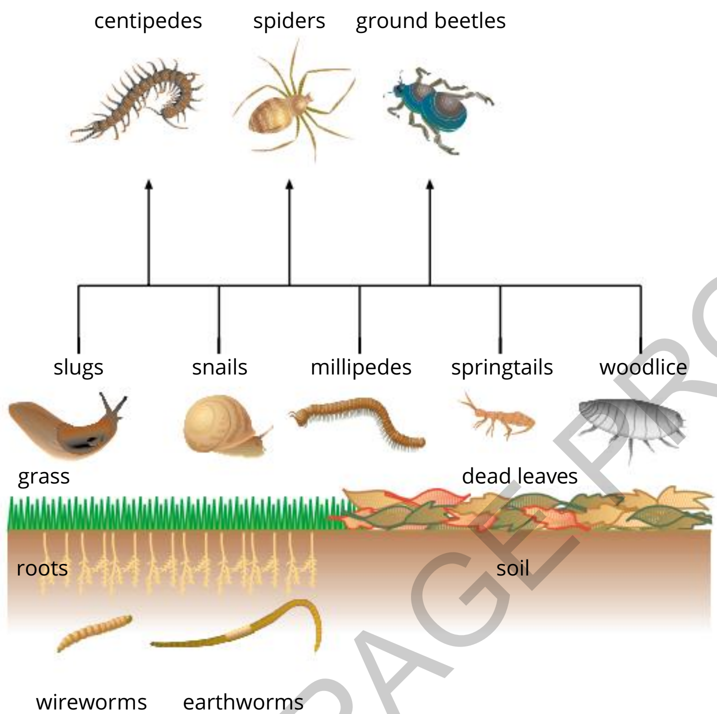
9 Continue adding questions until all specimens have been identified or classified.

10 Test your key (or get someone else to test it) and make changes to the questions if required.

Note that table dichotomous keys are much easier to build digitally as you can edit the table as you build it.

## Example

Ethan was asked to create a table key to identify minibeasts found in the soil.




His key is shown here.

| Step | Descriptions | Action |
|---|---|---|
| 1 | 1a Legs | Go to 5 |
| | 1b No legs | Go to 2 |
| 2 | 2a Antennae | Go to 4 |
| | 2b No antennae | Go to 3 |
| 3 | 3a 'Snake-like' shape | earthworm |
| | 3b Not 'snake-like' shape | wireworm |
| 4 | 4a Shell | snail |
| | 4b No shell | slug |
| 5 | 5a More than 10 pairs of legs | Go to 6 |
| | 5b Less than 10 pairs of legs | Go to 7 |
| 6 | 6a More than 20 pairs of legs | millipede |
| | 6b Less than 20 pairs of legs | centipede |
| 7 | 7a More than 3 pairs of legs | Go to 9 |
| | 7b 3 pairs of legs | Go to 8 |
| 8 | 8a Tail | ground beetle |
| | 8b No tail | springtail |
| 9 | 9a Two body segments | spider |
| | 9b More than two body segments | woodlouse |

## Materials

- multiple photos of animals belonging to the eight classes of chordates
- specimens (preserved), skeletons or fossils of the eight classes of chordates
- magnifying glasses
- butcher paper and coloured pens
- sticky notes or small pieces of paper

**SAFETY NOTES**

- The liquids used to preserve the specimens are hazardous and toxic.
- Do not open any jars or touch preserved specimens.

### Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

## Method

Your teacher will provide several photos and specimens of animals that belong to the phylum Chordata.

1 Observe each of the specimens and note the following on a piece of paper or sticky note:
- The name of the specimen (common or scientific name).
- The distinctive characteristics and structural features of the specimen.

Do not write about its habitat or how it moves.

2 Use the butcher paper and coloured pens to organise the specimens into groups. You can use colour coding to help here. This will help you to create the dichotomous keys.

3 Discuss the features that your group will use to create a dichotomous key and use these features to develop dichotomous questions.

## Results

Use your observations to create a dichotomous key, either a table key or branching key.

## Discussion

Discuss any improvements that you could make to the key to enable more effective classification.

## Conclusion

1 Ask other students to try using your key.

2 Classify an unfamiliar animal using your key.

# 5.8 First Nations Australians' classification systems

**Learning intention**

To understand similarities and differences between First Nations Australians' systems of classification and Linnaean classification

**Success criteria**

**SC 1:** I can describe how a group of First Nations Australians classify plants or animals in their environment.

**SC 2:** I can compare First Nations Australians' systems of classification and the Linnaean classification system.

**FIGURE 5.8.1** These grass trees are called *Xanthorrhoea australis* in the Linnaean system, but are called balga, bukkup, baggup or kawee by First Nations peoples (depending on the language groups)

**KEY TERMS**

**Country** the land that First Nations peoples have a cultural connection to through their ancestry

**totem** a specific animal, plant or natural feature that a person is spiritually linked to; determines rights and relationships with others

## Lesson overview

Various methods for organising and naming organisms are used within Australia and throughout the world. The Linnaean classification system, still widely used in Western science today, is a hierarchical method of grouping organisms into increasingly specific categories, starting with the broadest group (kingdom) and ending with the most specific group (species). In contrast, Aboriginal and Torres Strait Islander peoples have a unique classification system that draws on ecological knowledge alongside a deep spiritual and cultural understanding of their environment (Figure 5.8.1).

In this lesson, you will learn about the similarities and differences between First Nations Australians' systems of classification and Linnaean classification.

**SC 1** I can describe how a group of First Nations Australians classify plants or animals in their environment

First Nations Australians have a deep understanding of the plants and animals in their environment, as they have lived in Australia for more than 60,000 years. This traditional knowledge is often based on the connections between living things, as well as their connections to the land and the spiritual world. This is often described as their connection to **Country**. Accordingly, it is important to understand how First Nations peoples name and classify the organisms in their environment.

For example, First Nations Australians have given names to plants and animals that communicate their specific characteristics, uses and cultural significance. First Nations Australians also have a special way of grouping and understanding living things. Their classification systems can include how the organism is used, how old it is, what stage in its life cycle it is in, its gender, social status, and whether it is associated with a **totem**. First Nations Australians express their knowledge in many ways including through oral tradition and artwork (Figure 5.8.2). First Nations Australians' detailed knowledge of native plants and animals was initially ignored by European naturalists but in recent times has helped scientists to learn more about these organisms. This emphasises how important it is to respect and value different ways of understanding the natural world, and to work together to learn more about it.

**FIGURE 5.8.2** First Nations artwork of a dugong

## Eucalyptus trees

Many First Nations peoples have a deep understanding of the different species of Eucalyptus and how to use them for medicinal, nutritional and other practical purposes. For example, the bark of some Eucalyptus species is rich in tannin, which is traditionally used for tanning animal hides (Figure 5.8.3). The leaves of some other species, by contrast, are rich in oils that can be used for making ointments and other medicinal remedies.

**FIGURE 5.8.3** The bark of the river red gum (*Eucalyptus camaldulensis*) is rich in tannin.

## Kangaroos

First Nations Australians classify animals according to their characteristics, behaviours and relationships with other species. Therefore, they may classify different types of kangaroos according to their size, colour and habitat, as well as noting their seasonal movements and the types of plants they eat (Figure 5.8.4). This knowledge is passed down through generations through storytelling, song, dance and other cultural practices.

**FIGURE 5.8.4** First Nations Australians may classify kangaroos according to their seasonal movements and the plants they eat

**CHECK YOUR UNDERSTANDING**

Identify two characteristics that First Nations Australians may use to classify kangaroos.

**SC 2** I can compare First Nations Australians' systems of classification and the Linnaean classification system

## The Linnaean classification system

The Linnaean classification system, developed by Carl Linnaeus in the eighteenth century, is based on a hierarchical system of grouping organisms based on physical characteristics and similarities. It organises organisms into increasingly specific categories, starting with the broadest, kingdom, and ending with the narrowest, species.

## First Nations classification systems

The classification systems used by First Nations Australians are based on a different understanding of the natural world. These systems reflect a profound knowledge of the relationships between different organisms and their environment and often include both physical and **spiritual** aspects. For example, many plants and animals are totems or spiritual guides for specific communities that also appear in **Creation stories**, ritual and ceremony, art and storytelling and healing.

**KEY TERMS**

**spiritual** relating to the soul or spirit or religious beliefs

**Creation stories** stories that explain the origins of the universe, the rules for living and the relationships of people to each other and to the environment; also known by many as Dreaming stories

**billabong** a pond of still water in an isolated branch of a river, which fills during a flood

# Habitat

First Nations classification systems are often more fluid than the Linnean system and can change over time. For example, the Yanyuwa peoples' system of classification separates coastal and inland regions, so a turtle found in the sea may be classified as a marine organism, but if it is found in a freshwater **billabong**, it may be reclassified as an inland animal (Figure 5.8.5).

**FIGURE 5.8.5** Green Turtles are common in Australia's northern waters and around the Torres Strait Islands

**FIGURE 5.8.6** Dugongs have many similarities with turtles but are classified as mammals in the Linnaean system because they give birth to live young

## Time of life

The Yanyuwa language has one word for all dugongs and sea turtles as they both have flippers and live in water, but this category is broken down into at least 16 different names to distinguish between them. These names include variations based on the animal's age, size and even its status within its herd. Similarly, in the Meriam language of the Torres Strait, there is one word for a green turtle, but different words are used at different stages of the green turtle's development. In the Linnaean system, however, turtles and dugongs are classified in different groups or 'classes': turtles as reptiles and dugongs as mammals (Figure 5.8.6).

## Comparison of classification systems

The Linnaean classification system is a hierarchical system that organises organisms into increasingly specific categories based on their physical characteristics. First Nations Australian classification systems also include physical characteristics but are based on a different understanding of the natural world, which includes spiritual, cultural and practical aspects that can be more fluid and adaptive.

### CHECK YOUR UNDERSTANDING

Explain one key difference between First Nations Australians' classification systems and the Linnaean system.

# Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 Name one way that First Nations Australians classify plants.

2 Use the information in this lesson to suggest three criteria that Native Australians might use to classify fish.

3 Describe how an organism's habitat may alter its classification using a First Nations Australians classification system.

4 How would a kangaroo be classified differently between the Linnaean and First Nations classification systems?

# 5.9 Classification case study

## Introduction

As you have learnt throughout this topic, classifying organisms enables scientists to monitor environments, care for sick organisms, build up endangered populations, and determine important qualities such as the medicinal properties of different types of plants.

In this inquiry activity, you will classify an organism. Your teacher may give you an image, a binomial name or a description of an organism and, using the skills you have learnt throughout this topic, you will be asked to classify this organism. You may also be given a dichotomous key to help in classifying this organism.

**Learning intention**

To be able to classify a chosen organism and explain its characteristics

**Success criteria**

**SC 1:** I can explain the classification of a chosen organism.

**SC 2:** I can describe how an organism meets the criteria for living things and give some examples.

## Background

Throughout this chapter, you have been looking at structural, behavioural and physiological adaptations of organisms. The adaptations that an organism has allow it to use its environment effectively. Organisms can be classified based on their set of adaptations. To help scientists determine its classification, careful observations must be made of an organism and how it lives its life. To identify that an animal lays eggs with a protective shell is not enough to state with certainty that the animal is a bird. Other observations must also be made. For example, **monotremes** are not birds, but they do lay eggs.

## Aim

To classify an organism by looking at its adaptations and how it lives its life

## Plan

1 For your Classification case study, you will be assigned an organism by your teacher.
2 Observe your given organism. List structural, behavioural and physiological adaptations that you can observe. Identify key features of the organism.
3 Classify your organism based on the key features you have identified.
4 Explain how you developed the classification.
5 Identify how this organism meets the criteria for living things.

## Design

1 For your given organism, identify key features that help you to determine its classification. Remember to move from the highest level of classification to the lowest level.
2 Record the hierarchical level and explain how your organism fits into this level.

3 Create a written report, a slide presentation, a poster or other format specified by your teacher, that demonstrates which features of the organism enabled you to classify it.
4 List the criteria for living things and explain how your organism meets these criteria.
5 Present your presentation to your classmates. Comment on any aspects from your classmates' presentations that could also work for your presentation.
6 Finalise your presentation by incorporating any improvements identified after the sharing of ideas by the class.

## Conduct

1 Identify the sources that you used to research your organism.
2 Organise your material into a presentation from your research.

## Improve

1 Review your classmates' presentations. Describe how effective their presentations were at demonstrating the different adaptations of their animal.
2 What could you do to improve your own report and presentation?

## Discussion

1 Evaluate the way you researched the information about your organism and how this led to your classification.
2 Did you ensure that you moved from the highest classification level down?
3 Did you use effective images that clearly showcased the features that enabled you to classify the organism to a particular level?

# 5 Classification

## Topic summary

The key concepts included in this topic are:

- Organisms can be classified according to their similarities and differences.
- The Linnaean hierarchical system classifies from Kingdom through Phylum, Class, Order, Family, Genus and Species.
- The scientific name of an organism is binomial, as it provides both the Genus and Species name of the organism. For example, humans are *Homo sapiens*.
- Scientific classification models are used for accurate identification of organisms.
- Australian native species have many unusual characteristics when compared to other species around the world.
- Adaptations enable organisms to survive in their environments.
- Adaptations can help determine classification relationships.
- Dichotomous keys are tools used to identify and classify organisms.
- Changes to classification models occur over time.
- First Nation Australians use a variety of ways to identify and classify organisms.



## Review questions

The following questions will assess your success in achieving the learning intentions for this topic.

### Remember

1 Identify the main role of classifying biodiversity on Earth.

2 Describe the purpose of dichotomous keys.

3 Identify the first step in creating a dichotomous key.

4 Name one characteristic of the phylum Arthropoda.

### Understand

5 Explain how classification helps in the study of biodiversity.

6 Explain how a classification key, such as a dichotomous key, can determine which group an organism will belong to.

7 Classify a lion (*Panthera leo*) using the Linnaean hierarchical classification system up to its class.

8 Identify the Genus and Species of the plant *Salvia rosmarinus*.

### Apply

9 Gyaan is undertaking **fieldwork** to identify different organisms at the seashore.

a Suggest what type of data could be collected through direct observation.

b Describe the process of how Gyaan would use the data to classify a shell that was found.

10 A dichotomous key was created to identify plants in a section of forest. How could you incorporate First Nations Australians' knowledge of plants into this key?

### Analyse

11 There are many different species of kangaroo.

a Identify the phylum to which kangaroos belong and explain the reasoning behind their classification into this group.

b The western grey kangaroo (*Macropus fuliginosus*) and the red kangaroo (*Magaleia rufa*) share many common features. Describe the similarities and differences in the classification of these two types of kangaroos.


**12** A class was researching classification and found two organisms named after Sir David Attenborough: *Oedura attenboroughi* and *Materpiscis attenboroughi*. Janine suggested these were very closely related organisms whilst Raj said they were highly unlikely to be closely related. Identify who was correct and suggest why they were correct.

**13** When two organisms were compared, it was found they lived in water, swam great distances, had a protected spinal cord and required oxygen.

- **a** Discuss whether it is a certainty that they are both from the same Kingdom.
- **b** Suggest how it could be possible that they are not both in the same phylum and provide an example to support your answer.

## Extension: Communication and problem solving

**14** Australian native animals are an important part of biodiversity in Australia.

- **a** Create a set of instructions on how you could create a dichotomous key for classifying Australian native animals into their respective classes.
- **b** Use your instructions to create a branching dichotomous key using six different Australian animals.
- **c** Test how effective your key is by swapping with another student to see if they can correctly identify the animals you selected. Evaluate your key using feedback from the student. Adjust your key if necessary and swap it with another student to see whether your adjustments have improved the key.

## Topic reflection

The learning intentions for this topic are given in each lesson and at the beginning of the topic. Consider how well you have achieved them. Note down any particular areas that you are confident in, and others where you are not so sure.

# 5 Glossary

**arthropod** animal with an exoskeleton and jointed limbs; examples include crabs and insects

**behavioural adaptation** behaviour of an organism that gives it a survival advantage

**biodiversity** the number and range of species that exist in an ecosystem, biome or biosphere

**billabong** pond of still water in an isolated branch of a river, which fills during a flood

**characteristic** a feature of a living or non-living thing

**Chordata** the phylum that includes animals with backbones

**chordate** animal with a nerve cord running down its back which is protected by a backbone, and has an endoskeleton

**class** the third level in the classification of living things

**classification** the process of putting things into groups

**classification key** a tool that helps scientists classify organisms based on their observations and descriptions

**common name** a non-scientific name given to an organism

**Country** the land that First Nations peoples have a cultural connection to through their ancestry

**Creation stories** stories that explain the origins of the universe, the rules for living and the relationships of people to each other and to the environment; also known by many as Dreaming stories

**dichotomous key** a key with two choices at each stage

**dichotomous question** a question that limits responses to only two possible answers

**diverse** having variety

**diversity** the variety of differences

**ecosystem** a system formed by organisms interacting with each other and their nonliving surroundings

**family** the level in the classification system below order and above genus

**fieldwork** a practical investigation performed mainly outside in nature

**genus** the level in the classification system below family and above species

**hierarchy** an arrangement that shows items at different levels compared to others

**kingdom** the first level of classification of living things

**Linnaean classification** a hierarchical system of classifying organisms, aimed at reflecting their evolutionary relationships

**marsupial** subclass of mammal that gives birth to immature young that are suckled in a pouch; examples are koala, kangaroo and wombat

**monotreme** subclass of mammal that lays eggs; examples include echidna and platypus

**naturalist** a person who studies the natural world, including the relationships between organisms and the environment

**order** the level in the Linnean classification system below class and above family

**organism** a living thing

**phylum** the second level of classification of living things, below kingdom and above class

**physiological adaptation** an adaptation to the inner workings of an organism's body that enhances its survival in its environment

**qualitative** a description of something that is not measurable by a quantity or number

**quantitative** a description of something that can be measured by a quantity or number

**scientific name** a Latin name for an organism based on the binomial system

**species** the last level of classification of living things

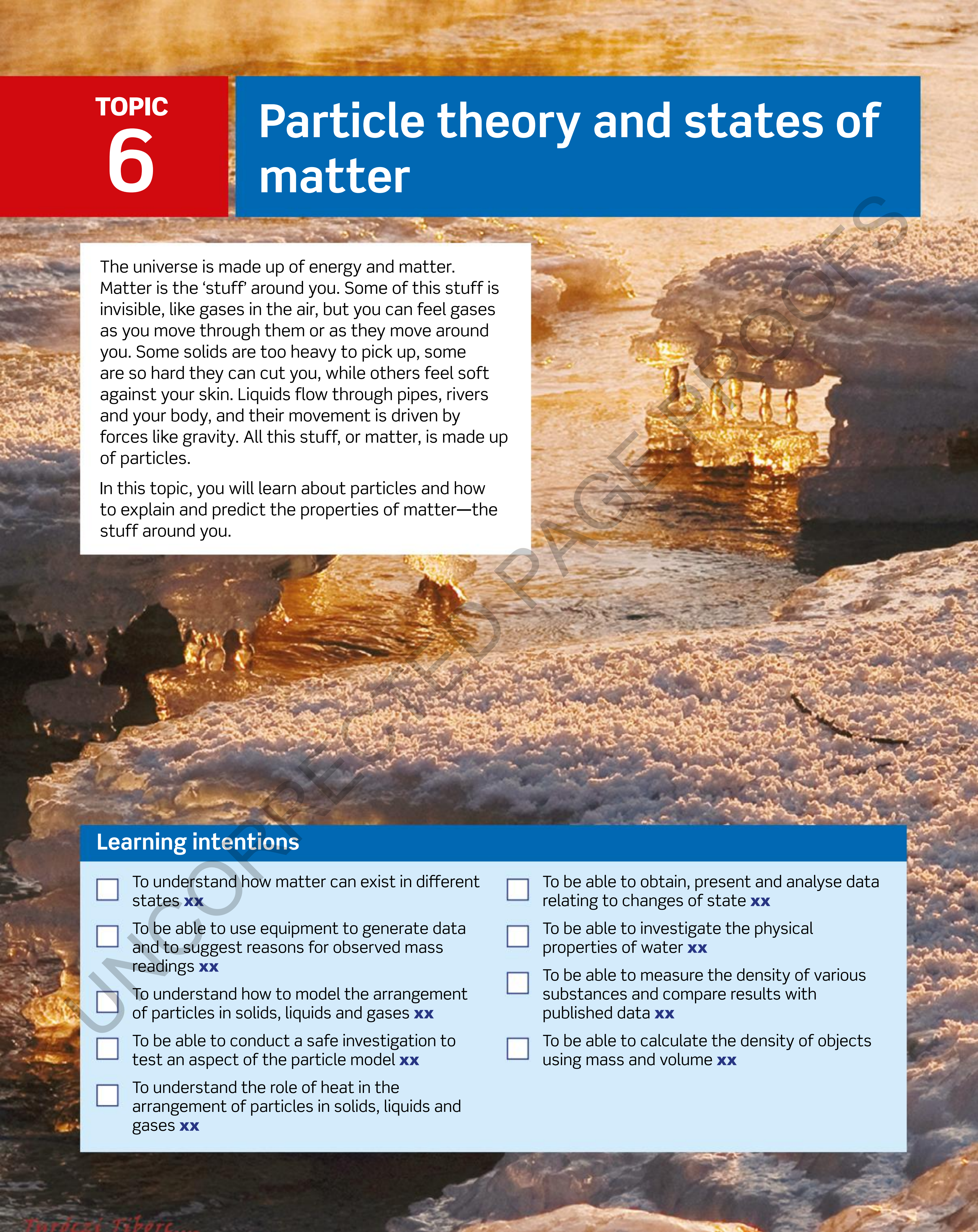
**spiritual** relates to the soul or spirit or religious beliefs

**structural adaptation** an adaptation in the way the body of an organism is built that enhances its survival in its environment

**totem** a specific animal, plant or natural feature that a person is spiritually linked to; determines rights and relationships with others

**taxonomist** a scientist who specialises in classifying and naming things

**taxonomy** the science of classifying and naming things



TOPIC 6

# Particle theory and states of matter

The universe is made up of energy and matter. Matter is the 'stuff' around you. Some of this stuff is invisible, like gases in the air, but you can feel gases as you move through them or as they move around you. Some solids are too heavy to pick up, some are so hard they can cut you, while others feel soft against your skin. Liquids flow through pipes, rivers and your body, and their movement is driven by forces like gravity. All this stuff, or matter, is made up of particles.

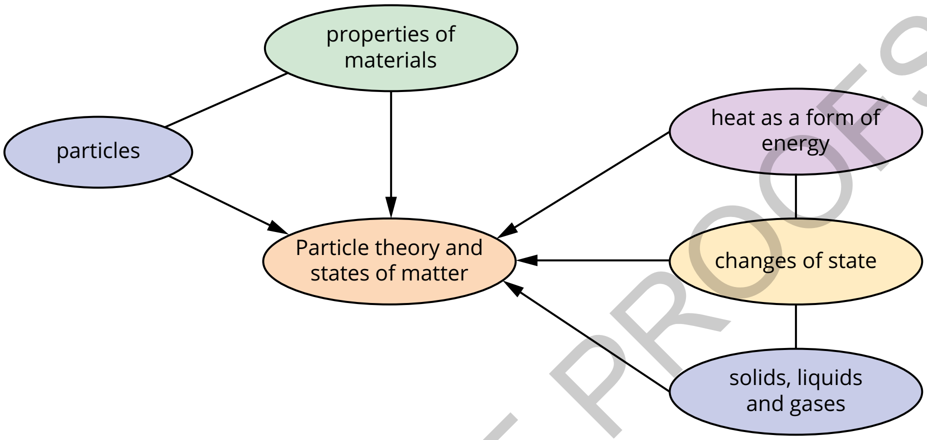
In this topic, you will learn about particles and how to explain and predict the properties of matter—the stuff around you.

## Learning intentions

- ☐ To understand how matter can exist in different states **xx**
- ☐ To be able to use equipment to generate data and to suggest reasons for observed mass readings **xx**
- ☐ To understand how to model the arrangement of particles in solids, liquids and gases **xx**
- ☐ To be able to conduct a safe investigation to test an aspect of the particle model **xx**
- ☐ To understand the role of heat in the arrangement of particles in solids, liquids and gases **xx**
- ☐ To be able to obtain, present and analyse data relating to changes of state **xx**
- ☐ To be able to investigate the physical properties of water **xx**
- ☐ To be able to measure the density of various substances and compare results with published data **xx**
- ☐ To be able to calculate the density of objects using mass and volume **xx**

# 6 Particle theory and states of matter

The key concepts that you will use in this topic:




The following prior knowledge questions will help to support your learning in the topic and can be attempted before the first lesson.

## Properties of materials

**1** A student provides the following observations of a substance: 'The substance is made up of hard, white, shiny crystals. It dissolves in water.'

Suggest what you think the substance was.

## Heat as a form of energy

**2** Describe how heat energy can change a block of chocolate.

**3** Explain why a metal object makes your skin feel cold when you touch it.

## Solids, liquids and gases

**4** Name the following.

- **a** three liquids that you might find in a bathroom
- **b** three gases that are in the air
- **c** three solids that are hard

**5** Describe one thing that liquids and solids have in common.

## Changes of state

**6** Explain the difference between melting and boiling and state one thing that these processes have in common.

## Particles

**7** The diagram represents particles in a substance.

- **a** Identify if the substance is a solid, liquid or gas.
- **b** Explain why you chose your answer to part **a**.
- **c** Suggest two improvements that could be made to the diagram.

# 6.1 States of matter

## Learning intention

To understand how matter can exist in different states

## Success criteria

**SC 1:** I can describe what matter is.

**SC 2:** I can classify different examples of matter as solid, liquid or gas.

## Lesson overview

The substances around you, referred to as 'matter', are made from many types of particles. You can touch, see and observe matter in a range of ways. Some matter is very visible and solid, like a tree. Other matter cannot be seen, like air, but it can be felt as a breeze and its effects can be seen when it moves the tree's leaves.

In this lesson you will learn what matter is, and how it is observed in the forms of solids, liquids or gases.

**SC 1** I can describe what matter is

### Matter

**Matter** is any substance that has volume (meaning that it takes up space) and mass (meaning that it can be weighed). You and almost everything around you are matter, including things that are too small to see.

### Solids, liquids and gases

There are three **states** (forms) that matter can exist in – **solid**, **liquid** and **gas**. These three forms are called the states of matter. Some examples of solids, liquids and gases are shown in Table 6.1.1.

**TABLE 6.1.1** Examples of solids, liquids and gases

| Solids | Liquids | Gases |
|---|---|---|
| Gym weights are solid and are made of the metals iron and steel. | Blood is one of the important liquids in your body. | Helium gas has been pumped into these balloons. |
|  |  |  |

### Matter and mass

The amount of matter in an object is known as its mass. Weighing an object provides a measure of its mass. It might appear that gases do not weigh anything but all matter, including gases, have mass. You might also think that gases don't take up space but again, just like all matter, they do. You can fill the space inside a balloon with a gas.

When people talk about matter, they often use the word **substance** to describe the thing that has mass. So, you can have solid substances such as steel, liquid substances such as mercury (the only liquid metal) or **gaseous** substances such as helium.

**KEY TERMS**

**matter** a physical substance; anything that has mass and occupies space
**state** solid, liquid, gas (also plasma at temperatures above 600°C)
**solid** the state of matter that has a fixed shape and a fixed volume
**liquid** the state of matter that will flow, with no fixed shape but a fixed volume
**gas** the state of matter that will expand to fill a container, having no fixed shape and no fixed volume

**KEY TERMS**

**substance** material that has physical properties; a solid, liquid or gas
**gaseous** in the form of a gas

## SC 1 CHECK YOUR UNDERSTANDING

Explain why air is considered to be an example of matter.

**KEY TERMS**

**property** an observable characteristic of a substance; what a substance looks like and how it behaves

**pure substance** a substance made up of only one type of material

**SC 2** I can classify different examples of matter as solid, liquid or gas

An understanding of the **properties** of solids, liquids and gases can be used to classify **pure substances** into their correct state.

## Identifying solids, liquids and gases

The key properties of solids, liquids and gases are shown in Table 6.1.2. These can be used to identify the state of a substance. Using water as an example, we can classify ice on a frozen lake as a solid because it has a fixed shape, the water running over a waterfall as a liquid because it flows, and the steam that rises when cooking as a gas because it does not have a fixed shape and spreads out to fill the container.

**TABLE 6.1.2** Properties of solids, liquids and gases

| Solids | Liquids | Gases |
| --- | --- | --- |
|  |  |  |
| • have a fixed shape<br>• have a fixed size and **volume**<br>• cannot be **compressed** | • do not have a fixed shape – the liquid takes the shape of the container it is in<br>• have a fixed volume<br>• cannot be compressed<br>• can flow | • do not have a fixed shape – the gas spreads out in all directions to fill the container it is in<br>• have no fixed size or volume<br>• can be compressed<br>• are often invisible, although some gases are coloured |

The properties listed in Table 6.1.2 can be used to classify a substance.

- If a substance has a set shape and cannot be compressed, it is likely to be a solid.
- If a substance cannot be compressed but takes the shape of the container, it is likely to be a liquid.
- If a substance can be compressed and spreads out to occupy the whole of the container, it is a gas.

**KEY TERMS**

**volume** the amount of space that a substance or object occupies

**compressed** reduced in volume (amount of space) or size by adding pressure

**temperature** how hot or cold a substance is as a result of the average kinetic energy of its particles

## Effect of temperature

Chocolate is usually classified as a solid but when it gets hot, it will start to flow and will take the shape of its container (Figure 6.1.1). It will become solid again when it cools. This is how chocolate is set in different shapes, such as a hollow egg. Most substances are like chocolate: they can change state if the **temperature** changes.

**FIGURE 6.1.1** Chocolate can have different properties at different temperatures. Liquid chocolate has been poured into this heart-shaped mould, and it will become solid as it cools.

Because substances can behave differently at different temperatures, room temperature (around 20–25°C) is used as a reference point when classifying matter as a solid, liquid or gas.

**Scifile**

**Dry ice magic**

Dry ice is solid carbon dioxide. Unlike regular ice, it does not melt into a liquid but turns directly into gas in a process called sublimation. It is often used for spooky fog effects in movies or performances.

## Plasma

There is a fourth state of matter called plasma. Plasma usually exists at very high temperatures; for example, in the Sun and other stars, in lightning and in the Aurora Australis (Figure 6.1.2). You do not see plasma very often, so this topic will focus on solids, liquids and gases.

**FIGURE 6.1.2** The Aurora Australis (southern lights) is a form of plasma.

## Is everything a solid, liquid or gas?

Some items are easy to identify as solid, liquid or gas, such as a plate (solid), water (liquid) and the air you breathe (gas).

However, some substances can be harder to identify as one of the three states of matter. For example, do you think bread, yoghurt, jelly and toothpaste are solid, liquid or gas? It is more difficult to identify their state of matter because they are **mixtures** of more than one substance.

**KEY TERM**

**mixture** a substance made from two or more pure substances that have been combined and that can be separated to recover the original substances

## Water – a unique substance

A unique property of water is that it can be found on Earth in all three states. Figure 6.1.3 shows how this feature of water makes the all-important water cycle possible. Liquid water evaporates from oceans and rivers, forming clouds over land masses, leading to rainfall (and, in colder parts of our planet, snow). Water is transported around Earth in this process, facilitating crop growth and sustaining living things. Glaciers store water in solid form and release it as liquid throughout the year.

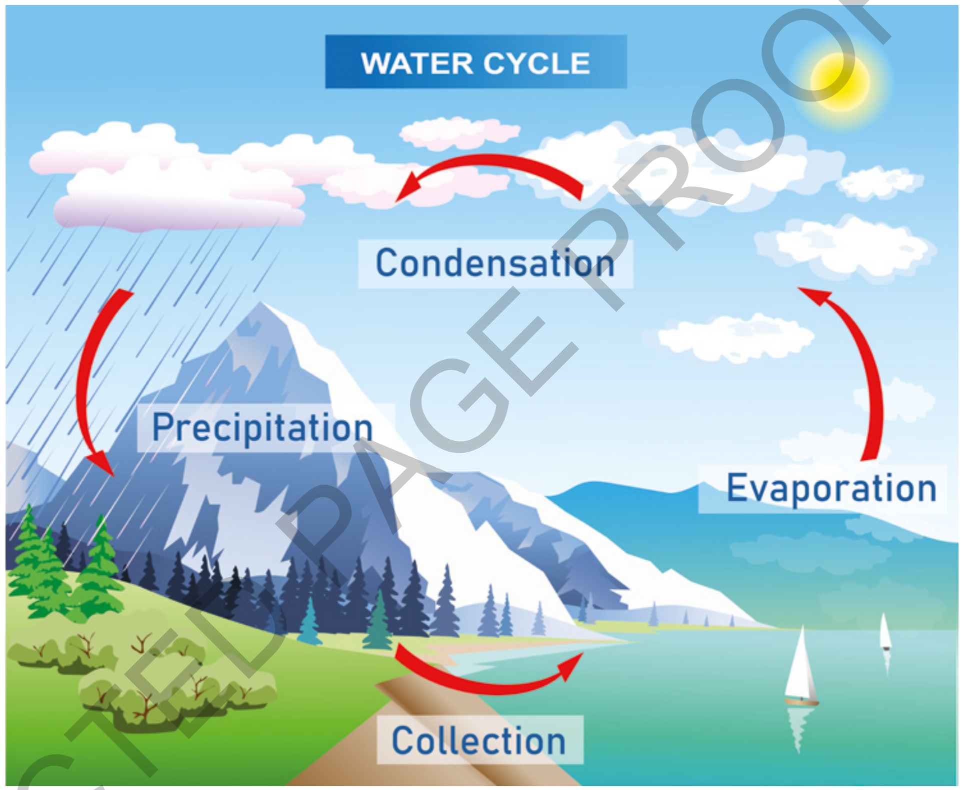



**FIGURE 6.1.3** Life as we know it relies upon the presence of water in all three states in nature.

**SC 2 CHECK YOUR UNDERSTANDING**

Compare the properties of a solid and a liquid.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

**1** Explain what is described by the term ‘matter’.

**2** Gold, milk and oxygen are all examples of matter.

- **a** Explain why these examples all qualify as matter.
- **b** Describe the differences between the properties of gold, milk and oxygen.

**3** Water is the only substance that can be found somewhere on Earth’s surface as a solid, liquid and a gas.

- **a** State a reason why living things rely on water being found as a liquid.
- **b** State a reason why living things rely on water being found as a gas.

**4** why a reference temperature needs to be used when classifying substances as solids, liquids or gases.

**5** A student was wanting to decide whether a type of yoghurt should be classified as a liquid or a solid.

- **a** Suggest one test that they could use to identify the state of the yoghurt.
- **b** Explain why yoghurt can be difficult to classify as a solid or liquid.

# 6.2 Matter and mass

### Learning intention

To be able to use equipment to generate data and to suggest reasons for observed mass readings

### Success criteria

**SC 1:** I can use an electronic balance to measure the mass of matter.

**SC 2:** I can use an electronic balance to measure the change in the mass of matter.

**SC 3:** I can explain the change in mass of solids, liquids and gases.

### KEY TERMS

**mass** the amount of matter in a substance or object; measured in grams (g), kilograms (kg) or tonnes (t)

**inference** an informed guess or logical conclusion based on previous experiences, observations and knowledge

### SAFETY NOTE

- Handle needle with care.

## Introduction

**Mass** is a measure of the amount of something. The units grams and kilograms are used to measure mass.

Even where there is no gravity, such as in outer space where an object will be weightless, it will still have mass. This is because it still contains matter.

In this practical investigation you will learn how to measure the mass of objects, investigate changes of mass and be asked to think about how mass and matter are connected.

## Background

The mass of substances is measured in grams (g) or kilograms (kg). A mass of 1000 g is equal to 1 kg. Mass can be measured using balances or scales.

## Aim

To compare the mass of objects and investigate how changes in mass can be used to make **inferences** about the nature of matter.

## Materials

- 2 × 100 mL beakers
- 2 balloons
- 3 lengths of string (each about 30 cm long)
- 1 m ruler
- needle
- electronic balance (accurate to at least 0.01 g)
- plastic cling wrap

## Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

## Part A: How does the mass of liquids and solids change?

### Method

1 Take two 100 mL beakers. Place one ice cube in one beaker and use the plastic cling wrap to completely seal the top of the beaker.

2 Use the electronic balance to measure the total mass of the beaker, the ice cube and the cling wrap, then leave the beaker in a safe place.

3 Add approximately 50 mL of warm water to the second 100 mL beaker and leave the beaker open.

4 Record the total mass of the beaker and the warm water then leave the beaker in safe place.

5 While you are waiting, carry out Part B of the investigation.

6 After 20 minutes, record the mass of each beaker in a table in your notebook.

## Results

Copy this results table into your notebook and record your results for Part A.

| | Mass of sealed beaker containing ice cube (g) | Mass of unsealed beaker containing warm water (g) |
|---|---|---|
| Mass at start of investigation (g) | | |
| Mass after 20 minutes (g) | | |
| Change in mass (g) | | |

## Conclusion

Write a conclusion for Part A of your investigation by answering the following questions in your notebook.

1 Which beaker lost the greater mass?

2 Suggest reasons for your answer to Question **1** and describe what might be happening in both beakers.

3 Suggest two things you could do to make your results more accurate.

## SkillBuilder

### Using an electronic balance

Electronic balances are the easiest way to accurately measure the mass of an object or a sample of a substance.

Most balances in school laboratories have a range of 0–1000 g (or 1 kg). The range of a balance is the difference between the minimum mass (zero) and the maximum mass that a balance is designed to measure. Never try to measure outside of the range of a balance.

## Accuracy of a balance

The **accuracy** of a balance is the 'exactness' of the measurements from the balance in terms of how close a measured value is to the true value. Many balances in school laboratories have an accuracy of ±0.1 g, This means that you can record the measurements to one decimal place, for example 45.7 g, or 112.1 g.

## Re-zero (tare) function

Most electronic balances have a re-zero (tare) function that allows you to set the display to zero after an object has been placed on the balance. This is very helpful if you want to measure the mass of a substance but do not want to include the mass of the container holding the substance.

## Care and safety

Avoid placing substances directly onto the pan (the top) of the balance. Chemicals may corrode the material of the pan or can get trapped inside the mechanism of the balance.

## Procedure

1 Make sure the balance is placed on a flat surface away from other equipment and chemicals.
2 Make sure the pan of the balance is clean and dry.
3 Turn on the balance and use the re-zero (tare) function to set the balance to 0.0 g.
4 Have your method of recording the measurement ready, such as a results table or spreadsheet.
5 Place the object on the scales, wait until the mass stops changing and then record the mass shown on the display. Make sure that you write down the unit (this should be grams (g)) of the mass as well as the value.
6 Remove the object from the balance, turn it off and ensure that the balance is clean and dry for the next person.

GO TO

For support with improving accuracy see Toolkit section x.x.

# Part B: Do gases have mass?

## Method

1 Blow up two balloons and tie one piece of string to each of the inflated balloons.
2 Tie one balloon to each end of the metre ruler.
3 Tie another piece of string to the middle of the ruler. Use a heavy object, such as a book, to anchor the string to the table as shown.

### HINT

Try and inflate the balloons to the same size at the start.

4 Hang the ruler from the edge of a table and try to balance the ruler so that it hangs parallel to the floor as shown (Figure 6.2.1).

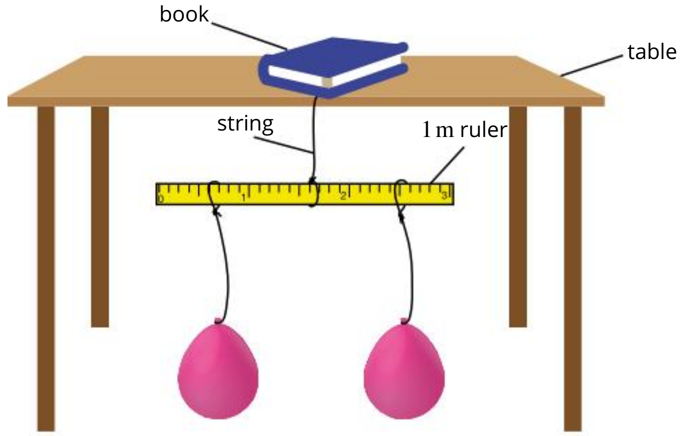



**FIGURE 6.2.1** How to set up your experiment

5 Once it is balanced, carefully use a needle to puncture one of the balloons (this is easiest if you push the needle into the balloon close to where it is tied).

### HINT

This experiment is a bit tricky but be patient when trying to balance the balloons.

## Results

In your notebook, record what you observed after the balloon was punctured.

## Conclusion

Write a conclusion for Part B of your investigation by answering the following questions in your notebook.

1 Explain what you observed in Part B.
2 What can you infer about the mass of gases from your observations?
3 If you sit a can of soft drink on a balance, open the can and leave it sitting on the balance for 30 minutes, predict whether the balance reading will change.

# 6.3 Matter and particles

## Learning intention

To understand how to model the arrangement of particles in solids, liquids and gases

## Success criteria

**SC 1:** I can describe how particle theory can be used to model substances.

**SC 2:** I can explain the different properties of solids, liquids and gases using particle theory.

**SC 3:** I can describe changes to particle movement when particles are heated or cooled.

## KEY TERMS

**particle theory** theory that states that all matter consists of tiny particles that are constantly moving, also known as the particle model

**model** representation that helps to describe or explain an object, event, system or idea

**particle** a tiny part of matter; particles include atoms and molecules

**FIGURE 6.3.2** Diamond fragments on the tip of a drill

## Lesson overview

All matter is made of particles so small that you cannot see them without the use of an electron microscope. To understand how matter behaves, you need to know about the particles that the matter is made from.

In this lesson you will learn how particles are arranged to form solids, liquids and gases.

**SC 1** I can describe how particle theory can be used to model substances

**Particle theory** is a scientific **model** that allows you to explain the properties (appearance and behaviour) of substances and predict what will happen to substances in different situations.

Scientific models are very helpful, especially when they explain things that are either too small or too big to be seen directly by humans, such as **particles**.

## Particle theory

Particle theory, also known as the particle model, states that all matter consists of tiny particles that are too small to be seen.

Particles are:

- always moving (they have energy); the higher the temperature, the faster they move (because they have more energy)
- attracted to other particles; these attractions affect the arrangement and positions of the particles.

The movement and attraction of particles determine the observable properties of matter (what substances look like and how they behave).

Particle theory helps us to understand why mercury is a liquid (Figure 6.3.1) at room temperature and why diamond is so hard (Figure 6.3.2).

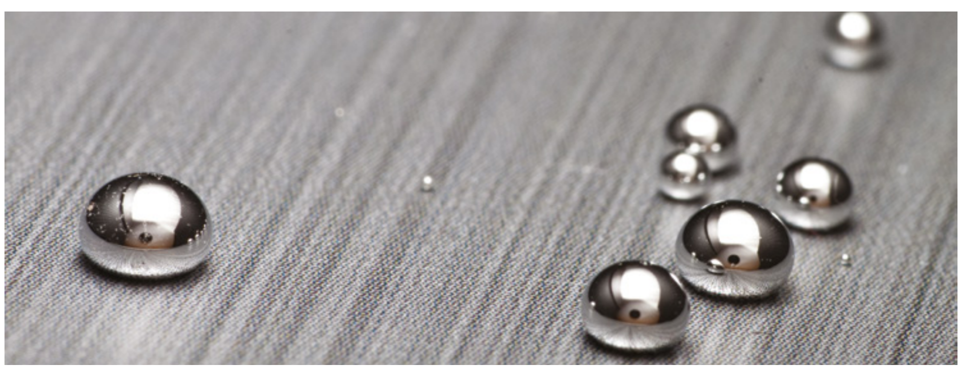


**FIGURE 6.3.1** Droplets of mercury on a steel surface

**SC 1 CHECK YOUR UNDERSTANDING**

State two properties of particles according to particle theory.

**SC 2** I can explain the different properties of solids, liquids and gases using particle theory

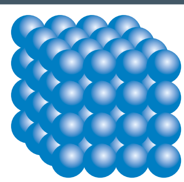
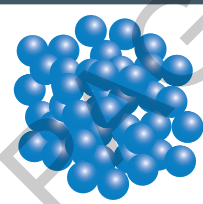
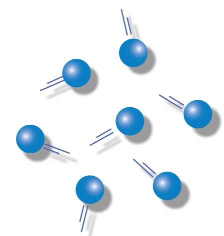
All properties of matter are linked to the behaviour of the particles that make up matter. The most important properties of matter include:

- whether it is solid, liquid or gas at room temperature
- its hardness
- its strength
- how well it mixes with other substances.

## Particle behaviour in solids, liquids and gases

The different ways that particles move and are attracted to each other in solids, liquids and gases can be used to explain their different properties. This is summarised in Table 6.3.1.

**TABLE 6.3.1** The structure and properties of solids, liquids and gases

| | Solids | Liquids | Gases |
|---|---|---|---|
| **Representation of particles** |  |  |  |
| **Movement of particles** | Particles vibrate backwards and forwards but stay in the same position. | Particles move slowly past each other in different directions. | Particles move in all directions at different speeds, some very quickly. |
| **Attraction between particles** | Strong attractions between particles keep them in a regular arrangement. | Fairly strong attractions between particles keep them close together but not fixed in the same positions. | Very weak attractions and particles are spread out with huge areas of space between them. |
| **How structure links to properties** | Solids have a fixed shape because the strong attractions between particles keep them in a regular arrangement. The shape of solids can be changed by applying a force. | Liquids have a fixed volume because particles are close together with no space between them, so they cannot be compressed. Liquids do not have a fixed shape and can flow because the particles are not in fixed positions. | Gases do not have a fixed shape or volume, and their particles spread out in all directions because of the high energy (speed) of particles and weak attractions between particles. |

**Scifile**

**Crystals and patterns**

Some solids, such as salt and sugar, form crystals where the particles are arranged in a regular, repeating pattern. This orderly structure is why crystals have such sharp edges and flat surfaces.

**KEY TERM**

**pressure** combined force caused by the movement of gas particles

## Pressure in gas

As particles in a gas move quickly in all directions, they collide with each other and the inside of the container that the gas is stored in. This causes **pressure**.

Increasing the number of particles in a container will increase the pressure because there are more collisions. The pressure will also increase if the particles are moving faster because the collisions will have more force. Reducing the volume of the container will also increase the pressure because there will be more collisions (Figure 6.3.3).

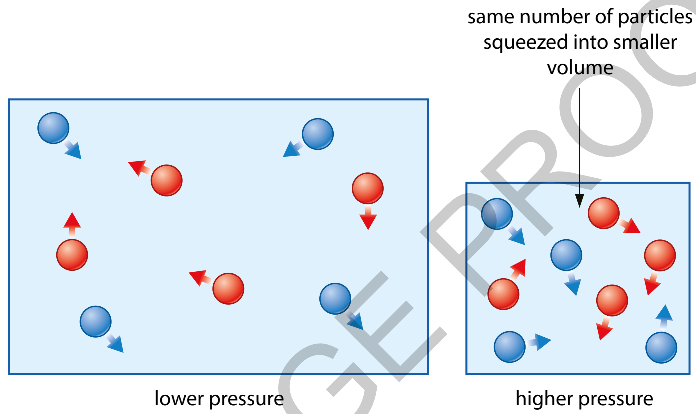



**FIGURE 6.3.3** The effect of reducing the volume of a gas

**SC 2 CHECK YOUR UNDERSTANDING**

Use particle theory to describe why gases can be compressed.

**SC 3** I can describe changes to particle movement when particles are heated or cooled

## Heating and cooling

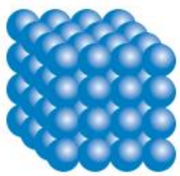
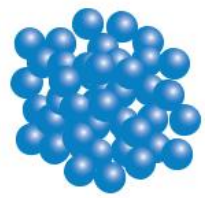
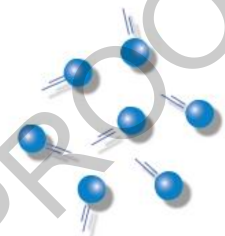
Heating something up requires transferring energy into it, while cooling involves transferring energy away.

When a substance heats up (temperature increases), particles move faster. When particles move, they bump into other particles and move apart. The faster the particles move, the further apart they become.

When a substance cools down (temperature decreases), particles move more slowly. As particle movement slows, there are fewer collisions between particles, and they move closer together.

Table 6.3.2 models how particles in the three states of matter behave when heated.

**TABLE 6.3.2** The behaviour of particles in solids, liquids and gases when heated

| Solids | Liquids | Gases |
|---|---|---|
| Particles vibrate backwards and forwards but stay in the same position. Heating the solid causes the particles to vibrate faster and move apart.  | Particles move relatively slowly past each other. Heating the liquid causes them to move faster and spread out more.  | Particles move in all directions at different speeds, some very fast. Heating the gas causes them to travel even faster and collide more.  |

## Density

The **density** of a substance describes how closely packed its particles are. Stated mathematically, density is equal to the mass of a substances divided by its volume (Figure 6.3.4).

The separation of particles in liquids and gases causes them to have less mass in the same volume compared to solids (Figure 6.3.5). Additionally, the separation between particles in gases and liquids allows them to expand more easily than solids as temperature increases.

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

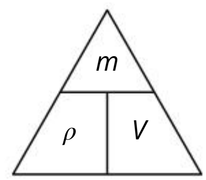



**FIGURE 6.3.4** The relationship used to calculate density can be shown as an equation or as a triangle where $\rho$ = density, $m$ = mass and $V$ = volume.

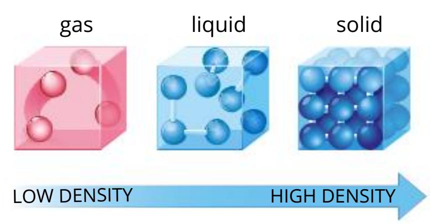



**FIGURE 6.3.5** Typically, gases are less dense than liquids, which are less dense than solids.

## Observing changes in particle movement

When a substance is heated, the particles in it move faster and further apart because they have more energy. This will cause the substance to **expand**.

When a substance is cooled, the particles in it move more slowly and closer together because they have less energy. This will cause the substance to **contract**.

For example, solid metal railway lines expand on hot days and contract on cold days. In extreme heat or cold, the metal of the railway lines can bend (Figure 6.3.6) or crack.

**FIGURE 6.3.6** Heat has caused the solid metal in the railway lines to expand, making it bend.

**KEY TERMS**

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

**expand** to increase in volume (to take up more space)

**contract** to decrease in volume (to take up less space)

The liquid in a thermometer also expands as it is heated, making the liquid travel up the narrow thermometer tube. When the liquid is cooled, it contracts and lowers in the thermometer tube (Figure 6.3.7).

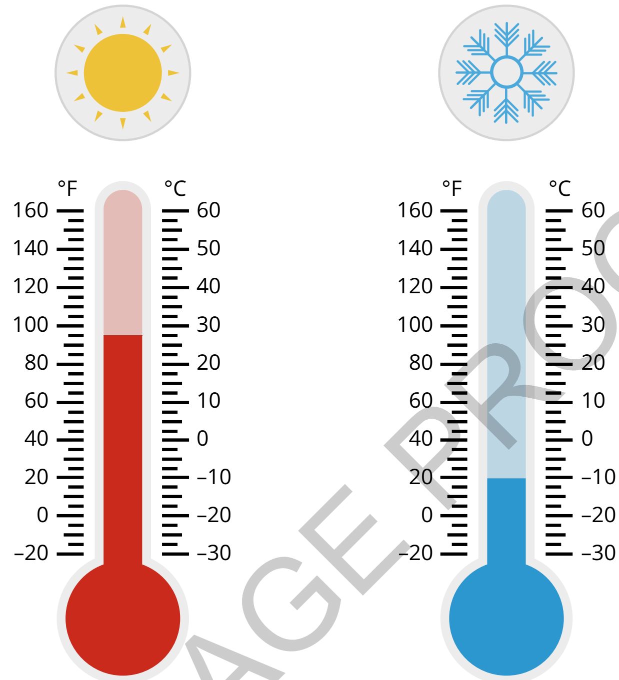



**FIGURE 6.3.7** You can use thermometers to measure temperature because the liquid inside them expands and contracts with changes in temperature.



## SCIENCE IN CONTEXT

### Expansion joints

Expansion joints are small but crucial components found in bridges (Figure 6.3.8). They allow the bridge to expand and contract as temperatures change. Expansion joints are typically made of flexible materials like rubber or special metals that can stretch and compress as needed.

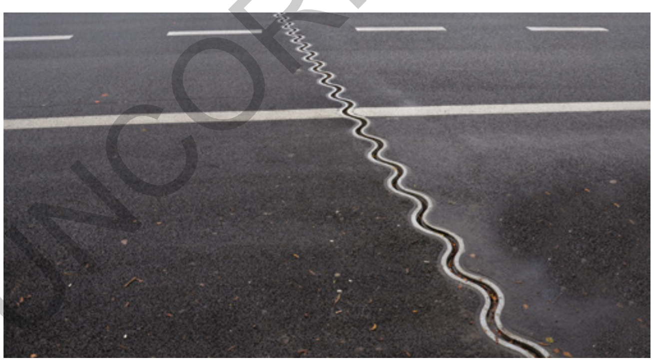


**FIGURE 6.3.8** Expansion joint joining two sections of road on a bridge

Imagine a bridge on a hot summer day. The metal and concrete that make up the bridge will expand due to the heat. If there were no expansion joints, the bridge could crack or even break because the solid materials would not have room to expand.

**SC 3 CHECK YOUR UNDERSTANDING**

Compare the particle movement in gas when it is heated versus when it is cooled.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1. State the two fundamental principles of particle theory.
2. Draw and label a diagram showing the arrangement of particles in a liquid.
3. Compare the particle arrangement in a gas to that in a liquid.
4. Explain how the strength of attractions between particles affects the behaviour of solids, liquids and gases.
5. Describe what happens to the movement of particles when a solid is heated.
6. Explain what happens to the movement of particles in a liquid when it is cooled.

# 6.4 Matter under pressure

**Learning intention**

To be able to conduct a safe investigation to test an aspect of the particle model

**Success criteria**

**SC 1:** I can make a prediction based on knowledge of particle theory.

**SC 2:** I can measure and record accurate results in a suitable format.

**SC 3:** I can suggest an explanation for results based on particle theory.

**FIGURE 6.4.1** Particles of gas cause pressure inside the balloon.

**SAFETY NOTE**

- Excessive force may cause the water to explode out of the syringe and cause a mess. Use only reasonable force.

**KEY TERMS**

**theory** an explanation of a set of observations that has been accepted through consensus by a group of scientists

**prediction** a statement that suggests what will happen in an experiment

## Introduction

Pressure is a force, caused by billions of collisions of tiny particles that you cannot see. It can act in any direction and can be very powerful.

Pressure prevents the balloon shown in Figure 6.4.1 from being compressed any more.

Pressure surrounds you all the time. You only notice it when there is a change in pressure. When air is blown into a balloon, the pressure inside the balloon is greater than the pressure outside and the balloon expands. If you drink a fizzy drink, you might feel the pressure increase inside your stomach.

In this practical investigation, you will learn how investigating the effects of pressure can provide evidence that supports particle theory.

## Background

A **theory**, such as particle theory, is an explanation of a set of observations. In this practical investigation you will use observations from the effect of pressure on liquids and gases to improve your understanding of particle theory.

## Aim

To investigate the behaviour of liquids and gases when they are compressed

## Apparatus

- 250 mL beaker
- water
- plastic syringe (10 mL)

### Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

## Prediction

1 What will you observe when you try to compress water in the syringe? Write your **prediction** in your notebook and explain your reasoning.

2 What will you observe when you try to compress air in the syringe? Write your prediction in your notebook and explain your reasoning.

## Method

1 Add water to the 250 mL beaker.

2 Fill the syringe to the 10 mL mark with water from the beaker.

3 Place your thumb over the end of the syringe as shown in Figure 6.4.2.
4 With your thumb over the end of the syringe, push down on the syringe plunger.
5 Record your observations in your notebook. In your observations, include the volume of the water in the syringe before and after it was compressed, and what you felt when compressing the water.
6 Empty the water out of the syringe and pull the plunger back to the 10 mL mark, ready for the next part of the experiment.
7 Repeat steps 4 and 5 with just air in the syringe.
8 Record your observations in your notebook. In your observations, include the volume of the air in the syringe before and after it was compressed, and what you felt when compressing the air.

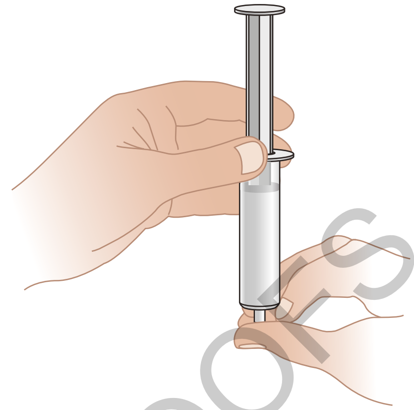


**FIGURE 6.4.2**

**HINT**

Make sure that you keep your thumb tightly pressed against the end of the syringe to prevent leakage. Ensure that there is no air in the syringe – only water.

## Results

1 Construct a results table like the one below in your notebook to record your observations. Remember to include a title above your results table.

| | Starting volume (mL) | Final volume (mL) | Other observations |
|---|---|---|---|
| Compressing water | | | |
| Compressing air | | | |

2 Compare the observations you recorded when compressing water and when compressing air.

## Conclusion

Write a conclusion for your investigation in your notebook by explaining how your observations provide evidence for the particle model of liquids and gases. Your response should include a discussion of distances between particles in a particular state.

# 6.5 Particles and changes of state

**Learning intention**

To understand the role of heat in the arrangement of particles in solids, liquids and gases

**Success criteria**

**SC 1:** I can describe changes to particle arrangements when substances are heated or cooled.

**SC 2:** I can explain observed changes of state caused by the heating and cooling of substances.

## Lesson overview

Particle theory helps you to explain the properties of solids, liquids and gases. It also explains what happens when a solid melts into a liquid, when a liquid evaporates into a gas and when a gas condenses into a liquid. These changes of state happen all around you and are essential not just for survival but for the sustainability of the environments where you live.

In this lesson you will learn about how changes of state that you can see are linked to the behaviour of particles that you cannot see.

**SC 1** I can describe changes to particle arrangements when substances are heated or cooled

## Changes to particle arrangements

Heating or cooling a substance affects the movement of its particles by increasing or decreasing their energy.

### Increasing energy (heating)

Increasing the energy of a substance by heating it causes the particles to move faster and spread apart. As the particles gain energy and move more rapidly, the attractive forces between them weaken, allowing them to move more freely. This leads to solids behaving like liquids and liquids behaving like gases.

Heating can cause:

- **melting** – a solid changing into a liquid; the temperature at which this occurs is called the **melting point**
- **boiling**/evaporation – a liquid changing to a gas; the temperature at which boiling occurs is called the **boiling point**.

For example, when solid ice is heated the increased energy increases the movement of the particles, which weakens the attractions between them. If enough energy is provided, the attractions holding the particles in place will no longer be strong enough to keep the particles in their positions, and the solid ice will melt and change to liquid water.

### Decreasing energy (cooling)

Decreasing the energy of a substance by cooling causes the particles to move more slowly and be closer together. As the particles cool down the attractions between them can become strong enough to hold the particles close together. This causes liquids to undergo a change of state to become solids, or gases to become liquids.

Cooling can cause:

- **freezing** – a liquid changing into a solid; the temperature at which this occurs is called the **freezing point**
- **condensation** – a gas changing into a liquid.

For example, when liquid water is cooled, the attractions between the particles become stronger, and the liquid water freezes and changes to solid ice.

## Reversing changes of state

Changes of state can be reversed by heating or cooling. For example, an ice cube can be melted into liquid water by heating, and that liquid water can be frozen into solid ice by cooling.

The temperature at which the changes of state happen (the melting point and freezing point) are the same. For example, the freezing point of water is the same as the melting point of water, 0°C. These changes are represented in Figure 6.5.1.

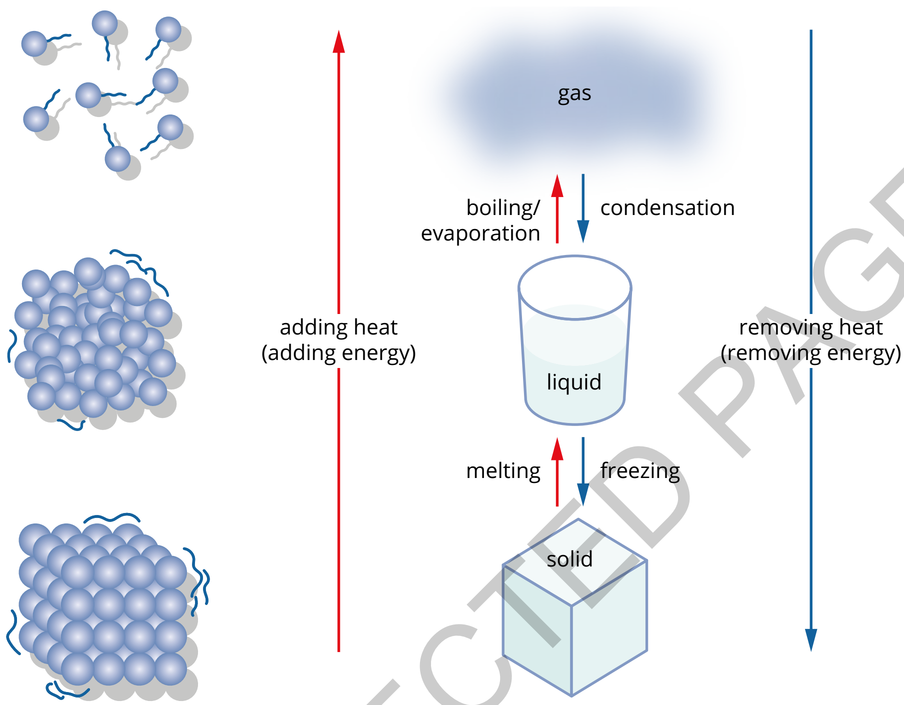



**FIGURE 6.5.1** Changes of state caused by heating particles (increasing energy); the opposite processes occur if particles are cooled (decreasing energy).

**SC 1 CHECK YOUR UNDERSTANDING**

Compare the behaviour of particles in a gas before and after cooling.

**SC 2** I can explain observed changes of state caused by the heating and cooling of substances

## Melting

A solid will melt when it reaches the melting point of the substance (Figure 6.5.2). It is at this point that the particles have enough energy to break the attractions that are holding them in fixed positions. This is when a liquid is formed.

**FIGURE 6.5.2** Solid gold melting to become liquid

## Freezing

A liquid will freeze when it is cooled to the freezing point of the substance. It is at this point that the movement of the particles is reduced enough so that attractions can form between them and hold them in fixed positions. This is when a solid is formed (Figure 6.5.3).

**FIGURE 6.5.3** Liquid iron becoming a solid

**FIGURE 6.5.4** Boiling water. Note that the boiling occurs throughout the liquid, not just at the surface.

## Evaporation and boiling

Evaporation is the process of liquid changing into gas and it occurs on the surface of the liquid. Evaporation can occur at temperatures below boiling point. For example, hanging your clothes up on a warm day causes them to dry via evaporation.

Boiling also involves a liquid changing into a gas but this only occurs at the boiling point of a substance. Boiling is a relatively fast process that occurs throughout the substance. You can see bubbles of gas forming in the liquid and rising to the surface (Figure 6.5.4). Once a liquid reaches its boiling point it will stay at that temperature until all the liquid has changed into a gas.

**FIGURE 6.5.5** Liquid nitrogen being used to make ice cream

## Condensation

Condensation is the process of a gas cooling to form a liquid. This can occur when water **vapour** touches a cold surface or cool air. Even gases that have a very low boiling point can be made to condense if they are cold enough. For example, nitrogen gas (Figure 6.5.5) will condense into liquid nitrogen if its temperature falls below the boiling point of nitrogen (−196°C).

**KEY TERM**

**vapour** matter that has been produced by evaporation from a liquid

### Scifile

**Boiling water on a mountaintop**

Water boils at 100°C at sea level. But did you know it boils at lower temperatures at higher altitudes? For example, the boiling point of water in Thredbo Village, in the New South Wales Snowy Mountains, is only 95.2°C. This is because the air pressure is lower at high altitude, making it easier for the water particles to evaporate and spread out into the surrounding air.

## Sublimation and deposition

When some solid substances are heated, they change directly into a gas, bypassing the liquid state. The reasons for this are quite complex but they relate to the strength of the attractions between particles and the pressure of the air around the substance. If the attractions between the particles in the substance are not very strong, the particles will not stay in the liquid form. This conversion of a solid straight into a gas is called **sublimation**.

Carbon dioxide is probably the most well-known example of a substance that sublimes. The solid form of carbon dioxide (Figure 6.5.6) is called dry ice and it changes from a solid to a gas when it is heated.

The reverse process of sublimation is called **deposition**. This is when a gas changes to a solid, bypassing the liquid state.

**SC 2 CHECK YOUR UNDERSTANDING**

Explain why water turns into ice when cooled below 0°C.

**KEY TERMS**

**sublimation** the change in state from a solid to a gas, bypassing the liquid state

**deposition** the change in state from a gas to a solid, bypassing the liquid state

**FIGURE 6.5.6** Dry ice is a solid that changes into a gas when it is heated—in a process called sublimation. The low temperatures cause clouds of water vapour to form.



## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 Explain how the arrangement of particles in a liquid changes when it is cooled.

2 Describe the changes in particle arrangement when water vapor condenses into liquid water.

3 Some substances will change straight from a solid to a gas when heated.
   a What is the term for this type of change of state?
   b Name one example of a substance that can do this.

4 Compare the effect on the particles in liquid water when it is heated to those in water vapour when it is heated.

# 6.6 Heating curve for water

**Learning intention**

To be able to obtain, present and analyse data relating to changes of state

**Success criteria**

**SC 1:** I can conduct a safe experiment to generate and record precise data.

**SC 2:** I can plot a line graph to display a pattern in data.

**SC 3:** I can use knowledge of particle theory to suggest reasons for the patterns shown by the experimental data.

## Introduction

When you heat substances, two things happen to the particles – they move more, and they move further apart. This can result in the substance expanding or changing state. If you keep heating a substance for a long time, it is likely that both things will happen.

In this practical investigation you will record the temperature of water as it is heated from its freezing/melting point up to its boiling point when the water changes state to become a gas (Figure 6.6.1). The temperature data collected during this investigation provides evidence for the behaviour of the particles in the water and the properties of the water itself.

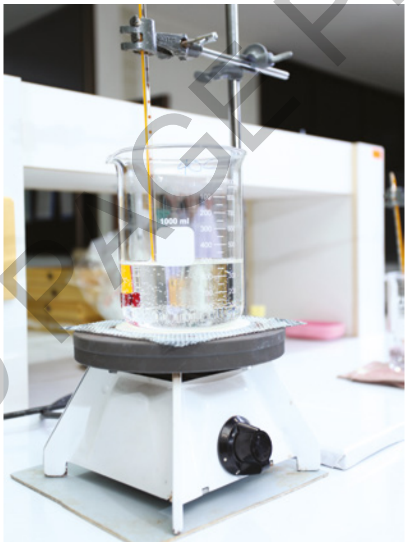


**FIGURE 6.6.1** Water changes as it is heated from below its melting point to its boiling point.

## Background

Water can exist as a solid, liquid or gas. When water changes between these states, its physical form changes but its particles remain unchanged. However, there are differences between the energy and arrangement of the particles in the different states.

**HINT**

Celsius (°C) is the unit for temperature most commonly used in school science.

Seconds (s) is the standard unit of time. If you are measuring longer periods of time, you can use minutes. Make sure to use just one unit of time (seconds or minutes) when doing calculations and presenting results.

## Aim

To observe the temperature of water as it is heated and changes from a solid to a gas

## Apparatus

- 250 mL beaker
- ice cubes (placed in freezer for at least 12 hours)
- 100 mL of chilled water

- thermometer
- stopwatch
- retort stand and clamp
- heatproof mat
- Bunsen burner, tripod and gauze (a hotplate can be used in place of the Bunsen burner)

## Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

## Method

1 Set up a Bunsen burner (or hotplate) ready for heating the water but do not light the Bunsen burner (or turn on the hotplate).

2 Place enough ice cubes to half fill the beaker.

3 Add a small amount of chilled water to just cover the ice cubes and place the beaker on the tripod (or hotplate).

4 Place the thermometer in the centre of the ice, making sure the thermometer is not touching the beaker. Clamp the thermometer in this position using a retort stand as shown in Figure 6.6.2.

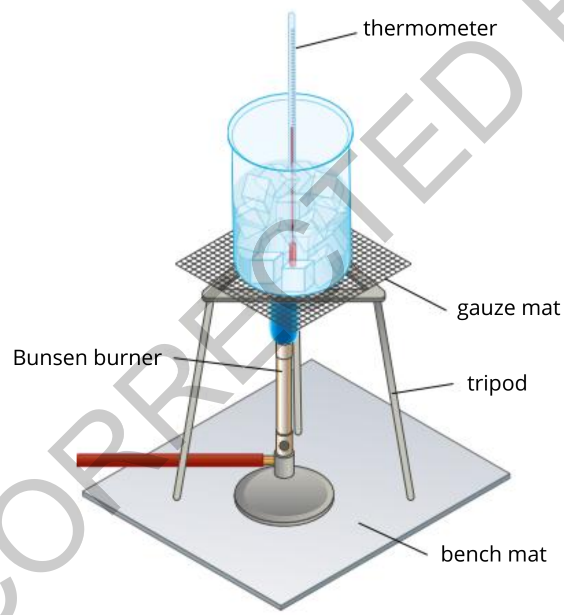



**FIGURE 6.6.2**

5 Start recording the temperature every 30 seconds.

6 After 1 minute, light the Bunsen burner (or turn on the hotplate) and continue to record the temperature every 30 seconds. Note the time when all the ice has melted, and the time when the water is boiling.

7 Note the approximate volume of the water now that the ice has melted.

### SAFETY NOTES

- Ensure that the thermometer is clamped securely and is easy to read. This will reduce the risk of the beaker tipping over during the experiment.
- Avoid touching the equipment, especially when the water is boiling.
- At the end of the experiment, leave all equipment to cool down for 10 minutes before it is cleared away.

8 Continue recording the temperature every 30 seconds for another 3 minutes after the water boils.

9 Check the volume of water in the beaker to see if a noticeable amount of water has evaporated.

**GO TO ➤**
For support with constructing re-sults tables, see Toolkit section x.x.

**KEY TERM**
**line graph** graph that uses lines to identify patterns and trends shown by data points from two sets of continuous measurements

**GO TO ➤**
For support with creating a line graph using a spreadsheet, see Toolkit section x.x.

**GO TO ➤**
For support with analysing a line graph, see Toolkit section x.x.

## Results

1 Design a suitable results table in your notebook. Alternatively, you can use a spreadsheet to record the temperature. Note: You will be recording the temperature of the water every 30 seconds for around 15 minutes, possibly longer. Make sure your table will be big enough for all the results.

2 Draw a **line graph** of your results with time on the x-axis and temperature on the y-axis. if you are using a spreadsheet, select an XY scatter graph.

3 Use your results to identify the times when all the ice had melted and when the water was boiling. Label your graph with these times.

## Conclusion

Write a conclusion for this investigation by answering the following questions in your notebook.

1 a State how the temperature of the water changed between the times when the ice melted and the water boiled.

b Explain how the movement of the particles was changing during this time.

2 a Describe what happened to the temperature of the water as the water changed state.

b Explain how the movement of the particles was changing during this time.

3 State a conclusion you can draw from this experiment about the amount of energy required to change liquid water to water vapour (gas).

# 6.7 Investigating properties of water

## Introduction

Water is a substance that we encounter every day. It is sometimes easy to forget that it is a chemical, with characteristic properties and reactions. Water has some fascinating properties, as is evident in Figure 6.7.1 where an astronaut is playing with a blob of water that stays as a blob, despite not being in a container. Many of water's properties are crucial for life on Earth.

In this inquiry activity, you will investigate the physical properties of water, including buoyancy, density and surface tension. You will observe these properties and describe how they work.

**Learning intention**

To be able to investigate the physical properties of water

**Success criteria**

**SC 1:** I can observe and accurately describe the physical properties of water.

**SC 2:** I can describe the concepts of buoyancy and density.

**SC 3:** I can describe the concept of surface tension.

**FIGURE 6.7.1** In space, water does not need a container the only forces acting are attractive forces.

## Background

Water is a unique substance with several physical properties that make it essential for life. These properties include buoyancy, density and surface tension.

**Buoyancy** is the ability of an object to float in water or another fluid, which is crucial for the survival of aquatic organisms and the functioning of boats and ships. A simple demonstration of buoyancy is to hold a ping pong ball under water in a beaker. When you release the ball, buoyancy causes it to shoot to the surface of the water. The ball then floats on the water surface because it has a lower density than the water.

Density refers to the mass of water in a given volume, affecting how substances interact with it.

**Surface tension** is the elastic-like force at the surface of water that allows small objects, like insects, to walk on it without sinking (Figure 6.7.2). Understanding these properties helps us to understand the world around us.

**FIGURE 6.7.2** Surface tension allows insects like pond skaters to walk over water without sinking.

## Aim

To investigate and describe the physical properties of water, including buoyancy, density and surface tension

## Plan

You will conduct an inquiry activity to observe the physical properties of water. Plan how you will observe and record your findings. Consider using diagrams, written descriptions and photographs to present your results.

The activity is separated into three parts so that each property can be studied independently.

## Part A: Sink or float?

### Design

Plan an activity to answer this question: Can you correctly predict whether an object will sink or float?

1 Make a sketch in your notebook of the equipment set-up you intend to use.
2 Draw a table that will enable you to record your predictions as well as your observations for each item.
3 List the items you will test, putting thought into selecting a variety of shapes and types. For example, you could include a few drops of cooking oil as one of your items to test.
4 Check in with your teacher for their approval of your design.

### Conduct

1 Assemble your materials and equipment.
2 Complete your predictions for each item.
3 Test each item.
4 Record your observations.

### Discussion

1 Discuss your results, considering:
   - whether your predictions were correct
   - if it was easy to predict the outcome for each item
   - why knowing the mass of an object is not enough to decide if it will float or sink.
2 Are there other factors that impact this testing? For example, does the shape of the object impact whether it floats? Does it matter if you 'place' or 'drop' the object?

### Improve

Now that you have completed the experiment, is there any aspect of your method that could be changed or improved?

# Part B: Can you change the density of water?

In this section you will add salt or sugar to water to see if the density of water is changed. You will use your observations from Part A to detect density changes.

## Design

Design your experiment, so that you have:

- a water sample(s) with added salt or sugar
- an item that almost floated in Part A to use in this part to see if the density of the water has changed.

## Conduct

1 Make a prediction as to the impact of the added salt or sugar.
2 Record the amounts you used in your solution preparation.
3 Prepare your solution.
4 Test your solution.
5 Record your observations.

## Discussion

Imagine that several groups in the same class are all conducting this investigation independently. Explain how you would need to improve the design of this activity to have each group obtain the same results. (Consider: What variables might you need to control?)

## Conclusion

Refer to your observations to draw a conclusion about the impact of salt or sugar on water density.

## Extension

If you add a food colouring to your salt solution, you can trickle a pure water sample onto the surface of your salt (or sugar) solution and the two layers of water will not mix.

# Part C: Surface tension

For this section, your challenge is to try to float a metal paperclip on water.

Add water to a petri dish, watch-glass or small beaker so that the water is completely filling the container.

Gently try and place the paperclip on the water surface so that it floats. You may find it easier to sit the clip on the container edge and gradually push it onto the water. If the clip sinks, do not try and reuse it. (The paperclips must be dry.)

When the clip floats look carefully from side-on to see that it is actually pushing into the water surface.

Now gently place one drop of detergent on the water surface on the opposite side to the paperclip. What do you observe?

## Discussion

1 Use your knowledge of how detergents help wash dishes to suggest why the detergent impacted the floating paperclip.

2 By sharing the experiences of others in your class, what advice would you offer to someone wanting to float paperclips on water?

# 6.8 Density

## Introduction

The term 'density' refers to the amount of matter in a given volume.

In this practical investigation you will conduct an experiment to determine the density of a water sample. You will investigate whether the value obtained varies with temperature or purity and you will compare your value to accepted scientific values. You will use your science inquiry skills to conduct a safe and valid experiment and to evaluate your experiment.

### Learning intention

To be able to measure the density of various substances and compare results with published data

### Success criteria

**SC 1:** I can conduct an investigation to measure the density of water and other substances.

**SC 2:** I can evaluate the accuracy of measurements of density using published data.

## Background

The formula for density is:

$$\text{density} = \frac{\text{mass}}{\text{volume}} \text{ or } \rho = \frac{m}{V}$$

where:

mass is usually measured in kg or g

volume is measured in units of $cm^3$, $m^3$, mL or L.

Depending upon the units used for mass and volume, density units might be g/mL which can be written as g $mL^{-1}$, g/$cm^3$ (g $cm^{-3}$) or kg/$m^3$ (k $gm^{-3}$).

In this practical investigation you will measure the mass and volume of a water sample to determine its density. You will develop and test a prediction about how temperature will impact density. In this practical investigation temperature is the **independent variable** and density is the **dependent variable**.

**KEY TERMS**

**independent variable** the factor that is changed in an investigation to find out how it affects another factor (the dependent variable)

**dependent variable** the variable that is being measured in an experiment

## Aim

To develop and test a prediction relating to the impact of temperature on the density of water

## Prediction

Use your knowledge of particle theory and your own experiences to write a prediction in your notebook relating to the impact of temperature on the density of water.

## Apparatus

- 80 mL water samples, from 4°C to 50°C
- 100 mL measuring cylinder
- thermometer (–10°C to 110°C)
- electronic balance (0.01 g resolution)
- plastic dropper
- rubber gloves

**SAFETY NOTE**

- You are handling warm water. Wear gloves and flush skin with cold water if warm water contact occurs.

## Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

## Method

You have access to an electronic balance, water samples and a 100 mL measuring cylinder. Design a method, using the above materials, to:

- determine the density of an 80 mL water sample at room temperature
- determine the density of similar water samples at three other temperatures.

Your method should describe best practice for measuring the water volume, as shown in Figure 6.8.1.

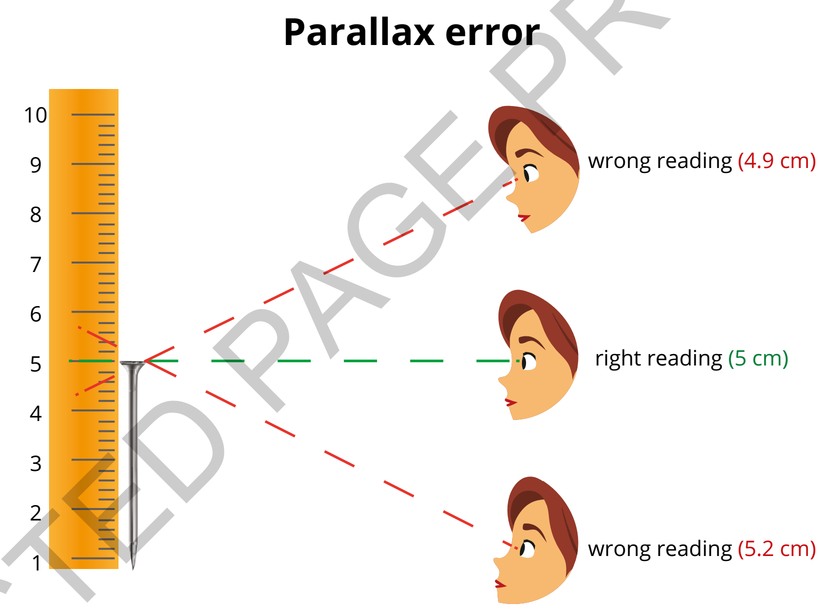



**FIGURE 6.8.1** Your eye needs to be at the same level as the volume reading you are taking.

Record your method in your notebook and show it to your teacher for approval.

Design a table that you can use to record your measurements and density calculations.

## Results

Answer the following questions in your notebook.

1. Calculate the density of water at each of the temperatures you tested.
2. Draw a graph of density versus temperature.
3. Does the density vary with temperature?

## Discussion

1. What variables were kept the same (**controlled variables**) in the two methods?
2. Discuss whether the method for this activity can be used to measure the density of all substances.

**KEY TERM**

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

## Conclusion

1 Review your prediction and your results. Explain how well your results support your prediction.

2 Explain why density might vary with temperature. Refer to the energy level of the particles in the liquids in your response.

3 Accredited laboratories such as the Department of Industry, Science and Resources have produced tables such as the one below that list the density of water at set temperatures.

| Temperature (°C) | Density ($g\,mL^{-1}$) |
|---|---|
| 0 | 1.000 |
| 5 | 1.000 |
| 10 | 1.000 |
| 15 | 0.999 |
| 20 | 0.998 |
| 25 | 0.997 |
| 30 | 0.996 |
| 35 | 0.994 |
| 40 | 0.992 |
| 45 | 0.990 |
| 50 | 0.988 |
| 55 | 0.986 |
| 60 | 0.983 |

Compare the results you obtained with those in the table above.

4 Use the data you have collected to predict how the density of water will change with depth in places where the ocean is very deep.

# 6.9 Calculating density

## Learning intention

To be able to calculate the density of objects using mass and volume

## Success criteria

**SC 1:** I can determine the volume and mass of regular-shaped objects.

**SC 2:** I can determine the volume and mass of irregular-shaped objects.

**SC 3:** I can calculate the density of objects from their mass and volume.

## Introduction

In this practical investigation you will determine the density of solid objects, starting with what are referred to as regular-shaped solids and then moving on to irregular-shaped solids. Figure 6.9.1 shows two regular solids and the mathematical expressions required to determine their volumes.

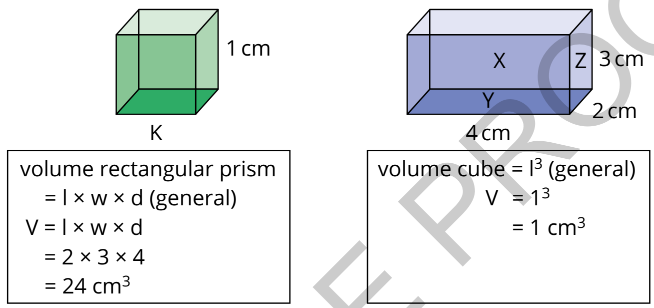



**FIGURE 6.9.1** Mathematical expressions for determining the volume of regular solids

In Part A of this practical investigation you will determine and compare the densities of some regular-shaped solids and in Part B you will problem solve determining the volume of some irregular-shaped solids.

You will use your science inquiry skills to conduct a safe and valid experiment and to evaluate your experiment.

## Background

A reminder that the formula for density is:

$$\text{density} = \frac{\text{mass}}{\text{volume}} \text{ or } \rho = \frac{m}{V}$$

where:

mass is usually measured in kg or g

volume can be measured in units of $cm^3$ or mL.

Depending upon the units used for mass and volume, density units might be as $g\,mL^{-1}$ (g/mL) or $g\,cm^{-3}$ ($g/cm^3$).

This practical investigation is separated into two parts. In Part A you will use a balance and ruler to determine the density of items with a regular shape (Figure 6.9.2) and in Part B you will design a method to determine the density of items with an irregular shape (Figure 6.9.3).

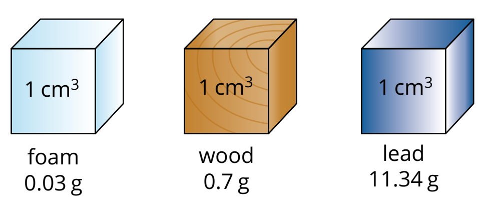



**FIGURE 6.9.2** Regular-shaped solids suitable for density measurements

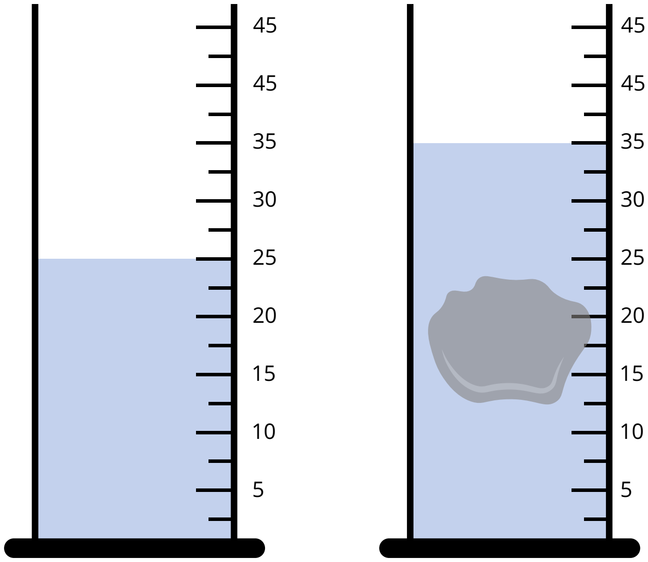



**FIGURE 6.9.3** Using the displacement of water to determine the volume of an irregular solid



## Aim

To determine the density of regular-shaped solids and to problem solve determining the densities of irregular-shaped objects

## Apparatus

- selection of solid cubes or rectangular prisms
- selection of irregular shapes that will fit in 100 mL measuring cylinder – for example, piece of foam, blob of modelling clay or plasticene, glass tube, stone, plastic strip
- 10 mL measuring cylinder
- 100 mL measuring cylinder
- big nail
- small nails
- electronic balance (0.01 g resolution)
- ruler

### Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

**SAFETY NOTE**

- Wear your laboratory coat, goggles and gloves for all testing.

## Part A: Determining the density of regular solids

### Method

Design a table in your notebook to record your measurements and calculations for all items you test. The table should include:

- name of item
- shape

- dimensions
- volume
- mass
- density.

## Results

1 For each item, measure the mass and dimensions and complete the table you have designed.

2 Complete your table by determining the density of each item.

3 Extension: Can you determine the density of the large nail?

## Discussion

Review your method. Are there any changes or modifications that you should adapt? Was this an easy experiment to conduct?

## Conclusion

1 Rank the items tested, from highest to lowest density.

2 Comment on how much the density of items varies across the items.

3 Student A determines the density of a cube of lead of side length 1 cm.
Student B determines the density of a cube of lead of side length 2 cm.
How will the measurements of the two students compare?

# Part B: Determining the density of irregular solids

## Method

1 Design a table in your notebook to record the volume, mass and density of each item to be tested.

2 Design a method to use to determine the density of the blob of modelling clay or plasticene. Show your method to your teacher for approval.

3 Test your method on the modelling clay/plasticene and other suitable items, completing the table you designed as you go.

4 Adapt your method to determine the density of the foam.

5 Adapt your method to determine the density of the small nail.

## Results

Density values for all items should be determined and recorded.

You should also record any design changes required for the foam.

## Discussion

1 State why is it more difficult to determine the density of irregular-shaped solids than regular-shaped solids.
2 Which step should be performed first in Part B – the weighing or the measuring of volume? Justify your answer.
3 Describe how you adapted the method used to test foam.
4 Describe how you adapted the method used to test the small nail.
5 Suggest two solids that the method in Part B would be unsuitable for.

# 6 Particle theory and states of matter

## Topic summary

The key concepts included in this topic are:

- All substances consist of particles.
- Substances can be identified as solids, liquids and gases based on their observable properties.
- Substances can change state due to changes in temperature or pressure.
- The properties of solids, liquids and gases can be explained by consideration of the movement and arrangement of particles.
- There are attractions between particles in substances, with the strongest attractions occurring in solids and the weakest in gases.
- Heat energy will increase the movement (kinetic energy) of particles and can cause particles to separate from each other.
- Melting occurs when the particles in a solid gain sufficient energy to become free to move past each other. If energy is removed from a liquid, the reverse process of freezing occurs to form a solid.
- If a liquid is heated sufficiently, the particles will gain enough energy to break free from each other and evaporate. If energy is removed from a gas the reverse process of condensation will occur.
- The density of a substance refers to the amount of matter in a given volume and can be calculated using the formula $\rho = \frac{m}{V}$.

## Review questions

The following questions will assess your success in achieving the learning intentions for this topic.

### Remember

1 Define what 'matter' is.

2 Use a fully labelled diagram to describe the arrangement and movement of particles in a solid.

3 Define what an independent variable is in an experiment and give an example of an independent variable that will affect the rate of freezing of a liquid.

### Understand

4 Explain, using particle theory, how heating affects the properties of a solid.

5 Sublimation is the process that occurs when a solid turns directly into a gas when it is heated.

- a Name an example of a substance that undergoes sublimation.
- b Suggest why sublimation occurs in some substances, referring to the attractions between particles.

6 Suggest a reason why the mass of a gas might be difficult to measure accurately using an electronic balance.

### Apply

7 Antonia placed some liquid paraffin in a syringe and was going to apply pressure to the syringe to try to compress the liquid. Predict, with an explanation, what would happen to the volume of the paraffin in the syringe.

8 Describe in detail what will happen to the particles in a liquid when it is cooled to its freezing point.

9 A student dissolved some salt in a beaker of water and found that the density of the water increased.

- a Explain how this has happened.
- b Suggest how adding the salt will change the buoyancy of the water. Explain the reason for your answer.

## Analyse

**10** Amrita was investigating the amount of condensation formed on different surfaces. They predicted that the most condensation will occur on glass. A summary of the method used is shown here.

1. Pour 100 mL of hot water (between 60–80°C) into each of three beakers.
2. Cover each beaker with a different material: beaker A use a glass Petri dish, beaker B a plastic Petri dish and beaker C a metal tin lid.
3. After three minutes, observe the underside of the three covers.

The experiment results are shown here.

| Beaker | Material of cover | Amount of condensation after 3 minutes |
|---|---|---|
| A | glass | bottom of Petri dish around 30% covered in water |
| B | plastic | bottom of Petri dish around 10% covered in water |
| C | metal | bottom of tin lid about 25% covered in water |

**a** Describe how well the experimental results support the initial prediction.

**b** State two ways that the experimental method could be improved.

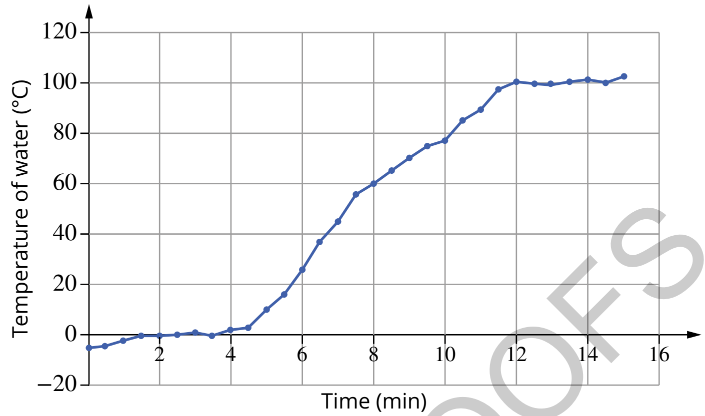
**c** For one of your suggestions in part **b**, explain why this would produce more valuable results.

**11** Mikayla was investigating the changes of state of water.

She started with approximately 100 g of ice in a beaker and heated it steadily with a Bunsen burner.

Every 30 seconds she measured the temperature of the ice and the water that the ice turned into.

The results that she obtained are shown on the following graph.




Use your knowledge of particle theory and the information on the graph to answer the following questions.

**a** State the melting point and boiling point of the water.

**b** Explain what was happening to the particles between 2 to 4 minutes.

**c** Describe the behaviour of the particles at 10 minutes.

**d** Explain why the temperature of the water stayed the same after 12 minutes.

**e** Explain why the results on the graph do not show a smooth curve.

**f** Explain how the graph would be different if Mikayla was carrying out this experiment in a town that was very high above sea level.

**12** A student was attempting to measure the density of a range of materials including wood, steel and copper. The materials were in the form of a range of irregular shapes. The student had access to a large measuring cylinder, water and an electronic balance.

**a** Describe how the volume of an irregular-shaped solid can be measured using the measuring cylinder.

**b** A piece of copper was found to have a volume of 2.5 $cm^3$ and a mass of 22.3 g. Calculate the density of the copper.

**c** Predict whether a piece of copper will float in water. Justify your prediction.

**d** The student then placed some copper wire carefully on the surface of some water and the wire seemed to float on top of the water. Suggest a reason for this.

## Extension: Research and problem-solving

**13** Water, like all chemicals, has a set of properties. Each part of this question shows a real-life example of the properties of water.

**a** The diagram below shows a drop of water on a smooth surface. Note the shape of the drop. During the topic, Figure 6.7.1 also showed a blob of water in space. Refer to the surface tension of water to explain why a water sample will form a sphere in space when left with no external forces acting on it.

**b** A colourful column like the one in the figure below can be formed using salt solutions and food dyes. Discuss how an understanding of density can be used to construct a column like this.

**c** When it rains, water can fill the cracks on large boulders on mountain ranges. When the water freezes, it can sometimes cause the hard rock to crack. What conclusion can you draw about the density of ice from this observation?

**14** An example of evaporation is the drying of clothes after they have been washed. Electric tumble dryers are used in just over 50% of Australian homes and as much as 80% of homes in the United States of America (USA).

You may need to conduct some research to answer some parts of this question, and other parts will require your own ideas.

**a** Describe briefly how an electric tumble dryer removes water from clothes.

**b** Suggest why this dries the clothes faster than hanging the clothes out to dry.

**c** Explain what happens to the water that is removed from clothing in a tumble dryer. Hint: there are two main types of dryer that do this in different ways.

**d** Explain why it is important to know when all the clothes in a tumble dryer are dry.

**e** Suggest, using your knowledge of matter, how a tumble dryer could measure when all the clothes are dry.

**f** Suggest why the proportion of homes with tumble dryers is lower in Australia compared to the USA.

## Topic reflection

The learning intentions for this topic are given in each lesson and at the beginning of the topic. Consider how well you have achieved them. Note down any areas that you are confident in, and others where you are not so sure.

# 6 Glossary

**accuracy** description of how close a measured value is to the true value

**boiling** a change of state in which a liquid is heated and changes to a gas within the liquid

**boiling point** temperature at which a liquid boils

**buoyancy** the ability of an object to float in water or another fluid

**compressed** squashed into a smaller volume

**condensation** a change of state in which a gas is cooled and forms a liquid

**contract** to decrease in size

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

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

**dependent variable** the variable that is being measured in an experiment; it changes as the independent variable changes

**deposition** the change in state from a gas to a solid, bypassing the liquid state

**evaporation** the change of state in which a liquid changes into a gas at the surface of the liquid

**expand** increase in volume (to take up more space)

**freezing** the change in state from a liquid into a solid

**freezing point** the temperature at which a liquid freezes (becomes solid); for example, 0°C for water

**gas** the state of matter that will expand to fill a container, having no fixed shape and no fixed volume

**gaseous** in the form of a gas

**independent variable** the factor that is changed in an investigation to find out how it affects another factor (the dependent variable)

**inference** an informed guess or logical conclusion based on previous experiences, observations and knowledge

**line graph** graph that uses lines to identify patterns and trends shown by data points from two sets of continuous measurements

**liquid** the state of matter that will flow, with no fixed shape but a fixed volume

**mass** the amount of matter in a substance or object; measured in grams (g), kilograms (kg) or tonnes (t)

**matter** a physical substance; anything that has mass and occupies space

**melting** the change in state from a solid into a liquid

**melting point** the temperature at which a solid melts (becomes liquid); for example, 0°C for ice

**mixture** combination of two or more pure substances that can be separated to recover the pure substances

**model** representation that helps to describe or explain an object, event, system or idea

**particle** tiny parts of matter; include atoms and molecules

**particle theory** theory that states that all matter consists of tiny particles that are constantly moving

**prediction** a statement that suggests what will happen in an experiment

**pressure** combined force caused by the movement of gas particles

**property** an observable characteristic of a substance; what a substance looks like and how it behaves

**pure substance** a substance made of only one type of material

**solid** the state of matter that has a fixed shape and a fixed volume

**state** solid, liquid, gas (also plasma at temperatures above 600°C)

**sublimation** the change in state from a solid into a gas

**substance** a material that has physical properties; a solid, liquid or gas

**surface tension** tension on the surface of a liquid that acts like a 'skin' and is caused by the attraction of the particles

**temperature** a measure of the average kinetic energy of particles in a substance that results in how hot or cold the substance is

**theory** an explanation of a set of observations that has been accepted through consensus by a group of scientists

**vapour** matter that has been produced by evaporation from a liquid; the term 'vapour' can be used to describe a pure gas, as in water vapour in the atmosphere, or a mixture which contains a combination of gas and small droplets of liquid

**volume** the amount of space that a substance or object occupies

TOPIC 7

# Solutions and mixtures

The word 'pure' appears frequently in advertisements – pure orange juice, for example, or pure mineral water. However, most substances labelled as pure are not pure substances at all. A pure substance contains only one type of substance, while anything with more than one substance is a mixture.

For instance, 'pure' orange juice is actually a mixture of various substances, including water, sugars (such as sucrose, glucose and fructose), ascorbic acid (vitamin C) and many other compounds that contribute to its flavour.

Substances are often mixed to enhance properties such as taste, colour and smell. However, separating mixtures is also essential for extracting valuable materials and removing waste.

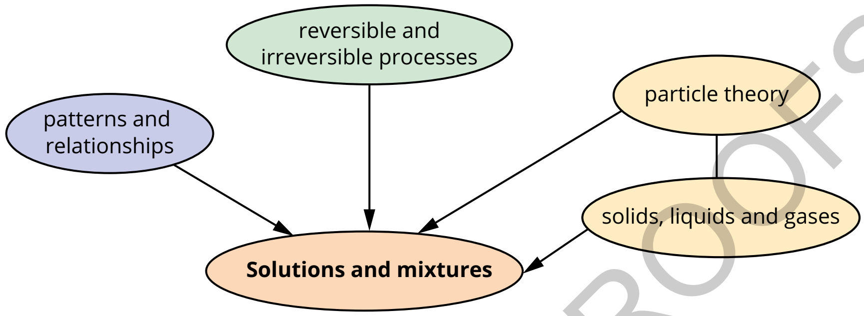
In this topic, you will explore different types of mixtures and the methods used to separate them into pure substances.

## Learning intentions

- ☐ To understand the differences between atoms, mixtures and compounds, and be able to explain their properties using particle theory **xx**
- ☐ To understand that matter can be classified as pure or impure substances **xx**
- ☐ To be able to plan and conduct an investigation to identify soluble and insoluble substances **xx**
- ☐ To understand the concept of a solution **xx**
- ☐ To be able to select and use appropriate equipment to investigate the solubilities of solutes in water **xx**
- ☐ To be able to conduct and interpret an investigation that provides data related to the rate of dissolving **xx**
- ☐ To understand the properties of solutions with different concentrations **xx**
- ☐ To be able to use filtration to separate solid materials in suspensions **xx**
- ☐ To be able to conduct an investigation, while recognising and managing risks, to separate the components in a given mixture **xx**
- ☐ To understand how groups of First Nations Australians use separation techniques **xx**
- ☐ To understand how separation techniques are used in industry **xx**
- ☐ To be able to investigate a method for solving a water pollution problem **xx**

# 7 Solutions and mixtures

The key concepts that you will use in this topic:




The following prior knowledge questions will help to support your learning in the topic and can be attempted before the first lesson.

## Particle theory

**1** All materials are made up of particles. Draw a simple diagram of a solid material using circles to represent the particles.

**2** Material X cannot hold its shape. Its particles move in random directions but are relatively close together. Use this information to determine if material X is a solid, liquid or gas. Explain your reasoning.

## Solids, liquids and gases

**3** Classify the following substances as a solid, liquid or gas at 25°C.

- **a** carbon dioxide
- **b** water
- **c** silver

**4** Explain why gases must be stored in a sealed container.

**5** Explain whether slime can be classified as a solid, liquid or gas.

## Reversible and irreversible processes

**6** Enjoying the outdoors on chilly evenings has resulted in firepits becoming very popular in backyards across New South Wales. The fire produces heat for warmth and cooking foods like marshmallows. Wood and oxygen react together to form charcoal, gases, steam and ash. Explain why this reaction is an irreversible process.

**7** Classify the following processes as reversible or irreversible processes. Explain the reasons for your answers.

- **a** boiling water
- **b** baking a cake
- **c** melting wax

# 7.1 Modelling atoms, compounds and mixtures

## Lesson overview

Atoms are the fundamental building blocks of all matter. Understanding how different materials are made of different combinations of atoms allows us to grasp the concepts of pure substances and mixtures.

In this lesson, you will learn how the particle model can illustrate the structure of different substances, including between atoms, mixtures and compounds, and explain some of their properties.

| SC 1 | I can distinguish between atoms, compounds and mixtures |
|---|---|

Everything around us, including ourselves, is made up of **atoms**. Atoms can exist as single atoms or can combine in different ways to form larger structures.

## Atoms

Some **substances** around us are made up of single atoms that are not chemically bonded (joined) to other atoms. The noble gases **helium (He)**, **neon (Ne)**, and **argon (Ar)** are all found in the air and are unique because their atoms exist independently and are not bonded to other atoms. For instance, **helium** is used in balloons because its atoms are less dense than air (Figure 7.1.1). **Neon** is commonly used in bright neon signs due to its ability to glow.

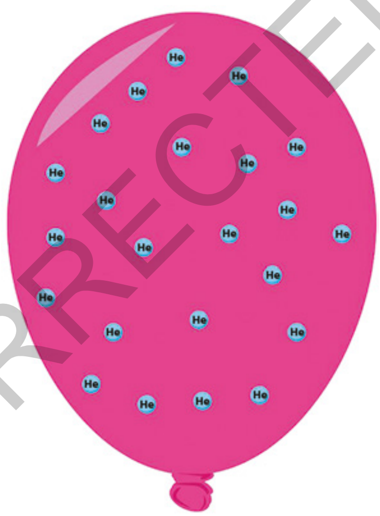



**FIGURE 7.1.1** Single atoms of a noble gas

## Compounds

**Compounds** are substances that are made up of two or more different types of atoms that are chemically bonded. A common example of a compound is water ($H_2O$), which consists of two hydrogen atoms bonded to one oxygen atom (Figure 7.1.2). Water is essential for all life and is found in rivers, oceans and even in the atmosphere as **vapour**.

Compounds have unique properties that are different from the elements they are made of, and they play important roles in everyday life.

### Learning intention

To understand the differences between atoms, mixtures and compounds, and be able to explain their properties using particle theory

### Success criteria

**SC 1:** I can distinguish between atoms, compounds and mixtures.

**SC 2:** I can use particle theory to explain why atoms, compounds and mixtures have distinct physical properties.

### KEY TERMS

**atom** the smallest unit of an element

**substance** material that has physical properties; solid, liquid or gas

**compound** a substance formed when two or more elements are chemically bonded together

**vapour** matter that has been produced by evaporation from a liquid

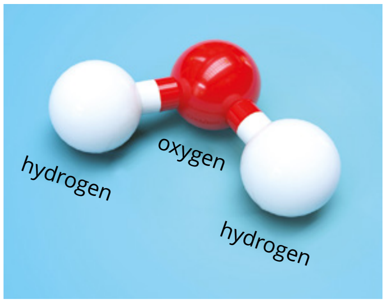



**FIGURE 7.1.2** The structure of water ($H_2O$), a compound made of two hydrogen atoms and one oxygen atom.

## Mixtures

**Mixtures** are made when two or more substances are mixed together but are not chemically bonded. There are many different types of mixtures. It is possible to have a mixture of:

- solids, e.g. washing powder (Figure 7.1.3)
- liquids, e.g. cordial and water (Figure 7.1.4)
- gases, e.g. air
- two different states of matter, e.g. the bubbles of gas in a bottle of soda water (Figure 7.1.5).

In a mixture, each substance keeps its own properties and can be separated out from the mixture again. For example, if you mix sand and salt, you get a mixture. The sand and salt don't change into new substances and can be separated from each other.

**FIGURE 7.1.3** A mixture of solids in washing powder

**FIGURE 7.1.4** A mixture of two liquids, cordial and water

**FIGURE 7.1.5** A mixture of a small bubbles of a gas in liquid water inside an aquarium

**SC 1 CHECK YOUR UNDERSTANDING**

Contrast the structure of an atom and a compound.

**SC 2** I can use particle theory to explain why atoms, compounds and mixtures have distinct physical properties

Scientists use the **particle model** (from **particle theory**) to model the differences in structure and properties between atoms, compounds and mixtures.

## Properties of atoms

Atoms are chemically pure, and they cannot be separated into different components. In the particle model, atoms are represented by circles (Figure 7.1.6). In the following images, if an atom is not touching any other atoms, it is not bonded and it exists independently as an element. If the atom is shown touching one or more other atoms, they are bonded together and behave as a unit.

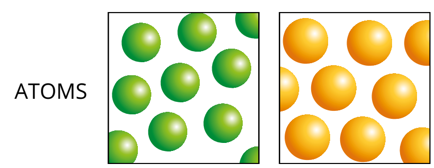



**FIGURE 7.1.6** Atoms are represented as individual circles

Particles are constantly in motion and the nature of their movement depends on their state of matter (solid, liquid or gas). The noble gases helium (He), neon (Ne) and argon (Ar) consist of individual atoms that are free to spread out and move. Because these atoms are not chemically bonded to each other, they tend to have lower boiling and melting points compared to compounds.

## Properties of compounds

Atoms that exist as part of a compound are not free to move independently of each other and are tightly held together by chemical bonds. For example, water is a compound in which the hydrogen and oxygen atoms are bonded together and behave as a single unit. Every particle of water has identical properties.

**KEY TERMS**

**mixture** a physical combination of two or more substances not bonded together

**particle model** representation used to help describe and explain the behaviour of particles

**particle theory** theory that states that all matter consists of tiny particles that are constantly moving

In the following images, compounds appear as different coloured circles touching each other. This shows us that they are bonded together and move and behave as a single unit. The different colours show us that the compounds are made from different atoms (elements) (Figure 7.1.7).

COMPOUNDS

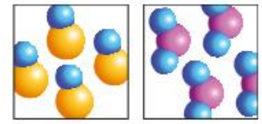


**FIGURE 7.1.7** Compounds have more than one type of atom bonded together.

Every compound has unique properties that are not the same as the properties of the individual elements that make it up. For example, at room temperature water is a liquid whereas both hydrogen and oxygen are gases (Figure 7.1.8).

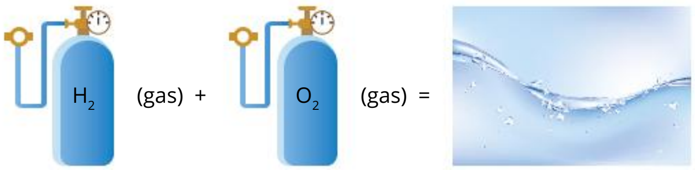



**FIGURE 7.1.8** Water ($H_2O$) is made from the two gaseous elements hydrogen ($H_2$) and oxygen ($O_2$) but is a liquid at room temperature.

## Properties of mixtures

Mixtures are combinations of substances (atoms or compounds) that keep their own properties. For example, if you mix sugar into water, the taste of the mixture is still sweet. The sugar has kept its property of tasting sweet.

In particle model diagrams there will be at least two different types of **particles** that are not attached. A mixture may include a variety of different particles including single atoms, **molecules** of the same element bonded to together (e.g. $O_2$ or $N_2$) or different compounds. You will learn more about the molecules in Lesson 10.1XX.

For example, the diagram on the left in Figure 7.1.9 shows a mixture of two different type of particles—three same-sized (purple) atoms bonded together, and a compound of a large (orange) atom bonded to a small (blue) atom.

The diagram on the right in Figure 7.1.9 shows a mixture of single, small (blue) atoms and a compound of one large (orange) atom bonded to three small (green) atoms.

### KEY TERMS

**particle** tiny parts of matter; includes atoms and molecules

**molecule** two or more atoms that are joined together to form a small, separate particle

MIXTURES

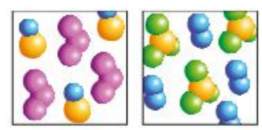


**FIGURE 7.1.9** Mixtures contain more than one type of particle in the same area.

### SC 2 CHECK YOUR UNDERSTANDING

When you add salt into a mixture, predict the taste of the mixture. Explain why.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

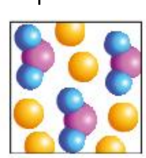
1 Choose whether ice cream is an atom, a compound or a mixture and explain why.

2 Identify an everyday mixture of:
 a solids
 b liquids.

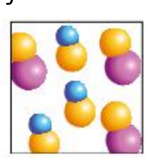
3 Describe the particle arrangement of the noble gas helium.

4 The image shows two mixtures. Identify each as a mixture of atoms, atoms and compounds or just compounds. Justify your decisions.

a



b



5 Water is made of hydrogen and oxygen. Compare the states of matter of oxygen and hydrogen to that of water.

# 7.2 Pure substances and mixtures

## Learning intention

To understand that matter can be classified as pure or impure substances

## Success criteria

**SC 1:** I can explain why elements and compounds are pure substances.

**SC 2:** I can explain why mixtures are impure substances.

**KEY TERMS**

**pure substance** only one type of particle present
**impure substance** more than one type of particle present

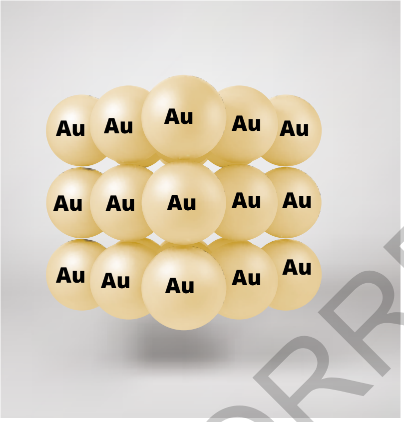



**FIGURE 7.2.1** Atoms in pure gold metal bonded together

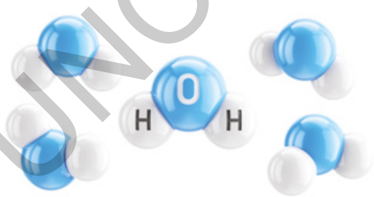



**FIGURE 7.2.2** Pure water, where only water molecules (all identical) are present

## Lesson overview

Every substance around us is made of matter. Matter can be either pure or impure. For example, the water you drink is a mixture of water molecules and other substances (including dissolved calcium and magnesium), making it impure. On the other hand, pure gold is made entirely of gold atoms.

In this lesson, you will learn why elements and compounds are considered pure substances and why mixtures are classified as impure substances.

**SC 1** I can explain why elements and compounds are pure substances

Matter is anything that has mass and takes up space. It can be classified into **pure substances** and **impure substances** (mixtures). Pure substances have a uniform composition where every particle is identical to the others. The two types of pure substances are elements and compounds.

Elements consist of only one type of atom. A list of all the elements is found in the periodic table of the elements. For example, gold is an element that we make into bars. Pure gold is pure substance made entirely of gold atoms bonded together (Figure 7.2.1).

Compounds are substances formed when two or more elements chemically combine in a fixed ratio. For example, water ($H_2O$) is a compound. Every water particle is made of two hydrogen atoms and one oxygen atom combined together. Water is a pure substance when all of the impurities in the water have been removed, leaving only water particles (Figure 7.2.2).

Pure substances have fixed chemical and physical properties throughout. For example, pure water always boils at 100°C at standard atmospheric pressure (Figure 7.2.3). This is due to the consistent composition of pure substances.


**FIGURE 7.2.3** Pure water boiling at 100°C at standard atmospheric pressure

## SC 1 CHECK YOUR UNDERSTANDING

Distilled water is used in laboratories where they require pure water. All of the other substances in the water are removed to make distilled water. Explain why distilled water ($H_2O$) is considered a pure substance.

**SC 1** I can explain why mixtures are impure substances

Mixtures are impure substances, where we can observe two or more substances mixed together but not bonded. Mixtures can be classified into homogeneous and heterogeneous mixtures. The components of a mixture retain their individual properties and can be separated by physical means, such as filtration, **distillation** and **evaporation**. For example, salt can be easily separated from salt water by evaporating the water, leaving the salt behind (Figure 7.2.4).

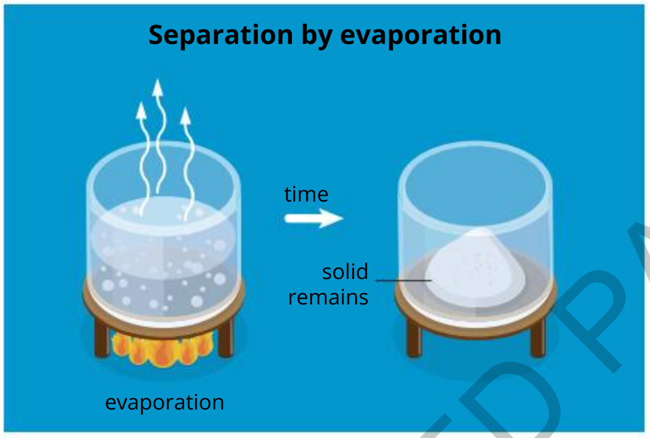



**FIGURE 7.2.4** Separating salt from salt water using evaporation

## Homogenous mixtures

**Homogeneous mixtures** have a uniform composition, meaning that they are the same throughout (Figure 7.2.5). Homogeneous mixtures are also called solutions. An example of a homogeneous mixture is salt water. When salt fully **dissolves** in water, the grains of salt can no longer be seen. A solution is formed where the dissolved salt particles are evenly distributed throughout the water.

## Heterogeneous mixtures

**Heterogeneous mixtures** have a non-uniform composition, meaning that they are not the same throughout (Figure 7.2.5). An example of a heterogeneous mixture is a salad. The different ingredients, such as lettuce, tomatoes and cucumbers, are not evenly distributed and can be seen separately. Similarly, soil has distinct components within it that vary in size, shape and distribution. This includes living organisms, air, water, the remains of dead plants, sand, silt and clay. Due to this varying distribution, heterogeneous mixtures also do not have consistent properties throughout. For example, some portions of soil may be wetter or denser than others.

### Scifile

**Elemental abundance**

Hydrogen is the most abundant element in the universe, making up about 75% of the universe by mass. Helium comes second, making up about 24%. All of the other elements that make up our world and our bodies are part of the remaining 1% of the universe.

### KEY TERMS

**distillation** using evaporation and then condensation to recover solvents from mixtures

**evaporation** liquid changing into a gas at the surface of the liquid

**dissolve** break up into tiny particles that are smaller than the eye can see

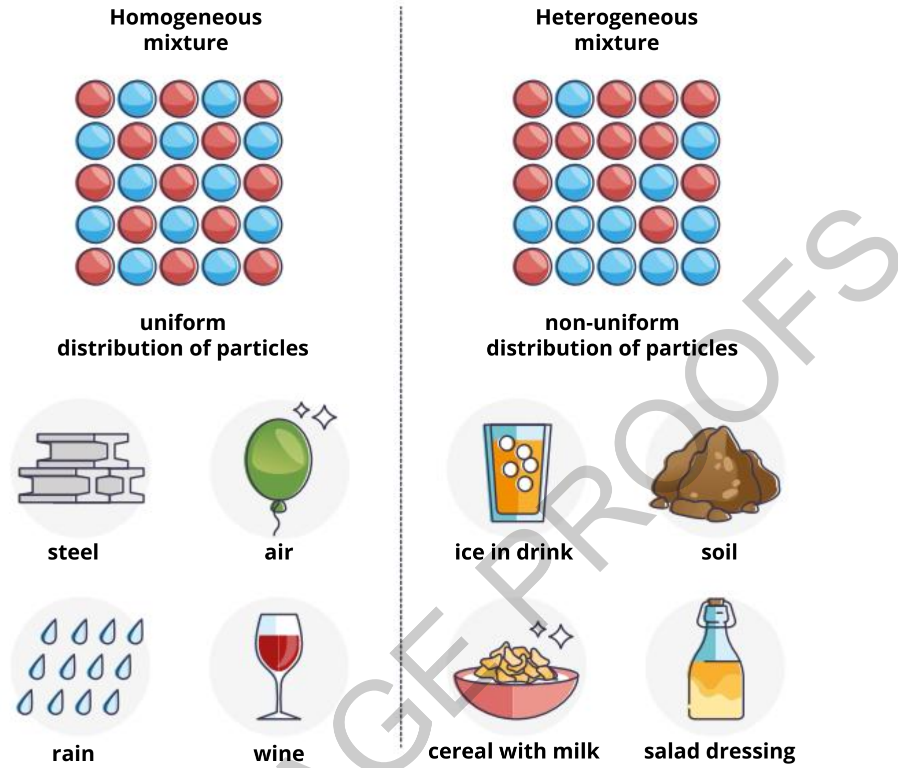



**FIGURE 7.2.5** Examples of common homogeneous mixtures and heterogeneous mixtures

**Scifile**

**Air as a mixture**

The air we breathe in is a mixture of gases, primarily nitrogen (78%) and oxygen (21%), with small amounts of other gases like carbon dioxide (0.04%) and argon. The air we breathe out still has (78%) nitrogen but contains slightly less oxygen (17%) and slightly more carbon dioxide (4%).

**SC 2 CHECK YOUR UNDERSTANDING**

Classify salt water as a pure substance or an impure substance. Justify your choice.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 Name the simplest form of matter that consists of only one type of atom.

2 Carbon dioxide is a compound made of one carbon atom bonded to two oxygen atoms. Identify whether carbon dioxide is a pure or impure substance and justify your choice.

3 Describe the difference between homogeneous and heterogeneous mixtures.

4 Explain why mixtures are considered impure substances.

5 Predict how the properties of a salad would change if you added more tomatoes.

6 Compare the boiling points of pure water and salt water shown here. Suggest why they are different values.

| Substance | Boiling point |
|---|---|
| pure water | 100°C |
| salt water | 102°C |

# 7.3 Soluble and insoluble substances

## Introduction

The use of a substance often depends on its ability to dissolve in another substance, such as water. For example, water-soluble substances can add colour or flavour to liquids, and soluble medicines are easily absorbed by the body.

Substances that do not dissolve cannot form solutions and are often difficult to remove from the body. Lead is particularly dangerous because most lead-containing compounds are insoluble (Figure 7.3.1), making it difficult to eliminate them from the body.

In this practical investigation, you will test a range of substances to see if they are soluble in water.

**Learning intention**

To be able to plan and conduct an investigation to identify soluble and insoluble substances

**Success criteria**

**SC 1:** I can use prior knowledge to predict whether a range of substances will dissolve in water.

**SC 2:** I can plan and conduct an investigation on solubility.

**SC 3:** I can record observations about the solubility of different substances and interpret these findings using the key language of solubility.

## Background

Substances that dissolve into another substance are said to be **soluble** in that substance. The substance dissolving is called the **solute** and the substance into which it is dissolving is called the **solvent**.

The solute is still present in the solution, but the particles are so small they appear invisible. However, the colour of the solution may now be changed if the solute was coloured. The solution is described as clear because the light passes through it and you cannot see any particles or cloudiness in it.

Substances that do not dissolve like this are called **insoluble**. The mixture may remain cloudy or contain lumps or layers where the two substances have not dissolved together.

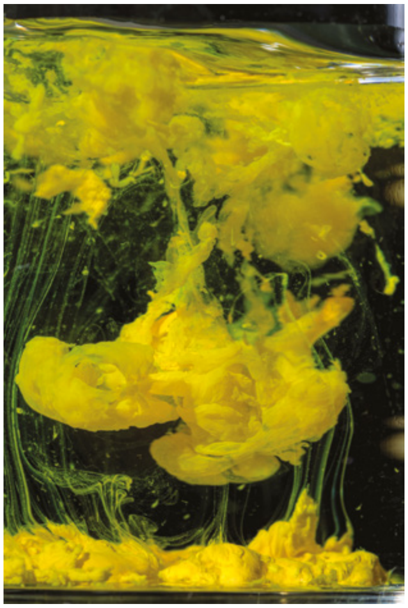


**FIGURE 7.3.1** Lead chromate, the yellow substance, is insoluble in water.

## Aim

To investigate which substances dissolve in water

## Prediction

Using your previous observations from everyday life, predict which substances you think will dissolve in water before you carry out the tests. Write down your predictions.

## Apparatus

You will have access to solid copper carbonate ($CuCO_3$), zinc sulfate ($ZnSO_4$), table salt ($NaCl$), cooking oil and golden syrup. You will produce each mixture in a separate test tube. Test tubes will need to be stoppered and shaken to enable dissolving to occur.

## SAFETY NOTES

- Zinc sulfate and copper carbonate are toxic so do not touch, sniff or taste them.
- Do not wash zinc sulfate or copper carbonate down the sink.
- Always wear safety glasses and rubber gloves to avoid contact of chemicals with your skin and eyes.

## HINT

Check with your teacher whether you can do repeat trials. The reliability of your results can be improved by carrying out repeat trials.

**KEY TERM**

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

Note that copper carbonate and zinc sulfate amounts cannot exceed $\frac{1}{2}$ teaspoon per test tube.

## Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity. Consider: How will you ensure you make no contact with the copper carbonate and zinc sulfate? How will you minimise the risk of solution escaping when you shake the solutions?

## Method

Write a step-by-step method for your investigation. Include quantities required and any safety notes needed. Include instructions for how to dispose of your mixtures at the end of the investigation.

Draw a scientific diagram showing an example test tube. Label the substances to place within the test tube.

## Results

Record your results in a suitable table. Ensure you have included columns for observations of each test tube and classification as 'soluble' or 'insoluble' for each mixture.

## Discussion

Discuss your practical investigation by answering the following questions.

1 Comment on the accuracy of your predictions.

2 Was your investigation a fair test? Were all the **controlled variables** kept constant for every mixture?

3 Describe two possible improvements to your method for the experiment. For example, are there any key amounts or instructions you need to add in?

## Conclusion

Write your conclusion by answering the following questions.

1 Describe the observations that helped you to decide that a solute dissolved to form a solution.

2 Identify the substance(s) that were insoluble in water.

3 In which test tubes did a solution form? In each case, identify the solute and solvent.

4 At another school the students used kerosene as a solvent and collected the following results.

| Test tube number | olvent | Solute | Observations after mixing for 1 min |
|---|---|---|---|
| 1 | kerosene | paint | clear solution |
| 2 | kerosene | sugar | white powder at the bottom of the test tube |
| 3 | kerosene | salt | white powder at the bottom of the test tube |
| 4 | kerosene | oil | two layers, one on the top and one on the bottom |

Describe their findings using the key terms: soluble, insoluble, solute, solvent and solution.

# 7.4 Solutions

**Learning intention**

To understand the concept of a solution

**Success criteria**

**SC 1:** I can describe some examples of solutions.

**SC 2:** I can describe solutions using the particle model.

**FIGURE 7.4.1** Sports drinks are solutions that can quickly replace water, salts and sugar in the body.

**KEY TERMS**

**solution** solution that has a liquid other than water as the solvent

**aqueous solution** solution that has water as the solvent

**non-aqueous**

## Lesson overview

Many everyday drinks are solutions. These include clear apple juice, black tea or soft drinks such as cola and soda water. Isotonic sports drinks (Figure 7.4.1) are designed to have similar concentrations of salt and sugar as the body's blood so that they are more quickly absorbed into the blood.

In this lesson, you will learn about solutions and how they can be explained using the particle model.

**SC 1** I can describe some examples of solutions

**Solutions** are formed when one substance, the solute, fully dissolves into a solvent. In a solution, the substances have completely mixed and the properties of the mixture are the same throughout. This means that there are no lumps of solid, no cloudy appearance and no layers of substances that have separated from each other. Because of this, solutions are clear, which means you can see through them, even though some solutions are coloured (Figure 7.4.2).


**FIGURE 7.4.2** The chemicals here are all solutions

## Liquid solutions

Most solutions in everyday life have water as the solvent. These are called **aqueous solutions**. All the solutions in your body are aqueous solutions, which is why human bodies have such a high water content (around 60%).

Sweat is a solution of small amounts of ammonia, urea, salts and sugar dissolved in water (Figure 7.4.3). Urine is another solution that contains some of the same chemicals as sweat. However, the additional waste products found in urine, such as uric acid, give this solution different properties to sweat, such as colour and smell.

**FIGURE 7.4.3** Sweat is a solution that has small amounts of chemicals dissolved in water.

While water is the most common solvent, not all substances dissolve in water, so often other solvents need to be used. These are called non-aqueous solvents and they can be used in **non-aqueous solutions**. These solvents are often used in cleaning products (Figure 7.4.4).

**FIGURE 7.4.4** These substances are all non-aqueous solvents that can be used for household cleaning.

## Gaseous solutions

When gases mix, they will always form a **gaseous** solution because one of the properties of gases is that they do not have a definite boundary. This means that the particles of a gas will quickly **diffuse** (spread) into each other. Solutions of gases consist of particles of the substances that are completely mixed.

**KEY TERMS**

**gaseous** in the form of a gas

**diffuse** the spreading out of particles

**SC 1 CHECK YOUR UNDERSTANDING**

Identify the solvent in an aqueous solution.

**SC 2** I can describe solutions using the particle model

When we use particle theory to model solutions, we focus on how the tiny particles of the solute and solvent interact and mix together. When you create a solution, the solute particles spread out and fill the spaces between the solvent particles. This mixing happens because the particles are always moving and bumping into each other, which helps them spread evenly throughout the solution.

Note that this model relies on the solute particles separating from each other. Therefore, if the attractions between these particles are very strong, the solute may not dissolve easily. In a solution, the solute particles are evenly distributed among the solvent particles, making the solution look the same throughout. For example, when you dissolve sugar in water, the sugar particles separate and spread out and mix with the water particles, so the sugar is not visible anymore (Figure 7.4.5). This is why solutions appear clear.

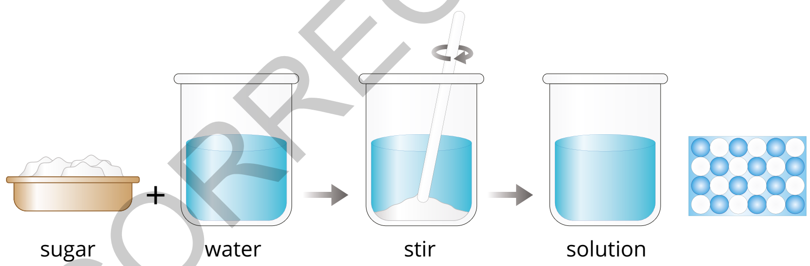



**FIGURE 7.4.5** Forming a solution from salt and water

The concentration of a solution can be visualised by the number of solute particles relative to the number of solvent particles. If there are many solute particles compared to solvent particles, the solution has a high concentration. If there are fewer solute particles, the concentration is lower (Figure 7.4.6).

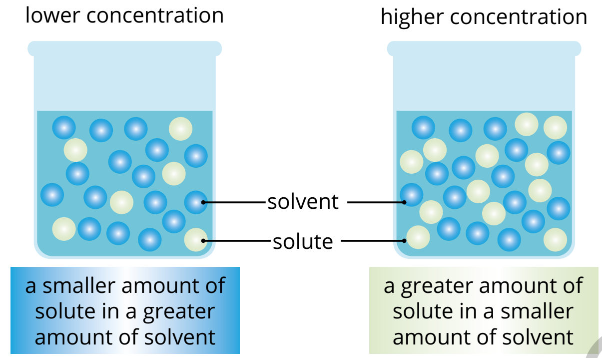



**FIGURE 7.4.6** A representation of a concentrated (higher concentration) solution and a dilute (lower concentration) solution

**SC 2 CHECK YOUR UNDERSTANDING**

Describe how you would increase the concentration of a salt water solution.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 Explain the difference between aqueous and non-aqueous solutions.

2 Describe an example of a solution in, or produced by, the human body.

3 Identify the solute and solvent in drinking chocolate dissolved in milk.

4 There are two main gases in air: nitrogen (78%) and oxygen (21%). Which of these would be considered the solvent of this gaseous solution? Justify your choice.

# 7.5 Solubility

## Introduction

Dissolving occurs when one substance, called the solute, dissolves into another substance, called the solvent. When solutes dissolve, they break up from a larger crystal of atoms or molecules into much smaller individual atoms or molecules in solution.

**Solubility** is a measure of how much solute can dissolve in a fixed amount of solvent. This fixed amount of solvent could be measured in litres or millilitres. At some point, the water can no longer dissolve any further solute particles. It is now a **saturated solution**.

### Learning intention

To be able to select and use appropriate equipment to investigate the solubilities of solutes in water

### Success criteria

**SC 1:** I can plan an experiment to test the solubility of different solutes in water.

**SC 2:** I can select and use equipment correctly to record the amount of solute that dissolved in water.

**KEY TERM**

**saturated solution** a solution that cannot dissolve any further amount of the solute

## Background

The three solutes to be tested all dissolve in water. However, they have different solubilities (different amounts that can be dissolved). You will be measuring the number of teaspoons of each solute that you can dissolve in a fixed volume of water. You may select a volume between 50 mL and 100 mL to test. The volume must be kept the same throughout all your trials. You will need to ensure a consistent time of stirring after every teaspoon addition before you decide if it is fully dissolved. Only add another teaspoon if the solute is fully dissolved.

## Aim

To carry out an experiment that will compare the solubilities in water of different solutes (salt, baking soda and Epsom salts)

## Plan

The chemicals that you are going to test are:

- sodium chloride (salt)
- sodium bicarbonate (baking soda)
- magnesium sulfate (Epsom salts)

You will have access to some or all of the following:

- beakers or transparent cups
- stirring rods
- measuring cylinders (for water)

Write a step-by-step method for your investigation. Include equipment and quantities of chemicals that you will use. You can also include a diagram of the equipment setup.

State how to reduce any risk in the experiment.

Ask your teacher to check your plan.

## Design

Make a suitable results table in your notes.

## Conduct

Conduct your investigation ensuring you follow all the safety procedures you identified.

## Discussion

Evaluate your practical investigation by answering the following questions.

1. Comment on the fairness of your experiment by considering the solutes' particle sizes, your stirring methods and your judgement of the number of teaspoons that dissolved.
2. Describe at least two modifications to your method that you either carried out or could apply to your method. Explain how these modifications would improve the reliability or the validity of your results.

GO TO ➤
For support with improving reliability and validity see Toolkit sections x.x and x.x.

## Conclusion

Use evidence from your results to explain which solute has the highest and lowest solubility in water at room temperature.

# 7.6 The rate of dissolving

## Introduction

When substances dissolve, particles in the solute need to separate and spread out into the solvent (Figure 7.6.1). Many factors may affect how quickly the process of dissolving happens. Particle theory can be used to predict the effect of these factors.

In this practical investigation, you will carry out an investigation to see how the rate of dissolving sugar in water is affected by the temperature of the water. You will have to ensure that other factors that may also affect the rate of dissolving are kept the same to make sure that this is a fair (valid) test.

## Background

Chemicals that are soluble will dissolve into a solvent. The particles of the solute mix with the particles in the solvent. How fast this happens can be important, especially in medicine when the solute could be a drug that needs to be absorbed quickly into the body.

Particle theory can be used to explain and predict how fast a solute will dissolve. Remember that if the temperature rises, the average energy of particles will increase and particles will be moving faster.

## Aim

To answer the question: Is the time it takes for sugar to dissolve in water related to the temperature of the water?

## Prediction

1 Identify the **independent variable** and **dependent variable** for this experiment.

2 Using the variables you identified in Question **1**, write a suitable prediction.

## Apparatus

- sucrose (sugar)
- 3 × 100 mL beakers
- stirring rod
- measuring cylinder
- thermometer
- electronic balance
- stopwatch
- teaspoon
- Bunsen burner
- matches
- tripod
- gauze mat
- heatproof mat
- heatproof cloth or glove

### Learning intention

To be able to conduct and interpret an investigation that provides data related to the rate of dissolving

### Success criteria

**SC 1:** I can conduct a valid investigation that tests a prediction about the rate of dissolving.

**SC 2:** I can develop a conclusion that identifies the relationship between the independent and dependent variable.

**FIGURE 7.6.1** A substance that dissolves in a solvent is called a solute.

### KEY TERMS

**independent variable** the factor that is changed in an investigation to find out how it affects another factor (the dependent variable)

**dependent variable** the variable that is being measured in an experiment

## SAFETY NOTES

- Hold the beaker with a heat-proof cloth or glove when stirring.
- Allow the hot water to cool down before emptying the beakers.
- Wear safety glasses during the experiment.

## Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

## Method

### At room temperature

1. Measure 30 mL of water that is at room temperature using a measuring cylinder. Record the temperature of the water using the thermometer.
2. Pour the 30 mL water into a 100 mL beaker.
3. Measure 20 g of sugar.
4. Have the timer ready and start timing as soon as you add all the sugar into the water. Stir with the stirring rod until the sugar dissolves.
5. Stop timing when there are no longer any solid particles present (it is fully dissolved).
6. Record the time it took for the sugar to dissolve at room temperature.

### At 40°C and 60°C

1. Measure 30 mL of water using a measuring cylinder.
2. Pour the 30 mL water into a 100 mL beaker.
3. Measure 20 g of sugar.
4. Place the beaker onto a heating device, either an electronic heating plate or above a gauze mat, tripod and heat mat.
5. Gently warm the water, watching the thermometer carefully.
6. When the temperature is at 40°C, place the beaker onto the heat mat.
7. Have the timer ready and start timing as soon as you add all the sugar into the water. Stir with the stirring rod until the sugar dissolves.
8. Stop timing when there are no longer any solid particles present (it is fully dissolved).
9. Record the time it took for the sugar to dissolve at 40°C.
10. Repeat steps 1–9 for 60°C.
11. Dispose of the solutions as directed by your teacher and clean all equipment used.

## Results

| Temperature (°C) | Time taken for 20 g of sugar to dissolve in 50 mL water (s) |
|---|---|
| room temperature (approx. 20) | |
| 40 | |
| 60 | |

Check with your teacher whether you can do repeat trials. The reliability of your results can be improved by carrying out repeat trials. Repeat trials will each need an additional column.

## Discussion

1 Evaluate how accurately you were able to ensure the temperature of the water matched the temperature you needed. Suggest an improvement to the method to make this more accurate next time.

2 Evaluate how accurately you were able to ensure you recorded the exact time when the solute had dissolved and there were no solid particles. Suggest an improvement to the method to make this more accurate next time.

## Conclusion

1 Write a conclusion to your experiment by describing the pattern you observed. Consider: How does temperature effect the rate of dissolving? Refer to your data as evidence.

2 Do your results support or not support your prediction? Was the pattern as you predicted?

3 Suggest why changing the temperature might affect how fast the sugar dissolves in the water.

# 7.7 Concentrations of solutions

**Learning intention**

To understand the properties of solutions with different concentrations

**Success criteria**

**SC 1:** I can describe the difference between dilute and concentrated solutions.

**SC 2:** I can explain the features and properties of saturated and supersaturated solutions.

**FIGURE 7.7.2** A small amount of sugar (solute) dissolving in water (solvent) to produce a dilute solution

**FIGURE 7.7.3** A large amount of sugar (solute) dissolving in water (solvent) to produce a concentrated solution

## Lesson overview

Have you ever noticed how some flavoured drinks look darker or taste sweeter than others? This difference is partly due to the concentration of the dissolved substances within the solution. A solution is a type of mixture where one substance is fully dissolved in another. The concentration of a solution tells us how much of the solute is present compared to the solvent. For example, a strong cordial drink has a high concentration of cordial syrup (solute) compared to water (solvent).

In this lesson, you will learn about the properties of solutions with different concentrations.

**SC 1** I can describe the difference between dilute and concentrated solutions

A solution is a homogeneous mixture of two or more substances. The substance that dissolves is called the solute, and the substance in which the solute dissolves is called the solvent (Figure 7.7.1). Water is a very common solvent as it can dissolve many different solutes, including sugar and salt.

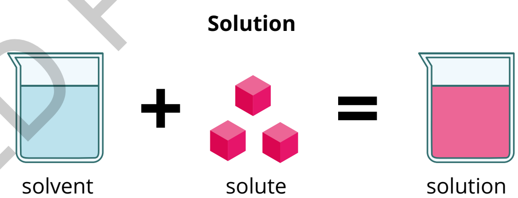



**FIGURE 7.7.1** The solvent and solute combine to produce a solution

**Dilute** solutions have a small amount of solute compared to the solvent. For example, if you add a small amount of sugar to a large amount of water, you get a dilute sugar solution (Figure 7.7.2). The taste of the solution will not be very sweet because there is not much sugar in it.

**Concentrated** solutions have a large amount of solute compared to the solvent. For example, if you add a large amount of sugar to a small amount of water, you get a concentrated sugar solution (Figure 7.7.3). The taste of the solution will be sweeter because there is a lot of sugar in it.

The **concentration** of a solution refers to the amount of solute present in a given amount of solvent. For example, you could make a dilute sugar solution by dissolving 2 grams of sugar into 1 litre of water, making a 2 g/L solution. Or you could make a concentrated sugar solution by dissolving 200 grams of sugar into 1 litre of water, producing a 200g/L solution. These units help quantify the concentration of solute present in a solution (Table 7.7.1). Note that grams per litre can be written as g/L or g $L^{-1}$.

**TABLE 7.7.1** Concentrations from most dilute to most concentrated

| | Most dilute | | | | Most concentrated |
|---|---|---|---|---|---|
| **Concentration of cordial (g $L^{-1}$)** | 2 | 40 | 100 | 200 | 500 |
| |  |  |  |  |  |

## SC 1 CHECK YOUR UNDERSTANDING

Describe the difference between a dilute solution and a concentrated solution.

## SCIENCE IN CONTEXT

### Concentrations in everyday life

In the medical field, the concentration of medications is critical for their effectiveness. Doctors prescribe medications with specific concentrations to ensure that patients receive the correct dosage. For example, saline solution used in hospitals has a specific concentration of salt to match the body's natural fluids (Figure 7.7.4).

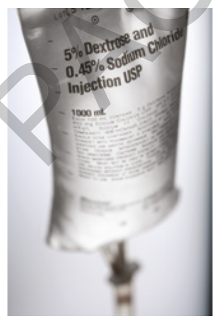



**FIGURE 7.7.4** This hospital drip contains 5% dextrose (a type of sugar) and 0.45% sodium chloride (salt).

| **SC 2** | I can explain the features and properties of saturated and supersaturated solutions |
|---|---|

A saturated solution is one in which no more solute can dissolve at a given temperature and pressure. In other words, the solution has reached its maximum capacity for dissolving the solute. For example, if you keep adding sugar to water and stirring it, eventually you will see sugar crystals on the bottom of the container that are unable to dissolve. This is because the solution is saturated (Figure 7.7.5).

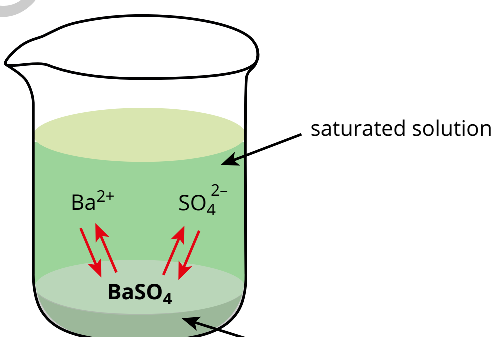



**FIGURE 7.7.5** A saturated barium sulfate solution with extra undissolved salt ($BaSO_4$ solid) at the bottom of the beaker

The amount of solute that can dissolve in a solvent to form a saturated solution depends on temperature. Generally, the solubility of solids in liquids increases as the temperature goes up (Figure 7.7.6). For example, more sugar can dissolve in hot water than in cold water.

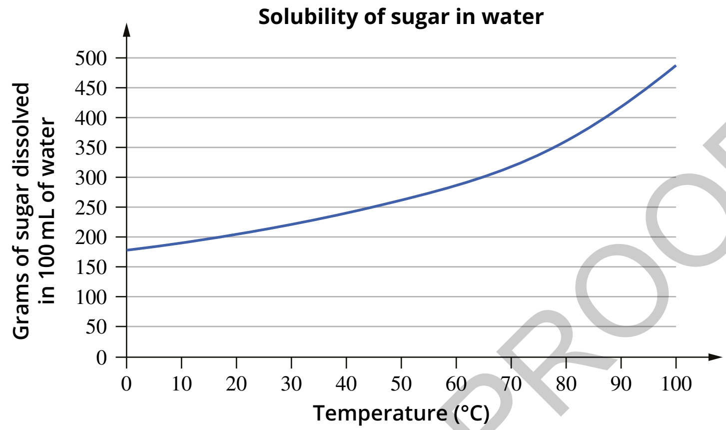



**FIGURE 7.7.6** The solubility of sugar in water increases as temperature increases

**FIGURE 7.7.7** An unstable supersaturated solution begins forming long solid crystals

A **supersaturated solution** contains more solute than can normally dissolve at a given temperature. Supersaturated solutions can be created by completely dissolving the solute in the solvent at a higher temperature and then slowly cooling the solution. Supersaturated solutions are extremely unstable and if even a tiny particle is added to a supersaturated solution, the extra solute will immediately solidify (Figure 7.7.7) and the solution will no longer be supersaturated.

Supersaturated solutions have unique properties and are used in various applications. For example, hand warmers contain a supersaturated solution of sodium acetate (Figure 7.7.8). When the hand warmer is activated, the excess solute solidifies, releasing heat.

**FIGURE 7.7.8** A chemical hand warmer. When the metal disc is bent the solidification of the supersaturated solution begins, releasing heat.

**SC 2 CHECK YOUR UNDERSTANDING**

Explain how a supersaturated solution is created.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1. Name the substance that dissolves in a solvent to form a solution.
2. Explain how a saturated solution is formed.
3. Predict what would happen if you added a small crystal to a supersaturated solution.
4. Compare the features and properties of a saturated solution and a supersaturated solution.

# 7.8 Filtering

## Introduction

Filtering is used in a huge range of situations, including water treatment, in washing machines and in the preparation of drinks such as tea and coffee.

Particle size is a key physical property used in separation techniques like filtration. Larger particles are trapped by the filter, while smaller particles pass through.

In this practical investigation, you will compare two ways of using filter paper to determine which one is the most efficient.

### Learning intention

To be able to use filtration to separate solid materials in suspensions

### Success criteria

**SC 1:** I can use filter paper in two different ways to separate solid materials in suspensions.

**SC 2:** I can describe, with consideration of sizes of particles and groups of particles, why some materials can pass through a filter and some materials cannot.

## Background

When a liquid mixture contains an insoluble substance, it can be described as a **suspension**. A suspension is a type of mixture where solid particles are not dissolved in the solvent. Suspensions appear cloudy due to the solid particles being spread throughout the liquid. If left over time, the particles will settle to the bottom of the container.

Suspensions can be separated through filtration. Filtration can separate the insoluble substance from the liquid. The **filtrate** can pass through the gaps in the filter paper, but the **residue** of the insoluble substance is trapped by the paper.

### KEY TERMS

**suspension** a mixture of an insoluble solid in a liquid
**filtrate** liquid that passes through the filter paper
**residue** solid left in the filter paper after filtration
**prediction** a statement about the relationship between two variables, which can often be tested experimentally; an 'educated guess'

## Aim

To compare conical and fluted filter papers

## Prediction

Predict which type of filter paper will complete the filtering of a suspension of sand and copper carbonate in a shorter time. Write a **prediction** and give a reason for your prediction.

## Apparatus

- 2 spatulas of copper carbonate ($CuCO_3$)
- 2 spatulas of sand
- 1 spatula
- 2 filter funnels
- 4 pieces of filter paper
- 4 × 100 mL conical flasks (or 4 × 100 mL beakers, plus retort stand, bosshead and clamp or filter stand
- 2 stirring rods
- 2 stopwatches or timers

### SAFETY NOTE

- Copper carbonate is toxic so do not touch, sniff or taste it.

## Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

### SkillBuilder

## Folding a filter paper

### Method for conical shape

1 Fold the filter paper in half.
2 Fold it in half again to get a quarter-circle shape.
3 Open out one 'layer' of the folded paper, keeping three layers on the other side.
4 Squeeze sides gently to bend into a cone shape.

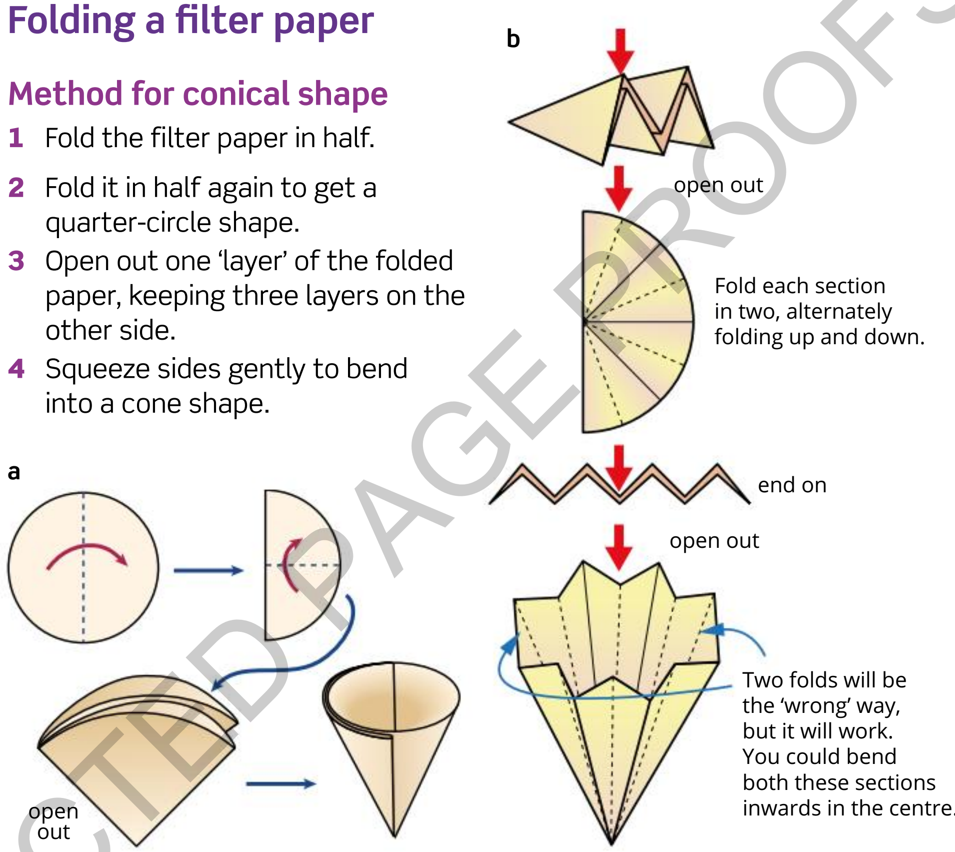



**FIGURE 1** **(a)** The filter paper folded to produce a conical shape; **(b)** the filter paper folded as a fluted shape

### Method for fluted shape

1 Fold the filter paper in half.
2 Fold it in half again to get a quarter-circle shape.
3 Open it up to half a semi-circle.
4 Fold in the edge of the paper to the first crease line. Do this on both sides.
5 Open it up to half a semi-circle.
6 Now you will fold the filter paper into pleats, alternating above and below for each crease. Start at one end and continue your way around the semi-circle, folding the paper up to each crease point and continuing on.
7 Open out the paper.

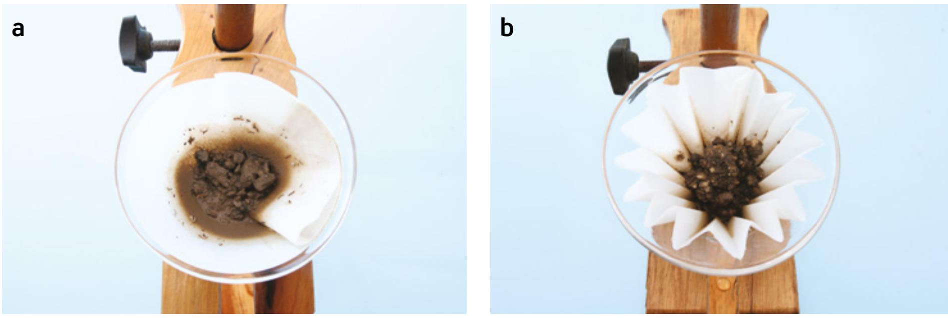


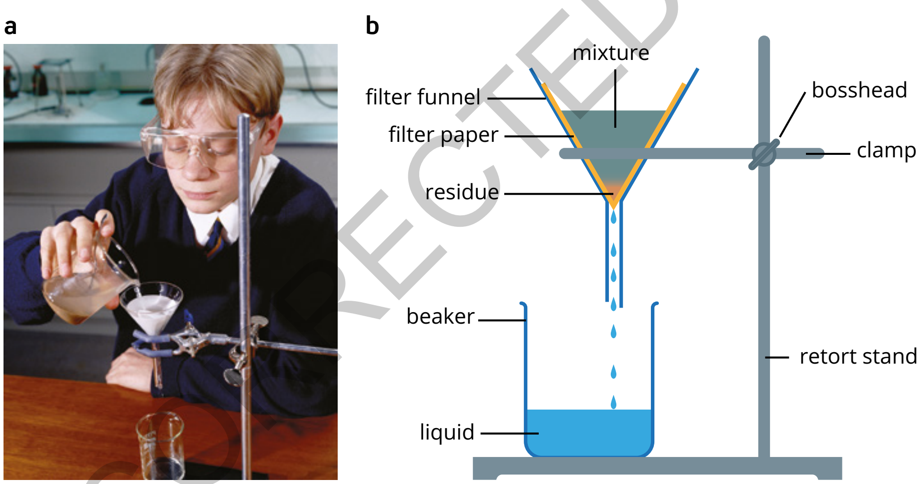

**FIGURE 2** **(a)** The filter paper folded to produce a conical shape; **(b)** the filter paper folded as a fluted shape

## SkillBuilder

### Setting up a filter funnel

#### How to filter

1. Place the folded filter paper in the funnel.
2. Set up the equipment shown in the diagram, or you can use a filter funnel stand, or place the filter funnel in a conical flask.
3. Slowly pour the mixture into the filter paper, ensuring the liquid goes into the cone shape and not outside the paper. The liquid that passes through the filter is called the filtrate. The solid that is trapped in the filter paper is called the residue.






## Method

1. Set up two filter funnels in two conical flasks or using clamps or filter stands. If using clamp or filter stands then also place a beaker under each funnel to collect the liquid.
2. Fold one filter paper into a conical shape and the other into a fluted shape. Place each filter paper in one of the funnels.
3. Collect one spatula of sand and place it in 40 mL of water in a clean beaker. Stir the mixture with the stirring rod. Repeat this step to create another beaker of the sand and water mixture.

**HINT**

Do not let the liquid in the filter paper get too close to the top of the paper.

The paper is very fragile once wet. Don't try to move the paper once you have started filtering and be very careful not to tear or poke any holes in the filter paper.

4 Be ready with the timer. As soon as some water is poured into the filter paper, the timer must be started. Pour some of the contents of one beaker into the conical filter paper. Do not let the water level reach the top of the filter paper and do not let the water level run out, slowly keep topping it up with the mixture of sand and water.

5 Pour the same amount of water from the other beaker into the fluted paper. Start the second timer as soon as the water goes into the fluted filter. Do not let the water level reach the top of the filter paper and do not let the water level run out, slowly keep topping it up with the mixture of sand and water.

6 Keep adding the sand and water mixture to each filter paper until all the liquid has been filtered. Stop the timer when all of the liquid has passed through the filter paper. Leave any remaining sand in the beaker.

7 Copy the results table below and record the time taken for each filter and how clear the filtrate is.

8 Repeat steps 1–6 with new filter papers, but this time use copper carbonate as the material to be suspended in the water instead of sand.

9 Dispose of all residues from the experiments as directed by your teacher.

## Results

| Type of filter | Substance added | Time taken to filter (min:sec) | Appearance of filtrate |
|---|---|---|---|
| conical | sand | | |
| fluted | sand | | |
| conical | copper carbonate | | |
| fluted | copper carbonate | | |

## Discussion

1 Describe, in terms of particles, how filter papers separate mixtures that are suspensions.

2 Propose a reason why one folding method was better than the other.

## Conclusion

Write your conclusion by answering the following questions.

1 Write a conclusion to your experiment by describing the pattern you observed. Consider: Which filter paper type filtered the mixtures the fastest? Refer to your data as evidence.

2 Does your conclusion support or not support your prediction? Was the pattern as you predicted?

# 7.9 Testing separation techniques

## Introduction

Filtering, distillation, evaporation and decanting are all methods of separation that scientists can use to collect pure substances from mixtures. Choosing a suitable technique depends on the properties of the substances in the mixture (Figure 7.9.1). Once the technique has been identified, the scientist can design a method to ensure that separation is as efficient as possible. This means that they can extract a significant amount of the required product in a reasonable amount of time in a way that reduces any possible risks.

In this inquiry activity you will be presented with a mixture to separate and have the challenge of designing a method that uses a separation technique, conducting the experiment and then evaluating the effectiveness of your method.

### Learning intention

To be able to conduct an investigation, while recognising and managing risks, to separate the components in a given mixture

### Success criteria

**SC 1:** I can identify the correct separation technique to use based on the properties of the substances.

**SC 2:** I can recognise and manage risks in setting up equipment to successfully separate an unfamiliar mixture.

**SC 3:** I can write success criteria and use them to evaluate the effectiveness of the method and suggest changes that will improve the method.

## Background

Filtering techniques depend on the properties of the substances in the mixture. More specifically, you need to identify a difference in the substances' properties to effectively separate them. Some properties that can be used to separate mixtures include:

- solubility—if one substance dissolves in water and the other one does not, filtering can be used to separate them
- magnetic properties—magnets can be used to separate magnetic materials from non-magnetic ones
- density—decantation involves pouring off a liquid from a mixture, leaving the denser solid that sinks to the bottom of the container behind
- boiling point
  - evaporation involves heating a mixture until the substance with the lowest boiling point all changes to a gas; the substances that did not evaporate are left in the dish
  - distillation is another separating technique that relies on separating mixtures by differences in their boiling points.

You will be given a mixture of salt, sand and iron filings. You will need to separate each of them and collect three piles at the end, one with salt, one with sand and one with iron filings.

**FIGURE 7.9.1** Sieving is a simple method of separating out larger particles from smaller particles.

### HINT

When you plan your experiment, make sure that you know which substance you are trying to collect (the product).

## Aim

To select, trial and evaluate chosen separation techniques

GO TO ➤

For support with selecting equipment see Toolkit section x.x.

For support with writing a method see Toolkit section x.x.

For support with reducing risk see Toolkit section x.x.

### HINT

Ways to know how successful your activity is could include questions such as:

How much product did I/we produce?

Did I/we remove all the waste products?

## Plan

Plan how you will carry out your experiment. Write your method in a series of numbered steps. Include any equipment required and how to reduce any risk in the experiment. You can also include a diagram of the equipment setup. Ask your teacher to check your method.

## Conduct

1 Write three success criteria that you could use to determine the effectiveness of your method.
2 Conduct your investigation.
3 As you work through your method, note your observations and ideas for improvements to your inquiry activity.

## Improve

Describe how you can improve your separation method. Use the notes that you made during the experiment to help you.

## Discussion

Copy the table below into your notebook and write your three success criteria in the first column. Use your success criteria to evaluate the effectiveness of your separation method. Describe how well you were able to achieve this. Include observations as evidence.

| Success criteria for separation method | Comments |
|---|---|
| | |
| | |
| | |

# 7.10 Separation techniques used by First Nations Australians

## Lesson overview

**Learning intention**

To understand how groups of First Nations Australians use separation techniques

**Success criteria**

**SC 1:** I can describe ways that groups of First Nations Australians separate mixtures including hand picking, winnowing, yandying, sieving and filtering.

**SC 2:** I can describe how First Nations Australians use specific products from separation techniques.

First Nations Australians possess a unique knowledge system that has been developed over many thousands of years. Guided by a deep interaction with the Australian environment and the natural resources available in place, their skills and practices can and have contributed to modern understandings of ecology and sustainability. A key example is the separation techniques used by First Nations Australians (Figure 7.10.1), which maximise the use of natural materials to produce substances that are useful in many areas including nutrition, health and hygiene.

In this lesson you will learn how groups of First Nations Australians use separation techniques including hand picking, winnowing, yandying, sieving and filtering.

| SC 1 | I can describe ways that groups of First Nations Australians separate mixtures including hand picking, winnowing, yandying, sieving and filtering |
|---|---|

**FIGURE 7.10.1** Seeds can be separated from waste material by techniques such as yandying and winnowing.

First Nations peoples in Australia use numerous separation techniques in the production of foods, clean water and medicines. These techniques require in-depth knowledge of the properties of the substances in each mixture, such as their density, colour, shape, solubility and boiling point. They also rely on natural materials to create the necessary equipment.

Let's take a closer look at some of the separation techniques used by First Nations Australians.

## Hand picking

Hand picking is an effective method for separating materials that are large enough to be identified – visually or by feel – and handled. Specifically, it is used either to separate different types of food materials from each other or to separate the useful parts of a harvest, like seeds or fruits, from waste materials such as stalks, leaves and bad fruit (Figure 7.10.2).

**FIGURE 7.10.2** Materials that are visually different, like this range of seeds and berries gathered in the Northern Territory, can be separated using hand picking.

The Aṉangu people in Central Australia, for example, use hand picking to gather bush tucker, including bush tomatoes (*Solanum centrale*). Ripe fruits are removed from the plant, leaving others to mature for future harvesting.

## Winnowing

Winnowing separates lighter objects, like husks or seed shells, from heavier or denser materials such as the seeds themselves (Figure 7.10.3). Before the winnowing takes place, seed pods are crushed or beaten to release the seeds, leaving a mixture of seeds, pods, husks and small sticks. This mixture is placed in a container called a koolamon and then thrown in the air.

FIGURE 7.10.3 Winnowing to separate rice from its husk is the same process used by First Nations Australians to separate seeds and pods.

The lighter materials will get blown away, but the heavier items will fall back into the container to be collected. Koolamons are containers used for carrying and storing various items – including food, water, and tools – which distinguishes them from the yandy (discussed in the next section).

Winnowing is employed by various First Nations groups to process seeds for food, including the Alyawarre people who inhabit traditional lands spanning over 46 000 kilometres in the region now recognised as the Northern Territory.

## Yandying

Yandying is like winnowing because it is used to extract heavier, useful materials from lighter waste materials (Figure 7.10.4). The mixture is placed in a curved wooden container that is raised at one end and then shaken in a deliberate, back and forth motion. The combination of this applied force, gravity and the friction generated between the materials and the container causes the denser particles to fall to the lower end of the yandy while the less dense (normally larger) objects remain higher up.

FIGURE 7.10.4 Traditional wooden yandies

Yandying has widespread use across Australia but the term 'yandy' is thought to originate from the Yindjibarni people from the northwest of what is now recognised as Western Australia.

## Sieving and filtering

Sieving works in a similar way to a net and the tool used often resembles a basket, which has gaps of the size required to trap solid materials or objects. Filtering, on the other hand, works on a smaller scale, where soluble materials pass through paper or fabric to leave insoluble materials behind. This process is often used by First Nations Australians to extract harmful **toxins** from seeds and leaves so that they are edible and useable.

**KEY TERM**

**toxin** a poisonous substance

**SC 1 CHECK YOUR UNDERSTANDING**

Explain how First Nations Australians use yandying.

**SC 2** I can describe how First Nations Australians use specific products from separation techniques

First Nations Australians use a range of separation techniques to produce useful products. These processes do not always produce pure substances; the products may still have more than one component but there will be fewer components mixed. Berries that have been filtered to remove toxins still exist as a mixture of substances, but separation of the toxin has made them useful: in this case, safe to eat.

## Safe water

If you drink muddy water through the cone of a flowering honeysuckle (banksia), the dirt and other substances will be filtered out by the cone (Figure 7.10.5). The Gunditjmara peoples of what is now recognised as southwestern Victoria use this technique to drink safely from undrinkable water.

FIGURE 7.10.5 A banksia cone in flower. You can see how the structure of the flower resembles a filter.

## Essential oils

Some of the most common ways in which First Nations Australians use essential oils include the following.

- Medicine—for example, eucalyptus oil is used to relieve coughs and colds, while tea tree oil is used to treat skin infections.
- Insect repellent—essential oils such as citronella, lemon myrtle and eucalyptus are used to repel insects and other pests.
- Rituals—sandalwood oil is used in sacred ceremonies and eucalyptus oil is used in smoking ceremonies (Figure 7.10.6).

**FIGURE 7.10.6** Smoking ceremony at the Darwin Festival in 2022

## Seeds

Seeds are a major source of nutrition. For some First Nations communities, over 30 different types of seeds may be harvested, including black wattle and mulga seeds, to provide the essential nutrients for a balanced diet (Figure 7.10.7). The seed pods first need to be separated from the trees and bushes during harvesting. Next, the seeds must be separated from the pods and husks, which are inedible. In some cases, further separation techniques are also used to remove harmful substances from the seeds.

**FIGURE 7.10.7** Wattle seeds require separation from their seed pods and other waste material before consumption.

## Kakadu plum

The Kakadu plum (*Terminalia ferdinandiana*) has been an important bush food for First Nations Australians in northern Australia for many thousands of years (Figure 7.10.8). It also goes by a number of other regional names including the gubinge, the kabiny or the murunga. Known for its exceptionally high vitamin C content, the Kakadu plum is considered to be the richest natural source of this essential nutrient in the world. In traditional First Nations medicine, it is also used to treat colds and support the body's immune system, due to its antibacterial properties. The fruit and seeds can be eaten raw, while the sap can be separated to treat skin conditions and wounds.

**FIGURE 7.10.8** The Kakadu plum, found in northern parts of what are now recognised as Western Australia, the Northern Territory and Queensland

## Soap

The red ash tree (*Alphitonia excelsa*) contains a chemical called saponin in its leaves that can be used as soap (Figure 7.10.9). It can be separated by simply rubbing the leaves in your hands with water. The friction caused by the movement of your hands breaks down the structures of the leaves and allows the saponin to mix with the water to produce a soap lather, which can be used for washing.

**FIGURE 7.10.9** Leaves of the red ash or soap tree

**SC 2 CHECK YOUR UNDERSTANDING**

What are some of the ways in which First Nations peoples have used the Kakadu plum fruit?

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 List three separation techniques used by First Nations Australians.

2 Explain how purified water is obtained using traditional separation techniques.

3 Describe the process of winnowing and how it is applied to separating grains from chaff.

4 Predict the outcome of using yandying to separate a mixture of seeds and sand.

5 Compare the effectiveness of winnowing and sieving for separating grains from chaff.

# 7.11 Separation techniques in industry

## Introduction

Separation techniques are essential in various industries to obtain pure substances from mixtures. For example, in the mining industry, separation techniques including magnetic separation are used to extract valuable minerals from ore (Figure 7.11.1). In the food industry, techniques like filtration and centrifugation are used to process products like milk and juice. In this lesson, you will investigate how different separation techniques are used in industry and evaluate their effectiveness.

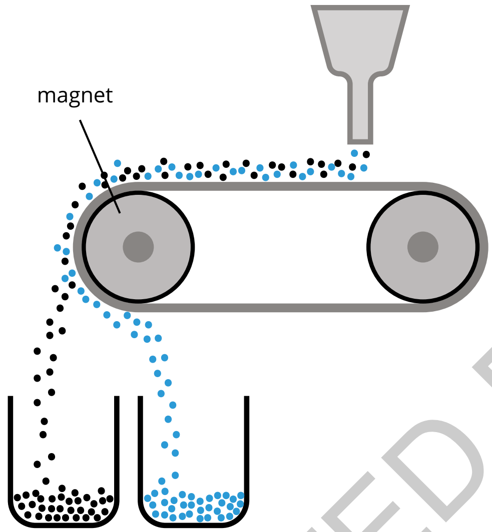



**FIGURE 7.11.1** Industrial magnetic separation separates a magnetic material from a non-magnetic material.

### Learning intention

To understand how separation techniques are used in industry

### Success criteria

**SC 1:** I can use reliable information sources to research and investigate industrial separation techniques.

**SC2:** I can evaluate the use of industrial separation techniques.

## Background

Separation techniques are methods used to separate mixtures into their individual components. These techniques are selected based on the physical properties of the substances in the mixture, such as particle size, solubility, density, boiling point or magnetic properties.

## Aim

To investigate and evaluate the use of separation techniques in industry

## Plan

Identify the separation technique you will investigate. Consider how you will find reliable information and how you will present your findings. Use a variety of sources, such as websites, books and articles.

## Design

1. Choose an industry that uses separation techniques (e.g. mining, food processing, pharmaceuticals).
2. Identify one specific separation technique used in that industry.
3. Decide how you will present your findings (e.g. report, presentation, poster).

## Conduct

1. Use websites, books and articles to research and gather information.
2. Research and take notes on the chosen separation technique, including its purpose and the processes involved in it.
3. Evaluate the effectiveness and efficiency of the separation technique. Is all the present material separated and collected after the separation technique has been performed?
4. Consider the environmental impact and cost of the separation technique. What resources does it use and what waste does it produce?

## Improve

1. Review your notes and identify any gaps in your information. Have you addressed the purpose, process steps, effectiveness, environmental impact and cost of this technique?
2. Look for additional sources to fill in the gaps.
3. Ensure that your information is reliable, up-to-date and accurate.
4. Consider different perspectives and potential improvements to the separation technique.

## Discussion

1. Assess the reliability of your sources. Consider the credibility of the author/publisher and the publication date.
2. Reflect on what you have learned and the impact this separation technique has on people and the environment.

# 7.12 Removing water pollution by separation

## Introduction

Water pollution is a significant environmental issue that affects ecosystems and human health. Pollutants can come from various sources, such as industrial waste, agricultural run-off and household chemicals. For example, oil spills can contaminate water bodies, harming marine life and making the water unsafe for human use (Figure 7.12.1).

In this inquiry activity, you will investigate how water becomes polluted and explore methods to remove impurities using separation techniques.

**Learning intention**

To be able to investigate a method for solving a water pollution problem

**Success criteria**

**SC 1:** I can model how water becomes polluted.

**SC 2:** I can attempt to remove impurities from water by applying suitable separation techniques.

**FIGURE 7.12.1** An oil spill in the ocean, showing the impact of water pollution

## Background

Water pollution occurs when harmful substances contaminate water bodies, making the water unsafe for use. Common pollutants include chemicals, heavy metals, plastics and organic waste. These pollutants can enter water bodies through various means, such as industrial discharge, agricultural run-off and improper waste disposal.

To remove impurities from polluted water, you can apply various separation techniques based on the physical properties of the pollutants. Common separation techniques include filtration, decantation and magnetic separation.

**Scifile**

**Microplastics**
Microplastics are tiny plastic particles less than 5 millimetres in size. They come from various sources, including cosmetics, clothing and plastic waste. Microplastics can be harmful to marine life and may enter the human food chain.

Filtration is used to separate solid particles from a liquid (Figure 7.12.2). You can use a filter paper or a coffee filter to remove soil, sand and plastic pieces from water. The filter traps the larger particles of solid, allowing the smaller liquid particles of clean water to pass through.

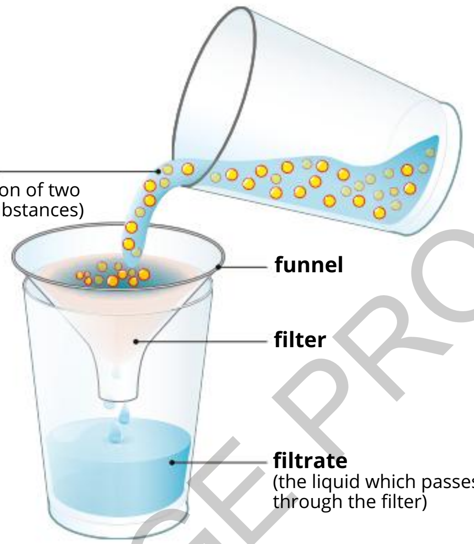



**FIGURE 7.12.2** Filtration separates soil and plastic pieces from water using a paper filter that traps the solid particles.

**KEY TERM**

**immiscible** cannot be mixed together

Decantation can be used to separate **immiscible** liquids, such as oil and water (Figure 7.12.3). You can carefully pour off the oil layer from the water, leaving the water behind. This technique works because oil is less dense than water and floats on the surface.


**FIGURE 7.12.3** Decantation separates oil from water by pouring off the less dense oil.

Magnetic separation is used to remove magnetic particles from a mixture. If your polluted water sample contains magnetic particles (such as iron filings) you can use a magnet to attract and remove them.

SCIENCE IN CONTEXT

## Water treatment plants

Water treatment plants use a combination of separation techniques to purify water and make it safe for consumption. The process typically involves several stages, including coagulation, sedimentation, filtration and disinfection (Figure 7.12.4).

Coagulation involves adding chemicals to the water, which forces small, solid particles to form clumps of larger sized particles. Sedimentation allows the clumps to settle at the bottom of a tank, separating them from the clean water. Filtration removes any remaining particles by passing the water through filters made of sand, gravel or activated carbon. Disinfection involves adding chlorine or other disinfectants to kill harmful microorganisms.

These techniques ensure that the water is free from pollutants and safe for drinking. Water treatment plants play a crucial role in providing clean water to communities and protecting public health.

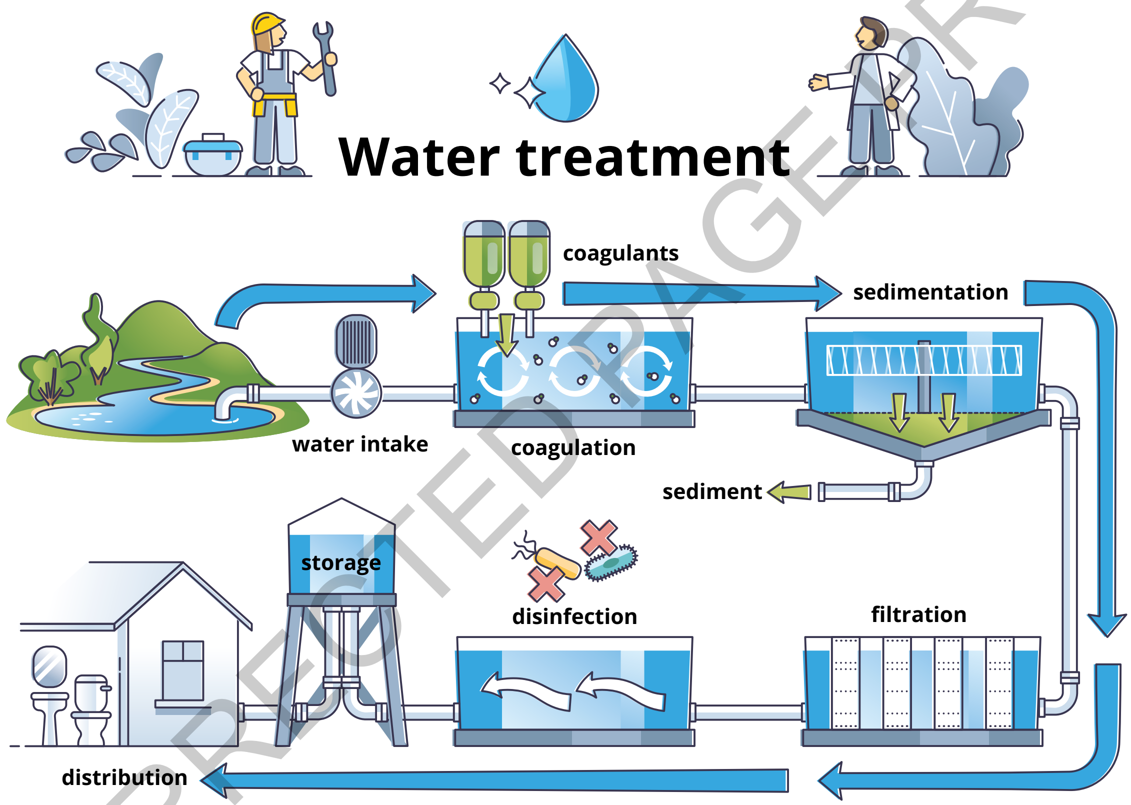



**FIGURE 7.12.4** Water treatment steps include coagulation, sedimentation, filtration and disinfection before distribution to homes.



## Aim

To model water pollution by creating a simulated polluted water sample. Then to use separation techniques to clean the water and remove all of the pollutants

## Apparatus

- clean water
- soil or sand
- cooking oil
- food colouring
- small pieces of plastic (e.g. plastic beads)
- clear container

## Method

1 Add approximately 50 mL water to a clear container.
2 Add 1 teaspoon of soil or sand to represent sediment pollution.
3 Add 5–10 mL of cooking oil to represent oil pollution.
4 Add a few drops of food colouring to represent chemical pollution.
5 Add small pieces of plastic to represent plastic pollution.

## Plan

Plan how you will carry out your experiment to separate the impurities from the water. Write your method in a series of numbered steps. Include any equipment required and how to reduce any risk in the experiment. You can also include a diagram of the equipment setup. Ask your teacher to check your method.

## Design

Decide how you will measure and record how effective your separation techniques were at cleaning the water sample.

## Conduct

Conduct your investigation ensuring that you follow all the safety procedures you identified. As you work through your method, note your observations and ideas for improvements to your method.

## Improve

Describe how you can improve your separation method.

## Discussion

1 Name three common pollutants that can contaminate water.
2 Describe the process of decantation and how it separates mixtures.
3 Predict what would happen if you used magnetic separation to remove plastic pieces from water.
4 Compare the effectiveness of filtration and decantation for removing impurities from polluted water.

# 7 Solutions and mixtures

## Topic summary

The key concepts included in this topic are:

- Pure substances contain particles from only one substance whereas mixtures are made up of two or more substances.
- Soluble substances form solutions when dissolved in a solvent.
- The concentrations of a solute will affect its properties.
- Insoluble substances form suspensions when added to a liquid.
- Temperature affects the rate of dissolving solutes into solvents.
- Methods of separating substances in mixtures can include filtration, evaporation and distillation.
- Separation techniques play a major role in industry and the home.
- First Nations Australians use various separating techniques to produce useful products.



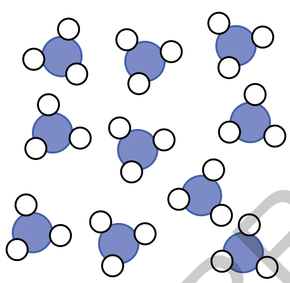
## Review questions

The following questions will assess your success in achieving the learning intentions for this topic.

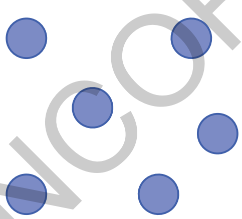
### Remember

**1** Are the substances shown elements, compounds or mixtures?

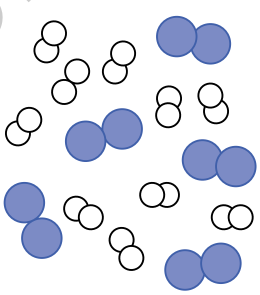
**a**



**b**



**c**



### Understand

**2** Select which of the following substances are pure substances. Note: There may be more than one correct answer.

**A** tap water
**B** cotton fabric
**C** a gold bar
**D** steam coming from a kettle

**3** A student conducts an experiment to test the solubility of salt, sand and oil in water.

**a** Describe the observations that would indicate that a substance is soluble.
**b** Predict the observations for each substance when mixed with water.

### Apply

**4** A student has table salt and water and wants to design experiments to test the effect of temperature on how fast salt dissolves in water.

Describe a method to complete these investigations.

**5** Describe how First Nations Australians might use yandying to separate seeds from sand.

6 Two identical coffee cups, X and Y, contained the same volume and temperature of coffee. A student added one teaspoon of sugar to cup X and three teaspoons of sugar to cup Y.

Define 'concentration' and select which coffee cup has the lowest concentration of sugar.

## Analyse

7 A student pours concentrated cordial into a glass of water. The mixture appears clear.

- a Classify the final mixture as a solution or a suspension.
- b Define the concentrated cordial as soluble or insoluble.
- c The glass of cordial mixture sat on a shelf for a week. The student observed that crystals had formed on the glass. Identify what has occurred and explain your reasoning.

8 Compare and contrast the use of distillation versus evaporation to separate a solid from a liquid.

9 Mixed recycling bins can contain plastic bottles, ice cream containers, glass jars and bottles, metal cans and aluminium cans. Using your knowledge of separation techniques, describe the methods that you could use to separate these items.

## Extension: Research and problem-solving

10 Food organics and garden organics (FOGO) is organic waste from both the kitchen and garden such as food scraps, chicken bones, vegetable peel, grass clippings, leaves and dead plants. Many councils collect FOGO in a separate bin, to stop it going to landfill. Instead, FOGO is converted to organic compost on an industrial scale. However, people (intentionally or unintentionally) add contamination in their FOGO bin.

Three common contamination items are: rocks, stickers found on fruit, and metal.

Research how you could go about separating these items from one tonne of organic waste.

## Topic reflection

The learning intentions for this topic are given in each lesson and at the beginning of the topic. Consider how well you have achieved them. Note down any areas that you are confident in, and others where you are not so sure.

# 7 Glossary

**aqueous solution** solution that has water as the solvent

**atom** the smallest unit of an element

**compound** a substance formed when two or more elements are chemically bonded together

**concentrated** description of a solution that has a large amount of dissolved solute compared to the amount of solution

**concentration** the measure of the amount of solute compared to the amount of solvent in a solution

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

**dependent variable** the variable that is being measured in an experiment; it changes as the independent variable changes

**diffuse** the spreading out of particles

**dilute** description of a solution that has a small amount of dissolved solute compared to the amount of solution

**dissolve** break up into tiny particles that are smaller than the eye can see

**distillation** a process that uses evaporation followed by condensation to recover solvents from mixtures

**evaporation** the change of state in which a liquid changes into a gas at the surface of the liquid

**filtrate** liquid that passes through the filter paper

**gaseous** in the form of a gas

**heterogeneous mixture** a mixture that is not consistent throughout

**homogeneous mixture** a mixture that is consistent throughout

**immiscible** cannot be mixed together

**impure substance** a material that is made up of more than one kind of particle

**independent variable** the factor that is changed in an investigation to find out how it affects another factor (the dependent variable)

**insoluble** unable to dissolve in a particular solvent

**mixture** combination of two or more pure substances that can be separated to recover the pure substances

**molecule** two or more atoms that are joined together to form a small, separate particle

**non-aqueous solution** solution that has a liquid other than water as the solvent

**particle** tiny parts of matter; includes atoms and molecules

**particle model** representation used to help describe and explain the behaviour of particles in solids, liquids and gases

**particle theory** theory that states that all matter consists of tiny particles that are constantly moving

**prediction** a statement about the relationship between two variables, which can often be tested experimentally; an 'educated guess'

**pure substance** a material that is made up of only one type of particle

**residue** solid left in the filter paper after filtration

**saturated solution** a solution that contains as much dissolved solute as possible

**solubility** a measure of the amount of the solute that can dissolve in the solvent

**soluble** able to dissolve in a particular solvent

**solute** a substance that dissolves to make a solution when it is mixed into another substance

**solution** a mixture in which one substance is dissolved in another

**solvent** a substance that dissolves another substance

**substance** material that has physical properties; a solid, liquid or gas

**supersaturated solution** a solution that has more solute dissolved than would normally dissolve at that temperature

**suspension** mixture in which a substance will not dissolve in another and separates out if left to stand

**toxin** a poisonous substance

**vapour** matter that has been produced by evaporation from a liquid; the term vapour can be used to describe a pure gas, as in water vapour in the atmosphere, or a mixture which contains a combination of gas and small droplets of liquid

TOPIC 8

# Systems in plants and animals

Multicellular organisms use coordination between their cells, tissues and organs to create systems that allow them to live in their environments. These systems have a vital role in sustaining the life of the organism.

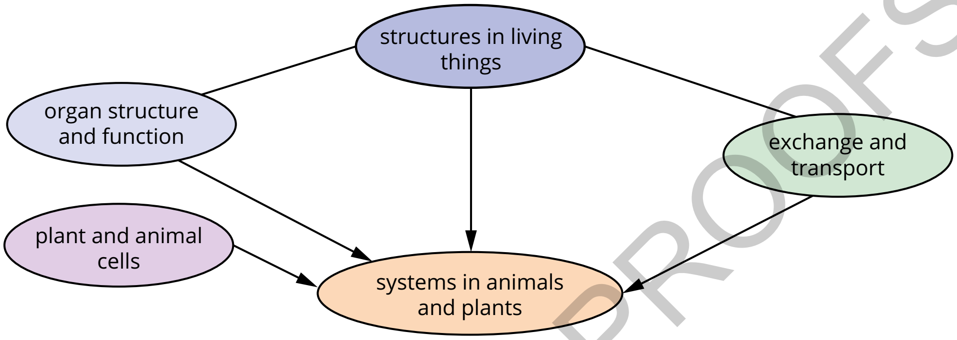
In this topic you will learn about different organs and systems in multicellular animals and plants, noting similarities and differences in their functions. This will include systems for the transport of nutrients, gases, water and blood in organisms.

## Learning intentions

- ☐ To understand the role of organ systems within the human body **xx**
- ☐ To understand how gases are transported in humans **xx**
- ☐ To understand how blood is transported in humans **xx**
- ☐ To be able to use appropriate equipment to observe the structure of an animal's heart **xx**
- ☐ To be able to design, conduct and evaluate a repeatable experiment to test a hypothesis about heart rate **xx**
- ☐ To understand how food is digested and transported in the human body **xx**
- ☐ To be able to model a component of the human digestive system **xx**
- ☐ To understand how waste products are managed in humans **xx**
- ☐ To understand how disorders, diseases, and the removal of organs can affect the body's function **xx**
- ☐ To understand how and why water is transported in a plant **xx**
- ☐ To be able to conduct an investigation to observe the transport of water in a plant **xx**

# 8 Systems in plants and animals

The key concepts that you will use in this topic:

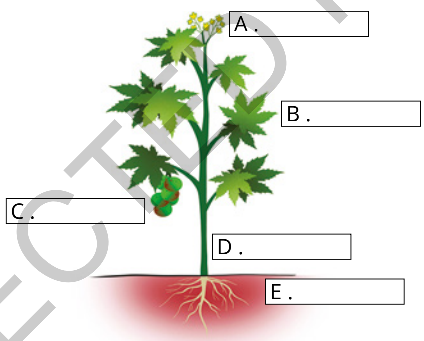



The following prior knowledge questions will help to support your learning in the topic and can be attempted before the first lesson.

## Structures in living things

1 Identify two different systems of the human body.

2 Identify each structure of the plant labelled A–E in the picture below.




## Plant and animal cells

3 Name three types of specialised cells found in humans.

## Exchange and transport

4 Describe how the human lungs function for the process of breathing.

5 Compare the processes by which plants and animals take in water.

## Organ structure and function

6 Name the organs you know that help humans to remove waste products.

7 Describe the function of the heart in the human circulatory system.

# 8.1 Cells, tissues and organ systems

## Lesson overview

Cells carry out all the necessary functions for an organism to survive and reproduce. **Unicellular organisms** that are made up of only one cell can perform all the functions they need to stay alive. **Multicellular organisms**, such as humans, birds (Figure 8.1.1), insects, flowering plants and ferns, have specialised cells that group to form tissues. These tissue groups are specialised and form organs with important functions. For example, some organs enable the organism to take in nutrients and water. Then other organs enable those substances to be circulated throughout the body and to the cells. **Systems** are comprised of organs that work together to keep an organism functioning.

In this lesson you will learn about the roles of the systems that work together to keep an organism alive.

**Learning intention**

To understand the role of organ systems within the human body

**Success criteria**

**SC 1:** I can explain how cells and tissues make up organs.

**SC 2:** I can describe the main functions of the human respiratory, circulatory, excretory and digestive systems.

**SC 1** I can explain how cells and tissues make up organs.

## Specialised cells

Organisms that are multicellular have many **cells** making up the structures that enable the organism to function. They do all the work required for the body to stay alive. They need nutrients, oxygen and water to be able to function. **Specialised cells** are cells that have specific functions. Their shapes, sizes and organelles vary depending on their function (Table 8.1.1). For example, nerve cells in the brain have multiple extensions. Muscle cells tend to be elongated and fat cells are large and round.

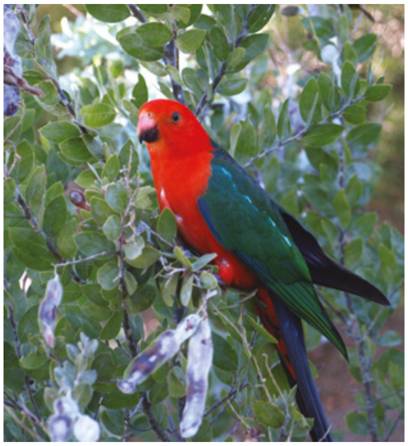
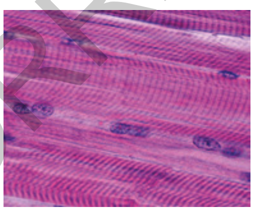
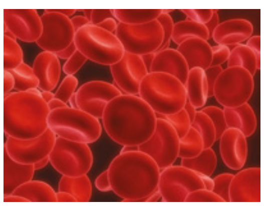
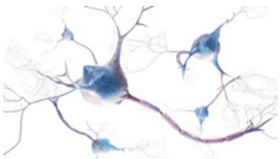


**FIGURE 8.1.1** An Australian male king parrot and the wattle tree where it is perched are both multicellular organisms

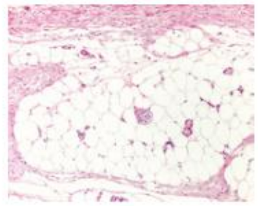
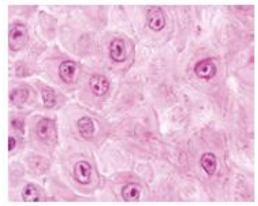
**TABLE 8.1.1** Specialised cells of the human body

| Specialised cell | | Structure and function |
|---|---|---|
| Skeletal muscle cells |  | Skeletal muscle cells attached to bones via tendons have striations (stripes) and contract to move bones for body movements. |
| Red blood cells |  | Red blood cells have a flexible disc shape that allows them to transport oxygen and also squeeze through blood vessel walls in single file. |
| Nerve cells |  | Nerve cells can conduct electric currents along their long branching extensions to other cells or tissue. |

**KEY TERMS**

**cell** the building blocks of all living things

**specialised cell** cell that has specific structures to allow it to perform specialised functions

| | | |
|---|---|---|
| White fat cells |  | White fat cells have a structure that allows large amounts of energy to be stored for the body. |
| Skin cells |  | Skin cells are tough and waterproof. They form a protective layer around the body and together make up the largest organ. |

**KEY TERM**

**tissue** similar cells grouped together to perform the same function in an organism

## Tissues to organs

**Tissues** are groups of specialised cells that work together and have specific functions. Muscle tissue found in your arms and legs can contract to move your bones (Figure 8.1.2). Plants have xylem tissue that is specialised to transport water from the roots through the stems to the leaves (Figure 8.1.3).

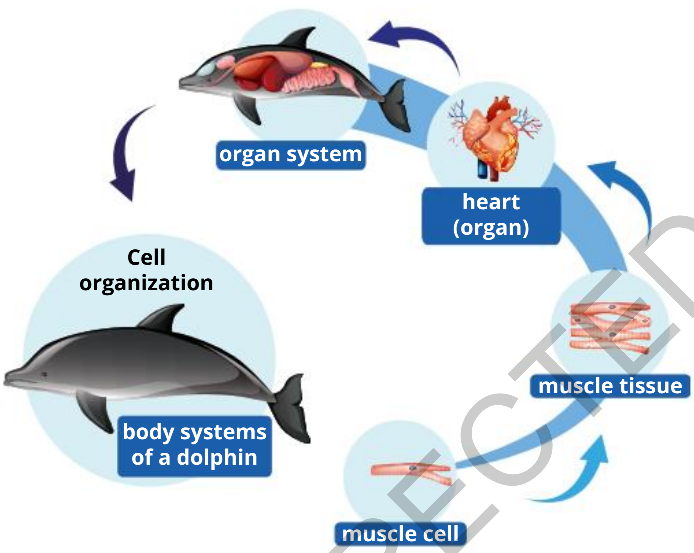



**FIGURE 8.1.2** The levels of organisation in the body of a dolphin

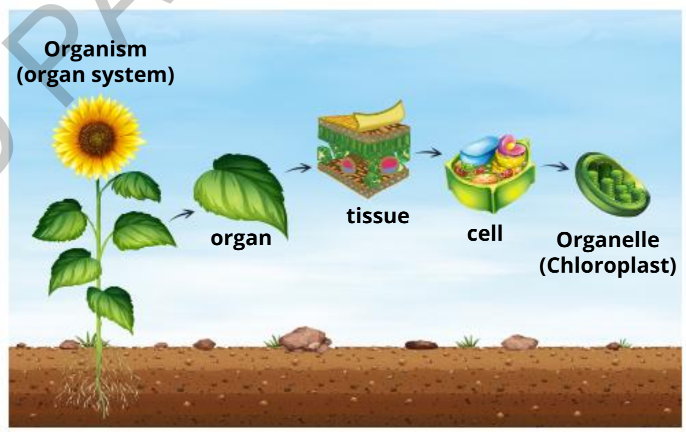



**FIGURE 8.1.3** The levels of organisation in a vascular plant

**KEY TERM**

**organ** a structure that contains at least two different types of tissues that work together to complete a function

**Organs** are groups of tissues that work together to perform a specific function. For example, some parts of the heart are made of a type of muscle tissue called **cardiac** muscle. A different type of tissue covers the exterior of the heart and **coronary** artery tissue is used to supply blood to cardiac muscle. Another example can be found in Figure 8.1.4 and Figure 8.1.5 which show how bone tissue makes up bones.

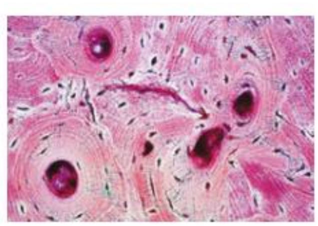


**FIGURE 8.1.4** Bone tissue is structured in concentric rings to provide strength and rigidity

**FIGURE 8.1.5** Bone tissue makes up bones

**SC 1 CHECK YOUR UNDERSTANDING**

What are tissues in the human body made from?

**SC 2** I can describe the main functions of the human respiratory, circulatory, excretory and digestive systems.

Multicellular organisms must have efficient ways of obtaining oxygen, food and water, getting rid of wastes and transporting all substances around the body. **Organ systems** are made of organs that work together to perform a specific task in keeping the organism alive. For example, the heart and blood vessels take essential substances to all cells of the tissues in the body and take away the waste substances that the cells produce. There are many organ systems that allow the human body to function. Some examples of systems include the respiratory, circulatory, digestive and excretory systems (Figure 8.1.6).

**KEY TERM**

**organ system** collection of two or more interconnected organs working together for a collective purpose

## The respiratory system

The **respiratory system** takes oxygen gas from the air we breathe and removes the waste gas (carbon dioxide) which we breathe out. Oxygen is essential for healthy functioning of cells. The major organs in the respiratory system include the mouth, nose, trachea and lungs.

## The circulatory system

The **circulatory system** sometimes called the transport system, is responsible for moving substances such as oxygen, carbon dioxide and glucose, to and from cells. The major organs in the circulatory system include the heart, blood vessels and blood.

## The digestive system

The **digestive system** converts food into nutrients that the cells can use. Food that is taken into the body must be broken down (digested) into smaller and smaller particles to be carried in the bloodstream. The major organs in the digestive system include the mouth, oesophagus, stomach, small intestine and large intestine.

## The excretory system

The **excretory system** removes waste from the cells that would otherwise become toxic and could cause cell death. The main organs in the excretory system include the kidneys, bladder, and urethra.

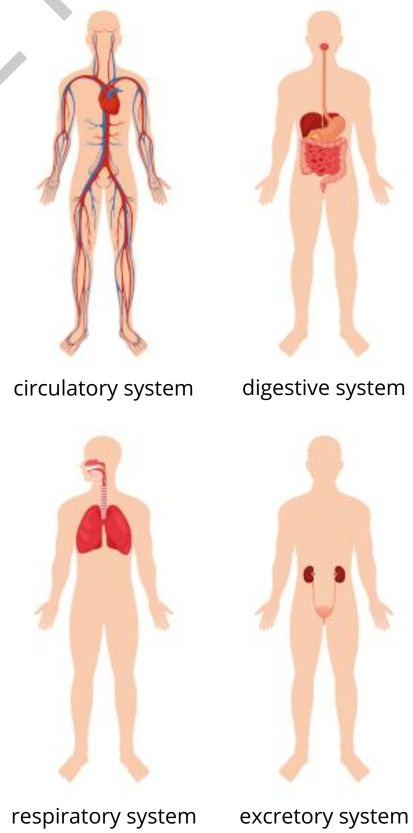



**FIGURE 8.1.6** Four major organ systems in the human body

## Body systems work together

The body systems work together to keep the whole organism alive. An example can be seen in Figure 8.1.7 where organs of the circulatory and respiratory systems work together to supply oxygen and remove carbon dioxide from the human body.

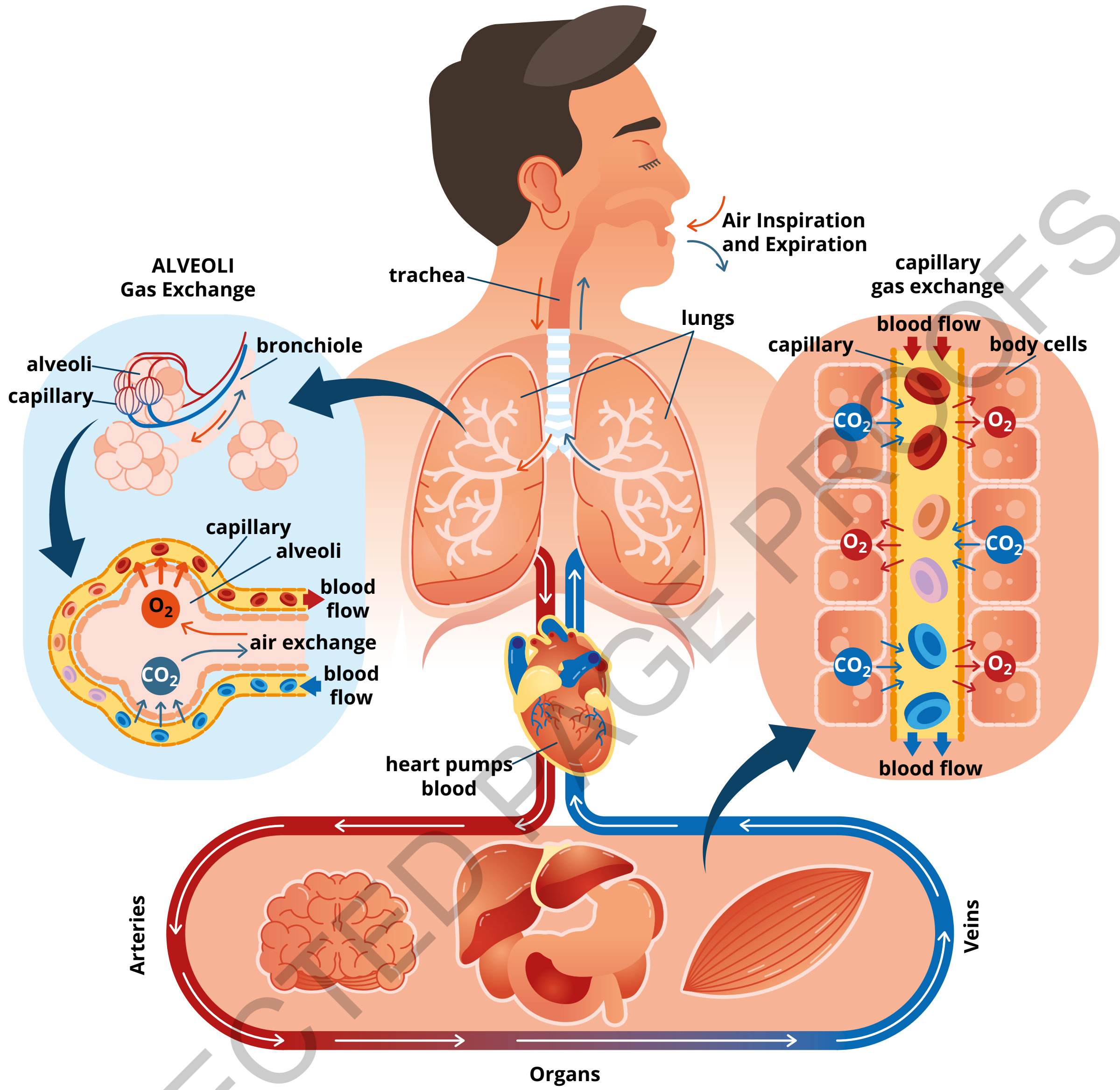



**FIGURE 8.1.7** The circulatory and respiratory systems with their organs work together to supply oxygen to the body.

**SC 2 CHECK YOUR UNDERSTANDING**

Identify the main function of the human respiratory system.



## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 Arrange these terms in order of size from smallest to largest: systems, cells, organs, tissues.

2 Name four main organ systems in the human body.

3 Explain how cells and tissues make up the structure of organs.

4 Describe how the digestive system and circulatory system work together to nourish the body.

5 Compare the roles of the circulatory and respiratory systems.

# 8.2 Transport of gases

## Lesson overview

The respiratory system provides the oxygen that all cells in the body need. Cells must have oxygen and glucose to undergo a chemical reaction called cellular respiration. This process produces energy for all cell functions. Cellular respiration also produces carbon dioxide as a waste product. The respiratory system removes this toxic waste from the body.

In this lesson you will learn about the role of the respiratory system and the structures used for gas exchange in and out of the lungs when you breathe.

**Learning intention**

To understand how gases are transported in humans

**Success criteria**

**SC 1:** I can describe the structure and function of the trachea, bronchi, bronchioles and alveoli

**SC 2:** I can explain the mechanism for inhalation and exhalation of air

**SC 1** I can describe the structure and function of the trachea, bronchi, bronchioles and alveoli.

The main function of the respiratory system is to deliver **oxygen** to the bloodstream. It does this by taking air in through the mouth and nose, delivering it to the **lungs** and then into the blood. Oxygen is essential for **cellular respiration** and the functioning of all body cells.

You can learn more about the structure and function of each part of the respiratory system in Figure 8.2.1.

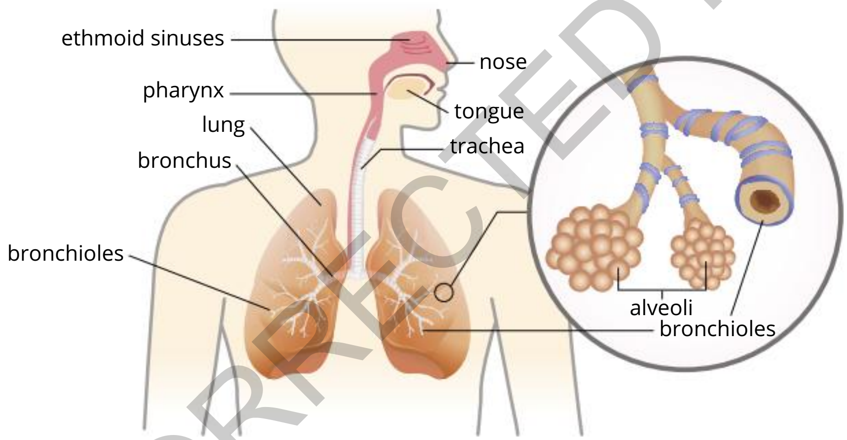



**FIGURE 8.2.1** The human respiratory system is made up of a series of tubes and air sacs (alveoli).

**KEY TERMS**

**oxygen** a gas that animals, including humans, breathe in from the air and use to help their bodies produce energy

**lung** the organs in the chest cavity where gas exchange occurs

**cellular respiration** a set of chemical processes inside cells that converts nutrients into a form of energy (stored in the chemical ATP) that can be readily used by the body

## Structures and functions of the respiratory system

### Nasal cavity

The **nasal cavity** is an air-filled space behind the nose that connects to the throat (pharynx) (Figure 8.2.1). Here the air is warmed by the body and the lining has tiny hairs and mucous that trap dust and foreign particles to prevent them from entering the airways.

**KEY TERMS**

**trachea** the tube that carries air from the nose and mouth into the chest cavity
**bronchi** two tubes formed by the division of the trachea to reach each lung
**bronchiole** small tubes formed by the division of the bronchi inside each lung
**alveoli** tiny air sacs in the lungs where oxygen from the inhaled air enters the bloodstream and where carbon dioxide from the bloodstream is removed into the exhaled air
**gas exchange** one gas moves in and another moves out

## Trachea

The **trachea** is also known as the windpipe. It is a strong but flexible tube that has tiny internal hairs to trap dust. Air travels down this tube from the pharynx to each bronchus (Figure 8.2.2).

## Bronchi and bronchioles

The trachea has two branches, the **bronchi** (singular: bronchus) that are the smaller tubes that go right and left to each lung. The tubes of each bronchi get narrower and narrower as they form **bronchioles** inside each lung (Figure 8.2.2).

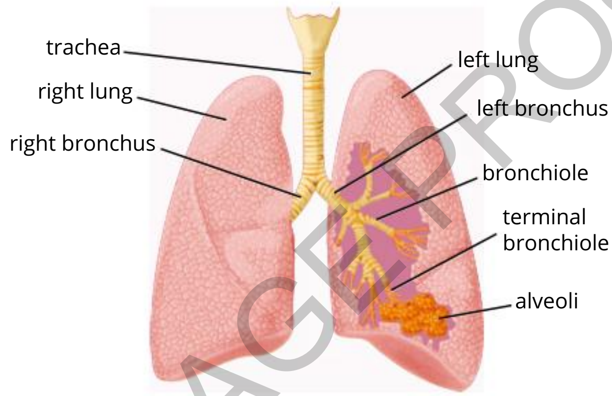



**FIGURE 8.2.2** Bronchioles are the tubes found within the lungs

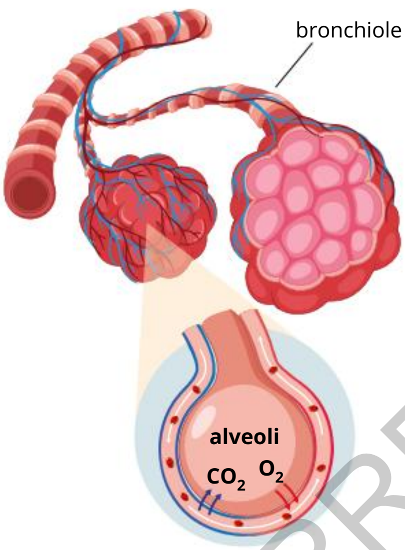



**FIGURE 8.2.3** Alveoli structure and function

## Alveoli

The lungs are not hollow sacs like balloons. They have lobes that are more like sponges filled with airspaces. At the end of the bronchioles are microscopic bunches of air sacs known as **alveoli**. This is where **gas exchange** takes place with the bloodstream. Alveoli are surrounded by blood vessels where oxygen is pushed into the blood and carbon dioxide extracted from it. In Figure 8.2.3, red arrows show oxygenated air that is moving into the bloodstream from the alveoli. Blue arrows show waste carbon dioxide gas that is being drawn out of the blood to be exhaled out of the alveoli.

**SC 1 CHECK YOUR UNDERSTANDING**

Describe how the structure of the bronchi and bronchioles allow air to move deep into the lungs.

**SC 2** I can explain the mechanism for inhalation and exhalation of air.

## The ribs and the lungs

The ribcage surrounds the lungs and protects them. Muscles found in between the ribs are known as intercostal muscles. They assist with raising the ribcage up and down when breathing in and out. The **diaphragm** is a sheet of muscle stretched across inside the body under the ribs. It separates the lungs from the abdomen and works by changing the volume of the chest cavity causing us to breathe in and out.

**KEY TERM**

**diaphragm** an internal sheet of muscle that separates the chest from the abdomen

## Breathing

Breathing involves air moving in and out of the lungs. This allows for a constant supply of oxygen-rich air to enter the alveoli and for the removal of **carbon dioxide** from the blood.

**Inhalation** (breathing in) is the process of air moving into the lungs (Figure 8.2.4a). This occurs when the diaphragm and intercostal muscles contract, which moves the ribcage up and outward. The diaphragm flattens. The volume of the chest cavity increases, causing air to be pulled into the lungs.

**Exhalation** (breathing out) is the process of moving air out of the lungs (Figure 8.2.4b). The diaphragm and the intercostal muscles relax, and this moves the diaphragm up and the ribcage down and inward. The volume of the chest cavity decreases which increases the air pressure in the lungs, causing air to move out of the lungs.

**KEY TERM**

**carbon dioxide** a waste gas that animals, including humans, exhale when they breathe out, produced as a result of their bodys' chemical processes

**Inhalation**

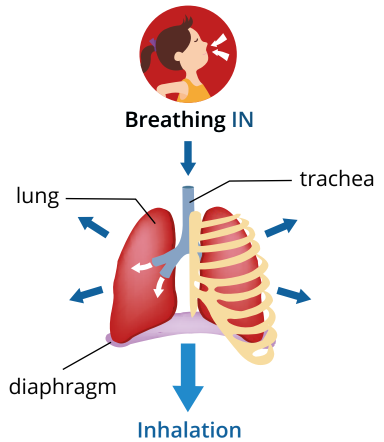



**FIGURE 8.2.4a** Inhalation is the process of air moving into the lungs

**Exhalation**

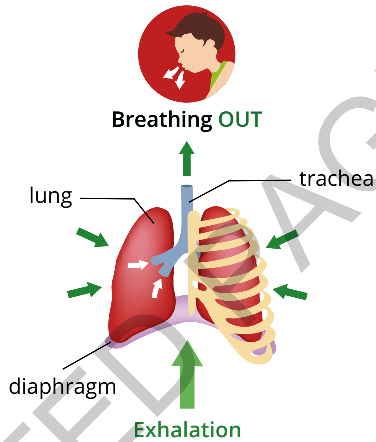



**FIGURE 8.2.4b** Exhalation is the process of air moving out of the lungs

Breathing is an involuntary process; it occurs without thinking about it. For some tasks, such as speaking, singing or holding your breath underwater, breathing can be somewhat controlled.

**SC 2 CHECK YOUR UNDERSTANDING**

Explain how the diaphragm and intercostal ribcage muscles work together during inhalation.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 Identify the four main structures involved in the passage of air into the lungs.

2 Recognise why two gases found in air are important in the human body.

3 Define the term 'gas exchange'.

4 Describe the movement of the diaphragm during the processes of inhalation and exhalation.

5 Explain the role of the alveoli in the respiratory system.

# 8.3 Transport of blood

**Learning intention**

To understand how blood is transported in humans

**Success criteria**

**SC 1:** I can describe the structure and function of the heart in the human circulatory system using a model diagram

**SC 2:** I can explain the movement of blood through the circulatory system

## Lesson overview

The movement of blood around the body is essential for health and survival.

In the human body, the circulatory system is a transport system to move blood from a central pump, the heart, through tubes called blood vessels. Using the example of a city road transport system (Figure 8.3.1) you can think of the city as the central point—like the heart; the road network to and from the central city are like the blood vessels; the cars and buses are the blood; and offices, shops, sports centres, schools and homes are the tissues and organs relying on the transport system.

In this lesson you will explore the circulatory system's role in maintaining an organism's life by transporting blood and the nutrients it carries.

**FIGURE 8.3.1** A city road transport system is somewhat like the system of vessels that carry blood around the body.

**SC 1** I can describe the structure and function of the heart in the human circulatory system using a model diagram.

## The flow of blood in the human body

The human circulatory system has a major function to transport oxygen and nutrients to cells and to remove wastes such as carbon dioxide.

In humans, the heart is a four-chambered organ that pumps blood collected from the body to the lungs, and then from the lungs back to the heart and onwards to the rest of the body (Figure 8.3.2). The blood that returns to the heart from around the body is **deoxygenated** because oxygen has been used by cells for cellular respiration. The heart pumps this deoxygenated blood to the lungs where it picks up oxygen again as it travels around the alveoli. The freshly **oxygenated** blood flows back to the heart and is then pumped around the body (Figure 8.3.3). The structure of the heart allows separation between deoxygenated and oxygenated blood.

A simplified model of the heart structure can be drawn as a diagram such as in Figure 8.3.2.

**KEY TERMS**

**deoxygenated** blood that is low in oxygen and high in carbon dioxide content

**oxygenated** blood that is high in oxygen and low in carbon dioxide content

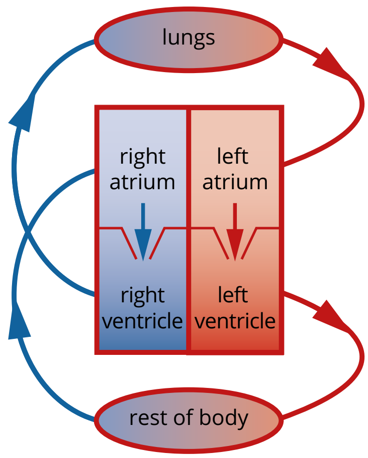



**FIGURE 8.3.2a** This simplified model shows the flow of blood through the four chambers of the human heart.

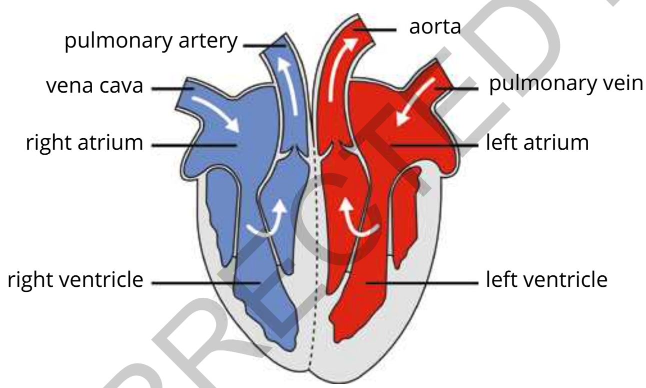



**FIGURE 8.3.2b** This diagram is a more realistic model for the structure of the human heart. Pulmonary refers to blood vessels to and from the lungs.

## How the heart works

The heart is made of cardiac muscle tissue. This special type of muscle does not get tired like the skeletal muscles so it can continuously contract on average of 72 times per minute for a lifetime. The heart has four chambers: two small chambers, the right and left **atria** (singular: **atrium**), and two larger chambers, the right and left **ventricles**. The right and left sides are kept separate by a thick wall of muscle (Figure 8.3.2b).

There are **valves** between the atria and ventricles, and between the ventricles and the arteries they pump into, to prevent back flow of blood.

**KEY TERMS**

**atria** the upper chambers that take blood into the heart

**ventricle** the lower chambers of the heart that pump blood to the body or lungs

**valve** flaps in the heart and blood vessels that control the direction of blood flow, preventing blood from flowing backwards

**KEY TERMS**

**vena cava** the large vein that carries deoxygenated blood from the body to the heart
**pulmonary vein** the veins that bring oxygenated blood from the lungs to the heart
**pulmonary artery** the arteries that carry deoxygenated blood from the heart to the lungs
**aorta** the largest artery in the body, carrying oxygenated blood from the heart to the rest of the body

In Figure 8.3.3 you can follow the direction of blood flow through the heart and lungs, and find the names of the major blood vessels involved—**aorta**, **vena cava** and the **pulmonary vessels**.

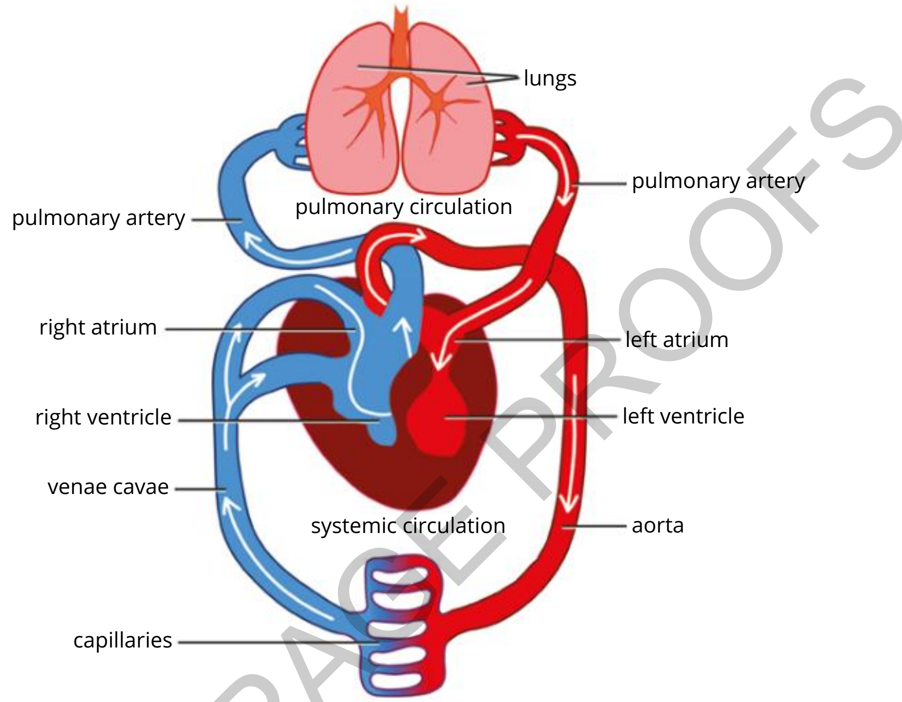



**FIGURE 8.3.3** A model of the blood flow between heart, lungs and the rest of the body.

**SC 1 CHECK YOUR UNDERSTANDING**

Name the parts of the human heart on a simple diagram.

**SC 2** I can explain the movement of blood through the circulatory system.

**KEY TERMS**

**plasma** (biology) clear yellowish liquid part of blood that carries blood cells and other substances such as nutrients and wastes
**platelet** a small cell fragment in blood that helps with clotting to prevent excessive bleeding when there is an injury
**red blood cell** a cell in the blood that carries oxygen from the lungs around the body

Blood consists of a clear yellowy liquid called **plasma**, blood cells and cell fragments called **platelets**. It also carries substances such as nutrients and wastes that are dissolved in the plasma (Figure 8.3.4). **Red blood cells** carry oxygen from the lungs to every cell in the body and they give the blood its red colour (Figure 8.3.5).

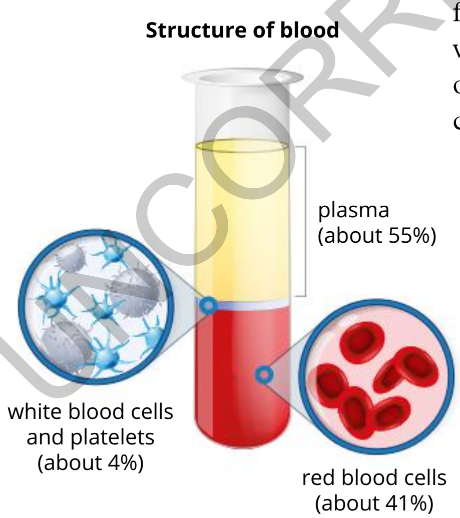



**FIGURE 8.3.4** Components of human blood

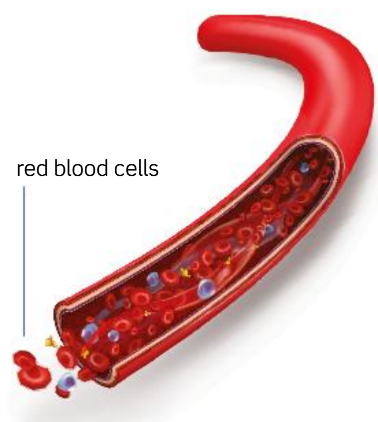



**FIGURE 8.3.5** A blood vessel carries blood full of microscopic red blood cells

The blood is carried to various parts of the body through a double circulatory system of blood vessels. This means one pulmonary circuit to and from the lungs, and another systemic circuit that loops through the rest of the body. There are three main types of blood vessels.

1. **Arteries** carry blood away from the heart to other areas of the body. They have thick muscular walls and are under high pressure from the heart to help push the blood along, even to the farthest parts of the body.
2. **Veins** carry blood toward the heart from other areas of the body. They are less muscular than arteries as they carry blood under less pressure than the arteries. Most veins must carry blood back to the heart against gravity as blood moves from the feet to the heart. They contain internal valves to help prevent backflow of blood.
3. **Capillaries** are delicate and narrow, typically only 5 to 10 **micrometres (μm)** in diameter. They have very thin walls and are in close contact with cells to allow the exchange of substances. Capillaries form a microcirculation system between arteries and veins and are used to deliver oxygen, glucose and other nutrients to the cells. They also carry wastes away from cells throughout the body (Figure 8.3.6).

**KEY TERMS**

**artery** a blood vessel with thick muscular walls that carries blood away from the heart to different parts of the body

**vein** a blood vessel with thinner walls and internal valves that carries blood back to the heart

**capillary** the narrowest type of blood vessels that reach nearly every cell of the body and connect arteries to veins

**micrometre (μm)** measurement of length 10−6 or one-millionth of a metre

## Scifile

### Capillary diameter

Try to imagine the internal size of a capillary vesselnarrower than a human hair. The millimetre space on your ruler would have to be divided into 100 or more parts, that is 5 to 10 m. In the narrowest capillaries, the microscopic red blood cells (diameter 6–8 μm) can only squeeze through one at a time by squashing their disc shape. They can distort their shape because red blood cells that are in circulation have lost their central nucleus.

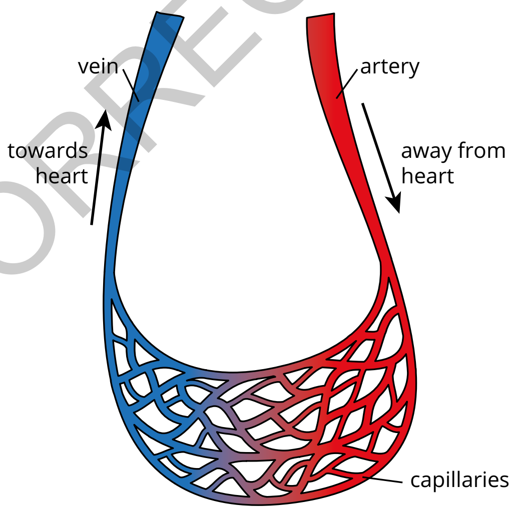



**FIGURE 8.3.6** The diagram shows how arteries and veins connect via the capillaries, and the direction of blood flow to and from the heart

## How the main parts of the human circulatory system work together

1. Heart pumps blood through two circuits: pulmonary (to/from the lungs) and systemic (to/from the body).
2. Heart receives oxygen-rich blood from the lungs.
3. Heart pushes oxygenated blood out through the aorta to circulate around the body.
4. Oxygenated blood travels through arteries to narrow capillaries.
5. Capillaries deliver blood carrying oxygen and nutrients to cells, and collects waste like carbon dioxide.
6. Deoxygenated blood returns to the heart through veins.
7. Heart pumps deoxygenated blood to the lungs to exchange gases, repeating the cycle.

**SC 1 CHECK YOUR UNDERSTANDING**

Explain how veins differ from arteries in structure and function in moving blood around the body.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 Identify the main components of blood.

2 Name the three main types of blood vessels.

3 Compare the functions of the atria and ventricles in the heart.

4 Describe how blood moves from the heart to the rest of the body and back.

5 Suggest why it is an advantage for oxygenated and deoxygenated blood to be separated in the chambers of the heart.

# 8.4 Structure and functions of the heart

## Introduction

In humans, the heart is a four-chambered organ. Like humans, other mammals also have hearts with four compartments. You will be asked to consider if it is ethical to dissect the heart of an animal for your learning; an animal that has already been killed to supply humans with food. **Ethics** in science refers to upholding moral principles and responsible conduct, in brief 'doing the right thing'.

In this practical investigation you will explore the structure and function of a heart by dissecting a sheep's heart (Figure 8.4.1).

### Learning intention

To be able to use appropriate equipment to observe the structure of an animal's heart

### Success criteria

**SC 1:** I can label a diagram to show the components of the heart

**SC 2:** I can infer, from observation, the flow of blood through the left and right chambers of the heart.

**FIGURE 8.4.1** Students dissecting a sheep heart

## Background

In humans, blood that returns to the heart from the body has less oxygen because oxygen has been used by the many body cells during cellular respiration. The deoxygenated blood is circulated to the lungs where it is oxygenated and returns to the heart. The right and left sides of the heart are divided by a thick wall of muscle that separates oxygenated and deoxygenated blood.

Mammalian hearts have four chambers:

- two smaller chambers—the right and left atria
- two larger chambersthe right and left ventricles

The sheep's heart that you will investigate has a similar structure to a human heart, but is slightly smaller.

## Aim

To investigate the structure of the heart and to link components of the heart to their functions

## Prediction

That I will increase my understanding of the structure and function of a four-chambered heart.

## Apparatus

- sheep heart
- scalpel
- forceps
- blunt probe
- disposable gloves
- dissection board

## SAFETY NOTES

- Take care with sharp instruments.
- Wear disposable gloves and safety glasses when handling the heart.
- Wash your hands thoroughly after you have completed the dissection.
- Dispose of all materials as directed by the teacher. Do not place any material in normal rubbish bins.

## Assessment of risk

- Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity

## Method

Before you start the experiment, read the questions in the Discussion. During and immediately after the dissection, make notes in your notebook. You may need these notes to answer the questions later.

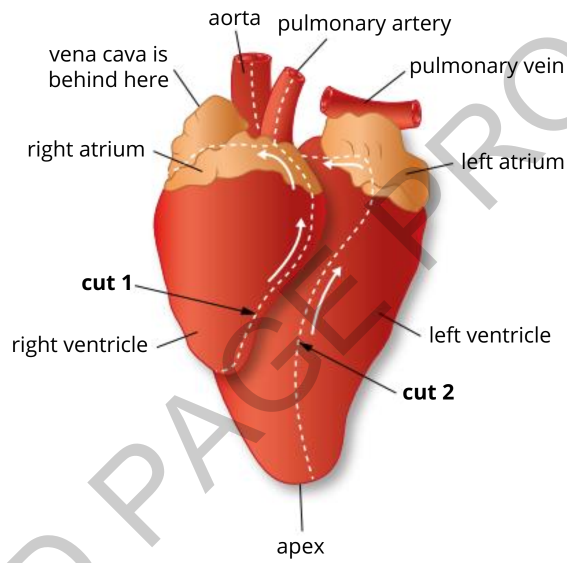



**FIGURE 8.4.2** Structure of a four-chambered heart ready for dissection

1. Position the heart on the dissecting board as illustrated in Figure 8.4.2.
2. Identify, sketch and label a diagram of the external features of the heart, including: right and left atria, right and left ventricles, aorta, vena cava, pulmonary arteries and veins.
3. Apply light pressure to the heart using the palm of your gloved hand, mimicking a slight squeezing motion.
4. Use the blunt probe to explore the entry and exit points of blood vessels for the heart chambers. See Hint
5. Carefully use the scalpel to create cut 1 (Figure 8.4.2). Ensure the blade is directed upward and away from you. As you cut observe the right ventricle wall thickness.
6. Gently spread open the right ventricle to reveal its internal structures.
7. Study the tendons (thick strings) associated with valves (flaps), noting their positions (Figure 8.4.3)
8. Make cut 2 (Figure 8.4.2) to expose the left ventricle and continue the incision upward into the aorta which will be sitting behind the right atrium.
9. Compare the wall thickness of the left ventricle to that of the right ventricle.
10. Locate the valve position at the start of the aorta. Just above these valves, find two small openings that are branches of the arteries supplying the heart. Use the blunt probe to trace the path of these coronary arteries.

### HINT

A blunt probe is very useful to trace blood vessels. Pass the probe through each vessel opening into a heart chamber.

**FIGURE 8.4.3** Tendons and valves exposed in a dissected sheep's heart

## Results

Record notes and diagrams from your experiment into your notebook.

## Discussion

1 How hard was it to compress the heart? What does this mean about the tissues that make up the heart?

2 Compare and explain the thickness and texture of the aorta and the vena cava vessels.

3 Compare the thickness of the walls of the right and left ventricles. Propose a reason for the difference.

4 Describe the purpose of the coronary arteries that you examined in step 10.

5 Analyse and understand from your observations how the valves regulate the flow of blood.

6 Label a diagram of the heart as a pumping system and use arrows to show the path of blood flow through the heart.

7 Describe at least one ethical issue with using dissections to learn about living things. Suggest at least one way to address any ethical concerns.

## Conclusion

Write your own assessment of how much you increased your understanding of the heart's structure and function.

Inquiry activity

**WS** Questioning and predicting
Processing data and information
**DS** Patterns and prediction

# 8.5 Investigating heart rate

### Learning intention

To be able to design, conduct and evaluate a repeatable experiment to test a hypothesis about heart rate

### Success criteria

**SC 1:** I can design a method for a repeatable investigation to test a hypothesis about heart rate and exercise.

**SC 2:** I can conduct a valid investigation by controlling variables.

**SC 3:** I can evaluate the validity of the results and conclusions from an investigation.

**KEY TERM**

**pulse** the regular expansion and contraction of the arteries in response to the heartbeat

## Introduction

One important role of blood is to transport oxygen around the body. This oxygen is used by muscle cells to release energy for the muscles to move. The more energy required, the more oxygen is needed. Therefore, the flow of blood around the body can be related to muscle movement.

In this inquiry activity, you will investigate how exercise affects heart rate.

## Background

Aerobic exercise, or cardio, means 'with oxygen'. It includes activities such as fast walking, jogging, swimming or cycling.

Anaerobic exercise is fuelled by stored muscle energy. It includes intense activities such as sprinting, jumping or weightlifting.

During exercise, your muscles need more oxygen, so your heart rate increases to pump blood around your body faster. The effect on heart activity during exercise can be monitored by measuring the **pulse**, which is normally measured as heart beats per minute. Heart rate can be measured by feeling the pulse of the radial artery in the wrist or the carotid artery in a person's neck (Figure 8.5.1).

**FIGURE 8.5.1** Measuring pulse at the carotid artery

Many sports watches are able to give an instant reading of heart rate (Figure 8.5.2).


**FIGURE 8.5.2** Heart rate data from an app connected to a sports watch

## Aim

To investigate the effect of exercise on heart rate

## Plan

You should decide which aspect of exercise you want to investigate. You could choose one of the following questions to investigate or construct one of your own.

- How much does heart rate change after exercise?
- How long after exercise does it take to return to the resting heart rate?
- Does the speed of running affect the change in heart rate?
- Does the length of running time affect the change in heart rate?
- What techniques can be used to reduce the increase in heart rate while exercising?
- What techniques can be used to return to a resting heart rate after exercise?
- Which has a greater effect on heart rate, push-ups or pull-ups?

GO TO
For support with writing predictions go to Toolkit section x.x.

## Design

Once you have identified a way to investigate the effect of exercise on heart rate, write out a design for your investigation. Include a list of required apparatus.

## Assessment of risk

Ensure you are aware of the risks of this inquiry activity and have considered how safety can be improved before carrying out the activity.

**SAFETY NOTE**

- Write your own safety notes for this inquiry.

## SkillBuilder

### Measuring your pulse

#### Taking the radial pulse

1. Place your index and middle fingers on your wrist as shown.
2. Find the area between the tendons of the wrist and the outside bone. You should now be able to feel your pulse.
3. Count the number of beats for 15 seconds. Calculate the heart beats per minute by multiplying this number by 4.

### Taking the carotid pulse

1. Place the tips of your index and middle fingers on one side of your neck.
2. Find the area between the muscle and your windpipe as shown and press gently. You should now be able to feel your pulse.
3. Count the number of beats for 15 seconds. Calculate the heart beats per minute by multiplying this number by 4.


### Example

Amy counted 17 pulses in her carotid artery in 15 seconds. Therefore, her heart rate is 17 multiplied by 4 which equals 68 beats per minute.

---

## Conduct

Carry out your plan and record the results of your inquiry.

Collect data from other students in the class. Can this data be combined to see if there is a pattern between exercise and heart rate?

## Discussion

1. Was it easy to measure an accurate pulse?
2. What did you find out about the effect of exercise on heart rate?
3. Would it be valuable to gather data from all the class groups?
4. Evaluate the design of your inquiry, including suggesting any improvements that could be made. What design changes would enable the class data to be combined?

GO TO ➤
For support with evaluating validity, go to Toolkit section x.x

## Conclusion

Write a conclusion based on your data.

# 8.6 Digestive system

## Lesson overview

The digestive system breaks down food into simple units which can be absorbed and carried by the bloodstream. This function is the job of a group of organs including the mouth, oesophagus, stomach, small intestine and large intestine.

The proteins, carbohydrates (starches and sugars), and lipids (fats and oils) that you eat are converted by the digestive system into much simpler nutrients. These nutrients from digested food are taken to body cells by the blood of the circulatory system.

In this lesson you will learn about the processes and organs involved in the digestion and transport of food in the human body.

**Learning intention**

To understand how food is digested and transported in the human body

**Success criteria**

**SC 1:** I can describe the main role of the digestive system

**SC 2:** I can explain how the structure of the digestive organs and the specialised cells within them enable them to carry out their function.

**SC 1** I can describe the main role of the digestive system.

The human digestive system is basically a long, muscular tube that starts at the mouth and ends at the anus (Figure 8.6.1). The wall muscles keep ingested food moving from mouth to anus with enough time for digestion along the way. The digestive system uses mechanical (physical) and chemical means to break down different food types so that nutrients can be absorbed.

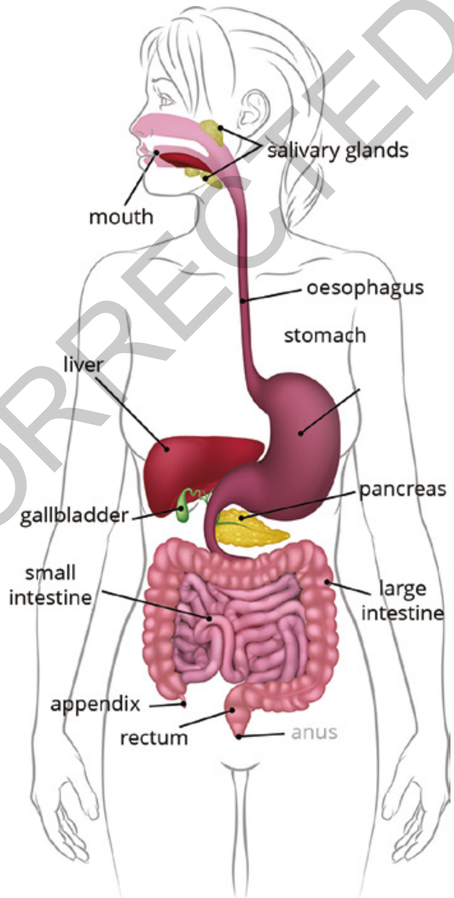



**FIGURE 8.6.1** Structure of the human digestive system

**KEY TERMS**

**villi** folds on the inner lining of the small intestine that increase surface area for absorption of nutrients into the associated blood vessels

**microvilli** microscopic projections on the surface of villi cells

Absorption is the process by which simple nutrients from digested food are taken into the bloodstream. This primarily occurs in the small intestine, where the inner walls are folded into many finger-like projections called **villi** (Figure 8.6.2). Villi increase the surface area for absorption and contain a rich supply of blood vessels that transport nutrients to the rest of the body. On the inner surface of the villi there are even thinner hair-like projections called **microvilli** that further increase nutrient absorption.

Normally, only undigested waste food reaches the large intestine. Water is taken from this waste back into the bloodstream and faeces are formed in the bowel to be eliminated through the anus.

**FIGURE 8.6.2** Photomicrograph of the inner wall of the small intestine. Microvilli are seen as a fuzzy brush-like border along the folded villi surface. Capillaries can be seen in the infoldings of the villi.

**SC 1 CHECK YOUR UNDERSTANDING**

What is the main role of the digestive system?

**SC 2** I can explain how the structure of the digestive organs and the specialised cells within them enable them to carry out their function.

**KEY TERM**

**mechanical digestion** physical breakdown of food into smaller pieces by chewing, softening and emulsification

Throughout the digestive system food is physically broken into smaller pieces. These processes are known as **mechanical digestion**. It begins by softening and chewing in the mouth. The tongue pushes food around the mouth to be softened by saliva and chewed into smaller pieces by the teeth and gums.

Once the food passes down the oesophagus it reaches the stomach. Here strong muscular contractions mechanically churn and mix the food with **enzymes** and acidic stomach juices. In the stomach the food turns into a thick soup, called **chyme**.

After the stomach, the chyme enters the duodenum which is the start of the small intestine. Here mechanical and chemical digestion are completed. A process to **emulsify** fats and oils (lipids) uses bile from the liver and gall bladder. Note that emulsification is a mechanical process (not a chemical change) to break fatty substances into droplets small enough to be transported in the blood.

Mechanical digestion creates smaller food particles with greater surface areas that allow for more efficient **chemical digestion**. Chemical digestion of food occurs when specialised cells in the digestive organs produce enzymes. The enzymes control chemical reactions to produce small molecules that can be absorbed and carried by the bloodstream as nutrients for the cells. An example is the starch carbohydrate in bread, pasta, rice and potatoes that is broken into simple soluble glucose molecules (Figure 8.6.3).

The two types of digestion are compared in Figure 8.6.3.

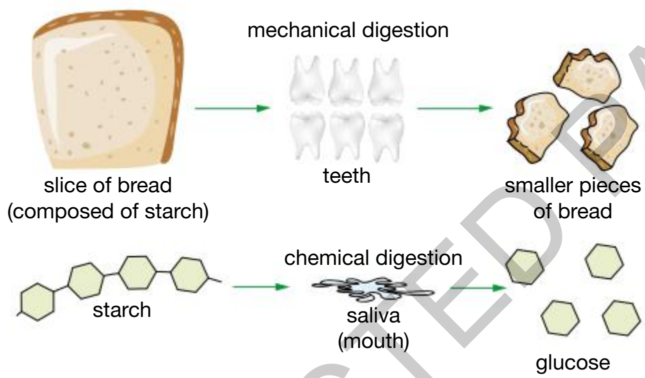



**FIGURE 8.6.3** The digestive system uses mechanical digestion to break food into smaller pieces. Chemical digestion changes complex substances into different, simpler units.

Each food type has specialist enzymes for chemical breakdown. For example, saliva in the mouth contains amylase enzyme to start digestion of starchy foods. In the stomach there are enzymes for digesting proteins that only work in an acidic environment. The acid has the added benefit of killing off bacteria that have entered with the food. In the stomach a soupy mix called chyme is formed. When chyme moves on through a valve into the small intestine, the chemical digestion is completed with a new set of enzymes. The small intestine is also the primary site for nutrients to be absorbed through the villi of the tube wall into the bloodstream (Figure 8.6.4).

**KEY TERMS**

**enzyme** a specialist protein that controls a chemical reaction to change complex food into small molecules

**chyme** soup-like acidic mix of partly digested food in the stomach

**emulsify** mechanical process to split fats and oils (lipids) into smaller droplets that mix with water

**chemical digestion** breakdown of complex food chemicals into simpler units that can be absorbed and carried in the bloodstream

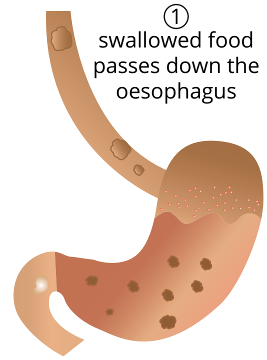



**FIGURE 8.6.4** The digestive system uses mechanical digestion to break food into smaller pieces. Chemical digestion changes complex substances into different, simpler units.

**Scifile**

**Acid in the stomach**

Your stomach has a special lining for protection from its own acid. Each day a healthy lining makes at least 2 litres of hydrochloric acid of about pH 2; a very high level of acidity. The acid is necessary for chemical digestion of protein in food and it also kills most harmful bacteria that have been swallowed with the food.

**SC 2 CHECK YOUR UNDERSTANDING**

Outline the two types of digestion that occur in the human digestive system.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1. Identify the type of digestion that occurs in the mouth.
2. Name the part of the small intestine where most food is chemically digested and absorbed.
3. Why does a strong acid need to be present in the stomach?
4. Explain why the starch molecules in bread have to undergo mechanical and chemical digestion before body cells can use them.
5. Explain why villi are useful in digestion.

# 8.7 Chemical digestion

**Learning intention**

To be able to model a component of the human digestive system

**Success criteria**

**SC 1:** I can set up an experiment that models a component of the human digestive system.

**SC 2:** I can use the model to explain a digestive process.

## Introduction

The chemical activities in living systems require enzymes to function. There are many different types of enzymes within living organisms, each specific to one type of biochemical reaction. Pepsin is an enzyme that controls the digestion of proteins and it is secreted by the stomach lining of most mammals. It functions best at a very low (acidic) pH.

In this experiment, you will investigate the action of pepsin enzyme on the protein of egg white.

## Background

Imagine having lumps of hardboiled egg white floating around in your bloodstream. This would not be healthy at all. The white of chicken eggs is a mix of proteins known as albumen. Proteins are valuable in the human diet, as long as they have been digested first into simpler molecules that can be carried safely by the blood. All food undergoes mechanical and chemical digestion, so that the body can use the nutrients for important biological processes.

The chemical digestion of boiled egg white (albumen) can be modelled outside the body using a commercially available source of pepsin enzyme.

## Aim

To investigate chemical digestion of albumen protein by pepsin enzyme

## Prediction

Refer to the Results data table and predict which tube (A, B, C or D) is most likely to show changes in the cube of egg white. You can discuss this with your teacher and your student group.

## Apparatus

- 4 cubes of hard-boiled egg white (about 1 $cm^3$)
- distilled water
- pepsin solution
- 0.25 M HCl (dilute hydrochloric acid)
- 5 ml graduated pipette or 10 ml measuring cylinder
- 4 test tubes labelled A to D in a rack (if possible use screw top tubes with caps)
- warm water bath or incubator at 35°C for the class

## SAFETY NOTES

- Check if any class members have an allergy to eggs.
- Wear safety glasses while handling the solutions.
- Handle any acid with care.
- Wash your hands thoroughly after you have completed the experiment.
- Dispose of all materials as directed by the teacher. Do not wash chemicals down the sink unless told it is safe to do so.

## Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out the activity.

## Method

Before you start, read ahead and complete answers to questions 1–4 in the discussion, as a class or in your group. During the investigation, make notes in the results table that you have copied into your notebook. You will need these notes to answer further questions.

1. Carefully measure the correct amount of each liquid into test tubes A, B, C, D (Figure 8.7.1).
2. Tap gently on the low side of each tube to mix the liquids.
3. Add a cube of hard-boiled egg white to each tube.
4. Label your group's tubes and place them in the warm water bath or incubator at approximately 35°C (Figure 8.7.2).
5. Check the tubes over 2 to 3 days and record your observations.

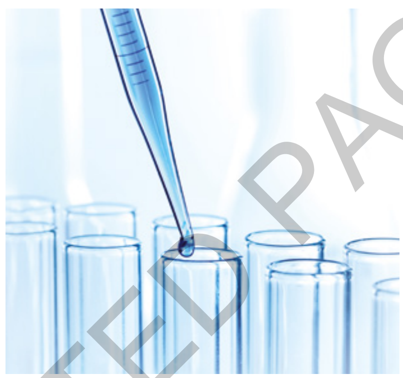


**FIGURE 8.7.1** A graduated pipette is used to add pepsin solution to the tubes.

**FIGURE 8.7.2** The tubes are incubated in a warm water bath.

## Results

Copy the following table into your notebook and use it to record the results.

Observations of the hard-boiled egg white in each tube

| Test tube | Day 1 | Day 2 | Day 3 |
|---|---|---|---|
| A. egg-white + water (5 mL) | | | |
| B. egg-white + pepsin (3 mL) + water (2 mL) | | | |
| C. egg-white + HCl (1 mL) + water (4 mL) | | | |
| D. egg-white + pepsin (3 mL) + HCl (1 mL) + water (1 mL) | | | |

## Discussion

1 List the variables in this experiment under the headings: Independent variable and Dependent variable.

2 What are three experimental factors (controlled variables) you should keep constant?

3 Identify which one of the tubes is being used as a control in this experiment design. That means it is set up to compare if pepsin and/or acid make a difference to the egg white. Or whether egg white changes over time without pepsin or acid.

4 Were your observations in the results table qualitative or quantitative?

5 Explain why a temperature of 35°C was chosen for incubation. Predict how the results might change if the tubes were left at room temperature.

6 Identify the tubes showing the most and the least amount of change to the egg white. Determine the reason for the difference.

7 Suggest a further extension to this experiment that could be investigated.

## Conclusion

Assess how accurate your predictions were for changes to the egg white.

# 8.8 Excretory system

**Learning intention**

To understand how waste products are managed in humans

**Success criteria**

**SC 1:** I can describe the main role of the excretory system

**SC 2:** I can describe the main structure and function of the kidneys

## Lesson overview

Waste is a continuous product of the human body; all body systems use materials and produce waste. The circulatory and respiratory systems work together to remove carbon dioxide waste by exhalation from the lungs. The digestive system passes undigested waste food as faeces through the anus at the end of the digestive tract. However, a different system is needed to remove other toxic wastes from the circulatory system.

In this lesson you will learn about the system that produces urine in order to remove waste products.

**SC 1** I can describe the main role of the excretory system.

To function properly, our bodies need to get rid of waste produced by the cells and transported by the bloodstream. This is the job of the excretory system with its main organs: two kidneys, two ureters, one urethra and a single bladder (Figure 8.8.1).

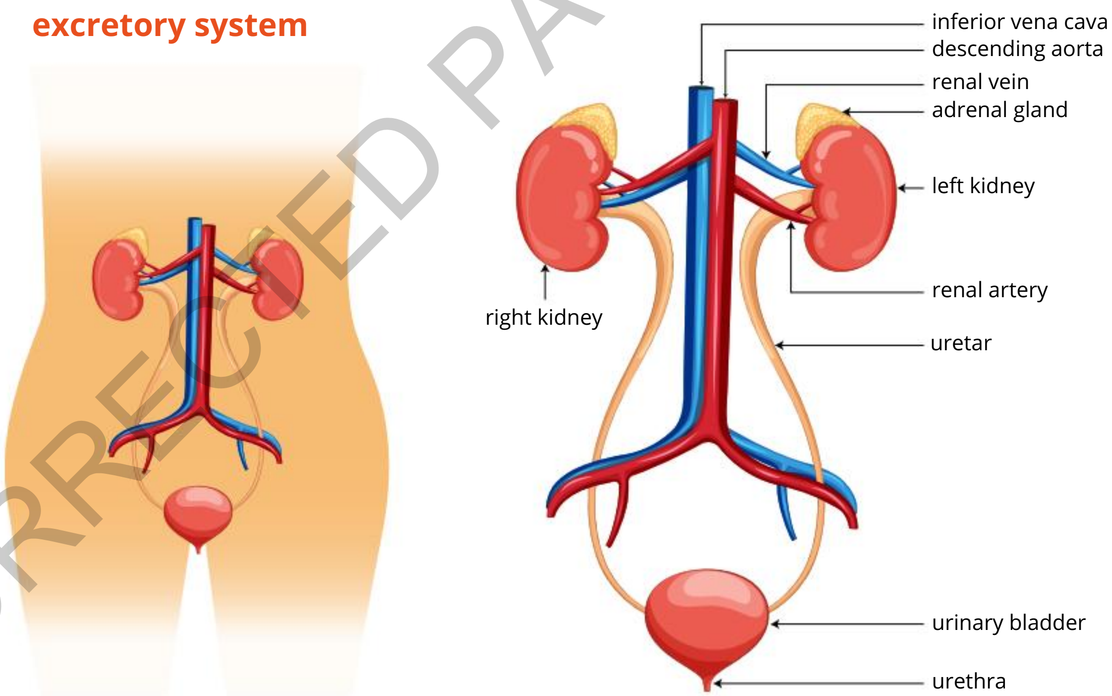



**FIGURE 8.8.1** Structure of the human excretory system

The excretory system is responsible for removing waste products from the body. As our bodies use food and drinks for energy and growth, they produce waste that needs to be safely removed. The kidneys filter the blood to get rid of harmful substances like extra salts, water, and particularly those containing nitrogen. These wastes are turned into **urine**, which is stored in the bladder and eventually passed out of the body. This process helps keep the body healthy and balanced.

**KEY TERM**

**urine** liquid produced by the kidneys and stored in the bladder, used to remove nitrogen compounds and maintain water-salt balance

## SC 1 CHECK YOUR UNDERSTANDING

Describe the main role of the excretory system.

## SC 2 I can describe the main structure and function of the kidneys.

The kidneys are two bean-shaped organs located on either side of the spine, just below the rib cage. Each is about the size of a fist and plays a crucial role in filtering the blood to convert waste into urine for excretion. Each kidney contains around a million tiny filtering units called **nephrons**, which are responsible for this filtration process.

Tissues associated with the kidney are identified with the word **renal**. A blood vessel known as the renal artery carries blood to each kidney where it is filtered to remove waste and also restore the water-salt balance of the body. The filtering is done by the many microscopic nephrons (Figure 8.8.2).

**KEY TERMS**

**nephron** microscopic-sized filtering unit inside the kidney
**renal** relating to the kidney

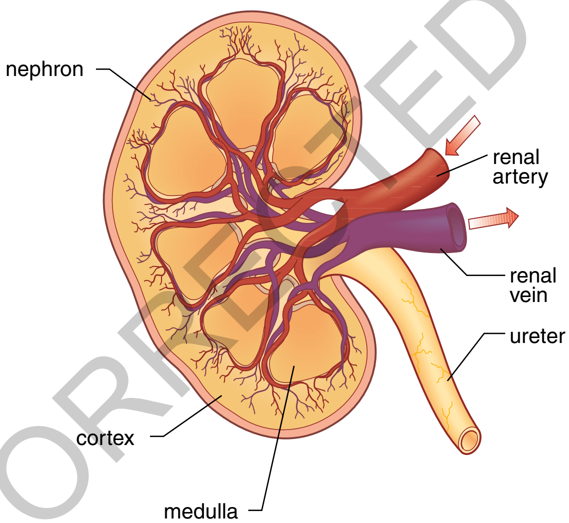



**FIGURE 8.8.2** Cross-section of one human kidney showing the blood supply and the position of one nephron.

**Scifile**

**Urine colour**

The colour of your urine can indicate your hydration level. Clear or light yellow urine usually means you are well hydrated, while dark yellow or amber urine may indicate some dehydration. Anyone playing sport needs to be mindful of their water intake to avoid dehydration, which can lead to decreased performance and health issues.

The nephrons use some water to form urine. Urine passes down each ureter tube from the kidney to the bladder where it is stored until we urinate through a single urethra tube. In males the urethra runs through the penis. In females the urethra is shorter with the outside opening just in front of the vaginal opening.

**SC 2 CHECK YOUR UNDERSTANDING**

What is the main structure and function of the kidneys in the human body?

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1. Identify three waste products to be removed by the body.
2. Name the microscopic-sized filtering units found inside the kidneys.
3. Identify the blood vessels that servethe kidneys.
4. Describe why it is important for the kidneys to have a good blood supply.

# 8.9 Organ disorders

## Lesson overview

The body is complex. It is made up of many different specialised cells, tissues, organs and systems that all need to coordinate to maintain function. When parts of the body are removed or not able to function correctly, this can lead to disorders in those parts of the body and also in other related body systems.

Disorders of the body are common causes of diseases that may require medical treatment.

In this lesson you will learn about some common disorders that can lead to organ dysfunction and how the removal of certain organs affects the body's function.

**Learning intention**

To understand how disorders, diseases, and the removal of organs can affect the body's function

**Success criteria**

**SC 1:** I can explain how a disorder in a cell or tissue can cause organ dysfunction.

**SC 2:** I can describe the impact of removing certain organs.

**KEY TERMS**

**disorder** an illness that disrupts normal physical or mental functions of an organism

**dysfunction** the impaired or abnormal functioning of a tissue, organ or system within the body

**disease** an illness or sickness that can be characterised by specific signs or symptoms

**SC 1** I can explain how a disorder in a cell or tissue can cause an organ to dysfunction.

Many **diseases** and **disorders** that cause organ **dysfunction** start at the lowest level of organisation—within the cells and tissues that they are made of. Damage and dysfunction of cells and tissues can occur for a variety of reasons. Sometimes it is unknown why a particular dysfunction has arisen. Different diseases may affect individuals in different ways. Medical professionals and research scientists are always searching for the causes and ways to reduce the impact of disease.

A healthy lifestyle can reduce the chance of many disorders occurring in the body.

## Causes of organ dysfunctions

There are many factors that contribute to disorders of cells and tissues that can lead to dysfunction and diseases in organs.

These disorders can be:

- genetic and passed on from parents to children
- from an infection or disease within the body
- from lifestyle choices such as smoking or vaping
- from poor diet
- from lack of exercise
- from an environmental cause such as pollution.

## The respiratory system

The lungs are important for the uptake and supply of oxygen to all cells within the body. If cells cannot be oxygenated, then they are unable to carry out cell functions such as cellular respiration, which is critical for survival. Some diseases caused by dysfunctions of the lungs within the respiratory system include cystic fibrosis, silicosis, and asthma.

### Asthma

The bronchioles of the lungs have a very thin layer of muscle tissue to keep them open. When a person suffers from asthma, the tube muscles tighten and the bronchioles become inflamed with the tissues swollen and red. This reduces the diameter of the tube and leads to difficulties in air reaching and leaving the alveoli (Figure 8.9.1). Asthma can be triggered by an allergy, by environmental pollution or by stress, and tends to run in families.

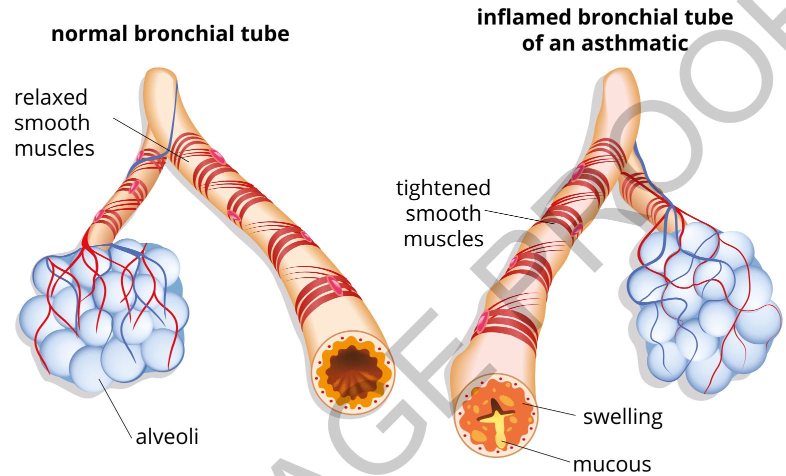



**FIGURE 8.9.1** During an asthma attack the bronchiole tubes become constricted and less air reaches the alveoli.

## The circulatory system

The circulatory system is the transport system that supplies blood to all areas of the body. If the heart is unable to pump the blood well enough, then cells may not receive important nutrients for chemical reactions, or be able to remove sufficient wastes. Some diseases caused by dysfunctions of organs within the circulatory system include strokes, aortic disease, and heart attacks.

### Heart attacks

For the heart to function, there are arteries that supply the muscle tissues of the heart itself with oxygenated blood (Figure 8.9.2). This allows the cells in the heart to create energy from cellular respiration for the muscular contractions that keep the heart beating. If **plaque** builds up inside the coronary arteries it reduces the width of the blood vessels, decreasing blood flow and may lead to a heart attack (Figure 8.9.3).

**KEY TERM**

**plaque** a substance made up of fatty deposits that sticks to the inside of blood vessels

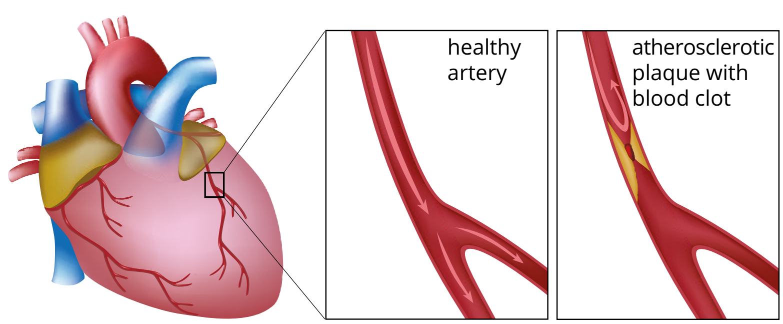



**FIGURE 8.9.2** Plaque inside coronary arteries may lead to a heart attack.

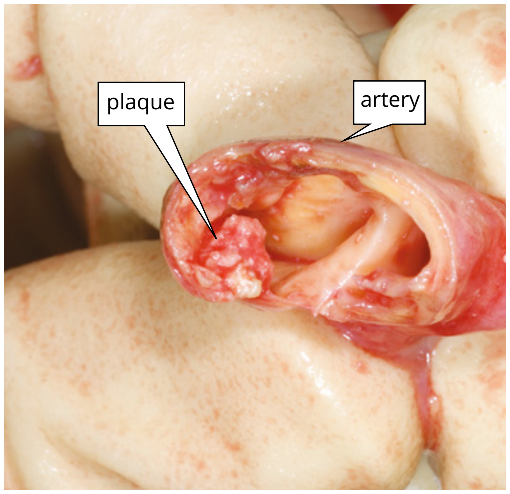



**FIGURE 8.9.3** A human artery partly blocked by build-up of plaque

**SC 1 CHECK YOUR UNDERSTANDING**

Explain how a disorder that narrows blood vessels can affect the circulatory system.

**SC 2** I can describe the impact of removing certain organs.

Certain disorders or dysfunctions can lead to the removal of organs when they severely impact the body's ability to function properly. In some cases, an organ may become so damaged or diseased that it poses a risk to the individual's health, requiring its removal to prevent further complications. For example, organs affected by cancer might be removed to stop the spread of cancerous cells.

Additionally, organs that fail to perform their essential functions, such as filtering waste or producing vital hormones, might need to be removed to protect the body from accumulating toxins or experiencing hormonal imbalances.

An example of a dysfunction that can lead to organ removal is kidney failure, which may require dialysis or a kidney transplant. The kidneys are responsible for filtering waste products from the blood and maintaining fluid and electrolyte balance. When the kidneys fail, these functions are compromised, leading to the accumulation of toxins in the body. **Dialysis** is a medical intervention that mimics the kidney's filtering process, helping to remove waste from the blood. However, in severe cases, the damaged kidneys might be removed, and the patient may require a kidney transplant to restore normal function.

**KEY TERM**

**dialysis** a medical treatment that cleans the blood by removing waste and extra fluids

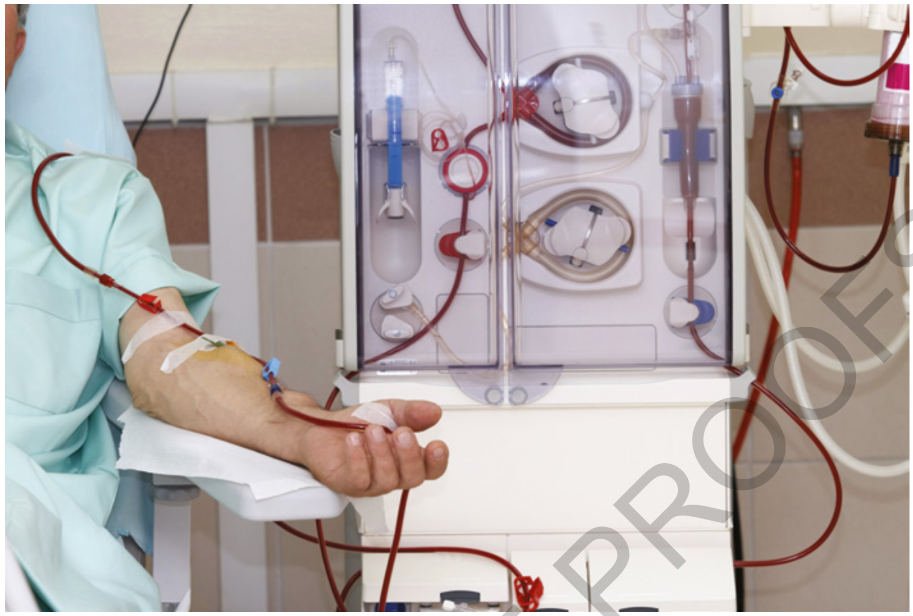


**FIGURE 8.9.4** A dialysis machine helps remove waste from the blood of a patient.



## SCIENCE IN CONTEXT

### Artificial heart valves

Understanding how the circulatory system transports blood helps researchers develop new technologies and treatments. For example, vascular bioengineers are working to create parts of an artificial heart to mimic the complex functions of the human circulatory system.

Bioengineered organs, like artificial hearts, valves and blood vessels, can potentially reduce waiting times and complications associated with organ transplants, offering more patients life-saving medical treatment (Figure 8.9.5).

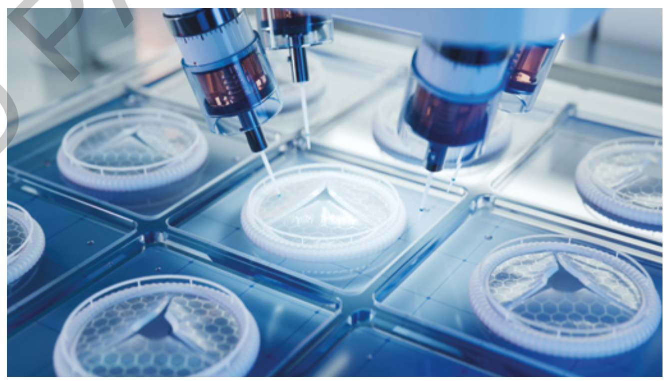


**FIGURE 8.9.5** Artificial bio-printed heart valves could be used for some heart disorders.

**SC 2 CHECK YOUR UNDERSTANDING**

Describe how a person with kidney failure would still be able to live a relatively normal life.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 Identify one disease caused by a disorder of an organ system.

2 Identify two causes of disease in organs.

3 Describe how the dysfunction of lung tissue can lead to respiratory diseases like asthma.

4 Explain the impact on the body if cells cannot be oxygenated.

# 8.10 Tranportation of water and nutrients in plants

## Lesson overview

The plants that are complex multicellular organisms have a range of specialised cells, tissues and organs which allow them to function.

In this and the next lesson you will learn about the types of specialised cells and tissues that transport water and the sugars formed by photosynthesis within the plant.

**SC 1** I can describe the structure and function of different plant cells.

## Plant cells

Plants have highly specialised cells that are capable of different functions. Plant cells have **cell walls**, **chloroplasts** and large **vacuoles**.

Whilst most plant cells have a similar basic structure, different cells in a plant can have specialised functions. These form plant tissues and organs that perform various functions.

## Root cells

**Roots** play a crucial role in the absorption of water from the soil. **Root hairs** extending out into the soil increase the surface area for water uptake (Figure 8.10.1).

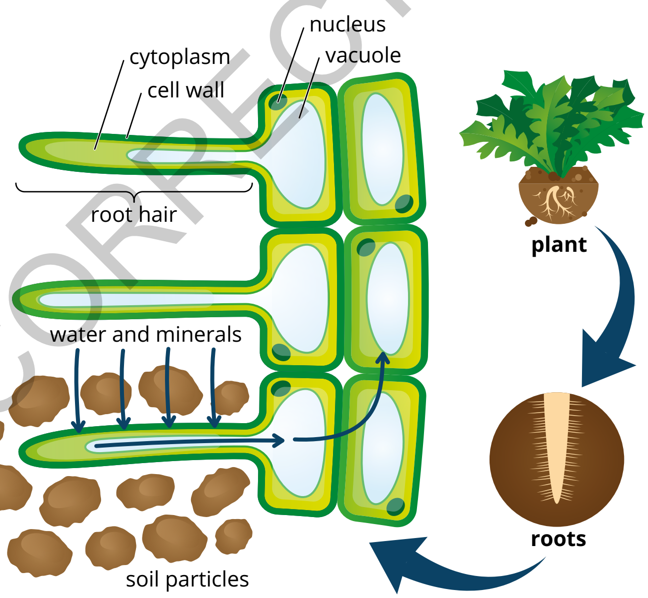



**FIGURE 8.10.1** Water with dissolved minerals moves out of the soil into root hair cells. A healthy soil also has small air spaces around the root hairs.

### Learning intention

To understand how and why water is transported in a plant

### Success criteria

**SC 1:** I can describe the structure and function of different plant cells.

**SC 2:** I can explain the role of cells and tissues in the transport of water in plants.

**SC 3:** I can explain the role of cells and tissues in the transport of nutrients in plants.

### KEY TERMS

**cell wall** a strong, rigid layer outside the cell membrane in plant cells that provides structure, support, and protection
**chloroplast** an organelle within some plant cells where photosynthesis takes place
**vacuole** a storage space inside a cell that holds water, nutrients, and waste products, helping to keep the cell firm and healthy

### KEY TERMS

**root** underground part of a plant that absorbs water and nutrients from the soil
**root hair** extension on the outer surface of some root cells that increases the surface area for water absorption

**KEY TERMS**

**xylem** vascular tissues in a plant that carry water upwards from the roots to the rest of the plant

**tracheid** narrow tube-like cell found in xylem tissue

## Xylem cells

**Xylem** is a special tissue in plants that helps transport water from the roots to the stems and leaves. This tissue forms a tube that allows water to move upwards. The xylem is made of cells called xylem vessels and **tracheids**. These cells are long and cylinder-shaped. Xylem vessels are made from dead cells that keep their cell walls but lose their insides. When these cells are arranged together, they form a continuous hollow tube with small holes in the side walls, called pits. These pits allow water to pass from one xylem vessel to another (Figure 8.10.2).

**KEY TERM**

**phloem** vascular tissues in a plant that carry sugar solution from the leaves to all other parts of the plant (pronounced 'flome')

## Phloem cells

**Phloem** is made up of special cells. The main transport cells are called sieve tube cells and they work with companion cells. These long sieve cells are stacked on top of each other to form tubes. They have tiny holes in their end walls, which let the sugar solution flow through continuously. Unlike xylem tubes, phloem sieve cells are still alive (Figure 8.10.2).

## Leaf cells

Leaves consist of various cell layers (Figure 8.10.3). The palisade layer of cells in the image are nearest the top surface of the leaf. They receive the most sunlight and are the main cells conducting photosynthesis, and require a water supply.

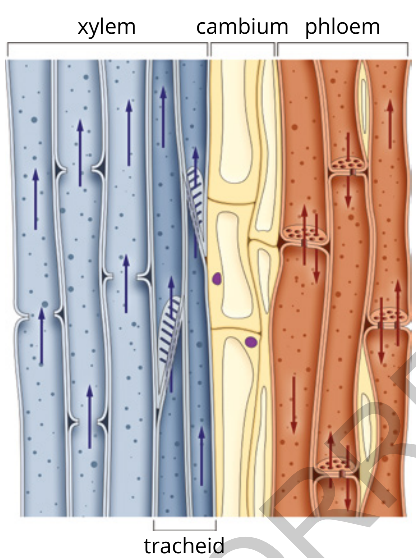



**FIGURE 8.10.2** A plant vascular bundle has long cylinder-shaped xylem vessels bunched together with cambium (another tissue type) and phloem.

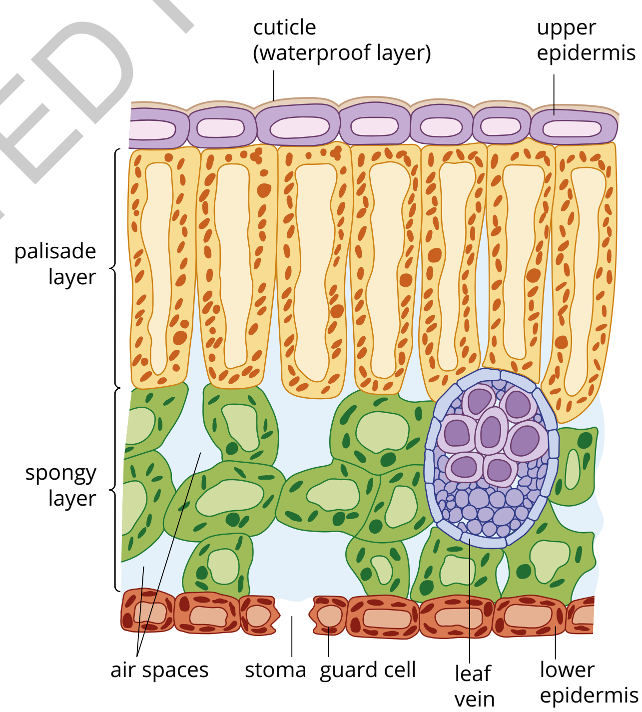



**FIGURE 8.10.3** A transverse section diagram of specialised leaf cells

**SC 1 CHECK YOUR UNDERSTANDING**

Describe one difference between xylem and phloem cells.

**SC 1** I can explain the role of cells and tissues in the transport of water in plants.

Maintaining water balance is a function that is vital to a plant's survival. The plant's **vascular system** transports water from the roots to the leaves. Water is either used by the plant or lost through the leaves via evaporation. The process of the evaporation of water from the leaves is called **transpiration** (Figure 8.10.4).

**KEY TERM**

**transpiration** the passive movement of water through a plant and its evaporation from the leaves

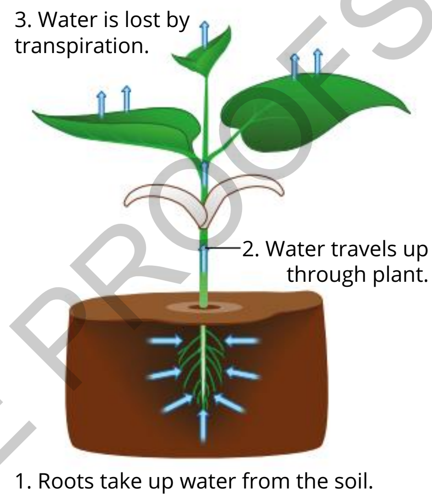



**FIGURE 8.10.4** Water movement through a plant occurs by transpiration streaming.

## Water and photosynthesis

Water travels in the plant from the roots through the xylem to the leaves where it is used in **photosynthesis** (Figure 8.10.5). Photosynthesis is a complex chemical process in which chlorophyll, the green pigment in leaf **chloroplasts**, captures sunlight energy.

This energy is used to split water molecules and capture carbon dioxide to create a simple type of sugar called glucose. Photosynthesis also forms oxygen as a by-product. That oxygen is released into the atmosphere where it is available for animals, including humans.

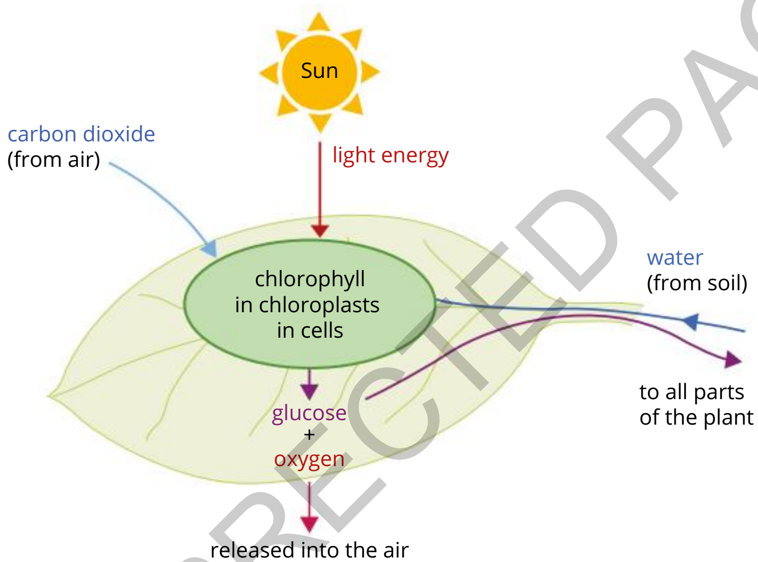



**FIGURE 8.10.5** The process of photosynthesis requires water from the soil

**KEY TERM**

**photosynthesis** chemical reaction in plants that converts carbon dioxide and water into oxygen and glucose using energy from sunlight

**SC 2 CHECK YOUR UNDERSTANDING**

Explain how xylem cells transport water though the plant.

**SC 3** I can explain the role of cells and tissues in the transport of nutrients in plants.

**KEY TERMS**

**organic nutrient** nutrients in living things with chemical structures based on carbon atoms

**translocation** transport of dissolved sugars from source to sink by phloem in a vascular plant

The xylem takes in dissolved minerals, such as nitrogen and calcium compounds, with the water and delivers them to different parts of the plant above the roots. For **organic nutrients** a different transport system is used. Adjacent to the xylem is the phloem, the other component of a plant's vascular system. Phloem tissue transports sugars produced by photosynthesis in the leaves to all other parts of the plant. These sugars are essential for cellular respiration in all cells, and also for repair and growth. A plant cannot grow taller or produce flowers and fruit without these nutrients.

Leaf cells produce sugars by photosynthesis. They are known as the 'source' cells. There is a high pressure (concentration) of sugar at the leaves. Water is drawn across through the pits in xylem tissue to form a sugar solution in the adjacent phloem. The solution moves to low-pressure parts of the plant where sugars are being used up or stored by 'sink' cells, such as in the roots, fruit or flowers (Figure 8.10.6). The process is known as **translocation**, as it moves the organic sugars from one part of the plant to all other parts.

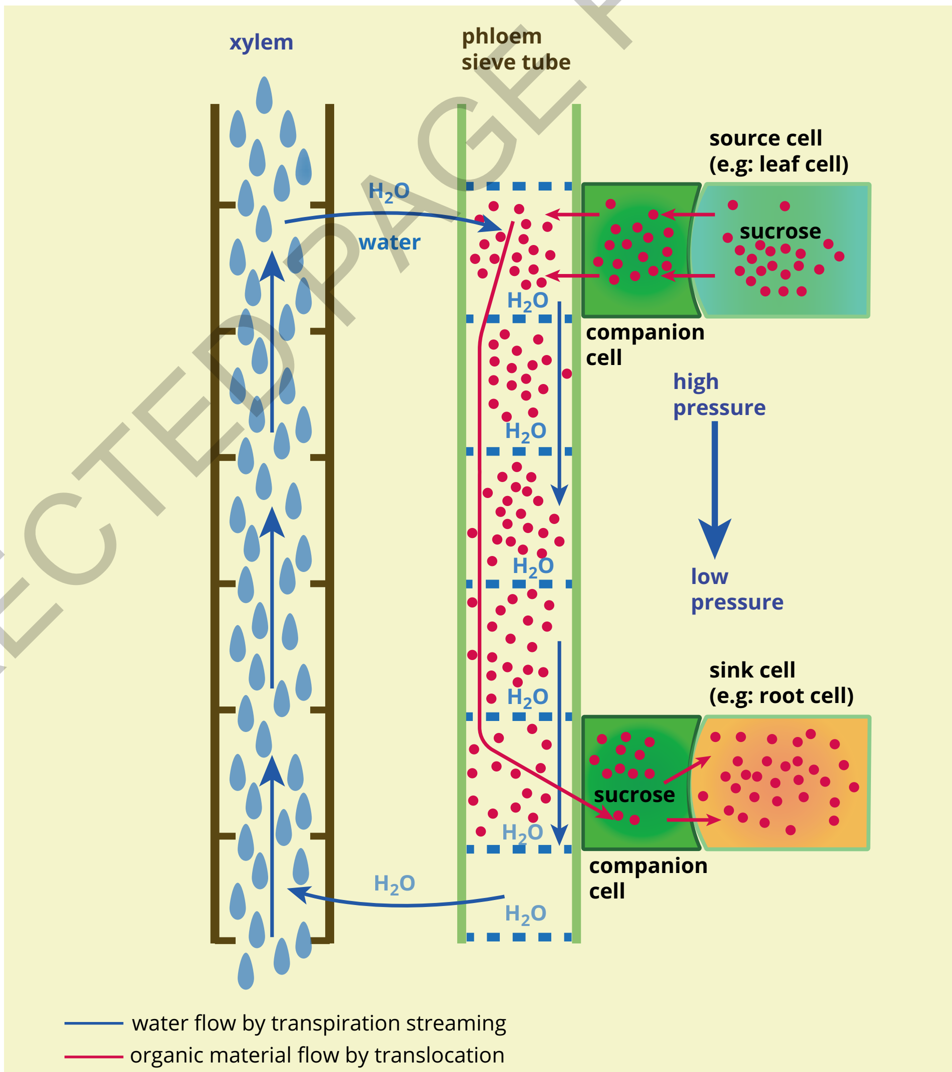



**FIGURE 8.10.6** Phloem tissue in a vascular plant transports sugars in solution from source to sink. The red dots are sugar molecules. Water is drawn out through the xylem pits into the phloem. Each phloem sieve tube is a stack of living cells separated by porous sieve plates (the blue dotted lines).

## SCIENCE IN CONTEXT

### Ringbarking, canoes & coolamons

Ringbarking of large trees was common during early European settlement in Australia as settlers started to clear land for agriculture and grazing. It was an easier way to kill trees than felling them with hand tools on large hardwood trunks. A ring of bark was removed around the whole trunk, cutting deep into the phloem (Figure 8.10.7). The disruption of phloem caused a slow tree death as root cells deprived of their energy supply died off, then leaves lost their source of water and photosynthesis was inhibited. Cutting into the xylem would have resulted in a faster tree death but xylem is protected deeper inside the trunk and would be more difficult to access.

**FIGURE 8.10.7** Close-up of ringbarking around a tree trunk

### SC 3 CHECK YOUR UNDERSTANDING

Describe how phloem tissues transport organic nutrients throughout a plant.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 Name the process that allows organic nutrients to move throughout the plant.

2 Identify the main tissues responsible for transport of water and organic nutrients (sugars) in vascular plants.

3 State the types of specialised cells that are responsible for transport of organic nutrients (sugars) in vascular plants?

4 Explain how some cells in the vascular system are specialised for water transport.

5 Explain why water transport is essential for plant survival.

# 8.11 Transport in vascular plants

### Learning intention

To be able to conduct an investigation to observe the transport of water in a plant

### Success criteria

**SC 1:** I can draw a scientific diagram to communicate findings from an investigation.

**SC 2:** I can explain observations using knowledge of transport in plant systems.

**SC 3:** I can evaluate the method of an investigation and suggest improvements.

## Introduction

Plants take in water and mineral nutrients via roots and carry out photosynthesis in the leaves to make glucose sugar. These substances are essential for growth, repair, reproduction and other functions in the plant.

There are two types of transport tissues in vascular plants—xylem and phloem. Both tissues are continuous, tubular pathways that run throughout a plant and can be seen as veins in leaves or as the stringy parts of a celery stem. Xylem transports water and minerals upwards from the roots, and phloem transports sugars from the leaves in all directions within the plant.

In this practical investigation you will explore water intake through vascular tissues in various environments.

## Background

The transport system in plants is a network of vascular tissues that moves water, minerals and sugars throughout the plant.

Plants can transport water from their root systems to their leaves through specialised cells and vascular tissue known as xylem. This transport system maximises the amount of water reaching leaf tissue, so that photosynthesis can occur. Plants use this process of transpiration streaming to transport water at different rates in different environments, depending on the plant's needs.

## Aim

To observe the tissues that transport water in plants placed in different environmental conditions

## Prediction

Sample prediction: There will less water remaining in the beaker for the plant that is placed in warmer conditions.

## Apparatus

- 2 celery stalks with leaves
- tap water
- coloured food dye (red works well)
- 2 × 250 mL tall beakers or jars
- scalpel blade or safety razor blade
- cutting board
- stereo microscope or hand lens
- measuring cylinder
- ruler marked in millimetres
- heated room position or another warm environment

## Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

**SAFETY NOTES**

- take care when using glassware not to break it
- take care when using a scalpel or razor blade not to cut yourself

# Method

## Prepare the celery

1. Use a scalpel to cut the bottom 5 cm off two celery stalks.
2. Place 150 mL of water into each tall beaker.
3. Add five drops of food dye into each beaker and stir to spread the colour.
4. Place one celery stalk into each beaker (Figure 8.11.1).
5. Cover the top of the beaker around each stalk with cling wrap to prevent direct evaporation of water.
6. Label the beakers and place one with celery in a cool environment (room temperature).
7. Place the second beaker with celery into a warmer environment.
8. Leave both beakers with celery for 1–3 days until the colour in one reaches the leaves.
9. Remove the celery from each beaker and attach a label to identify each stalk.
10. Pour the remaining water from the cool environment into a measuring cylinder and record the amount of water left over.
11. Pour the remaining water from the warm environment into a measuring cylinder and record the amount of water left over.
12. Strip one coloured string from the length of the celery stalk. Identify which plant tissue you are holding.
13. Use a ruler to measure the highest point reached by coloured water in each stem.
14. Place each celery stalk on the cutting board and cut thin 3–5 mm slices at three measured points up each stem, as shown in Figure 8.11.2. Remember to keep track of which slice was from each temperature and of each position up which stem.
15. View each slice of celery using a stereo microscope or a hand lens. Lay the slice flat on a white background to view the structure of the vascular tissue (Figure 8.11.3).

**FIGURE 8.11.1** Place the celery stalks into beakers of coloured water

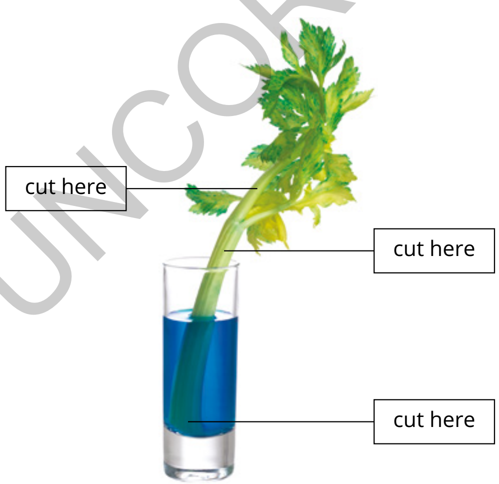



**FIGURE 8.11.2** Cut the celery stalks as shown

**FIGURE 8.11.3** The slices at each section of the plant will look like this, and the xylem vessels may show evidence of the food colouring

## RESULTS

1 Draw and label a diagram for each celery slice cut at their highest point (slice 3). Colour it to show the distribution of the food dye.
2 Compare the heights that food colour moved up the stem for each temperature environment.
3 Copy the table below into your workbook to record your results.

| | Initial volume of water (mL) | Final volume of water (mL) | Difference in volume of water (mL) | Highest point of colour up the stem (mm) |
|---|---|---|---|---|
| **Plant in cool environment** | | | | |
| **Plant in warm environment** | | | | |

## Discussion

1 Identify the tissue in the celery's transport system that moved the water.
2 Describe how you determined that water moves up the celery stems inside one vascular system only.
3 Compare your results for celery stalks kept at two different temperatures.
4 Explain the term 'transpiration streaming'.
5 Propose one improvement to make the investigation more scientific.

## Conclusion

Describe the effect of temperature on transpiration streaming in celery plants.

# 8 Systems in animals and plants

## Topic summary

The key concepts included in this topic are:

- Specialised cells and tissues make up complex systems in both plants and animals.
- Plants and animal systems can have similar functions such as gas exchange and transport.
- Gases are transported in humans through the respiratory system while blood is transported through the circulatory system.
- Humans have a complex digestive system to process their food before it is transported by the blood.
- Humans use a specialised system to excrete some wastes as urine.
- In a vascular plant water is transported via roots and xylem vessels.
- In a vascular plant sugar made by photosynthesis is transported via phloem vessels.
- Tissue disorders or removal of a body part can cause dysfunction in both plants and animals.



## Review questions

The following questions will assess your success in achieving the learning intentions for this topic.

### Remember

1 Name one important organ in each of the four main systems of the human body.

2 Identify how many lungs and how many kidneys there are in the human body.

3 Identify the number of chambers in the human heart.

4 Name the group of chemicals that control chemical digestion in humans.

### Understand

5 Describe how a microscope can be used to observe plant structures.

6 Explain why heart rate is likely to increase when a person is exercising.

### Apply

7 Summarise the role of chemical digestion in the human body, including an example.

8 Outline a way to model the role of bile in the digestive system.

### Analyse

9 Evaluate the ethics of using animal parts in dissections.

10 Compare the structures responsible for transport of water in plants to the structures responsible for the transport of blood in animals.

11 Design an investigation to model transpiration in plants.

### Extension: Research task

12 Research and describe the possible medical interventions for treating kidney disorders. For example, the use of dialysis for renal failure.

## Topic reflection

The learning intentions for this topic are given in each lesson and at the beginning of the topic. Consider how well you have achieved them. Note down any particular areas that you are confident in, and others where you are not so sure.

# 8 Glossary

**alveoli** tiny air sacs in the lungs where oxygen from the inhaled air enters the bloodstream and where carbon dioxide from the bloodstream is released into the exhaled air

**aorta** the largest artery in the body, carrying oxygenated blood from the heart to the rest of the body

**artery** a blood vessel that carries blood away from the heart to different parts of the body

**atria** (singular: **atrium**) the upper chambers of the heart that receive blood from the body or lungs

**bronchi** (singular: **bronchus**) tubes formed by the division of the trachea

**bronchiole** small tubes formed by the division of the bronchi

**capillary** the narrowest type of blood vessel; capillaries reach nearly every cell of the body

**carbon dioxide** a waste gas that animals, including humans, exhale when they breathe out, produced as a result of their bodys' metabolic processes

**cardiac** of the heart

**cell** the building blocks of all living things

**cellular respiration** a set of processes in the cells that converts chemical energy from nutrients into energy (ATP) that can be used by cells

**cell wall** a strong, rigid layer outside the cell membrane in plant cells that provides structure, support, and protection.

**chemical digestion** breakdown of complex food chemicals into simpler units that can be absorbed and carried in the bloodstream

**chloroplast** an organelle within the cell where photosynthesis takes place

**chyme** soup-like acidic mix of partly digested food in the stomach

**circulatory system** the system that carries materials around the body; it consists of the heart, blood vessels and blood

**coronary** blood vessels that supply the heart

**deoxygenated** blood lacking oxygen and high in carbon dioxide

**dialysis** a medical treatment that cleans the blood by removing waste and extra fluids

**diaphragm** a sheet of muscle that separates the chest from the abdomen

**digestive system** the system where food is broken down and nutrients absorbed

**disease** an illness or sickness that can be characterised by specific signs or symptoms

**disorder** an illness that disrupts normal physical or mental functions of an organism

**dysfunction** the impaired or abnormal functioning of a tissue, organ or system within the body

**emulsify** mechanical process to split fats and oils (lipids) into smaller droplets that mix with water

**enzyme** protein molecule that controls chemical reactions in the body

**ethics** a set of principles by which your actions can be judged morally acceptable or unacceptable

**excretory system** the system in the body that processes and removes waste products that the body has produced

**exhalation** process of air moving out of the lungs

**gas exchange** one gas moves in and another moves out

**inhalation** process of air moving into the lungs

**lung** organ in the chest cavity where gas exchange occurs

**mechanical digestion** physical breakdown of food into smaller pieces by chewing, softening and emulsification

**micrometre (μm)** measurement of length $10^{-6}$ or one-millionth of a metre

**microvilli** microscopic projections on the surface of villi cells

**multicellular organism** an organism that is made up of many cells

**nasal cavity** the hollow space inside the nose that air passes through when breathing, helping to filter, warm, and moisten the air before it reaches the lungs

**nephron** microscopic-sized filtering unit inside the kidney

**organ** a structure that contains at least two different types of tissues that work together to complete a function

**organ system** two or more different organs that work together

**organic nutrient** nutrients in living things with chemical structures based on carbon atoms

**oxygen** a gas that animals, including humans, breathe in from the air and use to help their bodies produce energy

**oxygenated** supplied or enriched with oxygen

**phloem** cells in a plant that carry sugars from the leaves to all other parts of the plant

**photosynthesis** the chemical reaction in plants that converts carbon dioxide and water into oxygen and glucose using energy from sunlight

**plasma** (biology) clear yellowish liquid part of blood that carries blood cells and other substances such as nutrients and wastes

**platelet** a small cell fragment in blood that helps with clotting to prevent excessive bleeding when there is an injury

**plaque** build-up of a fatty deposit on the inner wall of a blood vessel

**pulmonary artery** the arteries that carry deoxygenated blood from the heart to the lungs

**pulmonary vein** the veins that bring oxygenated blood from the lungs to the heart

**pulse** the regular expansion and contraction of the arteries in response to the heartbeat

**red blood cell** cell that carries oxygen from the lungs around the body

**renal** of the kidney

**respiratory system** the system of organs and tissues that takes air into the body

**root** underground part of a plant that absorbs water and nutrients from the soil

**root hair** extension on the outer surface of some root cells that increases the surface area for water absorption

**specialised cell** cell that has specific structures to allow it to perform specific functions

**system** collection of interconnected organs working together for a collective purpose

**tissue** a group of cells of the same type that carry out the same function in the body

**trachea** the tube that carries air from the nose and mouth into the chest cavity

**tracheid** narrow tube-like cell found in xylem tissue

**translocation** transport of sugar solution in the plant phloem from source to sink

**transpiration** the passive movement of water through a plant and its evaporation from the leaves

**unicellular organism** living thing made up of only one cell

**urine** liquid waste product of animals that contains a range of substances, including urea, removed from the blood by the kidneys

**vacuole** a storage space inside a cell that holds water, nutrients, and waste products, helping to keep the cell firm and healthy

**valve** a structure in the heart and blood vessels that controls the direction of blood flow, preventing backflow

**vascular system** system of hollow tubes or vessels that transports water and nutrients around an organism

**villi** infoldings on the inner wall of the small intestine

**vein** blood vessel that carries blood back to the heart

**vena cava** the large vein that carries deoxygenated blood from the body to the heart

**ventricle** the lower chambers of the heart that pump blood to the body or lungs

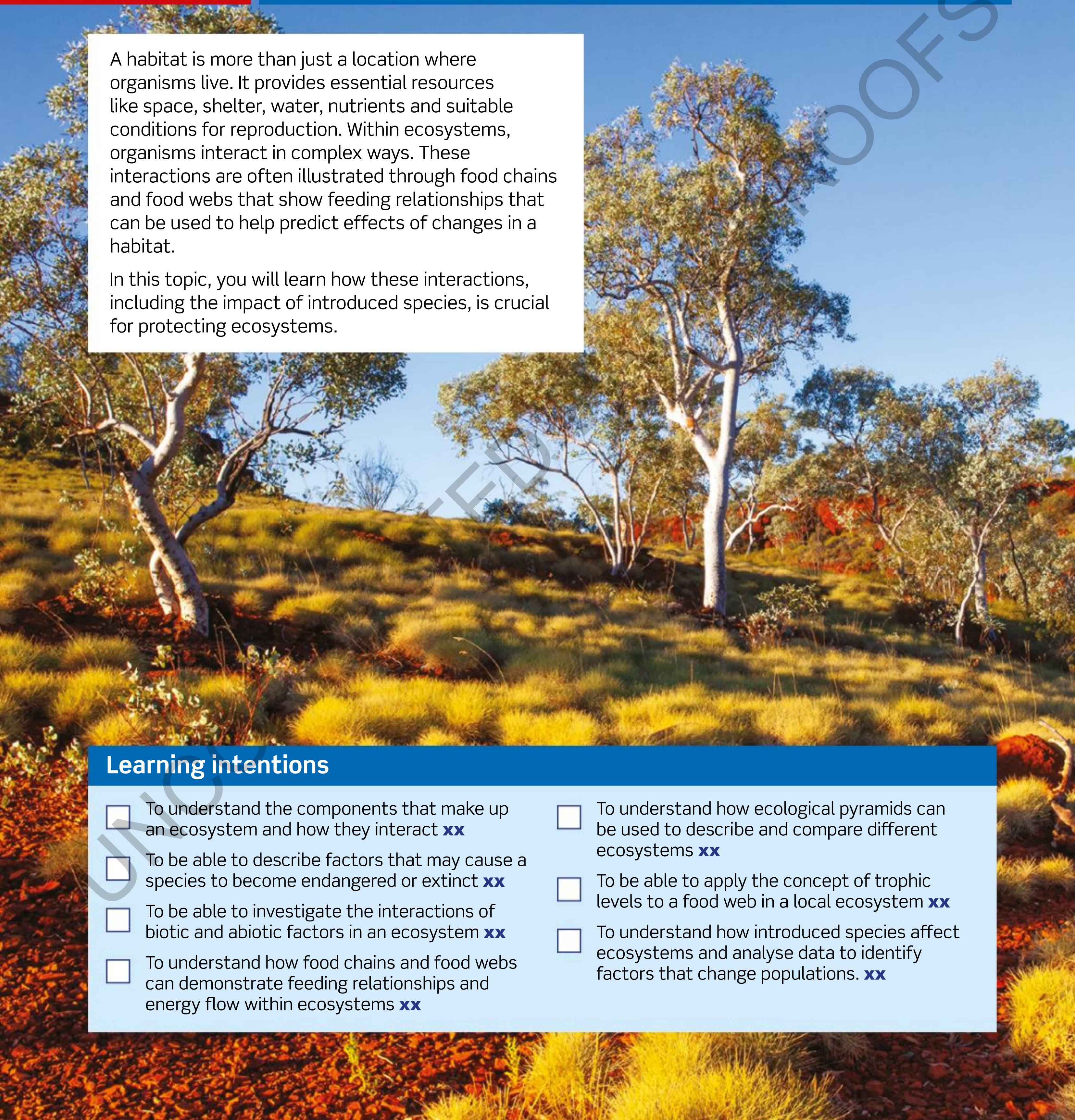
**xylem** tissues in a plant that carry water from the roots to the rest of the plant

TOPIC 9

# Ecosystems

A habitat is more than just a location where organisms live. It provides essential resources like space, shelter, water, nutrients and suitable conditions for reproduction. Within ecosystems, organisms interact in complex ways. These interactions are often illustrated through food chains and food webs that show feeding relationships that can be used to help predict effects of changes in a habitat.

In this topic, you will learn how these interactions, including the impact of introduced species, is crucial for protecting ecosystems.

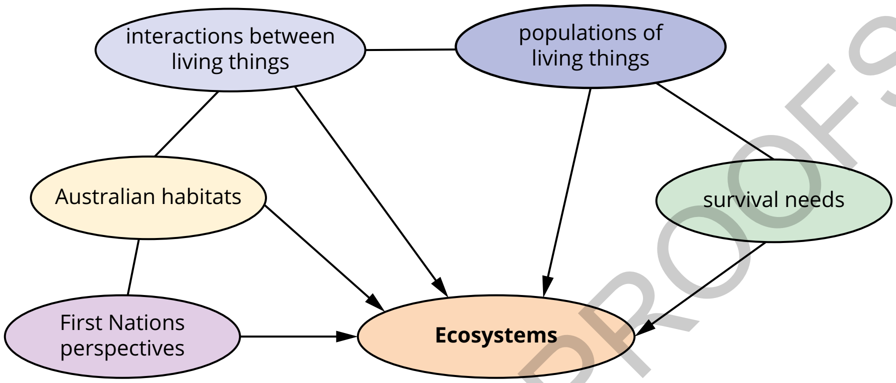


## Learning intentions

- ☐ To understand the components that make up an ecosystem and how they interact **xx**
- ☐ To be able to describe factors that may cause a species to become endangered or extinct **xx**
- ☐ To be able to investigate the interactions of biotic and abiotic factors in an ecosystem **xx**
- ☐ To understand how food chains and food webs can demonstrate feeding relationships and energy flow within ecosystems **xx**
- ☐ To understand how ecological pyramids can be used to describe and compare different ecosystems **xx**
- ☐ To be able to apply the concept of trophic levels to a food web in a local ecosystem **xx**
- ☐ To understand how introduced species affect ecosystems and analyse data to identify factors that change populations. **xx**

# 9 Ecosystems

The key concepts that you will use in this topic:




The following prior knowledge questions will help to support your learning in the topic and can be attempted before the first lesson.

## Survival needs

1 Outline the basic requirements that living things need to survive.

## Populations of living things

2 Explain the factors that make an environment biodiverse.

## Interactions between living things

3 Describe how energy flows in a food chain.

4 Draw a food chain that demonstrates the following description:

A rabbit eats the grass. The rabbit is then eaten by a snake and the snake is preyed upon by a kookaburra.

5 Outline two ways humans can have an impact on Australian native plants and animals.

## Australian habitats

6 List three types of Australian habitats.

## First Nations perspectives

7 Describe how First Nations peoples use traditional knowledge to protect the environment.

# 9.1 The components of an ecosystem

## Lesson overview

Ecosystems are fascinating and complex systems where living and non-living things interact. Imagine a pond in your local park. The fish, plants, water and even the sunlight all play a role in this ecosystem. Each component, whether living or non-living, and their interactions are important for ensuring the health and balance of an ecosystem. In this lesson, you will explore the different components that make up an ecosystem and understand how they interact with each other.

### Learning intention

To understand the components that make up an ecosystem and how they interact

### Success criteria

**SC 1:** I can describe biotic factors that make up an ecosystem.

**SC 2:** I can describe abiotic factors that make up an ecosystem.

**SC 3:** I can describe the interactions between biotic and abiotic factors in a range of ecosystems.

**SC 1** I can describe biotic factors that make up an ecosystem

**Biotic factors**, also known as biotic components, are the living parts of an **ecosystem**. These include plants, animals, bacteria, fungi and any other living **organisms**. Each of these organisms play a specific role in maintaining the balance of an ecosystem.

A wide variety of organisms exist on Earth, and each organism has different requirements for survival; however, all organisms require the same six basic things (Figure 9.1.1):

- **nutrition** (food sources)
- a water source
- a place to live and shelter
- mating partners for **reproduction**
- gases including oxygen, carbon dioxide and nitrogen
- suitable living conditions, such as a suitable temperature and **salinity**.

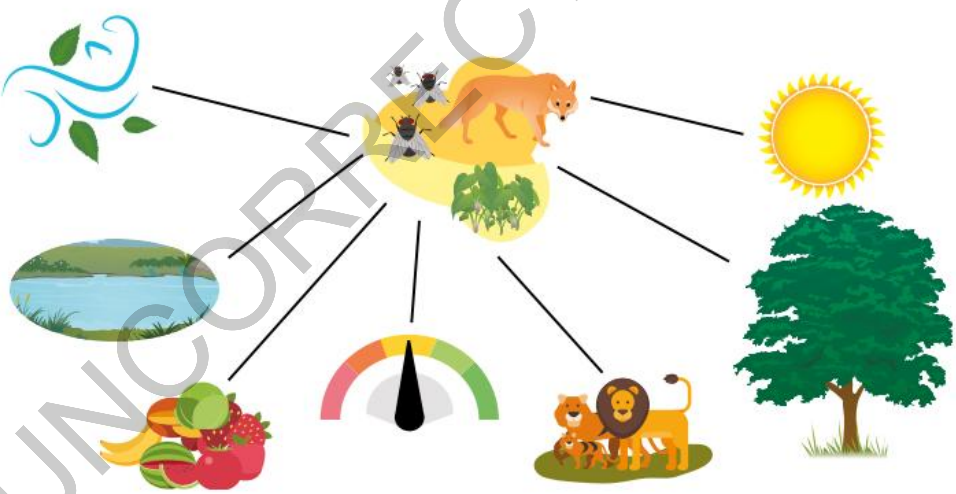


**FIGURE 9.1.1** All living things have basic needs in order to survive.

## Producers

**Producers** are organisms that can make their own food through the process of **photosynthesis**. Plants, algae and some bacteria are examples of producers. They use sunlight, carbon dioxide and water to create **glucose**, which provides

### KEY TERMS

**biotic factors** all living parts of an ecosystem
**ecosystem** a system formed by organisms interacting with each other and their nonliving surroundings
**organism** a living thing
**nutrition** the process of obtaining the food needed for an organism to grow, stay healthy, and have energy
**reproduction** the process by which animals and plants create offspring.
**salinity** the amount of salt that is dissolved in water
**producer** an organism able to manufacture its own food; plants are producers
**photosynthesis** the chemical reaction in plants that converts carbon dioxide and water into oxygen and glucose using energy from the Sun
**glucose** a type of sugar made by producers such as plants

energy for themselves and other organisms in the ecosystem. For example, in a forest ecosystem (Figure 9.1.2), trees and shrubs are the primary producers.

**FIGURE 9.1.2** A rainforest that includes many producers such as trees, shrubs and other plants

**KEY TERMS**

**consumer** organism that must eat other organisms to get the energy and nutrients it needs

**energy** the ability to do work; can be in many forms including heat, movement and electricity

**herbivore** an animal that eats only plants

**carnivore** consumer that eats only other animals

**omnivore** an animal that eats both plants and animals

**decomposer** organism that gets the energy it needs by breaking down dead matter and waste products

## Consumers

**Consumers** are organisms that cannot make their own food and must eat other organisms to obtain **energy**. There are different types of consumers, including **herbivores**, **carnivores**, **omnivores** and **decomposers** (Figure 9.1.3).


**FIGURE 9.1.3** Examples of types fo consumers

### Scifile

**Nutrient necessity**

Just as humans need vitamins and minerals to stay healthy, all organisms need specific chemical nutrients to survive. For example, plants need nitrogen for leaf and stem growth, phosphorus for root and seed development, and potassium for water balance and to prevent disease.

**SC 1 CHECK YOUR UNDERSTANDING**

Explain how decomposers contribute to an ecosystem.

**SC 2** I can describe abiotic factors that make up an ecosystem

**KEY TERM**

**abiotic factors** nonliving parts of an environment

**Abiotic factors**, sometimes called abiotic components, are the non-living parts of an ecosystem. These include sunlight, water, air, soil, temperature, and minerals. Abiotic components play an important role in determining the types of organisms that can live in an ecosystem and how they interact.

## Sunlight

Sunlight is the primary source of energy for most ecosystems. Sunlight and water are needed for the process of photosynthesis in producers, which in turn supports the entire ecosystem. The amount of sunlight an ecosystem receives can affect the types of plants and animals that live there.

**KEY TERM**

**foliage** the leaves on plants or trees

For example, a desert receives a lot of sunlight and little rainfall compared to a rain forest where the dense, leafy layer of **foliage** reduces the amount of sunlight that reaches the lower layers of the forest floor (Figure 9.1.4). The varying amount of sunlight is one of the factors that influences what organisms live in these environments.

a

b

**FIGURE 9.1.4** Sunlight is essential for photosynthesis and the amount of sunlight can affect the variety of plants in different ecosystems, such as in a desert (a) and a rainforest (b).

## Water

Water is essential for all living organisms. It is involved in various biological processes, including digestion, respiration and photosynthesis. The availability of water in an ecosystem can influence the types of organisms that live there. For example, a desert ecosystem has limited water availability, so only organisms that are adapted to dry conditions, like cacti and camels, can thrive there (Figure 9.1.5).

**FIGURE 9.1.5** Cacti are adapted to survive in desert ecosystems with limited water.

## Soil

Soil provides nutrients and a place for plants to anchor their roots. The composition (make up) of soil can affect the types of plants that grow in an ecosystem (Figure 9.1.6). For example, sandy soil drains water quickly and is found in coastal ecosystems, while clay soil retains water and is common in wetlands.

**FIGURE 9.1.6** Forest soil showing the root systems of trees and grasses. Different soil types support different plant species.

**FIGURE 9.1.7** Emperor penguins are adapted to survive in Arctic ecosystems.

## Temperature

Temperature influences how fast an organism uses energy to do all the things it needs to survive. The types of species that can survive in an ecosystem is dependent on the temperature of their environment. For example, polar ecosystems have extremely low temperatures, so only organisms adapted to cold conditions, like polar bears and penguins (Figure 9.1.7), can live there.

**SC 2 CHECK YOUR UNDERSTANDING**

Describe how temperature can affect the types of organisms that live in an ecosystem.

**SC 3** I can describe the interactions between biotic and abiotic factors in a range of ecosystems

An ecosystem involves interactions between the living (biotic) and non-living (abiotic) factors in an **environment**. This dynamic **community** includes animals, plants and microorganisms as well as the soil type, climate and water availability. Communities contain different types of living things known as **species**, which fill specific roles in the ecosystem and can interact in positive or negative ways.

All species differ from one another in their resource use, tolerance to changes in the environment (such as temperature or rainfall), and in their interactions with other species.

**KEY TERMS**

**environment** all the factors in an organism's surroundings that affect its survival
**community** groups of organisms that interact within an ecosystem
**species** a group of living organisms that share similar characteristics and can reproduce with each other to produce offspring that can also reproduce
**biodiversity** the number and range of species that exist in an ecosystem, biome or biosphere

## The importance of biodiversity

The types of interactions in the ecosystem determine how many organisms can live in a particular space at any time. A healthy ecosystem is home to many different species. The more species an ecosystem has, the higher its **biodiversity**.

Ecosystems thrive when there is variation. Biodiversity has three important and intertwined parts (Figure 9.1.8):

- species diversity
- ecosystem diversity
- **genetic** diversity.

**KEY TERM**

**genetic** relating to characteristics or features passed on from parent to offspring

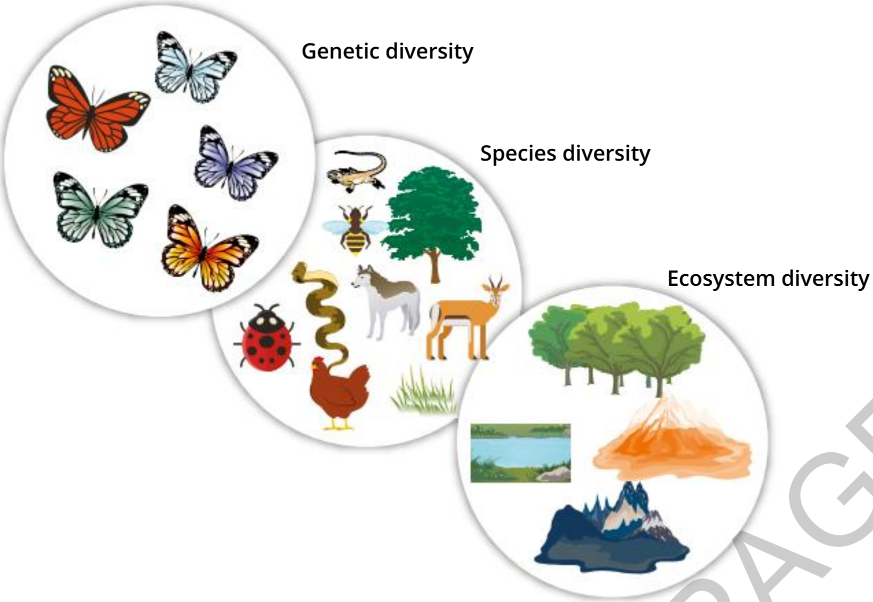



**FIGURE 9.1.8** Biodiversity has three important parts.

When any of these parts are missing, it reduces the ability of an ecosystem to adapt to environmental changes. In some environments, taking away just one important factor can weaken the entire ecosystem causing damage that cannot be repaired. For example, in a reef ecosystem, if coral dies due to rising ocean temperatures, many fish will lose their **habitat** and food source. This harms the whole reef ecosystem and causes lasting damage.

**KEY TERMS**

**habitat** the place where an organism lives

**population** a group of organisms of the same species, which live in the same area

**Populations** change all the time and, for a variety of reasons.

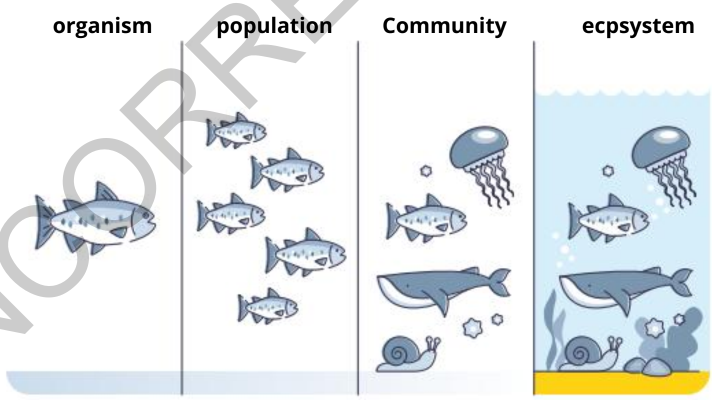



**FIGURE 9.1.9** The components of an ecosystem

Sometimes changes in a population are related to the availability of resources in an ecosystem.

**KEY TERM**

**competition** relationship between organisms that are trying to use the same limited resource

Changes in resource availability can include:

- a lack of food sources
- **competition** for shelter
- significant changes in temperature
- introduction of disease-causing organisms
- soil erosion.

## Interactions in an ecosystem

There are a variety of interactions that occur in an ecosystem. These interactions can be between two different species, such as when two organisms compete for the same food source or shelter, or they can be between members of the same species, such as when two organisms compete for a mate or space (Figure 9.1.10).

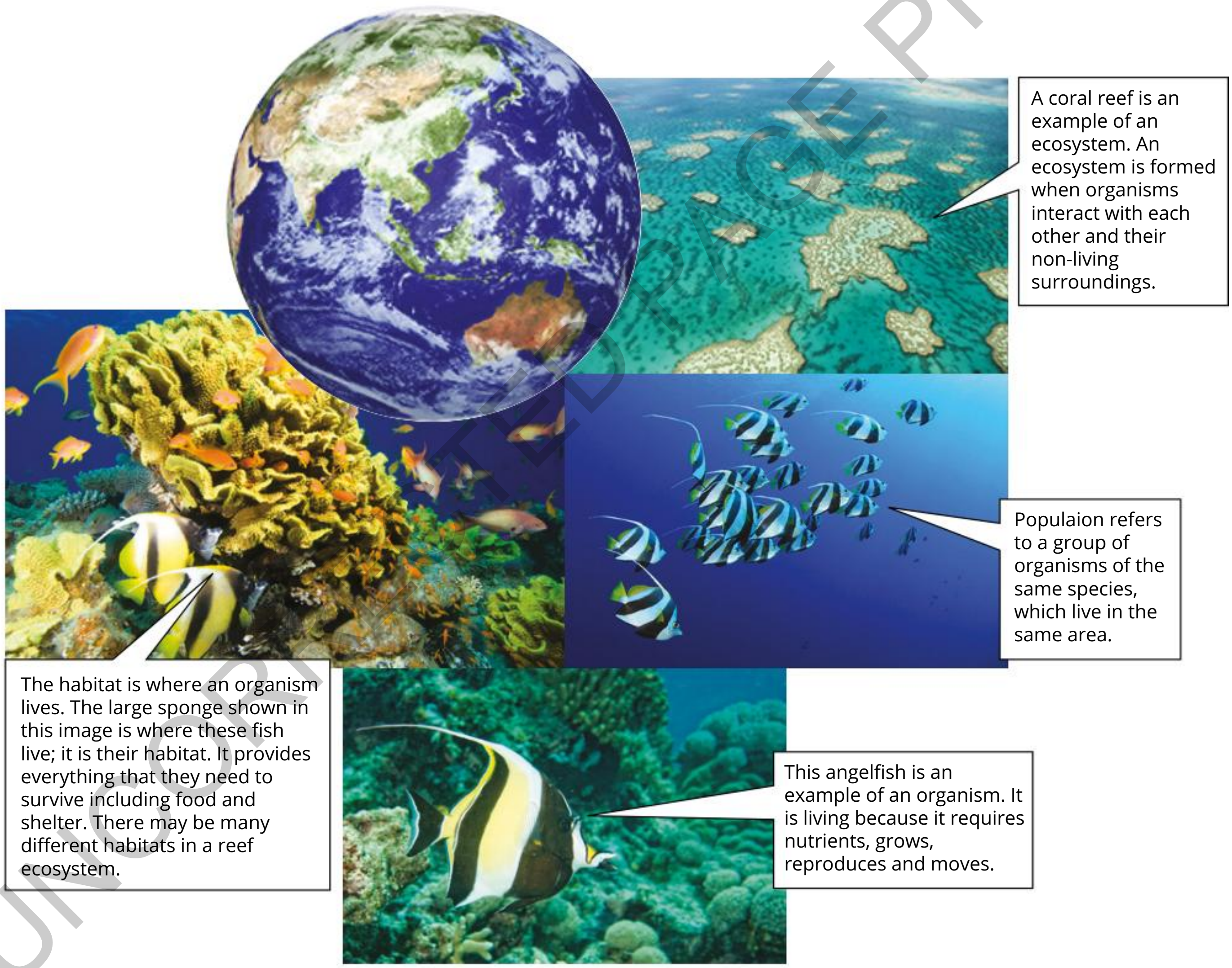



**FIGURE 9.1.10** The relationship between ecosystems, habitat and the organisms that live there

Biotic components of ecosystems interact with each other in various ways; one type of interaction is known as **symbiosis**. For example, Australian native bees and the bottlebrush shrub live in a mutual **symbiotic relationship**, known as **mutualism**. Bees get their nectar from the bottlebrush flowers, and in return, they help **pollinate** the plant (Figure 9.1.11).

**FIGURE 9.1.11** Native Australian bee collecting nectar from an Australian Crimson Bottlebrush

Another example is **commensalism**. This is where two different species live closely together and one benefits from the relationship while the other one is unaffected. For example, where cockatoos nest in hollow trees, the cockatoo receives shelter and the tree is unharmed (Figure 9.1.12).

**Parasitism** is another type of symbiotic relationship. This is where one organism survives on or in another organism (a host). The **parasite** gets its **nutrients** and shelter from the organism it is living on, while the **host** is usually harmed. An example of a parasite is a tick; they obtain nutrients from the blood of other organisms (Figure 9.1.13).

**FIGURE 9.1.13** An Eastern grey kangaroo with two large ticks on its left eye

**KEY TERMS**

**symbiosis** a close relationship between two different living things where at least one of them benefits

**symbiotic relationship** an interaction between two different living things where they help each other

**mutualism** a type of relationship where both living things help each other and benefit from the relationship

**pollination** the process where pollen from a flower is moved from the male part of the flower to the female part of the flower

**FIGURE 9.1.12** Native Australian sulphur crested cockatoos nesting in a hollow of a tree trunk for shelter

**KEY TERMS**

**commensalism** a symbiotic relationship where one organism benefits and the other organism is unaffected

**parasitism** a relationship where one organism benefits and the other organism is usually harmed

**parasite** a living thing that lives on or inside another living thing (host), usually harming the host while helping themselves

**nutrients** substances found in food that living things need to survive, grow and stay healthy

**host** a plant or animal that a parasite lives on or in

**KEY TERMS**

**predator** an animal that kills and eats other animals

**prey** an animal that is eaten by a predator

**Predator-prey** relationships are those where one organism (the predator) hunts and eats another organism (the prey). In a grassland ecosystem, a dingo (predator) might hunt a kangaroo (prey) (Figure 9.1.14).

**FIGURE 9.1.14** A group of dingoes (*Canis dingo*) feeding on a kangaroo carcass

**SC 3 CHECK YOUR UNDERSTANDING**

List three types of ways that organisms can interact in an ecosystem.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1. List three types of consumers in an ecosystem.
2. Explain the role of producers in an ecosystem.
3. Describe how soil composition can affect plant growth in an ecosystem.
4. Predict how a decrease in sunlight would affect both the biotic and abiotic factors of a forest ecosystem.
5. Predict how water extraction (the removal of water) would affect both the biotic and abiotic factors of a river ecosystem.
6. State one example of a symbiotic relationship and describe the interaction that occurs between the organisms in this relationship.

# 9.2 Endangered species and extinction

## Introduction

To remain healthy and sustainable, an ecosystem needs a variety of organisms in its environment. Areas with a wide range of organisms are said to have high biodiversity. Globally, many species of plants and animals are at risk of disappearing forever.

In this inquiry activity, you will investigate the factors that lead to species becoming endangered or extinct and determine some of the reasons a population is in decline. You will also consider the dangers to an ecosystem if the population continues to decline and use this to investigate the interactions of biotic and abiotic factors in an ecosystem.

## Background

Ecosystems that are diverse and can provide for the needs of the organisms that live there are known as **sustainable** ecosystems.

However, many factors can affect the long-term health of an ecosystem. These factors include habitat loss and natural disasters such as fire, drought, flood or introduced threats such as invasive species and disease. The maintenance of a sustainable ecosystem is a delicate balance and as human activity causes changes to ecosystems, many species are now considered **vulnerable**, **endangered** and some have even become **extinct**.

For example, the Tasmanian tiger (*Thylacine cynocephalus*), a large marsupial Australian predator (Figure 9.2.1a), is now extinct due to human hunting, loss of habitat and disease. Other predators, such as raptors (hawks) are at risk of serious decline due to habitat destruction (Figure 9.2.1b). Understanding why species become endangered or extinct helps us to protect the biodiversity of our planet.

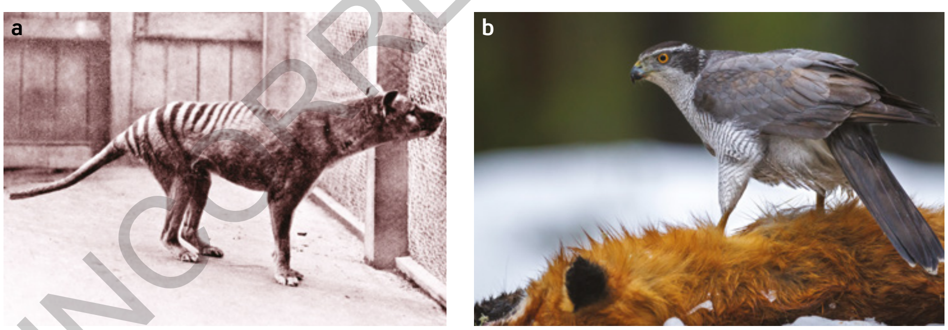



**FIGURE 9.2.1** (a) An image of a Tasmanian tiger, or thylacine (*Thylacinus cynocephalus*), in captivity in the 1930s. The species is believed to have become extinct in the early 20th century. (b) Raptors such as this hawk are at risk of population decline because of habitat alteration or destruction.

### Learning intention

To be able to describe factors that may cause a species to become endangered or extinct

### Success criteria

**SC 1:** I can identify factors that may cause a species to become endangered or extinct.

**SC 2:** I can explain why Australia has high rates of species population decline and extinction.

### KEY TERMS

**sustainable** using resources in a way that keeps Earth's ecosystems healthy for a long time

**vulnerable** an animal or plant that is at risk of becoming endangered

**endangered** an animal or plant that is at serious risk of disappearing forever

**extinct** an animal or plant that no longer exists anywhere in the world

## Endangered Australian species

The Australian organisms in Table 9.2.1 are all endangered species and can be used to help you conduct your inquiry.

**TABLE 9.2.1** Endangered Australian species

| Leadbeater's possum | Helmeted honeyeater |
|---|---|
| The Leadbeater's possum is one of Australia's most endangered species. It is estimated that there are about 2000 adults remaining in the wild. | The helmeted honeyeater is an endangered bird species in Australia. Conservation efforts have increased the numbers of these birds from 70 to about 200. |
|  |  |

| Southern corroboree frog | Lord Howe Island stick insect |
|---|---|
| The southern corroboree frog is an Australian endangered amphibian species. They are only found in the Jagungal Wilderness Area in Kosciuszko National Park in southern New South Wales. Their range has reduced by 90% and they are now considered extinct, or are in very small numbers, in nearby locations. | The Lord Howe Island stick insect is a critically endangered Australian insect species. There are only about 20–30 individuals left in the one remaining population in the wild. |
|  |  |

## Aim

To create a pamphlet or poster through print or digital media that will educate your community about an Australian endangered species.

## Plan

**1** Select an Australian plant or animal species that is endangered. You may use the examples given in Table 9.2.1.

**2** Think about what information the community will need to know about your species to protect it from extinction and what information should go on your poster or pamphlet. This information should include the answers to the following guiding questions.

- What is the species habitat? Include the biotic and abiotic factors.
- How many of the species are left in the wild?
- When is the species breeding season, and how often does it breed?
- How many young does the species have in each breeding season?
- What is the species diet?
- What threats to the ecosystem have contributed to this species being endangered?
- What **conservation** strategies are already in place?
- What future strategies can be put into place to prevent this from happening in the future?
- What are the risks to the ecosystem if the population of the species continues to decline?

**KEY TERM**

**conservation** taking care of natural resources making sure they stay healthy and are around for a long time

## Design

Plan what your poster or pamphlet will look like; it should be informative and eye-catching and should have a balance between information and visual appeal.

Remember to include and think about:

- your audience
- headings
- key information
- images
- materials you will use to create your poster or pamphlet.

Complete your research to get all the information required on your chosen species. Remember to think about the guiding questions listed in the Plan section and to use scientific sources to gather your research.

## Conduct

Prepare your poster or pamphlet using available craft materials (such as cardboard, markers or pencils), or create your poster digitally.

## Improve

Have a look around the class to see what other students have done. Consider how each poster or pamphlet communicates the information about the species. Look back at your own poster and identify two strengths of your poster and two areas for improvement.

## Discussion

1 List three biotic and three abiotic factors that affect the species you investigated in its ecosystem.

2 Predict what would occur if the species you investigated became extinct. Explain how this would affect the other organisms in the ecosystem.

3 Describe three threats that could lead to an organism in an environment becoming endangered.

4 Provide one future solution that could be used to prevent this organism from becoming extinct.

# 9.3 Organisms and habitats on the school grounds

## Introduction

The study of ecosystems often involves sampling areas for the presence of organisms living in habitats. Populations of organisms can be recorded and monitored using a range of sampling techniques.

In this practical investigation you will use the school grounds to investigate a range of habitats and learn about sampling and data collection techniques (Figure 9.3.1).

### Learning intention

To be able to investigate the interactions of biotic and abiotic factors in an ecosystem

### Success criteria

**SC 1:** I can carry out a sampling technique and analyse first-hand data.

**SC 2:** I can consider ways to reduce risk and damage to the environment when conducting fieldwork.

**SC 3:** I can use evidence from primary data to predict observations.

## Background

Living organisms can survive in a range of habitats. There are very few places in the world that have no living organisms, particularly bacteria or other microscopic organisms that we cannot see without a microscope.

The organisms living on school grounds will vary depending on the location of the school, but there will be habitats available for this practical.

**FIGURE 9.3.1** When you explore a habitat and conduct fieldwork, you collect samples and data to learn more about the ecosystem and make predictions.

## Aim

To investigate the organisms that are living in various habitats on the school grounds and analyse field data.

## Materials

- small paintbrush
- dissecting tweezers
- protective gloves
- magnifying glass
- sweep net
- 4 m of string
- 4 weights or stones
- field guide for identification of organisms
- large resealable plastic bags or specimen jars
- map of the school grounds

## Assessment of risk

Ensure you are aware of the risks of this inquiry activity and have considered how safety can be improved before carrying out the activity.

### SAFETY NOTES

- Wear protective gloves when handling any organisms, and wash hands after activity.
- Use dissecting tweezers to pick up any leaves; avoid handling directly.
- If there are any animals still caught in the net, avoid touching them directly.

## Method

1 Using the map of the school grounds, choose the location for your experiment. If possible, each group should choose a location with a different type of ground cover.

2 Draw a sketch of your location, noting the date and time, types of plants present and the ground conditions. Take photographs if you can.

3 At your location, measure and construct a 1 m × 1 m square area. Mark the area using the string and weights. This is the area you will sweep and investigate.

4 You will now sweep your 1 $m^2$ area. To do this, you will brush your net back and forth over the surface of your site in a figure-of-eight pattern. You should keep the open side of the net facing away from you. The aim is to capture any organisms at your site in the net.

   Alternatively, you can collect plant samples in your location to identify the variety of plant organisms in your chosen area.

5 Immediately after sweeping, hold the bag of the net halfway up to make sure that the organisms in the net do not escape. Another student should prepare the resealable bag.

   Alternatively, place any leaves collected in the resealable bags or specimen jars.

6 While another student holds the resealable bag, place the net over it, loosen your hold on the net and turn it inside out into the bag. Carefully shake the net and remove it from the bag. Immediately seal the resealable bag or jar so that the organisms do not escape.

7 Observe the organisms through the resealable bag or specimen jar and try to identify them using your field guide. Count and record the numbers of each type of organism in a suitable table.

8 When your observations are complete, release the organisms. If possible, release them where you found them.

## SkillBuilder

### Recording results using sampling techniques

#### Using sampling to gather data

When studying an ecosystem, it is impossible to observe the whole environment. Instead, **sampling techniques** are used to measure aspects of the ecosystem (such as the number of organisms in the ecosystem).

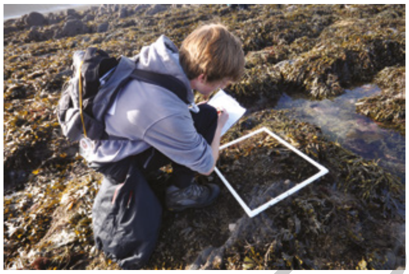
When using a sampling technique, a part of the ecosystem is selected for observation. It is important to select a part that is a fair representation of the wider ecosystem. If the sample is representative of the wider ecosystem, the data gathered about that location can be used to draw conclusions about the wider ecosystem.

**KEY TERM**

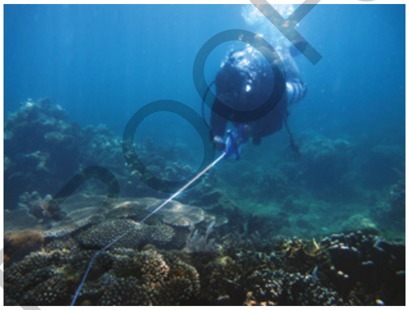
**sampling technique** method that scientists use to collect information about plants, animals and other living things in a certain area

## Sampling techniques

Quadrat sampling: A square (or quadrat) is placed on the ground. All the stationary organisms or other features of interest within the quadrat are identified and counted.



Transect sampling: A length of string or measuring tape is used to mark a line through the area to be studied. All the organisms or other features of interest that touch the line are identified and counted.



Time sampling: If recording events, such as animals feeding or sightings of birds returning to nests, it is possible to record results by measuring for only some of the time. When choosing the length of time or when to sample, it is important to keep the sampling fair. For example, some events may only happen at certain times of the day.

Using digital devices: Sampling techniques can be improved with the use of digital technology, such as taking photos, using drones or web cam footage. Smart phones can also use apps to measure several things that will affect an ecosystem such as sound levels, light intensity and air pressure.

## Example

Amin wanted to know how many dandelions were on the oval of his school grounds. Amin used a 1 m × 1 m (1 m$^2$) quadrat to survey an area of the oval. He recorded the following results in a table.

He calculated the average number of dandelions in all 10 quadrats:

$$\text{Average number of dandelions} = \frac{\textit{total dandelion count}}{\text{total number of quadrats}}$$

$$\text{Average number of dandelions} = \frac{3+2+0+0+1+4+3+1+4+2}{10}$$

$$= \frac{20}{10}$$

$$= 2 \textit{ dandelions per quadrat on average}$$

The total area of the oval was 40 m$^2$. Then, he used the following formula to estimate the total population:

$$\text{Total population} = \textit{Average number of individuals} \times \left(\frac{\textit{area of habitat}}{\textit{area of quadrat}}\right)$$

$$\text{Population} = 2 \times \left(\frac{40}{1}\right)$$

$$= 80 \textit{ dandelions}$$

## Results

1 Record your results as described in the method including the time and date of your data collection and a description of the sample area. Construct a table showing the appearance and number of each type of organism at your site and record your results in the table.

2 Predict if the results from other members of the class will show the same trend across the school grounds or if some areas will be more densely populated than others.

3 Record the results of other members of your class on your map of the school grounds.

## Discussion

Evaluate your practical investigation. Include how you considered ethics, including ways to reduce risk and damage to the environment when conducting fieldwork.

## Conclusion

Write your conclusion by answering the following questions.

1 Compare the numbers and different types of organisms caught at the various sites. For example, which site had the largest number of organisms observed? Which site had the largest variety of organisms observed?

2 Discuss the differences between the sites that could cause these variations.

3 a Discuss whether you would expect the same organisms in your sweep if you conducted this experiment at different times of the day and different times of the year. If you think you would observe different results, propose reasons for this variation.

b Describe a way of testing your predictions.

# 9.4 Food chains and food webs

## Lesson overview

Energy from the Sun is captured by producers to make food. Most producers are green plants and without them there would be no life because animals cannot make their own food (Figure 9.4.1). All organisms must have a source of food to make energy to survive. Food chains show feeding relationships and energy flow within ecosystems in a single path.

**FIGURE 9.4.1** A koala snacks on eucalyptus leaves

In this lesson, you will learn about the relationships organisms have with each other and how energy flows through ecosystems.

**Learning intention**

To understand how food chains and food webs can demonstrate feeding relationships and energy flow within ecosystems

**Success criteria**

**SC 1:** I can identify producers as well as primary, secondary and tertiary consumers in a food chain.

**SC 2:** I can explain the energy pathways in a food web, including identifying producers, different levels of consumers and apex predators.

**SC 3:** I can create a food web from information about feeding relationships in an ecosystem.

**SC 1** I can identify producers as well as primary, secondary and tertiary consumers in a food chain

All organisms need energy to survive. Plants are called producers because they make their energy from sunlight. All other organisms are called consumers, because they get their energy from the plants and other animals they eat. The flow of energy from one organism to another can be represented as a **food chain**. The arrows in a food chain show the direction of energy flow from one organism to another (Figure 9.4.2).

**KEY TERM**

**food chain** the flow of energy from organism to organism in a series of feeding relationships

The flow of energy from organism to organism in an ecosystem can be shown in a food chain. For example:

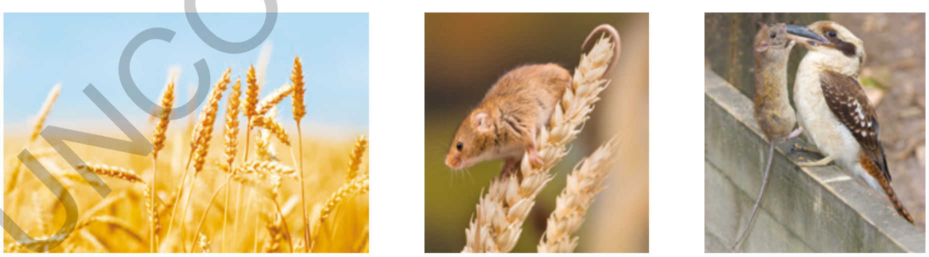


**FIGURE 9.4.2** The Sun fuels the wheat, which fuels the harvest mouse, which fuels the kookaburra

If the kookaburra in this food chain dies, then decomposers such as bacteria or fungi break down the remains and return the nutrients to the soil to be reused by plants.

**KEY TERMS**

**primary consumer** a consumer that only eats plants, algae and other producers; also known as a first-order consumer

**secondary consumer** a consumer that eats a primary consumer; also known as a second-order consumer

**tertiary consumer** a consumer that eats a secondary consumer; also known as a third-order consumer

**trophic level** the position of an organism in a food chain

**apex predator** a predator that has no natural predators except humans

**faeces** solid waste products made from consuming other organisms after digestion

## Energy flow in a food chain

The direction in which the arrow is pointing (Figure 9.4.3) shows the direction of energy flow. The grass is the producer as it obtains its energy from the Sun. The grasshopper is called a **primary consumer** or first-order consumer as it consumes the producer. Each organism in the food chain increases in consumer level. The bird is a **secondary consumer** and the fox is a **tertiary consumer**. These are also known as **trophic levels**.

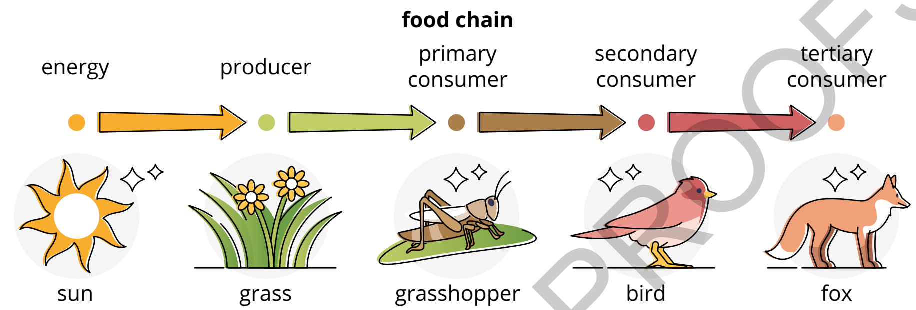



**FIGURE 9.4.3** A food chain showing different producers and consumers

In this food chain, the fox has no natural predators so it is the **apex predator**.

Food chains are not usually bigger than four steps. This is because there will be too much energy lost between each step and the energy available for the next organism will be lost.

Energy can be lost in a few ways: through heat and through the removal of waste such as **faeces**.

**SC 1 CHECK YOUR UNDERSTANDING**

Explain why apex predators are important in a food chain.

**SC 2** I can explain the energy pathways in a food web, including identifying producers, different levels of consumers and apex predators

**KEY TERM**

**food web** a diagram representing two or more connected food chains

When food chains are connected in an ecosystem a **food web** (Figure 9.4.4) is created. Food webs are a representation of the relationships between many organisms.

## Energy pathways in food webs

Food webs show the flow of energy between organisms and visually represent who eats who in a habitat. Food webs demonstrate the energy pathways between each organism. Energy is passed from one organism to the other and flows out as heat. For example, energy absorbed from the Sun is stored in plants. The energy is then passed on to the herbivores that eat the plants, and is then passed on to the carnivores that eat the herbivores. Decomposers like bacteria and fungi will then break down all dead organisms and return the nutrients to the soil to begin the cycle again (Figure 9.4.4).

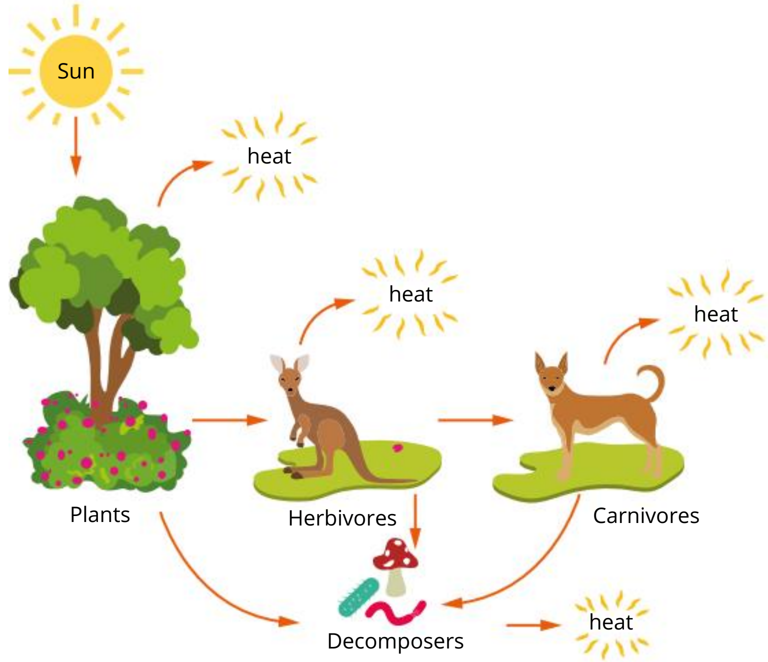



**FIGURE 9.4.4** Energy moves from producer to consumer and eventually to decomposers where energy is recycled.

In Figure 9.4.5 there are multiple food chains in one complex food web. Food chains typically involve around four to five steps because too much energy would be lost if there were too many feeding levels.

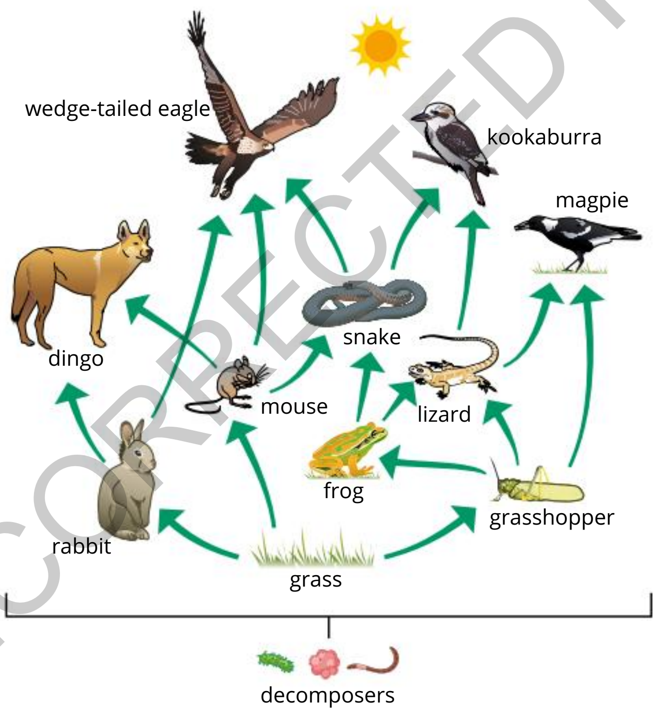



**FIGURE 9.4.5** This food web shows the flow of energy in a eucalypt woodland



## Food chains and food webs

Two of the food chains within the food web shown in Figure 9.4.5 are:

grass → grasshopper → frog → snake → wedge-tailed eagle

grass → mouse → snake → wedge-tailed eagle

**Scifile**

### Apex predators

Apex predators are at the top of the food chain. They have no natural predators and play a crucial role in maintaining the balance of ecosystems by reducing the population numbers of lower-level consumers. Sharks (Figure 9.4.6) are often the apex predators in an ecosystem.

**FIGURE 9.4.6** Great white shark (*Carcharodon carcharias*) hunting and eating a seal

The snake sits within both food chains. In the first, the snake is a tertiary consumer. In the second, it is a secondary consumer.

Can you see any other examples of organisms occupying more than one trophic level in the food web?

**SC 2 CHECK YOUR UNDERSTANDING**

Describe the energy transfer in a food web.

**SC 3** I can create a food web from information about feeding relationships in an ecosystem

## Creating food webs

A food web is made up of every food chain in an ecosystem. One type of organism can be part of many food chains. Like food chains, food webs start with producers and show the path that energy may take as it moves through the ecosystem. The producers are at the bottom of the food web, and the carnivores are at the top of the food web.

The food web in Figure 9.4.7 contains several food chains, including:

1 carrot → rabbit → fox
2 grass → grasshopper → owl
3 grass → grasshopper → bird → fox
4 grain → mouse → owl

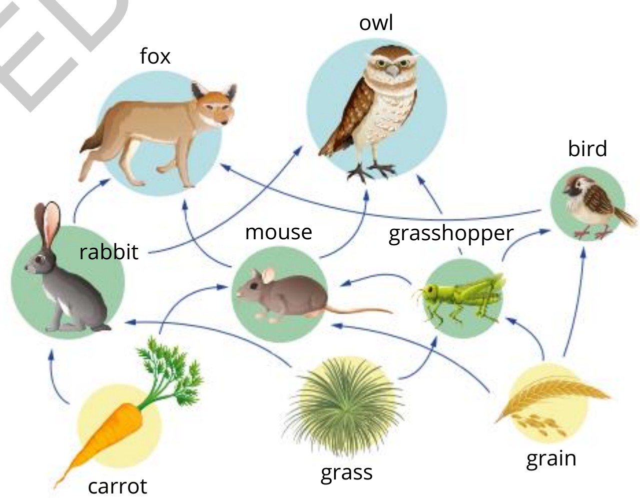



**FIGURE 9.4.7** Food webs show the many places that energy can flow

Similar to food chains, food webs use arrows to show the flow of energy between organisms. The arrows point from the organism being eaten to the organism doing the eating. The arrows also show the direction the energy is transferred to.

Several organisms can have the same food source, and there can be multiple producers as well as many primary, secondary and tertiary consumers in any given food web (Figure 9.4.8).

**FIGURE 9.4.8** In a grassland environment, kangaroos and insects eat grass (same resource), while dingoes and wedge-tailed eagles eat kangaroos and snakes.

When constructing a food web, it is best practice to draw all the producers at the same level on the diagram. Make sure that the primary consumers and secondary consumers are aligned. This is not always possible, especially with complex food webs, but it makes the food web easier to follow.

**SC 3 CHECK YOUR UNDERSTANDING**

Use Figure 9.4.7 to identify one organism from each of the following trophic levels.

- **a** producer
- **b** primary consumer
- **c** secondary consumer
- **d** tertiary consumer

**Scifile**

**Energy flow**

Energy flows through a food web from primary producers to various consumers. Understanding this flow helps scientists predict how changes in one species can affect the entire ecosystem.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1. Describe the importance of producers in a food chain.
2. Outline the ways in which primary consumers differ from secondary consumers in a food chain.
3. Identify the producer, primary consumer, secondary consumer and tertiary consumer in the following food chain:

   eucalyptus tree → koala → dingo → eagle
4. Explain why food webs in a rainforest are more complex than food webs in a desert ecosystem.
5. An organism eats leaves, roots and insects and it sometimes eats small mammals. Identify the organism's position in the food chain and its feeding relationship. Give reasons for your answer.
6. Predict how an increase in the population of a primary consumer, such as the rabbit, may affect the food web in a grassland ecosystem.

# 9.5 Ecological pyramids

**Learning intention**

To understand how ecological pyramids can be used to describe and compare different ecosystems

**Success criteria**

**SC 1:** I can explain how ecological pyramids can be used to represent the flow of energy between populations in a food chain.

**SC 2:** I can measure and compare the flow of energy within ecological pyramids using provided data.

## Lesson overview

Imagine a bustling forest filled with tall trees, colourful flowers and a variety of animals. Every living thing in this ecosystem plays a role in the balance of its environment (Figure 9.5.1). But have you ever wondered how energy moves through these different levels of the ecosystem?

**FIGURE 9.5.1** The smallest sea creatures, plankton, attract bait balls of sardines which then attract sea lions.

In this lesson you will learn about different types of ecological pyramids which tell us about the **mass** of all of the organisms at each level of a food chain.

**SC 1** I can explain how ecological pyramids can be used to represent the flow of energy between populations in a food chain

A **biomass pyramid** is a type of **ecological pyramid** (Figure 9.5.2) that can be used to visualise the total **biomass** in a food chain or ecosystem.

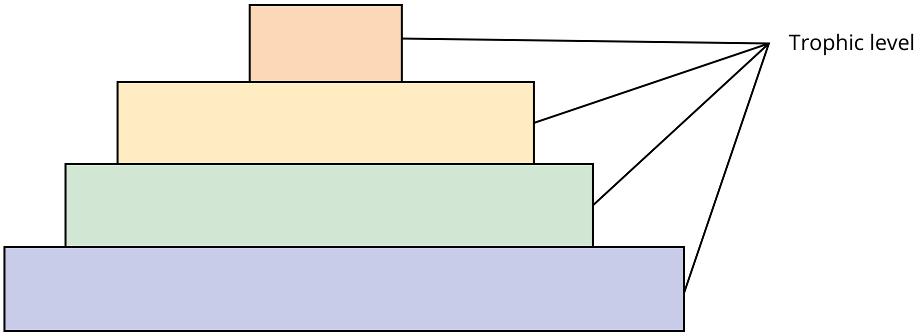



**FIGURE 9.5.2** A generalised terrestrial biomass pyramid showing each trophic level from largest (bottom level – producers) to smallest mass (top level – apex predators)

**KEY TERMS**

**mass** the amount of matter in a substance or object measured in grams (g), kilograms (kg) or tonnes (t)
**biomass pyramid** a visual representation used to show how mass and energy are distributed in an ecosystem
**ecological pyramid** a graphical representation showing the relationship between different organisms in an ecosystem
**biomass** all plant and animal matter found on Earth

## Terrestrial biomass pyramids

Energy in a **terrestrial** biomass pyramid is passed up from the bottom of the pyramid to the top. The energy is being transferred up the pyramid because the organisms are being consumed by the organisms in the **trophic level** above them.

### SCIENCE IN CONTEXT

#### Australian rainforests

In an Australian rainforest, the base of the biomass pyramid is made up of the large number of plants that produce energy through photosynthesis. These plants support a smaller number of herbivores, which in turn support an even smaller number of predators. By comparing the biomass pyramids of different ecosystems, scientists can gain insights into the structure and function of those ecosystems. This information is crucial for developing conservation strategies and managing natural resources.

To understand the **ecology** and health of an area, **ecologists** will survey the number of each organism in a food chain and draw a diagram to represent the mass of organisms at each trophic level (Figure 9.5.2).

In a biomass pyramid, the producers are at the bottom (first feeding level), followed by herbivores (primary consumers) and then carnivores (second and third-order consumers).

Figure 9.5.3 shows a similar pyramid for a community made up of grasses and blackberries, rabbits, corn snakes and eagles. The rabbits eat the grasses and blackberries, then pass their energy on to the corn snake, which is then killed and eaten by the eagle. It is important to recognise that without the producers (grasses and the blackberries) the eagle could not survive.

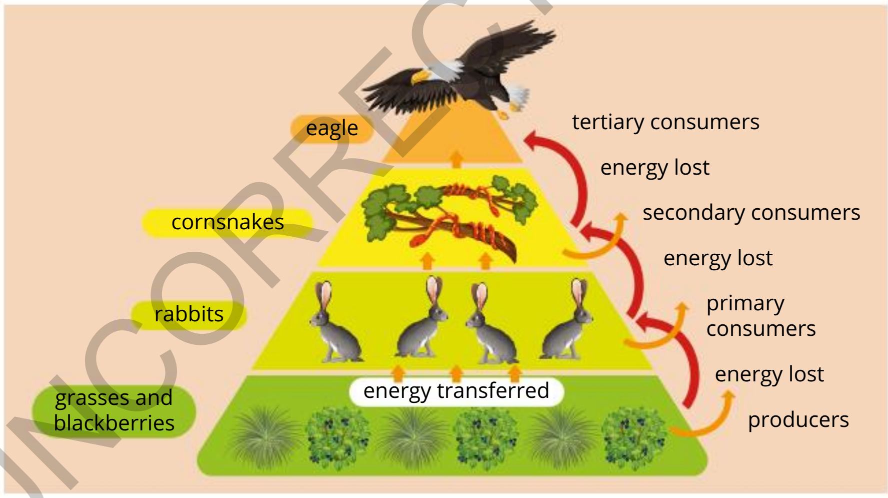



**FIGURE 9.5.3** A biomass pyramid showing how energy flows through a terrestrial ecosystem

**KEY TERMS**

**terrestrial** on land; environments such as grasslands, savannahs, deserts and forests

**trophic level** feeding level in a food chain, such as a producer or consumer

**ecology** the study of how organisms interact with each other and with their non-living surroundings

**ecologist** a scientist who studies the interactions between living things and their environment

## Energy flow

Biomass pyramids can be used to show the flow of energy from producers to consumers. Only 10% of the energy in a feeding level is transferred to the next level. The rest of the energy is used in animal body functions and waste removal.

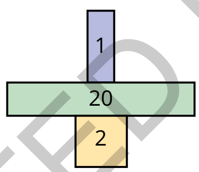
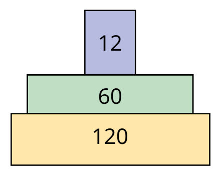
## Pyramids of numbers

A **pyramid of numbers** is like a biomass pyramid, but instead of being based on the total mass of organisms, a pyramid of numbers is based on the individual number of organisms at each level.

Pyramids of numbers can have a variety of shapes, especially when there are many small consumers feeding off a large producer. The number pyramid might not look like a pyramid at all.

For example, when 20 caterpillars, with an average mass of 3 g, feed on two lettuces, with an average mass of 60 g, the pyramid of numbers might look quite different to an original pyramid (Table 9.5.1).

**TABLE 9.5.1** Pyramid of numbers versus pyramid of biomass

| Organism | Average mass of one organism (g) | Pyramid of numbers (includes the total number of organisms in each feeding level) | Pyramid of biomass (includes the total mass of all organisms in each feeding level) |
|---|---|---|---|
| sparrow | 12 |  |  |
| caterpillar | 3 | | |
| lettuce | 60 | | |

### SC 1 CHECK YOUR UNDERSTANDING

Describe the difference between a biomass pyramid and a pyramid of numbers.

**SC 2** I can measure and compare the flow of energy within ecological pyramids using provided data

## Energy transfer in food chains

Healthy ecosystems have lots of producers, many herbivores and relatively few carnivores and omnivores. In this way the ecosystem can maintain and recycle its biomass quickly without running out of resources. In an ecosystem, biomass shrinks at each level of the food chain or at each trophic level because about 90% of an organism's energy is lost as heat or waste. A predator is only able to consume the remaining energy in the biomass of its prey.

## Efficiency of biomass transfer in food chains

The efficiency of **biomass transfer** is used to calculate the amount of biomass that is transferred from a lower feeding level to a higher one.

The efficiency of biomass transfer can be calculated using a simple equation:

$$\text{efficiency of biomass transfer} = \frac{\text{amount of biomass transferred to the next level}}{\text{biomass that was available at the previous level}} \times 100\%$$

**KEY TERM**

**biomass transfer** energy and nutrients of one living thing move to another living thing after being eaten

## Calculating energy flows

Using Figure 9.5.5 as an example, if there were 100 kg of grasshoppers and they were eaten by 10 kg of birds, the efficiency of energy transfer would be calculated as follows:

$$\frac{10\,\text{kg birds}}{100\,\text{kg grasshoppers}} \times 100\% = 10\%\ \text{transfer}$$

This means that only 10% of the energy consumed by the grasshoppers is passed on to the birds. The remaining 90% will have been used by the grasshoppers.

Using calculations such as these, the energy flow in different biomass pyramids can be compared.

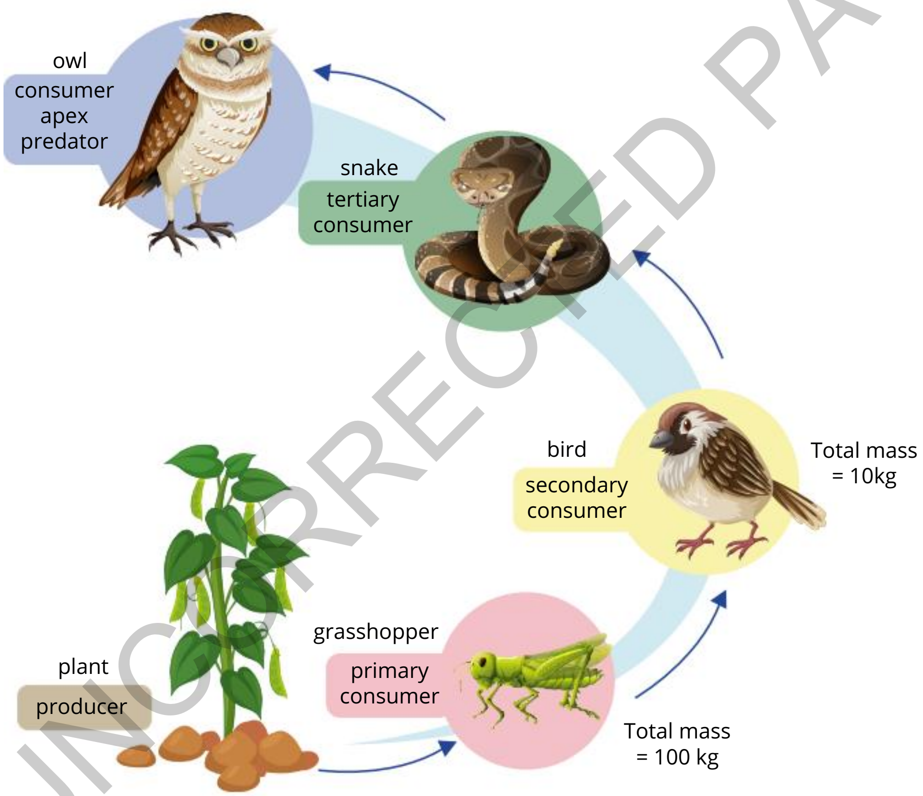
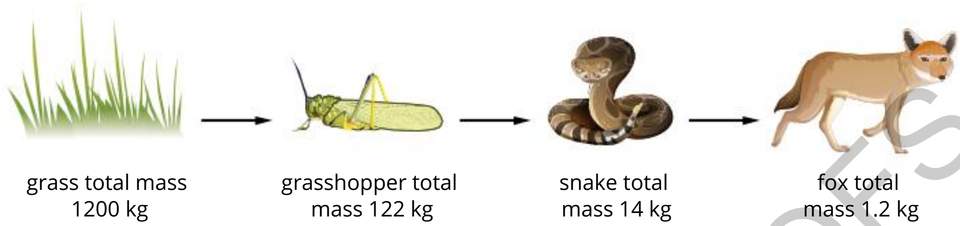



**FIGURE 9.5.5** Energy flow among the organisms in a food chain through biomass transfer

## SC 2 CHECK YOUR UNDERSTANDING

Calculate the efficiency of biomass in this food chain.




# Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1. Describe the structure of a biomass pyramid.
2. State the primary source of energy for most biomass pyramids.
3. Compare the structure of biomass pyramids of a rainforest and a desert ecosystem in Australia.
4. Calculate the efficiency of transfer if 60 kg of eastern brown snakes were eaten by 2 kg of kookaburras.

# 9.6 Food webs and ecological pyramids in a local ecosystem

## Introduction

Understanding feeding relationships and interactions between organisms is important for the management and conservation of ecosystems and species. By understanding the complex interactions between organisms, scientists can predict the impact of disturbances to ecosystems. Food webs are useful tools for understanding these interactions and the trophic levels within them. In this practical investigation you will observe the feeding relationships in your local environment to create a food web and an ecological pyramid.

**FIGURE 9.6.1** Ecologists analyse data on plants, animals and the environmental conditions in which they live. This an example of school oval where you can conduct your own ecological analysis.

## Background

There is a complex network of organisms living all around you – even in your backyard or school oval (Figure 9.6.1). You may not have thought about the connections before, but producers, such as plants, use energy from the Sun to make their own food through photosynthesis. This energy is then passed on when herbivores eat plants and continues to transfer through food webs as predators eat their prey. From small plant-eaters to top predators, all organisms in an ecosystem depend on the energy that starts with the producers.

## Aim

To conduct a survey of a local ecosystem and construct a food web and an ecological pyramid to represent the feeding relationships between the organisms that live there

## Apparatus

Write a materials list for your investigation.

## Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

### Learning intention

To be able to apply the concept of trophic levels to a food web in a local ecosystem

### Success criteria

**SC 1:** I can collaboratively plan to survey an ecosystem including selecting appropriate equipment.

**SC 2:** I can propose at least one possible food web based on the organisms observed in the ecosystem.

**SC 3:** I can predict, with reasoning, the effect of a change on populations within the ecosystem.

### HINT

Remember that, in part, science is carried out through observation. You do not need a lot of specialist equipment to observe your local environment. You will, however, need to document your results. What equipment will you need? What if you cannot see an organism clearly or do not know what it is? What equipment can you use to help you?

### SAFETY NOTE

- Write safety notes for your investigation. Think of three to four different aspects of your investigation that might need some more careful consideration.

## Method

Working in a small group of approximately three to four students, write a method for your investigation.

Remember, you will need to collect information that will help you to create a food web when you are back in the classroom. Your method will vary depending on your location and time available but consider including:

- exactly where the survey will take place
- what actions are required from each team member
- what kind of data sheet you will use for recording the ecosystem survey data
- how you will identify and record all the organisms you observe, and what they are eating.

## Results

1 Using your survey data, classify each organism that you observed as a:
   - producer
   - herbivore (primary consumer)
   - carnivore (secondary consumer)
   - carnivore (tertiary consumer)
   - omnivore, or
   - decomposer.

   If you are not sure which trophic level an organism belongs to, research its diet and then classify it. Consider how you could present this information.
2 Construct a food web to show the relationships between the organisms that you have observed.
3 Construct an ecological pyramid to demonstrate the predicted mass of the organisms in the food web that you have observed.

## Discussion

1 Identify all the organisms in your food web that compete for the same food.
2 Modify your food web to include an invasive species that could be introduced into the ecosystem.
3 Identify at least one problem with the procedure you used to conduct your practical investigation. Suggest an improvement you could make to overcome this problem.

## Conclusion

1 How does the food web you created assist you in understanding the interactions between organisms in this ecosystem?
2 How could a food web be used to predict the impact of human activities on an ecosystem? Describe one example to support your answer.
3 Describe ways ecologists use biomass pyramids when conducting ecological surveys.

# 9.7 The effect of introduced species

## Lesson overview

An introduced species (also known as an exotic or invasive species) is an animal, plant or other organism that is not native to the place or area where it is found. These species can have considerable impacts on local ecosystems, sometimes causing harm to native species and significantly altering the environment. For example, the introduction of deer to Australia has led to widespread environmental damage and competition between native animals (Figure 9.7.1).

In this lesson, you will learn about how introduced species affect ecosystems and how to examine and analyse data to understand the factors that change populations.

**Learning intention**

To understand how introduced species affect ecosystems and analyse data to identify factors that change populations

**Success criteria**

**SC 1:** I can describe how introduced species affect ecosystems.

**SC 2:** I can analyse secondary data to identify factors that change populations.

**FIGURE 9.7.1** Introduced European Fallow Deer (*Dama dama*) are herbivores and mammals. They are the most widespread and established of the feral deer species in Australia.

**SC 1** I can describe how introduced species affect ecosystems

Ecosystems are affected by many factors. Introduced species can cause long-term changes that can affect many native organisms in an ecosystem, upsetting the natural balance of food webs and food chains.

## Predation

Predation is one factor that can change populations. Predator and prey populations follow a repeating pattern over time. When prey numbers are low, predator numbers decrease, and the lack of predation allows prey populations to recover. For example, the introduction of the red fox to Australia has led to increased predation on native species such as the bilby. This has caused a decline in bilby populations (Figure 9.7.2).

**FIGURE 9.7.2** An image of a red fox hunting a bilby

## Competition

Competition occurs when two or more species compete for the same resources, such as food, water or shelter. For example, the introduction of the European starling to Australia has led to competition with native birds for nesting sites. This has caused a decline in native bird populations (Figure 9.7.3).

**FIGURE 9.7.3** Native kookaburras and introduced European starlings use the same nesting sites, creating competition between the two species and declines in the native kookaburra population.

**FIGURE 9.7.4** An Australian Peron's Tree Frog (*Litoria peronii*) that has recently died from chytrid fungus disease

## Disease

**Infectious disease** can also affect populations of a species. Disease is usually caused by parasites or **pathogens** and can affect individual organisms, communities of species and entire ecosystems.

For example, the introduction of the chytrid fungus to Australia has led to a decline in many frog populations. The fungus causes a disease called chytridiomycosis, which affects the skin of frogs and can be fatal (Figure 9.7.4).

**KEY TERMS**

**infectious disease** disease caused by infectious agents such as bacteria, fungi or parasites

**pathogen** an agent or factor that causes infectious disease such as bacteria, fungi, parasites or viruses

## Habitat

Habitat changes can occur when introduced species alter the environment in ways that affect native species. For example, the Bitou Bush substantially alters coastal dune habitats by forming dense thickets which impacts native plant and animal species by reducing where they can live and creating habitats that are more favourable for introduced species to survive (Figure 9.7.5).

**FIGURE 9.7.5** Bitou Bush from South Africa has invaded native vegetation at Myall Lakes, New South Wales, Australia

**SC 1 CHECK YOUR UNDERSTANDING**

Describe how the European starling has impacted the native kookaburra.

**SC 2** I can analyse secondary data to identify factors that change populations

Secondary data refers to information that has been collected by someone else and is available for use by others. This data can come from scientific studies, government reports, or other reputable (trustworthy) sources. When examining secondary data that affects ecosystems, it is important to identify the factors that can lead to a change in a population of a species. These factors can include analysing data on predation between organisms, competition within or between species, introduction of disease or invasive species, and habitat changes in an ecosystem.

## SCIENCE IN CONTEXT

### Risks from introduced species

In Australia, introduced species have had significant impacts on the environment. One example is the introduction of rabbits in the 19th century. Rabbits were brought to Australia for hunting, but their population quickly grew out of control. They caused widespread damage to vegetation, leading to soil **erosion** and loss of habitat for native species (Figure 9.7.6). The government has implemented various control measures, such as the introduction of the myxoma virus, in an effort to reduce rabbit populations.

**FIGURE 9.7.6** European Rabbit (*Oryctolagus cuniculus*) outside of its burrow showing the damage done to a grassy field

Another example is the introduction of the cane toad in the 1930s. Cane toads were brought to Australia to control beetles that were damaging sugar cane crops. However, the cane toads quickly spread and became a major pest. They secrete a toxin that is harmful to native predators, leading to declines in populations of native Australian snakes (Figure 9.7.7).

**FIGURE 9.7.7** Australian carpet python feeding on a cane toad



## Using graphs and tables to analyse data

Analysing secondary data involves interpreting the information to understand the factors that affect populations of species. This can include looking at **trends** and patterns over time, comparing data from different sources, and identifying **correlations** between factors.

**KEY TERMS**

**trend** the general direction that the data is moving over time, for example the data can go up, down, or stay the same

**correlation** when two factors are connected in some way

Scientists use graphs and tables to help them come to conclusions about different types of experiments or results they have gathered. By demonstrating results in this way, scientists can easily compare and observe:

- **trends or patterns** – if data is increasing, decreasing or staying the same over time
- relationships between variables – if one variable affects or relates to another
- differences or similarities – if any comparisons can be made between groups, categories or time periods
- outliers – if there are any unusual data points that don't fit the pattern and may need further analysis.

One way to analyse secondary data is to create graphs or tables to summarise the information. This summary can help identify trends and patterns. For example, you can create a line graph to show changes in populations sizes over time (Figure 9.7.8).

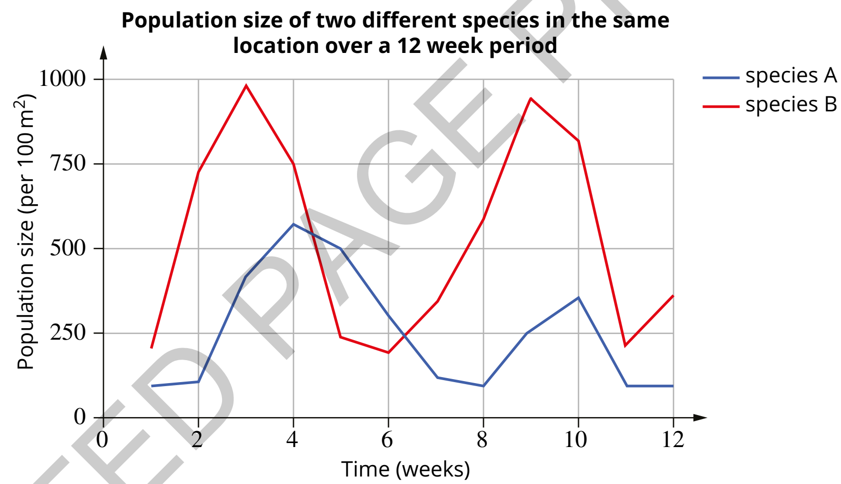



**FIGURE 9.7.8** A line graph demonstrating populations of species changing over time

Another way to analyse secondary data is to compare data from different ecosystems or use information from a variety of data sources. For example, you can compare data on the population size of a species before and after the introduction of an introduced or invasive organism. This can help you identify the impact of the invasive species on the population over a period of time (Figure 9.7.9).

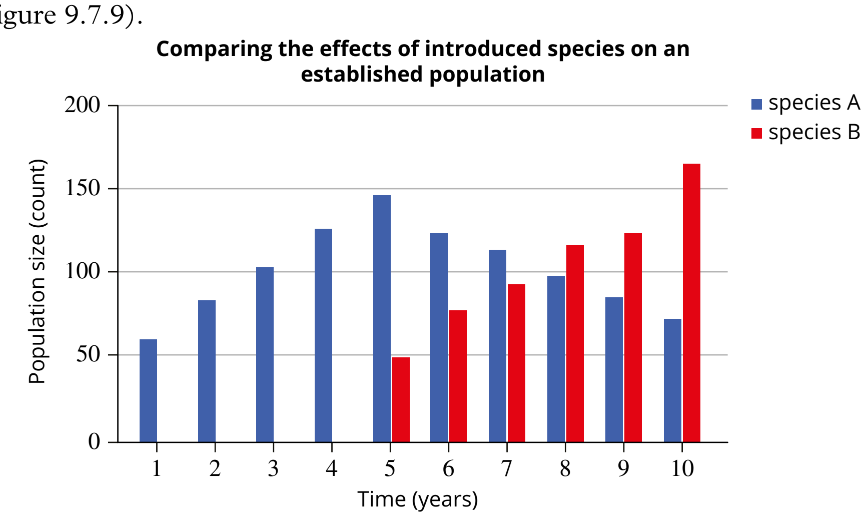



**FIGURE 9.7.9** A column graph comparing population size before and after the introduction of an invasive species

You can also look for relationships between different organisms or other factors that may affect populations in the ecosystem. For example, you can examine data on the population size of a species and the availability of food resources. If there is a correlation between the two, it can suggest that food availability is a factor that affects the population size (Figure 9.7.10).

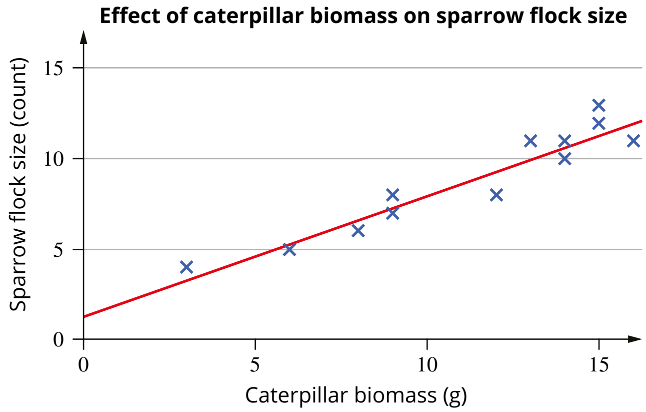



**FIGURE 9.7.10** A scatter graph comparing population size (sparrow flock size) and availability of food (caterpillar biomass)

When analysing secondary data, it is important to consider both the **reliability** and the **validity** of the sources.

Reputable sources include scientific studies, government reports, and data from organisations relevant to the field you are studying that is written by authors that are experts in their field. When gathering data, it is also important to consider the time period and location of the information to make sure it is relevant to your research, analysis and that it is current.

**KEY TERMS**

**reliability** when referring to secondary sources, means that the information is consistent between reputable sources

**validity** when referring to secondary sources, means that the information has been gathered from scientific studies, official websites or reports and it is current

## SC 2 CHECK YOUR UNDERSTANDING

Analyse the data in Figure 9.7.11. How has the introduction of the cane toad affected the population of the blue tongue lizards?

**GO TO ➤**

For more help with analysing data go to Toolkit section x.x.

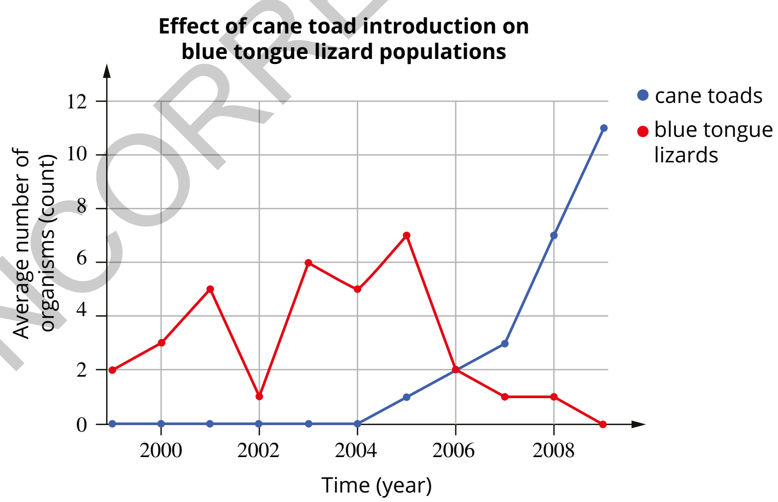



**FIGURE 9.7.11** The graph shows the average number of blue tongue lizards and cane toads encountered per night over a 10-year period.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 Describe what an introduced species is.

2 The introduction of species can lead to significant ecological changes.

   a Explain why introduced species can thrive in new environments.

   b Discuss how introduced species can lead to the extinction of native species.

3 Imagine a scenario where a new fish species is introduced to a freshwater lake.

   a Predict how the fish might affect the existing fish population.

   b Suggest a method to control the population of the introduced fish.

4 Population changes can be influenced by various factors.

   a List three factors that can lead to changes in population sizes.

   b Identify one method used to collect secondary data on populations.

5 Imagine you have secondary data showing a decline in a bird species population.

   a Predict possible reasons for the decline using the data.

   b Suggest a conservation strategy based on the data findings.

# 9 Ecosystems

## Topic summary

The key concepts included in this topic are:

- All ecosystems contain both living (biotic) and non-living (abiotic) factors.
- Changes in populations are affected by biotic and abiotic factors and their interactions.
- In order to be healthy and sustainable environments need to be biodiverse.
- Food chains and food webs represent the feeding relationships in an environment.
- Habitat destruction and pollution have a significant effect on the environment.
- Introduced species can have a significant impact on the diversity of an ecosystem.
- Analysing data in a reliable and valid way can help to observe trends, patterns and make conclusions about population changes in an ecosystem.



## Review questions

The following questions will assess your success in achieving the learning intentions for this topic.

### Remember

**1** Identify the two main factors that make up an ecosystem.

**2** List three reasons for population changes in an ecosystem.

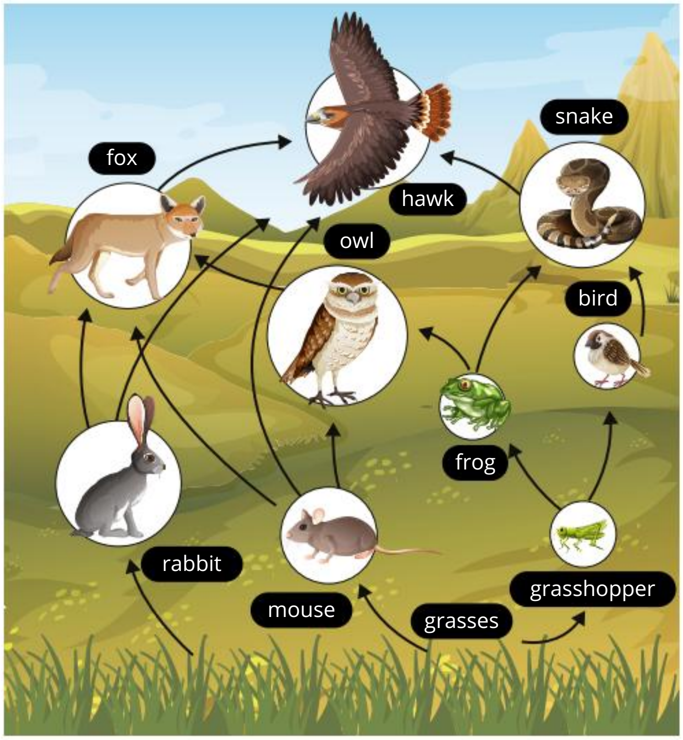
**3** Name three specific threats to Australian ecosystems.

**4** Define the term biodiversity.

**5** What does a food chain represent and how does it show the flow of energy between organisms?

### Understand

**6** Construct one food chain that exists within the grassland food web below.



**7** Using the grassland image above, identify:

- **a** an abiotic factor and explain how that factor can affect the survival of the mouse in its grassland environment
- **b** a biotic factor and explain how that factor can affect the survival of the mouse in its grassland environment.

**8** Describe one way cane toads have contributed to species decline.

**9** Describe one way that scientists can analyse populations.

**10** Explain how invasive species can lead to a decline in populations.

## Apply

**11** Using the grassland image above, identify the producer, primary consumers, secondary consumers and tertiary consumers in the food web.

**12** Describe a predator-prey relationship in an Australian ocean ecosystem.

**13** Construct an African savannah biomass pyramid that has the following organisms and masses.

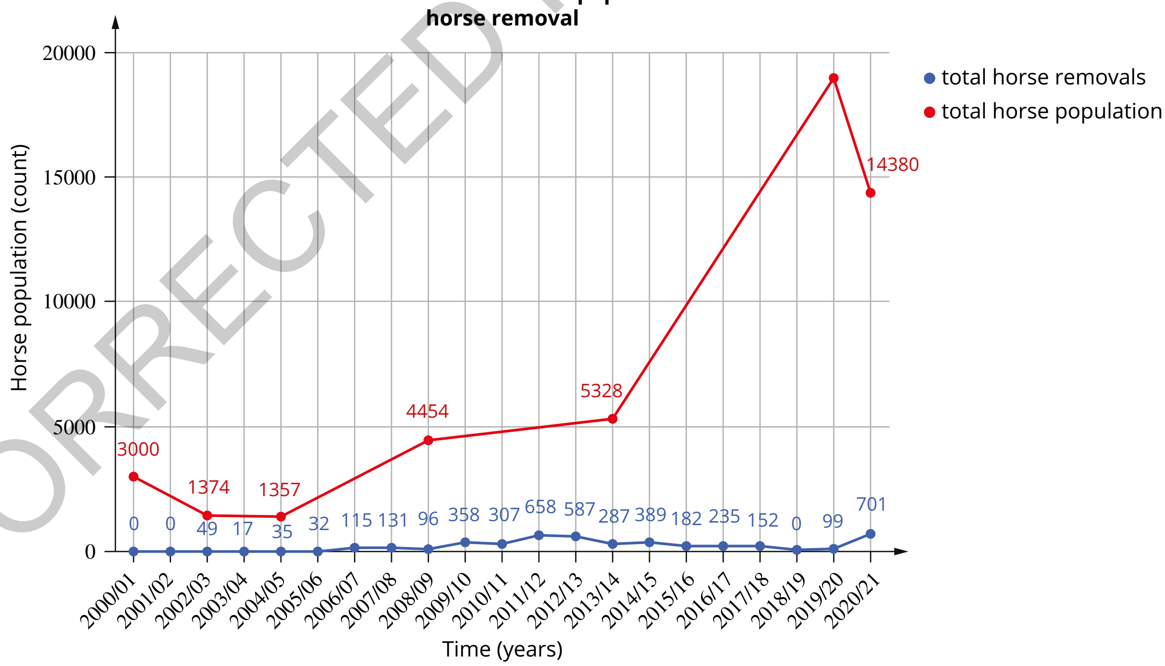
- Lions are the tertiary consumer with a mass of 100 kg.
- African wild dogs are the secondary consumers with a mass of 200 kg.
- Springboks are the primary consumers and have a mass of 700 kg.
- Grasses are the producers and have a mass of 1200 kg.

## Analyse

**14** Discuss the impacts of intensive farming practices on ecosystems.

**15** Scientists are interested in the number of feral horses removed from Kosciuszko National Park in NSW since the horse removal program began in 2002. Data was collected from the area over a period of 20 years. Using the graph below:

**Kosciuszko National Park horse population versus horse removal**




- **a** Describe the trend in the total horse population over time.
- **b** Analyse the trend that is occurring in the total horse population and the total horse removals over time.
- **c** Determine whether the horse removal program has been successful in reducing the total number of horses in Kosciuszko National Park.

**16** Australian organisms have specific needs and depend on several factors to survive.

- **a** Identify the basic survival needs of a native Australian animal of your choice.
- **b** Compare how increased drought conditions caused by climate change may affect your chosen organisms in their environment.

## Extension: Research and create

**17** You will use the internet and other sources to research and compare traditional First Nations medicines to those found in common supermarkets or pharmacies. Then create a poster to advertise this medicine.

- **a** Name one bush medicine and the health issues or problems it treats.
- **b** Describe how First Nations peoples create the medicine and the process involved.
- **c** Compare your chosen bush medicines to a similar medication found in supermarkets or pharmacies.
- **d** Describe the benefits of your chosen bush medicine.

## Topic reflection

The learning intentions for this topic are given in each lesson and at the beginning of the topic. Consider how well you have achieved them. Note down any particular areas that you are confident in, and others where you are not so sure.

# 9 Glossary

**abiotic factor** nonliving parts of an environment

**apex predator** a predator that has no natural predators except humans

**biodiversity** the number and range of species that exist in an ecosystem, biome or biosphere

**biomass** all plant and animal matter found on earth

**biomass pyramid** a visual representation of the biomass at different levels of a food chain

**biomass transfer** energy and nutrients of one living thing moves to another living thing after being eaten

**biotic factor** living parts of an environment

**canopy** the top of the forest

**carnivore** consumer that eats only other animals

**commensalism** a symbiotic relationship where one organism benefits and the other organism is unaffected

**community** groups of organisms that interact within an ecosystem

**competition** relationship between organisms that are trying to use the same limited resource

**correlation** when two factors are connected in some way

**conservation** the protection of resources, such as land and biodiversity

**consumer** organism that must eat other organisms to get the energy and nutrients it needs

**decomposer** organism that gets the energy it needs by breaking down dead matter and waste products

**ecologist** scientists who study the interactions between living things and their environment

**ecology** the study of how organisms interact with each other and with their non-living surroundings

**ecological pyramid** a graphical representation showing the relationship between different organisms in an ecosystem

**ecosystem** a system formed by organisms interacting with each other and their nonliving surroundings

**endangered species** an animal or plant that is at serious risk of disappearing forever

**energy** the ability to do work; can be in many forms including heat, movement and electricity

**environment** all the factors in an organism's surroundings that affect its survival

**erosion** the removal of sediments from one place to another

**extinct** a type of animal or plant no longer exists anywhere in the world

**faeces** solid waste products made from consuming other organisms after digestion

**foliage** the leaves on plants or trees

**food chain** the flow of energy from organism to organism in a series of feeding relationships

**food web** interconnected food chains representing the varied sources of energy for organisms

**genetic** relating to characteristics or features passed on from parent to offspring

**glucose** a type of sugar made by producers such as plants

**habitat** the place where an organism lives

**herbivore** an animal that eats only plants

**host** a plant or animal that a parasite lives on or in

**infectious disease** disease caused by infectious agents such as bacteria, fungi or parasites

**mass** the amount of matter in a substance or object; measured in grams (g), kilograms (kg) or tonnes (t)

**mutualism** a type of relationship where both living things help each other and benefit from the relationship

**nutrition** the process of obtaining the food (nutrients) needed for an organism to grow, stay healthy, and have energy

**omnivore** an animal that eats both plants and animals

**organism** a living thing

**parasite** a living thing that lives on or inside another living thing (host) usually harming the host while helping themselves

**parasitism** a symbiotic relationship where one organism benefits and the other organism is usually harmed

**pathogen** an agent or factor that causes infectious disease such as bacteria, fungi, parasites or viruses

**photosynthesis** the chemical reaction in plants that converts carbon dioxide and water into oxygen and glucose using energy from the Sun

**pollination** the process where pollen from a flower is moved from the male part of the flower to the female part of the flower

**population** a group of organisms of the same species, which live in the same area

**predator** an animal that kills and eats other animals

**prey** an animal that is eaten by a predator

**primary consumer** a consumer that only eats plants, algae and other producers; also known as a first-order consumer

**producer** organism able to manufacture its own food; plants are producers

**pyramid of numbers** a diagram representing the number of organisms in an ecosystem

**reproduction** the process by which animals and plants create offspring

**sampling technique** method that scientists use to collect information about plants, animals, and other living things in a certain area

**secondary consumer** a consumer that eats a primary consumer; also known as a second-order consumer

**species** a group of living organisms that share similar characteristics and can reproduce with each other to produce offspring that can also reproduce

**species diversity** the variety of species in an ecosystem

**sustainable** using resources in a way that keeps Earth healthy for a long time

**symbiosis** a close relationship between two different living things where at least one of them benefits

**symbiotic relationship** an interaction between two different living things where they help each other

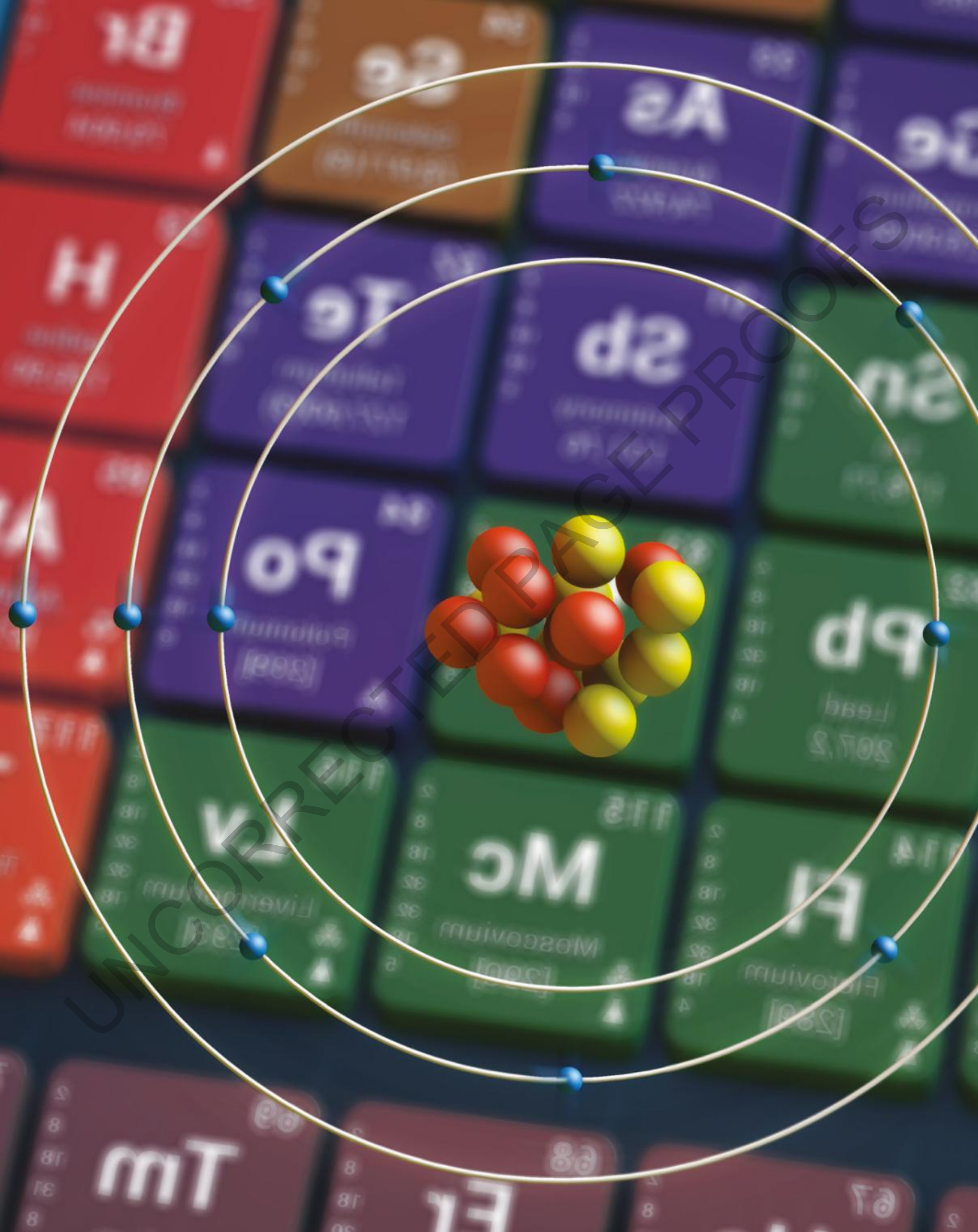
**terrestrial** on land, environments such as grasslands, savannahs, deserts and forests

**tertiary consumer** a consumer that eats a secondary consumer; also known as a third-order consumer

**trend** the general direction that the data is moving over time, for example the data can go up, down, or stay the same

**trophic level** the position of an organism in a food chain

**vulnerable** an animal or plant is at risk of becoming endangered



TOPIC 10

# Elements and compounds

Atoms are the tiny building blocks that make up everything around us. Sometimes an atom can join with other atoms to form a molecule. Elements are substances that only contain one type of atom, and each element can be represented using an atomic symbol, for example, C for carbon and Ne for neon. There are 118 known elements in the universe. Scientists represent the elements in an organisational tool called the periodic table.

Atoms are made up of even smaller subatomic particles called protons, neutrons and electrons. The protons and neutrons make up the middle of the atom, called the nucleus, while the electrons orbit the nucleus.

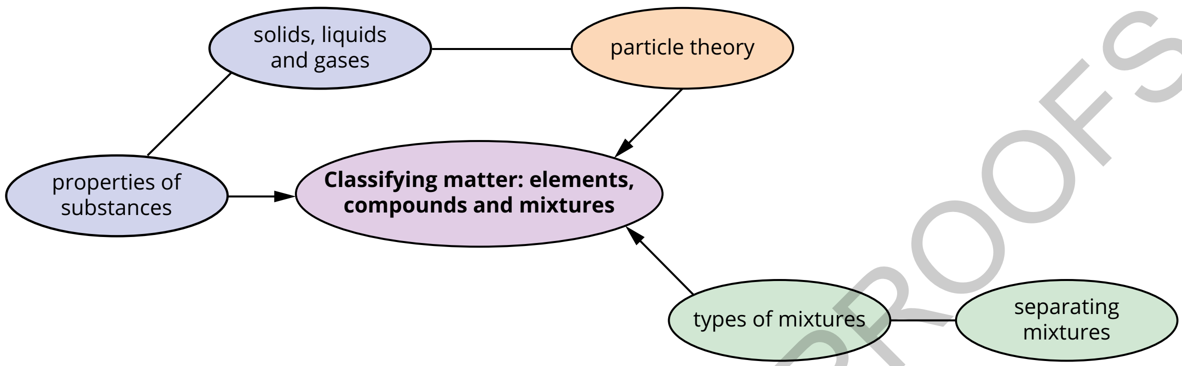
In this topic you will learn about atoms, elements and compounds. You will also look more closely at how the structure of the periodic table is linked to the structure of atoms, and you will use this knowledge to explain and predict the behaviour of substances made up from atoms.

## Learning intentions

- [ ] To understand the differences between elements and compounds **xx**
- [ ] To understand that elements are made up of only one type of atom **xx**
- [ ] To be able to conduct investigations that identify and compare the physical properties of metals, non-metals and metalloids **xx**
- [ ] To be able to investigate some tests that are used to identify metal and non-metal elements **xx**
- [ ] To understand how properties of elements relate to their uses **xx**
- [ ] To be able to investigate how the properties and availability of materials influence their uses **xx**
- [ ] To be able to use a model to show how atoms are made up of subatomic particles **xx**
- [ ] To understand that different atoms have different numbers of subatomic particles **xx**
- [ ] To be able to describe discoveries that contributed to the knowledge of the structure of the atom **xx**
- [ ] To understand the historical processes involved in the development of the periodic table as a model for the organisation of elements **xx**
- [ ] To be able to observe characteristic properties of group 1 metals **xx**
- [ ] To understand the Bohr model of the atom **xx**
- [ ] To be able to conduct a valid, safe investigation to test the reactivity of metals within a group **xx**

# 10 Elements and compounds

The key concepts that you will use in this topic:




The following prior knowledge questions will help to support your learning in the topic and can be attempted before the first lesson.

## Properties of substances

**1** The three key states of matter are solids, liquids and gases. Name the state(s) that:

- **a** have a fixed shape
- **b** have a definite boundary
- **c** can diffuse quickly
- **d** cannot be compressed.

**2** When a balloon is filled with helium gas, it can float upwards in the air. A student suggested that this must be because the helium makes the balloon lighter. State whether you agree with this, explaining the reasons for your answer.

## Particle theory

**3** All materials are made up of particles. Describe the behaviour of particles in a liquid in terms of their movement, spacing and attractions between particles.

**4** Liquified petroleum gas (LPG) is a fuel used for barbeques and some cars. When released from a cylinder it turns into a gas. Explain, using the ideas of particle theory, why it is in liquid form when contained in the cylinder.

**5** Describe what happens to the particles in a solid when the solid is heated.

## Types of mixtures and separating mixtures

**6** When salt is added to water and stirred, the salt seems to disappear.

- **a** Using the terms solute, solvent, soluble, dissolves and solution, describe what has happened to the salt.
- **b** Describe a way to recover the salt from the water.

**7** Air in the atmosphere contains a number of gases including oxygen, nitrogen, carbon dioxide and helium.

- **a** Which one of these gases is the most abundant in the atmosphere?
- **b** State whether you think the amounts of each gas in the atmosphere are fixed or can change. Explain the reasons for your answer.

# 10.1 Elements and compounds in everyday life

## Lesson overview

The desk you are sitting at, the pen you are holding and the clothes you are wearing are all made of matter. Chemistry is the study of matter, and all matter is made up of atoms.

In this lesson you will learn about the differences between atoms, elements and compounds. You will also learn about compounds that are found in everyday items and how to draw particles in elements and compounds.

**SC 1** I can describe differences between elements and compounds.

All matter in the universe is made up of tiny particles of different kinds of **atoms**. There are 118 different types of atoms, which can combine to form everything we know. These combinations can be in the form of elements, compounds or mixtures.

### Learning intention

To understand the differences between elements and compounds

### Success criteria

**SC 1:** I can describe differences between elements and compounds.

**SC 2:** I can draw diagrams that demonstrate the differences in particle arrangement between elements and compounds.

## Elements

An **element** is a substance that is made from one type of atom. Elements have a wide range of different properties: from hydrogen, which is a colourless gas, to mercury, a metal that is a liquid at room temperature. Some examples of elements found in everyday items include:

- oxygen (O)—found in the air we breathe and in water ($H_2O$)
- carbon (C)—found in pencils (as graphite) and in all living things
- iron (Fe)—found in tools, cutlery and steel objects like bikes or cars
- aluminium (Al)—found in foil, drink cans and some cooking pots
- calcium (Ca)—found in milk, cheese and bones.

**KEY TERMS**

**atom** the smallest piece of individual matter that can exist by itself
**element** a substance made up of only one type of atom
**compound** a pure substance that is made up of two or more different types of atoms chemically joined

## Compounds

A **compound** is a substance made of two or more different types of atoms that are chemically bonded together. The acid in your stomach is hydrochloric acid and it contains the elements hydrogen and chlorine. Other examples include:

- water ($H_2O$)—found in drinks, showers, rain and almost everywhere!
- salt (sodium chloride, NaCl)—found in table salt used for cooking
- carbon dioxide ($CO_2$)—found in fizzy drinks and in the air we exhale
- baking soda (sodium bicarbonate, $NaHCO_3$)—used in baking and cleaning
- sugar (sucrose, $C_{12}H_{22}O_{11}$)—found in sweet foods like lollies and soft drinks.

## Molecules

In many compounds, the atoms are joined together to form a **molecule**. Molecules can have atoms of the same element, like oxygen ($O_2$), or different elements, like water ($H_2O$).

Not all atoms joined together form a molecule. Salt (NaCl) is not a molecule because it doesn't exist as small, separate particles. Instead, it's made of sodium

**KEY TERM**

**molecule** two or more atoms that are joined together to form a separate particle and chloride ions that are arranged in a big, repeating grid. Water is an example of a compound, made up of molecules of two hydrogen atoms and one oxygen atom (Figure 10.1.1).


**FIGURE 10.1.1** Water is one of the most common compounds. It is made up of hydrogen and oxygen and its chemical formula is $H_2O$.

**KEY TERMS**

**pure substance** a material that is made up of only one type of substance

**mixture** a combination of two or more pure substances that can be separated to recover the pure substances

## Pure substances

In science, 'pure' refers to the presence of only one substance or element. This applies to both elements and compounds, which are known as **pure substances**. Neon gas (Ne) is a pure substance containing only Neon atoms that are not joined together. Nitrogen gas ($N_2$) on the other hand is a pure substance containing only molecules of two nitrogen atoms joined together.

Particle diagrams such as those in Figure 10.1.2 represent the particle arrangement in elements, molecules, compounds, **mixtures** and pure substances.

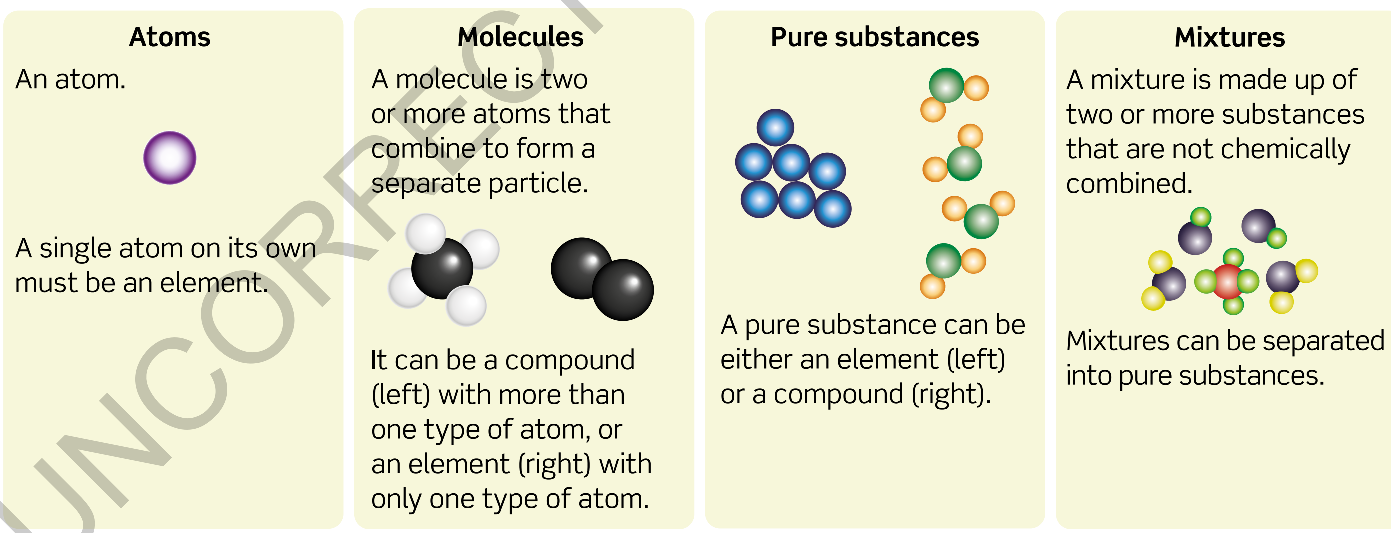



**FIGURE 10.1.2** Particle diagrams

**SC 1 CHECK YOUR UNDERSTANDING**

A student said that carbon dioxide ($CO_2$) and oxygen ($O_2$) must both be compounds as they contain molecules. Explain why this is incorrect.

**SC 2** I can draw diagrams that demonstrate the differences in particle arrangement between elements and compounds.

Many everyday substances are elements, for example, copper, tin, neon and oxygen. Elements are made of one type of atom.

Other substances might be compounds. Table salt, sugar, water and ammonia are all examples of compounds. This means that they are made of two or more elements chemically joined together. Compounds have a fixed ratio of elements, which can be described using a **chemical formula**.

**KEY TERM**

**chemical formula** a representation of a substance that uses chemical symbols and numbers to show the relative numbers of the atoms present in the substance

## SkillBuilder

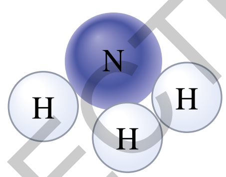
### Drawing elements and compounds

Atoms and molecules can be represented with diagrams.

- Each atom can be a circle.
- Every element will have its own colour/shading to distinguish it from other elements.
- Atoms that are joined (bonded) together should be shown as touching each other.
- Use a key or labels to identify the different elements.

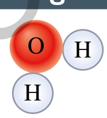
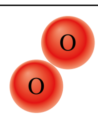
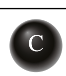
### Example

Lottie is asked to draw ammonia. She knows that it has one nitrogen atom and three hydrogen atoms. She represents this as one nitrogen atom (coloured blue and labelled with 'N') in contact with three hydrogen atoms (coloured white and each labelled 'H').




Diagrams can represent the differences between atoms and molecules and whether the substance containing these particles is an element or a compound. Table 10.1.1 shows examples of diagrams for some simple substances.

**TABLE 10.1.1** Examples of atoms and molecules in elements and compounds

| Substance | Diagram | Description |
|---|---|---|
| water |  | Water's chemical formula is $H_2O$. Because it has more than one element, it must be a compound. Because there are two or more atoms joined together, the particle is also a molecule. |
| oxygen |  | Oxygen is an element. Oxygen has the chemical formula $O_2$ so it contains molecules with two oxygen atoms joined together. |
| carbon |  | Carbon is an element. It is made from just carbon atoms. |

**SC 2 CHECK YOUR UNDERSTANDING**

Methane has the chemical formula $CH_4$. Carbon can bond with four other atoms but hydrogen can only bond with one other atom. Draw a labelled diagram of a molecule of methane.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

**1** Identify the following as a mixture, an element or a compound.

- **a** air
- **b** gold (Au)
- **c** muddy water
- **d** baking soda ($NaHCO_3$)

**2** Read the following statements about elements and compounds. Rewrite any that are wrong to make them correct.

- **a** Compounds are not pure substances because they contain more than one element.
- **b** Compounds do not contain atoms.
- **c** All elements are made up of individual atoms that are not joined together.

**3** Oxygen gas has the formula $O_2$.

- **a** Describe the particles that exist in a sample of pure oxygen.
- **b** Water is a compound that contains oxygen. Describe the particles present in pure water.
- **c** Name three other compounds that contain oxygen.

**4** Carbon tetrachloride is a compound that is made up of molecules that each contain one carbon atom and four chlorine (Cl) atoms. Draw a labelled diagram of a molecule of carbon tetrachloride.

**5** Air is a mixture that contains a number of gases, including oxygen ($O_2$), nitrogen ($N_2$), carbon dioxide ($CO_2$) and argon (Ar).

- **a** Using these examples, explain the difference between elements and compounds.
- **b** Using Ar and $N_2$, explain the difference between atoms and molecules.
- **c** Explain why air cannot be described as a compound.

# 10.2 Elements, atoms and symbols and the periodic table

## Lesson overview

Over time, scientists have gained a deep understanding of the structure of atoms, which are the basic building blocks of matter. In 1802, an English scientist called John Dalton presented the first atomic theory of matter. Dalton described elements as materials containing just one type of atom.

There are 118 elements that have been identified and named, and each has its own unique symbol. Sometimes these symbols are obvious, like Ne for neon; other times they are less obvious, like Au for gold. All known elements are represented and organised in the periodic table.

In this lesson you will learn about atoms and elements. You will learn that atoms make up all matter, that an element is a collection of one type of atom, and that each element has a unique symbol represented on the periodic table.

**Learning intention**

To understand that elements are made up of only one type of atom

**Success criteria**

**SC 1:** I can explain what an atom is.

**SC 2:** I can state the names of a range of elements and represent them with symbols.

**SC 1** I can explain what an atom is.

Imagine small building blocks making up everything around you, which can be modelled as tiny spheres. You cannot see them, but they make up all matter. Previously, you have learned that matter is anything that has a mass and takes up space. This could be something solid, like a piece of wood, or it could be the air around you.

All matter is made up of atoms. Atom comes from the ancient Greek word *atomos*, which means 'uncuttable' or indivisible. Atoms are the smallest individual pieces of matter that can exist by themselves. Think of an atom like a grape: there are parts that make up a grape (the skin, the flesh, the seed) but for it to be a grape you need all the parts.

Figure 10.2.1 shows a simplified model of an atom. Atoms are very small and cannot be seen, even under a microscope. For example, a human hair could fit approximately a million carbon atoms across its width. You will learn more about the structure and parts of an atom in Lesson 10.9.

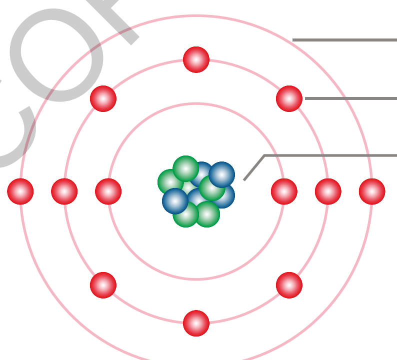



**FIGURE 10.2.1** Atoms are too small to see. This is a simplified model of an atom.

One way to think about the idea of an atom is to carry out a 'thought experiment'. Imagine a solid, such as a piece of gold, then imagine cutting it in half, then in half again and again and again and so on. Eventually you would get to the point at which you cannot divide the gold anymore. At this point, you have reached one atom of gold.

## SC 1 CHECK YOUR UNDERSTANDING

The word atom is derived from the Greek word *atomos*, which was used to describe something that cannot be cut up into smaller pieces (something that is indivisible).

**a** Explain why this word was chosen to describe the idea of atoms.

**b** Describe two other characteristics of atoms.

**SC 2** I can state the names of a range of elements and represent them with symbols.

## The periodic table

All elements are listed on an organisational tool called the periodic table (Figure 10.2.2). Vertical columns are called groups, and horizontal rows are called periods. Periodic means repeating, and each row has similarities to the other rows, which is why the name 'periodic' table is used.

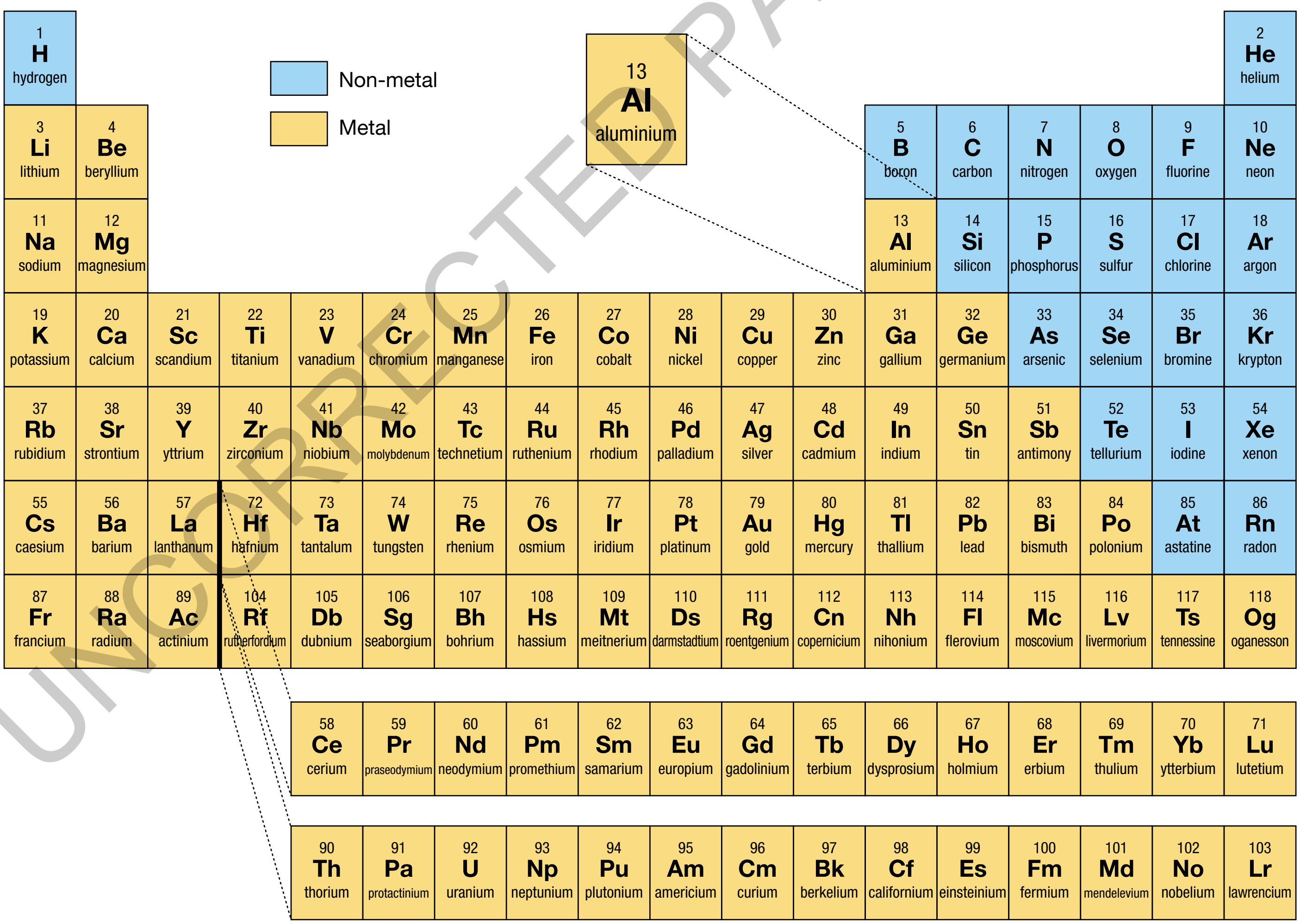



**FIGURE 10.2.2** The modern periodic table

All elements have a unique symbol. Some symbols seem obvious, like H for hydrogen. Others are not obvious, like Na for sodium. Some have been named after a place (e.g. Americium), some have been named after a famous scientist (e.g. Mendelevium, named after Dmitri Mendeleev, who developed the first periodic table) and some are named from ancient languages (e.g. helium is from the Greek word for sun, *helios*). Only elements are found on the periodic table.

Writing element symbols is an important skill that helps you communicate information. Consider the example of the symbol for magnesium (Mg) shown in Figure 10.2.3. Identify the element on the periodic table. The first letter (M) must be in upper case. If there is more than one letter, the rest must be in lower case. For magnesium, write Mg (never MG or mg).

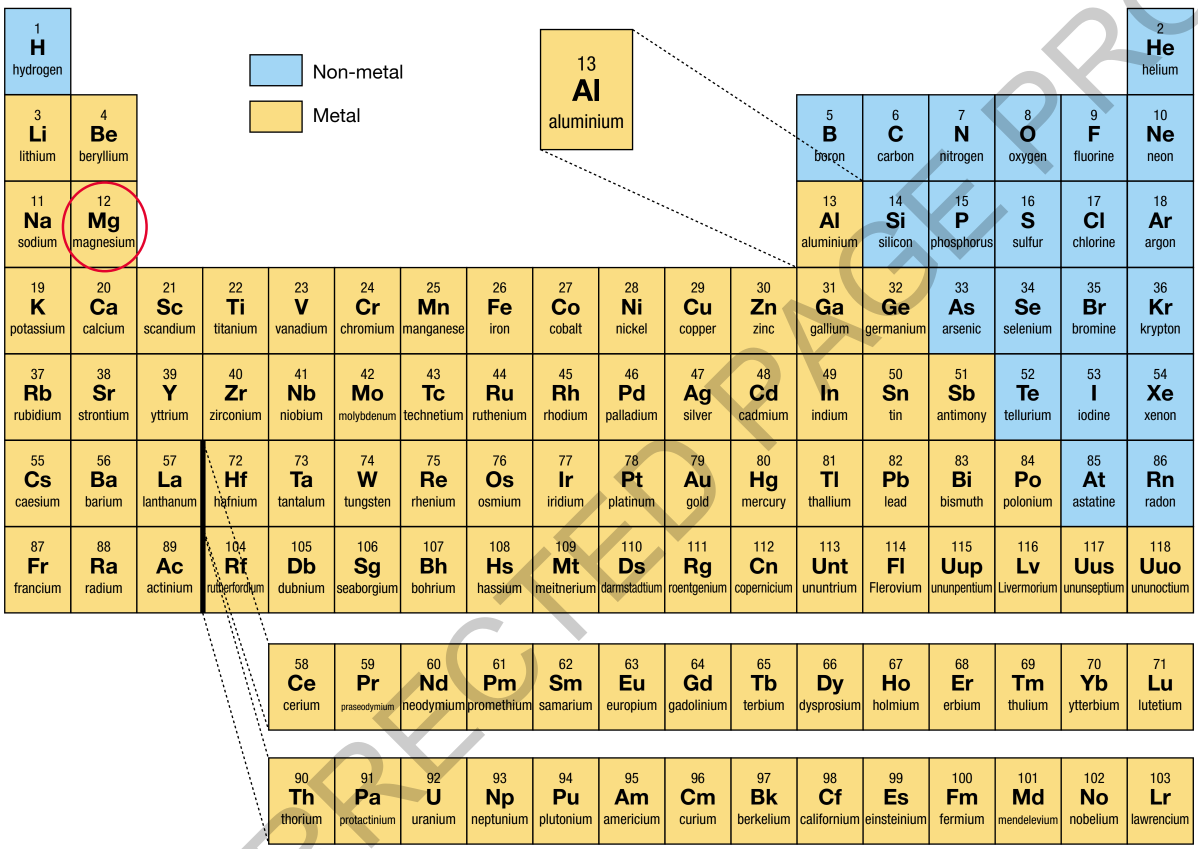



**FIGURE 10.2.3** The element magnesium

## New elements

When new elements are discovered in a laboratory, they are given a temporary three-letter symbol. Once the discovery has been confirmed, the element is given its official name and symbol (usually two letters). For example, element 117, previously known as ununseptium (Uus), is now called tennessine (Ts) after the American state of Tennessee (Figure 10.2.4).

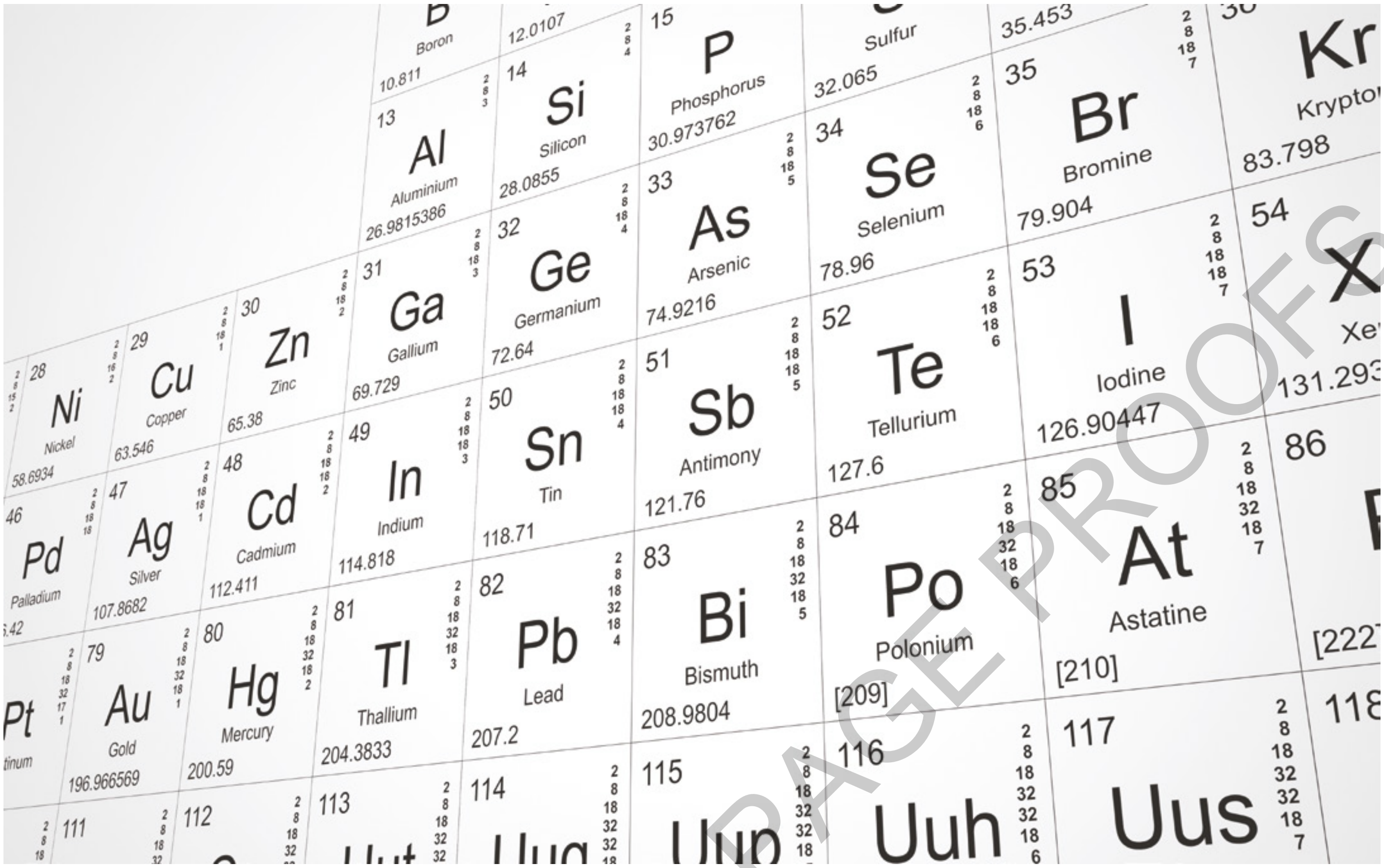



**FIGURE 10.2.4** Section of a version of the periodic table showing some three-letter symbols, including ununseptium (element 117)

## More elements

Table 10.2.1 provides information about four more common elements: sodium, nickel, iron and copper.

**TABLE 10.2.1** Four common elements

| Element | Symbol | Origin |
|---|---|---|
| sodium | Na | Latin (*natrium*)—soda in English |
| nickel | Ni | From German word *kupfernickel*, meaning devil's copper |
| iron | Fe | Latin (*ferrum*) |
| copper | Cu | The Romans first obtained copper on the island of Cyprus, and the Latin word for Cyprus is *cuprum* |

### SC 2 CHECK YOUR UNDERSTANDING

State the symbols for the following elements.

- **a** helium
- **b** mercury
- **c** gold
- **d** magnesium
- **e** manganese
- **f** iron
- **g** sodium
- **h** chlorine

# Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 Carbon is the element upon which life on Earth is based. Compounds, such as DNA, proteins and sugars (a type of carbohydrate) all contain carbon.

a State the chemical symbol of carbon.

b Suggest what two other elements are present along with carbon in all carbohydrates. (Hint: 'Hydrated' means 'contains water'.)

2 The following words can be spelt by combining chemical symbols. For each word identify the symbols and the names of the elements used to make the words. It would help to have a periodic table to refer to for this question.

For example:

band = Ba (barium) Nd (neodymium)

a flames

b dynamite

3 Consider the table below that shows a range of elements and their chemical symbols.

| Name | Symbol |
|---|---|
| copper | Cu |
| europium | Eu |
| curium | Cm |
| francium | Fr |
| sodium | Na |
| mendelevium | Md |

From these elements, state two:

a that are named after places

b that are named after people

c that have their symbols derived from the Latin names of the elements.

# 10.3 Metals and non-metals

## Learning intention

To be able to conduct investigations that identify and compare the physical properties of metals, non-metals and metalloids

## Success criteria

**SC 1:** I can conduct investigations to identify the physical properties of metals, non-metals and metalloids.

**SC 2:** I can compare the physical properties of metals, non-metals and metalloids.

### KEY TERMS

**metal** an element that is shiny, conducts heat and electricity, and can be hammered into sheets and drawn into wires
**metalloid** an element that usually displays the properties of a non-metal but conducts electricity like a metal under certain conditions
**lustre** the shine given off by a material, caused by reflected light
**lustrous** shines when polished or freshly cut
**malleable** able to be hammered or bent into a new shape
**ductile** able to be stretched to form a wire
**conductivity** a measure of the ability of a substance to conduct electricity
**reactive** a description of a substance that readily undergoes chemical reactions

## Introduction

Why do you think electrical wires are made of copper (Figure 10.3.1)? What about a saucepan being made of stainless steel or aluminium?

What is it about these substances that makes them suitable for use?

The answer to the last question is based on what properties the substances have. Some groups of substances, such as metals, have special properties that non-metals don't have. Some may show properties of both **metals** and non-metals. These elements are called **metalloids**.

**FIGURE 10.3.1** Copper is ductile which means it can be drawn into a wire.

## Background

This practical investigation will examine a range of materials (metals and non-metals) and test their properties.

Properties tested include the following.

- **Lustre**—the shine given off from a material. A highly polished metal has high lustre (or is **lustrous**), while a piece of unvarnished wood might be dull (not lustrous).
- Malleability—a substance is **malleable** if it can be moulded into shape. If you were to hit the substance with a hammer, would it flatten or would it break (brittle)?
- Ductility—a substance is **ductile** if it can be stretched into a wire. Do you think the substance could be pulled to make a thin wire?
- **Conductivity**—a measure of the ability of a substance to conduct electricity. A light globe (which can be replaced by an ammeter or multimeter) will indicate whether a current is passing through a substance and around a circuit.
- Reactivity—is it **reactive** with oxygen in the air (chemical property).

## Aim

To investigate the physical properties of some common metals, non-metals and metalloids

## Prediction

Read the method for the experiment and write a prediction about which properties will be observed for metals and which properties will be observed for non-metals.

**SAFETY NOTE**

- All these samples can irritate the skin and eyes and must be regarded as hazardous. Wear rubber gloves and safety glasses at all times. Wash your hands thoroughly with soap and water after the investigation.

## Apparatus

- samples to test: sulfur, aluminium, carbon, silicon, tin, zinc, magnesium, iron
- sandpaper
- three or four test tubes and test tube rack
- power pack or battery (about 2 V)
- wires with alligator clips
- light globe (or ammeter/multimeter)
- disposable gloves

## Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

## Method

1. Research the elements tested to determine which are metals, non-metals and metalloids. Classify each one in your results table.
2. Record the appearance of each sample in your results table.
3. Polish each sample with the sandpaper. Record its appearance now.
4. Try to bend the sample. Record whether it bends or crumbles.
5. Place some of the sample in a test tube with water. Record whether it floats or sinks and whether any change is obvious. For example, does it dissolve or react?
6. Test the sample for its conductivity.
   - Use the power pack or battery to set up the electrical circuit shown in Figure 10.3.2.
   - Record the brightness of the light globe or the current measured with the ammeter/multimeter.
7. Repeat steps 4–6 for each sample.

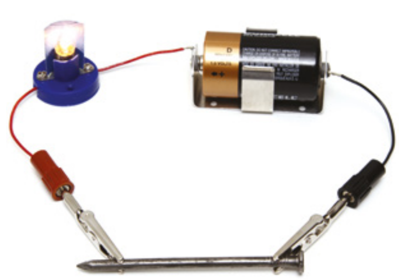


**FIGURE 10.3.2** Using the equipment to test the conductivity of the iron nail

## Results

Copy the following table into your notebook and use it to record results.

| Element | Metal or non-metal or metalloid | Appearance when polished | Bends or crumbles | Floats or sinks | Action with water | Electrical conductivity |
| --- | --- | --- | --- | --- | --- | --- |
| | | | | | | |
| | | | | | | |

## Discussion

Evaluate your practical investigation by answering the following questions.

1 Were there any elements that were difficult to classify as metal or non-metal? If so, why?

2 Describe where the element(s) identified in Question **1** are located on the periodic table.

3 If you were to conduct this investigation again, identify any steps that you might do differently in order to improve your results.

## Conclusion

Write your conclusion by answering the following questions.

1 Metals share certain physical properties. From your observations, what are they?

2 List the properties that were common in all the non-metals you tested.

3 Use the periodic table in Figure 10.2.2 on page XX to locate the elements tested. Can you make a conclusion about where metals, non-metals and metalloids are located on the periodic table?

# 10.4 Identifying metals and non-metals

## Introduction

In this practical investigation, you will observe some of the physical and chemical properties investigated in Lesson 10.3 and use the results to classify each of the tested substances as metal or non-metal.

### Learning intention

To be able to investigate some tests that are used to identify metal and non-metal elements

### Success criteria

**SC 1:** I can perform tests to identify metal and non-metal elements.

**SC 2:** I can analyse the results of tests to distinguish between metals and non-metals.

## Background

Metals have certain properties. They are malleable, ductile, can conduct electricity and are lustrous.

This practical investigation will examine a range of materials (metals and non-metals) and test their properties. The observed properties will be used to classify each material as metal or non-metal.

## Aim

To investigate common properties of various substances and classify them as metals or non-metals

## Prediction

Read the method for the experiment, then use your knowledge of the properties of metals and non-metals to predict which of the substances tested are metals and which are non-metals.

## Apparatus

- samples to test: iron nail, stainless steel nail, copper strip, magnesium strip, piece of chalk, plastic, brass tacks, wood, graphite rod
- sandpaper
- 3 or 4 test tubes and test tube rack
- power pack or battery (about 2 V)
- wires with alligator clips
- light globe (or ammeter/multimeter)
- copy of the periodic table
- disposable gloves

### SAFETY NOTE

- Keep any electrical equipment away from water.

## Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

## Method

Use this method for each sample.

1 Record the appearance, including lustre.
2 Try to bend the substance. Record whether you think the substance is malleable.
3 Record whether you think the substance is ductile.
4 Use sandpaper to scratch the surface of the material. If the fresh surface that you have uncovered is a different colour to the old surface, it is likely that the old surface had reacted with oxygen in the air. This suggests that the substance is reactive.
5 Check the sample for its conductivity.
   - Use the power pack or battery to set up the electrical circuit shown in Figure 10.3.2.
   - Record the brightness of the light globe or the current measured with the ammeter/multimeter.

## Results

Copy the following table into your notebook and use it to record results.

| Sample | Appearance | Malleable (yes/no?) | Ductile (yes/no?) | Reactive (yes/no?) | Conducts electricity (yes/no?) |
|---|---|---|---|---|---|
| iron nail | | | | | |
| stainless steel nail* | | | | | |
| copper strip | | | | | |
| magnesium strip | | | | | |
| chalk | | | | | |
| plastic | | | | | |
| brass tack* | | | | | |
| wood | | | | | |
| graphite | | | | | |

*Note that brass and stainless steel are metals that are alloys.

## Discussion

Evaluate your practical investigation by answering the following questions.

1 Were there any substances that were difficult to classify as metals? If so, why?
2 Identify any other challenges you encountered during this investigation.

## Conclusion

Write a conclusion to your experiment by answering the following questions.

1 Metals are shiny, malleable, ductile and can conduct electricity. Non-metals are usually dull, brittle (break easily) and do not conduct electricity. Look at the substances you tested and classify them as metals or non-metals. (You can include the alloys as metals.)

2 Find the position of the pure metals used in this experiment on the periodic table. What do you notice about where they are located?

3 Research the materials used to make brass. Name the metals used to make brass and suggest why alloys like brass are normally shiny, malleable, ductile and can conduct electricity.

4 Iron is a fairly reactive metal (it forms rust when in contact with oxygen and water). Chromium is a very resistant to corrosion. Suggest why stainless steel contains chromium.

5 Suggest why stainless steel is used instead of iron on boats.

6 Suggest why electrical wires are often coated with a plastic layer.

# 10.5 Uses of metals and non-metals

**Learning intention**

To understand how properties of elements relate to their uses

**Success criteria**

**SC 1:** I can describe the properties of common elements, compounds and alloys.

**SC 2:** I can explain how the properties of elements can determine their uses.

**KEY TERM**

**corrosion** the breakdown of metals due to their reaction with other chemicals

**Scifile**

**The iron triad**

Iron, cobalt and nickel are a group of three metals sometimes referred to as the 'iron triad' or 'iron group'. They share similar chemical and physical properties and are the only magnetic metals, making them suitable for use in electrical devices.

## Lesson overview

Metals and non-metals are all around us, from the aluminium in a drink can to the carbon in your pencil. These elements have specific properties that make them suitable for different uses.

In this lesson you will learn about the properties of common elements, compounds and alloys, and how these properties determine their uses.

**SC 1** I can describe the properties of common elements, compounds and alloys.

## Properties of common elements

Elements can be metals or non-metals. Metals, such as iron, copper and aluminium, are typically shiny, malleable (can be hammered into thin sheets), ductile (can be drawn into wires) and good conductors of heat and electricity. Non-metals, such as carbon, oxygen and sulfur, are usually dull, brittle (break easily) and poor conductors of heat and electricity.

The diverse properties of different metals make them suitable for many purposes. Metals are malleable so they are often shaped for use in different applications. For example, aluminium is used in drink cans because it is lightweight, non-toxic and resistant to **corrosion** (Figure 10.5.1).

**FIGURE 10.5.1** Aluminium drink cans

## Properties of common compounds

Recall from Lesson 10.1 that compounds are substances formed when two or more elements chemically combine. For example, water ($H_2O$) is a compound made of hydrogen and oxygen. Compounds have different properties from the elements that form them. For instance, sodium chloride (table salt) is formed from sodium, a highly reactive metal, and chlorine, a poisonous gas. However, sodium chloride is safe to eat.

Water is essential for life because it is a good solvent, meaning many substances such as salt and sugar can dissolve in it (Figure 10.5.2).

**FIGURE 10.5.2** Salt dissolving in water

## Properties of common alloys

**Alloys** are mixtures of two or more metals, or a metal and a non-metal. Alloys are created to improve the properties of the original metals. For example, steel is an alloy of iron and carbon. It is stronger and more durable than pure iron. Another example is brass, which is an alloy of copper and zinc. Brass is more resistant to corrosion than pure copper and has a pleasing golden appearance, making it suitable for decorative items and musical instruments. Stainless steel, which contains iron, carbon and chromium, is used in kitchen utensils because it is resistant to rust (Figure 10.5.3).

**KEY TERM**

**alloy** a substance formed when other materials, for example carbon or other metals, are mixed with a metal

**FIGURE 10.5.3** Stainless steel kitchen utensils

**SC 1 CHECK YOUR UNDERSTANDING**

Explain how the properties of sodium chloride (table salt) are different from the properties of sodium and chlorine.

**Scifile**

**Gold's unique properties**

Gold is highly malleable and ductile, meaning that it can be hammered into thin sheets or drawn into wires. A single gram of gold can be beaten into a one square meter sheet.

## SCIENCE IN CONTEXT

### The role of metals in technology

Metals play a crucial role in modern technology. For example, copper is used in electrical wiring because it is an excellent conductor of electricity. The properties of copper, such as its ductility and thermal conductivity, make it ideal for this purpose. In the medical field, titanium is used for implants because it is biocompatible, meaning that it does not react with body tissues. This property makes it ideal for use in joint replacements and dental implants, for example.

A typical mobile phone contains over 40 different metals. Circuit boards in home appliances, personal computers and mobile phones contain precious metals such as gold, silver and platinum and other metals such as copper, iron and aluminium.

Electronic waste is considered the fastest-growing source of hazardous waste in the world. City of Sydney residents can dispose of old and broken electronic devices by booking an e-waste pick-up or taking the items to a recycling station.

All electronics collected by the council are processed locally with a recycling rate of about 95%. Over 90% of mobile phone contents, including gold, silver and palladium, can be recovered and used to make new products (Figure 10.5.4). Battery materials such as mercury, lithium and zinc can be recycled many times to make new batteries.

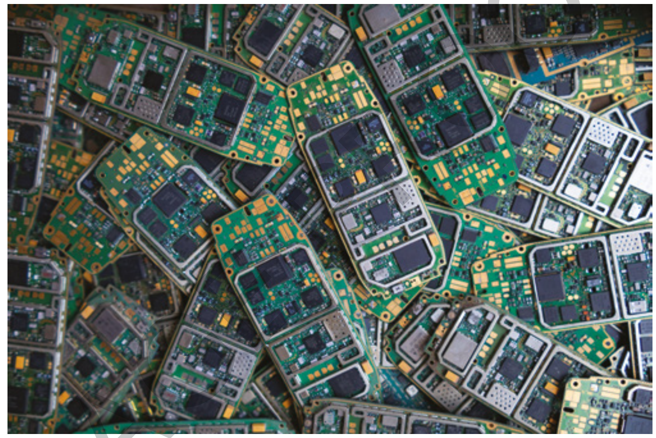


**FIGURE 10.5.4** Mobile phone circuit boards in e-waste

| | |
|---|---|
| **SC 2** | I can explain how the properties of elements can determine their uses. |

**FIGURE 10.5.5** A tungsten light bulb filament

## How properties determine uses

The properties of elements are key to understanding their uses. For example, the high melting point of tungsten makes it suitable for use in light bulb filaments (Figure 10.5.5). Tungsten can withstand the high temperatures without melting. Similarly, the low density of aluminium makes it ideal for use in aircraft construction and the high electrical conductivity of copper makes it ideal for use in electrical wiring.

**FIGURE 10.5.6** Sydney Harbour Bridge

## Metals in everyday life

Metals are used in various applications due to their unique properties. For instance, gold is used in jewellery because of its lustre and resistance to tarnish. Aluminium is used in packaging because it is lightweight and non-reactive. Iron is used in construction because of its strength and durability. The Sydney Harbour Bridge (Figure 10.5.6) was primarily constructed using steel, concrete and granite. The bridge's arch, road deck and rail lines are largely made of steel, with granite used for the decorative pylons and abutments, and concrete for the foundation structures and piers.

## Non-metals in everyday life

Non-metals also have important uses. For example, in living organisms, oxygen is essential for the production of energy by respiration. Sulfur is used in the production of sulfuric acid, which is important in the chemical industry. Carbon in the form of graphite is used in pencils because it is soft and can leave a mark on paper (Figure 10.5.7).

**FIGURE 10.5.7** Graphite is used in pencils.

**SC 2 CHECK YOUR UNDERSTANDING**

Explain why tungsten is used in light bulb filaments.

**Scifile**

**Carbon's versatility**

Carbon is incredibly versatile. It can form diamonds, which are the hardest natural substance, and graphite, which is soft and slippery. This versatility is due to the different ways carbon atoms can bond together.

## SCIENCE IN CONTEXT

### Metals in Australian industry

Australia is rich in mineral resources, including iron ore, bauxite (the ore for aluminium), silver and gold. These metals are crucial for the Australian economy. Iron ore is used to produce steel, which is essential for construction and manufacturing. Gold and silver are not only used in jewellery but also in electronics and as an investment. The mining industry provides jobs and supports local communities.

Broken Hill, in south-west New South Wales, is Australia's longest-lived mining city. In 1883, an ore body was discovered on an isolated 'broken hill'. This ore body became the largest single source of silver, lead and zinc ore ever discovered on Earth, generating over $100 billion in wealth. The lease for Junction Mine (Figure 10.5.8) was officially claimed in 1884. One of the largest mines in the region, Junction Mine produced over 7 million tonnes of ore until the closure of the original mine in 1923. The Broken Hill Proprietary Company Limited, better known as BHP Billiton, was established in Broken Hill in 1885 and is now the world's largest mining company.

**FIGURE 10.5.8** Junction open pit mine in Broken Hill

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 List three properties of metals.

2 Describe the properties of water that make it essential for life.

3 Explain why aluminium is used in aircraft construction.

4 Explain why graphite is used in pencils.

5 Suggest a suitable material for making electrical wires and explain why.

6 Compare the properties and uses of iron and aluminium in construction.

# 10.6 Case study on the uses of metals and non-metals

**Learning intention**

To be able to investigate how the properties and availability of materials influence their uses

**Success criteria**

**SC 1:** I can identify how the properties of metals, alloys and compounds influence their uses.

**SC 2:** I can explain how the availability of metals, alloys and compounds influence their uses.

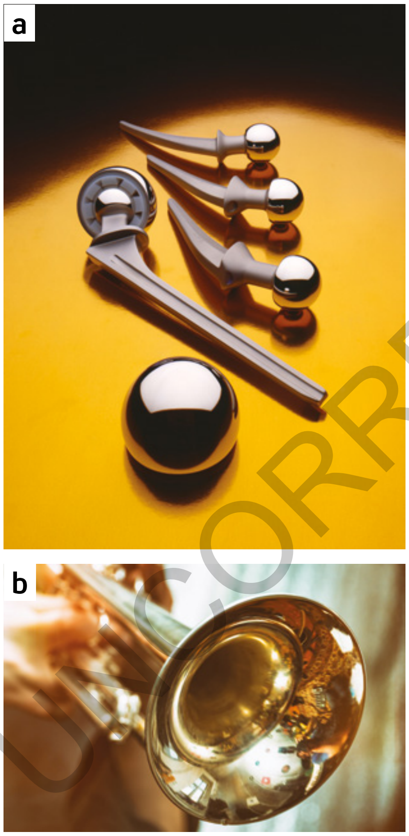


**FIGURE 10.6.1** (a) Titanium is used in replacement hip sockets and (b) trumpets are made from brass.

## Introduction

Metals and alloys are an essential part of our daily lives. From the titanium in medical implants to the brass in musical instruments, the properties and availability of these materials determine their uses. For example, the biocompatibility (ability to interact with a living system without causing harm or adverse effects) and strength of titanium make it ideal for use in joint replacements and dental implants (Figure 10.6.1a), while the acoustic properties (sound), aesthetic (visual) appeal and durability of brass make it perfect for trumpets and other musical instruments (Figure 10.6.1b).

In this lesson, you will investigate how the properties and availability of different metals and alloys influence their uses.

## Background

Metals and alloys have unique properties such as strength, conductivity and resistance to corrosion. These properties make them suitable for various applications. The availability of these materials also plays a crucial role in determining their uses. For instance, iron is often abundant and inexpensive, making it a common choice for construction and manufacturing.

## Aim

To investigate how the properties and availability of metals, alloys and compounds influence their uses

## Plan

Choose a metal or alloy and research its properties and availability. Present your findings in a report or presentation. Consider using images, diagrams and real-life examples to support your findings.

## Design

1 Select a metal or alloy to investigate.
2 Research its physical and chemical properties.
3 Investigate its availability and how it is obtained.
4 Identify common uses of the metal or alloy and explain how its properties and availability influence these uses.
5 Prepare a report or presentation to share your findings.

## Conduct

1. Use a variety of reliable sources to gather information about your chosen metal or alloy.
2. Take notes on its properties, availability and uses.
3. Use headings and subheadings to organise your findings into a clear and logical format
4. Create visuals such as charts, diagrams or images to enhance your presentation.
5. Include a bibliography and cite sources in your presentation.

## Improve

1. Review your research for accuracy and completeness.
2. Ensure your presentation is clear and engaging.
3. Seek feedback from peers or teachers and make necessary adjustments.
4. Add more real-life examples or case studies to support your findings.

## Discussion

1. Reflect on what you learned about the properties and availability of metals and alloys.
2. Assess how well your presentation demonstrates the influence of these factors on their uses.
3. Consider what you could do differently in future investigations.
4. Discuss how this knowledge could be applied in real-world situations.

**Scifile**

**Metallic marvels**

Did you know that the Eiffel Tower is made of iron? This iconic structure weighs approximately 10 100 tonnes and stands 324 meters tall. The iron used in its construction was chosen for its strength and availability at the time.

# 10.7 Modelling atoms

**Learning intention**

To be able to use a model to show how atoms are made up of subatomic particles

**Success criteria**

**SC 1:** I can create a representation of an atom that shows the relationships between the subatomic particles including protons, neutrons and electrons.

**SC 2:** I can describe the key features of each subatomic particle.

**KEY TERMS**

**subatomic particle** particle that atoms are made of—protons, neutrons and electrons
**proton** a subatomic particle with a positive electric charge located in the nucleus of an atom
**neutron** a subatomic particle with no electric charge located in the nucleus of an atom
**electron** negatively charged subatomic particle, located around the nucleus of an atom

## Introduction

What does an atom look like? Representations of atoms appear frequently in everyday life, often without being noticed. For example, in the television show *The Big Bang Theory*, atomic symbols are featured during scene transitions. While this model of atomic structure is widely recognised today, it has only been developed and understood in recent history.

In this practical investigation you will explore the structure of the atom and its subatomic particles through a practical process that should help you visualise what an atom looks like and describe the key features of the particles inside the atom.

## Background

You cannot see atoms, so how do you know they exist and what they look like? Scientists conduct experiments and share their findings, allowing them to build a model that fits all observations. In this practical investigation, you will explore this model to help visualise the structure of an atom.

Atoms contain three types of **subatomic particles**: **protons**, **neutrons** and **electrons**. Protons and neutrons form the nucleus, while electrons move around it. Protons and neutrons are much larger than electrons—if a proton has a relative mass of 1 and a neutron also has a relative mass of 1, an electron has almost no mass (about 1840 times smaller) in comparison.

In terms of charge, protons are positive (+), neutrons are neutral (0), and electrons are negative (–).

## Aim

To construct a model of an atom that shows the internal structure

## Apparatus

- different colour modelling clay (plasticine) with the different colours used to represent the three different subatomic particles
- large toothpicks or skewers
- A3 sheets of paper and colouring pens
- sticky labels

## Method

Using the materials provided, write the steps to construct a model of an atom. You can choose which atom to build, or your teacher may assign you an atom. The numbers of protons, neutrons and electrons in the most common form of atoms of the first 10 elements are shown in Table 10.7.1.

**TABLE 10.7.1** The first 10 elements and their numbers of protons, neutrons and electrons

| Atom | hydrogen | helium | lithium | beryllium | boron | carbon | nitrogen | oxygen | fluorine | neon |
|---|---|---|---|---|---|---|---|---|---|---|
| Symbol | H | He | Li | Be | B | C | N | O | F | Ne |
| Protons | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Neutrons | 0 | 2 | 4 | 5 | 6 | 6 | 7 | 8 | 10 | 10 |
| Electrons | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

You need to make the subatomic particles different colours and add labels to your model.

If you are not able to produce a 3D model, you can design a 2D representation.

**HINT**

You can mix different colours together to make more colours.

## Results

Present your model to other students and/or your teacher and request feedback.

## Discussion

1. Based on feedback received and after viewing other models, explain one improvement that you could make to your model.
2. Describe how constructing a model helped you to improve your understanding of atomic structure.

## Conclusion

1. What is the charge on the protons, neutrons and electrons. How did you represent this in your model?
2. What is the relative mass of the protons, neutrons and electrons? How did you represent this in your model?
3. The electrons in an atom move around the nucleus of the atom. How did you represent this in your model?

# 10.8 The structure of atoms

**Learning intention**

To understand that different atoms have different numbers of subatomic particles

**Success criteria**

**SC 1:** I can represent the number of protons, electrons and neutrons present in an atom.

**SC 2:** I can represent atoms using atomic notation.

**SC 3:** I can calculate the number of neutrons an atom contains from its mass number and atomic number.

## Lesson overview

The writer Bill Bryson describes atoms in the following way: 'Protons give an atom their identity and electrons their personality'. This is a great way to think about atoms, as the protons most certainly give an atom its identity. For example, all hydrogen atoms have one proton, and all carbon atoms have six protons (Figure 10.8.1). When you look at a picture of an atom, counting the number of protons will identify what type of atom it is.

In this lesson you will learn about the different numbers of subatomic particles in atoms.

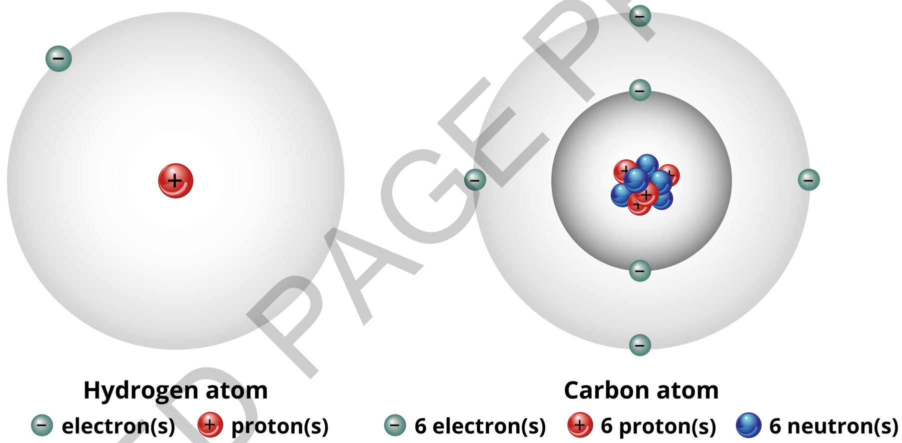



**FIGURE 10.8.1** A representation of a hydrogen atom and a carbon atom

**SC 1** I can represent the number of protons, electrons and neutrons present in an atom.

**KEY TERM**

**atomic number (*Z*)** the number of protons in the nucleus of an atom, indicated in the periodic table

### What's in an atom?

A periodic table provides lots of information about atoms of elements. It gives the name and symbol of an element and the number for that atom. This number is called the **atomic number (*Z*)** and it communicates the number of protons present in that atom.

All atoms shown in the periodic table have the same number of electrons as protons. This makes all atoms neutral, because the positive charge from the protons and the negative charge from the electrons cancel each other out. This means that an atom of carbon has 6 protons and 6 electrons. The number of neutrons can vary, which will be considered later in this lesson.

When you look at an illustration of an atom, count the number of protons and then use a periodic table to identify it. See Table 10.8.1 for some examples.

When drawing an atom, refer to the periodic table (Figure 10.8.2) and draw the correct number of protons in the nucleus. Then put the same number of electrons around the nucleus. (This is sometimes called the electron cloud.)

If you know the number of neutrons, these can be drawn in the nucleus with the protons.

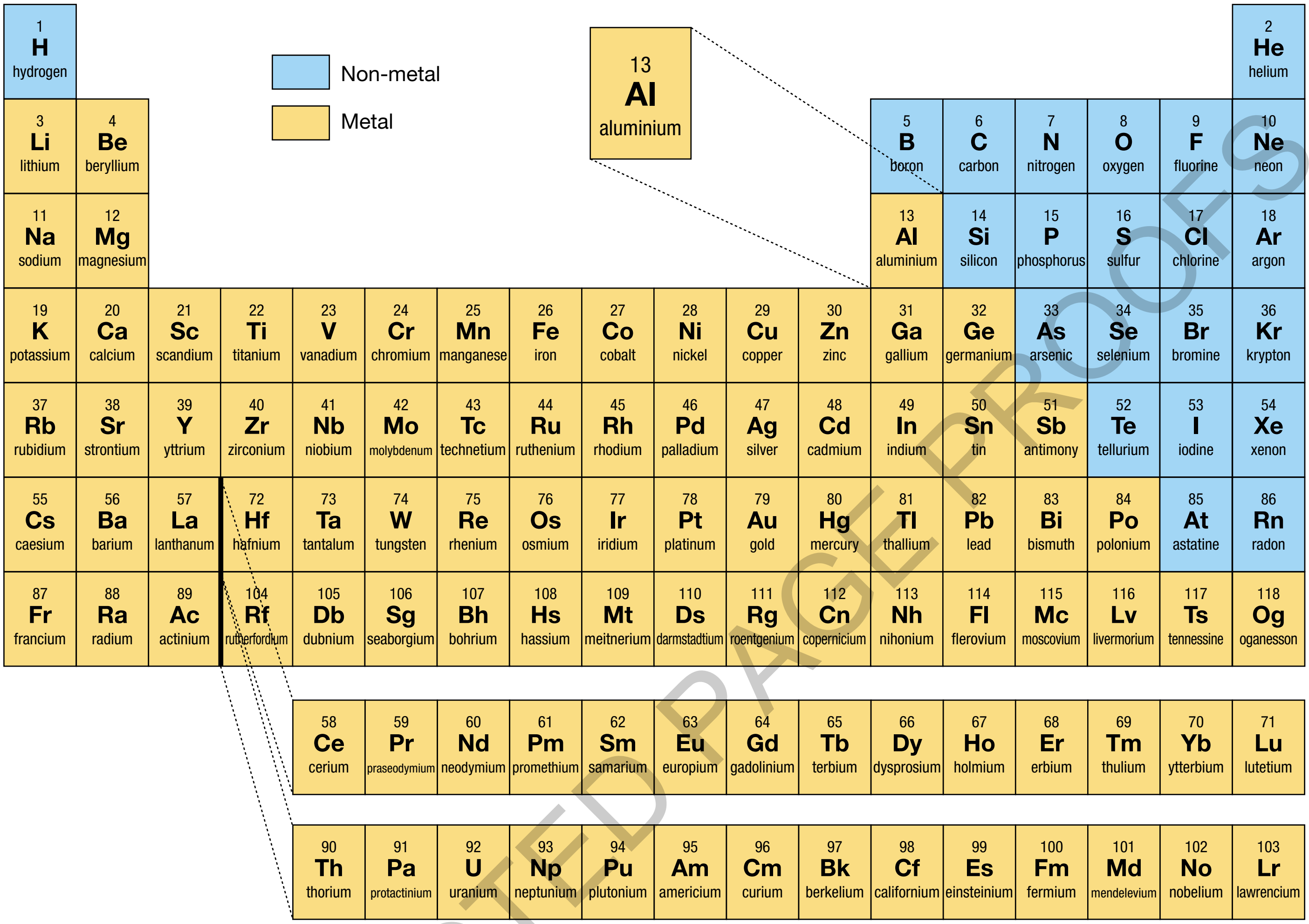
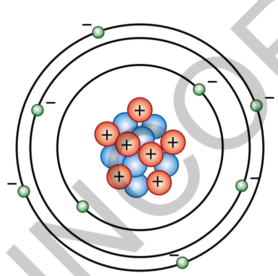
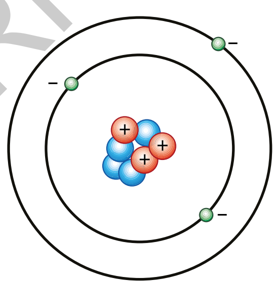
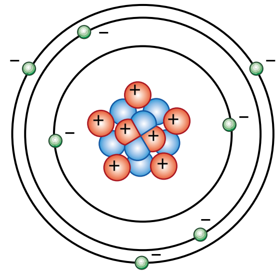
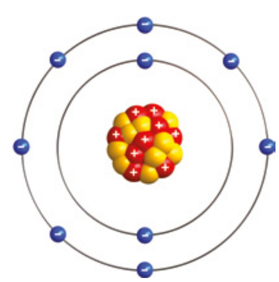



**FIGURE 10.8.2** The periodic table with elements discovered and named as of 2025

**TABLE 10.8.1** Examples of atoms, the elements they represent and the numbers of protons, neutrons and electrons they contain

| oxygen | lithium | nitrogen | fluorine |
|---|---|---|---|
|  |  |  |  |
| 8 protons<br>8 neutrons<br>8 electrons | 3 protons<br>4 neutrons<br>3 electrons | 7 protons<br>7 neutrons<br>7 electrons | 9 protons<br>10 neutrons<br>9 electrons |

**KEY TERM**

**mass number (*A*)** the number of protons plus neutrons in the nucleus of an atom

**SC 1 CHECK YOUR UNDERSTANDING**

Draw a 2D representation of helium, which has 2 protons, 2 neutrons and 2 electrons.

**SC 2** I can represent atoms using atomic notation.

In Figure 10.8.3, you can see that the protons and neutrons are in the nucleus at the centre of the atom and the electrons are surrounding it. The electrons are much smaller than the protons and neutrons. In fact, if they were drawn to scale, electrons would be impossible to see. Protons and neutrons are approximately the same size and mass, and the electrons are approximately 1840 times lighter than a proton or a neutron (Table 10.8.2). For this reason, most of the mass of the atom is in the nucleus. The mass of an atom can be represented by the **mass number (*A*)** of the atom.

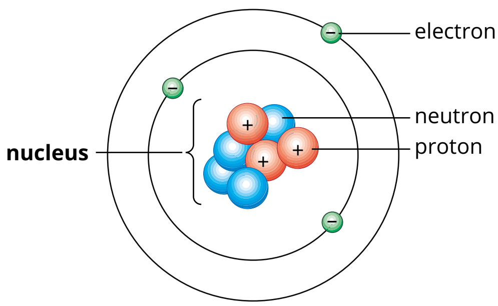



**FIGURE 10.8.3** An atom of lithium showing the charges on the subatomic particles

**TABLE 10.8.2** Summary of charge and mass for subatomic particles

| | Proton | Neutron | Electron |
|---|---|---|---|
| Location | nucleus | nucleus | surrounding nucleus |
| Relative charge | +1 | 0 | −1 |
| Relative mass | 1 | 1 | $\frac{1}{1840}$ |

The atomic number is the number of protons in the nucleus. The atomic number can be represented by the letter *Z* and is always smaller than the mass number.

Elements can be represented using their:

- chemical symbol (X)
- atomic number (*Z*) = number of protons
- mass number (*A*) = number of protons + number of neutrons

This is called **atomic notation**.

**KEY TERM**

**atomic notation** a way of representing an atom using the element symbol (X), atomic number (*Z*) and the mass number (*A*); $^{A}_{Z}X$

In atomic notation, the atomic number is written as a *subscript* before the chemical symbol of the element and the mass number (*A*) is written as a *superscript*. Figure 10.8.4 shows the atomic notation for a carbon atom that has 6 protons and 6 neutrons.

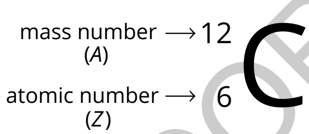



**FIGURE 10.8.4** The atomic notation for carbon: carbon has 6 protons so its atomic number is 6. In the illustration carbon has 6 neutrons, so its mass number is 12.

**SC 2 CHECK YOUR UNDERSTANDING**

Oxygen can be represented using atomic notation as $^{16}_{8}O$. Identify the number of protons and the mass of oxygen.

**SC 3** I can calculate the number of neutrons an atom contains from its mass number and atomic number.

## Numbers of neutrons in atoms

atomic number (*Z*) = number of protons

mass number (*A*) = number of protons + number of neutrons

Therefore:

number of neutrons = mass number − atomic number ($A - Z$)

This means that, if you know the mass number and atomic number, you can calculate the number of neutrons in an atom. Look at Table 10.8.3 for some examples.

**TABLE 10.8.3** Examples of elements, with the atomic number, mass number and the number of neutrons

| | | |
|---|---|---|
| $^{56}_{26}Fe$ | iron | number of neutrons = mass number − atomic number<br>= 56 − 26<br>= 30 |
| $^{64}_{29}Cu$ | copper | number of neutrons = atomic number − mass number<br>= 64 − 29<br>= 35 |
| $^{133}_{55}Cs$ | caesium | number of neutrons = atomic number − mass number<br>= 133 − 55<br>= 78 |

**SC 3 CHECK YOUR UNDERSTANDING**

Calculate the number of neutrons in an atom of argon with the atomic notation $^{40}_{18}Ar$ .



## Lesson review

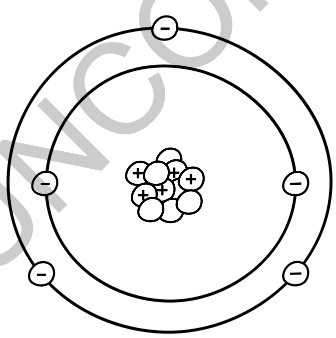
Use these questions to check whether you have met the learning intention for this lesson.

1 Draw a 2D representation of a beryllium atom, which has 4 protons, 5 neutrons and 4 electrons.

2 Calculate the mass number of a uranium atom, containing 92 protons and 146 neutrons.

3 Calculate the number of neutrons in an atom of phosphorus with the atomic notation $^{31}_{15}P$ .

4 Refer to the image below to answer the following questions.



a Determine the number of protons, neutrons and electrons in this atom.

b Calculate the atomic number.

c Calculate the mass number.

d Referring to the periodic table in Figure 10.8.2 on page XX, name this element and write its atomic notation.

5 Name the following elements.

a 17 protons, 18 neutrons and 17 electrons

b 12 protons and a mass number of 24

c 16 neutrons and a mass number of 31

6 Complete the following table. You can use a periodic table to help you answer this question.

| Element | Number of protons | Number of neutrons | Atomic number | Mass number |
|---|---|---|---|---|
| Na | | | 11 | 23 |
| As | 33 | 42 | | |
| Cu | | 34 | | |
| | | | 18 | 40 |

# 10.9 Development of the atomic model

**Learning intention**

To be able to describe discoveries that contributed to the knowledge of the structure of the atom

**Success criteria**

**SC 1:** I can describe the main findings of historical experiments that investigated the structure of the atom.

**SC 2:** I can describe how advances in technologies allowed the development of the understanding of atomic structure.

**SC 3:** I can compare the contributions of scientists to the development of the understanding of atomic structure.

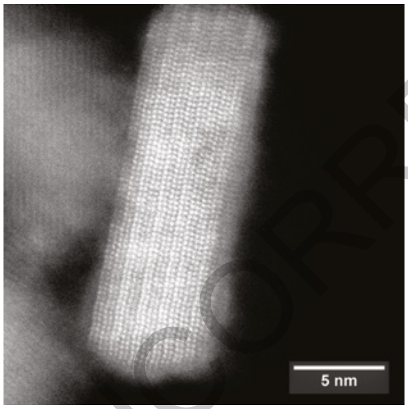



**FIGURE 10.9.1** An image of the atoms in a crystal, zoomed in 100 million times

## Introduction

The model of the atom has changed over the years as different scientists have developed new models to try to explain observed behaviour. Because the internal structure of the atom is not visible, even with the most powerful microscopes (Figure 10.9.1), these ideas have involved abstract thought, backed up with indirect evidence obtained using a range of technologies. As with all scientific discoveries, the ideas have to be checked by the wider scientific community before they are accepted as theories.

In this inquiry activity you will discover the work of some of the scientists who contributed to the modern understanding of atoms, how they used technology to obtain their evidence and how their ideas became accepted.

## Background

Today's understanding of atoms is a result of several scientific discoveries. Each development builds on the previous one, improving the model of atomic structure to explain the properties of atoms and the substances made from atoms, which of course is all substances! In recent years, research into atoms has progressed into the study of still smaller subatomic particles present in the nuclei of atoms, including particles such as quarks, bosons and neutrinos.

## Aim

To conduct research to explain how the model of the atom developed over time and consider the contributions of scientists to these discoveries

## Plan

As part of a team, each student should research the model of the atom proposed by one of the following scientists, including the evidence they used and how the idea was accepted.

1 John Dalton
2 J.J. Thomson
3 Ernest Rutherford
4 Niels Bohr

Keeping to this order, students should report key facts to the rest of the group. This can include both an advantage and a problem with each model.

Summarise your findings of the four models by:

- presenting your findings with 2D or 3D diagrams of the atomic models proposed by each scientist
- describing the technologies used to provide evidence for the models
- explaining how each model was accepted by the scientific community.

## Conduct

Using the information from your team, create a timeline that summarises the four models of the atom. In the timeline highlight key differences between each model.

## Improve

After receiving constructive feedback on your timeline, suggest one improvement that you could make to your representation that would enhance how it communicates the development of the atomic model.

## Discussion

1. For one of the models, describe in detail how advances in technologies allowed the development of that model.
2. Neutrons were discovered by English scientist James Chadwick in 1932. Suggest why the neutron was the last of the three main subatomic particles to be discovered and compare the importance and impact of this discovery to a discovery that led to one of the four models described in your timeline.

# 10.10 Development of the periodic table

## Learning intention

To understand the historical processes involved in the development of the periodic table as a model for the organisation of elements

## Success criteria

**SC 1:** I can describe early approaches to describing, classifying and representing elements, including how the relative masses of elements were predicted.

**SC 2:** I can explain how use of atomic numbers was essential for the creation of the modern periodic table.

## Lesson overview

If you were to go to a large chain store to buy a boardgame for a friend's birthday, you would first locate the toy section and then the boardgames within the toy section. The organisation of the store is designed to make it easy to find what you need. Similarly, to understand the world better, scientists organise living organisms and materials into categories. These categories assist learning and enable any new information to be adapted more easily. Biologists use classification for all living organisms. Chemists use the periodic table for all elements. The periodic table (Figure 10.10.1) holds a wealth of information that allows us to learn about elements. It enables us to identify patterns and properties.

In this lesson you will learn about the scientific discoveries that led to the development of the periodic table.

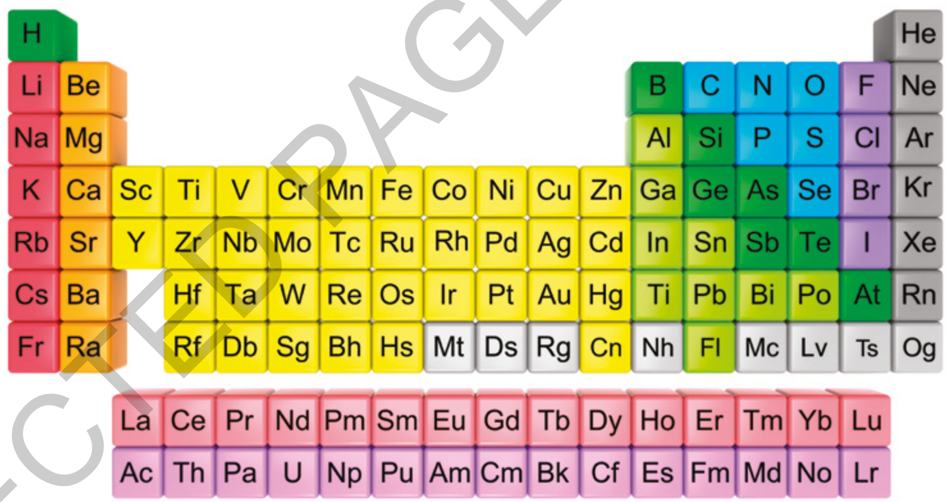



**FIGURE 10.10.1** A periodic table

**SC 1** I can describe early approaches to describing, classifying and representing elements, including how the relative masses of elements were predicted.

Before 1700, only 15 elements were known. With so few elements, it would have been difficult to establish patterns. These elements and their atomic masses are displayed in Table 10.10.1 below. Can you see any patterns that could be used to organise these elements?

**TABLE 10.10.1** The first known elements and their atomic masses

| | | | | |
|---|---|---|---|---|
| C 12.0 | P 31.0 | S 32.1 | Fe 55.8 | Cu 63.5 |
| Zn 65.4 | As 74.9 | Ag 107.9 | Sn 118.7 | Sb 121.8 |
| Pt 195.1 | Au 197.0 | Hg 200.6 | Pb 207.2 | Bi 209.0 |

Between 1700 and 1799, 26 new elements were discovered; between 1800 and 1899, another 42 were discovered. It was during this time of rapid discovery that scientists started seriously looking for ways to classify the elements. Table 10.10.2 shows a timeline of the history of the elements.

**TABLE 10.10.2** Timeline of history of the elements

| | | |
|---|---|---|
| 1789 | Elements are grouped into gases, metals, non-metals and earths. | French scientist Antoine Lavoisier was the first to group elements into gases, metals, non-metals and earths. |
| 1803 | Hydrogen is assigned a mass of 1. | English scientist John Dalton assigned hydrogen a mass of 1. He attempted to determine masses of other elements that reacted with hydrogen, but many were incorrect. |
| 1829 | Groups of three elements with similar properties are identified and called 'triads'. | German scientist Johann Döbereiner recognised 'triads' as groups of three elements that had similar physical and chemical properties, such as lithium, potassium and sodium. |
| 1860 | A revised list of the atomic masses of elements is developed. | A more accurate list of elements and their atomic masses was published at the first international chemistry conference in Germany. Because individual atoms are so small, relative atomic masses make comparisons possible. All other elements were assigned accordingly. This change paved the way for greater progress towards the modern periodic table. |
| 1862 | A 3D arrangement of the elements is developed. | French geologist Alexandre Béguyer de Chancourtois came up with a 3D arrangement of the elements, called the 'telluric screw' (Figure 10.10.2). |
| 1864 | The law of octaves is developed. The law states that every eighth element has similar properties. | British scientist John Newlands saw that every eighth element had similar properties, which he called the law of octaves. Newlands did not leave gaps for undiscovered elements, which made his findings a little inaccurate. |
| 1868 | Elements are ordered by increasing atomic mass, with elements that have the same valency (number of electrons in their outermost shell) in vertical lines. | German chemist Julius Lothar Meyer listed the elements by increasing atomic mass, with elements with the same valency shown in vertical lines. His work was very similar to Mendeleev's work but was not published until 1870. |
| 1869 | Mendeleev develops the periodic table. | Russian scientist Dimitri Mendeleev developed a system of cards with element names and properties. He organised the cards in order of increasing atomic mass and similar properties. He recognised the patterns that were occurring and left gaps when it seemed appropriate. He identified some unresolved issues, such as iodine and tellurium being the wrong way around based on atomic mass. This system of organising the chemical elements laid the foundation for the modern periodic table. |
| 1913 | The atomic numbers of elements are determined using an X-ray gun. | English physicist Henry Moseley used an X-ray gun to find the wavelength of atoms and was able to determine the atomic numbers of elements. Ordering the elements by atomic number rather than mass was the final piece that solved the jigsaw puzzle of the periodic table. This solved some of the issues that Mendeleev had identified. |

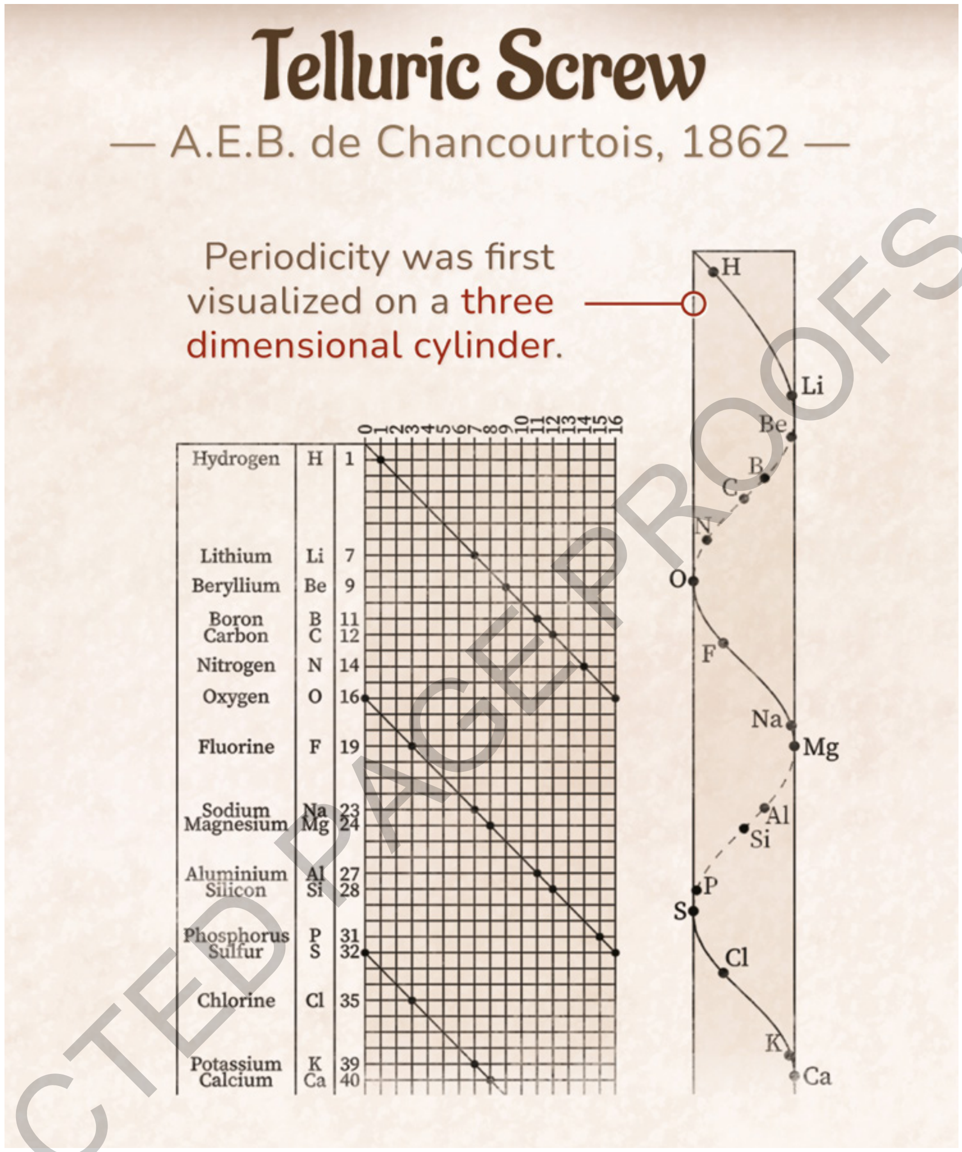



**FIGURE 10.10.2** The telluric screw periodic table

## SC 1 CHECK YOUR UNDERSTANDING

Which scientist contributed significantly to each of these periodic table findings?

**a** arranged the known elements, leaving gaps for undiscovered elements
**b** arrangements of triads
**c** law of octaves
**d** determined atomic numbers
**e** earliest arrangement of atoms

| SC 2 | I can explain how use of atomic numbers was essential for the creation of the modern periodic table. |
|---|---|

The journey to the modern periodic table started when scientists started grouping elements based on common characteristics. Three scientists, Döbereiner, Newlands and Mendeleev, are best known for this work.

In 1829, the German scientist Johann Döbereiner recognised ‘triads’, which are groups of three elements that have similar physical and chemical properties, such as lithium, potassium and sodium (Figure 10.10.3). Döbereiner found that the middle element of the triad had properties that were an average of the other two.

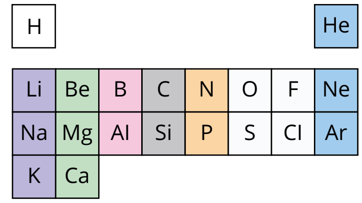



**FIGURE 10.10.3** In a section of a modern periodic table, three triads can be seen: lithium (Li), sodium (Na) and potassium (K), and beryllium (Be), magnesium (Mg) and calcium (Ca).

## Organising the periodic table by mass

Newlands organised the elements into increasing atomic mass and saw a pattern of reoccurring properties in elements. However, there were still gaps that many scientists ignored. Of course, at this stage in history subatomic particles had not yet been discovered, so while the patterns were observed, they were not explained.

## Mendeleev’s missing elements

Mendeleev wrote the names and properties of elements on cards and tried arranging them. He left gaps for elements that were not yet discovered. This was the real advantage of Mendeleev’s arrangement. He went as far as to predict the properties of the missing elements. When these elements were discovered, it was found that Mendeleev’s predictions were very accurate. Table 10.10.3 shows his prediction for an unknown element he called eka-silicon. When germanium was found, the correlation between his predictions and the actual properties of the element was amazing.

**TABLE 10.10.3** Comparing germanium’s properties with Mendeleev’s predictions

| | eka-silicon | germanium |
|---|---|---|
| atomic mass | 72 | 72.6 |
| density (g/cm$^3$) | 5.5 | 5.32 |
| melting point (°C) | high | 938 |
| colour | grey | grey |

## Organising the periodic table by atomic number

In 1913, Henry Moseley experimentally determined atomic numbers for elements. He recognised that atomic number, which was related to the charge in the nucleus, was far more important than atomic mass. He then created a periodic table with the elements in order of increasing atomic number, solving some of the issues that Mendeleev had recognised. The periodic table he created is used to this day.

**SC 2 CHECK YOUR UNDERSTANDING**

Why was the atomic number more important than the atomic mass for the creation of the modern-day periodic table?

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

**1** Name the scientist who discovered atomic numbers.

Use a periodic table to answer the following two questions.

**2** Explain the difference between a period and a group in the periodic table.

**3** List the elements of group 14 in order of increasing atomic number, and state whether each is a metal, non-metal or metalloid.

**4** Identify the elements from the following clues. State the name and chemical symbol for each one.

**a** atoms have 14 protons in each nucleus
**b** located in group 1, period 4 of the periodic table
**c** group 2 metal that has the least number of protons in its nucleus
**d** similar properties to fluorine
**e** group 1 metal in period 3 of the periodic table

# 10.11 Characteristic properties of group 1 elements

## Introduction

To understand the patterns that exist within groups in the periodic table, you need to consider the physical and chemical properties that could be investigated. Physical properties include melting point, hardness and conductivity of electricity. Chemical properties include reactions with oxygen, water and acid.

In this practical investigation you will explore some physical and chemical properties of the group 1 elements, which are called alkali metals (Figure 10.11.1) by watching either a practical demonstration or a video of their reactions with water.

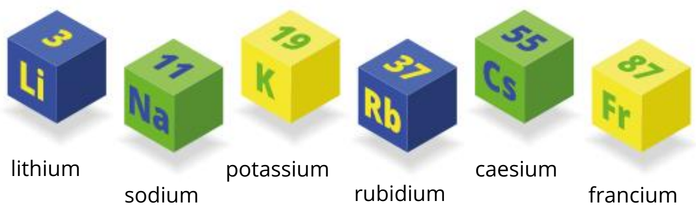



**FIGURE 10.11.1** The group 1 elements

**Learning intention**

To be able to observe characteristic properties of group 1 metals

**Success criteria**

**SC 1:** I can identify and name groups in the periodic table of elements.

**SC 2:** I can describe from direct observation and/or research, the patterns and trends in the properties of group 1 metals.

**SC 3:** I can compare properties of group 1 metals to other metals in the periodic table.

## Background

Groups are vertical columns on the periodic table. They are called groups, or sometimes families, as those elements have similar properties. Some groups have common names. Using the key on the diagram, locate the alkali metals. They are on the far left of the table in group 1 and are red in colour.

Periods are horizontal rows on the periodic table. They are called periods because periodicity is observed as you move across the table. Hydrogen and helium represent period 1. Lithium through to neon represent period 2 (Figure 10.11.2).

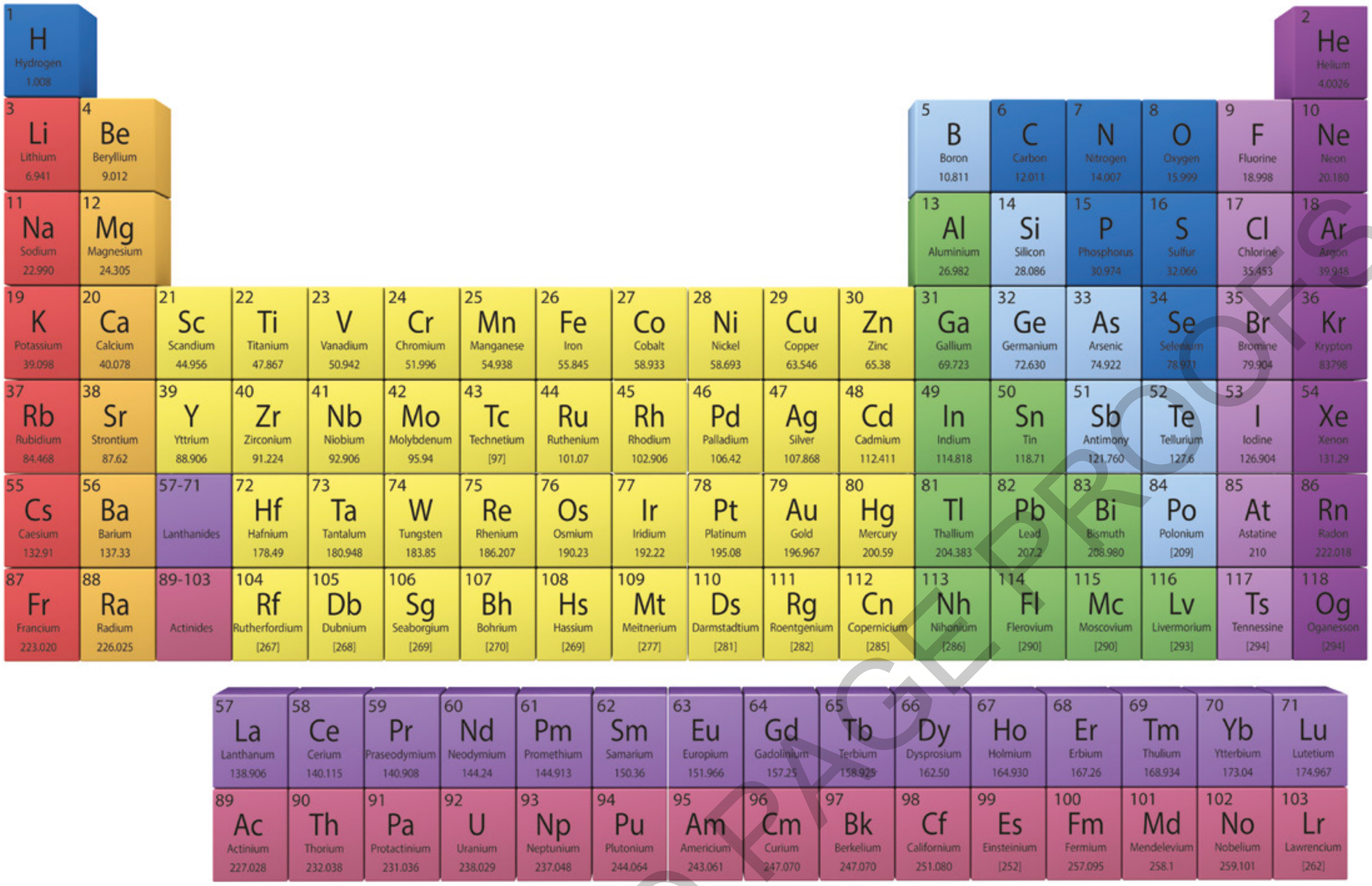



**FIGURE 10.11.2** The groups and periods that form the periodic table

## Aim

To describe, from direct observation, the patterns and trends in the properties of group 1 metals

## Prediction

Read the Method for the experiment and write a prediction for your investigation regarding the reactions of three of the group 1 metals: sodium, lithium and potassium. Consider whether you think the metals will be reactive, whether the reactions of the metals will be similar or whether there will be variation in the reactivity.

### SAFETY NOTES

- Wear safety glasses and lab coats/aprons for this demonstration.
- These metals are very reactive and must stay under oil until just before they are used.
- The tests will be done as a demonstration by your teacher or you will be shown a video of the reactions of the three metals.

## Apparatus

- samples of lithium, sodium and potassium
- 3 large troughs of water
- universal indicator solution
- forceps
- paper towel

## Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

## Method

The samples of the metals are added to cold water, and evidence for a chemical reaction is recorded for each of the three metals.

Universal indicator solution is added to the trough after the reaction to test the pH of the water.

## Results

Record your results in your notebook using a table such as this.

| Characteristic (describe each in detail) | Lithium | Sodium | Potassium |
|---|---|---|---|
| softness/hardness of metal | | | |
| surface of metal before and after cutting | | | |
| density when placed in water | | | |
| reactivity in water | | | |
| pH of water after reaction | | | |

## Discussion

1 Describe the observations of the softness of these metals. Was a pattern observed?

2 Compare the appearance of these metals before and after cutting. Why do you think there is this difference?

3 What does the observation about density allow you to infer?

4 Comment on the similarities and differences between these metals when they react with water. Is there a trend?

5 What does the observation about the pH of water tell you about the nature of these metals?

## Conclusion

How do you think these properties of group 1 metals compare with other metals on the periodic table? Consider each of the characteristics that you observed and recorded in your Results table and use the metal iron as a comparison.

# 10.12 Bohr model of the atom

**Learning intention**

To understand the Bohr model of the atom

**Success criteria**

**SC 1:** I can calculate the number of protons, electrons and neutrons found in the atom of an element using the periodic table.

**SC 2:** I can draw and annotate a diagram of Bohr's model of the atom.

## Lesson overview

When fireworks explode, they create a spectacular show of coloured light (Figure 10.12.1). The light is produced by metal atoms that have been heated by the explosion. This coloured light posed a problem for early scientists. The models the scientists were using could not explain the source of the light.

In this lesson you will learn that the light was ultimately a clue to the arrangement of electrons in atoms.

**FIGURE 10.12.1** New Year's Eve fireworks over Sydney Harbour

**SC 1** I can calculate the number of protons, electrons and neutrons found in the atom of an element using the periodic table.

### Representing atoms

Recall from Lesson 10.8 that atomic notation ${}^{A}_{z}X$ can be used to represent an atom, where:

- X is the chemical symbol
- $Z$ is the atomic number = number of protons
- $A$ is the mass number = number of protons + number of neutrons

The atomic number reveals the number of protons and electrons in a neutral atom. Changing the number of electrons affects the chemical properties but not the element itself. Use the periodic table to find the atomic number; for example, gold has 79 protons and 79 electrons.

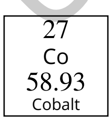



**FIGURE 10.12.2** Cobalt

The mass number isn't listed on the periodic table, only the standard atomic weight, which is often not a whole number. You can estimate the mass number by rounding the standard atomic weight. For example, the standard atomic weight for cobalt is 58.93, which rounds to 59. Since cobalt has an atomic number of 27, it has 27 protons and 59 – 27 = 32 neutrons (Figure 10.12.2).

**SC 1 CHECK YOUR UNDERSTANDING**

Locate phosphorus on the periodic table in the Data Book. Use the atomic number and standard atomic weight (rounded to the nearest whole number) to estimate the mass number and determine the number of protons, neutrons and electrons present in an atom of phosphorus.

**SC 2** I can draw and annotate a diagram of Bohr's model of the atom.

At first, scientists thought atoms were indivisible until an English physicist, J.J. Thomson, discovered the electron in 1897. Each time new information is found, the model of the atom is revised: this is part of the scientific method. In the development of the atomic model, scientists make observations and then propose theories to support their observations.

## The Bohr model of the atom

In 1913 a Danish physicist, Niels Bohr, developed the shell model of the atom. In his model the electrons, which surround the nucleus, are arranged in shells that represent different energy levels for electrons.

An atom of nitrogen with its seven electrons is shown in Figure 10.12.3. It contains two electrons in the first shell, or energy level, and five electrons in the second shell.

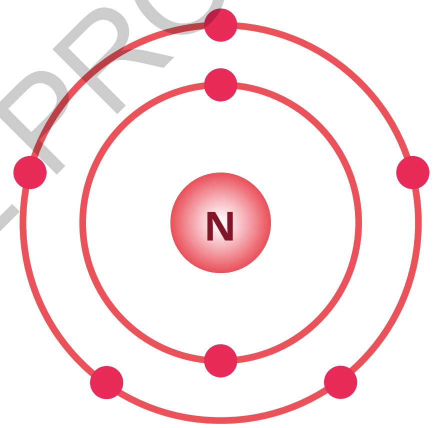



**FIGURE 10.12.3** The Bohr model of a nitrogen atom

The electrons are arranged with the shells closest to the nucleus filled first. The reason for the shell closest to the nucleus filling first is due to the attraction between the positive protons in the nucleus and the negative electrons. As electrons fill shells further from the nucleus, the attractive force is weaker because the distance is larger.

To draw a diagram of Bohr's model for any of the first 20 elements in the periodic table, first determine the number of electrons in the atom. Then place:

- up to two electrons in the first shell
- up to eight electrons in the second shell
- up to eight electrons in the third shell.

For atoms with more than 20 electrons, the third shell can hold up to 18 electrons. However, in this lesson you only need to consider the first 20 elements in the periodic table.

## SkillBuilder

### Representing electron configuration

Electron configuration is a method for representing the arrangement of electrons in an atom. The electron configuration can be determined from the location of an element in the periodic table or from its Bohr representation. Follow these steps to represent the electron configuration.

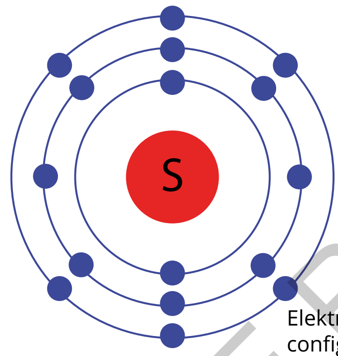
1 Identify the total number of electrons in the atom. (This is the atomic number.)

2 'Place' the first two electrons in the first shell.

3 'Place' the next eight electrons in the second shell.

4 Continue until all electrons have been allocated to a shell.

For example, Jessica was asked to write the electron configuration for sulfur, which has the atomic number of 16. Therefore, it has 16 electrons with an electron configuration of 2, 8, 6. This represents 2 electrons in the first shell, 8 in the second shell and 6 in the third shell.




## Atoms and coloured flames

The fact that electrons are arranged in shells or energy levels explains the different colours described at the beginning of the lesson. When substances containing atoms are heated, electrons move up and then down between the energy levels. These energy transitions result in energy being released to the surroundings in the form of visible light. Different gaps in the energy levels result in the different colours of visible light, and multi-coloured fireworks!

**SC 2 CHECK YOUR UNDERSTANDING**

Draw a labelled diagram showing Bohr's model for a fluorine atom, $^{19}_{9}F$.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 Which subatomic particles make up most of the mass of the atom and where are they found?

2 How many electrons would an atom of $^{65}_{30}Zn$ contain?

3 Draw a labelled diagram of the Bohr model for the following elements.

- a carbon, $^{13}_{6}C$
- b aluminium, $^{24}_{12}Al$
- c sodium, $^{23}_{11}Na$
- d oxygen, $^{16}_{8}O$

4 Use the shell model of the atom to write electron configurations for:

- a beryllium
- b silicon
- c nitrogen
- d chlorine

**5** Complete the following table.

| Element | Atomic number | Mass number | Number of protons | Number of neutrons | Atomic notation | Number of electrons | Electron configuration |
|---|---|---|---|---|---|---|---|
| He | | 4 | | | | 2 | |
| | 9 | | | 10 | | | |
| | | 20 | 10 | | | | |
| | | | | 16 | | | 2, 8, 5 |

# 10.13 The reactivity of group 2 metals

**Learning intention**

To be able to conduct a valid, safe investigation to test the reactivity of metals within a group

**Success criteria**

**SC 1:** I can write a specific reasoned prediction for observations based on knowledge of electron configuration of elements in group 2.

**SC 2:** I can conduct a valid and safe investigation, including the creation of a risk assessment, to test a prediction related to the reactivity of group 2 metals.

**SC 3:** I can explain how well the experiment was able to test the prediction, including evaluation of the experimental design.

## Introduction

Group 2 elements are metals known as alkaline earth metals, and they all have two electrons in their outer shell. These metals are quite reactive, so they are rarely found in their pure form. However, their compounds are common. For example, calcium carbonate ($CaCO_3$) is found in limestone, marble and chalk, while magnesium carbonate ($MgCO_3$) is used by gymnasts and climbers to keep their hands dry.

The reactivity of group 2 metals depends on their atomic structure, which helps predict how they will react with other substances. In this practical investigation, you will use your knowledge of electron configuration to predict how reactive magnesium and calcium are, and then conduct an experiment to test your predictions.

## Background

The alkaline earth metals (Figure 10.13.1) are relatively soft and very reactive, although in general they are not quite as reactive as group 1 alkali metals. In this practical investigation, you will investigate the trend in reactivity of group 2 elements.

**FIGURE 10.13.1** Group 2 metals

## Aim

To investigate the reactivity of group 2 metals, the alkaline earth elements, by predicting and testing the reactions of two of these metals with water

## Prediction

Based on your understanding of atomic structure and the organisation of the periodic table, predict whether calcium is more or less reactive with water than magnesium. Write your prediction in your notebook.

## Apparatus

- 5 cm strip magnesium
- small sample of calcium
- 2 test tubes
- test tube holder
- test tube rack
- Bunsen burner
- heatproof mat
- sandpaper
- matches
- splint

## SAFETY NOTES

- Magnesium metal can ignite and burn violently in a flame.
- Calcium metal can react with the moisture in skin, causing burns.
- There is a risk of the water in the test boiling over from the test tube if heated too strongly in Part A of the experiment.
- Wear safety glasses and lab coats/aprons as directed by your teacher.
- Follow the safety controls stated in your risk assessment.

## Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

Follow your teacher's instructions to complete a risk assessment for this investigation. You may be provided with a standard format in which to complete your risk assessment but ensure that you have considered in particular the three main areas of risk: equipment, substance and behaviour risk. Do not start the experiment until you have shown your risk assessment to your teacher.

## Method

1. Clean the magnesium strip with sandpaper and coil it around a pencil.
2. Place the coil in a test tube and cover it with water.
3. Observe the magnesium carefully over the next 5 minutes for any sign of a chemical reaction.
4. If there are no observable changes, heat the test tube gently over a Bunsen burner and continue to look for bubbles of gas.
5. Add a small piece of calcium to the second test tube and cover the sample with water. Record your observations.
6. If any bubbles are observed, place another empty test tube over the opening and collect any gas produced.
7. Remove the second test tube, keeping it inverted to trap any gas collected.
8. Light a splint and hold it to the opening of the inverted test tube and record what happens. If you hear a squeaky 'pop', this indicates that hydrogen gas has been produced.

## Results

Record your results in your notebook using a table such as this.

| Element | Observations in test tube | Identification of gas product |
|---|---|---|
| magnesium | | |
| calcium | | |

## Discussion

1 Arrange the tested metals in order of increasing reactivity with water.

2 What was the gas produced when calcium reacted with water?

3 Discuss how well the experiment was able to test the prediction, including evaluating the experimental design.

4 This experiment only tested two metals. Explain why it would be difficult to include more group 2 elements in the experiment.

## Conclusion

Write your conclusion by answering the following questions.

1 Compare your observations with your predictions.

2 Explain the results from this experiment in terms of the electron configuration of the element.

3 The reactivity of beryllium, strontium and barium with water were not studied. Predict these from your observations of magnesium and calcium.

# 10 Elements and compounds

## Topic summary

The key concepts included in this topic are:

- All matter is made of atoms, which are composed of a small, positively charged nucleus surrounded by a negatively charged cloud of electrons.
- Elements are made up of only one type of atom.
- The periodic table is a tool for organising elements according to their properties.
- Compounds contain two or more elements combined together.
- Elements and compounds are pure substances with fixed compositions whereas mixtures contain two or more pure substances that are not in fixed proportions and can be separated.
- Metallic elements have a range of distinctive properties including shiny appearance (lustre), malleability, ductility and the ability to conduct electricity.
- Alloys are formed when a substance, such as carbon or another metal, is mixed with a metal. Alloys are created to improve the properties of the original metals.
- Atoms are made up of protons, neutrons and electrons.
- Protons have a positive charge, electrons have a negative charge and neutrons have no charge.
- The atomic number, *Z*, and mass number, *A*, of elements are based on the number of protons and neutrons.
- The atomic number is equal to the number of protons in the nucleus. As atoms are neutral, the atomic number is also equal to the number of electrons.
- Understanding of the structure of atoms has changed over the decades as new discoveries have been made.
- Elements in the same group of the periodic table have similar properties.



## Review questions

The following questions will assess your success in achieving the learning intentions for this topic.

### Remember

1 You can use a periodic table to help you answer this question.

a State the symbols of the following elements.

i magnesium
ii manganese
iii mendelevium
iv mercury

b State the names of the elements represented by the following symbols.

i Au
ii Be
iii Ba
iv As

2 Identify which of the following substances are compounds: seawater, methane, bromine, glucose, germanium.

3 The elements in group 2 in the periodic table are called alkaline earth metals.

a How many outer shell electrons are in atoms of group 2 elements?
b State four properties of metals.

4 Define atomic number and mass number.

5 What is the overall order of elements in the modern periodic table based on?

6 What is the name given to the following features of the periodic table?

a horizontal row
b vertical column

## Understand

**7** The symbol for the element copper is Cu and the symbol for iron is Fe.

- **a** Describe where these symbols have been derived from.
- **b** Explain why the symbol Co cannot be used for copper and Ir cannot be used for iron.

**8** Using the examples of neon (Ne), nitrogen ($N_2$) and ammonia ($NH_3$), explain the difference between an element and a compound.

**9** Describe the key features of protons, neutrons and electrons.

**10** An atom contains 12 protons and 13 neutrons.

- **a** What element must it be?
- **b** Determine the mass number for the element.
- **c** Write the atomic notation for the element.

**11** Draw a Bohr diagram and write the electron configuration for an atom of argon.

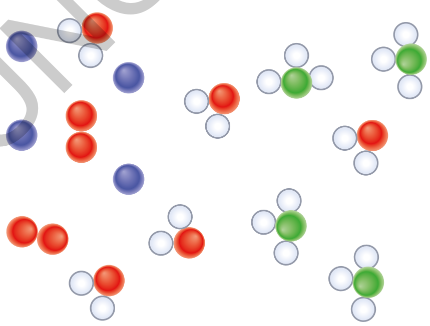
**12** You can use a periodic table to help you answer this question.

- **a** Identify the period and group for each of the following elements:

  arsenic, aluminium, potassium, radium, fluorine, bromine, tin.
- **b** Are any of the elements listed in part **a** in the same group? What would this tell you about them?
- **c** Are any of the elements listed in part **a** in the same period?

## Apply

**13** Consider the particle diagram of a mixture below. Each different colour represents a different element. How many elements and compounds are in the mixture?



**14** Arjun was investigating the properties of elements and watched a video about the element potassium (K). He recorded the following observations from the video.

'The potassium was in a small cube, which had a dull grey colour. It was cut in half with a knife and the inside was like silver. When a piece of the potassium was placed in cold water there was lots of fizzing and smoke. Another piece of potassium was heated using a Bunsen burner and it caught fire straight away, with a lilac-coloured flame.'

Using these observations, list four properties of potassium.

**15** A group of students was investigating the properties of a range of substances. Their observations are summarised below.

| Sub-stance | State | Hard-ness | Solubility in water | Melting point | Effect when hit with a hammer |
|---|---|---|---|---|---|
| A | solid | hard | insoluble | very high | changes shape |
| B | solid | very hard | soluble | very high | shatters |

- **a** Identify which of these substances is a metal.
- **b** Use evidence from the observations to explain your answer.

**16** Draw a 2D representation of a carbon atom (atomic number 6, mass number 12).

## Analyse

**17** Consider the following observations from the testing of some elements.

| Element | Appearance | Effect of hitting with a hammer |
|---|---|---|
| A | grey solid with some red solid on the surface | fairly hard to bend |
| B | smooth yellow shiny solid | shatters |
| C | brown/orange shiny solid | flattened |
| D | white solid | no change in shape |
| E | black solid with smooth surface | cracks when hit |
| F | silver-like solid | bends a little |

a Identify which of the above elements (A–F) are likely to be metals.
b Element C changes shape when it is hit. Name the property that allows the substance to do this.
c Describe a test that can be used to confirm which of the elements are metals.
d Suggest the identity of element C.
e Further testing showed that element C is ductile. Suggest a use for element C.
f Suggest the identity of element E.

## Extension: Research task

**18** The energy transition to renewable energy sources relies on the storage of electricity using batteries. This is because renewable energy sources such as wind, solar and tidal power do not generate electricity at all times of the day or every day of the year.

Australia is rich in a number of the elements required for the production of batteries including silver, lead, lithium, cobalt, nickel and copper.

a Write the symbols of these six metals.
b Choose two of these metals and, by conducting your own research, describe how they are used in batteries. In your answer you can include where the batteries are used and whether the metals are used in the batteries as elements or as compounds of the elements.

## Topic reflection

The learning intentions for this topic are given in each lesson and at the beginning of the topic. Consider how well you have achieved them. Note down any particular areas that you are confident in, and others where you are not so sure.

# 10 Glossary

**alloy** a substance formed when other materials, for example carbon or other metals, are mixed with a metal

**atom** the smallest piece of individual matter that can exist by itself

**atomic notation** A way of representing an atom using the element symbol (X), atomic number ($Z$) and the mass number ($A$); ${}^{A}_{Z}X$

**atomic number ($Z$)** the number of protons in the nucleus of an atom, indicated in the periodic table

**chemical formula** a representation of a substance that uses chemical symbols and numbers to show the relative numbers of the atoms present in the substance

**compound** a pure substance that is made up of two of more different types of atoms (elements) chemically joined

**conductivity** a measure of the ability of a substance to conduct electricity

**corrosion** the breakdown of metals due to their reaction with other chemicals

**ductile** able to be stretched to form a wire

**electron** negatively charged subatomic particle, located around the nucleus of an atom

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

**lustre** the shine given off by a material, caused by reflected light

**lustrous** shines when polished or freshly cut

**malleable** able to be hammered or bent into a new shape

**mass number ($A$)** the number of protons plus neutrons in the nucleus of an atom

**metal** an element that is shiny, conducts heat and electricity, and can be hammered into sheets and drawn into wires

**metalloid** an element that usually displays the properties of a non-metal but conducts electricity like a metal under certain conditions

**mixture** combination of two or more pure substances that can be separated to recover the pure substances

**molecule** a group of atoms joined together by chemical bonds

**neutron** a subatomic particle with no electric charge located in the nucleus of an atom

**proton** a subatomic particle with a positive electric charge located in the nucleus of an atom

**pure substance** a material that is made up of only one type of substance

**reactive** a description of a substance that readily undergoes chemical reactions

**subatomic particle** particle that atoms are made of—protons, neutrons and electrons

TOPIC 11

# Chemical change

Substances can undergo chemical changes, which is another term for a chemical reaction. A chemical change results in the formation of a new substance with different properties. This principle forms the foundation of chemistry. Chemistry is the modern form of the ancient science of alchemy, which included the search for the 'philosopher's stone'—a mythical substance believed to transform metals like mercury into gold.

Today, 118 chemical elements are known, with most found in nature whilst some are unstable and need to be made in a laboratory. These elements can undergo many different types of chemical changes to form millions of different chemical substances.

In this topic you will learn about a range of chemical changes and how energy is involved in these reactions.

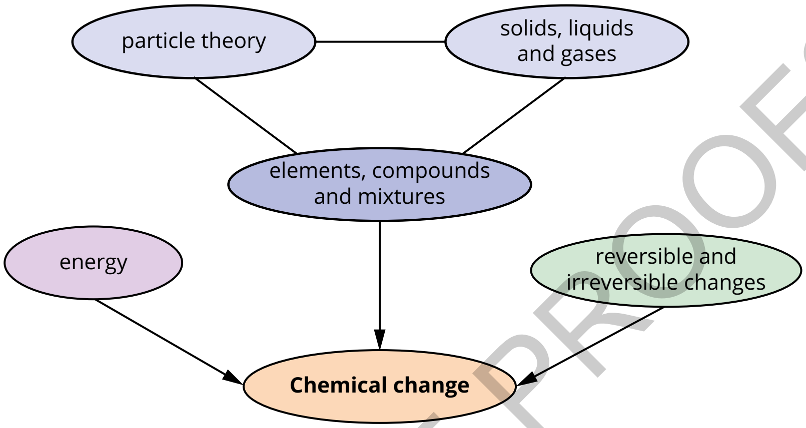
## Learning intentions

- ☐ To be able to identify evidence for chemical change **xx**
- ☐ To be able to use physical change and chemical change to make and use a chemical indicator **xx**
- ☐ To understand that chemical reactions have inputs and outputs in terms of substances and energy **xx**
- ☐ To understand how chemical reactions are represented by scientific models **xx**
- ☐ To be able to plan, conduct and evaluate a reproducible investigation to identify whether a reaction is endothermic or exothermic **xx**
- ☐ To be able to investigate which chemical is the most effective for a cold pack that uses an endothermic reaction **xx**
- ☐ To be able to conduct a practical investigation to model and observe energy changes in photosynthesis **xx**
- ☐ To be able to conduct a practical investigation to model respiration and write a scientific report documenting the findings **xx**

Prior knowledge

# 11 Chemical change

The key concepts that you will use in this topic:




The following prior knowledge questions will help to support your learning in the topic and can be attempted before the first lesson.

## Energy

1 List three types of energy.

2 State the difference between potential and kinetic energy.

3 Describe these two terms:

  a energy transfer

  b energy transformation

## Reversible and irreversible changes

4 Identify whether the following processes are reversible or irreversible.

  a evaporation of seawater to form salt crystals
  b cooking pancake batter
  c burning a piece of paper
  d dissolving sugar in water

## Elements, compounds and mixtures

5 Categorise the following substances as elements, compounds or mixtures.

water, aluminium, steam, air, paper, hand sanitiser, helium, petrol

# 11.1 Investigating evidence for chemical change

## Introduction

There are many examples of physical changes happening around us. They can include changes of state, substances mixing with each other or substances separating from each other. But there are many more changes occurring that create a different substance. These can include sugar changing into caramel or carbon dioxide being produced when bread is baked (Figure 11.1.1). These changes are called chemical changes.

In this practical investigation you will observe some chemical changes and consider if the observable evidence suggests that a chemical change has occurred.

**Learning intention**

To be able to identify evidence for chemical change

**Success criteria**

**SC 1:** I can conduct an investigation that identifies different signs of chemical change.

**SC 2:** I can determine if a chemical change has occurred by observation.

## Background

Chemical change will produce substances that were not present at the start. Therefore, if you are looking for evidence of chemical change, look out for significant changes in properties as these new substances are being produced. Such changes could include colours changing, heat or light being produced, gases being produced that are not caused by liquids evaporating, solids forming that are not caused by liquids freezing or by solutes crystallising.

**FIGURE 11.1.1** Bread undergoes chemical changes while baking in an oven

## Aim

To use evidence to identify whether chemical changes have occurred

## Apparatus

- dilute hydrochloric acid (1.0 M)
- 2 cm strip of magnesium metal (ribbon)
- silver nitrate solution (0.1 M)
- sodium hydroxide solution (1.0 M)
- 4 × large test tubes and a test-tube rack
- blue litmus paper
- 2 × droppers
- thermometer

**SAFETY NOTES**

- Silver nitrate stains the skin.
- Hydrochloric acid and sodium hydroxide are corrosive and burn, so avoid skin contact.
- Wear safety glasses throughout the experiment.

## Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

## Method

1 Read the following steps and design a suitable results table to record your observations for the four test tubes.

2 Place the four test tubes in the test-tube rack. Figure 11.1.2 outlines the four tests you will be conducting.

3 Place a strip of blue litmus paper into test tube 1. Add two drops of dilute hydrochloric acid, using a clean dropper, and record your observations.

4 Add dilute hydrochloric acid to a depth of 2 cm in test tube 2. Add a small strip of magnesium ribbon and record your observations.

5 Add dilute hydrochloric acid to a depth of 2 cm in test tube 3. Add 10 drops of silver nitrate, using a clean dropper, and record your observations.

6 Add dilute hydrochloric acid to a depth of 2 cm in test tube 4. Use a thermometer to record the temperature of the hydrochloric acid and then add 2 cm of sodium hydroxide solution. Record the temperature of the solution again.

7 Dispose of all the contents of the test tubes as directed by your teacher.

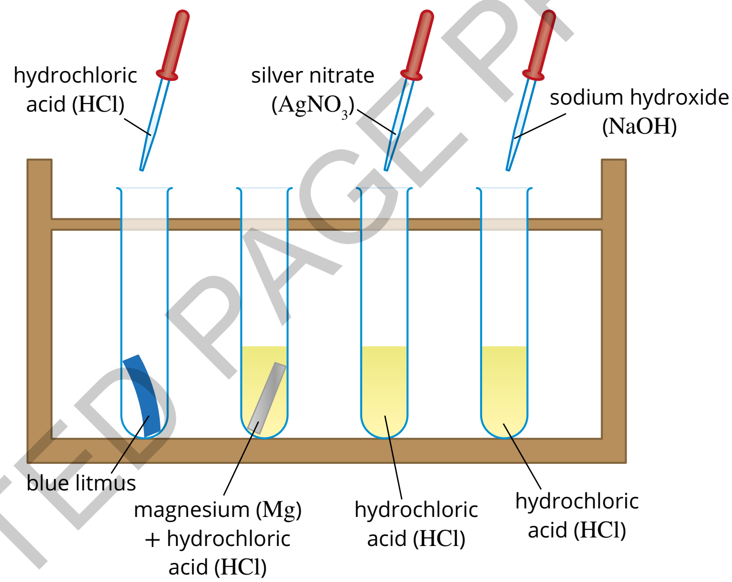



**FIGURE 11.1.2** A simplified image of the experimental setup

## Results

Record your results in a suitable table in your notebook.

## Discussion

1 Explain in detail the evidence of a chemical reaction in test tube 2.

2 Describe any physical changes that you also observed during the experiments.

3 Explain why chemical changes often cause a colour change.

## Conclusion

For each test tube, summarise the evidence that you observed and identify if a chemical reaction has occurred.

# 11.2 Making and using a chemical indicator

## Introduction

**Acids** are substances that have distinctive properties, such as being corrosive and having a sour taste. **Alkalis** are the chemical opposite of acids and are a type of **base**. They can have a bitter taste and often feel soapy to touch. Substances such as pure water, that are neither acid nor alkaline, are described as being **neutral**.

Acid/base indicators are substances that will change colour depending on whether they are in acidic, alkaline or neutral conditions (Figure 11.2.1).

In this practical investigation, you will extract a chemical from red cabbage that can act as an acid/base indicator and then use the indicator to test a range of substances.

Many plant-based substances contain chemicals that change colour depending on the level of acidity or alkalinity in their environment. For example, the colour of the flowers of geraniums, butterfly peas, hydrangeas (Figure 11.2.2), roses and tulips will depend on the acidity of the soil that they are growing in.

**FIGURE 11.2.2** The hydrangea on the left has been grown in an acidic soil, the centre one in neutral soil and the one on the right in alkaline soil.

If the chemicals that cause these changes can be extracted, they can be used to test the acidity of a range of other substances and mixtures. Red cabbage contains chemicals that can act as chemical indicators. The indicator can be separated from the other parts of the cabbage leaves as it is soluble in water.

## Background

**Physical changes** are changes to the form or appearance of a substance. The substance remains chemically the same, but changes size, shape or state (solid, liquid, gas). The atoms or molecules that make up the substance have not changed, the substance just appears different in some way.

State changes are a very common physical change (Figure 11.2.3). Whenever water changes between gas (vapour/steam), liquid and solid (ice), a physical change has occurred. Similarly, any substance that melts, boils/evaporates, freezes or condenses has undergone a physical change. Physical changes, such as changes of state, are often fairly easy to reverse.

### Learning intention

To be able to use physical change and chemical change to make and use a chemical indicator

### Success criteria

**SC 1:** I can take action to minimise risk when conducting an experiment.

**SC 2:** I can explain, with evidence, the parts of this experiment that use physical and chemical changes.

**FIGURE 11.2.1** A solution containing acid/base indicator is compared to a chart to determine its pH value

### KEY TERMS

**acid** a chemical that, when dissolved in water, is corrosive and will have a pH of less than 7
**alkali** a chemical that, when dissolved in water, has a bitter taste, can react with organic tissue and will have a pH of more than 7
**base** a substance that will neutralise an acid
**neutral** neither acidic or alkaline
**physical change** a change to a substance's appearance or form without changing its chemical identity

**KEY TERM**

**chemical change** a change that results in a new substance being formed

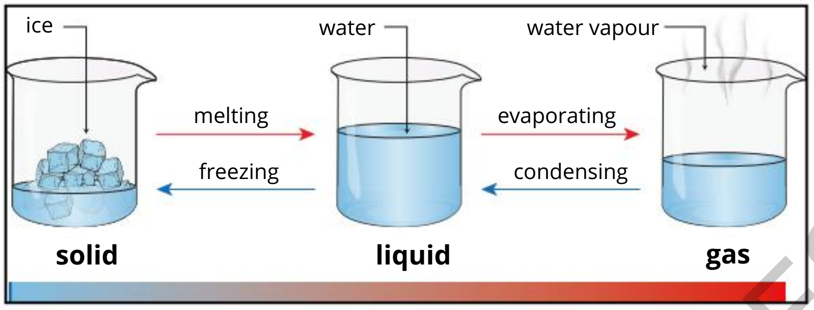



**FIGURE 11.2.3** Changes of state are physical changes as the substance remains the same.

Changing the size or shape of a substance is also a physical change. This can be done in many ways, from cutting, tearing or breaking substances. Mixing substances without chemical reactions occurring is also a physical change, like mixing two different coloured paints (Figure 11.2.4) or dissolving, for example dissolving sugar in water.

**FIGURE 11.2.4** Mixing substances together is a physical change

In this practical investigation you will cut up a leaf of red cabbage (physical change) and extract/dissolve a substance from the cabbage (physical change).

**Chemical changes** require a chemical reaction to occur and at least one new substance (product) to be formed. Often a colour change, light emission, temperature change and evidence of a new substance (including a new solid, liquid or gas) may be observed when a chemical change occurs. Most chemical changes are not reversible.

In this practical investigation the acid/base indicator collected will react with any acids or bases present and change colour as it reacts. This is an example of a chemical change. Thus, both physical and chemical changes are present in this practical investigation.

**Scifile**

**Red cabbage indicator**

The substance in red cabbage that changes colour is called an anthocyanin. The anthocyanin carries out reversible reactions with the acidity or alkalinity of the solution that is being tested. The colour change is due the chemical structure of anthocyanin changing its shape as it reacts with acids or bases.

## Aim

To safely make an acid/base indicator from red cabbage and to evaluate how effective the indicator is at testing the acidity of a range of household substances

## Prediction

For each of the substances in Table 11.2.1 predict whether it will be acidic, neutral or alkaline (basic).

**TABLE 11.2.1** Substances to test

| | | | |
|---|---|---|---|
|  |  |  |  |
| lemon juice | soft drink | tap water | soap |

## Apparatus

- dropper bottles of dilute hydrochloric acid (0.1 M), dilute sodium hydroxide solution (0.1 M), vinegar, salt (sodium chloride) solution
- approx. 2–3 mL distilled water, soft drink (lemonade) and lemon juice
- a few pieces of soap shavings
- red cabbage leaves
- filter funnel, filter paper and conical flask
- 250 mL beaker
- eyedropper
- hotplate or Bunsen burner, tripod, gauze mat and heatproof mat
- 9 × test tubes and a test-tube rack
- matches
- dropper

**SAFETY NOTE**

- Most chemicals in this experiment are corrosive or caustic so wear rubber gloves and safety glasses at all times.

## Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

## Method

### Part A: Making the indicator

1 Tear some red cabbage leaves into small pieces and place them in the beaker with approximately 50 mL of water (enough that the cabbage is just covered) (Figure 11.2.5).

2 Heat the beaker until the water is gently boiling. Continue to boil the water until it has been strongly coloured by the cabbage leaves.

3 Turn off the Bunsen burner and allow the indicator that you have made to cool.

### Part B: Testing the indicator

4 Copy the table in the Results section into your notebook.

5 Figure 11.2.6 demonstrates how to set up your experiment. Using the dropper bottle, add about:

- 1 cm (depth) of dilute hydrochloric acid to test tube 1
- 1 cm of vinegar to test tube 2
- 1 cm of distilled water to test tube 3
- 1 cm of salt (sodium chloride) solution to test tube 4
- 1 cm of sodium hydroxide solution to test tube 5.

6 Using a dropper, add a few drops of your indicator to each test tube and record the colour in the results table.

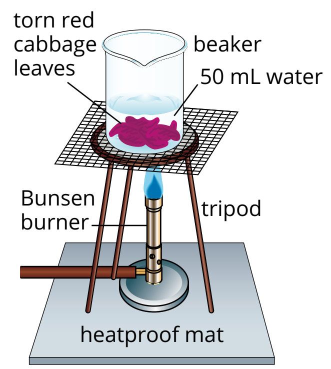



**FIGURE 11.2.5** How to set up your experiment

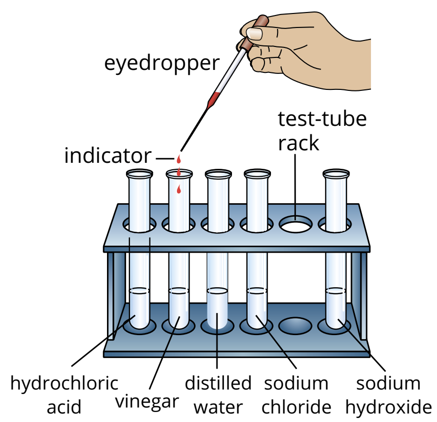



**FIGURE 11.2.6** A simplified image of your experimental setup for testing the indicator with acidic and alkaline substances

## Part C: Testing unknowns

7 Add about 1 cm (depth) of lemon juice to test tube 6.

8 Add about 1 cm of lemonade to test tube 7.

9 Add about 1 cm of tap water to test tube 8.

10 Add the pieces of soap and about 1 cm of tap water to test tube 9.

11 Using a dropper, add a few drops of your indicator to each test tube and record the colour in the results table.

## Results

Record your results in a table.

| Test tube | Name of substance | Colour with red cabbage indicator | Type of substance |
|---|---|---|---|
| 1 | hydrochloric acid solution | | acid |
| 2 | vinegar | | acid |
| 3 | distilled water | | neutral |
| 4 | salt water | | neutral |
| 5 | sodium hydroxide solution | | alkali |
| 6 | lemon juice | | |
| 7 | lemonade | | |
| 8 | tap water | | |
| 9 | soap | | |

## Discussion

1 Use the colours from the known solutions to classify the four unknown substances and add this to your results table.

2 Evaluate your practical investigation by answering the following questions.
Explain the actions that you took to minimise risk in this experiment.

3 Describe the physical changes that took place in the extraction of the indicator from the red cabbage.

4 How did you know a chemical change had occurred when you added the red cabbage indicator to the different substances?

GO TO ➤
For support with reducing risk see Toolkit section x.x.

## Conclusion

1 Summarise your findings by stating which substances were acidic, neutral or alkaline/basic.

2 Does each of your conclusions support or not support your predictions?

# 11.3 Reactants, products and energy in a chemical reaction

## Lesson overview

There are many different types of chemical reactions but they all have some features in common. They always result in substances (chemicals) changing into different chemicals. Cellular respiration, the digestion of food in your stomach and the movement of nerve impulses through your body all involve chemical reactions.

In this lesson you will learn about chemical reactions, how they can be represented and how they can be considered as processes that have inputs and outputs.

**Learning intention**

To understand that chemical reactions have inputs and outputs in terms of substances and energy

**Success criteria**

**SC 1:** I can identify the products and reactants of chemical reactions and write word equations.

**SC 2:** I can describe exothermic and endothermic reactions in terms of energy as an input or output.

**SC 3:** I can describe common uses of products or energy outputs from chemical reactions.

**SC 1** I can identify the products and reactants of chemical reactions and write word equations.

All chemical reactions can be represented by an equation. A chemical equation tells the story of a chemical reaction, with the reactants (the 'start of the story') on the left-hand side and the products (the 'end of the story') on the right-hand side. If multiple reactants or products are involved in a particular reaction, a plus sign, "+", is used to separate their formulas. The plus signs (+) means 'and' and an arrow (→) means 'changes into'.

For example, hydrogen and oxygen react together and change into water:

hydrogen + oxygen → water (This is called a word equation.)

Reactions can also be represented with equations that use the chemical formulas of the substances involved. This is a chemical equation for the same reaction:

$$H_2 + O_2 \rightarrow H_2O$$

Many types of chemical reactions occur in everyday life. In every reaction, atoms arrange themselves differently to form new products. The atoms in the products only come from the reactants. No new atoms are created and no atoms are destroyed.

Below you will discover five different types of chemical reactions: combustion, corrosion, respiration, photosynthesis and acid with reactive metals.

## Combustion

Combustion is the burning of a substance in the presence of oxygen. Oxygen is always a reactant. For many fuels (such as methane, which is the main component of natural gas) the products are carbon dioxide and water.

Example:

methane ($CH_4$) + oxygen ($O_2$) → carbon dioxide ($CO_2$) + water ($H_2O$)

**FIGURE 11.3.1** A rusty shipwreck—the brown substance is iron oxide

## Corrosion

Corrosion occurs when metals react with oxygen (Figure 11.3.1). Corrosion is a slow chemical process.

Example:

$$\text{iron (Fe)} + \text{oxygen } (O_2) \rightarrow \text{iron oxide } (Fe_2O_3) \text{ (rust)}$$

Iron and oxygen are the reactants and iron oxide is the product.

## Cellular respiration

Cellular respiration is a chemical reaction that also needs oxygen. It occurs in the mitochondria of plant and animal cells. It requires glucose ($C_6H_{12}O_6$) as a reactant and is how the cells generate energy. Cellular respiration can be summarised by the word equation:

$$\text{oxygen} + \text{glucose} \rightarrow \text{carbon dioxide} + \text{water}$$

The oxygen comes from the surrounding air. The glucose comes from the breakdown of food. The carbon dioxide is released back into the atmosphere (for example, through the lungs of animals, the gills of fish or the leaves of plants).

**Scifile**

**Anaerobic respiration**

There are microorganisms that undergo respiration without oxygen. They live in conditions where oxygen gas is not present, such as the bottom of lakes and oceans as well as inside animal digestive tracts. One example is denitrifying bacteria, which use a substance called nitrate instead of oxygen to react with glucose to give them energy.

## Photosynthesis

Photosynthesis is a chemical reaction that occurs in the leaves of plants using energy from sunlight. It can be summarised by the word equation:

$$\text{carbon dioxide} + \text{water} \rightarrow \text{oxygen} + \text{glucose}$$

The carbon dioxide comes from the surrounding air and the water normally comes from the soil through the roots of the plant. The glucose is then used by plants for energy. The oxygen is released back into the atmosphere (Figure 11.3.2).

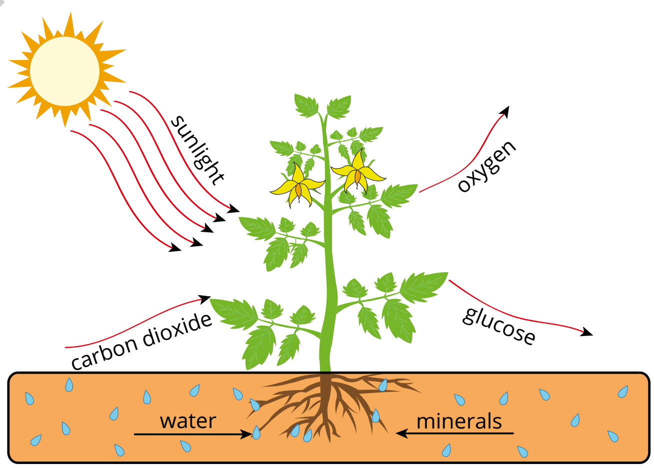



**FIGURE 11.3.2** The inputs and outputs of photosynthesis

**FIGURE 11.3.3** Magnesium reacts with acid to produce hydrogen gas.

## Acids and reactive metals

Reactive metals, such as magnesium (Mg) and sodium (Na), react with acids to produce hydrogen gas ($H_2$) and a salt. The name of the salt produced depends on which metal and which acid are reacting with each other (Figure 11.3.3).

Examples:

sodium (Na) + hydrochloric acid (HCl) → hydrogen ($H_2$) + sodium chloride (NaCl) (commonly known as table salt)

magnesium (Mg) + sulfuric acid ($H_2SO_4$) → hydrogen ($H_2$) + magnesium sulfate ($MgSO_4$) (commonly known as Epsom salt)

**SC 1 CHECK YOUR UNDERSTANDING**

List the products of the following reactions:

a methane and oxygen reacting by combustion

b iron and oxygen reacting by corrosion

c oxygen and glucose reacting in respiration

d carbon dioxide and water reacting in photosynthesis

e an acid and a reactive metal reacting

**SC 2** I can describe exothermic and endothermic reactions in terms of energy as an input or output.

## Chemical reactions

The **reactants** (initial substances) in a **chemical reaction** break down and their atoms rearrange in new combinations to make the **products** (final substances). The **surroundings** refer to the environment in which the reaction takes place; this could be the surrounding air or the water if the reaction involves solutions of chemicals.

When chemical reactions occur, energy may be absorbed from the surroundings. These are called **endothermic** reactions. Other reactions release energy as an output to the surrounding environment. These reactions are called **exothermic**.

### Exothermic reactions

Energy from chemical reactions can be released into the surroundings in a range of forms including light, sound, heat, electrical and kinetic energy. For example, a substance that glows when reacting is emitting light energy. A substance that bubbles when reacting is emitting sound energy (fizzing can be heard) and kinetic energy, as the bubbles move upward. In an explosive combustion reaction (see equation below), matter will be thrown in all directions (kinetic energy), observers would hear a loud bang (sound energy), sparks and flames may be seen (light energy) and heat energy will be given off.

Combustion can be summarised by the following word equation, including energies:

fuel + oxygen → carbon dioxide + water + sound energy + light energy + kinetic energy + heat energy

**KEY TERMS**

**reactant** a substance that takes part in a chemical reaction

**chemical reaction** the process of rearranging atoms in substances to form different substances

**product** a substance produced by a chemical reaction

**surroundings** the environment around the reaction

**endothermic reaction** a chemical reaction which absorbs energy from its surroundings as it reacts

**exothermic reaction** a chemical reaction which releases energy to its surroundings as it reacts

### Endothermic reactions

Chemical reactions can also absorb different types of energy from the surroundings. This includes electrical, heat and light energy. For example, the photosynthesis reaction absorbs light energy from the surroundings, and can be summarised in the following word equation, including energies:

carbon dioxide + water + light energy → glucose + oxygen

Electrical energy is absorbed in electrolysis reactions that are used to split up chemical compounds. These include producing aluminium from aluminium oxide (alumina) and hydrogen and oxygen from water.

## Heat as an input or an output

The most common form of input and output energy in chemical reactions is heat energy. You can observe this by measuring the temperature of substances as they react in a beaker.

### Heat as an output

If the temperature increases it means that heat energy was released to the surroundings and the reaction is exothermic. Touching the outside of this beaker would feel warm as heat energy has been released to the beaker and to your hand.

For exothermic reactions, heat can be added to the right-hand side of the equation to show that it is a product of the reaction. For example, the reaction that occurs in the engines of petrol-fuelled cars is the combustion of octane (in petrol):

octane ($C_8H_{18}$) + oxygen ($O_2$) → carbon dioxide ($CO_2$) + water ($H_2O$) + HEAT

### Heat as an input

If the temperature decreases as a reaction occurs it means that heat energy was absorbed into the substances and the reaction is endothermic. Touching the outside of this beaker would feel cold as heat energy is being absorbed from the beaker and from your hand.

For endothermic reactions, heat can be added to the left-hand side of the equation. For example, the reaction that occurs when limestone (calcium carbonate) is converted to quick lime (calcium oxide):

HEAT + calcium carbonate ($CaCO_3$) → calcium oxide ($CaO$)
+ carbon dioxide ($CO_2$)

### Heat used to start a reaction

Sometimes heat is required to get a reaction to start, such as using a burning match to light a Bunsen burner. However, once the reaction is going, it will continue to release heat. Therefore, despite the small amount of energy needed to start this reaction, much more is released, making it exothermic overall.

**SC 2 CHECK YOUR UNDERSTANDING**

Describe one form of energy that is released in an exothermic reaction and explain why that energy is released.

**SC 3** I can describe common uses of products or energy outputs from chemical reactions.

## Useful products

Chemical reactions can be used to produce useful products or generate energy, often in the form of heat. The following processes use chemistry to create useful products. In some cases, the overall processes might involve many reactions and the equation shown is a summary of the processes involved.

### Iron from iron ore

Iron ore contains mainly iron oxide ($Fe_2O_3$). The iron ore is crushed and separated from waste materials such as rock. It then takes part in a reaction with a gas called carbon monoxide (CO).

$$\text{iron oxide} + \text{carbon monoxide} \rightarrow \text{iron} + \text{carbon dioxide} + \text{HEAT}$$

Heat is used to help the reaction occur but overall this is an exothermic reaction (Figure 11.3.4). The iron (Fe) produced can be used in the construction industry.

**FIGURE 11.3.4** Molten iron produced from iron oxide in a blast furnace

### Making fertilisers

Fertilisers are used to provide more efficient plant growth (Figure 11.3.5). Most fertilisers used in agriculture contain one or more of the elements nitrogen (N), phosphorus (P) or potassium (K). Ammonium nitrate ($NH_4NO_3$) is a very commonly used fertiliser that can be produced by reacting concentrated nitric acid ($HNO_3$) with ammonia gas ($NH_3$). The reaction is highly exothermic.

$$\text{nitric acid} + \text{ammonia} \rightarrow \text{ammonium nitrate} + \text{HEAT}$$


**FIGURE 11.3.5** Ammonium nitrate fertiliser

### Making soap

If you add a strong alkali, such as sodium hydroxide, to an animal- or a plant-based oil, the alkali can convert the oil to soap (Figure 11.3.6). Fats and oils such as beef fat, coconut oil and olive oil produce different soaps with different properties. Glycerol is produced as a by-product.

The formation of soaps can be represented by the word equation:

$$\text{sodium hydroxide} + \text{natural fat/oil} \rightarrow \text{soap} + \text{glycerol}$$

**FIGURE 11.3.6** Soap is made by the reaction of sodium hydroxide and a fat or an oil

## Useful energy

Many exothermic chemical reactions are used to provide energy in a wide range of situations. Below are three everyday examples.

### Combustion engines

Combustion of octane in engines provides energy in petrol-fuelled cars. The heat produced causes gases to expand and to push the pistons in the car engine. The reaction can be controlled by changing the flow of petrol (octane) and the amount of oxygen available. This chemical reaction can be written as:

$$\text{octane } (C_8H_{18}) + \text{oxygen } (O_2) \rightarrow \text{carbon dioxide } (CO_2) + \text{water } (H_2O) + \text{HEAT}$$

## Batteries

Batteries use chemical reactions to produce electrical energy. An example of this is the lithium-ion battery that is used to power electric vehicles. Lithium carbide ($LiC_6$) reacts with cobalt oxide ($CoO_2$) and the reaction generates electricity.

When the batteries in the car are recharged, the reaction is reversed and the electrical energy provided is converted back to stored chemical energy in the battery. This chemical reaction can be written as:

lithium carbide ($LiC_6$) + cobalt oxide ($CoO_2$) → graphite (C) + lithium cobalt oxide ($LiCoO_2$) + ENERGY

## Safety airbags

Safety airbags in cars use incredibly fast exothermic reactions to inflate the airbag in a crash. The reaction also produces a large volume of gas very quickly. The heat generated in the reaction helps to inflate the airbag as the heat makes the particles of nitrogen gas separate more quickly. This chemical reaction can be written as:

sodium nitride ($Na_3N$) → sodium (Na) + nitrogen ($N_2$) + HEAT

### SC 3 CHECK YOUR UNDERSTANDING

Name one common everyday use of the energy output from a combustion reaction.



# Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 State the difference between reactants and products in a chemical reaction.

2 a Name the four primary forms of energy released during exothermic chemical reactions.

b For each form of energy listed, provide one example of how it is used in a practical application.

3 Categorise the following reactions into either combustion, corrosion, respiration, photosynthesis or acid with reactive metals.

a A strip of magnesium is placed into a solution of hydrochloric acid.

b Gas is produced by a plant kept in complete darkness.

c Green copper carbonate is formed on the copper domes on the roof on the Queen Victoria Building in Sydney.

4 List the main steps in an experiment that tests whether dissolving ammonium nitrate in water is endothermic or exothermic.

# 11.4 Representing chemical reactions

## Lesson overview

A chemical is a substance with a fixed composition. When chemicals undergo chemical changes, new substances are made, which are called the products of the reaction. In a chemical reaction the arrangement of the particles in the substances involved changes to make the new substances.

In this lesson you will learn how chemical reactions can be represented, including word equations, chemical equations and 2D and 3D models that show the arrangement of particles.

**Learning intention**

To understand how chemical reactions are represented by scientific models

**Success criteria**

**SC 1:** I can write word equations to summarise chemical reactions.

**SC 2:** I can describe the changes occurring in a chemical reaction from a chemical equation with familiar substances.

**SC 3:** I can represent changes in the structure of molecules in a simple chemical reaction using two- and three-dimensional models.

**SC 1** I can write word equations to summarise chemical reactions.

## Word equations

Word equations are a simple way to show what has happened in a chemical reaction. The reactants are shown on the left and the products are shown on the right. An arrow (→) is placed between the reactants and products and represents the change between the chemicals at the start (reactants) and the chemicals at the end (products).

### Examples of word equations

**Reaction of sodium and water**

sodium + water → sodium hydroxide + hydrogen

**Reaction of nitrogen and hydrogen to produce ammonia**

nitrogen + hydrogen → ammonia

**Reaction of an acid and alkali (base)**

hydrochloric acid + sodium hydroxide → sodium chloride + water

**Reaction of an acid and a carbonate**

sulfuric acid + calcium carbonate → calcium sulfate + carbon dioxide + water

**Combustion of butane**

butane + oxygen → carbon dioxide + water

**Decomposition of calcium carbonate**

calcium carbonate → calcium oxide + carbon dioxide

**SC 1 CHECK YOUR UNDERSTANDING**

Write the word equation for the reaction of sodium with chlorine to form sodium chloride.

**SC 2** I can describe the changes occurring in a chemical reaction from a chemical equation with familiar substances.

## Chemical equations

Chemical equations can be used to represent the changes that occur in a chemical reaction. The chemicals are represented by their formulas, which use the atomic symbols of the elements.

### Numbers of atoms in chemical formulas

Chemical formulas show the number of each type of atom in a substance.

**KEY TERM**

**molecule** a group of atoms joined together with chemical bonds

For example, oxygen gas has the formula $O_2$ because it contains two oxygen atoms in each **molecule**. The number tells you about the chemical symbol before the number.

Carbon dioxide has the formula $CO_2$ because it contains one carbon (C) atom and two oxygen atoms. Calcium carbonate has the formula $CaCO_3$ because for each calcium (Ca) atom it contains one carbon (C) atom and three oxygen (O) atoms.

### Numbers of atoms in chemical equations

Because atoms are not created or destroyed in a chemical reaction, the total number of atoms does not change. This means that the numbers of atoms on the reactant side and the product side of the equation must be the same. This is called a balanced chemical equation.

To make sure that this is the case, numbers can be placed before a formula in an equation to show that there is more than one atom or molecule of that substance taking part in the reaction.

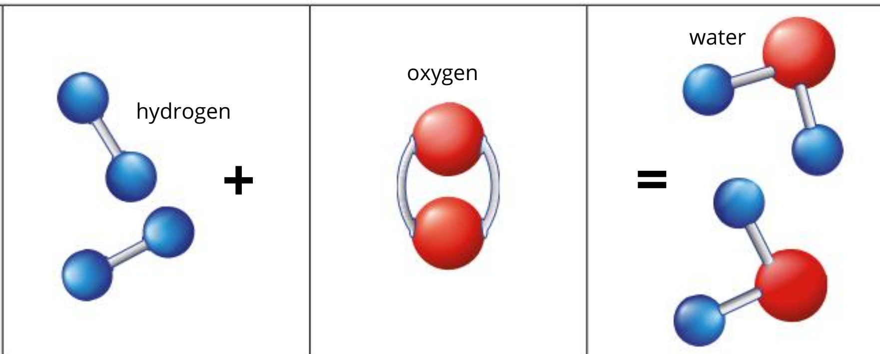
For example, the balanced chemical equation for the reaction of hydrogen and oxygen to form water is: $2H_2 + O_2 \rightarrow 2H_2O$

The number 2 before the hydrogen ($H_2$) and the number 2 before the water ($H_2O$) are there because each oxygen molecule needs to react with two hydrogen molecules for the reaction to happen (Table 11.4.1).

So $2H_2$ means two molecules of hydrogen and $2H_2O$ means two molecules of water.

Thus, a balanced equation shows us that a total of 4 hydrogen atoms needs to react with 2 oxygen atoms to produce 2 molecules of water. This ensures that the total hydrogen atoms at the start and end are both 4, and the total oxygen atoms at the start and at the end are always 2. The number of each type of atom is kept constant during a chemical reaction.

**TABLE 11.4.1** Reaction of hydrogen and oxygen to form water




| | | | |
|---|---|---|---|
| **Number of molecules** | 2 hydrogen molecules | 1 oxygen molecule | 2 water molecules |
| **Hydrogen atoms** | 4 atoms of hydrogen | | 4 atoms of hydrogen |
| **Oxygen atoms** | | 2 atoms of oxygen | 2 atoms of oxygen |

## State symbols in chemical equations

To show the state (solid, liquid or gas) of a chemical in a chemical reaction, the letters (g), (l) or (s) can be used. If the chemical is in the form of a solution in water, the letters (aq) are used, which stands for aqueous and means 'dissolved in water'.

For example, the chemical reaction between solid sodium and water to produce hydrogen gas and a solution of sodium hydroxide can be written as:

$$Na(s) + H_2O(l) \rightarrow NaOH(aq) + H_2(g)$$

Other examples include:

- the combustion of methane
- methane + oxygen → carbon dioxide + water
- $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$
- photosynthesis
- carbon dioxide + water → glucose + oxygen
- $6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(aq) + 6O_2(g)$

## Reversible reactions

Most chemical reactions only go one way; that is, they are **irreversible** reactions. The reactants are converted into the products. However, other chemical reactions are **reversible**. This means that the reaction can go both ways and the products can convert back to the reactants. If a reaction is reversible, this arrow $\rightleftharpoons$ is used.

- For example, the formation of carbonic acid can be written as:
- carbon dioxide + water → carbonic acid
- $CO_2(g) + H_2O(l) \rightarrow H_2CO_3(aq)$

**KEY TERMS**

**irreversible** a change that cannot be undone

**reversible** a change that can be undone

**SC 2 CHECK YOUR UNDERSTANDING**

Describe the changes occurring in the reaction represented by this chemical equation.

$$2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$$

**SC 3** I can represent changes in the structure of molecules in a simple chemical reaction using two- and three-dimensional models.

Models can be used to represent the changes to atoms and molecules that occur in a chemical reaction.

## 2D modelling of chemical reactions

2D models use diagrams of atoms and molecules to show changes in the arrangement of the atoms. Chemical equations can show which atoms are present, how many atoms there are, and which atoms are joined with others. The models can show how the atoms are joined at the start (in the reactants) and at the end (in the products).

### Combustion of carbon

Carbon dioxide is formed as one atom of carbon is combined with the two atoms in a molecule of oxygen. Figure 11.4.1 represents this reaction as a diagram.

The chemical equation is:

$$C + O_2 \rightarrow CO_2$$

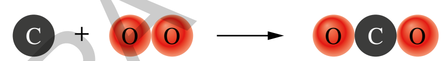
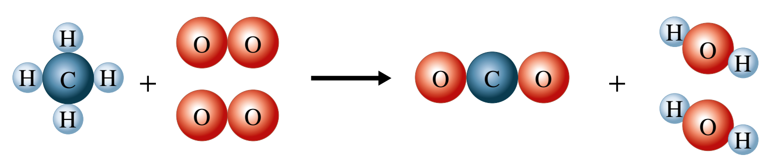



**FIGURE 11.4.1** A 2D model of the reaction: carbon + oxygen → carbon dioxide

### Combustion of methane

Figure 11.4.2 shows the 2D model, word equation and chemical equation for the combustion of methane. The molecules in the 2D model are represented with coloured atoms joined together. Note that there are two molecules of oxygen and two molecules of water included. If the extra molecules were not included the numbers of atoms on each side of the equation would not be the same and the equation would not be balanced.




fuel (methane) + oxygen → carbon dioxide + water

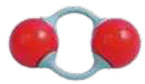
$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$

**FIGURE 11.4.2** The combustion of methane represented as a 2D model, word equation and chemical equation

## 3D modelling of chemical reactions

The arrangement of the atoms in a molecule, how they are bonded together and the shape of the molecule can be shown using 3D models (Table 11.4.2). Using a 3D model is a more realistic representation because real molecules are 3D.

**TABLE 11.4.2** A list of common chemicals and their 3D model

| | | |
|---|---|---|
| water ($H_2O$) | oxygen gas ($O_2$) | ammonia ($NH_3$) |
|  |  |  |
| carbon dioxide ($CO_2$) | nitrogen gas ($N_2$) | hydrogen gas ($H_2$) |
|  |  |  |

To observe the changes in 3D structure during a chemical reaction, an example of the production of ammonia using 3D models is given in Figure 11.4.3. The chemical equation for this reaction is:

$$N_2 + 3H_2 \rightarrow 2NH_3$$

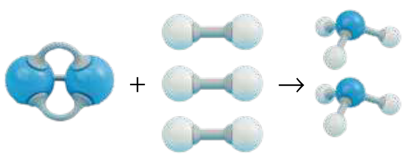


**FIGURE 11.4.3** A 3D model of the reaction of nitrogen and hydrogen gases to produce ammonia

### SC 3 CHECK YOUR UNDERSTANDING

Refer to the 3D model of ethene below, which is used as a fuel and to make plastics. The black coloured balls represent carbon atoms and the white coloured balls represent hydrogen atoms. Using this information, write down the chemical formula for ethene.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

**1** Write out the word equation for the reaction between silver and hydrogen sulfide that forms silver sulfide and hydrogen gas.

**2** Chlorine gas ($Cl_2$) and phosphorus trichloride ($PCl_3$) react to form phosphorus pentachloride ($PCl_5$) as represented in the reaction:

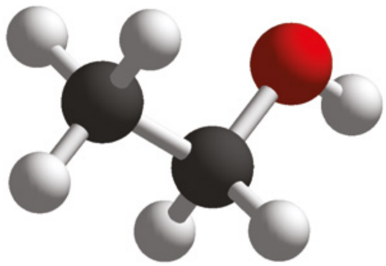
- **a** $Cl_2 + PCl_3 \rightleftharpoons PCl_5$
- **b** Determine whether the reaction is reversible or irreversible. Justify your choice with evidence from the equation.

**3** The reaction between magnesium (Mg) and hydrochloric acid (HCl) forms hydrogen gas ($H_2$) and magnesium chloride ($MgCl_2$) salt dissolved in water.

$Mg(s) + 2HCl(aq) \rightarrow H_2(g) + MgCl_2(aq)$

- **a** Write the word equation for this reaction.
- **b** Identify the chemical names of all the reactants and products in this reaction.
- **c** Explain why it is important to balance chemical equations.
- **d** Compare the information provided by the word equation and the balanced chemical equation.

**4** The 3D model of ethanol (a fuel made from plants) is provided below. Determine the chemical formula of ethanol using the model. Black balls represent carbon, red balls represent oxygen and white balls represent hydrogen.



**5** Draw the 2D model representation of the following chemical reaction.

**a** iron + hydrochloric acid → iron chloride + hydrogen

**b** $Fe(s) + 2HCl(aq) \rightarrow FeCl_2(aq) + H_2(g)$

**6** Photosynthesis has the following chemical equation.

$6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(aq) + 6O_2(g)$

**a** Determine how many water molecules are used in the reaction.

**b** List the chemical names of the products of the reaction.

**c** Calculate the total number of oxygen atoms present in the reactants.

# 11.5 Identifying energy change in a chemical reaction

## Introduction

One of the pieces of evidence that a chemical change (chemical reaction) has taken place is an increase or decrease in temperature. This is because chemical reactions involve energy. Reactions that cause the temperature to increase are called exothermic reactions. An example of an exothermic reaction is a burning match (Figure 11.5.1). Reactions that cause the temperature to decrease are called endothermic reactions.

In this practical investigation you will plan and carry out an experiment to test whether a given chemical reaction is exothermic or endothermic.

**Learning intention**

To be able to plan and conduct a reproducible investigation to identify whether a reaction is endothermic or exothermic

**Success criteria**

**SC 1:** I can design a valid experiment that tests whether a reaction is endothermic or exothermic.

**SC 2:** I can identify and manage risks in conducting an experiment involving exothermic and endothermic reactions.

## Background

When new substances (products) are made in chemical reactions, the total chemical energy of the products may be more than or less than the total of the reactants. Energy will be absorbed from or released to the surroundings, depending on whether the reactants or the products have more stored chemical **potential energy**.

Reactions that cause the temperature of the surroundings to increase are called **exothermic reactions**. The products have less chemical energy than the reactants and heat energy is released into the surroundings, causing an increase in temperature. Reactions that cause the temperature to decrease are called **endothermic reactions**. The products have more chemical energy than the reactants and heat energy is removed from the surroundings, causing a decrease in temperature.

In this practical investigation you will carry out a chemical reaction and determine whether it is exothermic or endothermic.

**FIGURE 11.5.1** A burning match is an example of an exothermic reaction.

### HINT

**Terminology tip:**

The terms *exothermic* and *endothermic* both end in the suffix -*thermic*, which means relating to heat or temperature.

Exothermic has the prefix *exo*-, which means exterior (or outside). This means that *exothermic* relates to sending the heat 'out of' the chemicals, or the heat 'exits'.

Endothermic has the prefix *endo*-, which means internal (or inside). This means that *endothermic* relates to the heat being absorbed from the environment.

**FIGURE 11.5.2** A reaction between an acid and an alkali

### HINT

You can conduct preliminary trials to test and improve your method.

Water is required for the reaction between the acid and the alkali to occur.

Check with your teacher whether you are able to do repeat trials. The reliability of your results can be improved by carrying out repeat trials.

### SAFETY NOTE

- Write down the steps you will follow to ensure you stay safe whilst completing the experiment.

GO TO ➤
For support with reducing risk see Toolkit section x.x.

## Aim

To determine whether a reaction between an acid and an alkali (Figure 11.5.2) is endothermic or exothermic

## Prediction

State, with reasoning, whether you think the reaction of an acid and an alkali is exothermic or endothermic.

## Apparatus

You will have access to polystyrene cups with lids, thermometers, solid citric acid as your acid and baking soda (sodium hydrogen carbonate) as your alkali. The change in temperature of the reaction mixture indicates whether heat is released or absorbed during the reaction. Your teacher will tell you how much you are able to use for the experiment. Include the list of required apparatus and safety notes as part of your method.

## Method

Write a step-by-step method for your investigation. Include apparatus required, the quantities of chemicals and any safety notes needed. Include instructions of how to dispose of your mixtures at the end of the investigation. Check these with your teacher.

Draw a labelled scientific diagram showing your set-up, including where you will place each chemical.

## Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

## Results

Copy the following table into your notebook and use it to record results. Add extra rows for any additional trials you carry out.

| Trial | Temperature (°C) | | |
|---|---|---|---|
| | Water before reaction | Mixture after reaction | Change |
| 1 | | | |

## Discussion

1 Comment on whether you think you need to conduct any further experiments to test your prediction.

2 Why do you think polystyrene cups with lids were used in this experiment? Think about how they affect the energy transfer between the system (the reacting chemicals) and the surroundings.

## Conclusion

1 Write a conclusion to your experiment by describing what you observed.

2 Does your conclusion support or not support your prediction? Was the outcome as you predicted?

3 Describe whether the reactants or products in this practical investigation contain more chemical potential energy. Justify your choice with evidence from your investigation.

# 11.6 Making an effective cold pack

**Learning intention**

To be able to investigate which chemical is the most effective for a cold pack that uses an endothermic reaction

**Success criteria**

**SC 1:** I can plan an experiment to identify the most suitable chemical to be used in a cold pack.

**SC 2:** I can select and use equipment correctly to record temperature change during an endothermic reaction.


**FIGURE 11.6.1** Instant cold packs use endothermic reactions

**SAFETY NOTE**

- Wear safety glasses throughout the experiment and avoid skin contact with the chemicals being used.

## Introduction

Cold packs are applied to sporting and other injuries to decrease the blood supply to an injured area. They reduce bruising and swelling that may result from an injury by cooling the area, which reduces bleeding in the body tissues. Some commercially available cold packs depend on an endothermic reaction (Figure 11.6.1). Often this is the reaction of a chemical as it dissolves in water.

In this inquiry activity you will test a range of chemicals to discover which would be the most effective for use in a cold pack. The temperature changes may not be very large so you will need to devise accurate ways to measure the temperatures in the experiment.

## Background

The endothermic reactions used in most instant cold packs involve chemicals dissolving in water. As the chemicals dissolve, their particles separate from each other, which requires energy. This process absorbs heat energy from the surroundings. As a result, the temperature of the surrounding environment (such as an injured part of the body) decreases.

You can choose to answer one of these questions.

Question 1: Which chemical will produce the greatest temperature decrease?

Question 2: Which chemical will produce the quickest temperature decrease?

## Aim

To carry out an experiment that will identify which chemical is the most effective for use in a cold pack

## Plan

The chemicals that you are going to test are:

- ammonium chloride ($NH_4Cl$)
- potassium iodide (KI)
- urea ($CH_4N_2O$)

You will have access to some or all of the following:

- thermometers
- glass stirring rods
- glass beakers (100 mL or 250 mL)
- measuring cylinders (50 mL or 100 mL)
- polystyrene cups
- stopwatches
- plastic teaspoons
- electronic balance

# Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

# Design

Your teacher will assign you one of the following questions to investigate.

## Part A: Temperature change

Question: Which chemical will produce the greatest temperature decrease?

### Notes for your method

Your method should be based on measuring the change of temperature during the reaction of the substance and water. This can be done by measuring the water temperature before and after the substance has been added to the water.

You can conduct preliminary trials to determine the quantities that work best for this experiment.

You should design a result table to record your results. If there is time, you may be able to conduct repeat trials for each substance.

## Part B: Time for temperature change

Question: Which chemical will produce the quickest temperature decrease?

### Notes for your method

Your method should be based on the time it takes for the reaction to cool the water to a 'target' temperature.

You can conduct preliminary trials to determine what this temperature could be, and the quantities that work best for this experiment.

You should design a result table to record your results. If there is time, you may be able to conduct repeat trials for each substance.

# Conduct

Once you have decided on a method, show it to your teacher before you start to carry out your investigation.

# Results

Copy the relevant results table into your notebook for recording your preliminary trials. Add extra columns for any additional trials you carry out.

## Part A: Temperature change

| Chemical | Temperature (°C) | | |
|---|---|---|---|
| | Initial | Final | Change |
| ammonium chloride | | | |
| potassium iodide | | | |
| urea | | | |

## Part B: Time for temperature change

| Chemical | Temperature (°C) | | |
|---|---|---|---|
| | Initial | Final | Time taken (s) |
| ammonium chloride | | | |
| potassium iodide | | | |
| urea | | | |

## Discussion

GO TO ➤
For support with evaluating reliability see Toolkit section x.x.

GO TO ➤
For support with evaluating validity see Toolkit section x.x.

1 Discuss how well your experiment was able to show differences between the three substances being tested.
2 Use your results to describe how reliable your method was.
3 Comment on the validity of your results.

## Improve

Describe at least two modifications to the method that you either carried out or could apply to the method. Explain how these modifications would improve the reliability or the validity of results.

## Conclusion

Use evidence from your results to identify which chemical is the most effective chemical in a cold pack.

# 11.7 Photosynthesis

## Introduction

**Photosynthesis** is the process by which green plants produce glucose, a type of sugar that serves as their main source of energy. Unlike animals, plants cannot move to find food so they must transform the available light energy into glucose, to store energy ready for use (Figure 11.7.1).

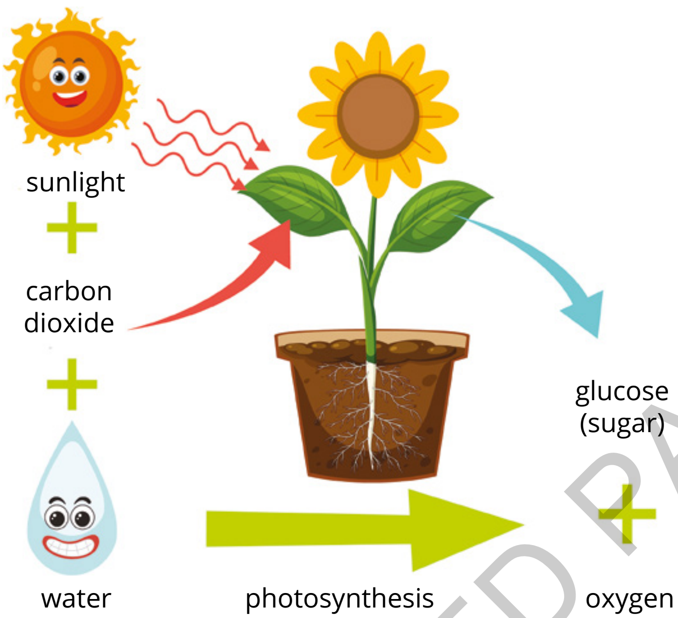



**FIGURE 11.7.1** Photosynthesis

When studying chemical reactions, you can observe either the disappearance of reactants or the formation of products. In the case of photosynthesis, the reactants are carbon dioxide (a gas) and water (a liquid), while the products are glucose (a solid) and oxygen (a gas).

## Background

Bromothymol blue solution is an acid/base indicator that will turn yellow/green in acid and blue in basic conditions. When carbon dioxide is present in solution this makes the solution acidic. If the amount of carbon dioxide present is low, the solution is basic.

Hydrilla is a green plant that carries out photosynthesis. Photosynthesis requires light, carbon dioxide and water. As the reaction progresses the light energy is being converted to chemical stored energy in glucose molecules. Photosynthesis can be represented by the word equation:

carbon dioxide + water → glucose + oxygen

## Aim

To demonstrate that light is needed for photosynthesis to occur, and that photosynthesis decreases the amount of carbon dioxide present

### Learning intention

To be able to conduct a practical investigation to model and observe energy changes in photosynthesis

### Success criteria

**SC 1:** I can conduct a practical investigation to model photosynthesis.

**SC 2:** I can document findings of a photosynthesis experiment in a written scientific report.

### KEY TERM

**photosynthesis** a process in which some organisms (e.g. green plants) use the sun's energy to produce energy-dense glucose molecules

## Apparatus

- bromothymol blue indicator
- 1 x aluminium foil piece cut to fully cover a test tube (approx. 20cm x 15cm)
- test tube with stopper
- 2 × pieces of hydrilla (*Hydrilla verticillata*)
- marker pen
- UV lamp (optional)
- drinking straw
- 50 mL beaker

**SAFETY NOTES**

- Wear safety glasses at all times.
- Be careful when blowing into any water or solutions.

### Prior preparation

Hydrilla need to be rinsed in pond water, or tap water that has been left to stand for 24 hours, before being cut into sections. The hydrilla should be kept in a bowl of pond water.

## Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

## Method

1. Two-thirds fill each test tube and the beaker with water. Add a few drops of bromothymol blue to give the solution a blue colour.
2. Using the drinking straw, blow air through the water in the beaker.
3. Write 'D' on one test tube and 'L' on the other test tube (for 'dark' and 'light' conditions).
4. Place one piece of hydrilla in each test tube.
5. Carefully fill both test tubes with the indicator solution from the beaker.
6. Record the initial colour of each solution.
7. Immediately wrap the test tube labelled D with aluminium foil. Ensure that it is fully covered and no light can enter.
8. Place both test tubes in direct sunlight or under a UV lamp, but make sure the water does not get hot.
9. Leave the test tubes for 24–48 hours.
10. Observe and record any changes in the colour of the indicator in a table like the one shown in the Results section.

## Results

Copy the following table into your notebook and use it to record results.

| Amount of light | Initial colour | Final colour |
|---|---|---|
| dark | | |
| light | | |

## Discussion

Write a scientific report in your notebook, including the sections: investigation title, aim, prediction, results, discussion and conclusion. Answer all the questions in the discussion and conclusion sections in full sentences.

1. Describe the observations you made when you bubbled exhaled air through the water containing bromothymol blue.
2. Bromothymol blue is blue in an alkaline or a neutral solution. It turns green and then yellow in an acidic solution. Carbon dioxide dissolved in water produces a weak acid.

   Use this information to identify whether each solution was alkaline, neutral or acidic.
3. State the word equation for the process of photosynthesis.
4. Explain how your observations confirm that light is needed for photosynthesis to occur.
5. State the energy change that occurs during photosynthesis.

## Conclusion

Write a conclusion to your experiment by explaining what happened in each of the test tubes.

# 11.8 Respiration

**Learning intention**

To be able to conduct a practical investigation to model respiration and write a scientific report documenting the findings

**Success criteria**

**SC 1:** I can conduct a practical investigation to model respiration.

**SC 2:** I can document the findings of an experiment in a written scientific report.

**KEY TERM**

**respiration** a process where some organisms (e.g. green plants) break down molecules like glucose to release energy to the organism

**FIGURE 11.8.1** The respiration of yeast producing bubbles of carbon dioxide

## Introduction

Have you ever wondered how cells use food to make energy?

Yeast is a type of fungus that is a microscopic single-celled organism. Yeast can be found in many environments including water, soil, the air, and on plants and animals. Yeast is alive and must break down sugars to release energy that it can use.

**Respiration** is a process that organisms undertake in order to release energy from food. In yeast, respiration involves the breakdown of glucose into ethanol and carbon dioxide. Carbon dioxide is a gas and will produce visible bubbles and foam (Figure 11.8.1).

$$\text{glucose} \rightarrow \text{ethanol} + \text{carbon dioxide}$$

In this practical investigation you will explore which environment promotes the most yeast growth.

## Background

You will investigate how temperature affects the rate of cellular respiration in yeast cells. When cells respire, they release a gas (carbon dioxide) and heat. The faster they respire, the more gas and heat they release. The amount of gas produced can be measured by measuring the height of foam produced.

Respiration requires glucose molecules, which contain stored chemical energy. As the reaction progresses the stored chemical energy is being converted to heat energy and kinetic energy (as the bubbles move).

## Aim

To investigate the effect of temperature on cellular respiration in yeast

## Prediction

1 Identify the independent and dependent variables for this experiment.

2 Using the variables you identified in Question , write a suitable prediction.

## Apparatus

- 15 g dry baker's yeast
- sugar
- water
- glass stirring rod
- 3 x 100 mL beakers
- 50 or 100 mL measuring cylinder
- a kettle (teacher only)
- electronic balance
- teaspoons
- 30 cm ruler
- a marker pen
- cling film (optional)

## Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

## Method

1 Take three beakers and add a spoonful of sugar to each one.
2 Add 50 mL water to each beaker. To the first beaker, you should add cold water. To the second beaker, add hot water (50–60°C) that your teacher has prepared. To the third beaker, add warm water (25–30°C).
3 Add 5 g of yeast to each beaker.
4 Place a line on the outside of the beaker to indicate the initial level of the water. This will be your zero mark.
5 After five minutes, measure the thickness of the foam in each beaker, from the line that is your zero mark.
6 After five more minutes, measure the thickness of the foam again, from the line that is your zero mark.

## Results

Record your results in a suitable table such as the one below.

| Temperature of water | Height of foam after 5 mins (cm) | Height of foam after 10 mins (cm) |
|---|---|---|
| cold | | |
| warm | | |
| hot | | |

## Discussion

Write a scientific report in your notebook including the sections: investigation title, aim, prediction, results, discussion and conclusion. Answer all the questions in the discussion and conclusion sections in full sentences.

1 Recall the word equation for the respiration of yeast. Identify the product that caused the yeast solution to rise.
2 Which environments promoted yeast growth and which environments limited yeast growth?
3 Did you notice any changes with time?
4 Produce a column graph of your results. Draw two columns together (5 min and 10 min measurements) for each water temperature along the *x*-axis.

## Conclusion

1 Write a conclusion for your investigation describing the best conditions for yeast to respire.
2 Assess whether your prediction was supported or not.

# 11 Chemical change

## Topic summary

The key concepts included in this topic are:

- When substances undergo chemical changes there are common observations that indicate this.
- Chemical indicators measure acidity/basicity.
- Exothermic and endothermic reactions and common examples of both reactions.
- Chemicals (including food) store energy as chemical potential energy. Energy is always conserved during transformations.
- Chemical reactions can be represented as word equations, chemical equations, and 2D and 3D models.
- Combustion reactions are a type of exothermic reaction that have specific inputs and outputs in terms of both matter and energy.



## Review questions

The following questions will assess your success in achieving the learning intentions for this topic.

### Remember

1 Identify four observations that indicate a chemical change has occurred.

2 Write the word equation for photosynthesis.

3 Identify the following as physical changes or chemical changes.

a smashing a cake
b boiling water
c burning paper
d dissolving salt
e metal rusting

### Understand

4 Write the word equations for the following.
a copper and sulfur react to produce copper sulfide
b silver bromide breaks down to form silver and bromine

5 Draw a 2D model of the molecule HCN.

6 Explain how you determine the number of atoms of carbon, hydrogen and oxygen that are present in $CH_3O_2$.

7 Explain how you can determine if a reaction is exothermic.

### Apply

8 Turmeric is an example of a natural acid/base indicator. It turns red in basic solutions and yellow in acidic or neutral solutions.
Deduce whether each of the following substances are alkaline or neutral/acidic from the results in the table and place a tick in the correct column.

| Substance | Colour in turmeric solution | Alkaline | Neutral/ acidic |
|---|---|---|---|
| lime juice | yellow | | |
| soap | red | | |
| laundry powder | red | | |
| carrot juice | yellow | | |

9 Apply your understanding of exothermic reactions to design an experiment to test the effectiveness of different chemicals in a heat pack.

## Analyse

**10** State the energy transformation that takes place when an electric vehicle battery is being recharged. How does this transformation differ from the one that occurs when the battery is being used to power the car?

**11** Draw the 2D model to represent the chemical reaction:

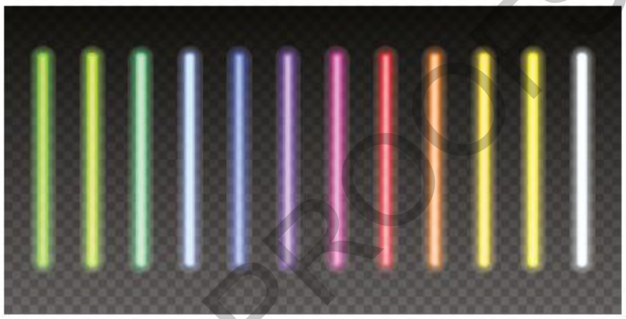
propane + oxygen → carbon dioxide + water

$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$

## Extension: Research task

**12** Chemiluminescence is the name given for a type of reaction done by a non-living system that produces light. Glow sticks are a typical example of a chemiluminescence reaction. Many different colours can be created by changing the dye. Glowsticks contain two compartments, separated by a thin sheet of glass or plastic. Breaking this sheet allows the chemical reactants to mix together. A reaction takes place in which the chemical energy is transformed into light energy. Once the chemical reaction has finished, no more light is produced. Fireworks are another example of a chemiluminescent reaction.

Research the ingredients in fireworks or glow sticks that produce the coloured light. Investigate the safety of these ingredients, where they are sourced and their impact on the environment when the glowsticks are disposed of. Explore which chemicals and their colours are safest for humans and the environment.



## Topic reflection

The learning intentions for this topic are given in each lesson and at the beginning of the topic. Consider how well you have achieved them. Note down any particular areas that you are confident in, and others where you are not so sure.

# 11 Glossary

**acid** a chemical that, when dissolved in water, is corrosive, can react with reactive metals to form hydrogen gas, can have a sour taste and will have a pH of less than 7

**alkali** a chemical that, when dissolved in water, can react with organic tissue and will have a pH of more than 7

**base** a substance that will neutralise an acid

**chemical change** a change that results in a new substance being formed

**chemical reaction** the process of rearranging atoms in substances to form different substances

**endothermic reaction** a chemical reaction that absorbs energy, often causing a temperature decrease in the surroundings

**exothermic reaction** a chemical reaction that releases energy, often causing a temperature increase in the surroundings

**irreversible** a change that cannot be undone

**molecule** a group of atoms joined together with chemical bonds

**neutral** neither acidic or alkaline

**photosynthesis** a process in which some organisms (e.g. green plants) use the sun's energy to produce energy-dense glucose molecules

**physical change** a change that does not result in a new substance being produced

**potential energy** stored energy possessed by an object (because of its position or chemical structure) that can be transformed into another form of energy

**product** a substance produced by a chemical reaction

**reactant** a substance that takes part in a chemical reaction

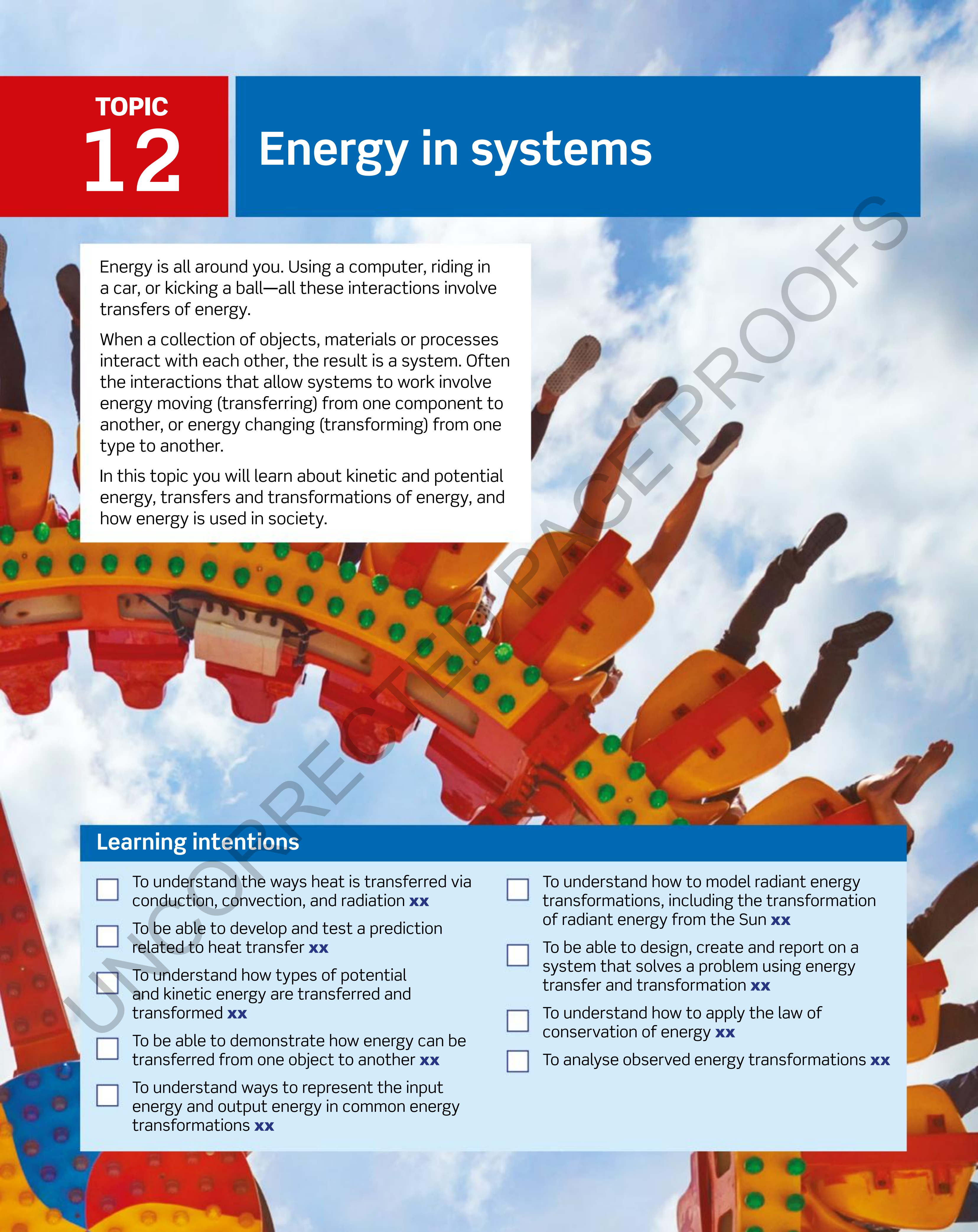
**respiration** a process where some organisms (e.g. green plants) break down molecules like glucose to release energy to the organism

**reversible** a change that can be undone

**surroundings** the environment around the reaction

TOPIC 12

# Energy in systems



Energy is all around you. Using a computer, riding in a car, or kicking a ball—all these interactions involve transfers of energy.

When a collection of objects, materials or processes interact with each other, the result is a system. Often the interactions that allow systems to work involve energy moving (transferring) from one component to another, or energy changing (transforming) from one type to another.

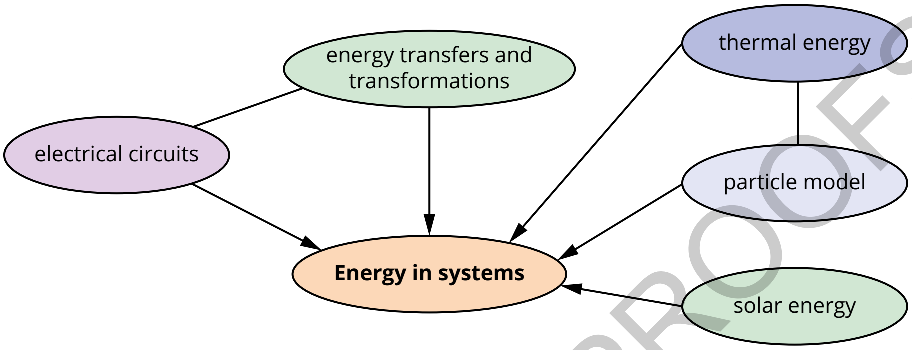
In this topic you will learn about kinetic and potential energy, transfers and transformations of energy, and how energy is used in society.

## Learning intentions

- ☐ To understand the ways heat is transferred via conduction, convection, and radiation **xx**
- ☐ To be able to develop and test a prediction related to heat transfer **xx**
- ☐ To understand how types of potential and kinetic energy are transferred and transformed **xx**
- ☐ To be able to demonstrate how energy can be transferred from one object to another **xx**
- ☐ To understand ways to represent the input energy and output energy in common energy transformations **xx**
- ☐ To understand how to model radiant energy transformations, including the transformation of radiant energy from the Sun **xx**
- ☐ To be able to design, create and report on a system that solves a problem using energy transfer and transformation **xx**
- ☐ To understand how to apply the law of conservation of energy **xx**
- ☐ To analyse observed energy transformations **xx**

# 12 Energy in systems

The key concepts that you will use in this topic:




The following prior knowledge questions will help to support your learning in the topic and can be attempted before the first lesson.

## Electrical circuits

1 A simple circuit requires a minimum of three components. Name these components.

## Energy transfers and transformations

2 Identify the energy transformations from a battery to a light bulb.

3 Identify three ways heat energy can be transferred from a warmer object to a colder object.

## Solar energy

4 Identify a renewable and a non-renewable energy source.

## Particle model

5 Contrast the properties of conductors and insulators.

## Thermal energy

6 What is the name of the property used to describe how hot a substance is.

# 12.1 Heat transfer

## Lesson overview

All matter is made up of particles. It is the motion of these particles that is responsible for how hot an object feels. The faster the particles move or vibrate, the greater their kinetic energy and the hotter the object will be.

In this lesson you will learn about how thermal energy is transferred and the process of conduction.

**SC 1** I can describe how heat is transferred via conduction.

In the **particle model**, all matter is made up of **particles** that are constantly in motion**.** As you may have learned in Topic 6, the particle model can be used to model solids, liquids and gases (Figure 12.1.1).

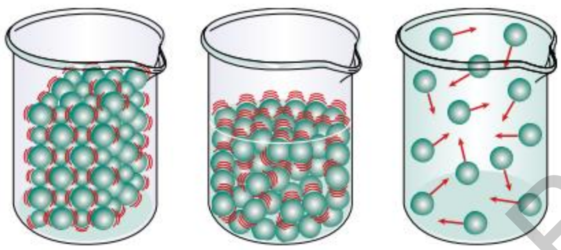



**FIGURE 12.1.1** In all states of matter, the particles are constantly in motion, even in solids.

## Heat

**Heat** is the movement of **thermal energy**. It moves from warmer to cooler substances. As a material is heated, its particles gain **kinetic energy** and they speed up. When particles collide, kinetic energy is transferred between them, passing on thermal energy and increasing the **temperature** of the material. As the particles speed up, they will spread out, causing the material to expand and get less dense (Figure 12.1.2).

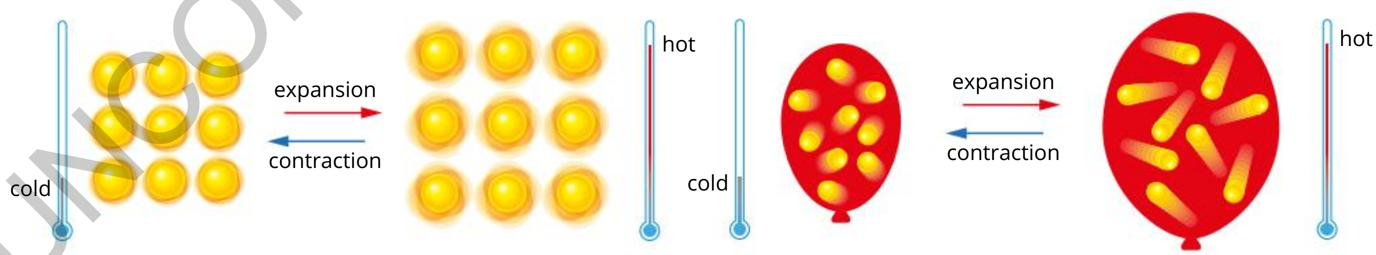



**FIGURE 12.1.2** As heat is added to a substance, the kinetic energy of the particles increases.

### Learning intention

To understand the ways heat is transferred via conduction, convection and radiation

### Success criteria

**SC 1:** I can describe how heat is transferred via conduction.

**SC 2:** I can describe how heat is transferred via convection.

**SC 3:** I can describe how heat is transferred via radiation.

### KEY TERMS

**particle model** model used to describe and explain the behaviour of particles in solids, liquids and gases
**particle** tiny parts of matter; includes atoms and molecules
**heat** thermal energy that is transferred from a warmer object or substance to a cooler object or substance
**thermal energy** the energy of a substance due to the motion of its particles
**kinetic energy** energy possessed by a moving object

### KEY TERM

**temperature** a measure of the average kinetic energy of particles in a substance that indicates how hot or cold the substance is

## Conduction

**Conduction** is the transfer of thermal energy (heat) through the collision of particles. For conduction to occur between two objects they must be in contact with each other. Conduction mostly occurs in solids and is the reason your hand gets burnt when you touch a hot pan sitting on the stove.

Imagine using a Bunsen burner to heat up a metal rod (Figure 12.1.3). The particles closest to the Bunsen burner will begin to vibrate faster and collide with neighbouring particles, causing them to vibrate faster (increased kinetic energy). These collisions cause thermal energy to move along the rod, which means the rod heats up.

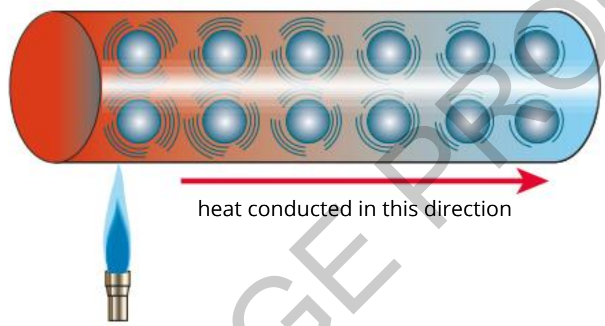



**FIGURE 12.1.3** In conduction, particles transfer heat via vibrations.

### Scifile

**Insulating materials**

Some materials, such as wool and foam, are poor conductors of heat. Their particles are not as tightly packed, making it harder for the particles to collide and transfer thermal energy. This is why poor conductors are used for insulation in clothing and homes.

### SC 1 CHECK YOUR UNDERSTANDING

Explain how heat is related to thermal energy.

**SC 2** I can describe how heat is transferred via convection.

**Convection** is the transfer of thermal energy via the overall movement of particles in a **fluid** due to differences in **density**. When liquids and gases are heated their particles spread out and the fluid gets less dense. This decrease in density causes warmer fluids to rise and cooler fluids to sink.

For example, when warming up a pot of water on a gas stove, thermal energy is transferred from the flame to the particles near the bottom of the pot (Figure 12.1.4). These particles speed up and move faster than the particles at the top of the water, which are further away from the heat source.

The increased motion of the particles near the bottom of the pot causes them to spread out. This results in hotter water at the bottom becoming less dense than the cooler water above it. The hotter water rises to the top, causing the cooler water to sink to the bottom, which creates a **convection current**.

The differences in temperature between the land and ocean throughout the day produce convection currents that make onshore breezes in the daytime and offshore breezes at night (Figure 12.1.5).

### KEY TERMS

**convection** transfer of heat in a liquid or gas due to less dense, warmer matter rising and denser, cooler matter falling

**fluid** substances capable of flow; liquids and gasses

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

**convection current** the circular movement of a fluid (liquid or gas) caused by differences in temperature and density within the fluid

**FIGURE 12.1.4** The particle model can be used to explain the convection of water in a saucepan.

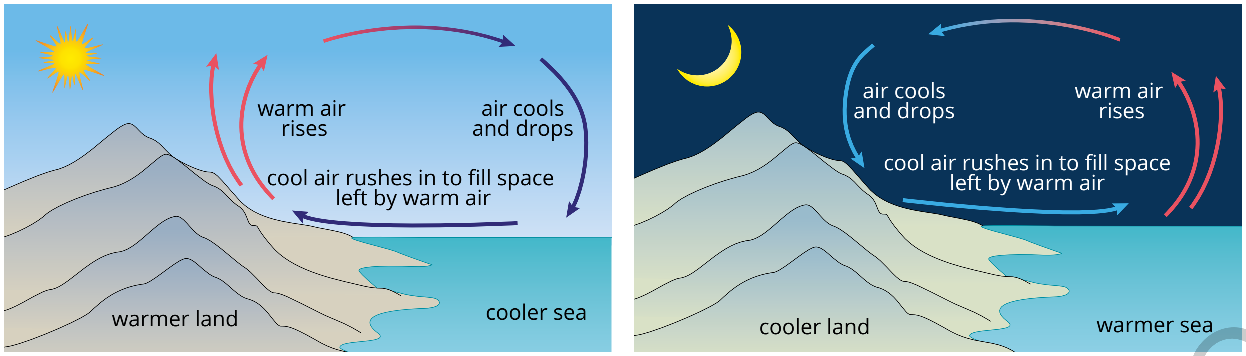



**FIGURE 12.1.5** Convection currents explain the difference in coastal wind direction at night compared to during the day.

## SC 2 CHECK YOUR UNDERSTANDING

Explain why warmer fluids rise and cooler fluids sink.

**SC 3** I can describe how heat is transferred via radiation.

Even if objects are not in physical contact, they are still able to transfer energy via **radiation**. Unlike conduction or convection, radiation does not need a solid,liquid or gas to travel through, so it can happen even through a **vacuum**, such as space. All objects will give off some form of radiation to their surroundings. The hotter the object, the more radiation it will emit.

Radiators are a type of heater that are commonly used to keep people warm in windy settings, like an outdoor café (Figure 12.1.6). Campfires also primarily keep you warm via radiation as they are too hot to touch and the warm air above them is more likely to rise into the sky than keep your warm.

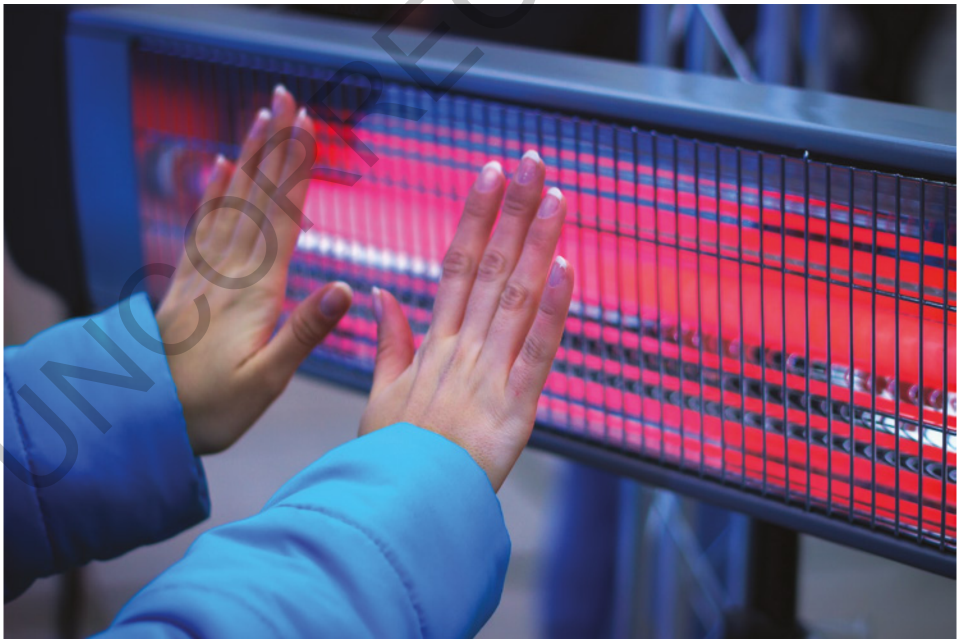


**FIGURE 12.1.6** Some heaters emit radiant energy in the form of infrared radiation.

**KEY TERMS**

**radiation** energy that travels from one place to another without requiring a solid, liquid or gas to move through

**vacuum** a space that contains no matter

**SC 3 CHECK YOUR UNDERSTANDING**

Explain why heat can travel from the Sun to Earth by radiation but not conduction or convection.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1. Identify the form of heat transfer responsible for burning your hand when you touch a hot pan.
2. Explain how convection currents form in a pot of boiling water.
3. Recall the basic principle of heat conduction. Outline how useful the particle model is in explaining how conduction occurs.
4. Consider how heat is transferred by conduction within a substance or between substances. Determine which state of matter—solid, liquid or gas—is likely to be the best conductor. Justify your answer.
5. Explain why the Sun is only able to transfer heat to Earth via radiation.

# 12.2 Heat conduction in materials

## Introduction

A heat transfer occurs when thermal energy moves from a warmer substance to a cooler substance. In conduction, this energy moves through the substance.

When a substance is heated, its particles move faster, gaining kinetic energy (Figure 12.2.1). This increase in kinetic energy is transferred to nearby particles, allowing thermal energy to spread throughout the material.

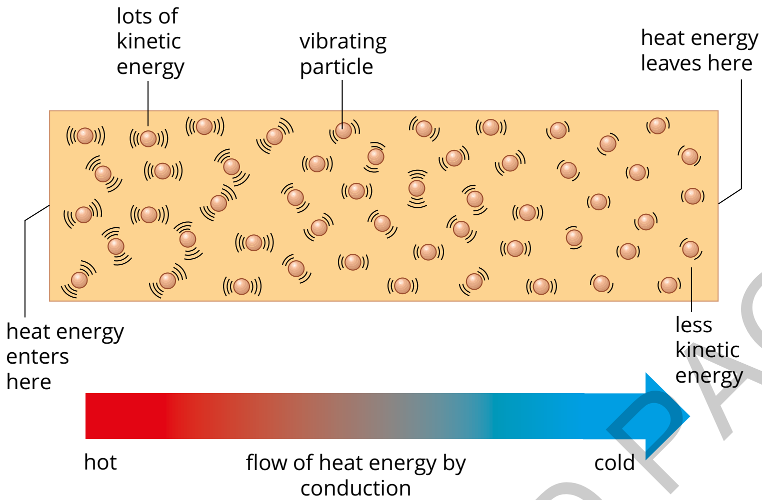



**FIGURE 12.2.1** The conduction of heat energy involves the transfer of kinetic energy from particle to particle.

In this practical investigation you will test a prediction about which of three materials will conduct heat energy the fastest.

### Learning intention

To be able to develop and test a prediction related to heat transfer

### Success criteria

**SC 1:** I can identify the dependent and independent variables of an investigation.

**SC 2:** I can develop a prediction that can be tested.

**SC 3:** I can use data to evaluate a prediction.

## Background

The way a material behaves in the presence of heat is determined by its internal properties. This includes how quickly a substance can heat up or cool down, and the rate at which heat can travel through the material. This last aspect—the rate of heat transfer—is what you will investigate in this practical investigation.

A substance that transfers heat quickly is described as a good **conductor** of heat. A material that transfers heat slowly is described as a poor conductor of heat. Another name for a poor conductor of heat is an **insulator**.

### KEY TERMS

**conductor** material through which heat, sound or electrical energy can be transferred

**insulator** a material that does not readily allow the transfer of heat, sound or electricity

## Aim

To compare how well plastic, wood and metal conduct heat

## Prediction

Write a prediction for your investigation by ordering the three substances according to how quickly you think they will conduct heat, from fastest to slowest.

## Apparatus

- butter or wax with a low melting point
- very hot water (from a kettle)
- plastic teaspoon
- metal teaspoon
- wooden teaspoon
- 250 mL beaker
- 3 small beads or similar
- stopwatch
- ruler

**SAFETY NOTE**

- Handle hot water with care.

## Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

## Method

1. Construct a suitable results table to record your observations and measurements.
2. Place a small 'dob' of butter or wax near the top of the handle of the plastic spoon.
3. Push a bead onto the dob of butter/wax.
4. Repeat steps 1 and 2 for the metal spoon and the wooden spoon. Make sure the beads are placed at similar positions along the spoon's handle and that approximately the same amount of butter/wax is used each time.
5. Carefully place the three spoons into very hot water in the beaker as shown in Figure 12.2.2 and start your stopwatch at the same moment.
6. Time how long each bead takes to fall off and record your results.

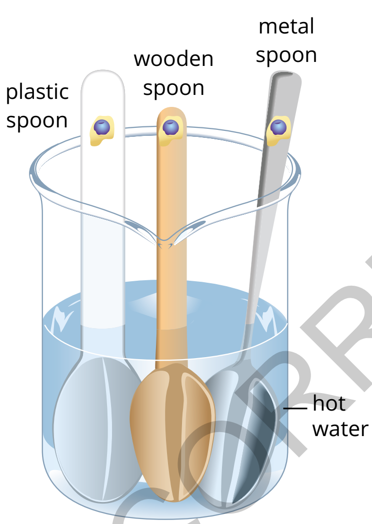



**FIGURE 12.2.2** Sample experiment set-up

## Results

Record your results in your results table. Use the headings 'Material' and 'Time taken for bead to drop (s)'.

## Discussion

1. Identify at least three controlled variables in this experiment.
2. What was the independent variable in this experiment?
3. What was the dependent variable in this experiment?
4. A student decided to place each spoon in a separate beaker. They asked the teacher for a measuring cylinder and a thermometer to use. Explain why these pieces of equipment are required.

## Conclusion

1. Identify the best conductor of heat and the best insulator.
2. Comment on how well your results supported your prediction.

# 12.3 Types of energy transformation

## Lesson overview

The two most analysed forms of energy related to motion are kinetic energy and potential energy. Kinetic energy involves movement, such as kicking a ball or the motion of particles, which can be transformed to other forms, such as heat and sound energy.

Potential energy, also known as stored energy, refers to energy that an object has due to its position or condition, giving it the potential to cause change. For example, when an athlete draws the string of a bow, the stretched string stores elastic potential energy, which is transformed to kinetic energy when released, launching the arrow (Figure 12.3.1).

**FIGURE 12.3.1** An athlete uses a recurve bow to transform potential energy to kinetic energy to propel an arrow

In this lesson you will learn about the different types of potential energy and the ways in which it can be transformed.

**SC 1** I can list examples of how types of potential energy can be transferred and transformed into kinetic energy.

## Types of potential energy

**Potential energy** describes the energy stored because of an object's position, condition or structure. There are different types of potential energy.

- **Thermal energy** is the energy stored in a substance due to the motion of its particles.
- **Elastic potential energy** is the energy stored in a stretched or compressed material, such as an elastic band.

**Learning intention**

To understand how types of potential and kinetic energy are transferred and transformed

**Success criteria**

**SC 1:** I can list examples of how types of potential energy can be transferred and transformed into kinetic energy.

**SC 2:** I can explain why thermal energy, sound and electricity can be modelled as forms of kinetic energy.

- **Gravitational potential energy** is the energy stored by an object because of its position above the ground, such as a diver on a diving board. The higher the object, the greater the gravitational potential energy.
- **Chemical potential energy** is the energy stored in substances, such as petrol, that can undergo chemical reactions to release energy.
- **Nuclear potential energy** is the energy stored in atoms, such as uranium. This potential energy is utilised in nuclear power plants.

## Energy transformations

**Energy transformations** involve energy transforming (changing) into different forms. For example, potential energy can be transformed into kinetic energy. **Energy transfers** involve one form of energy transferring (moving) from one **system** to another. For example, electrical energy can be transferred from a battery to a light bulb. In every transfer or transformation, energy is always conserved. This means that no energy is lost during a transformation.

If it appears that energy is lost in a transfer or transformation of energy this is because it has been converted into **waste energy**. Energy that is transferred to the surrounding environment (such as sound) or transformed into forms that are not **useful energy output** (such as heat) are described as waste energy.

**KEY TERMS**

**energy transformation** the conversion of energy from one form to another, such as the conversion of potential energy into kinetic energy as an object falls

**energy transfer** the movement of energy from one system to another without changing form

**system** collection of interacting components that form an integrated whole

**waste energy** energy that is not usefully transferred or transformed into another type of energy

**useful energy output** the form of energy that is intended to be produced by the device, such as sound energy from a radio, or light energy from a light bulb

### Thermal energy to kinetic energy

The conversion of thermal energy into kinetic energy occurs in most power generation methods. Conventional power plants use a fuel source to turn water into steam. This occurs regardless of whether the power plant is fuelled by coal, oil, gas or even nuclear power. The steam expands and rushes through a turbine that spins, creating kinetic energy (Figure 12.3.2). This kinetic energy can then be used to turn a generator, producing electrical energy.

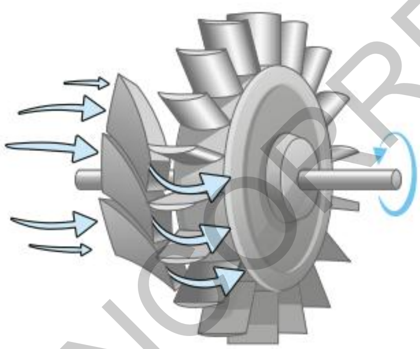


**FIGURE 12.3.2** Steam turbines convert thermal energy from steam into kinetic energy.

### Kinetic energy to elastic potential energy

Resistance bands are large elastic bands commonly used in fitness programs and physiotherapy (Figure 12.3.3). The person's movement (kinetic energy) is transformed into elastic potential energy within the resistance band as it stretches.

If the person lets go of the band while it is stretched, the elastic potential energy would be transformed back into kinetic energy as the band snaps back. In this process the bands become warm, which is evidence of waste energy.

**FIGURE 12.3.3** A resistance band transforms the kinetic energy of movement into potential energy stored within the band

## Gravitational potential energy to kinetic energy

Wingsuit flying is an extreme sport, similar to skydiving, where a webbed suit is used to increase time in the air compared to the freefall of skydiving (Figure 12.3.4). The surface area of the suit slows down the transformation of gravitational potential energy (due to height) into kinetic energy (movement) as the diver falls. A lot of noise is generated during this process, which is one form of waste energy in this transformation.

**FIGURE 12.3.4** As the diver falls, gravitational potential energy, due to their height above the ground, is transformed into the kinetic energy of movement.

## Chemical potential energy to kinetic energy

In open-pit mining, chemical explosives such as dynamite are used to fracture (break) rock to make it easier to excavate (Figure 12.3.5). In the explosion, chemical energy stored in the dynamite is transformed into kinetic energy, which fractures and displaces the rock. The explosion also produces waste energy in the form of sound and heat.

**FIGURE 12.3.5** Dynamite is used to blast apart rock, making it easier to mine; this shows a rapid transformation of chemical potential energy into kinetic energy.

### SC 1 CHECK YOUR UNDERSTANDING

Identify the energy transformations involved when a person swings back and forth on a swing.

**SC 2** I can explain why thermal energy, sound and electricity can be modelled as forms of kinetic energy.

**KEY TERMS**

**sound** energy that travels as vibrating waves and can be heard by the ears as sound

**electricity** the flow of charged particles (electrons) through a conductor

Thermal energy, **sound** and **electricity** can all be modelled in terms of kinetic energy.

Thermal energy moves from warmer to cooler substances as heat (Figure 12.3.6). When a substance is heated, the kinetic energy of its particles increases and they move faster.

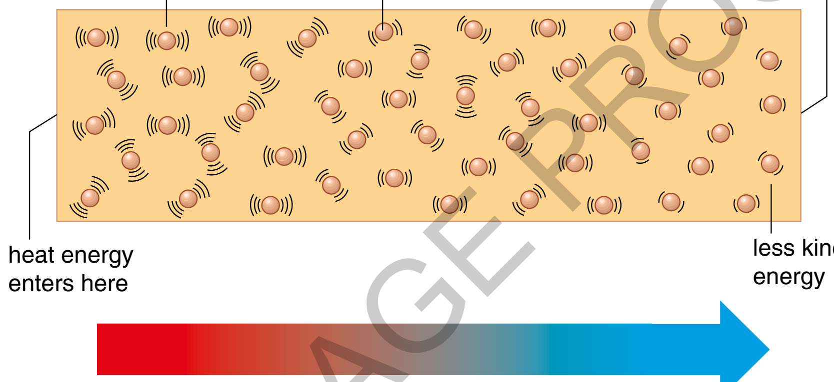



**FIGURE 12.3.6** As heat travels through a material by conduction, the kinetic energy of the particles reduces.

Sound travels as waves and is heard by the ears. Sound travels by vibrating particles. For example, when you hear music from a speaker (Figure 12.3.7), the movement of parts inside the speaker causes nearby air particles to vibrate. The kinetic energy of the vibrating air particles then transfers through the air where your ears hear it as sound.

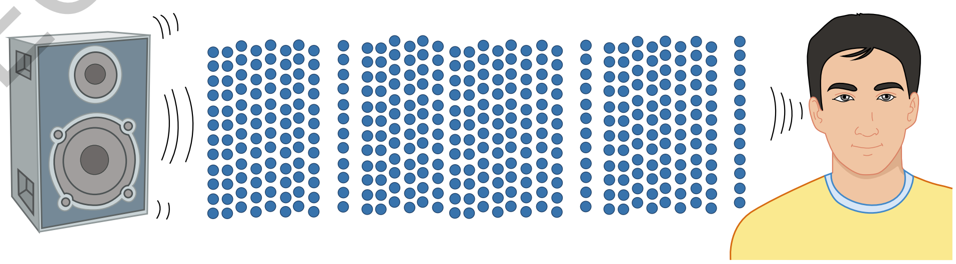


**FIGURE 12.3.7** Particle drawing used to show the vibration and movement of sound

**Scifile**

**Domino effect**

When you knock over the first domino in a line, it transfers its kinetic energy to the next one, causing a noisy chain reaction as they fall. This simple example demonstrates the transfer of kinetic energy and the transformation of some of the energy into waste energy (sound).

Electricity in a circuit is the motion of electrons through a wire (Figure 12.3.8). Electrons are small, negatively charged particles that are present in all atoms. The kinetic energy of the moving electrons is observed as electricity.

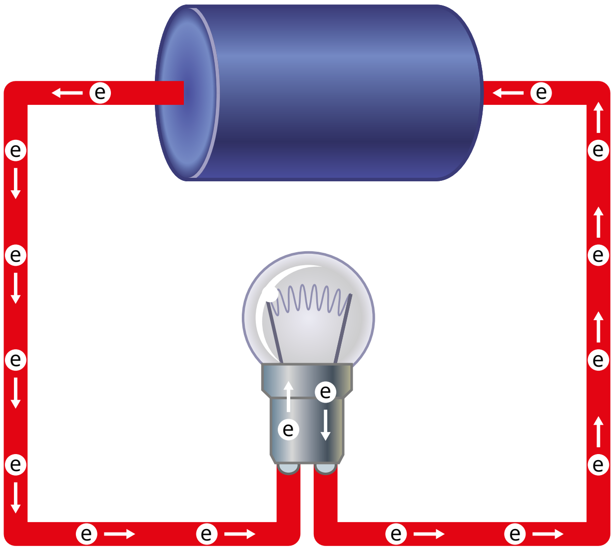



**FIGURE 12.3.8** The pathway of electrons through an electric circuit

**SC 2 CHECK YOUR UNDERSTANDING**

Explain why heat could be described as a form of kinetic energy.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 Identify a scenario that demonstrates each of the following energy transformations.
   a gravitational potential energy → kinetic energy
   b elastic potential energy → kinetic energy
   c chemical potential energy → kinetic energy

2 Describe how a rubber band can be used to demonstrate the transformation of elastic potential energy into kinetic energy.

3 Describe a scenario where an energy transformation is not entirely useful.

4 Explain why energy 'lost' as heat during a mechanical process is often considered wasteful.

5 Describe how an electric current demonstrates kinetic energy in a circuit.

6 Compare thermal energy and sound as forms of kinetic energy.

# 12.4 Transfer of kinetic energy

### Learning intention

To be able to demonstrate how energy can be transferred from one object to another

### Success criteria

**SC 1:** I can list real-life examples in which kinetic energy has been transferred from one object to another.

**SC 2:** I can investigate ways that kinetic energy can be transferred from one object to another.

**SC 3:** I can explain why not all energy is transferred from one object to another.

**FIGURE 12.4.1** As the player kicks the ball (collision), some of the kinetic energy from their foot is transferred to the ball.

## Introduction

One of the most obvious signs of kinetic energy is movement. Kinetic energy can be transferred between objects, particularly in situations involving collisions and within various types of machines.

In this practical investigation you will learn about the transfer of kinetic energy in moving objects.

## Background

One way in which kinetic energy can be transferred is through a collision (Figure 12.4.1).

Collisions are not the only way that kinetic energy can be transferred from one object to another. Many machines are designed to transfer kinetic energy. For example, riding a bicycle (Figure 12.4.2) involves several kinetic energy transfers. As the cyclist pushes on the pedals they transfer energy to the pedals, causing them to turn. The kinetic energy from the pedals is transferred through the crank, along the chain and into the sprocket to rotate the wheel.

**FIGURE 12.4.2** Energy of motion (kinetic energy) is transferred from the cyclist to the bicycle wheels, causing the bicycle to move.

### KEY TERM

**Newton's cradle** a device that demonstrates the transfer of kinetic energy through a series of swinging spheres

## Newton's cradle

**Newton's cradle** is a toy that is a useful tool for demonstrating the way kinetic energy can be transferred between objects. A simple way to use Newton's cradle is to raise the ball at the left side of the cradle (Figure 12.4.3a) and release it. It will swing down to strike the next ball and transfer its kinetic energy to it. The kinetic energy is then transferred through the remaining balls to the ball on the right, which swings up into the air (Figure 12.4.3b). This transfer of kinetic energy then repeats in reverse. Over time, the motion of the cradle decreases because energy is lost as heat and sound.

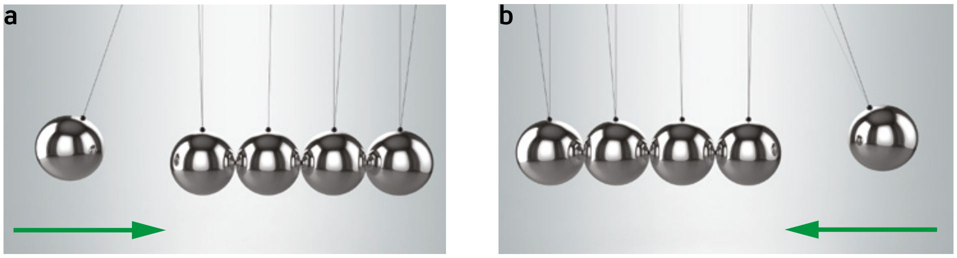



**FIGURE 12.4.3** In Newton's cradle one incoming ball (a) collides with the stack, causing a single ball (b) to rebound; this cycle then repeats, demonstrating the transfer of kinetic energy between objects.

In this practical investigation you will explore several different scenarios of energy transfers using Newton's cradle.

## Aim

To investigate how kinetic energy is transferred in Newton's cradle

## Prediction

Write predictions for your investigation. Copy the following table in your notebook. Complete the 'Starting condition' and 'Predicted outcome' columns of the table to identify what starting conditions you will use and what you expect to happen. The first row has been completed for you as an example.

| Starting condition | Predicted outcome | Observed outcome |
| --- | --- | --- |
| raise one ball on the left | one ball on the right will move | |
| | | |
| | | |
| | | |

## Apparatus

- Newton's cradle

## Method

1 Observe the outcomes for each of the starting conditions listed in your predictions table.

2 Investigate what happens to the balls if they are left to keep colliding for a long time.

## Results

Complete the predictions table with your results (observations).

## Discussion

1 List some examples of kinetic energy transfers that occur:

   a in a football match

   b riding a mountain bike

2 In Newton's cradle, how is kinetic energy transferred between the balls?

## Conclusion

1 Describe what happens to the balls over time if they are left to keep colliding.

2 If conservation of energy states that energy is never lost but can transform from one form of energy to another, explain your answer for Question **1**.

**WS** Processing data and information
**DS** Scientific models, Analysis of models, Creating models

# 12.5 Sankey diagrams

## Lesson overview

In science there are all sorts of diagrams that help to convey information. Sankey diagrams are a type of flow diagram that can be used to show the inputs and outputs in an energy transformation.

In this lesson you will learn about energy transformations and how Sankey diagrams can be used to describe them.

### Learning intention

To understand ways to represent the input energy and output energy in common energy transformations

### Success criteria

**SC 1:** I can describe the meaning of features of a Sankey diagram.

**SC 2:** I can draw Sankey diagrams with one energy input and two or more energy outputs.

**SC 1** I can describe the meaning of features of a Sankey diagram.

Named after the engineer Matthew Sankey, **Sankey diagrams** have been around since the 1800s. These diagrams are used to show the flow of energy in a system (Figure 12.5.1) and have specific features that are useful when analysing energy transformations.

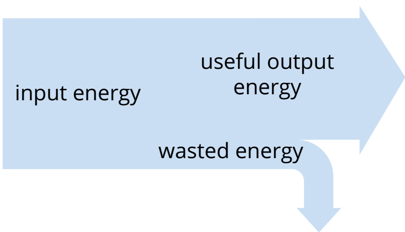



**FIGURE 12.5.1** Sankey diagrams show the flow of energy through a transformation.

The Sankey diagram in Figure 12.5.2, shows the transformation of electrical energy into useful **light energy** and wasted heat energy in an incandescent light bulb.

From Figure 12.5.2 you can see how these diagrams work.

- The arrows show the direction of energy flow. In this example, the arrows are pointing from electrical energy (the input) towards the output energies of light and heat energy.
- The widths of the two arrows show the ratio of the energy outputs; the heat energy arrow (equal to 90 J) is, therefore, nine times larger than the light energy arrow (equal to 10 J).
- The wasted energy in a transformation is highlighted. This can be done either by labelling the arrow as 'wasted energy' or, as in this example, by showing the energy leaving the system (that is, pointing down).

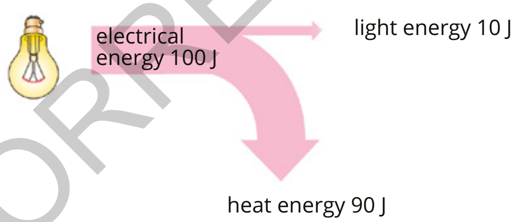



**FIGURE 12.5.2** A Sankey diagram showing the energy transformations in an incandescent light bulb

### SC 1 CHECK YOUR UNDERSTANDING

Explain the significance of the width of the arrows in a Sankey diagram.

### KEY TERMS

**Sankey diagram** a visual representation of the flow of energy through a system

**light energy** energy that is given off by luminous objects, or that reflects off non-luminous objects, enabling people to see them

**SC 2** I can draw Sankey diagrams with one energy input and two or more energy outputs.

To draw your own Sankey diagrams, you first need to determine:

- all energy inputs and outputs in the transformation
- the amount of energy involved in each transformation, converted to a ratio or a percentage
- which of the transformations are useful and which are wasted (if any).

Once you have this information, you can draw diagrams with any number of energy outputs.

## SkillBuilder

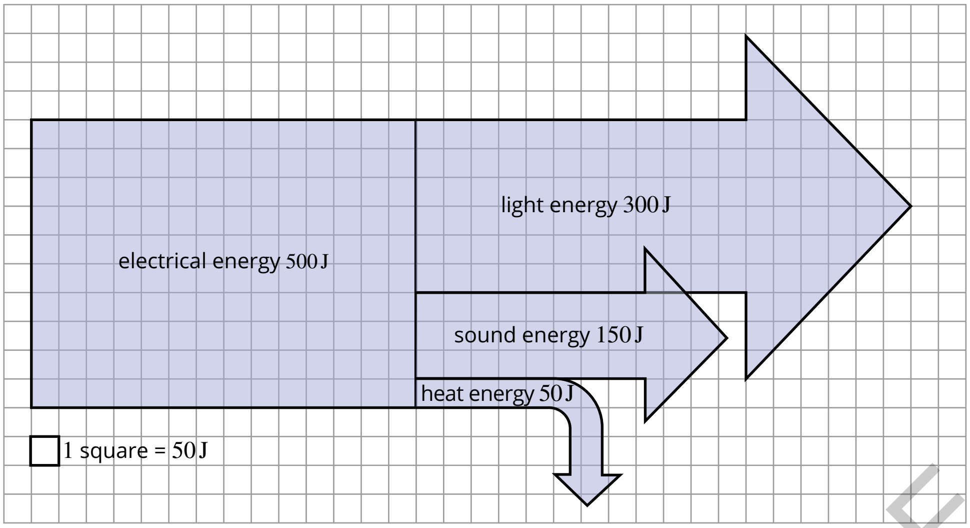
### Drawing Sankey diagrams

To draw your own Sankey diagram you can follow the steps below.

Consider the example of working on a laptop: the laptop transforms 500 J of electrical energy into light energy (300 J), sound energy (150 J) and heat energy (50 J).

1. To make sure the width of the arrows is correct it can be helpful to use grid paper or squares drawn into your notebook. In this example one square represents 50 J.
2. Determine the energy of the first useful energy output; in this case, light energy at 300 J.
3. Repeat for any other useful energy outputs.
4. Draw the width of the energy input arrow and make sure to include a label for it (the length of the input is not important). In this example, the energy input is 500 J, which is equivalent to a width of 10 squares.
5. Draw the first useful energy arrow pointing straight across at the top of the diagram. In this case, 300 J of light energy is equivalent to a width of 6 squares.
6. Draw any other useful forms of energy as arrows pointing in the same direction. In this example, 150 J of sound energy is equivalent to a width of 3 squares.
7. Finally, add in the arrow for any wasted energy, making sure it is pointing down to signify the energy leaving the system. In this case, the wasted energy is 50 J of heat energy, which is equivalent to a width of 1 square.

Tip: If you have correctly calculated the widths of the arrows representing the useful forms of energy, the width of the waste energy arrow should fill in the remaining width that follows on from the input arrow.




**SC 2 CHECK YOUR UNDERSTANDING**

A pool pump transforms 1000 J of electrical energy into 800 J of kinetic energy in the water and 200 J of heat energy. Draw a Sankey diagram to describe this transformation.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 What does the direction of the arrow in a Sankey diagram indicate?

2 What does an arrow that points downward in a Sankey diagram represent?

3 Explain how a Sankey diagram helps visualise energy usage.

4 Draw a Sankey diagram for an efficient LED light bulb. On your diagram include the electrical energy input (100 J), light energy output (60 J) and heat energy output (40 J).

# 12.6 Radiant energy transformations

**Learning intention**

To understand how to model radiant energy transformations, including the transformation of radiant energy from the Sun

**Success criteria**

**SC 1:** I can describe radiant energy and radiant energy transformations.

**SC 2:** I can use a model to show how energy from the Sun is transformed into different forms of energy.

## Lesson overview

The Sun is a powerful source of radiant energy (Figure 12.6.1) that impacts nearly every aspect of life on Earth. From the warmth you feel on a sunny day to the energy that powers your home, the Sun's energy is constantly at work. To use the radiant energy from the Sun, it must be converted into other forms.

In this lesson you will learn how to represent different energy transformations, including how radiant energy from the Sun is transformed into other forms of energy.

**FIGURE 12.6.1** A composite image of the different forms of radiant energy emitted by the Sun

**SC 1** I can describe radiant energy and radiant energy transformations.

Energy can move through space as radiant energy in the form of radiation. Radiation is different from conduction because it does not require a material to pass through. It is also different from convection because it does not require the movement of a gas or liquid. Radiant energy can, in fact, travel through a complete vacuum with no air. This is the case with all forms of electromagnetic radiation, such as sunlight and radio waves. This is how radiant energy travels from the Sun to Earth.

## Types of radiant energy

There are many forms of radiant energy. Three of the main forms are visible light, ultraviolet light and infrared radiation.

### Visible light

Visible light is radiant energy that is visible to the human eye. It is responsible for the daylight you experience and the colours you see. When sunlight passes through a prism, it separates into different colours, demonstrating the spectrum of visible light (Figure 12.6.2)

**FIGURE 12.6.2** A prism separating sunlight into the spectrum of visible light

## Ultraviolet (UV) light

Ultraviolet (UV) light is high-energy light that is not visible to the human eye. UV has both beneficial and harmful effects on living organisms. For example, UV helps your skin produce vitamin D but excessive exposure can lead to sunburn and an increased risk of skin cancer. UV light can cause objects to **fluoresce**, making them easier to see (Figure 12.6.3).

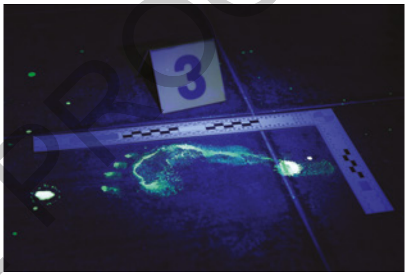



**FIGURE 12.6.3** UV is used in forensics because it causes certain fluids and fibres to fluoresce.

**KEY TERM**

**fluorescence** the ability to give off (normally) visible light after absorbing another form of radiation

## Infrared (IR) radiation

IR radiation carries lower energy than visible light. It is invisible to the human eye—you sense it as heat instead of light (Figure 12.6.4). When you feel the warmth of the Sun on your skin, you are feeling infrared radiation.

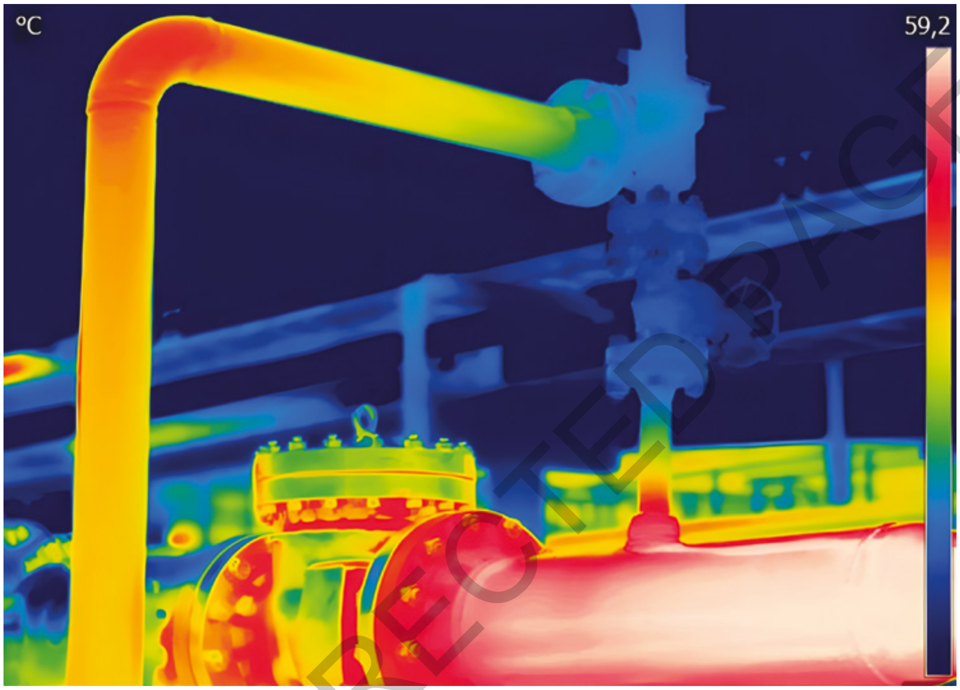



**FIGURE 12.6.4** A thermal camera uses infrared radiation to investigate the temperature of machinery as it operates. By analysing this data, the efficiency and safety of the machinery can be evaluated.

## Radiant energy transfers

Radiant energy transfers are unique because they occur over a distance, unlike conduction and convection where the objects must be in contact.

An example of how radiant energy transfers occur over a distance is a toaster (Figure 12.6.5). When a toaster is turned on, electrical energy is transformed into thermal energy, causing the heating element to become hot and emit both visible and infrared light. Infrared light is the useful energy in this scenario because it is the form of radiant energy that transfers heat to the bread, increasing its thermal energy and causing it to toast. The visible light has little effect and can be considered waste energy.

**FIGURE 12.6.5** The element inside a toaster emits radiant energy in the form of visible and IR light.

## SC 1 CHECK YOUR UNDERSTANDING

Identify the key difference between radiation and other forms of energy transfer.

**SC 2** I can use a model to show how energy from the Sun is transformed into different forms of energy.

**KEY TERM**

**energy flow diagram** a simple diagram that uses arrows to show the way energy is transferred or changed into other forms

Radiant energy from the Sun can be transformed into other forms of energy through different processes. These transformations can be modelled using various methods such as Sankey diagrams, flow charts and **energy flow diagrams**.

## Photosynthesis

The most vital form of radiant energy transformation for life on Earth is the process of photosynthesis in plants. Plants use chloroplasts to transform radiant energy from the Sun into chemical energy, which is stored in their leaves. This energy is then transferred to animals when they eat the plants. The animals transform chemical energy from the food they eat into energy that fuels all the processes in their bodies. This process is shown in the flow chart in Figure 12.6.6.

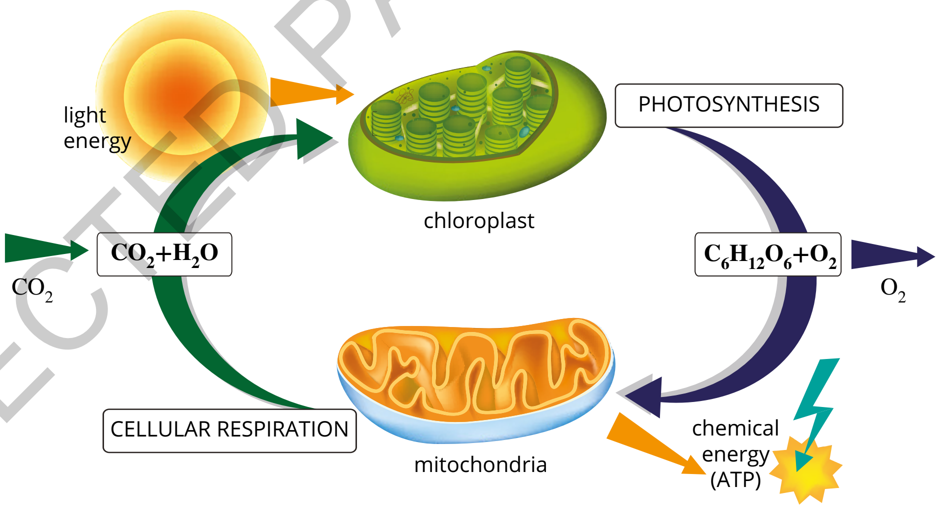



**FIGURE 12.6.6** Plants use chloroplasts to transform sunlight into chemical energy stored in their leaves

## Solar panels

Solar panels convert sunlight (primarily visible light) directly into electricity using photovoltaic cells. This process involves the transformation of radiant energy into electrical energy. Generally, solar panels can convert somewhere between 20 and 30% of light that falls on them into electrical energy. The best solar panels in the world are around 45%. The remaining energy is wasted because it is not successfully absorbed, is reflected or is transformed into thermal energy. This process is shown in the Sankey diagram in Figure 12.6.7.

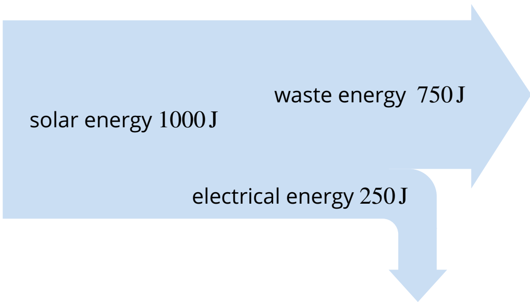



**FIGURE 12.6.7** Sankey diagram showing the conversion of 1000 J of sunlight into electrical energy and waste thermal energy

**SC 2 CHECK YOUR UNDERSTANDING**

Create a Sankey diagram for a plant that absorbs 200 kJ of visible light to create a 14 kJ piece of fruit.

**Scifile**

### Solar power

Australia is one of the sunniest countries in the world, making it an ideal place for solar power. In fact, Australia has the highest uptake of solar panels in the world, with more than 4 million rooftop solar power systems installed.

## Lesson review

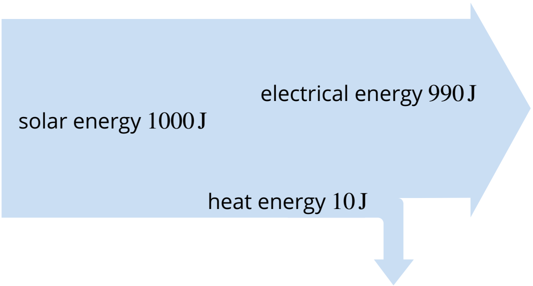
Use these questions to check whether you have met the learning intention for this lesson.

1 List three types of radiant energy emitted by the Sun.

2 Describe the energy transfers and transformations involved in the operation of the solar powered car shown below.

3 Draw a simple energy flow diagram using words and arrows to show how radiant energy from the Sun can be used to power a small solar powered garden light.

4 A Sankey diagram for a solar panel system is shown below.




a Analyse the Sankey diagram to identify the input energy, output energy and waste energy.

b Decide if this is a realistic Sankey diagram for a solar panel. Provide a reason for your response.

# 12.7 Solving a problem using energy

## Learning intention

To be able to design, create and report on a system that solves a problem using energy transfer and transformation

## Success criteria

**SC 1:** I can design or modify a design of a Rube Goldberg machine that involves a chain reaction of energy transfers and transformations.

**SC 2:** I can describe how energy is stored as potential energy within a Rube Goldberg machine.

**SC 3:** I can create a scientific report or presentation that explains the final design.

A Rube Goldberg machine is designed to perform a simple task in a roundabout way. For example, when the person in Figure 12.7.1 takes a spoonful of soup, this causes a complex and unnecessary chain reaction intended simply to bring a napkin to his mouth.

In this inquiry activity you will create your own Rube Goldberg machine to explore three different transformations of energy.

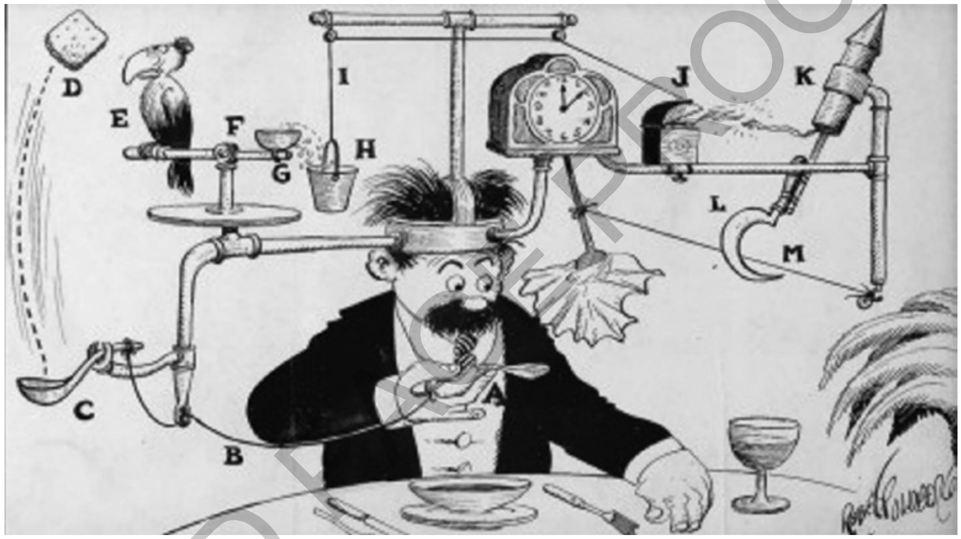



**FIGURE 12.7.1** A Rube Goldberg machine often overcomplicates a simple task in a humorous manner.

## Background

Rube Goldberg machines are named after a cartoonist born in 1883 who would draw cartoons of simple tasks being completed using a complicated chain reaction of energy transfers and transformations. These days, Rube Goldberg machines are usually created for entertainment. Some examples of energy transfers and transformations in Rube Goldberg machines are shown in Figure 12.7.2.

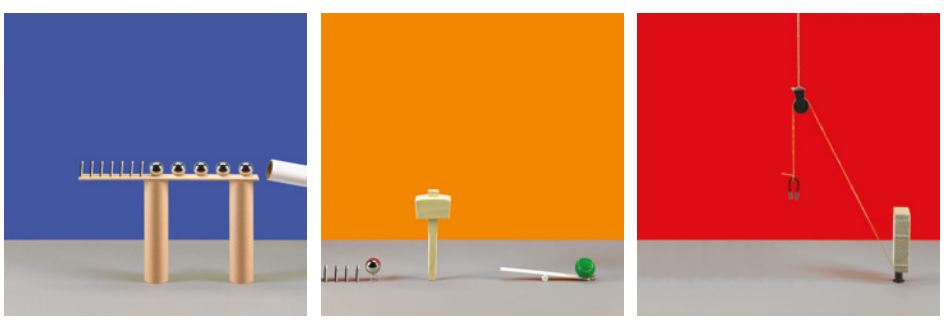


**FIGURE 12.7.2** A common energy transformation used in a Rube Goldberg machine is the transformation of potential energy into kinetic energy; for example, the falling domino pushing the steel ball, the falling hammer pushing the lever, or the rope causing the balance block to fall

## Aim

To build a Rube Goldberg machine that includes at least three energy transformations, including potential energy

## Plan

1 Determine the energy transformations that will occur in your Rube Goldberg machine. (Remember, your design needs to include at least three energy transformations and potential energy).
2 State how energy can be stored in an object in a Rube Goldberg machine.
3 Explain how you will store energy in your design, and what form of energy this will be transformed into.
4 Decide on an apparatus list.
5 Decide how you will evaluate your design. Will you record your machine in action?

## Design

Draw a diagram of your Rube Goldberg machine. If you are struggling to think of ideas, search for Rube Goldberg machines on the internet for inspiration.

### HINT

Note that you will need to summarise your findings in a presentation or scientific report. Keep this in mind when planning your design.

## Conduct

Make notes while your Rube Goldberg machine is in action. Note anything that worked well and anything that did not work as planned. You might want to draw or paste in details of your machine as well.

## Improve

1 Explain what worked and what did not work in your machine.
2 Discuss with your classmates their designs. Describe your favourite element of someone else's design.
3 Write how you can improve your machine.

## Discussion

Decide whether to write a scientific report or create a presentation to evaluate your design.

1 List the headings that you will use to structure your report/presentation.
2 List some of the key elements under each of your chosen headings.

# 12.8 Conservation of energy in systems

### Learning intention

To understand how to apply the law of conservation of energy

### Success criteria

**SC 1:** I can state the law of conservation of energy and describe examples of the application of this law.

**SC 2:** I can apply the law of conservation of energy to model energy transfers and transformations in systems.

## Lesson overview

The flow of energy through the universe is constant, shifting continuously between forms in long chains of interactions. Energy from the Sun warms Earth and grows plants. You consume these plants to fuel your body and the activities you do. These transformations are never perfect. Some energy is always wasted as heat, sound and other unwanted forms. Regardless of what form energy takes after a transformation, the total amount of energy remains constant. Understanding that energy is always redistributed—never created or lost—allows us to improve technology and better understand the world.

In this lesson you will learn about the law of conservation of energy and how different energy outputs can be involved in an energy transformation.

**SC 1** I can state the law of conservation of energy and describe examples of the application of this law.

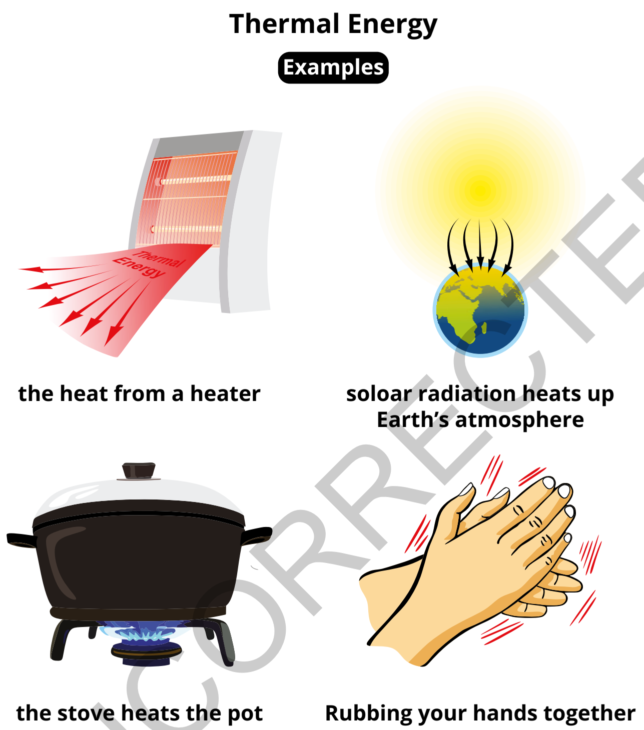



**FIGURE 12.8.1** When rubbing your hands together, waste sound is transferred to the environment.

There are different units that can be used to measure energy. One common unit is the **joule**. It is named after the English physicist James Joule, who researched the nature of heat in the 1800s. The joule is given the symbol J.

The **law of conservation of energy** says that no energy is created or destroyed. Instead, energy is transferred from one object or place to another, or transformed into another form of energy. If there is 500 J of energy available at the start of an interaction, 500 J of energy will remain at the end. During energy transformations, some energy is often transformed into a type of energy that is not useful for the system.

For example, when rubbing your hands together to warm them up the primary energy transformation is kinetic energy into thermal energy (Figure 12.8.1). However, some energy is also transformed into sound. This sound energy can be seen as wasted energy as it is not needed within the system. Instead, it is transferred to the surrounding environment, as shown in the Sankey diagram.

By applying the law of conservation of energy, it is possible to determine the types and quantities of energy in energy transfers and transformations.

For example, when you are using your laptop, the chemical potential energy from the battery that produces electricity is transformed into sound energy and light energy (Figure 12.8.2). After you have used the laptop for a while you may notice that the back or bottom feels quite warm. This is because some of the energy is being lost as heat, which is not a useful output for the system. This thermal energy dissipates or is transferred into the surrounding air.

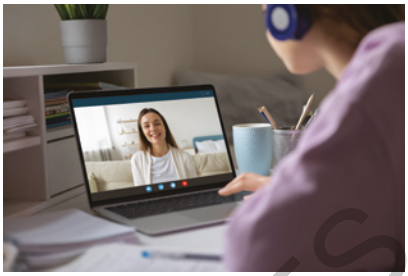


**FIGURE 12.8.2** Sound and light energy are useful forms of energy produced from the electrical energy in a laptop. However, thermal energy is not a useful form of energy for this device's intended use.

If the energy input to turn on your laptop is 500 J and you know that it produces 300 J of light and 100 J of sound energy, you can determine the amount of output thermal energy in this scenario.

$$\text{total energy input} = \text{total energy output}$$

$$500 = 300 + 100 + \text{thermal energy}$$

$$\text{thermal energy} = 100\ \text{J}$$

**SC 1 CHECK YOUR UNDERSTANDING**

Explain how the law of conservation of energy applies to a simple pendulum.

**SC 2** I can apply the law of conservation of energy to model energy transfers and transformations in systems.

Sometimes it may appear that energy is lost or destroyed in an interaction. However, it is important to remember that it is only transferred out of the system you are observing. It is important to consider how best to model a system when analysing an energy transfer.

## Types of systems

There are three different models of systems used in conservation of energy.

An **open system** (Figure 12.8.3a) is a system that transfers both energy and matter with its environment. An example is a campfire, which emits energy in the form of heat and light but also matter in the form of smoke.

A **closed system** (Figure 12.8.3b) is a system that only transfers energy with its environment. An example is a battery powered torch: when the torch is turned on, the energy of the torch decreases over time as it emits light.

An **isolated system** (Figure 12.8.3c) transfers nothing with its environment. It is important to understand that this is a model. There is no such thing as a perfectly isolated system in nature. Regardless, it is useful to model a system this way, particularly if the losses are very small or take a very long time.

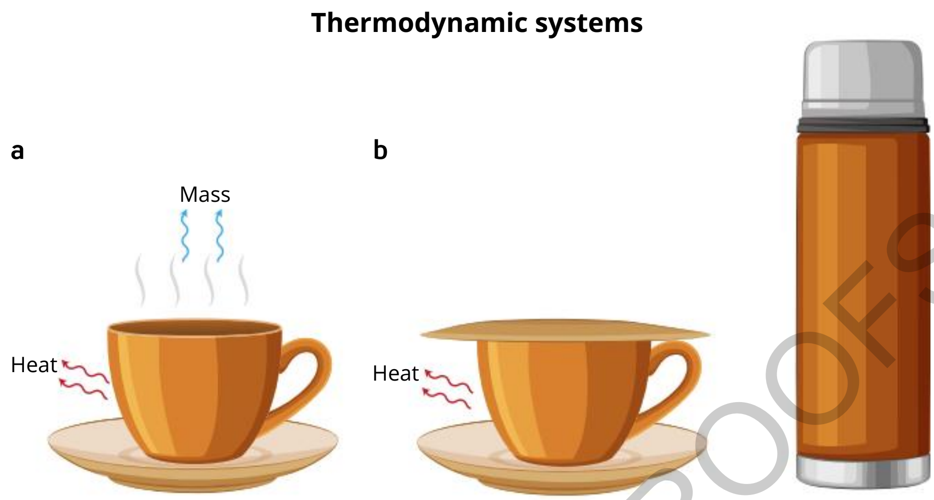



**FIGURE 12.8.3** (a) The cup exchanges heat energy as well as matter (steam) with the environment. (b) By placing a lid on the cup to prevent steam from escaping, this becomes a closed system. (c) The thermos is an isolated system because the insulation and lid significantly reduces the transfer of both steam and energy.

**FIGURE 12.8.4** Thermal energy is transferred from the tea into the ice.

## HINT

Remember, in physics you need to consider the movement of energy. This means that you analyse the movement of heat from the (hotter) drink into the (colder) ice. The ice does not add 'cold' to the drink.

Consider the example of placing an ice cube into tea to make a drink of iced tea (Figure 12.8.4). Thermal energy is transferred from the tea into the ice as the ice melts. Each ice cube absorbs around 8000 J of energy as it melts. This lowers the temperature of the tea.

If you consider the ice cubes as a system, the system (ice) has gained energy from its environment (tea). The energy of the system (ice) has increased. The energy lost by the environment (tea) is gained by the system (ice) and energy is conserved.

The tea and the ice cubes could also be considered as an isolated system. An energy transfer occurs within the system where thermal energy moves from one component of the system (tea) to another component of the system (ice). No energy is added or removed from the system and energy is conserved within the system.

Instead of looking at the ice you could model the entire drink as an open system instead. The drink has gained matter because the ice is now in the drink. The system has also gained energy: even though the ice is colder it still contains energy. This means the total energy of the system (drink) has increased! The energy added (ice) to the system (drink) has come from the environment (where you made your drink) but the total amount of energy is conserved.

Through this example, you can see that regardless of the type of system, energy is always conserved. What changes is how you model the different components involved.

## Applying conservation of energy

A 55 g bag of microwave popcorn requires 42 000 J of energy to pop in the microwave. The energy produced by the microwave does not completely transfer to cooking the popcorn. There are losses to unwanted forms such as sound, light and kinetic energy as the popcorn jumps around and as the microwave plate rotates. In total, the microwave consumes 260 000 J in this process.

The bag of popcorn will lose a small amount of steam through the vent in the side of the bag as it cooks (Figure 12.8.5). If you ignore this, you can approximate the bag of popcorn as a closed system and can calculate the energy lost in the cooking process.

$$\text{total energy input} = \text{total energy output}$$

$$260\,000 = 42\,000 + \text{waste energy}$$

$$\text{waste energy} = 218\,000\,\text{J}$$

**FIGURE 12.8.5** Microwave popcorn is not a completely closed system because steam is lost through the vent as it cooks.

**SC 2 CHECK YOUR UNDERSTANDING**

A cricket ball is thrown against a wall with 32 J of kinetic energy. Of this, 12 J of energy is lost to sound and 6 J is lost as waste heat energy. Calculate how much energy the cricket ball rebounds with.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 Apply the law of conservation of energy to identify the energy transformations that occur when sunlight shines on a solar panel.

2 Suggest whether it would be more useful to model energy transfers with the human body as an open or closed system. Explain the reasons for your answer.

3 Apply the law of conservation of energy to calculate the missing energies in the following systems.
   a A coiled spring with 22.5 J of potential energy uncoils, pushing on a ball that rolls away with 17.2 J of potential energy and the rest is lost to the environment.
   b An athlete consumes an apple containing 250 kJ of energy. Of this energy, 45 kJ is used for motion and the rest is lost as body heat.
   c A firework is launched into the sky with 180 J of energy. Of this energy, 35 % is converted into sound, heat and light. The remainder is used for the kinetic energy to launch the firework.

4 Roller coasters are a common example of energy transformation.
   a Apply the law of conservation of energy to describe the energy transformations in a roller coaster ride using an isolated system model.
   b Evaluate the validity of using an isolated system model in this scenario.

5 A family is considering buying either an electric car or an internal combustion engine car. Help them to decide which is best suited by answering the following questions.
   a What is the law of conservation of energy?
   b Describe the primary energy transformation in an electric car.
   c Describe the primary energy transformation in an internal combustion engine car.
   d Evaluate how the law of conservation of energy applies to both types of cars.

**HINT**

Consider the number of energy transformations required to result in kinetic energy.

# 12.9 Types of energy transformations

**Learning intention**

To analyse observed energy transformations

**Success criteria**

**SC 1:** I can analyse information collected from an experiment to draw conclusions.

**SC 2:** I can construct diagrams that describe energy changes.

## Introduction

An energy transformation occurs when energy is transformed from one form to another. Some examples include:

- A car engine transforming chemical potential energy from petrol into kinetic energy that causes the car to move.
- A light bulb transforming electrical energy into light energy (Figure 12.9.1).
- A wind turbine transforming kinetic energy into electrical energy.
- A toaster transforming electrical energy into heat energy to toast bread.

In this practical investigation you will observe a range of energy transformations and identify the forms of energy involved.

**FIGURE 12.9.1** Reading a book by the light of a torch

## Background

Many everyday situations involve energy transforming from one form to another. Often, more than one energy transformation is involved.

## Aim

To observe a range of energy transformations and identify the forms of energy involved using energy flow diagrams

## Apparatus

- matches
- torch
- tennis ball
- phone

- pop ball / rubber ball
- 50 g hanging mass
- retort stand and clamp
- 40 cm piece of string
- small wind-up toy

## Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

**SAFETY NOTE**

- Make sure no one is standing too close to the hanging mass when it is released.

## Method

1 Play music on a phone for five seconds, then turn it off.
2 Compress a pop ball and leave it on a bench as you watch it.
3 Light a match and then carefully blow it out.
4 Turn on a torch and see what happens. Switch the torch off.
5 Suspend a hanging mass from a retort stand. Pull the mass upwards in an arc, then carefully release it and allow the mass to swing.
6 Wind up a toy and release it on a bench top.

## Results

As you complete each task, record your observations in a results table in your notebook. The headings for this table should include: Situation, Initial type of energy present, Observations, and Energy flow diagram

## Conclusion

1 In which of the tested situations was the initial source of energy a type of potential energy?
2 Identify and explain which energy transformation was the most complex in terms of its energy flow diagram.
3 Which form of energy do all these transformations output?
4 Explain why an energy flow diagram was used in this investigation instead of a Sankey diagram.

# 12 Energy in systems

## Topic summary

The key concepts included in this topic are:

- To understand ways that thermal energy is conducted from particle to particle in solids, liquids and gases
- There are many forms of energy including kinetic, potential, chemical, thermal and more.
- Energy can be transferred from one object to another.
- Transformations from one form of energy to another can provide useful energy.
- Heat can be transferred via conduction, convection and radiation.
- Heat energy moves through fluids (gases and liquids) by convection due to density changing with temperature.
- There are several types of kinetic energy, such as sound, thermal energy and electric current.
- The energy output that is not useful energy can be classified as wasted energy.
- There are energy inputs into a system and energy outputs from a system.
- Sankey diagrams use arrows of different widths to show the quantities of the various energy outputs from a system as proportions of the energy input into the system.
- Radiation can transfer energy between two points without transferring matter.
- Radiant energy from the Sun can be converted into usable energy.
- The law of conservation of energy states that energy is never lost in transformations.



## Review questions

The following questions will assess your success in achieving the learning intentions for this topic.

### Remember

**1** List the different ways that thermal energy is transferred via particles.

**2** Energy transfers and categories of kinetic energy are fundamental concepts in physics.

- **a** Define kinetic energy.
- **b** List three types of kinetic energy.
- **c** Give an example of kinetic energy transfer in everyday life.

**3** State the law of conservation of energy.

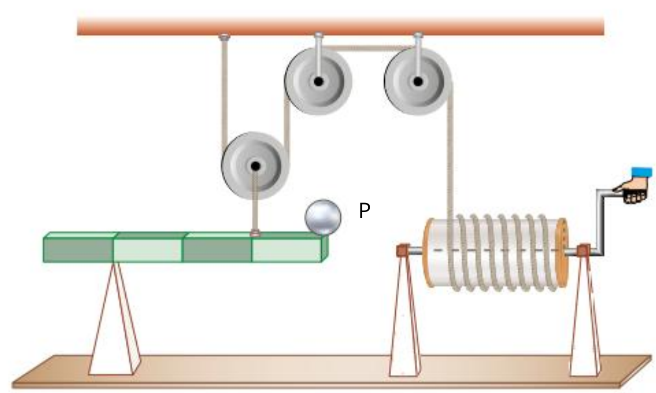
**4** Define wasted energy.

### Understand

**5** Provide an example of how the following types of energy can be transformed into kinetic energy.

- **a** chemical potential energy
- **b** gravitational potential energy
- **c** elastic potential energy

**6** Shown below is a simple Rube Goldberg machine that causes the ball at point P to roll down the ramp. Describe each step of the machine, including any energy transfers or transformations that take place.



## Apply

**7** Compare the energy transformation in photosynthesis with the energy transformation in solar power.

**8** Develop a prediction for an experiment comparing the heat transfer in metals of different conductivity.

**9** Draw a Sankey diagram for a light bulb with an electrical energy input of 100 J, 20 J of light energy output and 80 J of heat energy output.

**10** A smartphone battery contains 32 400 J of energy and lasts 9 hours. Each hour the phone wastes 600 J of heat. Determine how much energy the phone uses per hour to operate.

## Analyse

**11** Compare the effectiveness of conduction and convection in transferring heat in a liquid.

**12** Can a Sankey diagram have more heat energy output than electrical energy input? Explain your answer.

**13** A passenger jet flight from Sydney to Darwin requires 483 000 MJ of kinetic energy. One litre of fuel contains 35 MJ of chemical potential energy and the plane consumes 46 000 L during the flight.

Use the fuel consumption and the law of conservation of energy to determine how much energy is wasted to the environment in this process.

## Extension: Research task

**14** Research how kinetic energy in the form of sound is utilised in medical technologies. Describe your findings.

## Topic reflection

The learning intentions for this topic are given in each lesson and at the beginning of the topic. Consider how well you have achieved them. Note down any particular areas that you are confident in, and others where you are not so sure.

# 12 Glossary

**chemical potential energy** energy that is stored in molecules

**closed system** a system model where energy is transferred with the environment

**conduction** a method of heat transfer in which thermal energy travels through a material or between two objects in contact with each other

**conductor** material through which heat, sound or electrical energy can be transferred

**convection** transfer of heat in a liquid or gas due to less dense, warmer matter rising and denser, cooler matter falling

**convection current** transfer of heat in a liquid or gas due to less dense, warmer matter rising and denser, cooler matter falling

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

**elastic potential energy** energy stored within a stretched or compressed object, such as a spring or elastic material

**electricity** the flow of charged particles (electrons) through a conductor

**energy flow diagram** a diagram using arrows that shows the way energy is transferred or changed into other forms

**energy transfer** the movement of energy from one system to another without changing form

**energy transformation** the conversion of energy from one form to another, such as the conversion of potential energy into kinetic energy as an object falls

**fluorescence** the ability to give off (normally) visible light after absorbing another form of radiation

**fluid** substances capable of flow: liquids and gasses

**gravitational potential energy** the potential energy possessed by an object due to its position above the ground

**heat** thermal energy that is transferred from a warmer object or substance to a cooler object or substance

**insulator** a material which does not readily allow the transfer of heat, sound or electricity

**isolated system** a system model where neither energy or matter is transferred with the environment

**joule** a unit of measurement for energy

**kinetic energy** energy possessed by a moving object

**law of conservation of energy** a law stating that energy cannot be created or destroyed, but can only be transferred from one object to another or transformed into another form of energy

**light energy** energy that is given off by luminous objects, or that reflects off non-luminous objects, enabling people to see them

**Newton's cradle** a device that demonstrates the transfer of kinetic energy through a series of swinging spheres

**nuclear potential energy** energy that is stored in atoms, such as in the uranium used in nuclear power plants

**open system** a system model where energy and matter are transferred with the environment

**particle** tiny parts of matter; includes atoms and molecules

**particle model** model used to describe and explain the behaviour of particles in solids, liquids and gases

**potential energy** stored energy possessed by an object (because of its position or chemical structure) that can be transformed into another form of energy

**radiation** movement of radiant energy in the form of electromagnetic waves, which can travel through a vacuum

**Sankey diagram** a visual representation of the flow of energy through a system

**sound** energy that travels as vibrating waves and can be heard by the ears as sound

**system** collection of interacting components that form an integrated whole

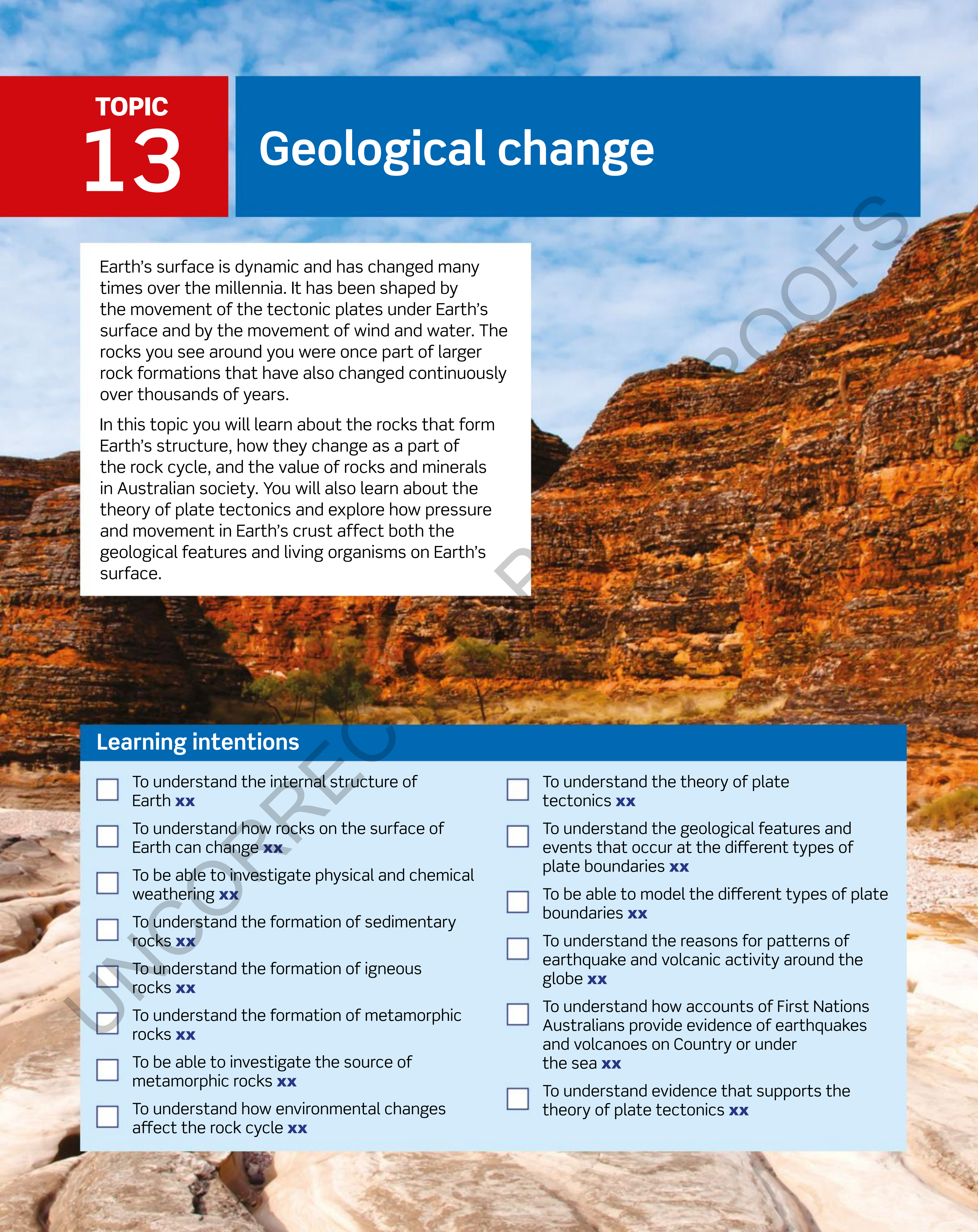
**temperature** a measure of the average kinetic energy of particles in a substance that indicates how hot or cold the substance is

**thermal energy** the internal energy of a substance due to the motion of its particles

**useful energy output** the form of energy that is intended to be produced by the device, such as sound energy from a radio, or light energy from a light bulb

**vacuum** a space that contains no matter

**waste energy** energy that is not usefully transferred or transformed into another type of energy



TOPIC 13

# Geological change

Earth's surface is dynamic and has changed many times over the millennia. It has been shaped by the movement of the tectonic plates under Earth's surface and by the movement of wind and water. The rocks you see around you were once part of larger rock formations that have also changed continuously over thousands of years.

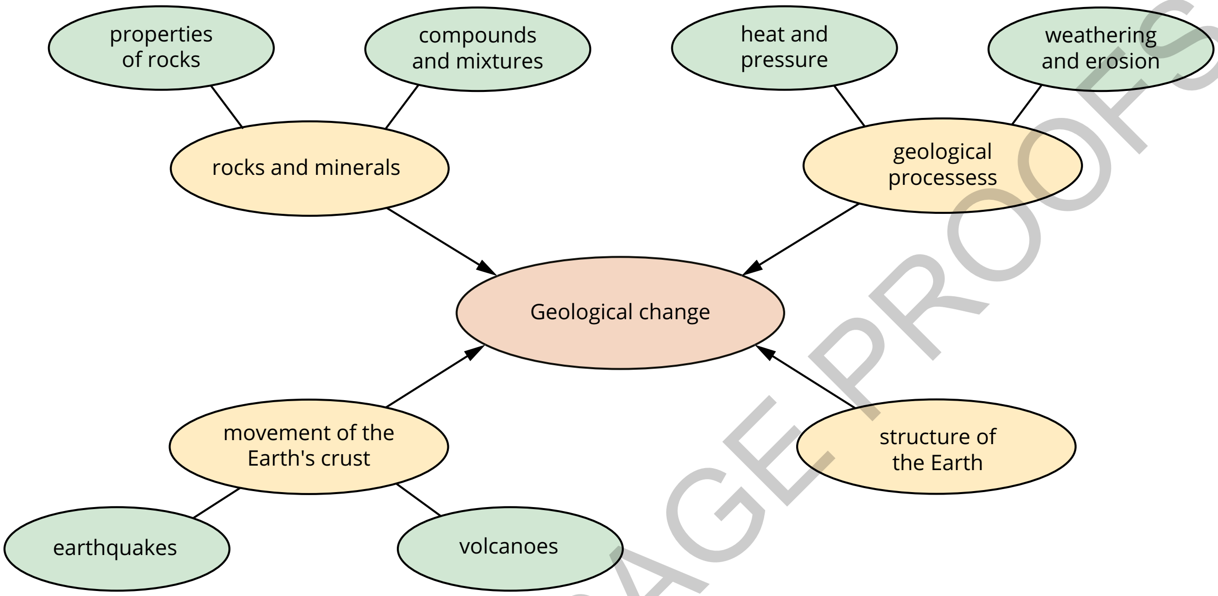
In this topic you will learn about the rocks that form Earth's structure, how they change as a part of the rock cycle, and the value of rocks and minerals in Australian society. You will also learn about the theory of plate tectonics and explore how pressure and movement in Earth's crust affect both the geological features and living organisms on Earth's surface.

## Learning intentions

- ☐ To understand the internal structure of Earth **xx**
- ☐ To understand how rocks on the surface of Earth can change **xx**
- ☐ To be able to investigate physical and chemical weathering **xx**
- ☐ To understand the formation of sedimentary rocks **xx**
- ☐ To understand the formation of igneous rocks **xx**
- ☐ To understand the formation of metamorphic rocks **xx**
- ☐ To be able to investigate the source of metamorphic rocks **xx**
- ☐ To understand how environmental changes affect the rock cycle **xx**
- ☐ To understand the theory of plate tectonics **xx**
- ☐ To understand the geological features and events that occur at the different types of plate boundaries **xx**
- ☐ To be able to model the different types of plate boundaries **xx**
- ☐ To understand the reasons for patterns of earthquake and volcanic activity around the globe **xx**
- ☐ To understand how accounts of First Nations Australians provide evidence of earthquakes and volcanoes on Country or under the sea **xx**
- ☐ To understand evidence that supports the theory of plate tectonics **xx**

# 13 Geological change

The key concepts that you will use in this topic:




The following prior knowledge questions will help to support your learning in the topic and can be attempted before the first lesson.

## Structure of Earth

1 Name the two layers of the Earth closest to the surface.
2 Describe how temperature and pressure change from Earth's surface to Earth's centre.

## Geological processes

3 Compare the processes of weathering and transportation of rocks.

## Rocks and minerals

4 Describe the difference between rocks and minerals, and give two examples of each.

## Movement of the Earth's crust

5 Movement of the Earth's crust can be responsible for what two natural disasters.
6 Suggest why marine fossils are found in rocks high up in the Himalayan mountains.

# 13.1 Structure of Earth

## Lesson overview

Earth is not a solid uniform mass. Instead, it is made up of different layers that have different properties. In this lesson you will learn about Earth's structure, its layers, and how heat energy is distributed throughout Earth.

### Learning intention

To understand the internal structure of Earth

### Success criteria

**SC 1:** I can identify the different layers of Earth.

**SC 2:** I can describe the layers of Earth's internal structure and compare them to other planets in the Solar System.

**SC 3:** I can describe the distribution of heat energy within the internal structure of Earth.

**SC 1** I can identify the different layers of Earth

The structure of Earth consists of four main sections: the crust, the mantle, and the outer and inner core. Figure 13.1.1 shows how these layers are arranged.

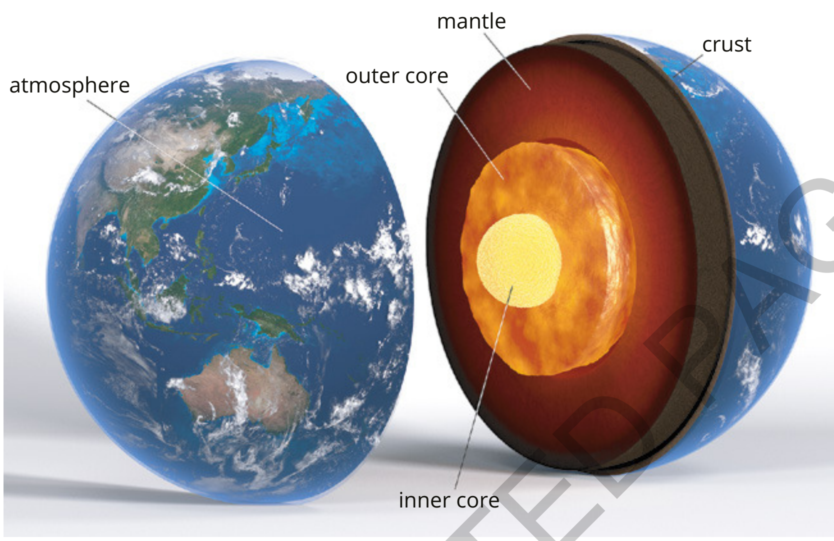



**FIGURE 13.1.1** The four layers of Earth

Earth was formed approximately 4.5 billion years ago. Over time, the internal structure of Earth became made up of a solid inner core, a liquid outer core, a hot, solid mantle that behaves like a fluid over long periods, and a solid **rock** crust. The liquid outer core is responsible for Earth's magnetic field.

**KEY TERMS**

**rock** a solid mass of one or more minerals.

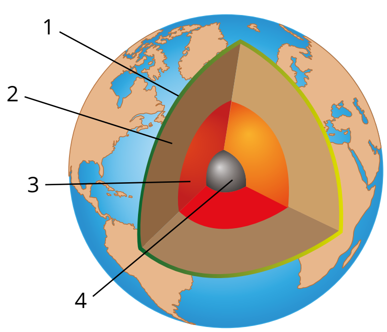
**crust** the outermost layer of Earth, composed of solid rock

### SC 1 CHECK YOUR UNDERSTANDING

Refer to the diagram below showing the internal structure of Earth.

**a** Identify each of the layers of Earth (numbered 1 to 4).

**b** For the two innermost layers, state whether they are solid or liquid.



**SC 2** I can describe the layers of Earth's internal structure and compare them to other planets in the Solar System.

Each layer of the Earth is different in its composition and state.

## Crust

The outermost layer of Earth is the **crust**. The crust is solid and very thin compared to the other layers. Its thickness varies from 7 kilometres beneath the oceans, to 30 or more kilometres beneath the continents. It is composed mostly of magnesium, silica and aluminium.

## Mantle

The **mantle** is the layer underneath the crust. It is much hotter than the crust, and the composition of this layer changes as it gets deeper. The mantle consists mainly of magnesium, silica and iron.

The uppermost solid layer of the mantle combines with the crust to create Earth's rigid outer shell called the **lithosphere** (Figure 13.1.2).

The **asthenosphere** is near the top of the mantle (Figure 13.1.2), just below the solid lithosphere, and it contains rock that can move very slowly. This rock is described as behaving plastically because it can bend or change shape under pressure, like plasticine, without breaking.

However, in the deepest part of the mantle (the lower mantle) the rock flow is also slow, but these rocks are rigid and break under pressure (Figure 13.1.2).

**KEY TERMS**

**mantle** solid layer of Earth between the crust and the outer core

**lithosphere** name for the crust and the upper mantle together

**asthenosphere** near the top of the mantle, just below the solid lithosphere, and it contains rock that can move very slowly

**Scifile**

**Earth's Deepest Hole**

The deepest hole ever drilled by humans is the Kola Superdeep Borehole in Russia. It is about 12 kilometres deep. That's not even halfway through Earth's crust! The attempt to reach the mantle had to stop after 20 years when the temperature in the crust reached 180°C – far too hot for the drilling equipment.

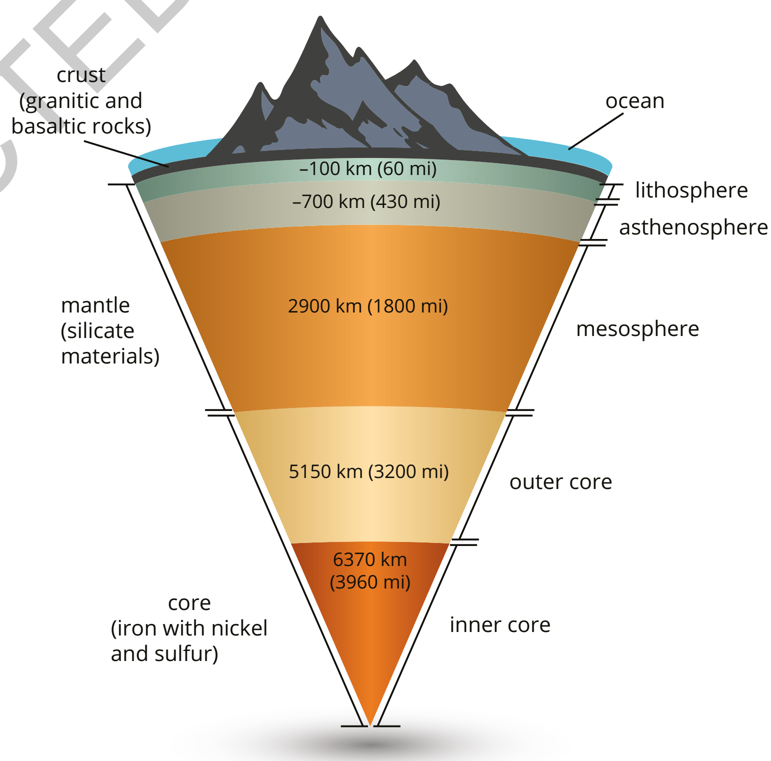



**FIGURE 13.1.2** The mantle is divided into the lithosphere, asthenosphere and lower mantle

## Outer core

The **outer core** is liquid (Figure 13.1.2). It is believed to consist of iron and nickel and is responsible for Earth's magnetic field.

## Inner core

The **inner core** of Earth (Figure 13.1.2) is also believed to consist of iron and nickel. It is so dense and the pressure so great inside the inner core that the iron and nickel do not melt.

## Comparing Earth to other planets

Earth is one of the four **terrestrial planets** in the Solar System. These terrestrial planets include Mercury, Venus, Earth, and Mars (Figure 13.1.3).


**FIGURE 13.1.3** The inner planets of the Solar System, called the terrestrial planets, have a similar structure and elemental composition

Earth, and Mars (Figure 13.1.3). Each of these planets have a core that consists mainly of iron, with some nickel and sulfur. Some of these planets have solid cores, while others can have liquid layers. Above the core is the mantle, which is composed of silicate minerals that contain iron and magnesium. These silicates are rocks that can be solid or can flow like plasticine over a long period of time. All the terrestrial planets have a solid crust made of lighter rock material like granite and basalt.

Other planets in the solar system are called **gas giant planets**, which include Jupiter and Saturn (Figure 13.1.4). Astronomers think that these planets could have a rocky metallic core surrounded by metallic hydrogen. Around the core are layers of atmosphere that contain hydrogen and helium under immense pressure. Higher in the atmosphere there are other gasses like ammonia, methane and water vapour.

Further out from the gas giants are the **ice giant planets**, which include Uranus and Neptune (Figure 13.1.5). These planets have a core of solid rock and metallic elements. Above their cores are semi-solid layers of water, ammonia and methane.

### SC 2 CHECK YOUR UNDERSTANDING

Compare the core of the Earth with the core of Neptune in terms of their composition and physical state.

### KEY TERMS

**outer core** a liquid layer of Earth's interior, primarily composed of liquid iron and nickel. Located beneath the solid mantle and surrounds the inner core

**inner core** extremely hot, solid ball made of iron and nickel at the very centre of Earth

**terrestrial planets** smaller planets in the Solar System that have a similar internal structure and composition as the Earth.

**gas giant planets** large planets in the Solar System that are mainly composed of hydrogen and helium gas.

**ice giant planets** large planets in the Solar System that are mainly composed of water, ammonia, and methane.

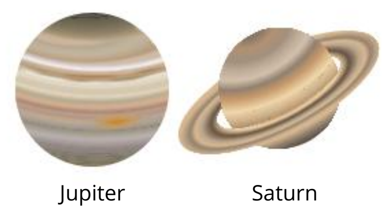



**FIGURE 13.1.4** The largest planets of the Solar System, called the gas giant planets, have a similar structure and elemental composition

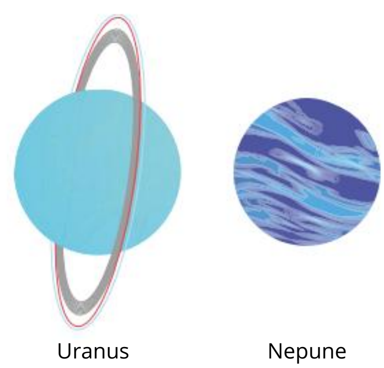



**FIGURE 13.1.5** The most distant planets of the Solar System, called the ice giant planets, have a similar structure and elemental composition

**KEY TERMS**

**primordial** something that originated during the planet's formation process a very long time ago

**geothermal energy** the heat energy that comes from within the Earth

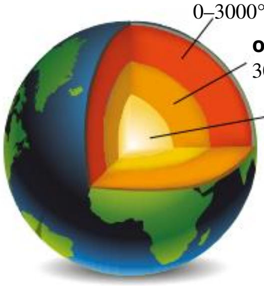



**FIGURE 13.1.6** Estimated temperatures within the Earth's three interior layers

**FIGURE 13.1.7** Geothermal energy produces hot springs that feed the Great Artesian Bore Baths in the tiny village of Goodooga in northern NSW

**SC 3** I can describe the distribution of heat energy within the internal structure of Earth

The inner core of Earth is very hot with a temperature ranging from 5000 to over 6000 degrees Celsius (°C) (Figure 13.1.6). The heat is generated from radioactive decay and **primordial** heat from when Earth was formed. The solid core is so dense, and the pressure inside the core so great, that it does not melt.

The outer core is liquid, and it is the movement of this liquid that helps distribute heat to the mantle and Earth's crust. Heat flows from warmer objects to cooler objects, so the heat from the warmer core is transferred to the cooler mantle and crust.

Heat energy that is generated within Earth is known as **geothermal energy**. It is geothermal energy that produces hot springs and geysers at the Earth's surface (see Figure 13.1.7).

**SC 3 CHECK YOUR UNDERSTANDING**

Why does heat makes its way from the inner core to the mantle and crust?

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 Explain the location of the Earth's mantle in relation to the other layers.

2 Which part of the Earth's internal structure is responsible for its magnetic field.

3 Which planets in the Solar System would have an internal structure and elemental composition similar to the Earth's internal structure and composition?

4 Identify the layers of Earth which have the following characteristics:
   a Generates the Earth's magnetic field
   b Contains the asthenosphere
   c Mainly consists of the elements nickel and iron in a solid state
   d Composed of solid rock with thickness ranging from 7 to 50 kilometres
   e Contains material at the hottest temperature and highest pressure
   f Consists mostly of magnesium, aluminium, and silica
   g Contributes to the rigid outer shell of Earth known as the lithosphere

5 Outline two sources of heat within Earth's internal structure.

6 Explain the formation of hot springs.

# 13.2 Changes to rocks on the surface of Earth

## Lesson overview

When you look at a rock, you may not consider that the rock was originally part of a larger rock. The rocks you see in your garden, parks and at the beach were once part of a larger rock mass. These larger rock masses have changed over time, affecting their appearance and creating smaller rocks. In this lesson you will learn how and why rocks change and how this impacts the landscape.

**SC 1** I can describe different types of weathering

**Weathering** causes rocks to change and break down. There are three main categories of weathering.

## Physical weathering

**Physical weathering** (sometimes referred to as mechanical weathering) breaks rock into smaller pieces without changing its chemical composition. Physical weathering can happen in four ways.

1. Wind can carry fine particles of rock which cause wear to the surface of other rocks as they scrape past.
2. Rocks can crack when they expand and contract quickly due to a change in temperature.
3. Water enters cracks in rocks and expands when freezing, causing rocks to break.
4. When salt water evaporates, it can form crystals inside cracks. This process is called **crystallisation**. The crystals apply a **force** on the rocks which causes fractures.

Often, more than one of these processes can occur at the same time, contributing to the formation of unique landscape features, like the ones shown in Figure 13.2.1.

**FIGURE 13.2.1** Sawn Rocks near Narrabri in New South Wales have been created through a combination of physical weathering processes.

### Learning intention

To understand how rocks on the surface of Earth can change

### Success criteria

**SC 1:** I can describe different types of weathering.

**SC 2:** I can describe, with examples from Australia, the difference between weathering and erosion.

**SC 3:** I can explain, with examples from Australia, the process of deposition and the land formations produced as a result.

### KEY TERMS

**weathering** processes that break rocks down into smaller pieces

**physical weathering** mechanical processes, such as wind, freezing water, changes in temperature, and crystallisation of salts, that break rocks down into smaller pieces

**crystallisation** evaporation of a solvent from a solution, leaving solute behind as crystals

**force** a push, pull or a twist that can change an object's shape or motion

**KEY TERMS**

**chemical weathering** chemical processes that break rocks down into smaller pieces, like acid rain, and oxidisation
**biological weathering** living organisms that break rocks down into smaller pieces through the action of roots, organic acids, and enzymes
**humus** dark material in soils produced by the decomposition of plant or animal remains
**erosion** the movement of weathered rock particles from the site of the weathering

## Chemical weathering

**Chemical weathering** occurs when water dissolves chemicals from the surrounding soil and air. These chemicals may then react with the minerals in a rock, causing it to crack or change.

Air contains 21% oxygen and 0.03% carbon dioxide. When these gases are dissolved in water, they can react with minerals in nearby rocks. These reactions may cause the rock to crumble or change colour on the surface.

Uluru is a well-known example of the process of chemical weathering. The original rock of Uluru is grey and called arkose. Water from the rain and oxygen in the air react with the iron in the rock to produce oxides of iron, which give Uluru its famous red colour (Figure 13.2.2).

## Biological weathering

**Biological weathering** is caused by moss, lichens, algae, and plant or tree roots forcing themselves through small cracks in rocks to create larger cracks (Figure 13.2.3). Biological weathering can even split the rock. Some plant roots can travel through rocks by releasing acids or an enzyme (a protein which speeds up chemical reactions) that softens the surrounding rocks. Some plant material will decay to produce **humus**, which contains a type of acid that seeps into the rocks below.

**SC 1 CHECK YOUR UNDERSTANDING**

Compare physical and chemical weathering in terms of their processes.

**FIGURE 13.2.2** The red colour of these rocks at Uluru is due to the presence of iron.

**FIGURE 13.2.3** These tree roots have pushed through cracks in the rocks and caused the rock to split.

**SC 2** I can describe, with examples from Australia, the difference between weathering and erosion

Weathering weakens rocks and creates small rock particles, but **erosion** moves these particles elsewhere by the action or movement of gravity, ice, water or wind.

## London Bridge, Victoria

The limestone rock formation known as 'London Bridge' (Figure 13.2.4) is on the Great Ocean Road in south-west Victoria. It was originally connected to the mainland until the inner span collapsed in 1990. When it rains, limestone slowly dissolves due to a chemical reaction with the rainwater in a process of chemical weathering. The limestone is further weakened by physical weathering (the action of wind and salt crystallisation). The movement of wind and water against rock, and gravity, causes small pieces of the rock to erode. Over time, this process has created natural arches or bridges, one of which has since collapsed.

**FIGURE 13.2.4** London Bridge, a natural arch limestone formation in coastal Victoria, has been formed by chemical weathering and erosion.

## Karlu Karlu (Devils Marbles), Northern Territory

Karlu Karlu (or the Devils Marbles) (Figure 13.2.5) are giant granite boulders in the Northern Territory. They were formed by molten rock that became solid when it cooled underneath a layer of sandstone. Once this rock solidified, vertical and horizontal cracks appeared due to physical weathering, forming rectangular blocks. These blocks have since become rounded due to further rapid temperature changes. The 'marbles' appear to be stacked on top of each other as the sandstone surrounding the granite has been eroded.

**FIGURE 13.2.5** Karlu Karlu (Devils Marbles) have formed as a result of rapid temperature changes (physical weathering) and erosion.

**SC 2 CHECK YOUR UNDERSTANDING**

Explain how weathering and erosion are different.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 What are the three main types of weathering?

2 Compare physical weathering and biological weathering in terms of their processes and their effects on rocks.

3 In the desert regions of Australia, how might weathering and erosion work together to shape the landscape?

4 Carlotta Arch in the Jenolan Caves at the Blue Mountains are a famous limestone rock formation. The caves in this area are the World's oldest known cave complex at 340 million years old. The cave network follows an underground section of the Jenolan river.

  a Describe the role of weathering in the formation of the Jenolan cave system. Consider the type(s) of weathering that has occurred.

  b Explain how erosion has contributed to the formation of the Jenolan cave system. Consider the main agents of erosion.

  c Predict the long-term impacts of weathering on Carlotta Arch.

# 13.3 Weathering of rocks

**Learning intention**

To be able to investigate physical and chemical weathering

**Success criteria**

**SC 1:** I can conduct an experiment to model and compare the weathering of rocks.

**SC 2:** I can use knowledge of weathering to explain observations.

**SC 3:** I can analyse the effectiveness of an experiment as a representation of the weathering of rocks in the environment.

## Introduction

Weathering is the process of rocks breaking down into smaller pieces. Weathering can occur because of physical, chemical and biological processes.

The rocks in Sydney's coastline in New South Wales (Figure 13.3.1) have been broken into smaller rocks and particles over thousands of years.

**FIGURE 13.3.1** Varied patterns, colours, shapes and layers of natural weathered sandstone rocks on the Sydney coast.

In this practical investigation you will investigate how chemicals and changes in temperature can cause the weathering of rocks.

## Background

The two types of weathering involve chemical or physical processes. Chemical reactions involve the creation of new substances. Physical processes involve changing the form of a substance and are easier to reverse than chemical processes.

Scientific models play a crucial role in understanding weathering processes. A scientific model is a representation based on data and observations of real-world phenomena. By analysing data from observations and experiments, scientists can create models that simulate the weathering process, providing valuable insights into how rocks change over time. These models are essential tools for predicting geological changes and for educational purposes, helping students visualise and comprehend the intricate processes involved in weathering.

## Aim

To investigate how the formation of ice, and the presence of chemicals, cause weathering

## Apparatus

- vinegar
- 2 small samples each of granite, limestone and sandstone (to fit in test tubes)
- 6 test tubes and a test-tube rack
- plaster of Paris
- 2 margarine containers or milk cartons
- small water balloon
- spoon or spatula
- rubber gloves

**SAFETY NOTES**

- Do not mix plaster with bare hands; mix with a spoon or spatula or use rubber gloves.
- Wear laboratory safety glasses and a dust mask when using dry plaster of Paris.

## Assessment of risk

Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

## Method

### Part A: The effect of acid and water

1 Label your test tubes with numbers 1 to 6 (Figure 13.3.2). Put small samples of granite into test tubes 1 and 2, limestone in test tubes 3 and 4, and sandstone in test tubes 5 and 6 as shown in the diagram.

2 Add water to test tubes 1, 3 and 5.

3 Add vinegar to test tubes 2, 4 and 6.

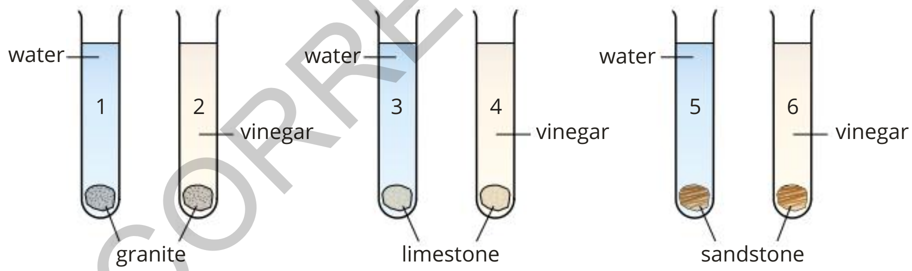



**FIGURE 13.3.2** Set-up of test tubes to investigate the effect of acid and water on three rock types.

4 Leave the test tubes in the test-tube rack overnight, or until your next science class, and record any observations.

## Part B: The effect of temperature

5 Mix enough plaster with water to half-fill two margarine containers or cut-down milk cartons.
6 Fill a small balloon with water and tie it. Push the balloon below the plaster in one container only. Ensure it stays below the surface as the plaster sets. The container without the balloon will be your control.
7 When the plaster is solid put both of the containers in a freezer overnight, or until your next science class, and record any observations.

# Results

Copy the results tables below into your notebook and record your observations.

## Part A

| Test tube | Rock | Liquid | Observations |
|---|---|---|---|
| 1 | granite | water | |
| 2 | granite | vinegar | |
| 3 | limestone | water | |
| 4 | limestone | vinegar | |
| 5 | sandstone | water | |
| 6 | sandstone | vinegar | |

## Part B

| Container | Observations |
|---|---|
| 1 Plaster without water balloon | |
| 2 Plaster with water balloon | |

# Discussion

Evaluate how well this experiment models the weathering of rocks in the environment.

# Conclusion

1 Use the observations in Part A to explain the weathering of rocks by chemicals.

2 Use the observations in Part B to explain a possible effect of freezing temperatures and water on rocks.

# 13.4 Sedimentary rocks

## Lesson overview

Sedimentary rocks are rocks made from sediments (Figure 13.4.1). Sediments are small particles of weathered rock or crystals that have been deposited and left behind by ice, water, and wind. In this lesson you will learn how sedimentary rocks are formed, the observable features of sedimentary rocks, and how fossils preserved in sedimentary rocks can be used to predict how and when a rock was formed.

**Learning intention**

To understand the formation of sedimentary rocks

**Success criteria**

**SC 1:** I can describe how and where sedimentary rocks are formed.

**SC 2:** I can explain how the law of superposition and fossil evidence can be used to predict how and when a rock was formed.

**SC 1** I can describe how and where sedimentary rocks are formed

## Sedimentary rocks

Sedimentary rocks are formed at the bottom of large bodies of water, including oceans and large lakes. Some also form in deserts and caves.

Sediments are small fragments of rocks that pile up over time. The laying down of these rock fragments is called deposition.

As sediments layer on top of one another, they push down on the underlying sediments. This squeezes out excess water, and a more compact denser structure forms. This process is known as **compaction**.

Naturally occurring minerals in water, such as silica and lime, can bind or cement the sediments together and create a more solid rock structure in a process called **cementation**.

Sediments that have undergone compaction and cementation form **sedimentary rocks** (Figure 13.4.2).

**FIGURE 13.4.1** Sediment has been deposited in layers to form sedimentary rocks.

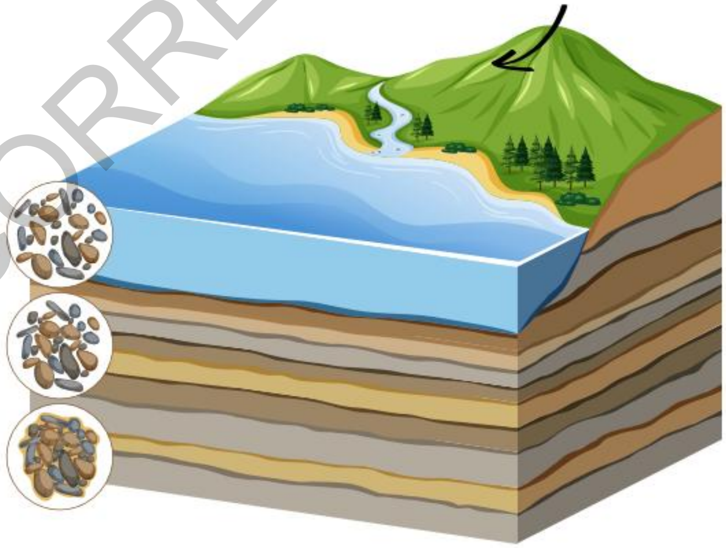



**FIGURE 13.4.2** The three main stages in the formation of sedimentary rock.

**KEY TERMS**

**compaction** the squeezing of layers of sediments caused by pressure from layers above

**cementation** the binding together of sediments as part of the formation of sedimentary rock

**sedimentary rock** rock made by sediments being compacted and cemented together

**SC 1 CHECK YOUR UNDERSTANDING**

Outline the three main stages of the formation of sedimentary rock.

**SC 2** I can explain how the law of superposition and fossil evidence can be used to predict how and when a rock was formed

Sedimentary rocks are formed from the accumulation and compaction of mineral and organic particles over long periods. These rocks often contain fossils and are typically found in layers, or strata, which provide valuable information about Earth's history.

## Law of superposition

One of the key principles used to understand sedimentary rocks is the law of superposition. This geological principle states that in any undisturbed sequence of sedimentary rocks, the oldest layers are at the bottom, and the layers become progressively younger towards the top. This allows geologists to determine the relative ages of rock layers and to construct a chronological sequence of geological events.

## Fossil evidence

Fossil evidence within these layers further aids in predicting the age and formation of sedimentary rocks. Fossils are the preserved remains or traces of ancient organisms, and they are often found in sedimentary rocks. By studying the types of fossils present in different layers, geologists can correlate the ages of rocks from different locations.

If the remains of a dead organism are quickly covered by sediment, then it may be preserved and become a fossil.

**FIGURE 13.4.3** An organism's remains can become buried in sediments in a water body.

Fossils are often found in deep water bodies such as oceans, lakes, or rivers (Figure 13.4.3). This means there is very little oxygen in the sediment which results in little or no decomposition.

The fleshy parts of the organism will gradually decompose. The hard remains of the organism, such as bones, are replaced by minerals and so turn into rock, becoming fossilised. Over time, sediments continue to build up, compacting and cementing, and become sedimentary rock (Figure 13.4.4).

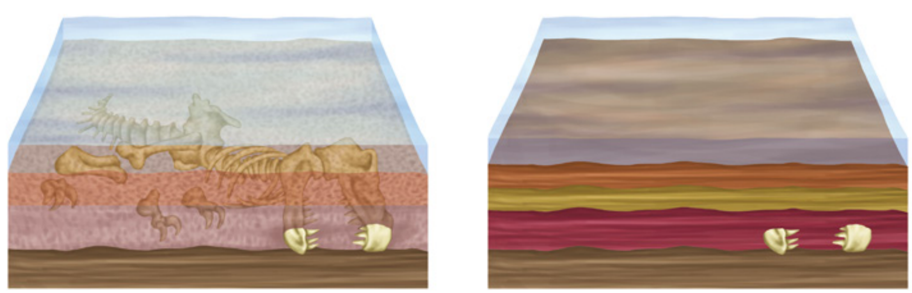


**FIGURE 13.4.4** Hard remains of the organism are replaced by minerals and become compacted in the surrounding sedimentary rock.

Changes to Earth's surface such as movements in Earth's crust, weathering and erosion can expose the fossil at Earth's surface (Figure 13.4.5).

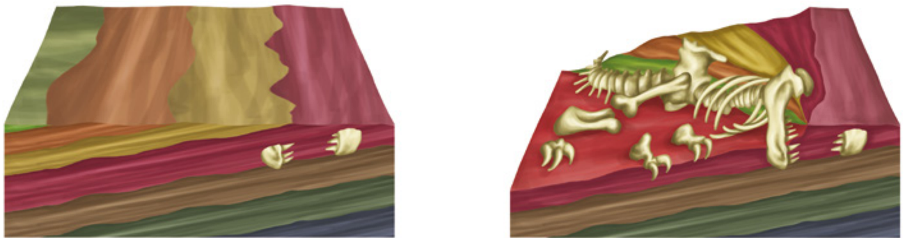


**FIGURE 13.4.5** Fossilised remains of an organism can become exposed at Earth's surface due to weathering and erosion.

## Index fossils

As layers of sedimentary rock are built up over time, deeper layers will generally be older than those closer to the surface (Figure 13.4.6). It is possible to compare the relative ages of rocks from different places using **index fossils**.

Index fossils within layers can mark layers that were formed around the same time but at different locations. Index fossils can be used to check the order of the layers and to check the age of the rock strata that housed the fossils.

**KEY TERMS**

**index fossil** a fossil that can be used to compare the relative age of rock strata in different locations

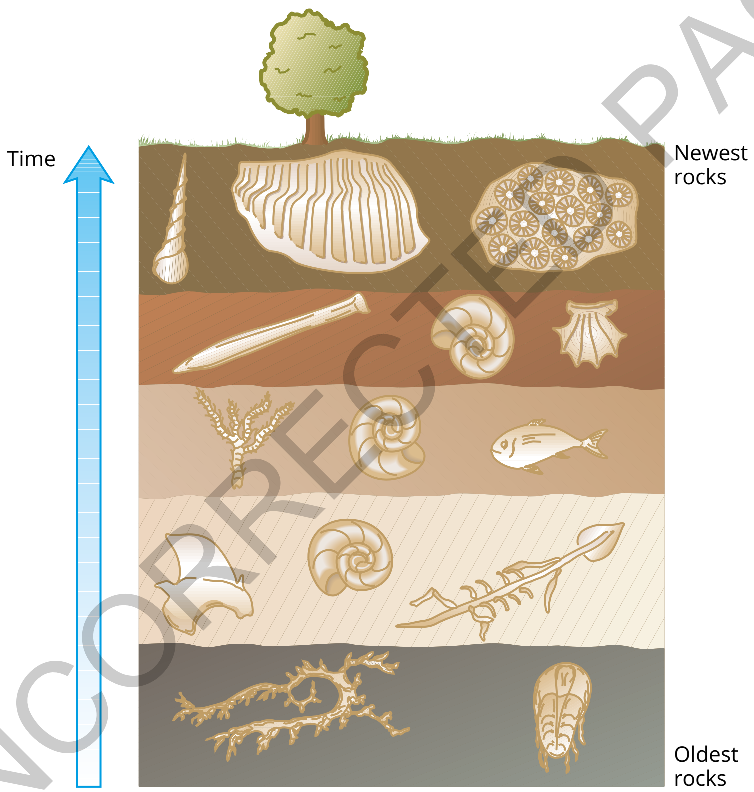



**FIGURE 13.4.6** Index fossils can help to date the age of sedimentary rock.

**SC 2 CHECK YOUR UNDERSTANDING**

Explain how fossils are preserved in sedimentary rocks.

# Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 Identify the type of environment in which sedimentary rocks are typically formed.

2 Explain the processes of compaction and cementation in the formation of sedimentary rocks.

3 Explain the law of superposition and how it helps in determining the relative age of rock layers.

4 Explain how fossil evidence can be used to determine the age of rock layers.

5 Explain the role of water in the formation of sedimentary rocks.

6 Compare and contrast the process of dating sedimentary rocks using the law of superposition and using fossil evidence.

# 13.5 Igneous rocks

## Lesson overview

Earth's crust was originally formed when molten rock cooled to form igneous rock. The word igneous means 'born of fire'. Molten magma and lava crystallise to form these rocks.

In this lesson you will learn how and where igneous rocks are formed, and the observable features of igneous rocks.

**SC 1** I can describe how and where igneous rocks are formed

A volcano is a formation that allows extremely hot material from inside Earth to erupt at Earth's surface (Figure 13.5.1). The molten rock below Earth's surface is called **magma**, and magma reaching Earth's surface is called **lava**.

**Igneous rock** is formed when magma or lava cools and hardens into rock.

This can happen in different ways:

1 Magma may cool on the surface of Earth, in the air, underwater, or underground.

2 Igneous rocks that form above the ground are called **extrusive igneous rocks**.

3 Igneous rocks that form when magma gets trapped underground and cools are called **intrusive igneous rocks**.

**SC 1 CHECK YOUR UNDERSTANDING**

Where are intrusive igneous rocks formed? Compare this to extrusive igneous rocks.

**SC 2** I can describe observable features of igneous rocks

As the molten rock cools into an igneous rock, it forms crystals that grow together. This causes the crystals to interlock, so the rock is hard.

## Making observations

When observing igneous rocks, you should note their texture and colour. For example, their texture could be rough or smooth and the varying size of the crystals should be noted. The colour of the rock indicates what **minerals** it may contain.

**KEY TERM**

**mineral** a naturally occurring solid substance that is inorganic, has a characteristic crystalline structure and a fairly constant chemical composition

**Learning intention**

To understand the formation of igneous rocks

**Success criteria**

**SC 1:** I can describe how and where igneous rocks are formed.

**SC 2:** I can describe observable features of igneous rocks.

**KEY TERMS**

**volcano** a place where extremely hot material from inside Earth erupts at the surface

**magma** molten rock below Earth's surface

**lava** molten rock that reaches Earth's surface

**igneous rock** rock formed by the cooling of molten rock, for example basalt

**extrusive igneous rock** igneous rock that forms on the surface of Earth

**intrusive igneous rock** igneous rock that forms below the surface of Earth

**FIGURE 13.5.1** Volcano Fuego (Antigua, Guatemala) erupts bringing molten lava to Earth's surface.

## Extrusive igneous rocks

Extrusive igneous rocks cool very quickly when lava is exposed to air or water. They have specific observable features:

- Large crystals don't have time to grow, so the crystals are tiny and are only visible under a microscope.
- They might have a bubbly texture as can be seen in Figure 13.5.2. This is due to trapped bubbles of gas within the lava as it cooled rapidly.

Some examples of extrusive igneous rocks are basalt, obsidian (volcanic glass), scoria, and pumice.

**FIGURE 13.5.2** Pumice is an example of an extrusive igneous rock that trapped gas as it cooled

## Intrusive igneous rocks

Intrusive igneous rocks cool more slowly because they cool underground. They tend to have large crystals that can be seen without the help of a microscope. The large crystals form because the slow cooling time means that large crystals have time to grow. Some examples of intrusive igneous rocks are dolerite, gabbro, and granite (Figure 13.5.3).

**FIGURE 13.5.3** Granite is an example of an intrusive igneous rock

**SC 2 CHECK YOUR UNDERSTANDING**

An igneous rock sample has been identified as being intrusive. What does this tell you about:

**a** where it formed?
**b** the size of its crystals?

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1. Explain the difference between the crystal size in intrusive igneous and extrusive igneous rocks.
2. If you find an igneous rock with large, visible crystals, what can you infer about its formation?
3. You are examining igneous rock samples to identify their features.
   - **a** List the observable features you would look for in igneous rocks.
   - **b** Explain how the cooling rate affects the texture of igneous rocks.
   - **c** Compare the textures of intrusive and extrusive igneous rocks.
   - **d** Explain the importance of colour in identifying igneous rocks.
   - **e** One of the rock samples has crystals of varying sizes – some are visible to the naked eye and others are microscopic. What type of igneous rock is this likely to be?
4. There are times when magma that is cooling below the ground is forced up above the ground. Explain how increasing the rate that igneous rocks cool affects the crystal size within the rock.
5. A fine-grained igneous rock with a bubbly texture has been found on the beach.
   - **a** Which type of igneous rock is this specimen most likely to be?
   - **b** Is the molten material from which it formed likely to be lava or magma?
   - **c** Describe the rate at which heat energy would have been lost as this rock cooled.
   - **d** What is the likely cause of the bubbly texture?
   - **e** Suggest the name of the igneous rock.

# 13.6 Metamorphic rocks

## Lesson overview

All rocks can be altered by heat and/or pressure to form metamorphic rocks. Even metamorphic rocks can be further metamorphosed. This process turns ordinary limestone into beautiful marble (Figure 13.6.1), and soft sandstone into hard quartzite.

In this lesson you will learn about the formation of metamorphic rocks, what a parent rock is, and the role of pressure and heat energy in the formation of metamorphic rocks.

**Learning intention**

To understand the formation of metamorphic rocks

**Success criteria**

**SC 1:** I can describe how and where metamorphic rocks are formed.

**SC 2:** I can describe examples of specific metamorphic rocks and their parent rock.

**SC 1** I can describe how and where metamorphic rocks are formed

When large amounts of heat energy and/or pressure are applied to rocks, the properties of the rock can change. This is how **metamorphic rocks** are formed.

Both physical and chemical changes can occur when rocks are metamorphosed. Crystals can transform into crystals of new minerals (recrystallisation). Crystals can deform into flattened sheets. Bands of different minerals can form when crystals are squashed flat by forces within Earth while they are hot.

**FIGURE 13.6.1** Marble caves in Chile have been formed from metamorphosed limestone.

**KEY TERM**

**metamorphic rock** rock formed when temperature and/or pressure alter existing rock

### Scifile

**Gemstones**

Many gemstones, like emerald and garnet, form in metamorphic rocks through the process of recrystallisation. The intense heat and pressure create the perfect conditions for these beautiful minerals to grow. Trace elements give the gemstones their different colours. For example, sapphire and ruby are varieties of the same mineral corundum, but ruby's red colour is due to traces of chromium in its structure. Sapphire's colours come from traces of elements such as iron, nickel and titanium.

**SC 1 CHECK YOUR UNDERSTANDING**

Name two effects of metamorphism on rocks.

**SC 2** I can describe examples of specific metamorphic rocks and their parent rock

**KEY TERMS**

**parent rock** the original rock that experiences metamorphism, or changes form, to become a new kind of rock

**foliate** a process where minerals under pressure realign and the rock develops layers or bands

## Parent rocks

Metamorphism changes the original rock or **parent rock** into a completely new rock. The parent rock can be sedimentary, igneous or metamorphic.

When the minerals in a rock are forced into layers, the rock is said to be **foliated**. These bands of minerals can also have a wavy pattern when pressure is applied and squeezes the layers. Metamorphic rocks are either foliated or non-foliated.

## Foliated metamorphic rocks

The following are examples of metamorphic rocks that are foliated.

Shale (mudstone) is the sedimentary parent rock that forms slate under pressure and heat.

Slate is a foliated metamorphic rock. Note the cleavage lines through the rock shown in Figure 13.6.2. Slate is still fine-grained like its parent rock.


**FIGURE 13.6.2** Shale is metamorphosed to foliated slate.

If slate is subject to more pressure and higher temperatures, it will change again to form schist (Figure 13.6.3). New minerals are formed, the crystals are larger, and the rock remains foliated.

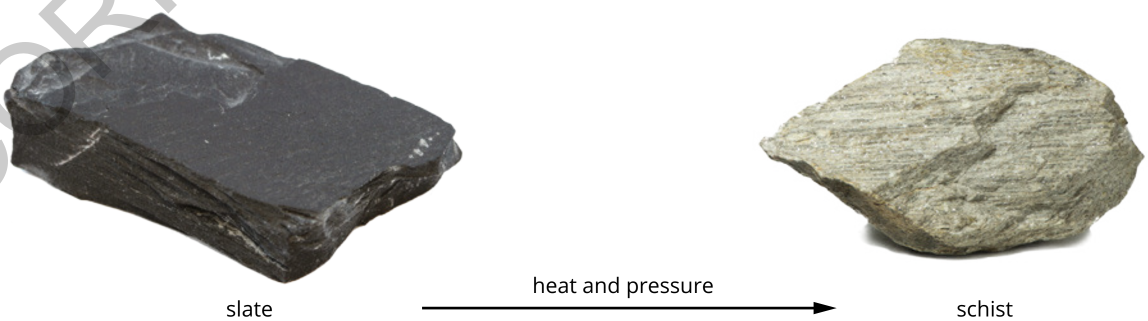



**FIGURE 13.6.3** Slate is metamorphosed to form schist.

## Non-foliated metamorphic rocks

The following are examples of metamorphic rocks that are non-foliated.

Quartzite is much harder than its parent rock sandstone (Figure 13.6.4). Sandstone will shatter into many individual grains of sand while quartzite will break across the grains. Quartzite is non-foliated.

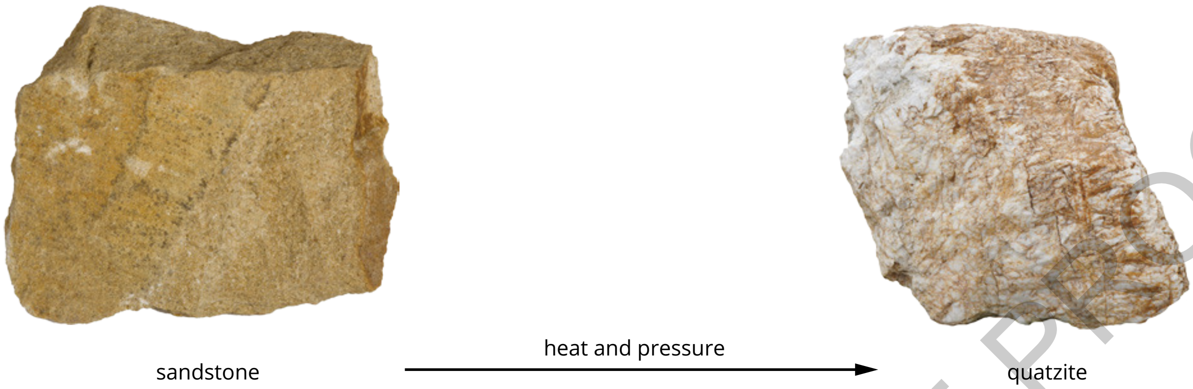



**FIGURE 13.6.4** Sandstone is metamorphosed to form quartzite.

**SC 2 CHECK YOUR UNDERSTANDING**

Shale can undergo a number of stages of metamorphism to form the metamorphic rock schist.

**a** Identify the original parent rock in this process.

**b** Is schist an example of a foliated or a non-foliated metamorphic rock?

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

**1** Describe how metamorphic rocks typically form.

**2** Explain the role of pressure and temperature in the formation of metamorphic rocks.

**3** If you find a rock that has been subjected to high pressure but low temperature, what type of metamorphic rock might it be?

**4** Compare the parent rocks and the resulting metamorphic rock types for both quartzite and schist.

**5** You are studying the formation of metamorphic rocks under different conditions of heat and pressure.
- **a** Describe the role of heat energy in the metamorphic process.
- **b** Explain how pressure influences the texture of metamorphic rocks.

**6** Slate is a metamorphic rock that has been used for centuries as roof, floor and wall tiles, and as the base for billiard tables. Outline the characteristics of slate that make it suitable for these purposes. Consider grain size, foliation, and hardness in your response.

# 13.7 The source of metamorphic rocks

## Learning intention

To be able to investigate the source of metamorphic rocks

## Success criteria

**SC 1:** I can use a dichotomous key to identify igneous, sedimentary and metamorphic rocks.

**SC 2:** I can use observations and secondary data to match the metamorphic rocks to their parent rocks.

**SC 3:** I can describe changes that have occurred to the properties of rocks because of the production of the metamorphic rock.

**KEY TERM**

**dichotomous key** a classification key with two choices at each stage

## Introduction

Metamorphic rocks, such as the marble shown in Figure 13.7.1, are formed from other rocks when placed under pressure and/or heat. In this practical investigation you will investigate the source of metamorphic rocks by using an identification tool called a dichotomous key.

**FIGURE 13.7.1** Marble formed from the parent rock of limestone.

## Background

**Dichotomous keys** are used in classification processes. They give the user two choices at each point in the procedure. Dichotomous keys can be used to classify rocks.

**SkillBuilder**

### Classifying rocks

#### Using dichotomous keys to classify rocks

Do the following when observing and classifying rocks.

1. Spray the rock with water to make it easier to see any contrasting colours.
2. View the rock through a magnifier.
3. Use a ruler to estimate the size of any crystals.

Note that very fine-grained rocks may be difficult to classify without extra techniques such as taking a thin slice of the rock to observe under a microscope.

## Dichotomous key for classifying rocks

| | |
|---|---|
| 1 | Rocks have crystals – go to 2.<br>Rocks do not have crystals – go to 6. |
| 2 | Rocks are made entirely of interlocking crystals.<br>*Igneous* – go to 3.<br>Rocks are not made entirely of interlocking crystals.<br>*Metamorphic* – go to 10. |
| 3 | Rocks have crystals large enough to see using a hand lens.<br>*Igneous intrusive* – go to 4.<br>Rocks have crystals but their crystals are difficult to see using a hand lens.<br>*Igneous extrusive* – go to 5. |
| 4 | Rocks are dark and dense.<br>*Igneous, intrusive and mafic (rich in magnesium and iron),* e.g. *gabbro*<br>Rocks are neither dark nor dense.<br>*Igneous, intrusive and felsic (rich in feldspar and silicon),* e.g. *granite, pegmatite* |
| 5 | Rocks are dark and dense.<br>*Igneous, extrusive and mafic (rich in magnesium and iron),* e.g. *basalt*<br>Rocks are neither dark nor dense.<br>*Igneous, extrusive and felsic (rich in feldspar and silicon),* e.g. *rhyolite* |
| 6 | Rocks are non-crystalline and are made of pieces or chunks of smaller rock.<br>*Sedimentary, clastic* – go to 7.<br>Rocks are non-crystalline but are not made of pieces or chunks of smaller rock.<br>Sedimentary, biogenic, e.g. limestone, chalk, coal |
| 7 | Rocks have large pieces or chunks of smaller rock – go to 8.<br>Rocks do not have large pieces or chunks of smaller rock – go to 9. |
| 8 | Rocks have large pieces or chunks of smaller rock that are rounded.<br>*Sedimentary, clastic,* e.g. *conglomerate*<br>Rocks have large pieces or chunks of smaller rock that are not rounded.<br>*Sedimentary, clastic,* e.g. *breccia* |
| 9 | Rocks have medium rounded pieces or chunks of smaller rock.<br>*Sedimentary, clastic medium grained,* e.g. *sandstone*<br>Rocks have pieces or chunks of smaller rock that are less than medium size.<br>*Sedimentary, clastic fine grained,* e.g. *siltstone, mudstone* |
| 10 | Rocks are foliated (or banded).<br>*Metamorphic,* e.g. *slate, schist and gneiss*<br>Rocks are not foliated (or banded).<br>*Metamorphic,* e.g. *quartzite and marble* |

## Worked example

### Classifying rocks

This worked example uses the dichotomous key from the SkillBuilder to classify a rock sample.

#### Problem

Use the dichotomous key to classify the unknown rock sample as shown in the figure. Note that each bar on the scale is 1 cm.

#### Solution

| Thinking | Working |
|---|---|
| Does the rock have crystals? | Yes, go to 2. |
| Are the crystals interlocking? | Yes, go to 3. |
| Can you see the crystals using a hand lens? | Yes, go to 4. |
| Is the rock dark and dense? | The rock is neither dark nor dense – it is light in colour. This means it is an igneous, intrusive and felsic rock (rich in feldspar and silicon), such as granite or pegmatite. (Note: The sample is granite.) |

#### Try yourself

Use the dichotomous key to classify this rock. Note that each bar on the scale is 3 cm.

## Aim

Your investigation has two aims:

1 To classify unknown rock samples as igneous, sedimentary or metamorphic

2 To compare metamorphic rocks with their parent igneous, sedimentary and metamorphic rocks

## Apparatus

For Task 1, you will need:

- numbered but unlabelled rock samples
- stereo microscope and/or hand lens.

For Task 2, you will need:

- labelled rock samples in containers: gneiss, granite, limestone, marble, quartzite, sandstone, schist, shale, slate
- stereo microscope and/or hand lens.

## Method

### Task 1

1 Choose a numbered rock sample. Your first task is to describe the characteristics of the rock.

2 Use your microscope and/or hand lens to take a closer look. Then, using the dichotomous key, decide whether it is igneous, sedimentary or metamorphic. Record your reasons in your results table. If you feel confident, try to name the rock.

3 Repeat step 2 for each rock.

4 Record all observations in your results table.

### Task 2

1 Use the microscope and/or hand lens to examine the rock samples.

2 Use the information in the 'Metamorphic rocks' lesson, and any other information available to you, to match each metamorphic rock to its parent rock.

3 For each pair of rocks, write the name of the parent rock first and describe its characteristics, including its rock type. Then, do the same for the metamorphic rock.

4 For each metamorphic rock, describe the characteristics that enable you to decide it is metamorphic.

5 Describe changes that have occurred in each metamorphic rock as it altered from its parent rock.

**HINT**

It is possible that a particular rock is the parent rock for more than one metamorphic rock.

It is also possible that a metamorphic rock may have more than one parent rock.

## Results

Copy the results tables below into your notebook and record your observations.

## Task 1

| Rock number | Description | Classification | Rock name |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |

## Task 2

| | Parent rock | Description | Metamorphic rock | Description |
|---|---|---|---|---|
| Pair 1 | | | | |
| Pair 2 | | | | |
| Pair 3 | | | | |
| Pair 4 | | | | |
| Pair 5 | | | | |

| Rock name | Reasons you have decided it is metamorphic | What changes occurred to make it metamorphic? |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |

## Discussion

Evaluate your practical investigation by considering how you could improve the process of classification.

GO TO ➤

For more help with evaluating investigations, go to Toolkit, section x.x, page yy.

## Conclusion

Summarise how you were able to classify rock samples (Task 1) and determine the parent/metamorphic rock relationships (Task 2).

# 13.8 The rock cycle in action

## Lesson overview

Rocks have been constantly changing since Earth formed. The rock cycle is a model that outlines these processes and the resultant changes to rock types. In this lesson you will learn about the formation of different types of rock within the rock cycle and the impact of environmental factors on the structure of rocks.

**SC 1** I can compare the formation of different types of rock within the rock cycle

### Learning intention

To understand how environmental changes affect the rock cycle

### Success criteria

**SC 1:** I can compare the formation of different types of rock within the rock cycle.

**SC 2:** I can predict and explain locations where specific types of rocks are found.

## The rock cycle

Since Earth was formed, rocks have been continually changing. The **rock cycle** is a model used by scientists to explain the endless cycling of rocks and rock types.

The rock cycle diagram in Figure 13.8.1 shows that a range of geological processes such as weathering, erosion, deposition, melting, heat, pressure, and crystallisation cause changes to the structure of rocks. Some of these occur deep in Earth's lithosphere where there are higher levels of heat and pressure. Others are the result of environmental changes on Earth's surface itself.

**KEY TERMS**

**rock cycle** a model geologists use to explain the endless cycle of change that rocks undergo

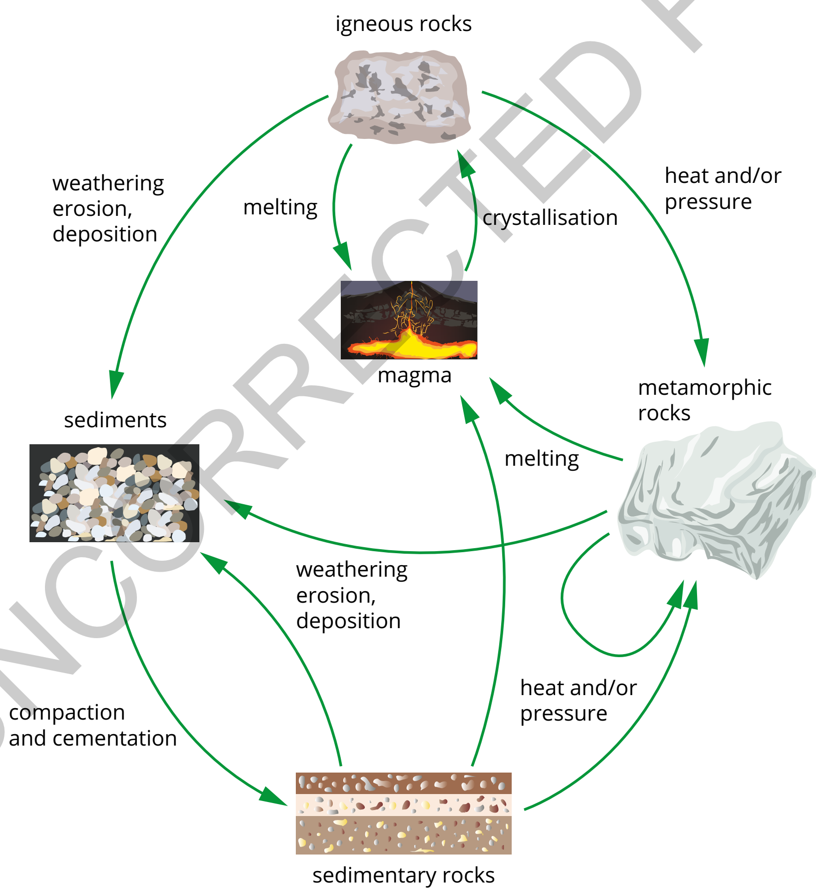



**FIGURE 13.8.1** A more detailed version of the rock cycle showing geological processes and changes to rock type.

The processes that form sedimentary, igneous and metamorphic rocks are a continuous cycle that began when Earth was first formed. It is possible for igneous rocks to melt and cool, forming new igneous rocks. A sedimentary rock may metamorphose when subjected to high levels of heat and/or pressure, then go through uplift and erosion to form a new sedimentary rock.

**SC 1 CHECK YOUR UNDERSTANDING**

Identify the series of geological processes that can change:

**a** an igneous rock into a sedimentary rock
**b** a sedimentary rock into an igneous rock
**c** a metamorphic rock into an igneous rock.

**FIGURE 13.8.2** Mount Kosciuszko is part of a mountain range formed when igneous granite was uplifted.

**SC 2** I can predict and explain locations where specific types of rocks are found

## Where specific types of rocks are found

Most of the rocks found in Australia are either igneous or sedimentary rocks. However, metamorphic rocks can be found in some regions of Australia, particularly in the East MacDonnell Ranges of the Northern Territory where ancient quartzite rock formations are common.

### Igneous landmarks

Mount Kosciuszko in New South Wales (Figure 13.8.2) is formed of igneous granite rocks. Igneous rocks are often found at mountain ranges where volcanic activity has occurred, or where there has been large-scale uplift of igneous rock formed deep in the crust.

**FIGURE 13.8.3** The headlands of Sydney's Bondi B each show the sandstone that is the bedrock under most of the Sydney area.

### Sedimentary landmarks

Most of the Sydney area is situated on a bedrock of Sandstone (Figure 13.8.3). Ancient sediments were buried and compressed to form harder rock, resulting in the sedimentary Sydney sandstone. This yellowish coloured rock can be seen in many of the coastal cliffs around Sydney.

**FIGURE 13.8.4** The MacDonnell Ranges formed when metamorphic quartzite was uplifted.

### Metamorphic landmark

Trephina Gorge is in the East MacDonnell Ranges of the Northern Territory (Figure 13.8.4). This gorge has sheer cliffs made of metamorphic quartzite. The rocks were once sandstone, but heat and pressure metamorphosed the sandstone to quartzite.

**SC 2 CHECK YOUR UNDERSTANDING**

Identify the rock type or types that are the most abundant in Australia.

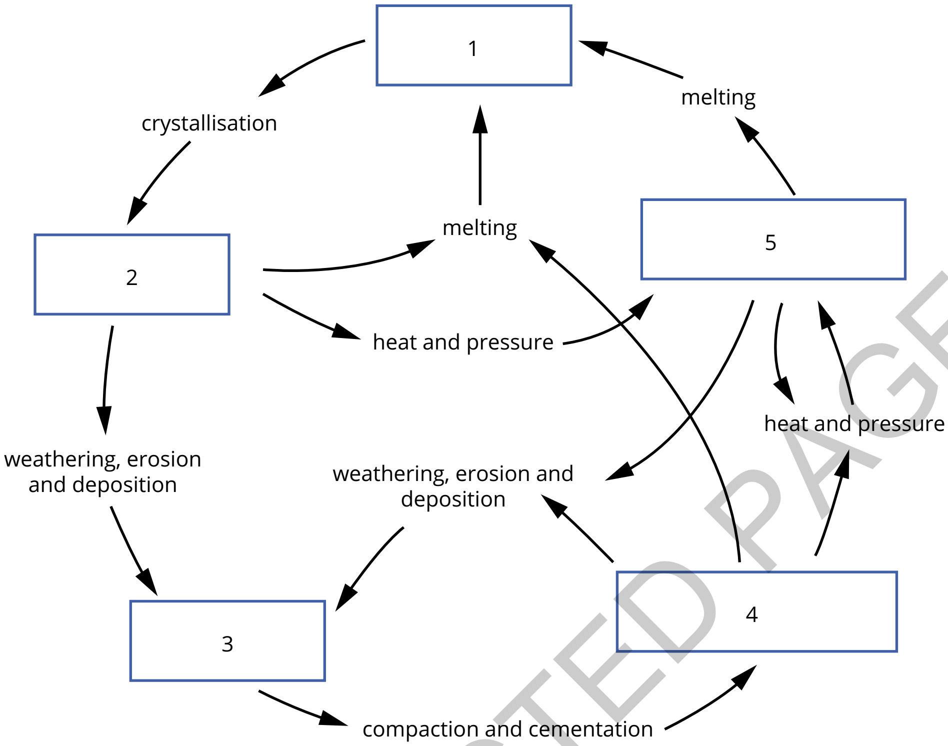
# Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

**1** Outline the five stages involved in the formation of sedimentary rocks.

**2** Compare the role of heat in the formation processes of igneous and metamorphic rocks.

**3** Identify the stages of the rock cycle labelled 1 to 5.




**4** You are mapping the distribution of different rock types in various geological settings.

- **a** Identify the types of rocks you would expect to find in a volcanic region.
- **b** Explain the processes that lead to the formation of these rocks.
- **c** Predict the types of rocks found at the mouth of a river and explain their formation.
- **d** Evaluate the role of uplift on the distribution of all three rock types.

**5** 'Australia has the best sand beaches in the world because the landscape is so old.'
Evaluate this statement, considering the role of the rock cycle in creating these beaches.

# 13.9 The theory of plate tectonics

## Learning intention

To understand the theory of plate tectonics

## Success criteria

**SC 1:** I can describe the formation of the Earth and the tectonic plates.

**SC 2:** I can identify the tectonic plates.

**SC 3:** I can explain the forces of motion of tectonic plates.

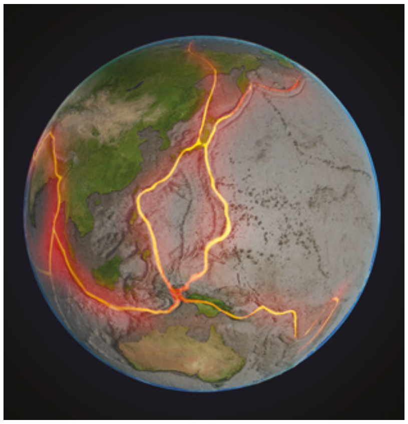


**FIGURE 13.9.1** Tectonic plate boundaries in the Asia-Pacific region.

**KEY TERMS**

**tectonic plate** large section of Earth's lithosphere that moves about on Earth's surface

**oceanic crust** more dense part of the crust that forms the ocean floor

**continental crust** less dense part of the crust that forms the continents

## Lesson overview

The tectonic plate theory says that the surface of Earth is divided into large segments (Figure 13.9.1). Due to the geology of Earth, these segments can move across the surface, pushing against, separating from, and sliding past each other. This theory was developed in the early 1900s, and today there is large body of evidence to support it.

In this lesson, you will learn about the theory of plate tectonics, how plates are able to move, and what impact these motions have on Earth.

**SC 1** I can describe the formation of the Earth and the tectonic plates

A very, very long time ago (4.5 billion years), Earth was formed when a part of a cloud of gas and dust, formed from a previous star's supernova explosion, clumped together under gravity.

Initially, Earth was an extremely hot, molten ball of all the elements. Due to gravitational forces, the heavy materials, such as iron and nickel, sunk to the centre of Earth, leaving the lighter materials near the surface. Eventually, this process created different layers within Earth, each of which have different properties.

These layers include the core, the mantle and the crust. The crust and the top layer of the mantle together form a hard, brittle layer called the lithosphere (Figure 13.9.2). Just below the lithosphere is the asthenosphere which is a part of the mantle that is solid but behaves plastically as the solid rock can bend and flow over long periods of time. At some point during the formation of Earth the lithosphere fractured into pieces which we call **tectonic plates**.

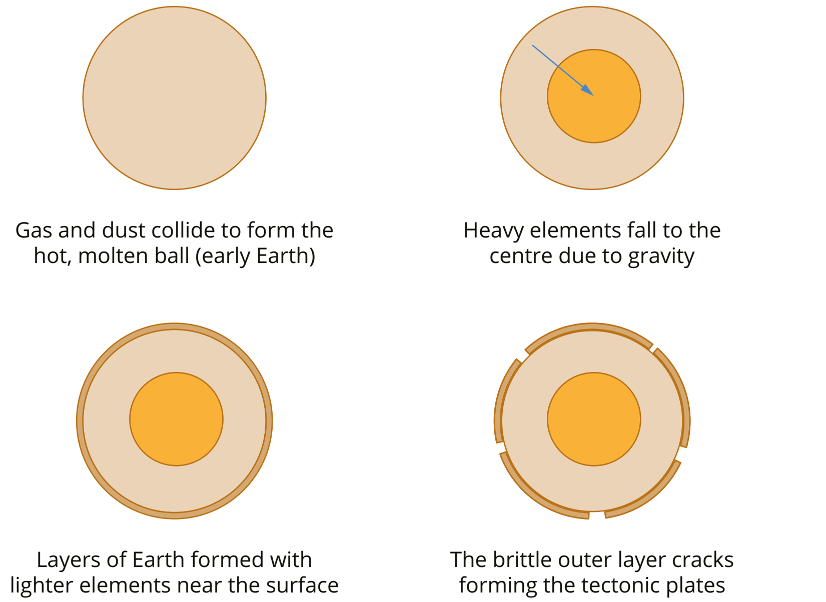



**FIGURE 13.9.2** Stages in the formation of Earth's layers and the tectonic plates.

## Continental or oceanic crust

The lithosphere's outer crust layer comes in two different types: oceanic and continental.

**Oceanic crust** is found on the ocean floor, and **continental crust** is found where there are continents.

Oceanic crust is generally more dense than continental crust.

**SC 1 CHECK YOUR UNDERSTANDING**

Compare the properties of the lithosphere and the asthenosphere.

**SC 2** I can identify the tectonic plates

In 1912, Alfred Wegener proposed a theory that the continents were drifting across the surface of Earth, and that they once had all been joined together in one super continent. Wegener called this large landmass Pangaea, meaning 'all Earth' (Figure 13.9.3).

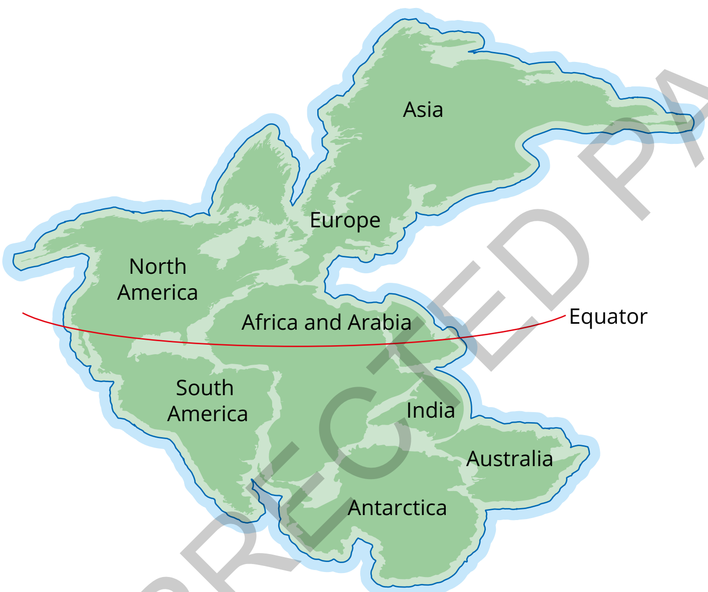



**FIGURE 13.9.3** Earth's continents are be lieved to have once been joined together in a supercontinent called Pangaea.

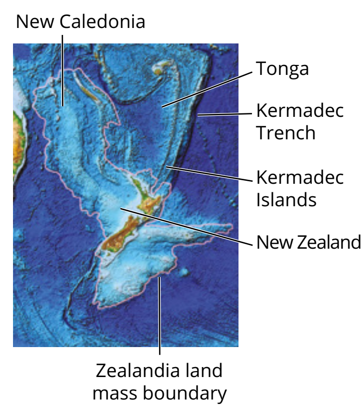
This theory was called continental drift, and at the time Wegener proposed it, it was highly contested. Today, the **theory of plate tectonics**, which now describes how this motion can occur, is widely accepted by the scientific community.

There are seven major tectonic plates on Earth. The massive, solid plates are constantly in motion over very long timescales. Each year, the tectonic plates move (on average) 1.5 cm. This isn't a big difference over a few years, but over geological time scales of millions of years, this movement causes some big changes to the structure of Earth's surface.

**Scifile**

### Australia's new and old neighbours

To Australia's east, the Pacific Plate is sinking beneath the Australian Plate. This forms the Kermadec Trench. Tonga and New Zealand's Kermadec Islands are island arcs forming as a result of this process. New Zealand and New Caledonia were once part of an ancient landmass, more than half the size of Australia, called Zealandia. It is believed that the central part of Zealandia sank under the ocean more than 23 million years ago. The remains of this landmass can be seen on satellite imagery.




**KEY TERMS**

**theory of plate tectonics**
scientific theory that describes the existence, and motion, of tectonic plates

The major tectonic plates are the African, Antarctic, Eurasian, North American, South American, Australian, and Pacific Plates. These are called major plates because they each have an area greater than 20 million km2. The smaller plates are called the minor plates. The minor plates include the Arabian, Caribbean, Cocos, Indian, Juan De Fuca, Nazca, Philippine (also known as Philippine Sea), and Scotia Plates (Figure 13.9.4).

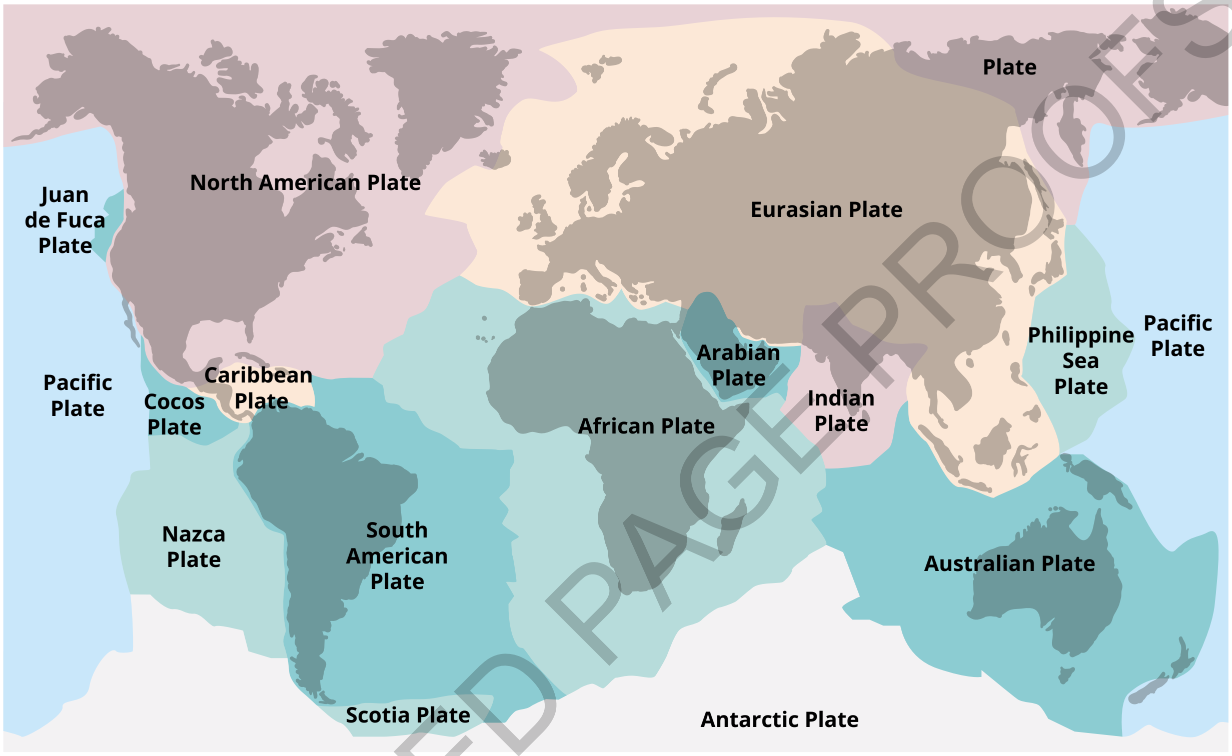



**FIGURE 13.9.4** Earth's lithosphere is broken up into major and minor tectonic plates.

**SC 2 CHECK YOUR UNDERSTANDING**

Name the seven major tectonic plates of Earth.

**SC 3** I can explain the forces of motion of tectonic plates

Tectonic plate movement is a fundamental process that shapes Earth's surface, leading to the formation of mountains, earthquakes, and volcanic activity. This movement is driven by several key mechanisms, including convection currents in the mantle, slab pull, and ridge push.

## Convection currents in the mantle

One of the primary drivers of tectonic plate movement is the convection currents in Earth's mantle. The mantle, which lies beneath Earth's crust, is composed of solid but slowly flowing rock. Heat from Earth's core causes the mantle material to heat up, become less dense, and rise towards the surface. As it reaches the upper mantle, it cools down, becomes denser, and sinks back towards the core. This continuous cycle of rising and sinking material creates **convection currents**.

**KEY TERMS**

**convection current** current that forms when warmer less-dense fluids rise while cooler, denser fluids sink

These convection currents act like a conveyor belt, dragging the overlying tectonic plates along with them (Figure 13.9.5). The movement of these plates can cause them to collide, pull apart, or slide past each other, leading to various geological phenomena.

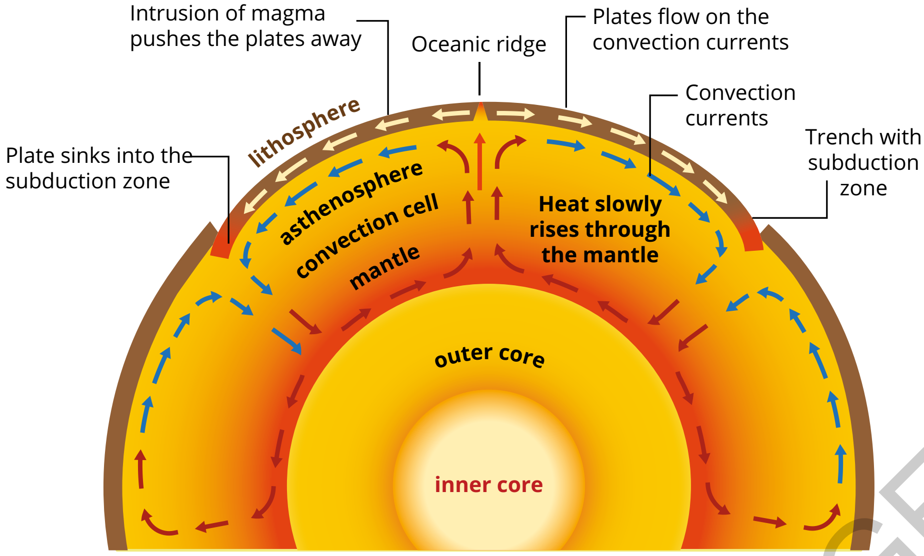



**FIGURE 13.9.5** Convection currents in the mantle drag the crust along with them.

## Slab pull and ridge push

New crust is made at places called **mid-ocean ridges**. A **rift valley** at the centre of a mid-ocean ridge is where magma rises to the surface. As the new crust cools and becomes denser, it spreads downwards and outwards from the ridge, pushing the tectonic plates apart with a force called **ridge push**. This allows new magma to rise to the surface and form rock at the mid-ocean ridge (Figure 13.9.6).

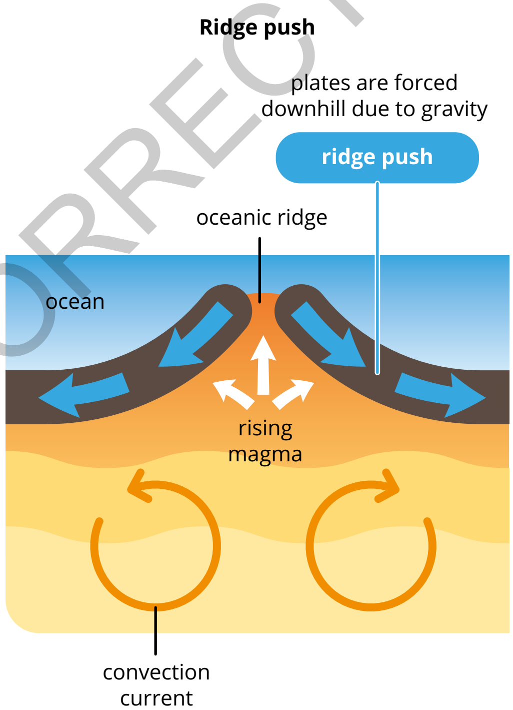



**FIGURE 13.9.6** Rising crust at an oceanic ridge is pulled down and outward due to gravity.

**KEY TERMS**

**mid-ocean ridge** a mountain chain on the floor of the ocean along the boundary of two tectonic plates
**rift valley** a low-lying valley created by the action of a geological rift or split, often at a diverging plate margin
**ridge push** older crust is pushed by new ocean crust at mid-ocean ridges, forcing plates apart

**KEY TERMS**

**subduction** when a more dense plate sinks below another, less dense plate during a collision

**slab pull** pulling force exerted by an older, colder and denser oceanic plate sinking down into the asthenosphere due to gravity, dragging the rest of the plate with it

At the boundaries between colliding plates, the plate that is denser will undergo a process called **subduction** due to gravity, in which the plate sinks below the less dense plate into the asthenosphere. The denser plate will then pull the following rock down with it. In the process of subducting the denser plate material heats up and melts to form magma. This process is called **slab pull** and is believed to be the main driving force for the motion of the tectonic plates (Figure 13.9.7).

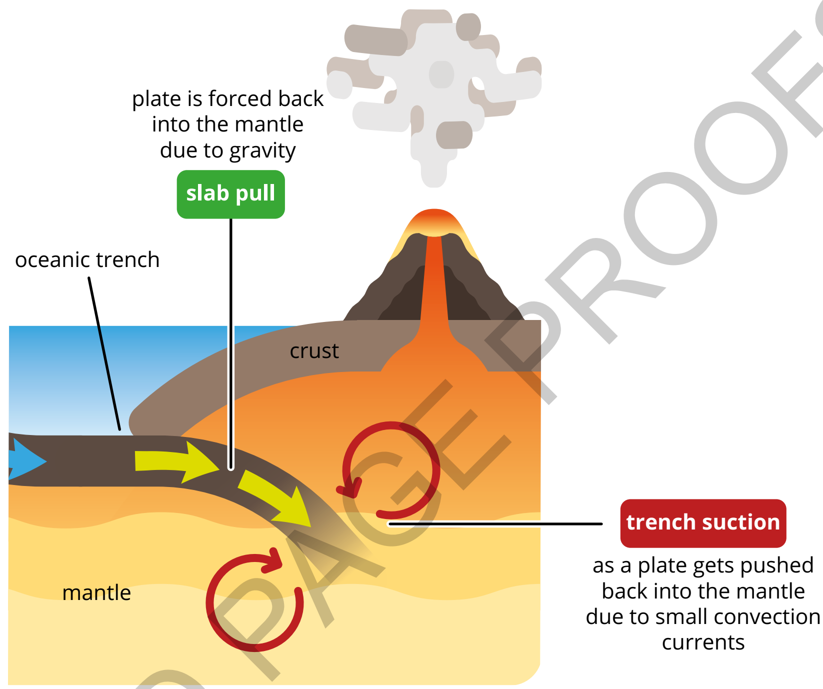



**FIGURE 13.9.7** Denser crust is pulled down under the less dense crust due to gravity.

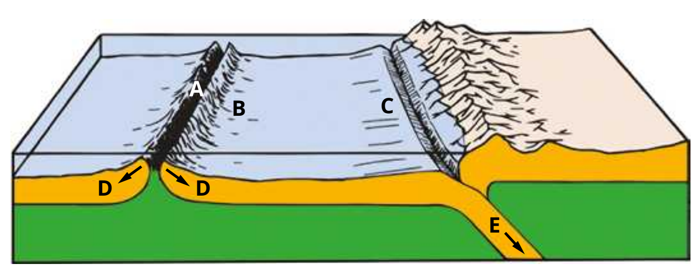
These two processes occur together so that, as sinking crust is destroyed while subducting into the mantle, new crust is created at the ridges.

Understanding the mechanisms behind tectonic plate movement, including the role of convection currents in the mantle, is crucial for comprehending the dynamic nature of our planet.

## SC 3 CHECK YOUR UNDERSTANDING

Choose from the following terms to identify the features and processes labelled A to E in the diagram below.

ridge push
mid-ocean ridge
newer oceanic crust
subduction and slab pull
older and denser oceanic crust



## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

**1** You are studying the internal structure of Earth.

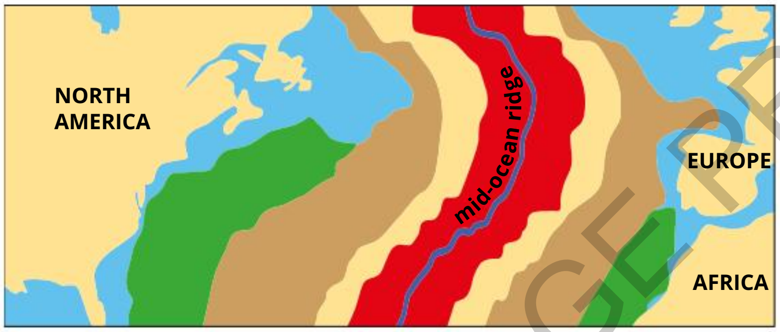
**a** State when scientists believe Earth first started to form.

**b** Describe the influence of gravitational forces on the formation of Earth's layers.

**c** What properties of the asthenosphere allow the tectonic plates of the crust move relative to each other?

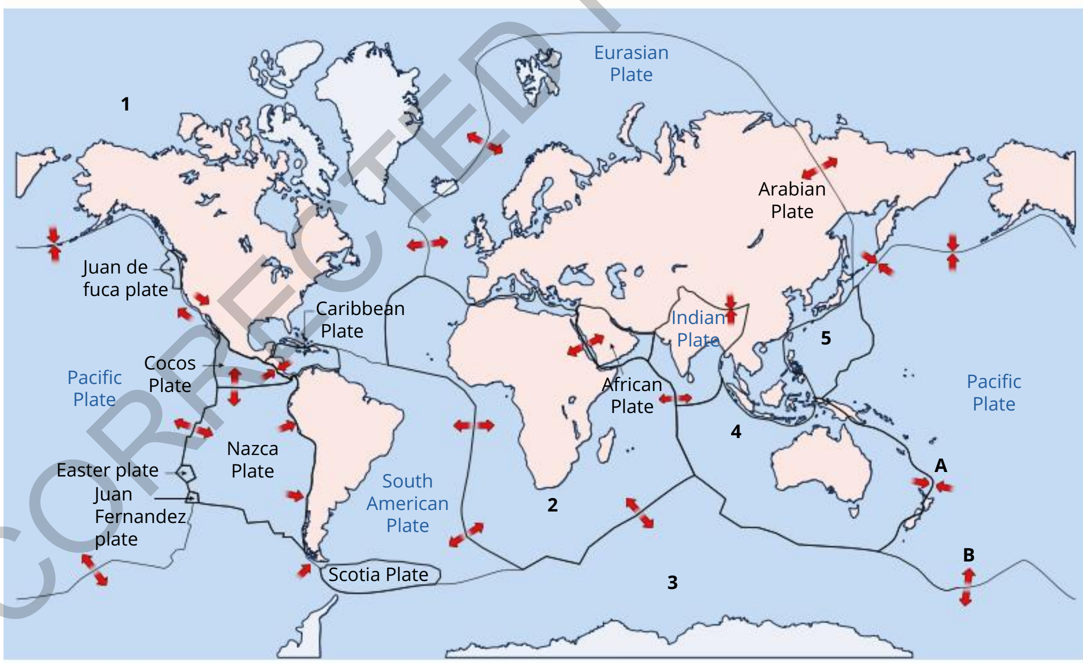
**2** Outline how oceanic crust differs from continental crust.

**3** The image below shows a mid-ocean ridge found in the Atlantic Ocean. Four colours (brown, green, orange and yellow) indicate different ages of the oceanic crust. Name the four colours in order from youngest crust to oldest.




**4** Describe the processes of convection in the mantle, slab pull and ridge push.

**5** Refer to the map of tectonic plates below.




Key

Magma can rise to the surface where plates are moving apart

Subduction occurs where plates are colliding

**a** Name the tectonic plates labelled 1 to 5.

**b** Slab pull and ridge push occur along many plate margins. Identify which process is occurring at the locations labelled A and B.

**c** Identify the location (A or B) where the oceanic crust would be younger and less dense. Explain why you selected this location.

# 13.10 Plate boundaries

**Learning intention**

To understand the geological features and events that occur at the different types of plate boundaries

**Success criteria**

**SC 1:** I can describe differences between convergent, divergent and transform plate boundaries.

**SC 2:** I can analyse the role of plate boundaries in the formation of geological features.

**FIGURE 13.10.1** The divergent tectonic boundary between the North American and Eurasian Plates forms a surface rift in the Mid-Atlantic Ridge at Silfra in Iceland.

## Lesson overview

The movement of the tectonic plates produces different geological features, changing the surface of Earth. The features that are formed depend on the types of plate boundaries that are interacting (Figure 13.10.1).

In this lesson, you will learn about the three types of plate boundaries and the different geological features they can produce.

| SC 1 | I can describe differences between convergent, divergent and transform plate boundaries |
|---|---|

### Convergent boundary

A convergent boundary is a boundary at which plates are being pushed together (Figure 13.10.2). Depending on the densities of the plates, one may subduct (go under) the other. Collisions between two lighter continental crusts produce mountain ranges as the equally dense continental crust is pushed up on both sides.

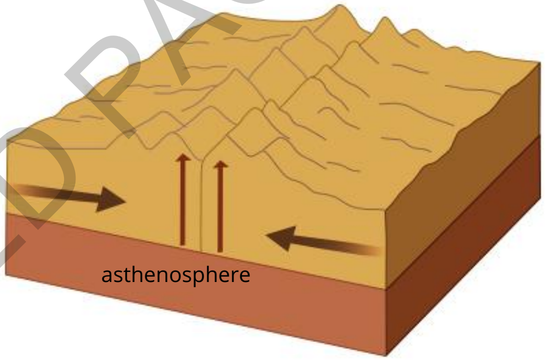



**FIGURE 13.10.2** Continental plates at convergent plate boundaries result in the uplift of the lithosphere to create mountain ranges.

### Divergent boundary

In a divergent boundary, two plates move apart from each other (Figure 13.10.3). New crust forms at a divergent boundary as magma rises from the mantle to Earth's surface between the two plates.

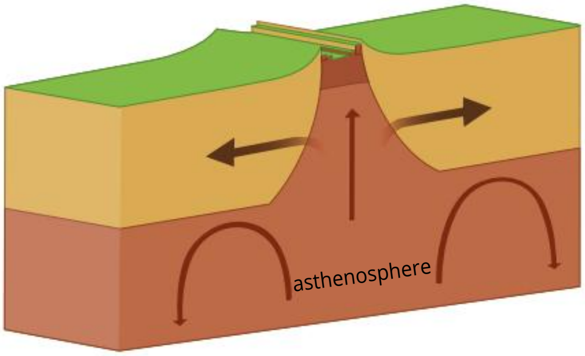



**FIGURE 13.10.3** At divergent plate boundaries, tectonic plates move apart allowing magma to rise to the surface.

## Transform boundary

In a **transform boundary**, two plates move alongside each other, either in opposite directions or in the same direction, but at different speeds (Figure 13.10.4). This movement sometimes generates earthquakes as pressure created by the movement is released.

**KEY TERMS**

**transform boundary** tectonic plate boundary where plates are sliding past each other either in opposite directions or in the same direction but at different speeds

### SC 1 CHECK YOUR UNDERSTANDING

Identify the type of plate boundary that shows the following features:

- **a** plates slide past each other either in opposite directions or in the same direction but at different speeds
- **b** plates collide with each other, resulting in subduction or the formation of mountain ranges
- **c** plates are moving apart from each other resulting in the formation of new crust at the plate boundary.

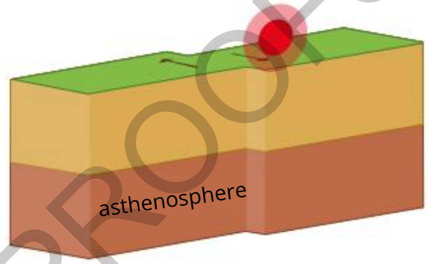



**FIGURE 13.10.4** At a transform plate boundary, tectonic plates move alongside each other, sometimes resulting in earthquakes.

**SC 2** I can analyse the role of plate boundaries in the formation of geological features

The interactions of different types of plate boundaries form different geological features. The outer crust of Earth can be categorised as either continental or oceanic. Oceanic crust is generally denser than continental crust. This difference in density can cause different formations to occur at plate boundaries.

## Mountains

When two plates collide the crust crumples and deforms, it can produce fold mountains (Figure 13.10.5).

The crust can be manipulated in two ways.

- At a convergent boundary of two continental plates, one plate may subduct under the other, but generally the plates are pushed upwards to form mountain ranges such as the Himalayas, due to their similar densities.
- At a convergent boundary between oceanic and continental crust, the denser oceanic plate subducts under the continental crust. During this process, the continental plate deforms and can create mountains and volcanoes such as in the Andes.

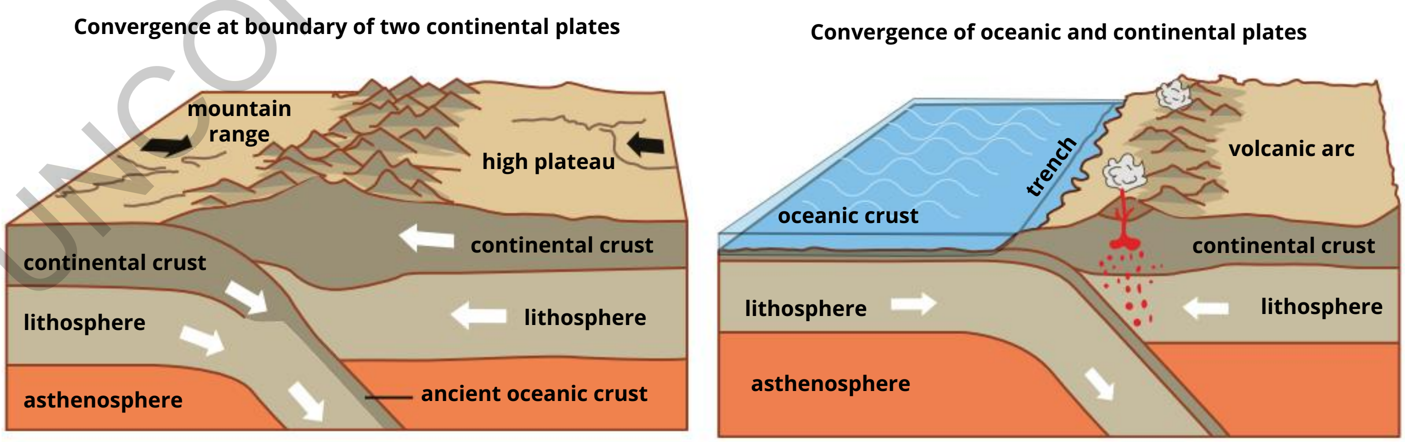



**FIGURE 13.10.5** Fold mountains form where two plates converge. When oceanic and continental plates converge, volcanoes also form.

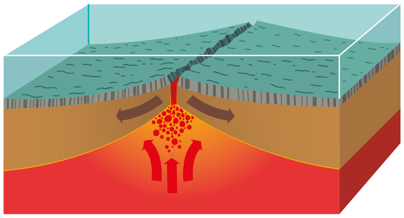


**FIGURE 13.10.6** Mid-ocean ridges form either side of a rift valley where magma rises to fill the gap left when two tectonic plates diverge.

## Rift valleys and ridges

Rift valleys are low-lying regions that form at divergent plate boundaries. When two tectonic plates separate, magma rises into the deep crack created. Rift valleys are mostly found at the bottom of the ocean where they are commonly associated with mid-ocean ridges (Figure 13.10.6). As the magma solidifies rapidly underwater, it creates new oceanic crust to form ridges with a rift valley in the centre of the ridge line, such as the Mid-Atlantic Ridge.

Rift valleys are sometimes found on continental lithosphere, such as the East African Rift Valley, which is forming where the African Plate and the Arabian Plate are diverging. On land, volcanoes may form along the ridge line when magma reaches the surface.

## Volcanoes

Volcanoes can be found at various types of plate boundaries:

- Convergent boundaries between oceanic and continental crust:
  When an oceanic plate subducts, or moves beneath, a continental plate, it causes the continental plate edges to crack, leading to the formation of volcanoes in the process (Figure 13.10.5).
- Convergent boundaries between two oceanic plates:
  In this scenario, when two oceanic plates converge, they create a chain of volcanic islands, forming what is known as a volcanic island arc (Figure 13.10.7).

Volcanoes can also form away from plate boundaries. These are known as hot spot volcanoes.

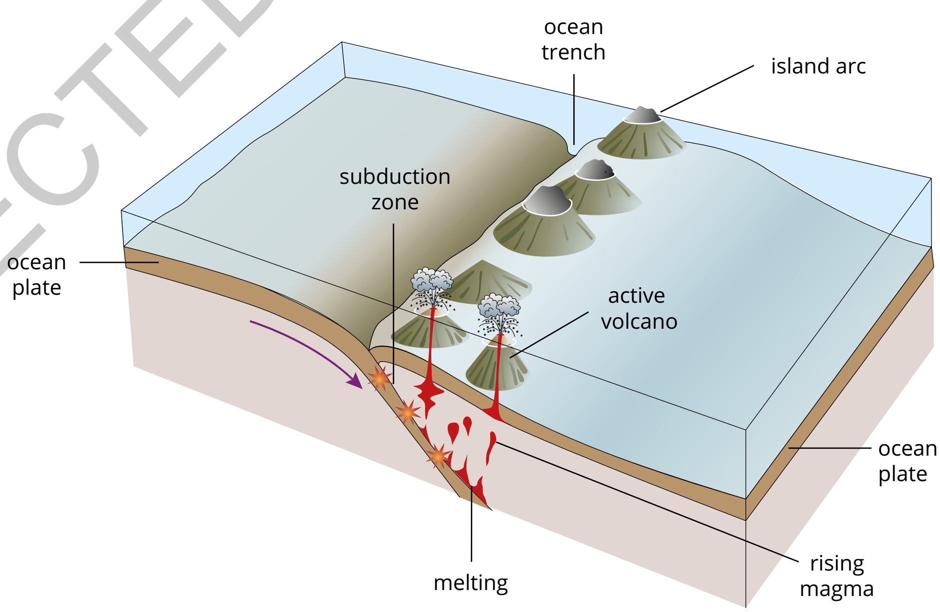



**FIGURE 13.10.7** Convergence between two oceanic plates can result in the formation of a volcanic island arc.

## SCIENCE IN CONTEXT

### Krakatoa – a world media sensation

Indonesia has over 150 active volcanoes, the most of any country. These are concentrated in the volcanic island arcs of Java and Sumatra where the Australian Plate subducts under the Eurasian Plate. Between the two lies Sunda Strait. Here, where the crust is believed to be stretched thin, magma rose to the surface to create four volcanoes in the Krakatoa Archipelago (Figure 13.10.8). One of these was known as Krakatoa.


**FIGURE 13.10.8** The Krakatoa Archipelago is located in Sunda Strait between the islands of Sumatra and Java in Indonesia.

On 26–27 August 1883, Krakatoa erupted violently in a series of explosions, destroying two thirds of the island and creating a caldera (a depression left by an exploding volcano). Scientists estimate that 25 km$^2$ of rock was ejected. Ash is estimated to have risen to 80 km in the atmosphere, with the local area in darkness for two and a half days. Global temperatures are recorded as falling by 0.5°C in the year following because the ash blocked radiation from the Sun. Pumice was so thick on the sea that it halted ships. The eruption was so violent it was heard in Alice Springs, Perth, and in Mauritius nearly 5000 km away. Scientists hypothesise that anyone within 16 km would have been deafened. However, people in this zone were more likely to have been killed either by the series of **tsunami** events triggered by the explosions, the suffocating ash cloud, and pyroclastic flows (eruptions of extremely hot gas, ash, and rock, some of which reached the Sumatran coast about 48 km away).

A total of 165 villages and towns were destroyed, and 132 seriously damaged, mostly by the series of tsunamis. The death toll was estimated to be up to 120 000 people.

Krakatoa still makes the news. However, it is now Anak Krakatoa (Son of Krakatoa) that is newsworthy. Anak Krakatoa emerged as an active volcano from the sea in the centre of the caldera in 1930 (Figure 13.10.9). In December 2018, part of Anak Krakatoa collapsed into the sea, generating a tsunami that killed more than 400 people and displaced 47 000.

**FIGURE 13.10.9** The active volcano Anak Krakatoa (Son of Krakatoa) emerged in 1930 in the caldera left behind by the 1833 explosion of Krakatoa.

**KEY TERMS**

**tsunami** a large and destructive ocean wave, or series of waves, caused by either a large earthquake on the seafloor, a landslide, or a volcanic eruption

**KEY TERMS**

**trench** a depression in the ocean floor

## Ocean trenches

A **trench** is a deep depression in the ocean floor. Trenches usually occur when an oceanic plate subducts (goes under) another oceanic or continental plate (Figure 13.10.10).

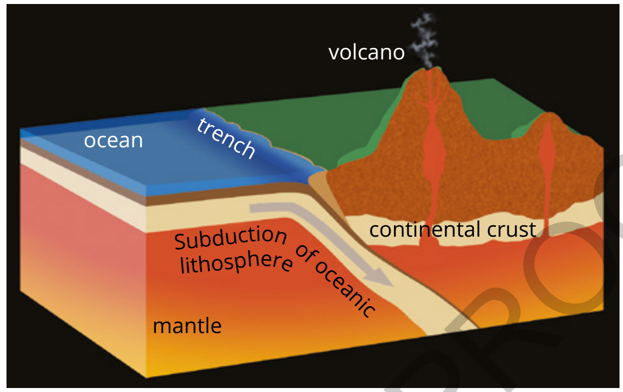



**FIGURE 13.10.10** Deep trenches form when an oceanic plate subducts under another tectonic plate.

**Scifile**

**Mariana Trench**

In the western Pacific where the Pacific Plate subducts beneath the Philippine Plate, the 2550 km long Mariana Trench and the Mariana Islands, a mostly dormant volcanic island arc, have formed. Mariana Trench is Earth's deepest oceanic trench, with the maximum known depth of 1000 m at a location called Challenger Deep.

## Earthquakes

Almost all earthquakes occur at the boundaries between plates. As the plates interact, sometimes energy is released. When one plate moves suddenly, we feel it as an earthquake.

Most earthquakes occur at convergent boundaries.

Earthquakes are also felt at transform boundaries, such as the San Andreas Fault between the Pacific and North American Plates which runs through California (Figure 13.10.11).

**FIGURE 13.10.11** The San Andreas Fault in California is a transform plate boundary.

**SC 2 CHECK YOUR UNDERSTANDING**

In the interactions between oceanic and continental plate boundaries, identify the crust that is most likely to subduct, and explain why.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 Define convergent, divergent and transform plate boundaries.

2 Explain why collisions between two continental crusts produce tall mountain ranges.

3 Identify the type(s) of plate boundaries involved in the formation of the following geological features:
   a fold mountains
   b mid-ocean ridges
   c earthquakes.

4 Compare the formation processes of ocean trenches and mid-ocean ridges.

5 Identify a real-world example of a geological feature found at each of the following types of plate boundary. Describe the processes involved in forming them.
   a convergent
   b divergent
   c transform

# 13.11 Inquiry activity: Modelling the different types of plate boundaries

## Introduction

There are three different types of boundaries between tectonic plates: convergent, divergent and transform. The boundaries produce different geological features due to the interactions between plates.

In this inquiry activity, you will create a model of one of the three boundary types and explore alternative models that you could use to demonstrate the interaction between tectonic plates.

**Learning intention**

To be able to model the different types of plate boundaries

**Success criteria**

**SC 1:** I can design a model that represents the different types of plate boundaries.

**SC 2:** I can use a model to explain the differences between types of plate boundaries.

**SC 3:** I can propose alternative models (physical or digital) to demonstrate plate boundaries.

## Background

The three boundary types are:

- convergent – where the two plates are moving towards each other
- divergent – where the two plates are moving away from each other
- transform – where the two plates are moving alongside each other (Figure 13.11.1).

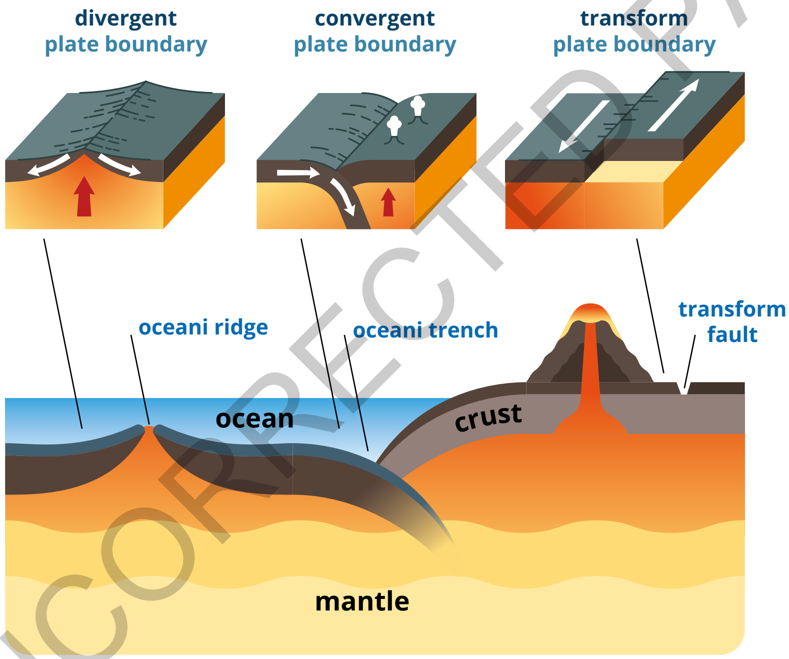



**FIGURE 13.11.1** The three types of boundaries between tectonic plat

When plates interact, geological features such as mountains, rift valleys, ridges, trenches and volcanoes are formed.

Oceanic crust is denser than continental crust, and this difference plays a part in the way plates interact between oceans and continents. You can make models by using different household items to show how the plates move and interact (Figure 13.11.2).

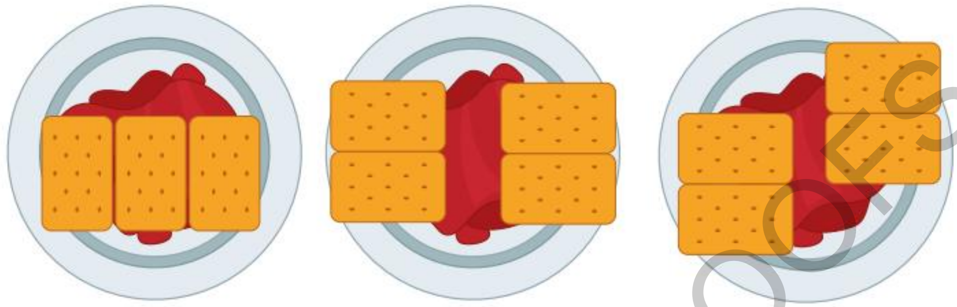



**FIGURE 13.11.2** Modelling plate boundaries with biscuits and jam

## Aim

To model the interactions between different plate boundaries by using household items.

To film a stop-motion video of your chosen plate boundaries.

## Plan

1 There are many types of interactions between plate boundaries that you can model. For your investigation, you will model one boundary type, which will be assigned by your teacher.

2 In your group, write down the boundary interaction you will be modelling. Work together as a group and note the types of crust (oceanic or continental) you will be representing with your model. Consider the density of the types of crust (i.e. is one crust type denser than the other?). Your group is to also select a geological formation formed at the boundary such as mountains, rift valley, ridge, ocean trench, volcano and fault.

3 Draw a diagram of your plate interaction. Include labels for the types of crust, lithosphere, asthenosphere and your chosen geological formation, and add arrows to show each plate's direction of movement.

4 Describe the physical properties of both the lithosphere and asthenosphere. Use the following terms in your descriptions: brittle, can flow, liquid, plastic and solid.

## Design

1 For your chosen plate boundary, select a household material to use for each layer. Some examples are:

- biscuits
- jam
- chocolate bars
- play dough
- deck of cards
- honey
- cardboard
- paper.

Record the materials you have chosen to model the lithosphere and the asthenosphere for both your boundary type and the types of crust involved in the interaction. Safety Note: If you chose a food to represent the crust, make sure you check with your teacher in case any of your classmates have allergies.

2 Explain why you chose each material.
3 Present your model design to your classmates. Comment on any design features or materials from your classmates' proposed boundaries that could also work in your boundary type.
4 In your group, finalise your model design by incorporating any improvements identified after the sharing of ideas by the class.
5 Determine how you will set up the recording of movement in your model to create the stop-motion video. Remember to get permission to the camera on a device, or alternately book a camera, or draw diagrams of the model.

## Conduct

1 Collect your materials and set up your model.
2 Manipulate your materials to represent the interaction at your designated plate boundary. As you do so, draw or get permission to record the interaction of the 'lithosphere' and 'asthenosphere' to create your stop-motion video.

## Improve

1 Review your classmates' videos. Describe how effective their presentations were at demonstrating the different boundary types.
2 What could you do to improve your own model?

## Discussion

1 Evaluate the benefits and limitations of each model in showing the differences between plate boundaries.
2 In this activity, you made a physical model of a plate boundary and used digital media to communicate it. Write a proposal to a STEM company about a digital model they could use to demonstrate the different plate boundaries and the importance of understanding plate tectonics. Your proposal could include:
   - software used or how the model is built
   - format of communication
   - annotations of the model
   - three key impacts of plate tectonics on the environment.

# 13.12 Earthquake and volcanic activity

### Learning intention

To understand the reasons for patterns of earthquake and volcanic activity around the globe

### Success criteria

**SC 1:** I can describe patterns in the locations of earthquakes and volcanoes.

**SC 2:** I can describe how earthquakes are detected.

### KEY TERMS

**earthquake** the rapid movement of the ground, usually back and forth and up and down in a wave motion, due to the movement of tectonic plates

**seismometer** an instrument that detects the seismic waves from an earthquake

## Lesson overview

Volcanic eruptions and earthquakes can cause a great deal of destruction. By understanding the processes involved when an earthquake occurs and a volcano erupts, scientists and engineers can better prepare people for a possible disaster.

In this lesson, you will learn about the locations of earthquakes and active volcanoes and how scientists measure the magnitude of an earthquake.

| | |
|---|---|
| **SC 1** | I can describe patterns in the locations of earthquakes and volcanoes |

## Earthquakes

**Earthquakes** are sudden movements in Earth's crust. Some can cause significant damage, while others are weak and can only be detected by sensitive instruments, called **seismometers**.

## Volcanoes

A volcano is formed where there are cracks or gaps in Earth's crust. This allows lava, ash and gases to escape from below the surface, often forced out by extreme pressures.

### Scifile

#### Volcano lightning

During eruptions from the more explosive composite volcanoes, lightning can often be seen in the ash plume or ash cloud. This happens because the ash particles create static electricity, similar to how thunderclouds produce lightning. During the eruption of Washington's Mt St Helens volcano in 1980, bolts of lightning struck the ground, sheet lightning lit up the ash plume, and very rare ball lightning was also observed.

## Volcanoes and earthquakes around the world

Figures 13.12.1 and 13.12.2 show data of earthquakes and volcanoes around the world. Notice some of the similarities between these two maps.

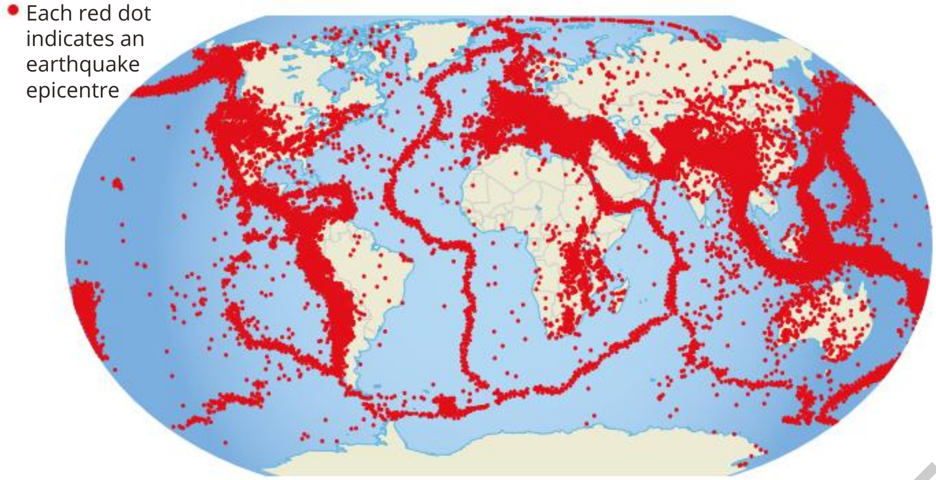



**FIGURE 13.12.1** Distribution of earthquakes around the world.


**FIGURE 13.12.2** Distribution of active volcanoes around the world.



Earthquakes and volcanic activity are recorded by a network of **seismographs**. The **seismic data** is then used to predict potential follow-up earthquakes (aftershocks) and the likelihood of volcanic eruptions. Countries use the live data to plan for evacuations and other disaster preparations.

**KEY TERMS**

**seismograph** a seismometer that is connected to a recording device

**seismic data** data about movements of the ground that is used by scientists to study and monitor earthquakes

## Patterns in the data

Active volcanoes and earthquakes don't usually occur evenly all over the surface of Earth. The live seismic data shows that volcanoes and earthquakes more commonly occur together in concentrated areas along tectonic plate boundaries. In the Asia-Pacific region, these areas are concentrated around Indonesia, Philippines, Japan and New Zealand. These islands coincide with where the Australian, Philippine, Eurasian and Pacific Plates interact.

## Tectonic plates

Earth is made up of different layers of material. The outermost layer is broken up into large pieces known as tectonic plates (Figure 13.12.3).

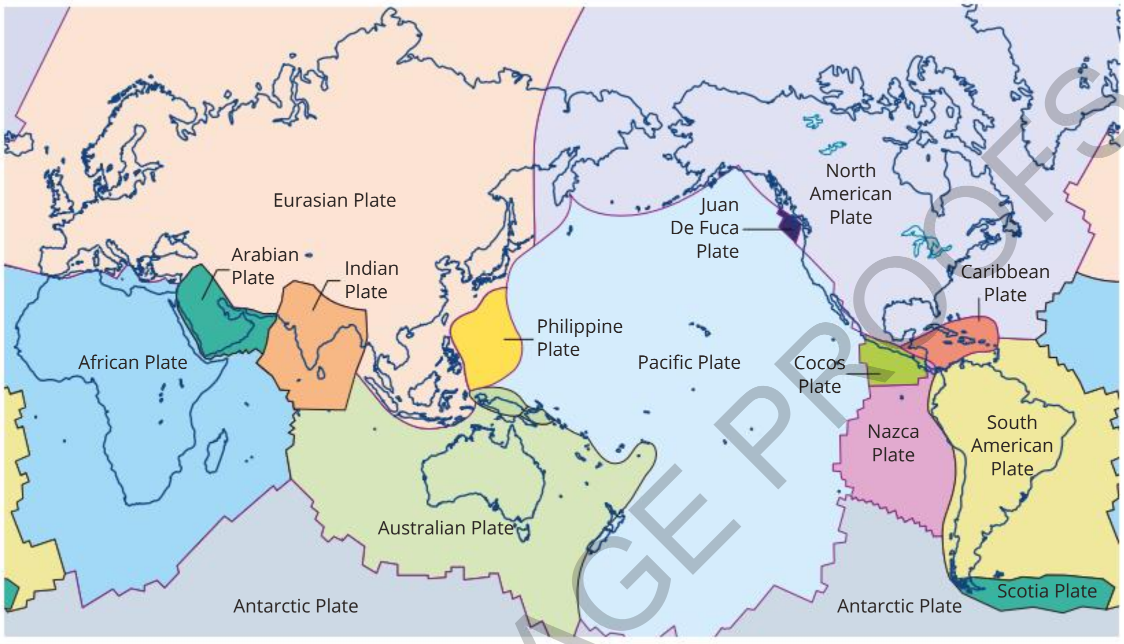



**FIGURE 13.12.3** The surface of Earth is broken up into major and minor tectonic plates.

The areas where two plates meet coincide with the areas where the greatest number of active volcanoes and earthquakes occur. The interaction of the tectonic plates generally causes both natural events to occur.

Not all volcanoes occur on these boundaries though.

**KEY TERM**

**hot spot** isolated place away from plate boundaries where a lot of hot magma is collecting

## Hot spot volcanoes

Sometimes volcanoes form far away from a plate boundary. These are known as **hot spot** volcanoes (Figure 13.12.4). A hot spot is an area where super-hot material rises from inside Earth. The hot spot does not move.

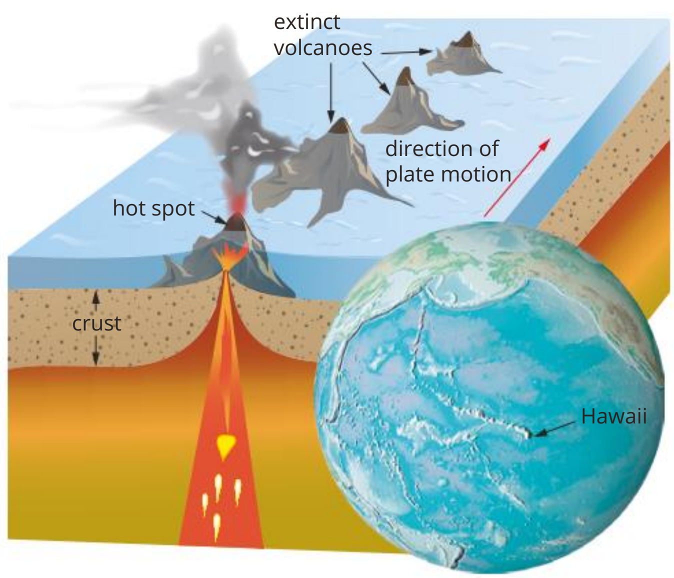



**FIGURE 13.12.4** Volcanoes are formed as a tectonic plate moves across a hot spot.

As a tectonic plate moves over a hot spot area, a volcano can form. As the plate continues to move, a chain of island volcanoes is created. The volcanoes become firstly dormant and then extinct as they move away from the hot spot. This phenomenon can be seen in Hawai'i, where a chain of extinct and active volcanoes has been formed as the plate moves over the hot spot.

**SC 1 CHECK YOUR UNDERSTANDING**

Compare the location of hot spot volcanoes and the location of most of Earth's active volcanoes.

**SC 2** I can describe how earthquakes are detected.

When an earthquake causes the ground to shake, it transfers energy from the interaction between the plate boundaries into the back-and-forth, up-and-down or side-to-side wavelike motion of the ground. These waves are called **seismic waves**. The waves travel outward from the point where the earthquake occurred underground. This point is called the **focus**. The focus can be anywhere from deep underground to close to the surface.

The **epicentre** of an earthquake is the point on the surface of Earth directly above the focus (Figure 13.12.5).

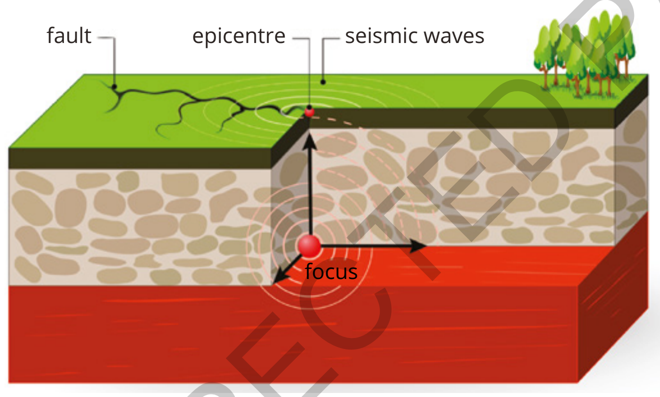



**FIGURE 13.12.5** The location of an earthquake's focus and epicentre.

There are three types of waves involved resulting from an earthquake:

## Primary waves (P-waves)

Primary waves travel the fastest and can travel through solids, liquids and gases.

## Secondary waves (S-waves)

Secondary waves are slower than P-waves and can only travel through solids.

## Surface waves

**Surface waves** only travel along the surface of Earth and can cause the most damage. They are also the slowest of the three waves.

### DISCOVER MORE

When a volcano no longer has a magma supply and it is unlikely to erupt in the future, it is considered extinct. Volc anoes that have not erupted for a long time but may erupt in the future are called dormant (or inactive). Active volcanoes show signs of activity and may erupt in the near future.

### KEY TERMS

**seismic wave** the shaking, wave-like movement of the ground in an earthquake
**focus** the place below ground where an earthquake starts
**epicentre** the point on Earth's surface directly above the focus of an earthquake
**surface wave** type of earthquake wave that does not penetrate Earth but travels along the ground

## Detecting earthquakes

Scientists invented instruments called seismometers, which can detect when an earthquake is occurring. The full device is called a seismograph when it is connected to some sort of recording device (Figure 13.12.6). A heavy mass resists the motion of the earthquake while the rest of the instrument is caused to shake. The motion is then recorded as a **seismogram** (Figure 13.12.7). Seismograms may be recorded on paper or recorded digitally.

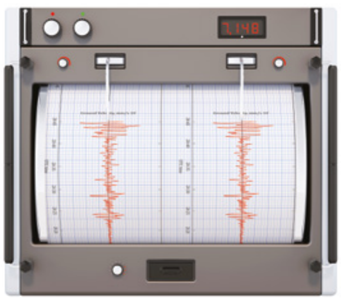


**FIGURE 13.12.6** A seismograph detects, measures and records seismic vibrations.

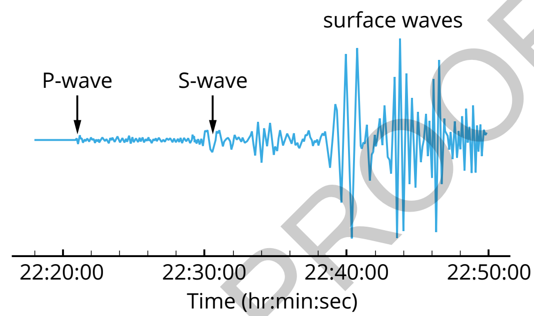



**FIGURE 13.12.7** A seismogram is a record of seismic vibrations including the different arrival times of P-waves, S-waves and surface waves.

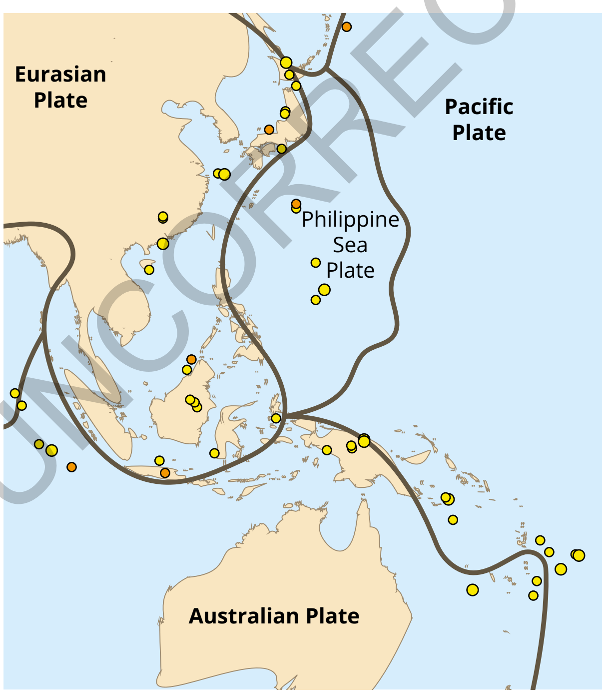
**SC 1 CHECK YOUR UNDERSTANDING**

Describe the relationship between the epicentre and the focus of an earthquake.

## Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

1 Refer to the image below which shows the locations of magnitude 4.5+ earthquakes in the Asia-Pacific region.




a Describe the distribution of earthquakes.
b Explain why the earthquakes are located where they are.
c Name the tectonic plates that are interacting in this section of the Asia-Pacific region.
d Identify a natural feature you could expect to see where earthquakes occur.

2 The Galapagos Islands are a series of volcanic islands in the Pacific Ocean. Many of the volcanoes are now extinct, but Isabela Island and Fernandina Island have several active volcanoes. The Galapagos Islands are located on the Nazca Plate at some distance from the plate's boundaries. Explain why these islands would be forming here.

3 Identify the type of seismic wave that has the following features:
a can only travel through solids and are slower than the waves that can travel through solids and liquids
b can only travel along Earth's surface but, despite being the slowest of the seismic waves, they can do the most damage
c travel the fastest and can travel through solids and liquids.

# 13.13 First Nations Australians' accounts of geological events

## Introduction

Australia's First Nations Peoples have a rich history of storytelling that has been passed down through generations. These stories often contain detailed accounts of natural events, both on land and under the sea. Understanding these accounts can provide valuable insights into the geological history of Australia. For example, the Yuin People of New South Wales have stories about Gulaga (Mount Dromedary) (Figure 13.13.1), which describe the mountain's creation and its significance to the Yuin People.

In this inquiry activity, you will investigate First Nations accounts of geological events and explain how these stories contribute to our understanding of Australia's geology.

**FIGURE 13.13.1** Gulaga (Mt Dromedary) in the Gulaga National Park.

## Background

First Nations Australians have a profound and enduring connection to the land and sea that spans tens of thousands of years. This connection is deeply rooted in their cultural practices, spiritual beliefs, and daily lives.

Their oral histories, passed down through generations, include detailed accounts of significant geological events such as volcanic eruptions, earthquakes, and changes in sea levels. For instance, the Awabakal and Worimi Peoples' Dreaming story, 'The Kangaroo that lives inside Nobbys', speaks of a kangaroo believed to reside within Nobbys, a prominent headland in Newcastle, New South Wales (Figure 13.13.2), reflecting the cultural and geological significance of the landscape.

### Learning intention

To understand how accounts of First Nations Australians provide evidence of earthquakes and volcanoes on Country or under the sea

### Success criteria

**SC 1:** I can describe a case study of a First Nations account(s) related to a geological event or events.

**SC 2:** I can explain how First Nations Peoples remember geological event(s).

**SC 3:** I can describe how accounts of First Nations peoples has informed understanding of the geology of Australia.

**FIGURE 13.13.2** The Kangaroo that lives inside Nobbys is a dreamtime story by the Worimi people about the formation of the Nobbys headland in Newcastle.

Similarly, the Bundjalung Peoples' Dreaming stories about Wollumbin (Mount Warning), such as 'the Warrior Chief' and 'the Turkey', describe the creation and significance of the mountain formed by an ancient volcanic eruption. These stories are not only cultural treasures that preserve the rich heritage and identity of First Nations communities, but they also serve as valuable scientific records.

## Aim

To investigate First Nations accounts of geological events and understand their significance in geology

## Plan

Choose a specific First Nations account of a geological event to research. Plan how you will gather information, including the sources you will use. Consider how you will present your findings, such as through a written report, presentation, or visual display.

## Design

1 Identify a First Nations group and a specific geological event they have documented.

2 Research the chosen account using reliable sources, such as academic articles, books, and reputable websites.

3 Take detailed notes on the account, focusing on the de cription of the event, how it was remembered, and its significance.

**Scifile**

**Volcanoes and memory**

Did you know that some First Nations Australians have stories about volcanic eruptions that happened thousands of years ago? These stories have been passed down through generations and provide valuable insights into the geological history of Australia.

4 Plan how you will present your findings, ensuring you address all success criteria.

5 Create an outline of your presentation or report, including key points and supporting evidence.

## Conduct

1 Use the following websites to gather information:

   a Australian Institute of Aboriginal and Torres Strait Islander Studies (AIATSIS): https://aiatsis.gov.au

   b National Library of Australia: https://www.nla.gov.au

   c Indigenous Weather Knowledge: http://www.bom.gov.au/iwk/

   d The Conversation: https://theconversation.com/au

2 Collect information from multiple sources to ensure accuracy and comprehensiveness.

3 Organise your notes and evidence logically, ensuring you cover all aspects of the success criteria.

4 Begin drafting your report or presentation, incorporating quotes and references from your sources.

## Improve

1 Review your draft to ensure all success criteria are met.

2 Check for clarity and coherence in your explanations and descriptions.

3 Seek feedback from peers or your teacher and make necessary revisions.

4 Ensure your presentation or report is visually engaging and well-organised.

5 Practice presenting your findings to ensure confidence and fluency.

## Discussion

1 Reflect on the quality and depth of your research.

2 Assess how well you have explained the significance of the First Nations account in understanding Australia's geology.

3 Consider how effectively you have communicated your findings.

4 Identify any areas for improvement in your research or presentation process.

5 Evaluate the overall impact of your work on your understanding of the topic.

# 13.14 Evidence for the theory of plate tectonics

**Learning intention**

To understand evidence that supports the theory of plate tectonics

**Success criteria**

**SC 1:** I can identify evidence to support the theory of plate tectonics.

**SC 2:** I can analyse sources of data related to the theory of plate tectonics.

**KEY TERMS**

**geology** the study of Earth
**geosphere** all the rocks, minerals and landforms that make up Earth
**divergent boundary** tectonic plate boundary where plates are moving apart from each other
**magnetic striping** patterns of magnetism trapped in rocks on each side of plate boundaries

## Lesson overview

The theory of plate tectonics has been developed over the past 100 years or so and became an accepted theory around the 1960s. Scientists use multiple pieces of evidence to support the theory.

In this lesson, you will learn about the types of evidence for plate tectonics, including the formation of mountains and volcanoes, seafloor spreading, and magnetic striping.

**SC 1** I can identify evidence to support the theory of plate tectonics

## Identifying evidence

**Geology** is the science of Earth's structure and the substances it is composed of. The **geosphere** describes any of Earth's layers, from the surface all the way to the core. A constantly growing body of evidence from geologists supports the theory of plate tectonics.

We cannot see the plates moving with our eyes, so how do we know the tectonic plates are moving?

Some evidence of plate tectonics is easy to see, such as the formation of mountains or the existence of hot spot volcanoes, but other evidence is less obvious. Examples of evidence related to plate tectonics are provided below.

## Seafloor spreading

Seafloor spreading is a process that occurs because tectonic plates are separating. It happens at **divergent boundaries** (Figure 13.14.1).

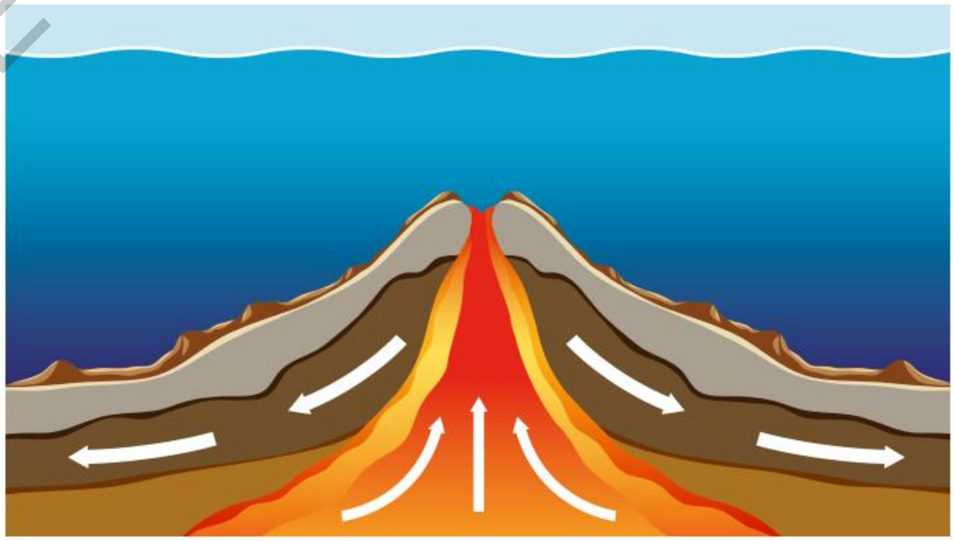


**FIGURE 13.14.1** Sea floor spreading occurs at divergent plate boundaries.

There is strong quantitative evidence to support the process of seafloor spreading, including **magnetic striping** and the dating of minerals.

## Magnetic striping

Earth has a magnetic field as discussed earlier in this topic. The direction of this magnetic field changes over time. For example, 780 000 years ago, Earth's magnetic field flipped, reversing the north and south poles.

When you hold a compass, the needle aligns itself with Earth's magnetic field so that it points north. Similarly, the particles in certain minerals (such as magnetite) align themselves with Earth's magnetic field.

In the 1950s, scientists analysed the data recorded of the direction of magnetism in the rocks along mid-ocean ridges. They found that as they moved further from the ridge on each side, an alternating pattern developed for the direction of Earth's magnetic field (Figure 13.14.2). This phenomenon is known as magnetic striping. The pattern that developed showed that the rocks magnetic direction recorded as they moved further from one side of the mid-ocean ridge matched the pattern on the other side. This pattern, recorded in the rocks, is what is referred to as 'magnetic striping'.

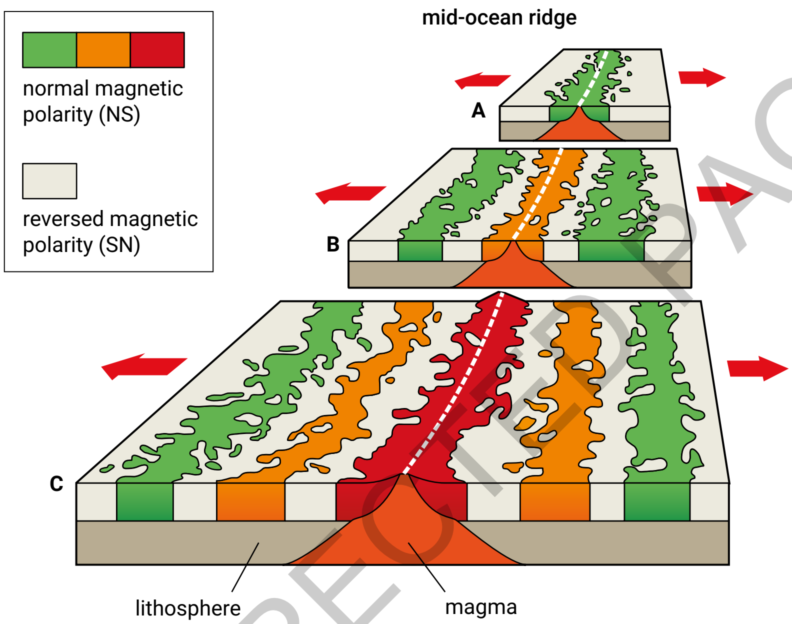



**FIGURE 13.14.2** Magnetic striping is due to new seafloor forming on each side of a crack or rift in the crust. The time sequence here goes from A (oldest) to C (youngest).

The symmetrical pattern emerges because, as new crust forms simultaneously along the ridge, the magnetic fields of the rocks at each individual location, or point, align consistently in the same direction. This empirical evidence supports the theory of seafloor spreading and tectonic plates because it shows that new crust is being produced at mid-ocean ridges and is moving away.

## Dating rocks

Scientists can determine the age of rocks with a range of dating techniques, including **radiometric dating**. Radiometric dating measures the radioactive elements in a substance. Some radioactive elements decay over extremely long periods of time. The amount of radioactivity left can be used to indicate the age of the substance it is found in.

**KEY TERMS**

**radiometric dating** a technique for determining the age of rocks that measures the radioactive elements in a substance

Dating measurements have found that the rocks of the oceanic crust are youngest near the mid oceanic ridge and get progressively older as they get further away. Rocks on continents are much older, with some rocks dating back billions of years. These empirical findings show that new rocks are formed closer to divergent boundaries (Figure 13.14.3).

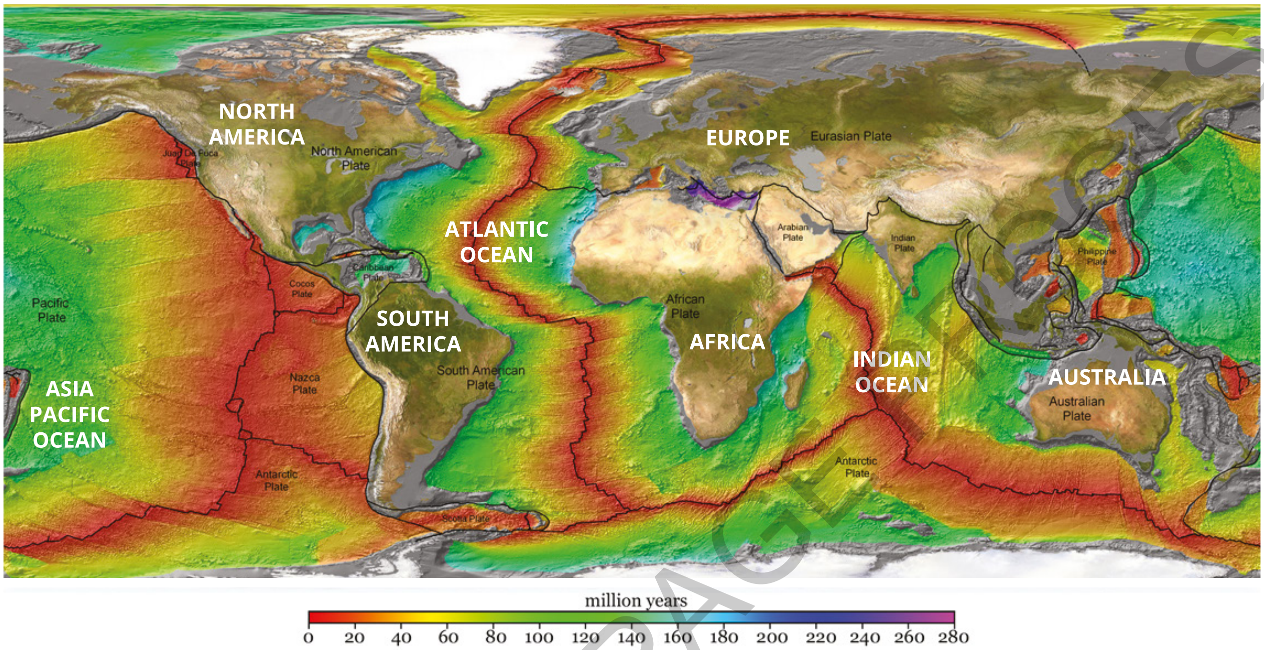



**FIGURE 13.14.3** Age of Oceanic Lithosphere in millions of years. Newer oceanic crust is found at mid-ocean ridges (shown in red). The further away from the mid-ocean ridges you go the older the rocks are.

This is evidence of plate tectonics because it shows new crust is being produced at mid-ocean ridges (similar to the evidence provided by magnetic striping). The evidence also supports the theory of ridge push occurring at these plate boundaries.

## SCIENCE IN CONTEXT

### Marie Tharp – Pioneering Geologist and Oceanographic Cartographer

Marie Tharp was a groundbreaking geologist and oceanographic cartographer whose work fundamentally changed our understanding of the ocean floor and the processes that shape it.

In 1948, Tharp joined the Lamont Geological Observatory at Columbia University, in New York, where she began working with geologist Bruce Heezen. Together, they embarked on a project to map the ocean floor, a task that had never been done before. Using data collected from echo soundings Tharp meticulously converted these measurements into detailed topographic maps.

### Discovery of the Mid-Atlantic Ridge

As she plotted the data, Tharp noticed a continuous, valley-like rift running down the centre of the Atlantic Ocean. This feature, known as the Mid-Atlantic Ridge, was a crucial piece of evidence supporting the theory of plate tectonics and continental drift, which were highly controversial at the time.

Tharp's discovery of the rift valley was initially met with skepticism. However, her detailed and accurate maps provided compelling visual evidence that the ocean floor was not a flat, featureless expanse but a dynamic landscape shaped by tectonic processes. Her work helped to convince the scientific community of the validity of plate tectonics and altered our understanding of Earth's geology.

## Hot spot volcanoes

Volcanic islands form where an oceanic plate sits over a hot spot. When the plate moves, the volcanic island moves with it, and a new volcanic island forms above the hot spot. The formation of volcanic island chains is implied evidence for the theory of plate tectonics.

The volcanoes on Fernandina Island and Isabela Island (Figure 13.14.4), two islands in the Galapagos Island arc, are very active as they are very near or above the Galapagos hot spot.

**FIGURE 13.14.4** The Galapagos hot spot has formed the active volcanoes on Fernandina and Isabela Islands.

## GPS monitoring

The global positioning system (GPS) is a system of satellites, ground-based sites and receivers. GPS is used for navigation. For example, maps on your phone use GPS to show your location.

GPS is used alongside other mapping techniques to accurately determine how fast plates are moving and in which direction. To do this, GPS monitoring stations are fixed to the ground so that they move with the continental crust. The position of these stations is monitored by satellites that record their exact latitude and longitude over time. GPS monitoring has shown that the Australian Plate is moving north-east at about 7 cm each year. This is empirical evidence for the theory of plate tectonics.

### SC 1 CHECK YOUR UNDERSTANDING

Use the descriptors below to identify the type of evidence used to currently support the theory of plate tectonics

**a** Satellites monitor both the direction and speed of movement of a particular point on Earth's surface.

**b** The same patterns of magnetism in the rocks occur at similar distances either side of mid-ocean ridges.

**c** New crust forms at mid-ocean ridges and slowly moves outwards.

**d** There is more radioactivity of elements in rocks in oceanic crust found closest to the mid-ocean ridges.

**SC 2** I can analyse sources of data related to the theory of plate tectonics

## Analysing evidence

Research into the theory of plate tectonics and the inner workings of Earth are ongoing. However, there are still some big unanswered questions. The collection and analysis of evidence can take many forms.

## Continental fit

One of the earliest pieces of evidence for plate tectonics is the jigsaw-like fit of the continents. If you look at a map (Figure 13.14.5), you can see how the coastlines of South America and Africa seem to fit together. This observation was first noted by Alfred Wegener in the early twentieth century. He proposed that the continents were once part of a supercontinent called Pangaea, which later broke apart.


**FIGURE 13.14.5** A stamp commemorating Alfred Wegener's life and work in plate tectonics

Wegener's observation was not just based on the visual fit of the coastlines. He also considered the geological structures and rock formations on these continents. For instance, the mountain ranges in eastern South America and western Africa align perfectly when the continents are placed together. This alignment suggests that these mountain ranges were formed as a single range before the continents drifted apart. Additionally, the types of rocks found in these regions are similar in age and composition, further supporting the idea that the continents were once connected.

## Fossil evidence

Fossils of the same species have been found on continents that are now widely separated by oceans. For example, fossils of the extinct plant *Glossopteris* have been found in South America, Africa, Antarctica, India, and Australia. This suggests that these continents were once connected, allowing the plants to spread across them (Figure 13.14.6). The distribution of *Glossopteris* fossils is particularly significant because this plant could not have dispersed across vast oceans.

Similarly, fossils of the reptile *Mesosaurus* have been found in both South America and Africa. *Mesosaurus* was a freshwater reptile, and it is unlikely that it could have crossed the Atlantic Ocean. The presence of its fossils on both continents supports the idea that they were once connected.

In addition to *Glossopteris* and *Mesosaurus*, other fossil evidence includes the remains of the land-dwelling reptile *Lystrosaurus*, which have been found in Africa, India, and Antarctica. The widespread distribution of these fossils provides strong evidence for the theory of plate tectonics and the existence of Pangaea.

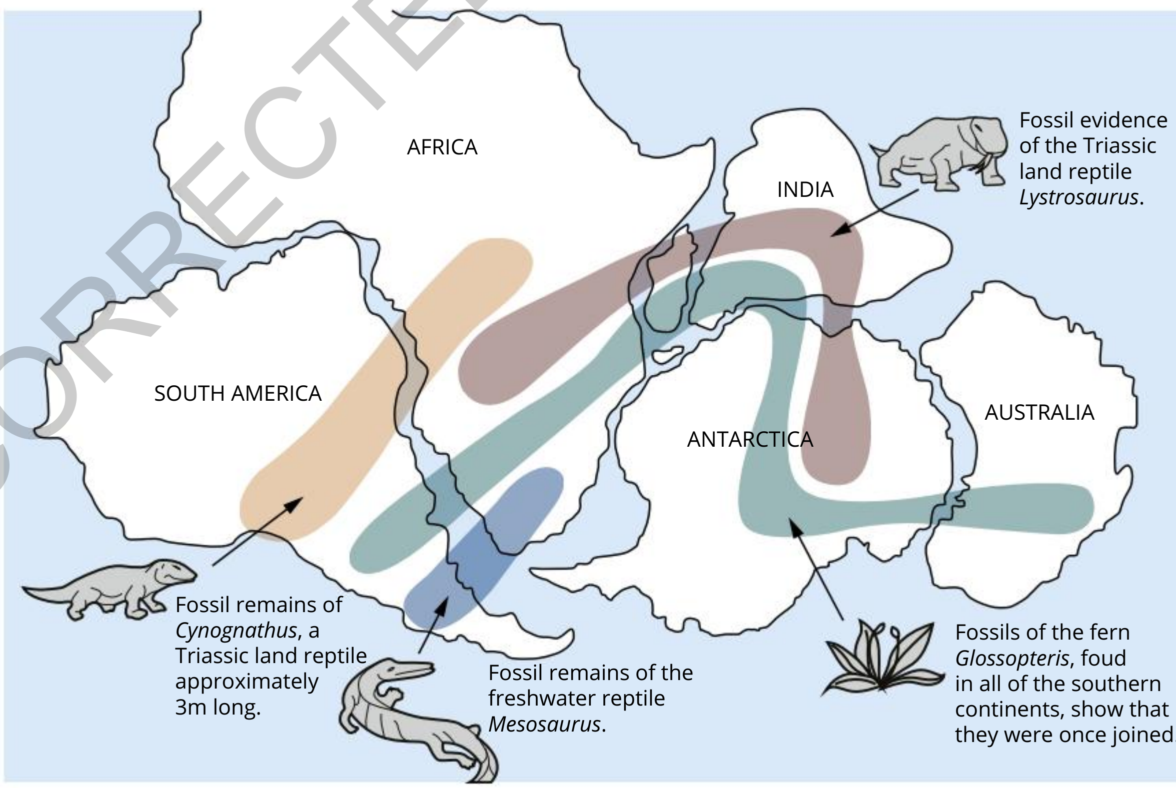



**FIGURE 13.14.6** Fossil evidence spread across different continents that are now separated by vast oceans.

## Rock formations and mountain ranges

Similar rock formations and mountain ranges are found on continents that are now separated. For instance, the Appalachian Mountains in North America are geologically similar to the Caledonian Mountains in Scotland and Scandinavia. This indicates that these regions were once part of the same landmass.

## Paleoclimatic evidence

Evidence of past climates (paleoclimates) also supports the theory of plate tectonics. For example, glacial deposits have been found in present-day tropical regions, suggesting that these areas were once located near the poles. Similarly, coal deposits, which form in warm, swampy conditions, have been found in Antarctica.

## GPS evidence

Ground-based stations are built into rock so they can move when the ground moves. GPS satellites monitor the positions of the ground-based stations over time.

Data from a Sydney-based site shows the position of the Australian Plate between 2003 and 2015 (Figure 13.14.7). Increasing positive numbers indicate that the plate is moving east. Increasing negative numbers indicate that the plate is moving west. Overall, this Sydney-based site moved in an easterly direction during the data collection period. Scientists can analyse the data in these graphs to find the overall rate at which a plate is moving by determining the gradient. For example, in the graph below, you can see that, between the years 2010 and 2012, the plate moved approximately 40 mm towards the east.

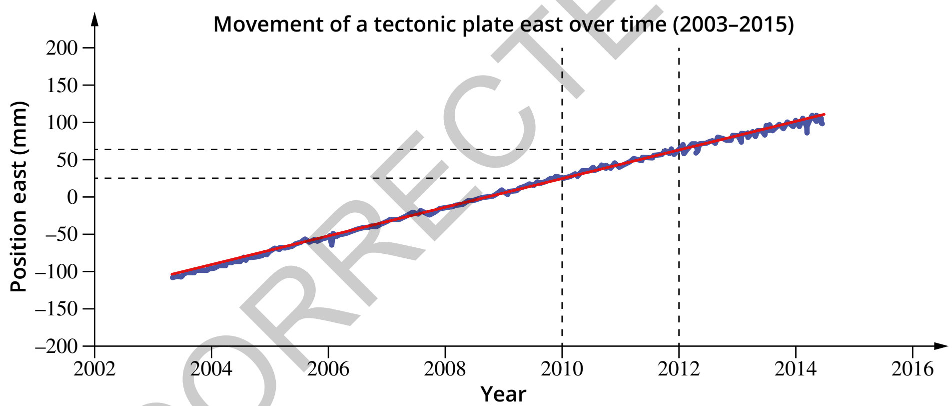



**FIGURE 13.14.7** Tectonic plate movement data from a ground-based GPS site near Sydney. Overall, the Australian Plate is moving in an easterly direction.

**SC 2 CHECK YOUR UNDERSTANDING**

Explain how the distribution of Glossopteris fossils supports the theory of plate tectonics.

# Lesson review

Use these questions to check whether you have met the learning intention for this lesson.

**1** Explain how magnetic striping provides evidence for seafloor spreading.

**2** Explain how the fit of the continents supports the theory of plate tectonics.

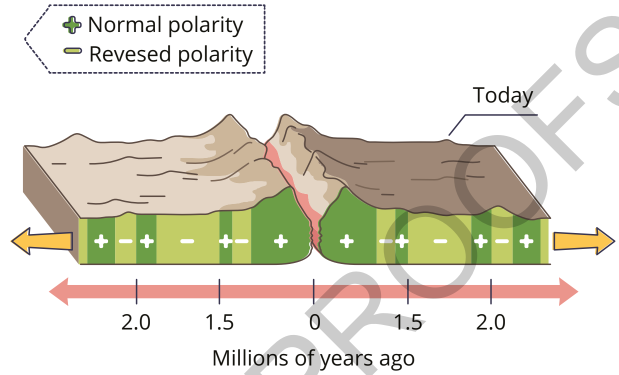
**3** Suggest one piece of evidence that may be found at a convergent plate boundary and one piece of evidence at a divergent plate boundary that support the theory of plate tectonics.

**4** The following is representative of data recorded at GPS stations in California in the region of the San Andreas Fault.

| Station | Location | Speed (mm/year) | Direction |
|---|---|---|---|
| 1 | West coast of California | 45.8 | NW |
| 2 | West coast of California | 46.2 | NW |
| 3 | West coast of California | 45.2 | NW |
| 4 | East side of California | 3.2 | NW |
| 5 | East side of California | 2.9 | NW |
| 6 | East side of California | 3.3 | WNW |

Compare the speed and direction of movement of the land on the west coast of California to the speed and direction of land on the east side of California.

**5** Refer to the following diagram to answer the questions that follow.




**a** How many episodes of normal polarity are shown on the image?

**b** Describe what happened to Earth's magnetic field between 2 million and 1.5 million years ago?

**c** Predict what will happen to Earth's magnetic field in the future.

**d** Evaluate the usefulness of changes in Earth's magnetic field as evidence to support tectonic plate theory.

**6** Compare and contrast the evidence provided by fossil distribution and magnetic stripes on the seafloor in supporting the theory of plate tectonics.

# 13 Geological change

## Topic summary

The key concepts included in this topic are:

- Earth's internal structure is made up of four main layers.
- Rocks on the surface of Earth undergo constant change.
- Weathering of rocks can be physical (mechanical), chemical and biological.
- Sedimentary rocks form when rocks are weathered, eroded and deposited as sediments, with the sediments then undergoing the geological processes of compaction and cementation.
- Intrusive igneous rocks form when rocks melt to form magma and then solidify below Earth's surface. Extrusive rocks form when lava solidifies on Earth's surface.
- Metamorphic rocks form when rocks are exposed to high heat and/or pressure.
- Environmental changes affect the processes and rock types in the rock cycle.
- The theory of plate tectonics explains the patterns of mountain building, earthquake, and volcanic activity around the globe.
- Rock in the mantle moves through convection, most likely driven by slab pull and ridge push in the lithosphere.
- The theory of plate tectonics is supported by evidence such as the formation of mountains, magnetic striping, similarities in fossil records on different continents, GPS monitoring of tectonic plate movement and radiometric dating of rocks.



## Review questions

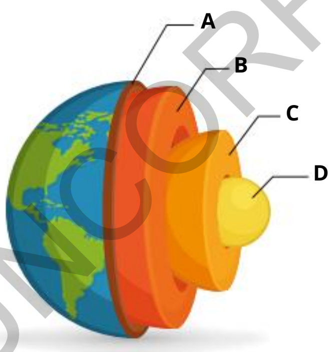
The following questions will assess your success in achieving the learning intentions for this topic.

### Remember

1 Compare the processes of erosion and deposition.

2 Identify the common features of sedimentary rocks.

3




a Identify the layers of Earth shown on the diagram.

b Which layer is liquid?

c How do scientists know about the composition of Earth's internal layers?

4 Define the following terms:

a subduction

b slab pull

c viscosity

d epicentre

5 Recall one way in which the fossil record contributes to the body of evidence in support of the theory of plate tectonics.

### Understand

6 Describe the difference between the lithosphere and the asthenosphere.

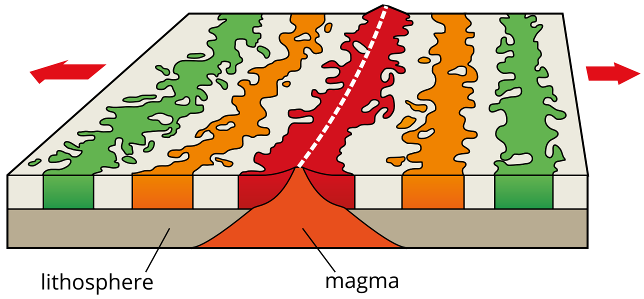
7 A dichotomous key is a useful tool to classify rocks.

a Describe the features of a dichotomous key.

b State the characteristics that would help you to distinguish an intrusive igneous rock from a clastic sedimentary rock while using a dichotomous key.

8 If a limestone rock is exposed to acid rain, which type of weathering will occur, and what will be the result?

**9** Refer to the diagram below.




**a** Identify the type of geographical evidence for the theory of plate tectonics illustrated by the colours in this diagram.

**b** State which of the bands represents the rocks that are the youngest. Identify a technique that can be used to establish that these rocks are the youngest.

**c** Identify the type of plate boundary that is shown in this diagram.

**d** Name two processes that are occurring as the oceanic crust moves away from the mid-ocean ridge in both directions.

**e** Would earthquakes be expected to occur along this boundary?

**f** Name two geological features that can form at a convergent plate boundary.

## Apply

**10** Deep-Earth imaging has found a possible coal deposit. The mining company needs to consider if mining the resource could be profitable. Name four deep-Earth imaging technique that could be used to locate this resource below the ground.

**11** Australia has a very extensive coastline with a variety of landforms.

**a** Name three landforms you might see on the coast.

**b** List two environmental factors that contribute to the weathering of rocks in a coastal area.

**12** Consider a crystal of quartzite. Draw a rock cycle diagram to show the geological processes required for quartzite to form:

- starting with lava forming the extrusive igneous rock rhyolite, then
- the sedimentary rock sandstone, then
- metamorphic quartzite.

**13** Compare the formation processes of the Himalayas and the Mariana Trench.

## Analyse

**14** You have been given a number of metamorphic rocks that have been organised into three metamorphic sequences (A, B and C). Some of the rocks' labels are missing.

**A:** 1 → slate → 2 → gneiss

**B:** limestone → 3

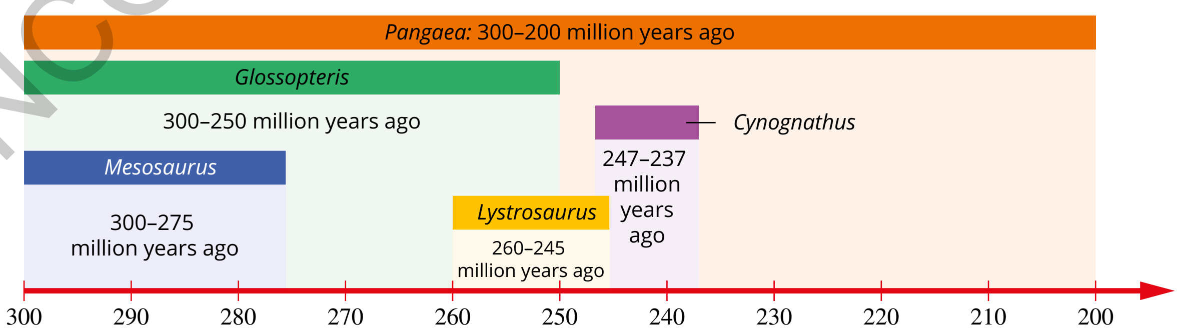
**C:** sandstone → 4

**a** Identify the unlabelled rocks numbered 1 to 4 that belong to the metamorphic sequences.

**b** Identify the parent rock in each sequence.

**c** Describe a feature you would expect gneiss to have that Rock 1 would not have.

**15** Fossils of four types of organisms have been identified as biological evidence supporting the theory of plate tectonics. These are the seed fern *Glossopteris*, and the reptiles *Mesosaurus*, *Cynognathus* and *Lystrosaurus*. The timeline below shows the periods of their existence and how this aligns with the existence of the supercontinent Pangaea.




**a** Name the organism that had the longest period of existence in Pangaea.

**b** Name the organism that had the shortest period of existence.

c Identify the organisms that occurred at the same time as *Glossopteris*.

d Determine which reptiles existed at the same time as each other.

e The Permian–Triassic extinction event occurred about 252 million years ago. State the organisms that appear to have become extinct at, or shortly after, this time.

## Extension: Research task

**16** Your task is to use live data to determine the locations of higher magnitude seismic activity in the world in the last 30 days. You will then compare your findings with the locations of the Great earthquakes (earthquakes of magnitude 8.0 $M_W$ and above) on the map below to determine if there is a correlation.

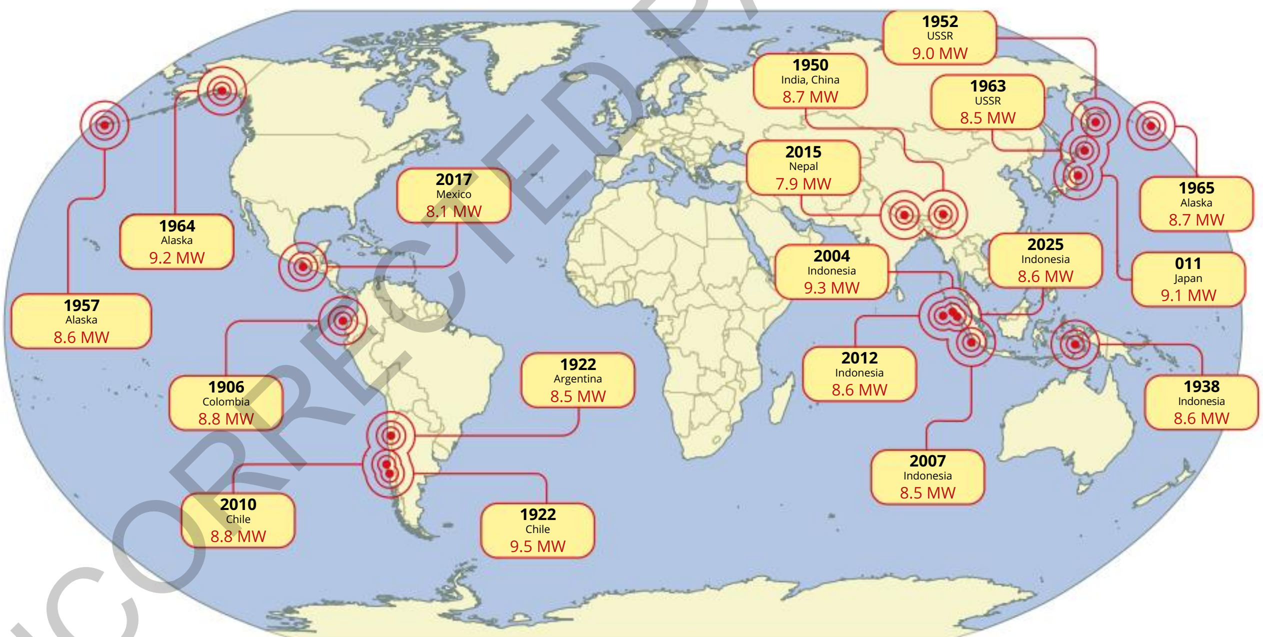
a Go to one of the following sites that show live earthquake data and investigate current seismic activity in the world. Select settings that look at earthquakes of magnitude 4.5 or more for the last 30 days.

- Geoscience Australia Earthquakes
- Unites States Geological Survey (USGS)
- ArcGIS Online Live Earthquakes and World Volcanoes

b Write a paragraph to describe where most of the earthquakes are concentrated. Use the names of tectonic plates in your descriptions.

c Refer to the map below, which shows the largest earthquakes of the twentieth and twenty-first centuries. Consider the following questions to work out if there is a correlation between the Great earthquakes and current seismic activity:

- Did the Great earthquakes occur where earthquakes are currently concentrated?
- Are there any Great earthquakes that occurred outside of current areas of concentration?
- Are there any current areas of concentration that are not included on the map of Great earthquakes?
- Are there tectonic plates or particular plate boundaries with more than their fair share of Great earthquakes?




d Write a second paragraph to describe the correlation between Great earthquakes and current seismic activity. Also indicate if there are any particular tectonic plates or plate boundaries that appear to be particularly active in the generation of Great earthquakes.

## Topic reflection

The learning intentions for this topic are given in each lesson and at the beginning of the topic. Consider how well you have achieved them. Note down any particular areas that you are confident in, and others where you are not so sure.

# 13 Glossary

**asthenosphere** near the top of the mantle, just below the solid lithosphere, and it contains rock that can move very slowly

**biogenic sedimentary rock** sedimentary rock formed mainly from dead organisms

**biological weathering** living organisms that break rocks down into smaller pieces through the action of roots, organic acids, and enzymes

**biosphere** the place where all life exists; consists of Earth's surface and its atmosphere

**cementation** the binding together of sediments as part of the formation of sedimentary rock

**chemical sedimentary rock** sedimentary rock that forms when dissolved materials precipitate from solution

**chemical weathering** reaction processes that break rocks down into smaller pieces, like acid rain, and oxidisation

**clastic sedimentary rock** sedimentary rock formed mainly from small rock particles

**continental crust** the less dense part of the crust that forms the continents

**convection** the transfer of heat through movement of particles in a liquid or gas

**convergent boundary** tectonic plate boundary where plates are colliding with each other

**compaction** the squeezing of layers of sediments caused by pressure from layers above

**contact metamorphism** a type of metamorphism where rock is altered mostly by heat

**crust** the outermost layer of Earth, composed of solid rock

**crystallisation** evaporation of a solvent from a solution, leaving solute behind as crystals

**deposited** the settling of broken rock material to form sediment

**deposition** the settling of broken rock material to form sediment

**dichotomous key** a classification key with two choices at each stage

**divergent boundary** tectonic plate boundary where plates are moving apart from each other

**dynamic metamorphism** a type of metamorphism where rock is altered mostly by pressure

**earthquake** the rapid movement of the ground, usually back and forth and up and down in a wave motion, due to the movement of tectonic plates

**epicentre** the point on Earth's surface directly above the focus of an earthquake

**erosion** the movement of weathered rock particles from the site of the weathering

**extrusive igneous rock** igneous rock that forms on the surface of Earth

**focus** the place below ground where an earthquake starts

**fold mountains** mountains formed by crust crumpling upwards as plates collide

**foliated** a process where minerals under pressure realign and the rock develops layers or bands

**force** a push, pull or twist that can change an object's shape or motion

**fossil** the preserved evidence in rocks or soils of organisms that were once alive

**fossil record** a list showing the classification of all the species on Earth that have been found as fossils

**gas giant planet** large planet in the solar system that is mainly composed of hydrogen and helium gas;includes Jupiter and Saturn

**geology** the study of Earth

**geosphere** all the rocks, minerals and landforms that make up Earth

**geothermal energy** the heat energy that comes from within Earth

**hot spot** isolated place away from plate boundaries where a lot of hot magma is collecting

**humus** dark material in soils produced by the decomposition of plant and animal remains

**ice giant planet** large planet in the solar system that is mainly composed of water, ammonia, and methane; includes Uranus and Neptune

**igneous rock** rock formed by the cooling of molten rock, for example basalt

**index fossil** a fossil that can be used to compare the relative age of rock strata in different locations

**inner core** extremely hot, solid ball made of iron and nickel at the very centre of Earth

**intensity** a measure of the effect of something

**intrusive igneous rock** igneous rock that forms below the surface of Earth

**lava** molten rock that reaches Earth's surface

**lithosphere** name for the crust and the upper mantle together

**magma** molten rock below Earth's surface

**magnetic striping** patterns of magnetism trapped in rocks on each side of plate boundaries

**magnitude** a measure of the size or strength of something

**mantle** solid layer of Earth between the crust and the outer core

**metamorphic rock** rock formed when heat and/or pressure alter existing rock

**mid-ocean ridge** a mountain chain on the floor of the ocean along the boundary of two tectonic plates

**mineral** a naturally occurring solid substance that is inorganic, has a characteristic crystalline structure and a fairly constant chemical composition

**oceanic crust** the denser crust that forms the ocean floor

**outer core** a liquid layer of Earth's interior, primarily composed of liquid iron and nickel, located beneath the solid mantle and surrounding the inner core

**P-wave** type of earthquake wave that are longitudinal pressure waves that spread through Earth, they can pass through solid and liquid layers

**parent rock** the original rock that experiences metamorphism, or changes form, to become a new kind of rock

**physical weathering** mechanical processes that break rocks down into smaller pieces, like wind, freezing water, changes in temperature, and crystallisation of salts

**primordial** something that originated during the planet's formation process a very long time ago

**radiometric dating** a technique for determining the age of rocks that measures the radioactive elements in a substance

**regional metamorphism** a type of metamorphism where rock is altered by both heat and pressure over a wide area

**ridge push** older crust is pushed by new ocean crust at mid-ocean ridges, forcing plates apart

**rift valley** a low-lying valley created by the action of a geological rift or split, often at a diverging plate margin

**rock cycle** a model geologists use to explain the endless cycle of change that rocks undergo

**rock** a solid mass of one or more minerals

**S-wave** type of earthquake wave that are transverse shear waves that spread more slowly than P-waves, they can only pass through solid layers

**sediment** solid material that was broken down by weathering, moved to a new location by erosion, and has now settled into layers

**sedimentary rock** rock made by sediments being compacted and cemented together

**seismic data** data about movements of the ground that is used by scientists to study and monitor earthquakes

**seismic wave** the shaking, wave-like movement of the ground in an earthquake

**seismogram** the recorded information from a seismograph

**seismograph** a seismometer that is connected to a recording device

**seismometer** an instrument that detects the seismic waves from an earthquake

**slab pull** pulling force exerted by older, colder and denser oceanic plates sinking down into the asthenosphere due to gravity, dragging the rest of the plate with it

**subduction** when a more dense plate sinks below another less dense plate during a collision

**supercontinent** one of several large land masses that are thought to have divided to form present-day continents

**surface wave** type of earthquake wave that does not penetrate Earth but travels along the ground

**tectonic plate** large section of Earth's lithosphere that moves about on Earth's surface

**terrestrial planet** smaller planet in the solar system that has a similar internal structure and composition as Earth; includes Mercury, Venus, Earth, and Mars

**theory of plate tectonics** scientific theory that describes the existence, and motion, of tectonic plates

**transform boundary** tectonic plate boundary where plates are sliding past each other either in opposite directions or in the same direction but at different speeds

**trench** a depression in the ocean floor

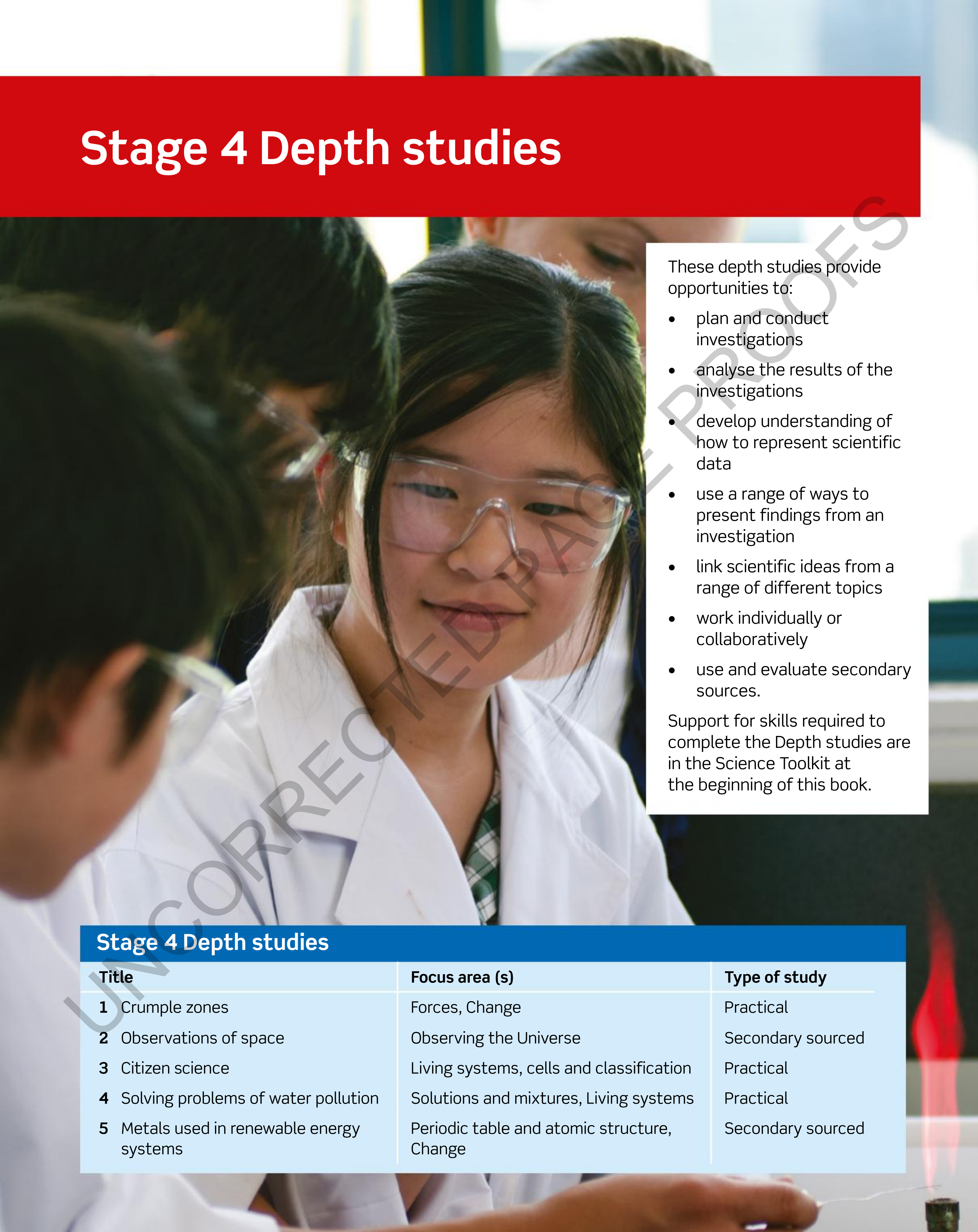
**tsunami** a large and destructive ocean wave or series of waves caused by either a large earthquake on the seafloor, a landslide or a volcanic eruption

**viscosity** the measure of a liquid's resistance to flow

**volcano** a place where extremely hot material from inside Earth erupts at the surface

**weathering** processes that break rocks down into smaller pieces

# Stage 4 Depth studies



These depth studies provide opportunities to:

- plan and conduct investigations
- analyse the results of the investigations
- develop understanding of how to represent scientific data
- use a range of ways to present findings from an investigation
- link scientific ideas from a range of different topics
- work individually or collaboratively
- use and evaluate secondary sources.

Support for skills required to complete the Depth studies are in the Science Toolkit at the beginning of this book.

## Stage 4 Depth studies

| Title | Focus area (s) | Type of study |
|---|---|---|
| **1** Crumple zones | Forces, Change | Practical |
| **2** Observations of space | Observing the Universe | Secondary sourced |
| **3** Citizen science | Living systems, cells and classification | Practical |
| **4** Solving problems of water pollution | Solutions and mixtures, Living systems | Practical |
| **5** Metals used in renewable energy systems | Periodic table and atomic structure, Change | Secondary sourced |

**WS** Planning investigations, Processing data and information, Analysing data and information, Communicating
**DS** Scientific models

# Crumple zones | Focus areas: Forces, Change

## Introduction

Road accidents are an unfortunate and at times tragic result of driving. Modern vehicle designs include crumple zones at the front, rear and sometime sides of the car to reduce the risk of injury to drivers and passengers in cars.

When a car has a head-on collision the front part of the car is compressed and absorbs some of the impact (Figure 14.1.1). Crumple zones are usually made from metals or plastics that can bend and crumple.

**FIGURE 14.1.1** Test car used in a head-on collision with a tree

In this depth study you will explore the design and operation of a crumple zone. First you will identify the most effective design. Then you will investigate how the performance of that crumple zone is affected by a change of a variable. Depending on instructions from your teacher, you will present the findings from your depth study in either a formal scientific report or a presentation, such as a poster or slideshow. This activity is designed as a group activity but you may be asked to complete the discussion and conclusion sections individually.

## Background

The aim of a crumple zone is to reduce the effect of the rapid deceleration as a car impacts another object. Without the crumple zone, the car would come to an immediate stop. This means that by increasing the time taken to slow down to a stop, the effect of the crash will be reduced, which lowers the risk of serious injury.

Before you start your planning, conduct research into crumple zones to obtain ideas for your designs.

# Aim

The aim of this depth study is to model and test two designs for a car crumple zone. Once the most effective design is identified by experiment, it can be investigated to see how changing a variable could change the performance of the crumple zone.

## Research questions

1 Which design of a crumple zone is the most effective for reducing the impact of a front-on collision?

2 How will a chosen variable affect the function of a crumple zone?

# Plan

## Apparatus

You will be provided with a range of apparatus that could include the following:

- cardboard and paper
- balloons
- aluminum foil
- soft clay
- rubber bands
- toothpicks
- ramp
- toy person or another small object
- dynamic trolley or large model car
- wooden blocks or bricks to provide an impact site
- digital video camera, smartphone or tablet
- electronic balance
- sticky tape
- meter ruler
- electronic force meter.

## Measuring impact

There are a number of ways that the impact can be measured. These include:

- Force meter—The use of a digital force meter allows for a direct measurement of the magnitude of the force of the impact of the car. If this is connected to a data recorder, the force can be measured during the impact and the maximum force can be recorded.
- Slow motion photography—If the impact is filmed using a digital video camera, smartphone or tablet, the recording can be viewed in slow motion and the length of time it takes for the model car to stop can be measured. The effect on the crumple zone and the car can also be observed.
- Inertia of an object on the car—If an object, such as a toy person is placed on the car, the greater the force of impact of the car, the further the object will be 'thrown forward' when the car stops. The distance of the object can then be measured.

A combination of these and other possible methods of observation can also be used.

## HINT

Because you may be testing your crumple zones more than once, and they will be destroyed in each test, ensure that your designs are easy and quick to construct.

# Design

In your team, design two different types of crumple zone for the first part of the depth study. Examples of how these could be different include:

- using different materials
- having different shapes
- being attached to the car in different ways
- holding together in different ways.

Ensure that you have captured the different designs either by drawing or with a photograph, to be used in your report.

Use a force diagram to show how your crumple zone works.

# Conduct

Depending on the resources available, you will be given guidance as to possible ways to set up the collision of the car and how the impact is measured. Plan a method and then check with your teacher that it is safe before continuing.

Once the apparatus is set up, trial the method to ensure that it will allow you to obtain results in a safe and repeatable way.

**KEY TERM**

**preliminary trial** a trial of an experiment used to test a method

## Part A: Determining the best design

As you carry out these **preliminary trials**, revise and refine the method until you are confident that the method will enable you to answer the first of the research questions. Make notes of any challenges that you had and how you solved any problems with the method used as this will be part of your report later.

Design a results table to record your results, including averages (mean values) for repeat trials.

Conduct as many trials as you need to determine which of the two designs of crumple zone is the most effective at reducing the impact of the collision. Ensure that all other variables are controlled, such as the mass and speed (at impact) of the trolley/car.

**GO TO ➤**

For support with designing results tables, see Toolkit section x.x
For support with calculating means, see Toolkit section x.x

## Part B: Investigating changes to the design

Once you have identified the most effective design, change a variable and conduct tests to determine how changes to this variable influence the effectiveness of the crumple zone. The variables could be related to the trolley, such as the speed, the mass or the angle of impact.

Alternatively, there could be changes to the crumple zone itself, such as its size or type/thickness of the material used to make the crumple zone. Note that you must maintain the same overall design from Part A of the study.

Before you start, make a prediction as to how you think the change in the variable will affect the effectiveness of the crumple zone.

**GO TO ➤**

For support with predictions, see Toolkit section x.x

Conduct up to five trials with the variable changed each time to determine how the changes affect the effectiveness of the crumple zone. Record all results in a results table and plot an appropriate graph for your results.

GO TO ➤
For support with using graphs, see Toolkit section x.x

## Communication

Depending on guidance from the teacher, ensure that you have recorded the following from your depth study in the correct format:

- drawings or photographs of your designs
- a step-by-step method
- results from Parts A and B of the study.

**HINT**

With this number of trials, there may not be time to conduct repeats of each test in this part of the study.

## Discussion

1 Describe how you overcame any challenges in the experiments, including how you reduced error in experimental results.
2 Discuss how well your experiment models crumple zones in real cars. Include benefits and limitations of this modelling approach.
3 Describe what is happening to the energy of the trolley/car during the collisions.

## Conclusion

1 Present your overall findings. These should include:
   a Which design was the most effective, with your answer supported by evidence from the experiment.
   b How the chosen variable affected the effectiveness of the crumple zone, supported by evidence from your graph of results.
2 Suggest how the findings from your depth study, as described in your answers to Question **1**, could be applied to the design of real crumple zones in cars.

## References

List all the references that you used in this depth study, including in the planning, design and explanation of the results. Use an approved format for citing references.

GO TO ➤
For support with referencing secondary data, see Toolkit section x.x

Depth study

**FA** Observing the universe
**WA** Processing data and information, Analysing data and information, Communicating
**DS** Sources of data

# Observations of space | Focus area: Observing the Universe

## Introduction

The ways that scientists observe space have undergone significant transformations over the last 50 years, driven by technological advancements and international collaboration. Australia has played a vital role in this evolution, contributing to space exploration and research. Understanding how space observation has changed and the benefits it brings helps to appreciate the impact of space exploration on society.

In this depth study, you will explore these aspects, focusing on Australia's involvement and the broader implications of the observation of space.

## Background

Fifty years ago, space observation relied heavily on ground-based telescopes and early satellite technology. The launch of the Hubble Space Telescope in 1990 marked a turning point, providing unprecedented views of the universe. In recent years, advancements in technology have led to the development of sophisticated instruments like the James Webb Space Telescope, which promises to further expand our understanding of space (Figure 14.2.1).

**FIGURE 14.2.1** The James Webb Space Telescope before its launch in 2021

Australia has been actively involved in space observation, with facilities such as the Parkes Observatory (Figure 14.2.2) contributing to significant discoveries, including the Apollo 11 moon landing. The establishment of the Australian Space Agency in 2018 has further strengthened Australia's role in space exploration, focusing on satellite technology, space research and international partnerships.

**FIGURE 14.2.2** The Parkes Radio Telescope in New South Wales was opened in 1961 and is still used to identify pulsars (spinning stars) and track spacecraft.

The Square Kilometre Array (SKA) is a huge radio telescope being built in Western Australia and Africa. It will use thousands of dishes and antennas to study the universe in great detail. Astronomers hope to learn about galaxy creation and mysterious dark energy, and possibly find signals from intelligent alien life.

Space observation has yielded numerous benefits, including advancements in technology, improved understanding of the universe, and contributions to fields like medicine and environmental science.

Looking ahead, the aims of space observation include exploring distant galaxies, understanding dark matter and dark energy, and searching for signs of life beyond Earth. These endeavours promise to expand our knowledge and drive innovation across various fields.

## Aim

To investigate how space observation has changed over the last 50 years, Australia's involvement in the observation of space, recent significant findings, and future aims, and present your findings

## Plan

1 Depending on the guidance from your teacher, work individually or in small groups to brainstorm ideas on how you might approach this depth study. Record any important information or ideas.

2 Use the internet and library resources to find information on the history of space observation, Australia's role, recent findings and future aims. Consider sources like NASA, the Australian Space Agency and scientific journals.

3 Discuss your list with your teacher or your peers to help refine your depth study focus.

4 Identify your final choice of topics to study. Ensure your research will cover all aspects outlined in the aim.

GO TO ➤
For help with research questions, see Toolkit section x.x

## Design

1. Write a research question (or a set of research questions) that outlines the aim of your depth study, focusing on the aspects you have chosen to investigate.
2. Write a list of the steps that you will need to take to complete your depth study, including research, data collection and analysis.
3. Plan a timeline for conducting your depth study and creating a presentation.

## Conduct

1. Follow the procedure you outlined in your planning and design. Modify the procedure where needed. Keep a record of any modifications or information that will help you to improve the procedure during the depth study.
2. Once the required research is completed, organise your data and findings for your presentation.

## Communication

1. Outline how you will present your depth study and data. Depending on the instructions from your teacher, you may be able to present your findings as a visual presentation, newspaper article, podcast or infographic. Your presentation should have clear sections and visual elements and be informative to your audience. Check in with your teacher to discuss your plan.
2. Present your findings in your chosen format.
3. After your presentation, note any comments you received and reflect on how your presentation could be improved. Based on this feedback and depending on instructions from your teacher, either as a group or individually, write a detailed reflection on your experience and how you could apply your learning to future projects that involve research and communication.

## Discussion

1. Describe the information you collected and how you went about it.
2. Explain how you verified and organised your data for your presentation.
3. Identify any problems you had with collecting information and organising it. Describe how you resolved each of these problems.
4. Suggest future aims for space observation and how they might impact our understanding of the universe.

## Conclusion

Present your overall findings from your depth study related to your research question(s).

## References

List all the references that you used in this depth study, including in the planning, design and explanation of the results. Use an approved format for citing references.

GO TO ➤
For support with referencing secondary data, see Toolkit section x.x.

# Citizen science | Focus areas: Cells and classification

## Introduction

Citizen science is research conducted by amateur scientists (citizens) on their own or in collaboration with professional scientists. The aim is to improve scientific knowledge and engage community members in scientific research. Students can make valuable contributions to a wide variety of projects in Australia or even internationally (Figure 14.3.1). In most cases, a mobile phone, camera and access to the internet is all you require.

**FIGURE 14.3.1** Students testing river water as a part of a citizen science project

In this depth study, you will engage with a citizen science project to contribute to the discovery of scientific knowledge and to improve your own scientific research and communication skills.

## Background

There is a huge variety of citizen science projects in Australia. Use the internet to identify current ones. Some recent examples in New South Wales include:

- Bats in Backyards
- Bellingen Riverwatch: Our Rivers, Our Future
- CoastSnap beach monitoring
- counting flying foxes
- Frog ID
- monitoring threatened shorebirds
- NSW TurtleWatch

- iNaturalist
- reporting dust storms
- Saving Our Species on DigiVol
- surveying koalas
- Waterbird Tracker
- Warrumbungle National Park Citizen Science.

Citizen science projects in Australia offer opportunities to engage in real-world scientific research. These projects often include collaboration with scientists by collecting data and making observations. Participants gain hands-on experience, enhance their understanding of scientific methods and develop critical-thinking skills. Projects like the Atlas of Living Australia encourage young people to explore their interests while contributing valuable data to national and global research efforts.

## Aim

To participate in a citizen science project and present a poster about your project

## Plan

1 Working individually or in small groups, brainstorm ideas on how you might approach this depth study. Note any important information.

2 Use the internet to find lists of citizen science projects that are active. The Australian Citizen Science Project Finder is one place to discover and connect with citizen science projects. You could also try the Australian Museum website, Atlas of Living Australia (ALA), Australian Citizen Science Association (ACSA)or ABC Science or SciStarter (global).

Make a short list of projects that you find interesting and that are suitable for this depth study.

3 Discuss your list with your teacher, peers, family and other people who could help you to decide on a project.

4 Identify your final choice of citizen science project. Make sure the project will be active at the time you will be participating.

### HINT

Search filters can be adjusted to find active projects in your local area and projects related to a particular subject or theme.

When looking for a citizen science project, check if it is active, occurring in a location near you, and suitable for your age and the equipment that is available to you.

## Design

1 Outline the aim of your chosen project. This should be based on the overall aim of the citizen science project but should also include how you will be contributing to its success.

2 Write a list of the steps that you will need to take to complete your part in the project.

3 Assess all risks associated with your procedure. Complete an assessment of risk that outlines the risks and the precautions that you need to take to minimise them.

GO TO ➤

For help with reducing risk, see Toolkit section x.x.

4 Check in with your teacher to discuss your procedure and assessment of risk before proceeding. Make sure that you have approval from your teacher and parent/guardian before you start your project. You may need to set up an account online or download an app to participate in the project.

5 Plan a timeline for your project and the creation of your poster. Try to choose a citizen science project that you can contribute to for a relatively short period of time.

## Conduct

1 Follow the procedure you outlined in the Design section. Modify the procedure where needed. Keep a record of any modifications or information that will help you to improve the procedure during the project.

   Show your teacher the data you have collected and ask for suggestions to improve your procedure.

2 Once the project is completed, submit your data to the project organisers.

### HINT

Keep a journal of all the data you collect, along with any other important information (e.g. dates, locations and weather). Data may be in the form of photos, sketches, screenshots, numerical records, text, etc. This is how professional scientists work and it will help you prepare your poster.

## Communication

1 Outline how you will present your project and data as an A3 poster. The poster should have short blocks of text and visual elements (including photos from your fieldwork and data collection) and be interesting to your audience. You should also justify the value of your citizen science project and make your personal contributions clear. Check in with your teacher to discuss your plan for presenting your findings.

2 Present your poster to your class.

3 After your presentation, note any comments you received and reflect on how your presentation could be improved.

GO TO ➤
For help with science presentations, see Toolkit section x.x

## Discussion

1 Describe the information you collected and how you went about it.

2 Explain how you verified and supplied your data to the project organisers.

3 Identify any problems you had with collecting information and uploading it. Describe how you resolved each of these problems.

4 List some suggestions you have for helpful feedback to the project organisers.

## Conclusion

Present the findings from your involvement in your chosen project.

## References

List all the references that you used in this depth study, including in the planning, design and explanation of the results. Use an approved format for citing references.

GO TO ➤
For support with referencing secondary data, see Toolkit section x.x.

# Solving problems of water pollution |

## Focus areas: Solutions and mixtures, Living systems



## Introduction

Water pollution is a significant environmental challenge affecting ecosystems, human health and economies worldwide. It can result from contaminants including chemicals, waste and sediments entering waterways such as rivers and streams.

Solving the problem of water pollution requires innovative solutions to remove pollutants or reduce their flow into waterways.

**FIGURE 14.4.1** Microplastics on an Australian beach

In this depth study, you will investigate the causes and effects of water pollution and develop a model or process to reduce its impact. In your planning, you can consider economic and environmental issues related to your ideas. How you present your solutions will depend on instructions from your teacher. You may be asked to present your findings using a physical model that you have created, a formal scientific report or a presentation such as a poster or slideshow.

## Background

Water pollution can originate from various sources, including industrial discharge, agricultural runoff and urban wastewater. In New South Wales (NSW), the Hawkesbury-Nepean River system has been affected by pollution from agricultural activities, leading to increased nutrient levels and algal blooms.

**FIGURE 14.4.2** Algal blooms can reduce oxygen levels and kill off other life in a waterway.

Similarly, Sydney Harbour faces challenges from the runoff of water from the surrounding urban areas and waste disposal. These impact water quality and the health of marine life.

Pollutants can harm aquatic life, disrupt ecosystems and pose health risks to humans. For example, excess nutrients can lead to eutrophication, causing oxygen levels in the water to be reduced, resulting in the reduction of and fish populations. Heavy metals, such as lead, cadmium, copper and manganese can build up in organisms. This can be passed on through food chains and lead to toxic substances spreading throughout an ecosystem. Understanding the types of pollutants and their effects is crucial for designing effective interventions.

Before you start your planning, conduct research into existing methods for reducing water pollution to obtain ideas for your designs.

## Aim

To research and develop a model or process that can remove or reduce pollution in water or decrease the flow of pollutants into a waterway

## Research question

How can a model or process be designed to effectively reduce water pollution and prevent contaminants from harming the ecosystem?

# Plan

## Apparatus

You will be provided with a range of apparatus that could include the following:

- sand and gravel
- activated carbon
- coffee filters, kitchen sieve or mesh such as fly screen
- plastic containers or tubs
- water samples with pollutants (e.g. soil, oil or detergent, small pieces of plastic litter to represent microplastics)
- measuring cups and spoons
- pH meter or test strips
- stopwatch
- safety goggles and gloves

## Measuring pollution reduction

There are several ways to measure the effectiveness of your model or process in reducing pollution, including the following.

### Chemical analysis

Use pH meters or test strips to measure changes in water acidity or alkalinity before and after treatment.

### Visual inspection

Observe changes in water clarity or colour after applying your model or process.

**KEY TERM**

**sediment** solid material in water that can be transported through a water supply and deposited in a new location

### Sediment removal

Measure the amount of **sediment** removed from the water using filters or containers.

### Microplastics removal

Count the number of pieces of micro plastics removed with the sieve and identify their possible origins.

A combination of these, and other possible methods of observation, can also be used.

# Design

In your team, decide on the type of water pollution you are seeking to address.

Design a model or process that could be used to reduce the effect of this pollution. Examples of how these could be different include:

- using different types of filtration materials
- incorporating chemical treatments

- utilising natural processes like plant absorption.

Ensure that you have captured the different designs either by drawing or with a photograph, to be used in your report. Use diagrams to show how your model or process works.

## Conduct

Depending on the resources available, you will be given guidance as to possible ways to set up your experiment and measure pollution reduction. Once you have planned a method, check with your teacher that it is safe before continuing.

Conduct a risk assessment to identify potential hazards and precautions.

As you carry out these **preliminary trials**, revise and refine the method until you are confident that it will enable you to answer the first of the research questions. Make notes of any challenges that you had and how you solved any problems with the methods used, as this will be part of your report later.

Design a results table to record your results, including averages (mean values) for repeat trials.

Conduct as many trials as you need to get to a point where you are confident that the model is having a positive effect on the quality of the water.

**KEY TERM**

**preliminary trials** trials of an experiment used to test a method

**GO TO ➤**

For help with designing results tables, see Toolkit section x.x.

### Improving the design

Once you have identified a design that works, you can now seek to improve the design. This can be done by trialling changes to the variables that affect the reduction of the pollution. These could include factors such as the filtration materials, chemical concentrations,or flow rate of water.

## Communication

Depending on instructions from your teacher, ensure that you have recorded the following from your study in the correct format.

- Drawings or photographs of your designs.
- A step-by-step method.
- Results from Parts A and B of the study.

## Discussion

1. Describe how you overcame any challenges in the experiments, including how you reduced error in experimental results.
2. Discuss the economic and environmental implications of your model or process. Consider costs, sustainability and potential impacts on ecosystems.
3. Describe the mechanisms by which your model or process reduces pollution.
4. Explain how your solution could positively affect an ecosystem, such as improving water quality, supporting biodiversity or restoring habitats.

## Conclusion

1 This should include answers to the original research question: 'How can a model or process be designed to effectively reduce water pollution and prevent negative impacts to ecosystems?'

2 Suggest how the findings from your experiment, as described in your answers to question 1, could be applied to real-world water pollution solutions and benefit ecosystems.

GO TO ➤
For more help with referencing secondary data see Toolkit section x.x.

## References

List all your references that you used in this study, including in the planning, design and explanation of the results.

FA Periodic table and atomic structure, Change
WS Planning investigations, Processing & analysing data, Communicating
DS Sources of data

# Metals used in renewable energy systems in Australia | Focus areas: Periodic table and atomic structure, Change

## Introduction

Metals are fundamental to the infrastructure of energy systems, enabling the generation, storage and transmission of power to homes and industries.

In Australia, a country rich in mineral resources, metals such as copper, lithium and aluminium are essential components of renewable energy technologies and electrical grids. Understanding the role of these metals, their extraction processes, environmental impacts and availability is crucial for advancing sustainable energy solutions.

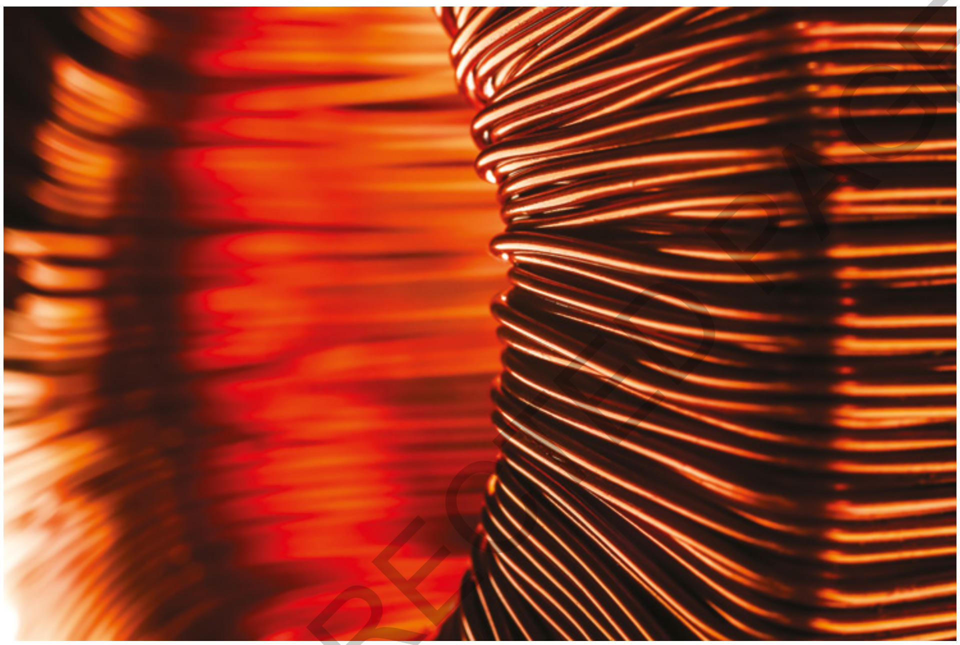


**FIGURE 14.5.1** Copper wire in a transformer, used to transfer electricity from one circuit to another

In this depth study, you should focus on the properties of these metals and how and where they are extracted. This will enable you to be able to explain how important they are for the transition from the use of fossil fuels such as coal and oil to alternative energy sources such as solar and wind energy.

## Background

### Renewable energy in Australia

In 2025, renewable energy provided over 30% of Australia's total electricity generation, with solar power being the largest contributor. Australia has very high rates of rooftop solar panel installations, with more than 3 million households equipped with solar systems. An increasing number of these household also have storage batteries so that the power produced from solar can be used at all times of the day and night.

As of the latest available data, Australia has over 100 operational wind farms. Approximately 30% of these are in New South Wales, with the largest being the Sapphire Wind Farm, near Glen Innes.

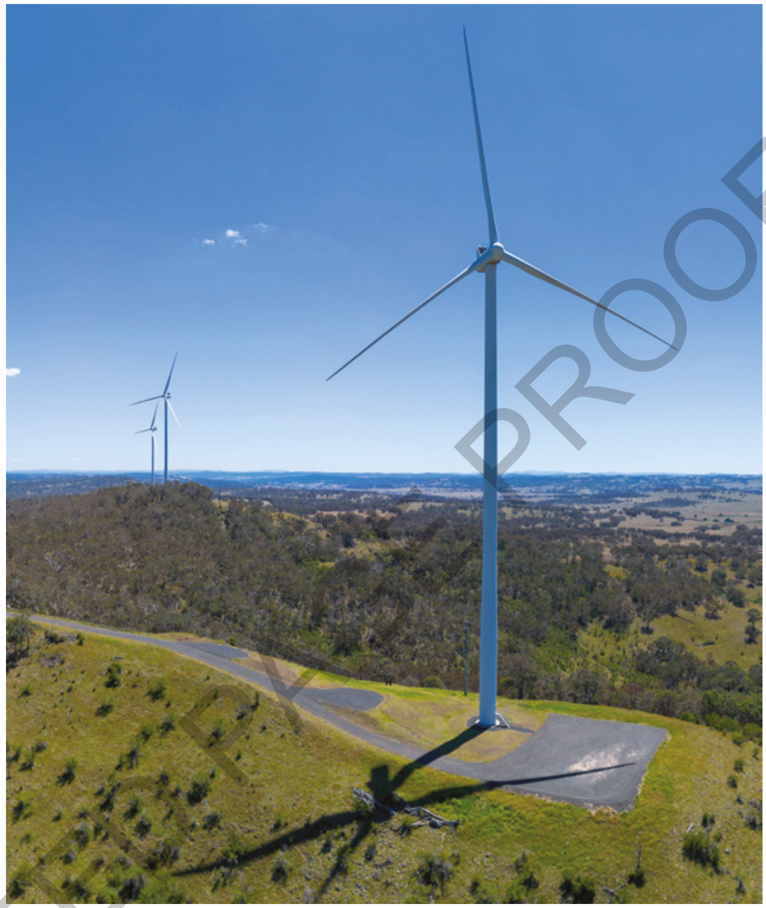


**FIGURE 14.5.2** The Sapphire Wind Farm in New South Wales produces 270 megawatts (MW) of power.

For the most current information on renewable energy in Australia you can refer to resources such as the websites of the Clean Energy Council or the Australian Government Department of Climate Change, Energy, the Environment and Water.

These renewable sources are clean and sustainable, meaning they don't produce harmful emissions and can be replenished naturally. However, a range of resources, including metals required for the building of renewable energy systems, which includes not only the generation of electricity, but also the storage and **transmission** of the electrical energy produced.

**KEY TERMS**

**transmission** the act of passing or transferring something from one place to another

**alloy** a mixture of two or more metals

**conductivity** a measure of the ability of a material to conduct electrical energy

## Metals used in renewable energy systems

Many metals are required for renewable energy systems. They include: copper (Cu), aluminium (Al), lithium (Li), cobalt (Co), nickel (Ni), neodymium (Nd), dysprosium (Dy) and steel (an **alloy** of iron).

Copper is widely used for electrical wiring and transmission due to its excellent **conductivity**. In NSW, copper mining operations, such as those in the Cobar region, contribute significantly to both local and national energy systems.

Lithium, a key component in batteries, is important for energy storage solutions, especially when using renewable energy sources like solar and wind.

Aluminium, known for its lightweight and corrosion-resistant properties, is used in solar panel frames and electrical conductors. The Tomago Aluminium Company in NSW is one of the largest producers of aluminium in the region, playing a vital role in supporting renewable energy systems.

**FIGURE 14.5.3** The frames of these solar panels are made from aluminium metal.

The extraction of these metals involves mining processes that can pose environmental risks, including habitat destruction, water pollution, and **greenhouse gas** emissions.

Before you start your planning, conduct research into the types of metals used in energy systems and their properties and extraction processes to obtain ideas for your study.

## Aim

To research how and why metals are used in renewable energy generation, storage and transmission in Australia and present a report on your findings. You should also include any risks linked to the use or extraction of the metals

## Plan

1. Working individually or in small groups, brainstorm ideas on how you might approach this investigation. Record any important information.
2. Use the internet to find information on metals used in energy systems in Australia. You can try resources like Geoscience Australia, Australian Renewable Energy Agency (ARENA) and mining company websites. Make a short list of metals that are commonly used and relevant to your study.

**KEY TERMS**

**greenhouse gas** a gas that traps heat close to Earth's surface

**bias** a preference for a particular idea

### HINT

Search for information on the extraction processes, environmental impacts and availability of these metals in Australia.

When researching, check for recent data and studies to ensure your information is up to date.

Look for any **bias** in the information sources that you use, especially if they are websites of commercial companies or environmental campaign organisations.

3 Discuss your ideas with your teacher and classmates who can help you refine your study focus.

4 Identify your final choice of metal(s) to study. If you are working in a group, you should choose more than one metal. Ensure your research will be relevant to current energy systems in Australia.

## Design

1 Outline the aim of your study, focusing on the metal(s) you have chosen.

2 Write a list of the steps you will need to take to complete your study, including research, data collection and analysis.

3 Plan a timeline for your study and the creation of your report.

### HINT

Keep a journal of all the data you collect, along with any other important information (e.g. sources, dates and findings). Data may be in the form of text, charts, graphs or images. This is how science researchers work and it will help you prepare your report.

## Conduct

1 Follow the procedure you outlined in the Design section. Modify the procedure where needed. Keep a record of any modifications or information that will help you improve the procedure during the study.

Show your teacher the data you have collected and ask for suggestions to improve your procedure.

2 Once the study is completed, organise your data and findings for presentation.

## Communication

1 Outline how you will present your study and data. Depending on instructions from your teacher, you may be able to present your findings as a report, a presentation to your class, or a discussion with your teacher. Your presentation should have clear sections and be informative to your audience.

You should include:

- details of how the metal is used
- why the metal is important in energy systems
- the environmental impacts of extracting and using these metals. Consider factors such as pollution, habitat destruction and resource depletion
- ways to reduce the environmental impacts or other risks associated with these metals
- whether they will be enough of the metal to supply demand as the use of alternative energy sources increases.

2 Present your findings in your chosen format.

3 If you had to learn about a new aspect of science, such as electrical circuits, chemical reactions, metal conductivity or storage batteries, explain what you have learned as part of your presentation.

## Discussion

1 Describe the sources of information that you used.

2 Comment on the validity of at least two of your data sources, including whether there was any bias in the content or how the content was presented.

3 Describe any instances of where you used information from a source other than the internet.

## References

List all your references that you used in this study, including in the planning, design and explanation of the results.

GO TO ➤
For more help with referencing secondary data see Toolkit section x.x.

***Pearson Science NSW Stage 4 Student Book 1e*** **Attributions**

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